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This article studied subchondral intraosseous pressure (IOP) in an animal model during loading and with vascular occlusion. IOP recordings from 5 femoral condyles and 7 proximal tibias in 5 rabbit subjects were obtained. The effect on IOP of loading by 1 body weight, arterial occlusion then loading, and venous occlusion then loading were assessed. A load of 1 body weight caused the basal IOP to rise as well as IOP at various sites. A clip applied to the proximal femoral artery caused the IOP to fall while a clamp on the femoral vein caused the IOP to rise. Saline injected into the femoral head caused pressure at the femoral condyle to increase and vice versa when saline was injected at the femoral condyle. IOP injection of saline in the femur had no effect on IOP at the tibia. The authors conclude that IOP is not constant.


This study explored the physiology of normal subchondral perfusion and IOP. Using 21 anesthetized rabbits intraosseous pressure (IOP) was measured using IO needles in the subchondral cancellous bone of the femoral head, femoral condyle, and proximal tibia. A series of experiments investigated the following: normal baseline IOP; method of measuring; IOP wave forms; drug administration; relationship between systemic blood pressure, IOP and pulse pressure; relationship between IOP and pulse pressure; and vascular occlusion. The authors concluded that subchondral cancellous bone behaves as a perfused tissue and that IOP is mainly a reflection of arterial supply. A single measure of IOP can vary and reflects only perfusion at the needle tip.


This article describes the anatomy and physiology of IO cannula insertion as well as indications and contraindications of IO use. Devices and techniques as applied to the pediatric population are discussed, including EZ-IO.


This article describes a retrospective, CT-assisted evaluation of IO cannula placement. Over a 5 year period all multislice-CT trauma scans performed in a trauma center were monitored for intraosseous devices in situ. 982 patients were evaluated and 13 IO cannulas were found in 11 patients. In all cases, the EZ-IO device was used. Evaluation of placement found that all applications were placed correctly, but none were according to current guidelines. The site of puncture deviated in all cases with the most common error of overshooting during needle introduction. (Article in German)


Study using 31 healthy volunteers to evaluate IO blood samples drawn from the proximal tibia compared to arterial and venous samples using a POC lab device. Two samples were drawn from each site with no significant difference observed in the results with or without waste blood. Results varied particularly between the arterial and IO samples; and for several parameters. Authors concluded that IO blood samples may be evaluated using the i-STAT® point-of-care analyser; and results should be interpreted with care in the clinical situation context.


This manuscript provides an overview of CPR physiology, especially as it relates to compression and ventilation. The placement of peripheral and central venous catheters can interfere with compressions. As such, IO access is an alternative that allows drug administration with similar pharmacokinetics and absorption as peripherally administered medications and a higher insertion success rate (>80%).


This study investigates infusion flow rates through a standard 16-gauge peripheral angiocatheter inserted into a single corpus cavernosum of the penis to support the hypothesis that the penis can be an efficient means of providing rapid fluid resuscitation. This study suggests that the penis may be an alternative to traditional vascular access routes (peripheral IVs, IO insertion, central venous catheters, and vein cutdown procedures) when vascular access is difficult. Flow rates in the study were comparable and in some cases superior to other alternative means of vascular access.


Preclinical RCT evaluating the relationships between the anatomical distance of IO epinephrine and measures of resuscitative outcome in an adult swine model of ventricular fibrillation (VF). There were no significant differences between the HIO, TIO, and IV groups relative to the occurrence of ROSC, 30-minute post-ROSC survival, and time to ROSC. The anatomical distance of IO epinephrine injection from the heart did not affect short-term measures of resuscitative outcome in an adult swine model of VF including the occurrence of ROSC, 30 minute post-ROSC survival, and time to ROSC. Rapidly administered epinephrine, irrespective of route of administration, increased the chance of ROSC and survival to 30 minutes post-ROSC in this study.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

This study examined the relationship between body mass index (BMI), the ability to palpate the tibial tuberosity (TT), and soft tissue depth at recommended IO insertion sites in obese patients using ultrasound. Authors concluded in obese adults with a palpable TT or BMI ≤ 43, a 25 mm IO needle is likely adequate at the proximal and distal tibial insertion sites; and at the proximal humerus site a 45 mm is recommended.

This article reports the results of a systematic review using PubMed for current evidence through 2015 for intraosseous (IO) vascular access use in adults requiring resuscitative procedures. General anatomy, indications and contraindications and available devices are discussed. Authors determined IO infusion is indicated in all critical situations with difficult vascular access; contraindications are few; and serious complications uncommon. France

A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.

A preclinical study comparing administration of Hextend via IV and tibial intraosseous (IO) access routes for time for administration and hemodynamic measures in a hypovolemic swine model. Following exsanguination, 500 mL of Hextend was administered via both routes; a control group received no Hextend. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for administration in the IV group was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the IO group it was 10 minutes 12 seconds (± 1 minutes 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.

YEAR: 2015

This document is a tutorial provided by the World Federation of Anaesthesiologists geared at understanding and establishing intraosseous access. It provides an overview of venous blood drainage from bones as well as indications, contraindications, common access sites, advice for establishing access, an overview of device types, insertion techniques, and complications.

This article describes various pediatric vascular anomalies, including intraosseous vascular malformations which can lead to weakness in the bone diaphysis, predisposing to pathological fracture.

Preclinical study to determine whether intraosseous pressure (IOP) could be consistently recorded and similarity of IOP to central venous and arterial pressure in a porcine hemorrhagic shock model. IOP tracings were tracked reliably from the proximal humerus, distal femur, and proximal tibia. Baseline IOP ranged from 16-18 mm Hg among the three sites, which was approximately 23% of arterial pressure. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Prospective preclinical study by to determine the effects of humeral IO (HIO) and IV epinephrine administration during cardiac arrest on pharmacokinetics, ROSC, and odds of survival. There were no significant differences in ROSC, maximum concentration; except at 30 s, and time-to-concentration-maximum between the HIO and IV groups. Significant differences existed between the experimental groups and the control. The HIO delivered a higher concentration of epinephrine than the IV route at 30 s, which they noted may be a survival advantage. Authors suggested clinicians consider using the IO route to administer epinephrine when IV access is unobtainable.

In a healthy adult volunteer study contrast media was injected through the proximal humerus site and captured under fluoroscopy as it entered the heart. The mean time it took from injection at the insertion site to visualize contrast entry into the superior vena cava and the right atrium was 2.42 seconds. Abstract presented at ACEP 2015. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology


Abstract describing preliminary results for the first 24 subjects of an EZ-Io study evaluating catheter dwell times for 48 hours. Initial data indicate that IO vascular access can be safely maintained for a period up to 48 hours without risk of osteomyelitis or other serious adverse events. Authors also noted that additional analgesics for IO infusion pain management may be more effective than the current solely administering lidocaine into the IO space. This study was sponsored by Teleflex Incorporated.


A cadaveric study evaluating intraosseous (IO) vascular access insertion sites for attainable flow rates under 300 mmHg. The EZ-Io was used to establish IO access at the proximal humerus and proximal tibia sites; the FAST1 was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 286 ± 218 mL for the humerus; and 154 ± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7 ± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.


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A preclinical study comparing three methods used to confirm intraosseous (IO) catheter tip placement within the IO space. Using an immature anesthetized swine, 8 IO needles were inserted, 4 properly placed within the IO space and 4 placed in the subcutaneous tissue. Physician sonographers (n=32) participated in the study and determine IO proper and improper IO line placement using physical examination, syringe aspiration, and ultrasonography after administering 5 cm3 of normal saline through each IO line. Confirmation via physical examination resulted in 32/32 successful evaluations; syringe aspiration resulted in 22/32 successful evaluations; and ultrasonography resulted in 30/32 successful evaluations.

YEAR: 2014


A letter to the editor questioning the practice of using IO blood for laboratory analysis. The author identifies there is a lack of clinical evidence supporting IO blood laboratory analysis and concludes that IO access should be limited to infusion of fluid and medications until the relationship of IO blood to peripheral blood is defined.


This letter to the editor includes a brief review of the literature, discusses the limitations associated with studies on IO derived blood samples, and recommends IO blood may only be useful in cases of suspected overdose for toxicology.


In this pre-clinical study, investigators sought to determine if the pressure readings at the proximal tibia IO site served as a good indicator of proper IO placement when the foot of the limb was squeezed. Traditional methods used to determine correct IO placement, including needle stability, aspiration of blood, and easy infusion, were used as comparators. Results showed the increased pressure reading at the IO site successfully predicted correct IO placement in all cases; syringe aspiration resulted in 22/32 successful evaluations; and ultrasonography resulted in 30/32 successful evaluations.


This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-Io and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.
This prospective study sought to evaluate intraosseous flush practices of emergency physicians. Using cadavers, 15 emergency physicians were asked to flush an IO catheter placed in the proximal tibia and proximal humerus IO insertion sites with 10 mL normal saline as they would in clinical practice; IO pressure measurements were recorded using an IO catheter inserted in the diaphysis of the target bones. Results showed the median IO pressure generated was 903 mmHg and the median flush duration was 5.2 seconds. Result showed significant interoperator variability with greater than 35-fold difference in flush forces. The authors concluded that it may be prudent practice for providers to extend the flush over several seconds to limit the maximal pressures.


This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.

YEAR: 2013


A pre-clinical study that evaluated use of intraosseous (IO) pressure as an indicator of changes in fluid volume status during a hemorraghic shock protocol. Central venous and arterial pressures were used as comparators. Results showed IO pressure decreased consistently during the controlled shock protocol. Authors concluded IO pressure appears to be equivalent to CVP as an indicator of fluid volume status. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A pre-clinical study that compared intraosseous (IO), central venous and arterial pressure tracings in a porcine model. Results showed that IO pressure was approximately 25% of arterial pressure. A sampling of IO blood gases revealed oxygenation levels of venous blood. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measureable blood pressure and it correlates with pressure obtained through conventional techniques.


Pre-clinical study comparing flow rates acheived after insertion with the EZ-IO in the proximal tibia, distal femur, and proximal humerus in a swine model. IO catheters were placed in each site and normal saline was infused for 10 minutes using a pressure bag at the highest achievable pressures greater than 300mmHg. The flow rates through the proximal humerus were statistically greater than that of the femur or proximal tibia. The femur flow rates were higher than the proximal tibia but similar. Post-mortem histopathologic evaluations done to assess for damage due to the high infusion pressures were consistent with IO catheter placement.


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.


This abstract describes a study in which the investigators sought to determine the approximate patient population in which the 25mm EZ-IO needle set was sufficient length to establish IO access in peripartum patients. Ultrasound was used to determine the tissue depth at four insertion sites. Twenty-six women were recruited with a median gestation of 34 weeks. In 88% of patients with a BMI<40 kg/m² the 25mm needle is sufficient to reach the bone marrow at both tibial sites. For the humeral site, IO placement may be more difficult for patients with a BMI>25 kg/m².
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

A clinical study evaluating the relationship between IO blood and peripheral venous blood lactate levels analyzed using the i-STAT point-of-care analyzer in healthy volunteers. Results showed IO blood lactate levels were comparable to venous blood lactate levels with a positive statistical correlation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.

A prospective study comparing IO and venous laboratory values obtained from a point-of-care analyzer (i-STAT) in 20 children. IO blood specimens were collected from the iliac crest; 2 ml were discarded before the sample was collected analysis. Results showed differences between venous and IO sample were clinically acceptable for pH, base excess, sodium, ionized calcium and glucose in hemodynamically stable patients. Authors concluded that analysis of IO samples with a bedside point-of-care analyzer is feasible and in emergency situations may be useful to guide treatment.

Wolfe HA, Donoghue A, Berg RA. Are we ready to put the squeeze into all IO placements? Resuscitation 2013;http://dx.doi.org/10.1016/j.resuscitation.2013.10.018
This article discusses the preclinical study by Lee 2013 in which successful IO placement in the proximal tibia was confirmed by squeezing the foot and obtaining a measured pressure at the IO cannula site greater than 80mmHg. The author challenges this method indicating that it should not be implemented clinically until additional research has been performed confirming its validity in humans.

YEAR: 2012

This editorial discussed a prior publication by Reades, et al that evaluated first attempt placement success rates for tibial IO, humeral IO, and peripheral IV in the prehospital setting. The author concluded that the research shows tibial IO access is the best route for adults with out-of-hospital cardiac arrest.

This article describes a post mortem study evaluating a newly developed technique to study the intraosseous vasculature of the humerus involving injection of ink directly into the anterior circumflex humeral artery. This technique allowed visualization of the main nutrient artery to the proximal humerus vasculature until they reached articular cartilage or crossed cortical bone again to enter the rotator cuff tendons.

An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider’s armamentarium.

This pre-clinical study sought to evaluate the various pressure levels obtained by 22 veterinary clinicians when administering a 10ml normal saline flush of an IO catheter. The EZ-IO was used to establish access in an isolated, cadaveric swine femur. The authors found the median peak intraosseous pressure was 615 mmHg with a range of 57 to 1,100 mmHg. Authors concluded that there is a great deal of variability between clinicians and their flush pressure and that a standardized flush protocol may be beneficial.

This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.

This preclinical study sought to determine the accuracy of IO blood lab values by comparing lab results obtained using an I-Stat for IO blood and arterial blood. The authors concluded that the agreement between intraosseous and arterial analysis seemed to be good enough to be clinically useful, and that there were no clinically significant differences between samples collected from the right and left tibia.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

This abstract presented at the 2012 NAEMSP scientific assembly described a study in which the comfort level of paramedics was evaluated as it related to establishing vascular access in out of hospital cardiac arrest resuscitation, using a predetermined method (PIV, humeral IO, tibial IO). Results showed that paramedics were typically comfortable with the method assigned.

This prospective observational study compared flow rates between distal and proximal tibia IO access in adults, with each adult serving as their own control. The EZ-Io was used to facilitate IO access. IO infusion was performed with and without pressure. The authors concluded that infusion flow rates were significantly higher in the proximal tibia as compared to the distal tibia, and that flow rates are significantly higher with pressured infusion vs. non-pressured infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2012 NAEMSP scientific assembly evaluated end-tidal carbon dioxide (ETCO2) levels under initial induction of hypothermia, rewarming, and a second induction of hypothermia, via IO and IV infusion in the swine model. The authors concluded that there was no demonstrated association of ETCO2 with brain temperature during the initial induction. However, during rewarming and second induction of hypothermia the association of ETCO2 and brain temperature had a direct and proportional association. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This study conducted by the San Antonio Fire Department evaluated the first-attempt success rate for humeral EZ-Io placement by paramedics in prehospital adult cardiac arrest patients. Humeral placement was attempted in 247 cardiac arrest patients; first attempt placement success rate was 91%. Authors concluded that humeral IO placement is a reliable method for vascular access in this patient population. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

YEAR: 2011

This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.

This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first responders to place IO lines for antidote administration using the EZ-Io device. First responders placed IO lines successfully in 100% of cases, and first receivers placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.

This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-Io, were discussed.

UK

In this abstract the authors attempted to establish a relationship in obese patients (BMI >30) between BMI, ability to palpate the tibial tubercle, and tissue depth at the IO insertion sites. Results showed that in obese patients, IO placement with a 25mm catheter is feasible at the proximal and distal tibial sites if the tibial tubercle is palpable and that insertion into the proximal humerus in this population is not recommended.

Abstract only

Miller LJ, Philbeck TE, Puga TA, Montez DF, Escobar GP. A pre-clinical study to determine the time to bone sealing and healing following intraosseous vascular access. Ann Emerg Med 2011;58(4S):S240
The objectives of this study were to evaluate the amount of time necessary following IO insertion and infusion for the bone to heal such that a second IO catheter can be placed in the same bone without the risk of extravasation from the first hole; and to determine the length of time required to show radiological evidence of closure. Four anesthetized goats were used for the study. Twenty-four hours post insertion, extravasation was observed in 2 of 4 tibial sites with no extravasation in 4 humeral sites. Forty-eight hours post insertion, no extravasation was observed in tibial or humeral sites. Authors concluded that IO infusion should not be attempted in the same bone as a previous IO insertion within 48 hours of removal of the first IO catheter. Radiological examination showed evidence of bone healing as early as 6 days post IO placement. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.

This article describes IO access in terms of efficacy, indications/contraindications for use, and the IO procedure and comparison of devices to make a case for IO use in oral and maxillofacial surgical practice. In discussing IO devices citing published data, the author identified the EZ-IO device as the most accurate, efficacious, and precise system when trying to achieve IO access.

YEAR: 2010

This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.

Authors describe an early observational study (N=120) comparing intraosseous access in the humerus and the tibia, using the EZ-IO. Investigators concluded that the humerus is an acceptable IO site, which may be preferable under certain clinical conditions. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article describes the vascular access options available to physicians caring for children, including details about each method, placement technique, indication, and complications.

This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.

In this study, using a swine model, investigators concluded that mild therapeutic hypothermia can be effectively induced after successful resuscitation of prolonged ventricular fibrillation through infusion of chilled saline via the IO catheter.

This abstract, presented at the 2010 ACEP Research Forum, describes a study designed to determine infusion flow rates through the proximal humerus and proximal tibia. Investigators found that, at all infusion pressure levels, the humerus provided substantially greater flow rates than the tibia. They concluded that, for most situations, adequate IO infusion rates can be achieved using the tibial site, but the proximal humerus site should be strongly considered when greater infusion flow rates are required. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2010 ACEP Research Forum describes a study designed to compare Lidocaine’s effect on pain during fluid infusion through the tibial and humeral IO routes. Authors concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article provides a brief history of IO infusion and further discusses this vascular access technique in terms of anatomy and physiology, indications and contraindications, performing the manual procedure, and possible complications. A case study is discussed in which a 7-month-old male was treated under emergency circumstances with IO infusion in the lower limb and developed compartment syndrome, resulting in a below the knee amputation.

This article discusses vascular access procedures in critically ill obese patients. Anatomic considerations, general procedural considerations such as location of the procedure and patient positioning, catheter insertion technique, ultrasound guided insertion, intraosseous insertion, and other various considerations are evaluated.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

This abstract describes an animal study, presented at the 2010 ACEP Research Forum, that examined shear and pressure changes within the medullary space during intraosseous infusion. Results suggest that resistance to flow depends on cannula placement site, IO pressure rises rapidly with infusion rates, and medullary compression and axial shear are present at high infusion rates.

This article provides an overview of IO anatomy and physiology, IO access indications, care, and management; describes therapies administered via IO access; and discusses the expanding use of IO access into areas within hospitals during nonemergency clinical situations. It also includes a table addressing indications for IO access in the hospital, as well as a table addressing the general insertion procedure for IO access.

This article in Chinese, describes a study that evaluated the effects to the bone marrow following IO infusion of hypertonic saline-hydroxyethyl (HSH) in the dog model; using a normal saline group (NS) and a non-infusion group. The test subjects were put into shock and resuscitated. Results showed that at 48 hours post infusion and 1 week post infusion changes were seen in the bone marrow and peripheral blood in the HSH and NS groups as compared to the non-infusion group. At 4 weeks post infusion, the NS group and HSH group recovered to normal level. Bone marrow morphology changed slightly but no bone necrosis occurred. The author concluded that HSH in small amounts via IO is safe and effective as a fluid resuscitation measure for shock, and little change in bone marrow has been found after infusion.

YEAR: 2009

Barrett J. Adult Intraosseous infusion: “Good to the bone!” Response 2009;36(3):19-21
This article addresses adult IO infusion, primarily in the pre-hospital setting, with regard to the history of IO, anatomy and physiology, training considerations, clinical guidelines and contraindications, and financial considerations.

This is a continuing medical education (CME) document discussing pediatric advanced life support guidelines. It is geared toward pediatric emergency medicine physicians. IO is a preferred route of drug administration.

In a preclinical study using a caprine model, researchers assessed the hemodynamics of hydroxocobalamin (OHCo) compared to normal saline (NS) by the intraosseous (IO) route and concluded that the effects of OHCo given by the IO route in non-CN-poisoned goats are mild and well tolerated. Investigators concluded that IO administration of OHCo may "find a role in the settings of individual patients with cyanide-induced cardiovascular collapse or mass cyanide casualties".

This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study that evaluated crystalloid fluid flow through an IO needle following nitroglycerin infusion in a swine model. Investigators concluded there was not a significant increase in flow rate after administration of IO nitroglycerin.

This abstract for a presentation at the 2009 ACEP Research Forum describes a volunteer study that examined the relationships between IO and venous blood samples when analyzed for complete blood count and chemistry profile. Researchers concluded that the IO space is a reliable source for blood used for CBC and chemistry profile. Results may be moderately reliable for carbon dioxide, but unreliable for WBC counts that appear to be elevated and platelet counts that appear lower.

Ong ME, Chan YH, Oh HH, Ngo AS. An observational prospective study comparing tibial and humeral intraosseous access using the EZ-IO. Am J Emerg Med 2009;27:8-15
Comparison of tibial and humeral IO use in 24 adults. Both sites suitable for IO infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

This article describes the first clinical study that focuses on the proximal humerus as an IO site. It is also the first article describing a comparison between IO access and peripheral IV (PIV) and central venous catheters (CVC). They found that IO catheter placement was significantly faster than PIV or CVC placement, and concluded that IO access is life-saving when PIV or CVC is difficult or impossible. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Color Doppler ultrasound revealed extraosseous flow in incorrectly placed IO insertions. Recommends point-of-care Doppler machine to verify placement.

This swine study was designed to determine if intraosseous infusion is suitable to delivery recombinant human factor VIIa (rFVIIa) during hemorrhagic shock. Investigators concluded that administration of rFVIIa via IO infusion is a safe route for delivery and is likely to produce blood levels required to improve hemostasis during shock.

YEAR: 2008

Animal (goat) study to determine the capacity and time required for protected hazardous materials responders and receivers to accomplish vascular access and hydroxocobalamin administration for antidotal treatment for exposure to cyanide and other poison agents. Using the EZ-IO device, researchers concluded that the time required for IO administration of the drug was shorter than intravenous administration; and that IO placement is readily accomplished wearing all levels of chemical protective garments and equipment.

Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation; the second notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.

Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter by S. Nicoll and S. Rochester states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation. The second by R. Salter notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.

UK

This article describes a prospective cross-over study that evaluated the effects on heart rate of intraosseous administration of 2% lidocaine at various deposition rates in dental practice. Results showed the mean maximum heart rate was statistically higher with the fast intraosseous injection over the two slow injections.

YEAR: 2007

Article describes the IO route to deliver epinephrine.

 Hoskins SL, Zachariah BS, Copper N, Kramer GC. Comparison of intraosseous proximal humerus and sternal routes for drug delivery during CPR. Circulation 2007;116:II_993
Results from this, study which sought to compare drug delivery time using the proximal humerus IO route to delivery time using the sternal IO route, suggest that IO proximal humerus is comparable to IO sternal for prompt drug delivery during CPR.

A cadaveric study evaluating the use of ultrasonography visualization of flow within the intraosseous space to confirm proper needle placement. In a sample of 4 freshly frozen, unembaled cadavers with bilateral distal tibia IO access, ultrasonography accurately detected the flow of crystalloids through the IO space 100%.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

YEAR:  2006

An overview of IO vascular access use in neonates, including focus on available evidence, history, technique, physiology, clinical indications, complications, and contraindications. The author closes acknowledging IO administration of resuscitation medications and fluids in neonates is an alternative when IV access is not possible.

Hoskins SL, Kramer GC, Stephens CT, Zachariah BS.  Abstract 79: Efficacy of epinephrine delivery via the intraosseous humeral head route during CPR.  Circulation 2006;114:I_1204 422
Results from this study which sought to determine the efficacy of intraosseous drug delivery using the proximal humerus during CPR in swine showed that the humeral route generated higher mean arterial pressures than central venous or endotracheal delivery.

An overview of intraosseous cannulation in the pediatric population. Anatomy, technique, contraindications, complications and laboratory investigations are all discussed.

YEAR:  2005

This animal study compared IO drug delivery in the tibia versus the sternum during CPR. Researchers concluded that during CPR IO infusions delivered via both sites were effective—although sternal delivery was faster; and that IO sternum access is comparable to IV access for drug delivery during CPR.

This study abstract discusses use of the EZ-IO to determine the pharmacokinetics (PK) and efficacy of tibial IO drug delivery during treatment of cardiac arrest in the swine model, as compared to IV access. Results showed that PK analysis of IO drug delivery via the tibial route showed a delay of 20-50 seconds compared to IV; however, physiologically significant levels of epinephrine were reached as MAP. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Animal study compared the sternal and tibial routes for IO drug delivery during CPR. Investigators concluded that both the sternal and tibial routes can effectively deliver near equivalent doses during CPR in swine.
http://www.aemj.org/cgi/content/abstract/12/5_suppl_1/67

Case report. Finds more positive outcomes with fluid restriction (permissive hypotension) in patients with uncontrolled hemorrhagic shock.

Arterial supply of the humeral head and the clinical relevance of the vessels in the proximal humeral fracture and in different techniques of fracture treatment.

This is a continuing medical education (CME) document that provides an overview of shock and discusses management of shock in the pediatric patient. It is geared toward pediatric emergency medicine physicians. IO is a supported route for obtaining vascular access.

YEAR:  2004

Cadaver study demonstrating immediate entry of methyl green dye into the venous system after IO infusion via the calcaneus in 14 of 20 cadaver legs (70%).

Web publication discussing the indications, contraindications, insertion sites and complications of IO access.

Review article describing how IO has replaced saphenous venous cutdowns in pediatric emergencies and decreased need for immediate central venous access.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

Evaluation of the Bone Injection Gun (BIG) for the administration of contrast media for urography. Concludes that BIG-assisted intraosseous urography may be an effective and reliable alternative to intravenous urography in pediatric and adult human patients.

YEAR:  2003

Investigation of the relationship between insertion site for the IO needle, epiphyseal growth plate and ease of needle insertion into the various locations of the tibia in newborn infants. Recommends that needle be placed 10 mm distal to the tibial tuberosity to avoid the epiphyseal growth plate and ensure ease of insertion.

Prospective radiographic study of 23 children who had received intraosseous infusion via trocar. Found no long-term effect on tibial growth with properly placed trocar.

Web article discusses IO cannulation procedure insertion sites, pathophysiology, risks, contraindications and complications.

A comprehensive and accessible review of the history, anatomy, technique, and clinical application of intraosseous infusion.

Study in human demonstrating transport of methyl green dye to the peripheral veins in 5 of 8 IO infusions (62%) in bones without medullary cavity (calcaneaous and radial styloid).

YEAR:  2002

Preclinical study in anaesthetized cats demonstrating that stimulation of intraosseous receptors decreased the threshold of evoked potential in the cerebral cortex in response to stimulation of the heart, stomach and duodenum. Concludes that stimulation of intraosseous receptors increases sensitivity of visceral sensory receptors and may provoke the development of pain syndromes.

Preclinical study in mice demonstrating that transplantation of bone marrow from normal allogenic mice injected directly into the bone marrow cavity of irradiated recipient mice can prevent and treat osteoporosis.

This article provides an indepth overview of intraosseous circulation including blood vessel anatomy, vascularization, intraosseous blood flow, angiogenesis, bone remodeling, osteonecrosis, bone infarction, and osteoporosis.

Basic research study in sheep demonstrating that intraosseous injection of ethanol directly into the center of the femoral head produced necrotic changes similar to the early stages of osteonecrosis. The model holds potential for evaluating new therapeutics for the disease.

Meechan JG.  Supplementary routes to local anaesthesia.  Int Endod J 2002;35(11):885-96
This paper describes supplementary techniques available to provide pulpal anaesthesia, of which IO administration is included.

Preclinical study in 21 horses comparing IV to IO infusion for delivery of amikacin sulfate to the tibiotalar joint. Concludes that IV infusion results in higher drug concentrations in the joint.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

YEAR: 2001

This article gives an overview for nurses of the treatment of shock in children. Intraosseous administration of fluids is a means of resuscitation.

YEAR: 2000

Laboratory study comparing flow rates through different IV cannulas with an 18 G IO cannula. Found that fluids could be infused more quickly with the IO cannula. Speculates that the bone marrow cavity of an infant has more capacitance than a peripheral vein.

Dental study demonstrating that intraosseous injection of 1.8 ml of 3% mepivacaine to augment nerve block in the first molar significantly increased the anesthetic success over 30 minutes and had a minimal effect on heart rate.

Hurren JS. Can blood taken from intraosseous cannulations be used for blood analysis? Burns 2000; 26: 727-30
Study comparing IO blood samples to IV samples for blood chemistry values. For many parameters, IO and IV levels were similar. Authors caution that potassium and glucose levels should be interpreted with care. Also found that white cell and platelet counts in the IO samples were very different from those measured in IV blood samples.

Overview of pediatric IO infusion targeted for an EMS/paramedic audience. Discusses anatomy of long bones, indications, advantages, contraindications, steps for insertion, fluid administration and ongoing assessment and documentation.

Case report of a 3-year-old collapsed child successfully resuscitated with the use of an intraosseous needle placed in the calcaneum. Includes detailed description of needle insertion technique.

Intraosseous transplantation of bone marrow in combination with long-acting Adriamycin may inhibit acute and chronic graft versus host reactions.

Preclinical model of hypothermia. Found intraosseous pCO2 levels correlated with arterial or mixed venous pCO2 during hypothermia within 10 mmHg. Intraosseous pH values were comparable with mixed venous or sagittal sinus pH within of 0.05 units during hypothermia.

Brief overview of IO infusion for an anesthesiology audience. Discusses technique, indications, contraindications, equipment, anatomical target sites and potential complications.

Osteoreflectory therapy (intraosseous injection of 0.5 to 1.0 ml of 0.9% saline solution) reduced alcohol craving in patients treated for alcoholism. Abstract only

YEAR: 1999

Preclinical study in anaesthetized piglets demonstrating that intraosseous blood samples reliable to assess acid-based balance in the early stages of cardiac arrest and first 15 minutes of cardiac pulmonary resuscitation.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

Efimov IuV, Zaitsev VG, Sychugov AV. [The treatment of patients with complicated mandibular fractures using a method for the intraosseous administration of biologically active drug agents]. Stomatologiia (Mosk) 1999; 78; 26-7. Russian
Article in Russian; no English translation.

Preclinical study in piglets comparing IO vs IV blood samples during CPR. Concludes that IO samples may not yield accurate results during resuscitation periods > 5 minutes or if drug or fluid boluses have been infused into the IO sample site.

YEAR: 1998

A 3-year old male presented at the emergency department with rapidly progressing circulatory collapse clinically aligned with meningococcal septicemia. Attempts at peripheral and central venous access were unsuccessful. Attempts at tibial IO insertion were unsuccessful with a number of needles bending when cortical penetration was attempted. IO insertion was successfully achieved at the medial aspect of the calcaneum. IO infusion was continued for 6 hours and removed when no longer needed. The patient fully recovered and the calcaneal site healed without complication.

Case report of a 34-week-old pre-term neonate with septic shock requiring emergency treatment. Umbilical vein was unusable. Resuscitation with IO access was successful. Concludes that IO access be used before attempting access with superior longitudinal sinus.

Review article discussing techniques for venous access in the pediatric patient includes anatomical target sites, clinical indications, advantages and disadvantages.

Year: 1997

Review article highlighting preclinical data and 1 clinical study. Demonstrates that IO administration can be used for safe and rapid infusion of hypertonic saline dextran with the hemodynamic effect as IV administration.

Preclinical study of piglets in cardiac arrest demonstrating divergent values for acid-base parameters between IO and IV blood samples during cardiac arrest. Speculates that divergence in acid-base values as CPR progresses may reflect local acidosis since IO samples resulted in lower pCO2 and higher pH values than IV blood samples.

Manley L. Pediatric hypovolemia: back to the basics. Int J Trauma Nurs 1997; 3:93-8
Review article for trauma nursing audience describing advances in trauma care.

Year: 1996

Preclinical study in pigs examining developmental and histopathologic changes in bone following IO infusion and effect of osmolality and infusion speed. Found that infusion osmolality and speed was not related to physiologic or histologic changes in the bone marrow or in complication.

Describes a miniature C-arm imaging device to accurately confirm proper needle placement in intraosseous infusions.

Found that IO infusion into the clavicle during adult CPR had similar effects and flow rates as central venous infusion.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

YEAR: 1995


Preclinical study in pigs demonstrating that IO hyperosmotic resuscitation increases circulatory performance and reduces the plasma and catecholamines concentrations during hemorrhagic shock.

YEAR: 1994


Review of IO infusion in children 6 years old and younger. Recommends IO for patients with life-threatening conditions requiring immediate vascular access. Reports less than 1% complication rate.


Comparison of flow rates for IO infusion through the clavicle and subclavian venous infusion. Found no significant differences between the two infusion routes.

Abstract only


Preclinical study in 86 injured dogs with hemostasis disorders. Plasma and platelet disorders normalized 3 hours after the onset of infusion therapy. The response was enhanced by IO infusion of isotonic saline.

Article in Russian-abstract only


Preclinical study in piglets comparing IO and central venous acid-base status during changes in cardiac output. Found IO samples can be easily obtained even during extreme hypervolemia. pH and pCO2 were similar in both IO and IV samples under all study conditions.


Discussion of IO infusion, including ease of use, low complication rates, and variety of fluids and drugs that can be administered through the IO route in children and adults.


Describes frustration associated with difficult venous access. Recommends intraosseous infusion technique as a non-collapsible vein for parenteral infusions.

Takada M, Yamamoto I, Morita R. Chronic intramedullary infusion of interleukin-1 alpha increases bone mineral content in rats. Calcif Tissue Int 1994; 55: 103-8

Preclinical study in rats examining bone mineral content following IO infusion of IL-1.

YEAR: 1993


Preclinical study in 20 immature rabbits receiving IO infusion of saline, bicarbonate, or dopamine solutions into the tibia. Found no changes in bone growth or ephyseal injury related to IO infusion.

YEAR: 1992


This prospective, nonrandomized, crossover study evaluated bone marrow aspiration from the posterior iliac crest and peripheral venous blood for ABO and Rh typing as well as the presence of human leukocyte activity. No differences were seen in the ABO and Rh typing, and human leukocyte activity was detected in both the marrow and venous samples.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology

Article promoting increased awareness of intraosseous infusion, familiarity with IO insertion techniques, and careful use of anatomical landmarks.
Abstract only

Preclinical study in piglets finding that IO infusion of a normal saline bolus decreased overall cellularity in the tibial bone marrow. Speculates this may be due to a pressure effect from rapid injection.

Preclinical study of an implantable intraosseous infusion device (the osteoport) in a goat model. The device allowed for ready access to the vascular system through intraosseous infusion fluids and medications. IO infusion may result in fewer complications than conventional methods of vascular access.

Preclinical study in pigs demonstrating that IO infusion of fluids and resuscitative drugs does not adversely affect subsequent bone growth and development.

YEAR: 1991

Discussion of case reports of IO infusion, as well as physiology of IO and technique for IO access. Concludes that IO infusion is simple and safe. The technique can be successfully performed under field conditions by paramedical personnel, even by untrained personnel.
Abstract only

Clinical study demonstrating blood from the IO space to be a viable alternative source of blood for laboratory studies.

YEAR: 1990

Review of the use of intraosseous infusion in children in the prehospital setting and in the emergency department. Outlines anatomy, indications and contraindications, technique, complications and role of intraosseous infusion in pediatrics.

Joffe M. Blasts in peripheral blood with intraosseous infusions. Pediatr Emerg Care 1990;6:106-7
Case reports of 2 children who died from Sudden Infant Death Syndrome (SIDS) with immature white cells in the peripheral blood. Blood was sampled near IO infusion site. Urges physician awareness of that patients receiving IO infusion may be at risk for immature white blood cells in the peripheral circulation in the absence of malignant, infectious, or infiltrative disease of the marrow.

Nursing article that describes benefits of intraosseous infusion. Recommends IO for cardiopulmonary arrest and other medical

This abstract describes a review of the literature on intraosseous pathways and reaches the conclusion that the rate of fluid administered is limited by the size of the marrow cavity and the complication is extravasation of fluids and/or drugs into the soft tissue.
Intraosseous Vascular Access Bibliography
Anatomy, Physiology and Pathology


A 15mg/kg dose of phenytoin was administered over 15 minutes to 6 pigs using the IV route and 6 pigs using the tibial IO route. Blood samples were taken every 5 minutes for 35 minutes to determine phenytoin levels. There was no statistical difference between the two groups. Bone cortex and marrow were microscopically examined and were normal after 5 weeks. Authors concluded the IO route is an effective alternative to the IV route for administering phenytoin without permanent damage to the marrow.

**YEAR: 1988**


Basic science study examining vascular drainage from the human tibia using x-rays and barium perfusion. Found that blood from the IO space is diverted simultaneously into two independent extraskeletal venous pathways. Found that IO blood drains directly into the systemic veins via large transcortical perforating vessels, which enables the blood to rapidly enter the general systemic circulation.

**YEAR: 1987**


Preclinical study of IO flow rates during hypovolemia. Concludes that IO flow rates may be insufficient for definitive treatment of severe hypovolemic or hemorrhagic shock.

**YEAR: 1979**

**Shoor PM, Berryhill RE, Benumof JL. Intraosseous infusion: pressure-flow relationship and pharmacokinetics. J Trauma 1979;19:772-4**

Preclinical study of IO flow and pharmacokinetics in the bovine tibia. Mean time to initial effect of IO administration of epinephrine was 17 seconds with 90% maximal effect in 45 seconds. Concludes that experiment provides quantitative evidence of utility of IO infusion for resuscitation.

**YEAR: 1978**


Preclinical study in dogs demonstrating active IO blood circulation even during acidosis and hypoxemia.

**YEAR: 1958**

**Schoenherr WF. Intraosseous infusion of bone marrow. JAMA 1958;166(7):853**

This letter to the editor is regarding the case of a 56 year-old man that ultimately developed aplastic anemia and required blood transfusions biweekly, and being considered for bone marrow transplants. The Editor’s response briefly addressed the process of bone marrow transplantation.

**YEAR: 1945**

**Henning N. Intrasternal and intraosseous injections and transfusions. JAMA 1945; 128: 240**

Recommends intrasternal IO transfusions when the IV route is not available.

**YEAR: 1944**

**Behr G. Bone-marrow infusions for infants. Lancet 1944; (Oct 7):472-3**

Describes the tibia as a useful route for infusions in infants. Main advantages over IV infusions are ease, speed, and firm placement.
**Intraosseous Vascular Access Bibliography**

**Case Studies**

**YEAR: 2019**


Retrospective case report of six patients describing the use of intraosseous (IO) administration for 23.4% saline administration to treat intracranial hypertension. In all six cases sodium levels were increased and there were no IO complications.


This is a case report of IO access for palliative sedation with propofol in a 56-year-old man with no venous access. IO access was gained using an EZIO driver and the patient was successfully treated with propofol for 4 days to manage intractable pain and agitation.

**Sampson CS.** Extravasation from a misplaced intraosseous catheter. *Clin Pract Cases Emerg Med* 2019;3(3):303-4

A 75-year old female presented by EMS to the Emergency Department (ED) after a ventricular fibrillation cardiac arrest. EMS defibrillated the patient and placed a right proximal tibial EZIO intraosseous (IO) catheter which multiple medications (epinephrine, magnesium, amiodarone, and calcium chloride) were administered; and she had return of spontaneous circulation prior to ED arrival. The IO catheter wasn't patent upon arrival in the ED and was removed. The patient was discharged on day four with ecchymosis near the insertion site. Three weeks post discharge the patient presented with tissue necrosis in an area surrounding the initial proximal tibial IO insertion site. The patient's leg was debrided and grafting was performed; the author reported "good healing" three months post-event.


Retrospective case-control feasibility study comparing proximal tibial intraosseous (PTIO) and peripheral intravenous (PIV) delivery of contrast media in 24 patients receiving emergent CT scans as part of trauma diagnostics (n=4 PTIO, n=20 PIV). Delivery of contrast media was by power injection with rates of 5cc/sec for CT images of the head and neck, chest, abdomen, and leg vessels. There were no significant differences in ability to complete imaging protocols or image quality. There were no complications. The study was limited by low patient numbers.

**YEAR: 2018**


This case review describes a complication of compartment syndrome post IO placement in a 64 year old male initially unresponsive and hypoglycemic. Approximately 15 minutes post-ED arrival compartment syndrome signs were noted and confirmed with compartment pressures. An ultrasound confirmed lack of flow from the IO needle and x-ray showed the needle set to be inserted 2 mm beyond the posterior tibial cortex. Patient was taken to surgery for fasciotomy and four compartment release with subsequent return of pulses.

*(Correspondence by the manufacturer 12-2018 with lead author confirmed the tibial placement was lateral and the patient had a full functional recovery)*


This study describes 3 cases in which tissue plasminogen activator (tPA) was administered via intraosseous (IO) access on a mobile stroke unit as part of the BEST-MSU study. IO access was obtained with the EZ-IO device as part of the study protocol.


This report from France reports a case of tibial osteomyelitis in a 40 year old male that was diagnosed by MRI and biopsy three months post-intraosseous (IO) catheter removal. The patient was given parenteral as well as oral antibiotics and had a good outcome. The initial IO catheter placement was for treatment of overdose after failed IV attempts. The catheter was removed on the first day and the patient was treated with oral antibiotics due to local inflammation at the insertion site. He left against medical advice before a full treatment course was completed.


This case study discusses the use of an IO vascular access device (EZ-IO) as a substitute for k-wire stabilization of mallet finger in a patient with distal fracture and tendon exposure of the third and fourth phalange. The needle driver of the EZ-IO was placed in a sterile glove and was then used to place the inner stylet of the device through the tip of the finger to achieve splint fixation in extension. The patient had a favorable outcome.
Intraosseous Vascular Access Bibliography

Case Studies


This is a case report of a 69 year-old male admitted to an ED in the UK with an extradural hematoma following closed head injury. He was treated with decompression of the hematoma using a 25 mm long EZ-IO intraosseous needle. This is believed to be the first reported use of an EZ-IO device in this manner in the UK. The patient succumbed to his injuries two days later. However, the authors recommend consideration of this technique when transfer to a hospital with a neurosurgery unit for craniostomy is not a feasible option.


This paper presents two case reports of IO anesthesia using a computer-controlled intraosseous system (CIAS) for non-surgical periodontal therapy (root planning). CIAS-based induction of local anesthesia during non-surgical periodontal therapy was more comfortable for both patients relative to previous conventional local infiltration anesthesia (CLIA) treatment.


This article describes a case report of a blood sample from a trauma patient that was drawn from a humeral head intraosseous device. The specimen gave correct blood typing results representative of the peripheral blood.


This article describes a complication of a deformed EZ-IO catheter which was noted following removal of the catheter in an adult patient. The catheter had been placed by a helicopter emergency medical service team following a motor vehicle accident. The cause of the catheter bending was most likely the result of arm positioning for thoracostomy. No difficulties in removing the catheter were noted and it appeared to have been functioning effectively.


This paper describes a case study of a 66 year-old female who presented to an emergency department with symptoms of an acute stroke. After failure of intravenous (IV) placement, humeral intraosseous (IO) access was obtained using the EZ-IO device. Contrast media (CM) for computed tomographic angiography (CTA) was later infused, off label, through the IO line. At the time of the CT scan 20 mL of CM was seen within the glenohumeral joint. The patient did not experience any ill effects from the extravasation following the procedure nor at her 1 week follow-up.

**YEAR: 2017**

**Bromberg R, Dave K, Mankodi D, Danckers M.** Soft tissue laceration caused by lower extemity intraosseous access insertion in an obese patient. *BMJ Case Rep* 2017;doi:10.1136/bcr-2017-220069. (United Kingdom)

This case report describes a complication of a laceration that occurred in an 85 year old morbidly obese female that presented in septic shock and received a proximal tibial IO placement. A 45 mm needle set was used for the initial insertion, which was completed without any initial problems; no stabilizer was placed. The patient had fluid resuscitation via the IO site with rapidly improved hemodynamics. During transport she developed a 7 cm laceration across the IO insertion site. The catheter was removed and laceration sutured. Authors opined that the lack of use of the EZ-Stabilizer dressing, the amount of soft tissue and thin skin and traction forces on the IO site applied during transport contributed to this complication.


This case report describes a CT angiography of the chest and abdomen done via an EZ-IO catheter placed in a critically ill patient’s proximal humerus. The contrast media was infused at a rate of 4 mL/s and the infusion pressure never exceeded 300 mmHg. No immediate or short term complications were observed. The authors describe the overall image quality and vessel contrast observed as excellent.


This case report describes use of an intraosseous needle for initial management of increased intracranial pressure from an extradural bleed in a 43 year old female with a traumatic head injury. The patient was taken to surgery for a craniotomy and recovered without deficit.

This case reports one patient in which they found a vascular air embolism via ultrasound when they were assessing the patient’s femoral access. J Emerg Med 2016;51(6):680-3. http://dx.doi.org/10.1016/j.jemermed.2016.05.064

Case report of a 29 year old that was diagnosed with osteomyelitis in his left tibia after a prehospital IO placement for resuscitation of cardiac arrest. Medsions infused included naloxone, epinephrine, and amiodarone. The patient had ROSC and his IO catheter was removed within one hour of ED arrival due to infiltration. Diagnosis of tibial osteomyelitis occurred approximately 8 weeks post-initial placement.


Case report of a 29 year old that was diagnosed with osteomyelitis in his left tibia after a prehospital IO placement for resuscitation of cardiac arrest. Medications infused included naloxone, epinephrine, and amiodarone. The patient had ROSC and his IO catheter was removed within one hour of ED arrival due to infiltration. Diagnosis of tibial osteomyelitis occurred approximately 8 weeks post-initial placement.

YEAR: 2016


This case reports one patient in which they found a vascular air embolism via ultrasound when they were assessing the patient’s femoral vessels prior to arterial line placement on the same side as a limb that had an IO device placed. The authors noted that it was possible air was introduced when the patient injected IV heroin to that same leg; but believe it was more likely the IO line or tubing was not flushed or left open for a period of time.
Intraosseous Vascular Access Bibliography

Case Studies

This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.

This article discusses the difficulty in defining the time to bone healing after IO access insertion in children. A case study is presented of a 23 month old male with multiple comorbidities that had a tibial and proximal humerus IO placed then 3 weeks post IO placement had tibial swelling. Upon follow-up he was diagnosed with a tibial fracture and incomplete healing of the tibial bone accessed for IO use. Repeated IO access to a limb previously accessed is advised regardless of time after access. Authors emphasize that IO access is a “critically important tool” in pediatric emergency medicine and IO access should be used early and often.

This article includes a case study of an adult patient who received an intraosseous (IO) catheter, that may have extravasated, resulting in vascular compromise. The patient was treated with pharmacologic intervention and the status was reversed. A review of the literature on adult IO complications is also described.

This article in German describes a case study of a 3 year old child with a serious heart defect (after total cavopulmonary anastomosis) in which bilateral humeral IO access sites were obtained to manage her condition and the patient was discharged after 30 days without neurological deficits. Key messages include that IO access in children should be a primary access route in emergent and urgent situations, unless a suitable venous access is already available; the humeral head insertion site is an accepted method in emergency situations in adults and children; and IO access is intended for regular emergency administration of drugs. The purely preventive use of an IO is not indicated. Article in German.

This case study describes a “lifeless child” who had been trapped by an electrically operated garage door. An IO needles was placed in each tibia and adrenalin was administered. Despite being asystolic for up to 19 minutes, the child eventually recovered with neurologic reflexes and motor abilities intact.

This article describes a case in which an EZ-IO catheter inserted into the proximal humerus required surgical intervention for removal after traditional removal efforts failed. Authors noted the patient refused an attempt to stabilize the insertion site. Discussion and a brief review of the literature discusses available IO devices and complications. In conclusions authors opined that with education and training, EZ-IO may become the preferred method of achieving rapid vascular access for emergent resuscitation with a low risk for complications.

This case study describes the medical management of a 20 year old male post high-speed motor vehicle crash with multitrauma and in shock upon air medical team arrival. Care entailed aggressive airway support, bilateral chest decompressions, management of potential pelvic bleeding with a pelvic binder, one peripheral IV through which packed red blood cells and plasma were given and one proximal humerus IO through which 1 g tranexamic acid (TXA) was given.
Intraosseous Vascular Access Bibliography

Case Studies

YEAR: 2015


This article presents a 5-case series describing use of IO vascular access by anesthesiologists in the perioperative and critical care settings. All insertions were made in the proximal tibia and there were no adverse events reported. The devices cited as being used were the EZ-IO and the Cook Surfash manual needle. A proposed perioperative vascular access algorithm incorporating IO access is presented. The authors address key topics around IO access including use of same drug dosings as IV administered drugs, frequent palpation and monitoring of the insertion site for extravasation, low complication rate and actual risks associated with fat emboli and bone injury, pain and anxiety management in the awake patient and clinician-perceived pain. Administration of blood products, ACLS drugs, Lactated Ringer’s solution and anesthetics are noted without complication. Use of IO aspirate for laboratory testing is noted, however use of the initial aspirate is indicated. Several patients in the case series were reported to find the discomfort of IO insertion preferable to multiple intravenous attempts. The authors concluded: IO lines can be placed quickly and safely in emergency situations or in elective surgical patients with difficult intravenous access; IO access can be useful in a wide variety of clinical settings; and is an important skill for anesthesiologist to learn.


This article discusses a retrospective analysis of data collected to investigate the possible time-dependent outcomes associated with adrenaline administration by personnel with Emergency Medical Services (EMS). Primary endpoint was survival to hospital discharge and positive neurological outcome. The study included 3,469 patients with out of hospital cardiac arrest (OHCA). Study concluded patients with OHCA that had been treated early with adrenaline and had a shockable rhythm had a survival rate to hospital discharge.


Case report of a prehospital misplacement of an IO catheter into the intra-articular space of the knee joint when access was attempted in the field. Upon arrival IO placement was noted to be high and intra-articular placement was confirmed by xray. A sterile NS lavage was done and patient recovered without complication. Authors note this as a previously unidentified complication of IO placement and advocate for xray confirmation of affected sites with follow-up of intra-articular placements for the septic arthritis. (Picture of site appears to be an EZ-IO).


This paper describes a case study of a 64 year old man who presented to the ED with symptoms of bleeding related to rivaroxaban and clopidogrel. Due to concern for bleeding, low BP, and perceived difficulty in IV access, IO access was obtained. After access the patient experienced significant pain and was unable to tolerate large volume administration through the IO site. The patient was successfully treated with prothrombin complex concentrate (PCC), which has a smaller volume when compared to blood products. This was the first reported case of IO PCC administration.


This is a case report of a 34 year old female with bilateral peripheral pulmonary emboli with bibasal consolidation and pleural effusions. Due to difficulty with establishing peripheral access, IO access was established in the proximal tibia and Alteplase was administered through the line. Central venous and arterial access were ultimately obtained, and extracorporeal membrane oxygenation (ECMO) was initiated. The patient ultimately recovered and was discharged from the hospital after 36 days. The authors note that the combination of IO thrombolysis and ECMO for treatment of acute massive PE has not been previously reported and highlights the importance of appropriate access for administration of pharmacotherapy in the critically ill patient.


This article presents a case report of a 7 month old female who received intraosseous vascular access via the EZ-IO in the distal femur that resulted in a dermal abrasion where the needle hub contacted the skin. The wound healed without significant complication however the scar at the IO site persisted at 11 months post the event. The authors recommend that providers use the minimal force necessary when operating the EZ-IO to avoid similar adverse events.


Case study of a 9-month-old patient (approximate weight 7 kg) presented with Ebola Virus Disease (EVD) and severe dehydration. IO access was obtained using a 15 g Jamshidi device to the right proximal tibia. A total bolus of 280 mL of lactated ringers solution was infused; then the IO infusion continued for 12 hours until an IV could be established. Authors stated it is important for emergency disaster responders, as well as their responding organizations, to know and understand that IO access is an important and safe modality to use in patients with EVD, and in the austere settings often found in disaster settings.
Intraosseous Vascular Access Bibliography
Case Studies


Case report of a 13 year old girl suffering from severe hemorrhagic shock due to blast injuries and gunshot wounds that received freeze-dried plasma via IO access as part ofprehospital resuscitative efforts. Her vital signs improved upon arrival to the hospital; and she was released after 3 weeks of hospitalization.


A case study report of a 24-year old female who presented to the emergency department after consuming an over dose amount of verapamil. Central and peripheral venous access were obtained for delivery of vasopressors and intravenous fat emulsion 20% (IFE). IFE was initiated via peripheral IV (PIV) access but access was lost; administration through central access was not possible due to the potential drug interaction. Intraosseous (IO) access was established using the Arrow EZ-IO system in the proximal tibia without complication and IFE administration was resumed. The patient reported some pain with infusion. After half the bolus administration was delivered, the infusion pump alarmed due to inadequate flow. PIV access was obtained and IFE administration was resumed using the newly obtained access route. The authors suggested that the viscosity of the medication may have caused the delivery failure by infusion pump through the IO route and recommend slowing down the bolus rate of infusion for clinicians attempting this route for IFE administration in the future.


This is an abstract of a study that analyzed possible technical and anatomical factors leading to the complication of amputation as a result of IO placement. The study was prompted by a case report of amputation in a neonate after IO access using the EZ-IO device. The study measured medullary diameter of the proximal tibia at the recommended IO access site in three groups: 1-28 day old full term neonates, 1-12 month old infants, and 3-4 year old children. The mean diameter in each group was 7.7 mm, 9.9 mm, and 12.4 mm, respectively. The small size of the IO space, especially in neonates and infants, makes correct placement difficult. As such, complications should be taken into consideration in this patient population.


This case study describes a neonate who suffered a cardiac arrest, had return of spontaneous circulation (ROSC) and was treated with multiple medications and therapeutic hypothermia. The patient had received three IO needle insertions, one in the left tibia that was removed following swelling with bolus injection; one in the left distal femur that dislodged with movement of the patient's legs; and one in the right proximal tibia. Twenty-four hours after initial IO needle placement the child developed pallor and discoloration and was diagnosed with compartment syndrome to the right lower extremity. Five days post-IO insertion a below the knee amputation was performed. Medications infused via the IO access included epinephrine and norepinephrine infusions.

YEAR: 2014


Literature search for complications associated with IO access included 5759 patients with overall complication rate of 2.1 %. Two cases involving retained needle fragment discussed; one with a proximal tibial EZ-IO that required surgical removal. Authors concluded IO catheters are reliable tools for fluid and drug delivery to critically ill patients with low complication rates (which can be potentially serious but managed).


This article describes a case study of a 31-month old infant that suffered hypovolemic shock due to epistaxis. After several failed peripheral and central line attempts an 18g needle was inserted intraosseously through the proximal tibia. The child received 300 mL of Ringer’s Lactate in one hour then 200 mL of blood via the IO route by syringe boluses resulting in improvement. Cloxacillin was also administered IO as prophylaxis for infection. Authors conclude an IO blood transfusion should be the immediate intervention in similar life-threatening situations.

Zambia


This letter to the editor describes a single case of a needle breaking off after a proximal tibial insertion of the EZ-IO into a volunteer (one of the letter’s authors) during a training session. "Divergent from manufacturer instructions the sterile steel stylet was put back into place to achieve better grip for a manual pull-out. Under steady pull in strict axial alignment and gentle clockwise turn, the needle broke away from the plastic connector". The needle was extracted using combination pliers and there is no evidence of damage to the leg. Authors acknowledge this can be avoided by adherence to manufacturer’s directions for use.

Germany
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This is a discussion of a case study involving a hospitalized woman who had an IO line placed during a code after becoming unresponsive. Several unsuccessful attempts at peripheral venous access were made prior to IO access. The patient was diagnosed 3 hours later with compartment syndrome due to extravasation that required complex ongoing care in the ICU for 2 months.

This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.

Case study of 36 year-old in septic shock with co-morbidities of IV drug abuse, endocarditis, tricuspid valve insufficiency and pulmonary embolism. Initially impossible to obtain PIV or CVC access; then unable to give desired fluids through 22 gauge PIV when finally placed. Proximal humerus IO access was established with the EZ-IO 45 mm needle set and the patient was resuscitated with 30 mL/kg fluids and multiple medications given in first hour. Conclusions included that CVCs are not always possible and volume treatment with an IO placed sooner rather than later, especially in children but also in adults, can be lifesaving. IO systems should be extensively available throughout the clinical setting. Article in German.

Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4
Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, “fluids” and calcium. Demarcation of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.

A case study report describing a 12-year-old male who expired following a fatal myocardial ischemia. The patient complained of severe chest pains within the week prior to the event and was misdiagnosed as having GERD. ECG by first responders showed STEMI; IO access was established in the PT for vascular access.

YEAR: 2013

Case report of 54-year-old male obtunded patient requiring a CT angiogram to diagnosis a suspected massive pulmonary embolism. After several failed attempts to reestablish PIV access, 150mL of contrast were injected through the proximal tibia IO catheter placed by EMS. Excellent opacification of the pulmonary arteries was achieved and there were no immediate complications from the injection noted.

Case study of adult multi-trauma patient that had an intraosseous device placed to a fractured left tibia and developed compartment syndrome. Authors concede it is unclear if the fluid infused through the IO device caused the compartment syndrome or if it was due to the multiple-fractures in the tibia. Authors advise against placing an IO line in an injured limb and mention the proximal humerus and sternum as alternative IO sites.
**Intraosseous Vascular Access Bibliography**

**Case Studies**


A letter to the editor reporting a case study of skin necrosis after IO administration of norepinephrine following resuscitation of a 74 years old in septic shock. The EZ-IO was placed to the proximal tibia; approximately 45 minutes post- norepinephrine administration symptoms of necrosis were evident.

Authors cite 3 hypotheses for the cause of necrosis and consider that amines’ high level concentration could induce local toxicity in the bone matrix and artery spasm; suggesting it is necessary to define an upper limit of amines’ concentration that should be administered through IO vascular access.


A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measurable blood pressure and it correlates with pressure obtained through conventional techniques.


This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handmade IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult.

**Plancade D, Millot I, Fetissof H, et al.. Sternal perforation with an intraosseous device and hemomediastinum infusion Ann Fr Anesth Reanim 2013;http://dx.doi.org/10.1016/j.anfar.2013.01.009**

A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for sternal use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.


A case study describing use of the EZ-IO in Afghanistan by US military on 5 patients with traumatic injury including one pediatric patient. Access was obtained in the proximal tibia on first attempt and was used to administer crystalloids in all patients along with opioids, analgesics and antibiotics. All ultimately received central venous access and peripheral access was established in one patient. There were no IO complications.


A case report describing administration of thrombolytics via tibial IO vascular access for pulmonary embolism in a 36-year-old woman. Due to the emergent nature of the situation, IO access was determined to be the best option for immediate vascular access. Alteplase was administered through the IO line at 100 mg over 2 hours without complication. The patient successfully recovered and was discharged from the hospital on day 7 without long-term disability. The authors concluded that this case study raised the potential use of IO lines to deliver thrombolytics in patients with massive pulmonary embolism and that further evaluation is needed to compare the risk and benefits of the alternative method of administration.


This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 mL of red blood cells via the EZ-IO in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock; and RBC infusions via the IO route are feasible in this age group.
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YEAR: 2012

This case study describes a 12 month boy who received IO access for administration of anticonvulsant therapy. Three days post IO infusion sensitivity to the leg was noted and the child returned to the ED. Blood work showed elevated white blood counts and C-reactive protein. A bone scan showed a small round lucency at the site of IO access. Two weeks later, x-rays were normal. The authors suggest that IO access may cause an increased uptake on bone scan in absence of osteomyelitis.

Physicians from two different emergency department settings reported 2 cases of supraventricular tachycardia (SVT) in infants (2 and 4 month old) in which IO administration of adenosine failed to convert SVT to a normal rhythm.

This is a case report of needle sheering associated with the use of the FAST-1 intraosseous infusion system. A soldier successfully placed a FAST-1 needle in the sternum of a healthy volunteer soldier during a training session. Upon completion of the training session, the soldier was unable to remove the needle. The retained needle was later removed surgically at a field hospital.

This letter to the editor describes a case in which a 53-year-old male in ventricular fibrillation received IO access via the EZ-IO in the ED with suspected massive pulmonary embolism. The patient was successfully resuscitated. Necrosis of the anteromedial side of the leg, at the IO site, presented 48 hrs post IO use. After 18 weeks the patient underwent surgical grafting. The authors linked the necrosis to adrenaline extravasation and local ischaemia. While the authors conclude that thrombolysis or repeated high doses of adrenaline should be given via the IO route when needed, it is not without the risk of complication.

This letter to the editor describes a case in which sternal IO access was established using a Jamshidi needle to administer iodinated contrast for a thoraco abdominal CT on a 61-year old male who presented to the ED with respiratory distress. Picture quality was deemed excellent by the radiologists. The authors conclude that the sternal IO route can be used with excellent picture quality but it should be used only in exceptional cases due to the potential risks of a high-power injection through the bone. EZ-IO is mentioned as an alternative IO device available.

This letter to the editor is written in response to the case report by Landy titled, Complication of intraosseous administration of systemic thrombolysis for a massive pulmonary embolism with cardiac arrest. The author suggests that the tissue necrosis described by Landy may have been due to the removal of the IO needle while there was still significant fibrinolytic activity at the needle insertion site. The author suggests a change in medical care after return of spontaneous circulation (ROSC) in patients following thrombolytic administration through IO access to convert the functioning IO line to a non-flowing saline lock. The EZ-IO was used to provide IO access in the case report by Landy.

YEAR: 2011

This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.

Brisson M. Trauma and the military medic. EMS1.com 12/01/2011
This article describes use of IO access along with other prehospital interventions in a traumatically wounded soldier in a combat zone. The IO site used was the proximal humerus as the patient had 3 of 4 limbs traumatically amputated.

The case report describes a woman experiencing massive hemorrhaging following emergency caesarean delivery. Though the patient possessed a peripheral IV catheter, additional IV access was needed and gained through the proximal humerus IO space using an EZ-Io. This vascular stabilization and additional filling of the central volume through the IO route allowed placement of a subclavian central line. Authors concluded that a key to the resuscitation process was the rapid utilization of the IO.


A case study report in French describing compartment syndrome secondary to intraosseous infusion in a 57-year-old burn patient. IO access was established in the proximal tibia on second attempt; both attempts were made in the same limb though it was noted that the first attempt did not penetrate the cortex. Drug and fluid infusion was initiated; ten hours later the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.


Case study of a 42-year-old woman with massive obstetric hemorrhage ultimately resulting in postpartum hysterectomy. Massive blood loss and inability to stop bleed prevented sufficient resuscitation via established PIV lines. IO access was established with the EZ-Io and used for fluid replacement and administration of cardiac resuscitation drugs. Fluid administered through IO access was 75% of the total infusion volume.


This report describes the case of a 62-year-old man who received emergency tibial IO infusion without complication in the pre-hospital setting and presented to the ED 6 months later complaining of shin pain. Drug and fluid infusion was initiated; ten hours later the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.


Case description of a critically ill 15 day old premature infant weighing 1300 g. Tibial IO access was placed perioroperatively for an urgent surgery.

Howarth D. Adult intraosseous access: experiences in a remote emergency department. Australian Family Physician 2011;40(7):510-1

In this article, the author makes a supporting case for remote emergency departments to stock adult intraosseous kits by referencing two adult septic shock cases in which IO access was used for rapid IV fluid replacement as well as IV antibiotics and inotrope support.


This article describes the case of an 11-year-old boy who suffered compartment syndrome of the lower leg following use of the EZ-Io for resuscitation and 24 hours of intraosseous infusion of adrenaline, calcium and potassium. The author concluded that further work is needed to develop recommendations for maximum duration, dose, volume and rates for intraosseous infusion.


This article reports a case in which IO access was used to deliver intravenous contrast agent in an adult blunt trauma patient. After placement in the proximal humerus, contrast agent was administered via the IO route, and clinicians found the CT scans of the thorax, abdomen, and pelvis to be adequate for diagnostic purposes and subjectively equivalent to those of studies using central venous access. There were no complications and the authors concluded that IO access appeared to be an effective alternative to traditional venous access for administering contrast agents for CT evaluation in adult blunt trauma patients.

This article in Spanish describes the Spanish military medical staff’s experience with the use of intraosseous lines for fluid therapy in a combat zone from March 2007 to June 2008. Twenty-five patients had an IO placed with the Bone Injection Gun (BIG). Placement success rates were 76% for the 19 pre-hospital placements and 100% for the 6 in-hospital placements. There were no complications during insertion. Conclusion was intraosseous access can provide an alternative to venous access for treating trauma patients in combat zones.


This article describes a case in which systemic fibrinolysis was administered through the intraosseous route in a patient with ST-segment elevation myocardial infarction. Fibrinolytics and antiarrhythmic drugs were administered through the IO line, resulting in resolution of coronary ischemia and electrical instability, without complications. Authors concluded that intraosseous cannulation represents a novel route for administration of systemic fibrinolysis in cases of difficult peripheral venous access in the out-of-hospital setting.

Taylor CC. Amputation and intraosseous access in infants. BMJ 2011;342:d2778. doi:10.1136/bmj.d2778

This article describes two cases of leg amputation after intraosseous infusion in a 5-month-old girl and a 17-month-old boy. The author concluded that fluid extravasation, exacerbated by tibial fracture and needle dislodgement during transportation, caused limb ischemia in these two patients, and that adherence to the principles of careful needle placement, splinting/securing the catheter and limb, limited length of infusion and repeated monitoring of the limb will help avoid this devastating complication.


A 7-month-old male infant in septic shock from Neisseria meningitides experienced a complication of bilateral extravasation of noradrenaline at the proximal tibia intraosseous infusion site resulting in severe soft tissue necrosis. Necrosectomy was performed bilaterally and surgical interventions were successfully performed to salvage both limbs. At 19 months the patient was able to crawl without extension deficit.

YEAR: 2010


Authors reviewed two complications (extravasation and compartment syndrome) associated with IO access in children with meningococcal disease. Authors concluded that IO systems need formal evaluation to assess safety and complication profiles.


This letter to the editor describes 2 cases in which IV administration of antivenom was not possible and was thereby administered via IO route, and in one case via the intramuscular route as well. In both cases the patients recovered.


In this abstract of a study presented at the 2010 National Association of EMS Physicians Meeting, researchers describe a study in which sternal and tibial IO devices were evaluated with and without chemical protective equipment. Researchers concluded that the use of the protective equipment did not affect the success rate or time to placement for the two IO devices.


A case study describing administration of scorpion antivenom via intraosseous (IO) vascular access in a 16-month old female. Following failure to obtain IV access in pre-hospital and upon arrival at the ED, IO vascular access was established in the proximal tibia and 3 vials of antivenom in 50 mL saline were administered over 10 minutes. Within 5 minutes, the patients respiratory status improved, intubation was averted, and vital signs stabilized immediately; nystagmus and writhing resolved. The patient was discharged home after a short observation period. The authors concluded that when IV access is difficult, IO access may be a rapid and reasonable rescue maneuver for patients requiring scorpion antivenom.


This article provides a brief history of IO infusion and further discusses this vascular access technique in terms of anatomy and physiology, indications and contraindications, performing the manual procedure, and possible complications. A case study is discussed in which a 7-month-old male was treated under emergency circumstances with IO infusion in the lower limb and developed compartment syndrome, resulting in a below the knee amputation.
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This case study describes a 25-year-old woman who had a massive pulmonary thromboembolism and was administered thrombolysis via IO route (internal tibial malleolus) in the air-transfer pre-hospital setting. The patient recovered.

Werner M, Daniel HP, Holtz J. [Intraossärer zugang beim innerklinischen notfall intensivmedizinischer fallbericht]. Der Anaesthesist 2010;59(7):628-32. German
This article in German reports a case of IO access performed in the ICU due to difficult peripheral access. The authors suggested that based on this case different strategies of critical care and possible improvements should be made.

YEAR: 2009

Burgert JM. Intraosseous infusion of blood products and epinephrine in an adult patient in hemorrhagic shock. AANA J 2009; 77: 359-63
Case report of IO infusion in 79-year old woman with hematemesis after intestinal surgery.

This case report describes a complication of use of a sternal IO device (FAST-1, Pyng Medical Corporation, Richmond, Canada) in a 21-year-old soldier who suffered multiple soft tissue fragmentation injuries, in which the needle tip broke in situ. The author concluded the complication resulted from the IO needle being placed when the patient was lying in a lateral position with the skin over the manubrium displaced from the midline.

Case study of a 9-month old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.

This article describes a case in which IO access, using the EZ-IO, was attempted in a patient with osteogenesis imperfecta. In each of 3 attempts, the needle became loose immediately after IO insertion. The author acknowledged that during emergencies it is difficult to assess and consider every possible contraindication for every intervention; and that IO access using the EZ-IO is the author’s choice for emergency vascular access when peripheral access is difficult or has failed.

Article in French. English translation not available.

YEAR: 2008

Case report of resuscitation and insulin infusion in a 5-year old child with severe diabetic ketoacidosis.
Intraosseous Vascular Access Bibliography
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This article presents a case study of an IO infusion during the anesthetic care of an infant with cyanotic congenital heart disease (CHD). The article also discusses the role of the IO route in perioperative care and reviews the adverse effect profile.

Case report of anesthetic use of IO infusion in a 8-month old infant during surgery.

Case reports in which intraosseous (IO) vascular access was successfully used on adults. Summarizes indications for use, complications, and precautions/considerations.

Moen TC, Sarwark JF. Compartment syndrome following intraosseous infusion. Orthopedics 2008; 31: 815
Case report of compartment syndrome in a 6-year old girl after IO infusion during cardiac arrest.

In this case study a 7-month-old female with comorbidities was taken to the ED in cardiopulmonary arrest. IO access was the only vascular access method available for resuscitation. Post mortem CT of the head showed a considerable amount of air within the aterial circulation; the cause of death was listed as undetermined. The authors conclude that considering the details of the patient, the only logical explanation for the cerebral arterial air embolism is that air was introduced into the bloodstream via the IO route.

YEAR: 2007

This case study describes a 4-month-old boy that was found unresponsive. Resuscitation was started and continued through arrival to the ED; IO access at the proximal tibia was established using a 15 gauge aspiration needle as the only vascular access. Post mortem multislice CT examination showed gas in the hepatic veins, the right atrium, right ventricle, the upper pole of the right kidney and the cerebral vessels. Though air embolism was ruled out as the cause this death, it could have caused death in another case. The authors conclude that gas may have entered the body during resuscitation due to IO needle disconnections and that resuscitation with an inserted, disconnected IO needle should be avoided.

YEAR: 2006

Two case studies of neonates that successfully received IO infusion.

YEAR: 2005

Nursing article discussing the utility of the sternum as a site for IO infusion. Includes clinical indications, insertions techniques, contraindications, potential complications, post-insertion care and considerations for discontinuing the sternal device.

Case studies in 2 children reviewed by 89 members of the Swiss Pediatric Anesthesia and heads of Anesthesia Departments of Swiss Teaching hospitals, IO was determined to be the safest method of vascular access on 1 of the cases. Abstract only

YEAR: 2004

Case report of acute osteomyelitis developing 10 days after IO infusion in a 5-month-old infant admitted for sepsis.

Schwartz SB, Kleid DM. Fictitious fracture after infusion of intravenous contrast material via an intraosseous needle. Pediatr Emerg Care 2004;20:829-31
Case report of misdiagnosis of a bone fracture as a result of IO infusion of radiographic contrast material in the involved extremity.
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YEAR: 2003

Case report of IO infusion complicated by iatrogenic fracture at the IO insertion site. Concludes that multiple attempts to achieve IO access weakened the bone cortex and that "considerable force" applied by an anxious 100-kg emergency room doctor led to the fracture.

Case report of a patient in asystolic arrest successfully resuscitated with an IO line inserted through deeply burned skin without complication. After multiple failed IV attempts, IO access was the only viable method of vascular access.

An 18 gauge butterfly needle was inserted into the proximal tibia of a premature infant born at 25-weeks gestation, following inability to establish other modes of vascular access due to gross oedema. The intraosseous line was left in place for 6 days until it was lost; there were no adverse events reported however the author noted that no safety data on long term use of the device was collected.

Case report of a 7-month-old infant who developed severe compartment syndrome associated with popliteal arterial thrombosis following IO fluid infusion resulting in limb amputation.

YEAR: 2002

Case report emphasizing that a cortical lesion in the proximal tibia corresponding to the site of IO insertion should not be mistaken for a radiographic sign of child abuse.

YEAR: 1999

This case study described administration of iodinated contrast via IO infusion in the tibia, for an abdominal CT scan in a 7 week old infant. CT imaging demonstrated adequate enhancement of the solid organs and vasculature.

Case report of a 6-week-old female infant with methemoglobinemia successfully treated with IO Methylene blue when other venous access was not feasible.

YEAR: 1998

A 3-year old male presented at the emergency department with rapidly progressing circulatory collapse clinically aligned with meningococcal septicemia. Attempts at peripheral and central venous access were unsuccessful. Attempts at tibial IO insertion were unsuccessful with a number of needles bending when cortical penetration was attempted. IO insertion was successfully achieved at the medial aspect of the calcaneum. IO infusion was continued for 6 hours and removed when no longer needed. The patient fully recovered and the calcaneal site healed without complication.

Case report of a 34-week-old pre-term neonate with septic shock requiring emergency treatment. Umbilical vein was unusable. Resuscitation with IO access was successful. Concludes that IO access be used before attempting access with superior longitudinal sinus. Abstract

Case report of successful use of an IO access line in an 800 gm pre-term infant.
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YEAR: 1997

Pediatric article detailing use of an IO line for bolus infusion of nonionic contrast material for CT contrast enhancement; a radiographic band may occur as a result of retained contrast material within the marrow.

Case report of an 18-month-old boy with cardiopulmonary arrest secondary to penicillin anaphylaxis successfully resuscitated by IO administration of emergency medications.

YEAR: 1996

Case report of successful resolution of supraventricular tachycardia in an infant following IO administration of adenosine.

YEAR: 1995

Case report of successful IO administration colloid, human albumin, and 1.4% sodium bicarbonate via the left hip of a 5-month-old infant with profound hypovolemia. Patient was discharged 4 days after admission.
Abstract only

Case report describing extravasation of fluids through a previous IO puncture site in the same tibia.

Case report finding IO a viable method of venous access in a child with burns.

Describes 2 cases of resuscitation of a scalded child by IO infusion following failed IV attempts. Reviews IO techniques.

Case report of IO access in a non-emergency situation. A blood transfusion was performed with no complications in a severely anemic 1-month old infant with an 18 G IO needle (Cook).

YEAR: 1994

Case report of resuscitation of a 10-day-old female infant with 2 IO infusion sites. Patient received 240 ml fluids, epinephrine, dopamine, sodium bicarbonate, human albumin, packed red cells, fresh frozen plasma, glucose, ampicillin, gentamicin, vitamin K, and pancuronium.

Case report of unilateral tibial osteomyelitis in a 20-month-old child following bilateral IO infusion. Reviews clinical indications, potential complications, and scan findings.

Case report of bilateral osteomyelitis secondary to intraosseous infusion.

Review
Case reports of 2 children with severe complications of IO infusions. One child developed severe tissue necrosis after IO placement. A second child developed compartment syndrome requiring fasciotomy.

Case report of compartment syndrome after prolonged intraosseous infusion (53 hours). Recommends that IO lines be used only temporarily until more permanent vascular access is established.

Case reports of 2 infants in the neonatal unit in which IO access was used for successful resuscitation from collapse.

Case report of fungal osteomyelitis following IO infusion in a child. Cautions that physicians consider both bacterial and fungal sources for infection.

This article presented two case studies in which pediatric patients received emergency IO infusions that ultimately resulted in compartment syndrome. In both cases the patients underwent a four-compartment fasciotomy and recovered without deficit. The authors conclude that though compartment syndrome is a risk of IO infusion, insertion of an IO line in emergency situations is a valuable technique.

Case reports of 2 9-month-old infants with severe dehydration treated with IO infusions after failed IV attempts. IO lines were replaced shortly after venous access was obtained.

Selby IR, James MR. The intraosseous route for induction of anaesthesia. Anaesthesia 1993;48:982-4
Case report of a 6-week-old infant with a head injury resulting in a fractured skull and scalp haematoma who was successfully resuscitated and anesthetized with IO infusions of colloid, blood, midazolam, suxamethonium and atracurium.

Case report outlining precautions to prevent compartment syndrome following IO infusion. Advocates early recognition and aggressive treatment to preserve function in the affected limb.

Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure.

YEAR: 1993

YEAR: 1992

Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure.

Abstract only
YEAR:  1991

Discussion of case reports of IO infusion, as well as physiology of IO and technique for IO access. Concludes that IO infusion is simple and safe. The technique can be successfully performed under field conditions by paramedical personnel, even by untrained personnel.
Abstract only

YEAR:  1990

Case report of a 6-month-old infant in cardiac arrest successfully resuscitated with IO epinephrine.
Abstract

YEAR:  1989

Case report of bone fracture following IO access in an infant.
**Intraosseous Vascular Access Bibliography**

**Case Studies**

**YEAR: 1988**


Case report of anesthetic induction through IO administration of succinylcholine chloride, atracurium besylate, and thiopental sodium in a child with seizure activity.


Article discussing IO infusion and associated rapid intravascular absorption of solutions.

**YEAR: 1987**


Several case reports illustrating the utility of IO in the emergency department. Includes discussion of IO administration of diazepam in succinylcholine.

**YEAR: 1986**


Case report illustrating value of familiarity with insertion technique for IO. Recommends that IO fluids and medications be considered early in patients requiring resuscitation.


Case report of an unresponsive 3-month-old infant with no cardiac activity. Patient was resuscitated and achieved stable cardiac rhythm and blood pressure through IO administered medications.


Case report of child with status epilepticus. IO phenytoin resulted in seizure resolution and therapeutic serum levels of drug.

**YEAR: 1984**

Berg RA. *Emergency infusion of catecholamines into bone marrow*. Am J Dis Child 1984;138(9):810-1

Case report of continuous IO infusion of dopamine hydrochloride and dobutamine hydrochloride in a 6 month old infant. Concludes that IO infusion is efficacious and complications rare.

**YEAR: 1983**


Case report of 3-year-old child permanently blinded and brain damaged because of inability to administer anesthetic intravenously. Patient was on oxygen following an inhalation anesthetic. Concludes that IO administration of anesthesia would have prevented this poor outcome.


Recommends IO infusion of fluids in cases of shock, burns, mass casualties, and also for long term parenteral nutrition whenever peripheral veins cannot or should not be used.

**YEAR: 1979**

Shoor PM, Berryhill RE, Benumof JL. *Intraosseous infusion; pressure-flow relationship and pharmacokinetics*. J Trauma 1979; 19:772-4

Preclinical study of IO flow and pharmacokinetics in the bovine tibia. Mean time to initial effect of IO administration of epinephrine was 17 seconds with 90% maximal effect in 45 seconds. Concludes that experiment provides quantitative evidence of utility of IO infusion for resuscitation.

**YEAR: 1958**

Schoenherr WF. *Intraosseous infusion of bone marrow*. JAMA 1958;166(7):853

This letter to the editor is regarding the case of a 56 year-old man that ultimately developed aplastic anemia and required blood transfusions biweekly, and being considered for bone marrow transplants. The Editor’s response briefly addressed the process of bone marrow transplantation.
Intraosseous Vascular Access Bibliography

Case Studies

YEAR: 1954

Marill F. Death from sternal puncture. JAMA 1954;155:1276
Case report of death following pericardial rupture with hemorrhage, associated shock, and peripheral circulatory collapse.

YEAR: 1951

Fortner JG, Moss ES. Death following sternal puncture: report of two cases. Annals of Internal Medicine 1951;34:809-15
Case reports of 2 deaths from sternal puncture. Discusses 4 additional cases from the medical literature. Comments of the mechanism of death.

YEAR: 1944

Recommends IO cavity of the manubrium as useful as IV for anesthetic infusion.

Bailey H. Bone marrow as a site for the reception of infusions, transfusions and anaesthetic agents: a review of the present position. Anesthesiology 1944;5(5):545-6
This abstract describes one physician's summary of experience using the sternum as an intraosseous vascular access site for 60 cases. Discusses potential benefits and complications compared to intravenous access.

YEAR: 1943

This article provides a brief history of intraosseous infusion beginning in 1903 with supportive literature through the writing of this article in 1943. An overview of mediastinitis, a complication of intrasternal blood transfusion, is also provided followed by a case report of anterior mediastinitis in an infant.

YEAR: 1941

Tocantins LM, O'Neill JF, Jones H. Infusion of blood and other fluids via the bone marrow: Application in pediatrics. JAMA 1941a; 117(5):1229-34
Describes emergency IO infusion of citrated blood and saline into the tibia or femur of 9 infants. IV access was impossible. Found no complications upon clinical or x-ray examination post-infusion.

Early study of 4 patients with acute failure of the peripheral circulation. IO infusion of blood, fluids, or drugs via the bone marrow resulted in a prompt recovery from the state of collapse. Recommends IO route when peripheral veins are not available and a fluids are urgently needed.

YEAR: 1934

This article describes one clinician's use of sternal IO access for infusion of campolon to treat anemia in 1930. The author performed over 50 injections without serious complications.

Sweden
Retrospective case-control feasibility study comparing proximal tibial intraosseous (PTIO) and peripheral intravenous (PIV) delivery of contrast media in 24 patients receiving emergent CT scans as part of trauma diagnostics (n=4 PTIO, n=20 PIV). Delivery of contrast media was by power injection with rates of 5cc/sec for CT images of the head and neck, chest, abdomen and leg vessels. There were no significant differences in ability to complete imaging protocols or image quality. There were no complications. The study was limited by low patient numbers.


This study compared IO insertions with the EZ-IO device (tibial/humeral insertions) to the FAST-R device (sternal insertions only) in a physician-staffed helicopter emergency medical service. Insertion time, insertion site, flow, indication for IO access, and complications were compared. Median insertion time was 15 seconds for EZ-IO and 20 seconds for FAST-R. Overall, 35.1% of EZ-IO insertions resulted in poor flow and required a pressure bag while 85.7% of FAST-R insertions had good or very good flow. EZ-IO complications included extravasation (2.4%), aspiration failure (11.9%), and insertion time >30 seconds (4.8%). Complications associated with FAST-R included user failure (12.5%) and insertion time >30 seconds (12.5%). The authors suggest that although EZ-IO is faster the FAST-R device may be more useful when high-flow infusion rates are required. The authors indicate that a low number of insertions were made with the FAST-R device and many OUTliers were observed in the data. However, the article does not present the total number of insertions per device.

https://doi.org/10.1007/s12028-018-0637-2

Retrospective analysis of 76 patients exhibiting clinical symptoms of intracranial hypertension (ICH) that received 23.4% NaCl via the central venous catheter (CVC, n=38) or intraosseous (IO, n=38) access. IO insertion success was 97%; 33 were placed in the proximal humerus and 5 in proximal tibia. Transient hypotension was noted in 10 patients with IO devices and 3 with CVCs, an insignificant difference. No IO specific complications were noted. Time to delivery of 23.4% NaCl was faster with IO access; outcomes for CVC and IO were similar. Limitations include retrospective data, no ICP monitors, small numbers of patients.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

This study sought to investigate the reliability of ROTEM parameters in IO blood for the purpose of allowing a target-oriented administration of procoagulant agents in patients with IO access only. Healthy subjects and subjects undergoing minor surgery under anesthesia were enrolled. The EZ-IO device was used to obtain IO samples. Tibial and humeral sites were used. Due to clotting in a majority of samples, only 9/23 samples were evaluable and ROTEM was feasible in only 3/23. The authors conclude that ROTEM measurements from IO samples are not reliable and should not be used for guidance of procoagulant therapy in the emergency setting.

YEAR: 2018

This article describes a study using prospective sampling of bone marrow (BM) to assess the feasibility of using bone marrow samples for blood group serotype analyses. Peripheral blood (PB) from each subject was used as that subject's control. 71 pairs of BM and PB samples were tested for ABO type, D type, and RBC alloantibody screening. All BM samples were successfully analyzed with no inconclusive results. The study concluded that BM samples collected from IO devices can be utilized for blood group serologic analyses.

This article describes a prospective, comparative, nonrandomized study to compare flow rates using the sternal IO route with two different devices (EZ-IO and Fast1) when transfusing warm fresh whole blood as well as measuring post-infusion hemolysis when compared to IV infusion. Post procedure blood samples from all patients were within normal ranges with no statistically significant differences between groups. This study had a high catheter insertion failure rate in the IO groups. This was most likely due to subjects, healthy Norwegian military volunteers, performing the procedures on each other. The results suggest that infusion of fresh whole blood via the IO route is safe and reliable.

This study compared tissue concentrations of low-dose vancomycin via intraosseous regional administration (IORA) vs actual body weight-adjusted IV dosing in total knee arthroplasty (TKA) in obese patients (BMI>35). The obese patient population has an increased risk of periprosthetic joint infection after TKA. 22 patients were randomized to receive either 15mg/kg (max 2 g) of systemic vancomycin or 500 mg vancomycin via IORA. Fat and bone samples were taken and antibiotic concentrations measured. The overall mean tissue concentration in the subcutaneous fat was 39.3 µg/g in the IORA group vs 4.4 µg/g in the IV group (P<0.01). Mean tissue concentrations in bones were 34.4 µg/g in the IORA group vs 6.1 µg/g in the IV group (P<0.01). Low-dose IORA vancomycin was effective in providing tissue concentrations 5-9 times higher than IV administration in this high risk patient population.

This study was a prospective, single-center, observational, cohort study of 10 patients comparing the ventricular enhancement time between humeral intraosseous (HIO) access and brachial intravenous (BIV) access during CPR in adult humans. HIO access was obtained via the EZ-IO device. Endpoints were right and left ventricular enhancement times after administration of a contrast agent. Results indicated that arrival times of medication at the right and left ventricles were significantly lower with HIO than BIV.

Prospective cohort study done by review of video footage which was taken over a 15 month period as part of a quality improvement initiative for patients in extremis (the absence of a palpable pulse or measurable blood pressure) undergoing thoracotomies during trauma resuscitation. Data recorded for vascular access included types intraosseous (IO), peripheral intravenous (PIV), central venous (CVC) and intracardiac (IC)) and site of attempted access, number of attempts and success rates, procedure time, demographics, and mechanism of injury. 145 access attempts were made in 38 patients (median 3.8 (SD 1.4) attempts per patient). Time to access was similar for PIV and IO but longer for CVC and success rates for IO insertion were significantly higher than for PIVs or CVCs (95% vs. 42% vs. 46%, p<0.001). Authors "recommend placement of IO cannulae as a best practice to rapidly establish first line vascular access for resuscitation and as a bridge to additional access."

This article is a systematic review and meta-analysis of risk factors and interventions related to IV administration of contrast media.

Prospective randomized clinical trial in which IO access was compared to peripheral intravenous access (PIV) in pediatric patients with septic shock. Children’s ages ranged from 1 month to 36 months old and weights ranged from 4 to 14 kg with similar characteristics in both groups; 30 patients in each subset. The IO group had significantly shorter vascular access insertion times, shorter length of stay and reduced mortality. IO access was achieved in the proximal tibia on first attempt for all insertions; 50% of PIV attempts failed on first attempt. There were no complications for the IO subset compared to 26.7% for PIV. There was a reduced ability to aspirate for labwork via the IO access. This study supports existing literature that early use of IO insertion is safe and effective with minimal complications.

Feinstein BA, Stubbs BA, Rea T, Kudenchuk PJ. Intraosseous compared to intravenous drug resuscitation in out-of-hospital cardiac arrest [Letter to the Editor, Authors’ Reply]. Resuscitation 2018;127:e2

This letter to the editor is the authors’ response to another letter to the editor by Drs. Soar and Hormis for their review of the authors’ study comparing initial access between IV and IO during out-of-hospital cardiac arrest (OHCA) resuscitation. Reference: Feinstein BA, Stubbs BA, Rea T, et al. Intraosseous compared to intravenous drug resuscitation in out-of-hospital cardiac arrest. (Initial publication: Resuscitation 2017;117:91-96)


This study evaluated emergency department (ED) nurses’ success rate, compared with paramedics, in establishing pediatric IO access using semiautomatic devices. The NIO and EZ-IO devices were used by both nurses and paramedics on uncooked bones of 8- to 12-week-old piglets. A total of 34 and 30 insertion attempts were performed by 17 ED nurses and 15 paramedics, respectively. First attempt success rates were 79.4% for nurses and 83.3% for paramedics. 82.3% of nurses and 73.3% of paramedics recorded the EZ-IO as their “first choice device”. The findings of this study suggest that ED nurses have the competence to perform IO insertions and this technique should be used in nursing school curriculum.

Fenwick R, Nutbeam T, Lowther A, Mann T. Maximising flow in intraosseous: An in vitro study. Poster presented at: Trauma Care Conference; April 15, 2018; Staffordshire, United Kingdom

This poster presents the findings of an in-vitro study to measure the time taken to administer 500 mL of saline via the intraosseous (IO) route using three different methods of administration: fluid giving set placed directly on the IO needle hub (DTO), fluid giving set connected to the EZ-IO device extension set (EZS), and fluid giving set connected to a simple 3-way extension set (TWS). The EZS set produced the slowest administration times. The authors concluded that clinicians may be able to increase IO flow rates by replacing the extension set that is supplied with the EZ-IO.


A retrospective analysis of data collected in the prehospital setting to evaluate the effect of either intravenous (IV) or intraosseous (IO) vascular access management of non-traumatic, adult, out-of-hospital cardiac arrest (OOHCA) cases on patient (pt) outcomes. Results: 23.9% IO patients achieved ROSC vs 38.3% IV; 3.8% IO subjects survived to hospital discharge vs 10.3% IV subjects. The authors concluded that in patients with non-traumatic OOHCA, use of IO access is associated with lower survival and poor neurologic outcomes as compared to IV access. Limitations: 660 pts received IO access (5%) and 12,495 received IV access (95%); selection bias by paramedics choosing the vascular access method based upon presenting conditions; and IO access had a higher proportion of non-shockable initial rhythms, fewer public location and witnessed arrests and shorter times from call to first ALS paramedics arrival.


This letter to the editor is in response to Nurii et al.’s letter to the editor regarding Kawano et al.’s article on the effect of time to vascular access in out-of-hospital cardiac arrest (OHCA). Kawano et al. performed Nurii et al.’s suggested sensitivity analysis by modifying their multivariable logistic regression model to include duration of out-of-hospital resuscitation among patients with return of spontaneous circulation (ROSC) or termination of resuscitation as measured from the 911 call to either ROSC or termination of resuscitation. The authors conclude that the model continued to demonstrate that IO access, when compared to IV access, was associated with a decreased probability of a favorable neurologic outcome.


This letter to the editor is in response to Kawano et al.’s article on the effect of time to vascular access in out-of-hospital cardiac arrest (OHCA). Kawano et al. found an association between intraosseous vascular access and lower survival and worse neurologic outcome in OHCA. Nurii et al. express concern regarding selection bias and confounding factors not being accounted for in the original study. Nurii et al. suggest accounting for time from call to vascular access or return of spontaneous circulation (ROSC). Nurii et al. also suggest considering whether ROSC is an appropriate outcome. Reference: Kawano T, Grunau B, Scheuermeyer FX, et al. Intraosseous vascular access is associated with lower survival and neurologic recovery among patients with out-of-hospital cardiac arrest. (Initial article: Ann Emerg Med. 2018;71:588-596).
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

Investigators assessed the ability of EMS providers with various skill levels to correctly identify the insertion sites for both the proximal tibia and proximal humerus. Participants were attending a state EMS conference. The distances from the sites identified to correct site was significant. The study concluded the accuracy of landmark identification was low and proper training is important.

This study compared the success rates and time to placement for Manual IO versus EZ-IO needles in pediatric emergency department (PED) patients ≤8 kg and >8 kg at a single institution. It was a retrospective, cross-sectional, descriptive study. All identified patients with an IO attempted in the PED were included. Fifty patients were identified. In patients ≤8 kg, overall success rates were 55% (17/31) for Manual IO and 47% (8/17) for EZ-IO. In patients >8 kg, Manual IO success rates were 100% (2/2) and EZ-IO success rates were 93% (14/15) for overall attempts. Time (minutes) to successful placement in patients ≤8 kg was 4.5 for Manual IO vs 12.8 for EZ-IO (P=0.02). In patients >8 kg, time to successful placement was 8.5 for Manual IO vs 10.2 for EZ-IO (P=0.70). Overall success rates in this study were poor in both groups, most likely due to lack of experience at IO insertion or inadequate device training. Access in smaller patients was more difficult and required greater time to insertion.

Redfield C, Suarez S, Daniels, Sanchez C, Siples H, Landry K. The effect of IV vs. IO access in prehospital cardiac arrest ROSC rates. Prehosp Emerg Care 2018;22(1):38
Retrospective study reviewing data from one EMS service that compared return of spontaneous circulation (ROSC) in cardiac arrests when intraosseous (IO) or intravenous (IV) access was obtained. An IV was placed in 361 patients with a ROSC in 148 (41.1%); and 360 patients had an IO placed with a ROSC in 80 (22.2%). The difference for greater ROSC rates with IV vs. IO use was significant.

This article investigates intraosseous fluid (IOF) as an alternative matrix for drug testing in deceased patients, especially in cases where the cadaver is severely compromised following death. IO access was obtained at 4 sites, bilateral proximal tibia and bilateral proximal humerus, using the EZ-IO device. Samples in 29 subjects were collected and screened for a host of illicit substances. Study results support the possible use of IOF as an alternative postmortem specimen for toxicological investigations when necessary.

This article examines emergency vascular access during newborn resuscitation. It discusses the time needed to place an emergency umbilical vein catheter (eUVC) and intraosseous kits (EZ-IO) in a series of simulated newborn resuscitations across 4 studies. In all 4 studies IO placement was significantly faster than eUVC placement. An additional study found eUVC placement to be significantly faster with real human umbilical cords than with simulated umbilical cords as used in the aforementioned studies. While IO access in newborns appears faster then eUVC in simulated models, to date, no randomized trials or large case-cohort studies have systematically evaluated the short and long-term safety of IO placement during newborn resuscitation. Current guidelines still support eUVC as the preferred method of obtaining vascular access during newborn resuscitation. The authors suggest further studies are needed to determine short and long-term safety of IO access in newborns before widespread adoption of the process can be recommended.

This letter to the editor provides a response to Feinstein et al and refutes their findings, from comparison of IO and IV drug resuscitation in out-of-hospital cardiac arrest (OHCA), that a tibial IO access was associated with a decreased likelihood of return to spontaneous circulation (ROSC) in OHCA patients. Author A Hormis provides a conflict of interest stating he has undertaken educational cadaveric teaching on behalf of Teleflex. Reference: Feinstein BA, et al. Intraosseous compared to intravenous drug resuscitation in out-of-hospital cardiac arrest. Resuscitation. 2017,117:91-96.

This study aimed to compare the success rates of 4 commonly used IO devices (NIO Pediatric, BIG Pediatric, EZ-IO, and a manual Jamshidi IO needle) in a pediatric model. Speed of insertion, ease of use, and complications were secondary outcomes. Seventy-five novice physicians from Warsaw, Poland participated in this study; none of whom had prior experience with IO devices. First attempt success rates were 43% (Jamshidi), 90% (BIG), 97% (EZ-IO), and 100% (NIO-P). Median time to achieve IO access was 18 seconds (NIO), 23 seconds (EZ-IO and BIG), and 34 seconds (Jamshidi). 39/68 participants preferred the NIO device, 18/68 preferred the EZ-IO device, 11/68 preferred the BIG device, and none of the participants preferred the Jamshidi needle.

This paper describes a project where information was collected using a paper survey from EMS and ED providers in Nebraska. The purpose of the survey was to identify gaps in their skills, knowledge and abilities in order to aid curriculum development for a mobile training unit to be used in rural areas of the state. Intraosseous placement is a clinical skill in which the participants would like further training.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies


This is a prospective, randomized, controlled trial of patients undergoing revision total knee arthroplasty (TKA). Twenty patients were randomized to receive systemic IV or IO regional administration (IORA) of vancomycin as prophylaxis. Higher tissue and bone concentrations were consistently achieved in the IORA group with tissue concentrations during the procedure 5 to 20 times higher in the IORA group versus the IV group. The EZ-IO device was used to gain IO access in this study.

YEAR: 2017


This journal article discusses the importance of early in medical school and/or residency training of intraosseous access by use of cadaver courses can help increase the skills for IO use needed for use in real life situations thus improving patient safety.

Afzali M, Kvisselgaard AD, Lyngeraa TS, Viggers S. Intraosseous access can be taught to medical students using the four-step approach. BMC Medical Education 2017;17(50):doi:10.1186/s12909-017-0682-7. (Denmark)

This study evaluated the ability to teach the skill of IO access in a four hour timeframe to medical students using a modified Walker and Peyton's four-step approach teaching method and a cadaveric model. The learner's competencies were evaluated with an objective structured clinical examination checklist. This study found the teaching method was successful. Authors recommend repetitive training to be integrated to medical curriculum for maximal skill retention.


This study compared success rate, procedure time and user satisfaction of pediatric NIO vs. Pediatric BIG, EZ-IO and Jamshidi intraosseous access devices in pediatric manikins. Study was randomized, crossover trial with 87 paramedics participating. The study evaluated each device on the ease of use in performing their procedures. Results of this study found that paramedics favored the NIO in ease of use in the pediatric manikins.


A retrospective chart review was done to analyze data of three EMS agencies over an 18 month timespan. Analysis was done on charts from adults who suffered OOHCA and received epinephrine through EMS established IV or IO access. An IO first approach was found non-inferior to an IV first approach based on the end point ROSC at time of emergency department arrival.


This is an abstract of a cross-over study comparing the ease-of-use and success rates of cadaver IO insertions performed by paramedics while wearing their standard pre-hospital clothing or Chemical, Biological, Radiation and Nuclear (CBRN) personal protective equipment. Insertion times were significantly longer while wearing CBRN (25 seconds vs 34.38 seconds). IO access was obtained using the EZ-IO device.


This study reviews current IO administration of antidotes for patients that have presented to the emergency department with serious poisoning and IV access is not available. The study concluded that the evidence supporting the use of IO route for administering antidotes for poisoning patients is rare. Most evidence of IO access administration of antidotes has occurred in animal studies and case reports. Per author, despite lack of evidence, IO access is a potential option for antidotal treatments for resuscitation for patients where IV access is not available.


This study addresses the need for the development of a reliable and validated tool to evaluate technical resuscitation skills in a pediatric simulation setting. The authors created four resuscitation and emergency simulation checklist and evaluation tools were created, (RESCAPE). Study found that use of the RESCAPE tools are reliable and validated tools for evaluation of resuscitation skills in pediatric simulation-based educational programs.
Intraosseous Vascula


This retrospective cohort study evaluated emergency medical services (EMS) that treated adult patients with atraumatic out of hospital cardiac arrest (OHCA) in order to compare drug administration via intraosseous (IO) versus intravenous (IV) and the effectiveness. Study endpoints were survival to hospital discharge, return of spontaneous circulation (ROSC), and survival to hospital admission. The study included 1,800 patients, 1,525 of whom received IV access and 275 who received IO access. The practice for OHCA management in the EMS system from which the data was obtained was to attempt tibial IO access after failed IV attempts. The authors concluded that use of IO access was associated with a lower likelihood of ROSC and hospitalization; and acknowledged that further study of how vascular access routes affect OHCA patient outcomes is warranted.

Iskrzycki L, Smerka J, Szarpak L. Knowledge, skills, and attitudes concerning intraosseous access among hospital physicians. Crit Care Med 2017;45(1):e117

This letter to the editor describes a manikin study that compared use of the Teleflex EZ-IO to the Persys Medical NIO intraosseous vascular access devices. Insertion times were statistically different, favoring the NIO but not considered clinically relevant. The authors concluded that, while hospital physicians' knowledge of intraosseous access was limited, with simple training they could learn the procedure and place IO needles safely in less than 30 seconds.


This article describes a retrospective, CT-assisted evaluation of IO cannula placement. Over a 5 year period all multislice-CT trauma scans performed in a trauma center were monitored for intraosseous devices in situ. 982 patients were evaluated and 13 IO cannulas were found in 11 patients. In all cases, the EZ-IO device was used. Evaluation of placement found that all applications were placed correctly, but none were according to current guidelines. The site of puncture deviated in all cases with the most common error of overshooting during needle introduction. (Article in German)


Study using 31 healthy volunteers to evaluate IO blood samples drawn from the proximal tibia compared to arterial and venous samples using a POC lab device. Two samples were drawn from each site with no significant difference observed in the results with or without waste blood. Results varied particularly between the arterial and IO samples; and for several parameters. Authors concluded that IO blood samples may be evaluated using the i-STAT® point-of-care analyser; and results should be interpreted with care in the clinical situation context.


This study evaluated the efficacy and safety of Shengxue mixture when combined with IO blood infusion for the treatment of aplastic anemia patients at Shaanxi Medical University in China. Patients were treated with oral Shengxue mixture, stanozolol tabs, mycophenolate and IO infusion of recombinant human EPO, G-CSF, IL-11, and dexamethasone. After 1 month of treatment the response rate was 90.57%. After 3-6 months the response rate was 96.23%. The authors concluded that Shengxue mixture combined with IO infusion was a fast, efficient, and safe method of treatment of aplastic anemia. Article in Chinese.


This poster presents a complication and unexpected ultrasound findings associated with IO infusions attributed to fat embolism. At necropsy, lung histology of 35 female swine revealed numerous large fat emboli consisting of bone marrow cellular elements and adipose cells within medium-sized arteries. High IO infusion rates also contributed to fat embolism in the femoral vein. Providers should be aware of the potential for pulmonary embolism.


This study investigates infusion flow rates through a standard 16-gauge peripheral angiocatheter inserted into a single corpus cavernosum of the penis to support the hypothesis that the penis can be an efficient means of providing rapid fluid resuscitation. This study suggests that the penis may be an alternative to traditional vascular access routes (peripheral IVs, IO insertion, central venous catheters, and vein cutdown procedures) when vascular access is difficult. Flow rates in the study were comparable and in some cases superior to other alternative means of vascular access.
This article describes a prospective, observational study that attempted to establish baseline values of IO pressure (IOP) in a healthy human population. Subjects had an IO device placed in the tibia and humerus. IO pressures, vital signs, and pain scores were monitored for 60 minutes. Absolute IOP values were not consistent between subjects. Future research is needed to determine how IO pressure can be used to guide therapy in ill and injured patients.

Using a porcine hind leg model authors compared the success rate and ease-of-use ratings of an IO device, the NIO® in comparison to the Arrow® EZ-IO by novice users. NIO success rates were comparable to those of EZ-IO; 54% of the participants preferred using the EZ-IO over the NIO.

This article assesses the usability of the Partial Task Trainer (PTT) to train certain military medical providers on the technique of humeral head intraosseous infusion (HHIO). The PTT consists of an arm with functional structures and characteristics that allow trainees hands on practice locating anatomical landmarks, inserting the IO needle, and introducing the catheter into the humerus. Currently the US Army utilizes the EZ-IO Intraosseous Infusion System for HHIO infusions.

A prospective study comparing results of intravenous (IV) and intraosseous (IO) blood specimens when analyzed using an EPOC point of care analyzer during resuscitation. Seventeen patients who had IO and IV specimens collected within 5 minutes of each other were included in the study; IO samples were collected before administration through the IO catheter in the proximal tibia or proximal humerus. Results showed that based upon Bland Altman plots, there was reasonable agreement between IV and IO values for pH, bicarbonate, sodium and base excess, and moderate agreement for lactic acid. The intraclass correlation co-efficient was excellent for sodium and reasonable for pH, pO2, bicarbonate and glucose. The primary limitation noted was the small sample size (n=17) and the substantial impact of single outliers in the data.

This retrospective study of a quality and safety database compared procedures performed by use of intraosseous vascular access for contrast media infusion to a control group of the studies in the database performed with antecubital intravenous access. The quality metrics of the two groups were similar, with the intraosseous needle group being slightly better. There were no complications related to IO use in general or specifically associated with the procedures. Limitations included this was a single-center study with small sample size and possible selection bias due to unfamiliarity with IO access.

This retrospective non-inferiority study examined EMS data extracted from a statewide EMS data system over a two year period. IO placements were with the EZ-IO®. The investigators concluded successful IO access was not different among AEMTs and Paramedics of Orthopaedic Surgeons Annual Meeting; March 14-18, 2017; San Diego, CA. Abstract P118

This is an abstract of a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Overall geometric mean tissue concentrations in fat samples were 3.7 µg/g in the IV group vs 49.3 µg/g in the IORA group (P<0.001) while mean tissue concentrations in the femoral bone were 6.4 µg/g in the IV group vs 77.1 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

Young SW, Clarke HD, MoorGA, Zhang M, Spangehl MJ. Higher tissue concentrations of vancomycin are achieved with intraosseous versus intravenous administration in revision TKA. The Knee 2017;24(6):XIV (Abstract 0018).
https://doi.org/10.1016/j.knee.2017.08.045.

This abstract describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Mean tissue concentrations in fat samples were 4.1µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 8-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

Young SW, Clarke HD, Pitto R, et al. Higher tissue concentrations of vancomycin with low-dose intraosseous regional versus intravenous systemic prophylaxis in revision TKA. ePoster presented at: International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine Biennial Congress; June 4-6, 2017; Shanghai, China. ePoster 1230

This e-poster describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty-two patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin with 20 patients analyzed. Mean tissue concentrations in fat samples were 4.1µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

Young SW, Zhang M, MoorGA, Pitto RP, Clarke HD, Spangehl MJ. Higher tissue concentrations of vancomycin with intraosseous regional prophylaxis in revision TKA: A randomized controlled trial. Manuscript submitted for publication

A randomized controlled study comparing antibiotic tissue concentrations when vancomycin is administered for total knee arthroscopy via IO and IV access. Ten subjects were randomized to each group. The IO group received 500 mg vancomycin injected directly into the proximal tibia IO insertion site below an inflated thigh tunicate, and the IV group received 1 gram vancomycin, both were given before skin incision. Results showed IO tissue concentrations of vancomycin were 5-20 times higher than systemic IV despite the lower dose. This study was sponsored by Teleflex Incorporated.

YEAR: 2016


This study compared maximum concentration time (Cmax) to maximum concentration mean (Tmax) of mean serum concentration of vasopressin, return of spontaneous circulation (ROSC), time to ROSC, with odds of survival to vasopressin administration by tibial intraosseous, proximal tibia IO (PTIO), and intravenous (IV) routes in a cardiac arrest model. Authors concluded TIO and PHIO provide rapid and reliable access in administration of life-saving medications during cardiac arrest and may be faster due to IV difficulty.


Investigators conducted a retrospective prehospital study over a 3 month time period comparing IV vs. IO access for return of spontaneous circulation (ROSC). With approximately 800 cases of out-of-hospital cardiac arrest (OOHCA) they found a significantly greater success rate for IO access but no difference between IO and IV for ROSC or time to first epinephrine.


Preclinical RCT evaluating the relationships between the anatomical distance of IO epinephrine and measures of resuscitative outcome in an adult swine model of ventricular fibrillation (VF). There were no significant differences between the HIO, TIO, and IV groups relative to the occurrence of ROSC, 30 minute post-ROS C survival, and time to ROSC. The anatomical distance of IO epinephrine injection from the heart did not affect short-term measures of resuscitative outcome in an adult swine model of VF including the occurrence of ROSC, 30 minute post-ROSC survival, and time to ROSC. Rapidly administered epinephrine, irrespective of route of administration, increased the chance of ROSC and survival to 30 minutes post-ROSC in this study.


The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.

Singapore
This prospective, experimental study was to characterize and compare the pharmacokinetics of atropine that is administered via sternal intraosseous (IO) route in hypovolemic and non-hypovolemic swine. Main outcomes PK parameters, maximum concentration (Cmax) and time to reach maximum concentration (Tmax). Authors concluded sternal IO route is effective for administration of atropine and data gained from this study was found to be similar to previous information reported on tibial IO and IV administration even in situations of significant hemorrhage.


The abstract describes the interim results of an investigational device exemption study evaluating use of EZ-IO in volunteers for a 48 hour dwell time period. At the time of the report, 39 subjects completed the study with no serious adverse event reports. Subjects were randomized to receive IO insertion in the proximal tibia or proximal humerus insertion sites. Pain has been managed using oral hydrocodone/acetaminophen and/or intravenous/intramuscular ketorolac. This study is sponsored by Teleflex Incorporated.


This study was conducted to determine the level of experience as well as the beliefs and attitudes of trauma practitioners in Canada, Australia and New Zealand about using IO devices in adult trauma patients. The study used a web-based survey submitted to 1771 to all members of 4 national emergency and trauma organizations. Surveys were completed by 425 participants and most participants surveyed were comfortable using the IO device in resuscitation of adult trauma patients.


This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access "should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation".


This study examined the relationship between body mass index (BMI), the ability to palpate the tibial tuberosity (TT), and soft tissue depth associated with IO needle insertion in obese patients using ultrasound. Authors concluded IO access "should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation".


Authors described a randomized, double-blind trial, comparing parenteral amiodarone, lidocaine, and saline placebo, along with standard care, in adults who had non-traumatic out-of-hospital cardiac arrest, shock-refractory ventricular fibrillation or pulseless ventricular tachycardia after at least one shock, and vascular access (N=3026). The focus of the study was not intraosseous access, but eligible patients had intravenous or intraosseous access (n=661).


This article describes an experimental study to determine patient perception of discomfort during IO injection for dental procedures involving the mandibular molars. Subjects (N=70) received either IO injection (N=35) or inferior alveolar nerve block (N=35) with articaine/epinephrine. Both groups reported similar rates of supplemental injection (P=0.80) while the IO group reported less perceived discomfort (P=0.00), differing statistically.

A prospective study with 30 evaluable healthy volunteers receiving PH and sternal IO access (Arrow® EZ-IO® Vascular Access System and T.A.L.O.N.™, Teleflex, Wayne, PA) was conducted to determine if there is a significant difference between pain after a total of 60mg or 40mg of 2% preservative-free and epinephrine-free lidocaine. Endpoints were subject reported pain scores during 5 minutes of rapid infusion at 300 mmHg and 15 and 30 minutes at a rate of 125 mL/hour per pump. Authors concluded infusion pain through a PH IO may be managed with a single 40mg lidocaine prior to infusion, but a total of 60mg may be considered for sternal IO infusion. This study was sponsored by Teleflex Incorporated.


This letter to the editor describes a novel training technique employed to provide training to clinicians on use of the EZ-IO system, in 15-minute sessions. Implementation of this program has resulted in 97% of participants reporting an increase in confidence using the EZ-IO system and 100% were able to correctly identify the locations of the devices for their clinical areas.


This abstract describes the results of a healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used safely and successfully in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9,587±2,706mL/hr (n=27); mean PH infusion rate was 6,292±3,277mL/hr (n=92). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.


A study comparing use of the Bone Injection Gun (B.I.G.) and the NIO by paramedics in a manikin model simulation of CPR. Following training, 40 paramedics performed device insertion in the manikin using both devices; and completed a questionnaire regarding their knowledge of indications and contraindications of IO access and experience with each device. Successful insertion was achieved 100% with the NIO and 95% with the B.I.G. Authors concluded that after a short training program, paramedics can perform intraosseous injection with a high degree of efficacy.


This retrospective study evaluated 3 years of data in an urban EMS system to determine if out-of-hospital intraosseous (IO) access results in shorter time to epinephrine than peripheral intravenous (PIV) access. The proximal humerus was the most common IO access site with a first pass IO success rate of 95.6%; and a significantly lower complication rate when compared to the tibia. Authors reported the time to epinephrine administration was faster in the IO access group; and concluded the out-of-hospital use of IO vascular access for time-dependent medical conditions is recommended.


A retrospective study evaluated vascular access routes used for US Military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) use including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. PIV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

A cadaveric study evaluating the function and safety of a manual, screw IO device designed to gain access to the medullary space. Twelve insertions were performed by the same device operator, of which 10 were successful. The 2 failed insertions were due to overshooting of the needle. The authors concluded the new device could successfully penetrate the bone cortex in adult cadaver bones, and that further testing and comparison to commercially available devices is needed.

A survey study evaluating the perception and use of intraosseous vascular access among nurses in Poland. The study included 210 respondents. Fifteen (15) had previous experience with IO access and 10.9% had received intraosseous access training, suggesting a low level of knowledge. The authors concluded that providing intraosseous vascular access training to nurses will help improve their perception of IO access.

This letter to the editor describes a simulation study evaluating use of the NIO device by 47 firefighters in a simulated anaphylactic shock model. The firefighters were trained on use of the device and standard anaphylactic shock management. An improvement in knowledge of intraosseous vascular access and anaphylactic shock protocol was demonstrated by the group.

This randomized crossover manikin trial compared the NIO and EZ-IO devices for time to placement and ease of use. For both parameters the NIO performed better.

A questionnaire study among sixty junior doctors, in Poland, regarding their knowledge of intraosseous vascular access. The authors concluded the level of knowledge was insufficient.

A manikin study in which 40 paramedics dressed with and without CBRN PPE attempted to establish tibial intraosseous (IO) access using the jamshidi and BIG devices, time to placement was measured. Results showed that in participants with and without CBRN PPE, BIG access was faster than Jamshidi.

A prospective study comparing use of the NIO device by 84 paramedics to establish proximal humerus and proximal tibia intraosseous (IO) access for first attempt success rate, time to access, and user feedback on ease of use and preference. IO access was established in fresh (within 72 hours of expiration) cadavers. The first attempt success rate with tibial IO access was 89.3% vs 73.8% humeral; procedure time was significantly faster for the tibial IO site; and participants found IO access in the proximal tibia as easier to obtain than the proximal humerus IO site.

This letter to the editor describes a prospective, randomized, cross-over cadaveric study that evaluated use of the EZ-IO and NIO devices by novice paramedic device users. Following a brief in-service on use of both devices and practice insertions using a leg-trainer manikin, each participant attempted to establish IO access using each device in a resuscitation simulation with an adult cadaver with CPR in progress. Results showed first attempt success rates of 97.4% with the NIO and 100% with the EZ-IO; and mean time to insertion was 16.8 seconds with the NIO and 42 seconds with the EZ-IO.
### Intraosseous Vascular Access Bibliography

#### Clinical, Observational and Other Studies


This article describes a questionnaire study regarding knowledge and application of intraosseous vascular access among 420 clinical medical staff in 8 Beijing Hospitals. Based upon results of the questionnaire, the authors concluded that the awareness rate of intraosseous infusion in Chinese medical staffs and carry-out rate in the hospital is very low and strengthening of knowledge and training is necessary.


This is an abstract of a study conducted in the UK to determine the success rate of the EZ-IO Intraosseous Infusion System on return of spontaneous circulation (ROSC). Patient records were examined for 195 cardiac arrest patients who had an EZ-IO placement attempt. ROSC was achieved for 29% of patients. In patients who received IV administration of medications, 46% achieved ROSC. While IV access appears more favorable in this study, there may be other factors associated with achieving ROSC that were not taken into account.


A simulation study comparing use of peripheral IV access and tibial intraosseous access via the NIO device, by internal medicine specialists. Forty-three participants attempted to establish access using the two methods in a manikin; first attempt success, time to access and ease of procedure were measured. The NIO device was superior to IV access with regard to all endpoints.

**YEAR: 2015**


This article describes the strategies used at one hospital (Penn Presbyterian Medical Center) to increase the use of intraosseous catheter to rescue patients in all care settings.


This crossover study using mature mini-swine was performed to assess the efficacy of intraosseous administration of contrast agents for CT (computed tomography) imaging of the chest and abdomen. Authors concluded that in the model used, an injection intraosseous (IO) of contrast material through the proximal humerus resulted in improved quality of trauma-protocol CT images.


This study examined whether the use of dual-intraosseous needles to deliver fluid and medication when vascular access is insufficient. The study used a single porcine humerus. The authors concluded that dual intraosseous needles are feasible and may help the rapid resuscitation of patients.

**Eriksson M, Strandberg G, Lipcey M, Larsson A.** Intraosseös provtagnings kan vara vardefull i akuta lagen [Intraosseous sampling can be valuable in emergency situations]. *Lakartidningen* 2015 Feb 24;112pii:DCR3. Swedish

This article in Swedish describes a study evaluating use of aspirate obtained from the IO space for laboratory analysis. The authors note that point-of-care equipment should be used for analysis. Creatinine, morphine and troponin was successfully analyzed; leucocytes and platelets were noted to possibly cause falsely elevated values.


A preclinical study in which 8 anesthetized swine were put into an induced septic shock state to allow troponin I level measurements to be compared from serial venous plasma, arterial plasma and intraosseous aspirate specimens collected hourly. Two milliliters of IO aspirate were wasted before collecting each IO specimen for analysis. The levels of IO troponin I increased during the first 3 hours of shock but then plateaued at a high level while the venous and arterial levels continued to increase. Authors concluded that troponin I can be analyzed in bone marrow aspirates in a shock model and that this information may be useful in medical emergencies where cardiac damage is suspected to be involved.


A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.
Lantis D, Goforth D. Intraosseous needles reduce time to first medication for coding inpatients without intravenous access. Crit Care Nurse 2015;35(2):e69

This abstract describes data from a small hospital study after a 2013 policy change which allowed rapid response team nurses to place IO access for in-hospital cardiac arrests. Prior to the change the mean time to first medication was 4.3 minutes with 53.1% patients surviving to ICU. Post-policy change patients that received IO access had a mean time to medication of 1.7 minutes and 85.7% survival to ICU.


This single center, prospective, observational clinical study compared use of intraosseous (IO) access to central venous catheter (CVC) access for inpatient medical emergencies, managed by the medical emergency team (MET), within an urban teaching hospital. CVC access training included percutaneous, landmark-guided CVC placement without ultrasound guidance, using the femoral vein as the primary site. For IO access, the proximal tibia was the primary site and proximal humerus was secondary. Results showed IO access was significantly superior to CVC access with regard to first pass success rates, overall success rates, time to placement, and number of attempts for proper placement. On average more CVC kits were used per patient; complications were greater with CVC. There was one serious complication of tissue necrosis secondary to extravasation in the IO group.


In a healthy adult volunteer study contrast media was injected through the proximal humerus site and captured under fluoroscopy as it entered the heart. The mean time it took from injection at the insertion site to visualize contrast entry into the superior vena cava and the right atrium was 2.42 seconds. Abstract presented at ACEP 2015. This study was sponsored by Teleflex Incorporated.


A simulation study comparing use of manual (Cook Medical) and mechanical (Arrow EZ-IO) intraosseous (IO) devices to establish IO access in mannequin bones representing infant, pediatric and adult tibias. Twenty-two anesthesiologists with no prior experience with IO devices participated in the study. The outcome measures were success rate, insertion time and operator reported difficulty of use. Results were in favor of the mechanical device for insertion time in each category, and success rate in the adult tibia group; there was no statistical difference in the difficulty of use evaluation.


Abstract describing preliminary results for the first 24 subjects of an EZ-IO study evaluating catheter dwell times for 48 hours. Initial data indicate that IO vascular access can be safely maintained for a period up to 48 hours without risk of osteomyelitis or other serious adverse events. Authors also noted that additional analgesics for IO infusion pain management may be more effective than the current solely administering lidocaine into the IO space. This study was sponsored by Teleflex Incorporated.


A cadaveric study evaluating intraosseous (IO) vascular access insertion rates for attainable flow rates under 300 mmHg. The EZ-IO was used to establish IO access at the proximal humerus and proximal tibia sites; the FAST1 was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 286 ± 218 mL for the humerus; and 154± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.


This abstract describes pilot data regarding initial vascular access device use in emergency department management of patients with out-of-hospital cardiac arrest. Twenty-six patients were included, and only 10 arrived to the ED with venous access established in the field: 4 via intraosseous and 6 via peripheral IV. Of the 16 subjects without access upon ED arrival, PIV was selected for 12 and IO was selected for 4. Nine patients experienced a delay in obtaining access attributed to the selection of PIV as the initial mode of gaining access. Median time required for access was reported as: 50 seconds for IO; 95 seconds for PIV and 780 seconds for CVC. The authors concluded that selection of PIV as the initial access method may be associated with delayed vascular access in the ED.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies


This abstract describes a pilot observational study of vascular access devices (VAD) and their use in management of 20 out of hospital cardiac arrest patients. VAD selected, number of attempts for successful placement and time to insertion were recorded. Twenty patients were included in this study, 10 of whom received IO access upon ED arrival.


An abstract describing preliminary data evaluating the effect of initial vascular access device selection on the management of out-of-hospital cardiac arrest (OOHCA) patients by the ED. Twenty patients were included. Success rate by vascular access device selected was: 66% IO lines (2/3); 25% for PIV lines (3/12); and 100% for CVC (1/1). Eight patients experienced a delay in access due to initial method selected, 7 were attributed to PIV and 1 to IO. The authors concluded that the results suggest use of PIV as the initial mode of access may be associated with delays in access when compared to IO access in patients with OOHCA.


A healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. Military trained medics performed all device insertions. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used by military and tactical medicine personnel to safely and successfully establish IO access in the sternal with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating attempts to establish intraosseous vascular access in pediatric patients using a manual device and the EZ-IO, in a tertiary care pediatric emergency department. Results showed 35 patients had IO access attempted using manual and EZ-IO devices. In patients greater than and less than 8kg the EZ-IO had a higher success rate but time to placement was longer. Overall success rate including both devices was 64%. There were 2 complications of transient leg swelling after EZ-IO placement in 2 patients.


A retrospective study evaluating the use of pre-hospital and emergency department placed IO access in children before transport to a children's hospital. Data were extracted from a Level 1 trauma, tertiary care children's hospital transport database from 1993-2009. There were 143 eligible patients with an average transport distance of 33 miles; all but 8 catheters were placed by the ED. The most common reasons for IO placement were no IV access (53%) and no perfusion (33.6%); the most commonly reported complication was infiltration (27.3%); 46.6% of patients experienced no complication. The authors concluded IO access plays a significant role in promoting life-saving efforts when IV access is unachievable or no perfusion is determined.


This preclinical study evaluated the occurrence of fat intravasation resulting from intraosseous (IO) flush and infusion in anesthetized swine. Intravasated fat was assessed using a lipophilic fluoroprobe (Nile red) and by vascular ultrasound imaging. Fat intravasation was observed during all IO infusion regimens, with subclinical pulmonary fat emboli persisting 24 hours post infusion. It was noted that initial flush was a significant factor in fat intravasation, low levels of intravasation occurred with infusions ≤300 mmHg, fat intravasation and bone marrow shear-strain increased with IO infusion rates, and intravasation was influenced by cannula insertion site.


A pilot study evaluating the relationship between intraosseous (IO) pressure measurements and blood pressure obtained via external blood pressure cuff in ICU patients. Patients with IO access established by EMS or in the emergency department with planned admission to the ICU or surgical ICU were included in the study. External pressures were recorded every 15 minutes and IO pressure was monitored via a transducer for 12 continuous hours. Results showed IO pressures were approximately 30% of external blood pressure cuff readings.


The authors described a proof of concept pilot study conducted to determine intraosseous (IO) pressure measures and their relationship to blood pressure obtained using an external blood pressure cuff in ICU patients. The average IO systolic blood pressure, IO diastolic blood pressure, and IO mean were 39.5±12.7 mm Hg, 31.5±7.6 mmHg, and 35.0±8.8 mm Hg respectively. The ratio of IO systolic blood pressure to cuff systolic blood pressure, IO diastolic blood pressure to cuff diastolic blood pressure, and IO mean to cuff mean are 34.5±13.4%, 40.5±22.3%, and 40.1±17.1% respectively. There were no adverse events reported. Investigators concluded that in their convenience sample of severely ill and injured patients, IO pressure was reliably obtained and appeared to be 35% to 40% of blood pressure readings obtained via external blood pressure cuff; and that this method of pressure monitoring may be an appropriate alternative to invasive monitoring option in the future. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies


This abstract describes a study (SAFER) reporting initial emergency department efforts in obtaining adequate vascular access (AVA) and initiating appropriate fluid resuscitation for hypovolemic patients with undifferentiated hypotension within the first 60 minutes following ED arrival. AVA was defined as any two of the following: PIV, IO, or CVC catheter. No data was given regarding time to IO access in the results.


This is an abstract of a study that analyzed possible technical and anatomical factors leading to the complication of amputation as a result of IO placement. The study was prompted by a case report of amputation in a neonate after IO access using the EZ-Io device. The study measured medullary diameter of the proximal tibia at the recommended IO access site in three groups: 1-28 day old full term neonates, 1-12 month old infants, and 3-4 year old children. The mean diameter in each group was 7.7 mm, 9.9 mm, and 12.4 mm, respectively. The small size of the IO space, especially in neonates and infants, makes correct placement difficult. As such, complications should be taken into consideration in this patient population.


This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive drug in pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.

YEAR: 2014


This article in French is a survey of residents and doctors in France that practice in ED, ICU and anesthesiologists units seeking their opinions and practice habits in regard to IO access. Only 29% had ever used an IO kit; with a correlation between years of experience in practice and use of IO access. 555 had received some IO access training; 90% of untrained doctors believed training was necessary. The powered system was the most utilized (EZ-Io).

France

Anson JA. Vascular access in resuscitation: Is there a role for the intraosseous route? Anesthesiology 2014;120(4):1015-31

Literature review through August 1, 2013 with primary aim to determine whether there is a role for intraosseous vascular access in the resuscitation of critically ill patients. Secondary aims were to investigate the evidence regarding clinical use, drug administration, and complications of IO access. The authors concluded that IO access can be achieved quickly and accurately in emergency situations and there is clearly a role for it in resuscitation of ill patients; anesthesiologists should become familiar with IO access.


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-Io and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.


Randomized comparative study of adult pigs infused intraosseously with either: 7.5% hypertonic solution (HTS), 3% HTS or normal 0.9% isotonic saline. The animals were observed daily for infection, necrosis and gait up to 5 days, then necropsy and histological analysis was performed for tissue necrosis. Observations included regular tissue morphology and normal gait scores over the 5 day observation period; and absence of gross tissue necrosis and microscopic ischemia post IO HTS infusion in this swine model. Authors concluded this study confirms the clinical safety of IO HTS infusion and its use as an alternative lifesaving treatment.

Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) whole blood transfusion relative to hemolysis and transfusion time. IO transfusion does not significantly increase hemolysis (using free hemoglobin as outcome measure) or transfusion time compared with IV transfusion. Authors concluded transfusion of whole blood through an IO device is an effective transfusion method that may be used until other vascular access is obtained.

Cheung WJ, Rosenberg H, Vaillancourt C. Barriers and facilitators to intraosseous access in adult resuscitations when peripheral intravenous access is not achievable. Acad Emerg Med 2014;21:250-6. doi:10.1111/acem.12329

This survey study sought to identify the barriers and facilitators to use of intraosseous vascular access for adult resuscitations when peripheral IV (Piv) access is not available, among physicians from various clinical care settings in 3 teaching hospitals in Ottawa, Ontario. Completed survey responses were received from 205 physicians; results suggest that to increase IO use educational interventions need to address their attitudinal, normative, and control beliefs. Specific beliefs that act as barriers are described.


This was a prospective, randomized controlled clinical pilot study comparing the BIG and EZ-IO intraosseous (IO) vascular access devices in 52 adult patients admitted to an emergency department with difficult peripheral venous access. Twenty-six patients were randomized to each device; results were first attempt insertion success BIG 92.3%, EZ-IO 84.6% (P=0.668); procedure time: BIG 2.8 ± 1.2 seconds, EZ-IO 5.2 ± 2.2 seconds (P<0.001), significant; difficulty of use (with visual analogue scale): BIG 8.6 ± 6.4 mm, EZ-IO 25.4 ± 12.6 mm (P<0.001), significant. Authors concluded both EZ-IO and BIG are shown to be reliable and safe methods for insertion of intravascular access in emergency conditions. There were no adverse events or complications reported.

Derikx HJGM, Gerritse BM, Gans R, vander Meer NJM. A randomized trial comparing two intraosseous access devices in intrahospital healthcare providers with a focus on retention of knowledge, skill, and self-efficacy. Eur J Trauma and Emerg Surg 2014;doi:10.1007/s00068-014-0385-8

This article describes a randomized trial comparing the retention knowledge, skill and self-efficacy among anesthesiologists and registered nurses of anesthesia with use of the EZ-IO and Bone Injection Gun (B.I.G.). Participants were randomized to be trained on one device and were tested at 0, 3, and 12 months post training. The authors concluded that training anesthesiologists on use of the EZ-IO with the educational tools provided by the manufacturer will ensure optimal performance for a period of one year.


The objective of this study was to use a competency exam to compare different emergency skills and knowledge between out of hospital emergency physicians (OOHEP) and those who are not OOHEP at the time of their mandatory biannual refresher courses. Results from 836 respondents suggested that OOHEP are significantly more likely to initiate intraosseous access, initiate mild-therapeutic hypothermia, and had higher knowledge about the used defibrillator.


A cadaveric study performed by dentistry and medical students evaluating the feasibility of gaining vascular access via the anterior mandible bone.

Haggglund H, Remberger M, Ringden O. Twenty-year follow-up of a randomized trial comparing intraosseous and i.v. BM transplantation [letter to the editor]. Bone Marrow Transplant 2014;49(12):1541-2. doi: 10.1038/bmt.2014.184

This letter to the editor reports the 20 year follow-up of a randomized study comparing IO and IV transplantation of allogeneic hematopoietic stem cells from sibling donors conducted in 1998. At the 20 year follow-up the probability of graft versus host disease, treatment related mortality, and relapse probability were similar between the two groups. None of the patients in the trial developed a secondary malignancy.

Ibrahim M, Cairney K. A comparison of intravenous and intraosseous vascular access during simulated cardiac arrest on an Advanced Life Support course. Resuscitation 2014;85:S20

This abstract describes a simulation study that evaluated the time to access and rate of first attempt success for establishing IV and proximal humerus IO access in an ALS training course. Thirty-three participants had a first attempt IV success rate of 70% compared to a 100% success rate with IO access. The authors concluded that successful humeral IO access can be achieved following a short education intervention.

A preclinical study comparing intraosseous (IO) and intravenous (IV) administration of Hextend in 27 swine for time of administration and hemodynamics. IO access was established in the proximal humerus using the EZ-IO. Results showed time for administration was not significant; there were no significant differences between IV and IO relative to hemodynamics. The author concluded that the IO route is an effective method of administering Hextend.


Manikin study conducted in Poland with 107 paramedic operators designed to investigate the success rate, time of insertion and perceived difficulty of intraosseous access devices during simulated resuscitation using the EZ-IO, Bone Injection Gun and Jamshidi needles. Results were first attempt success: B.I.G.: 91.59%; EZ-IO: 82.66%; Jamshidi: 47.66%; mean procedure time: B.I.G.: 2.0 min ± 0.7; EZ-IO: 3.1 min ± 0.9; Jamshidi: 4.2 min ± 1.0; and ease of use (1-very easy to 5-very hard): B.I.G.: 1.83; EZ-IO: 2.92; Jamshidi: 4.68.


The objective of this study was to evaluate inclusion of IO access in Korean medical education with a selected group of 50 medical students. Students received 1 hour of didactic lecture and a 1 hour hands on session using the EZ-IO and artificial tibias and were tested. Results showed an insertion success rate of 88%. The authors concluded IO access was adequate for medical education in Korea.


In this pre-clinical study, investigators sought to determine if the pressure readings at the proximal tibia IO site served as a good indicator of proper IO placement when the foot of the limb was squeezed. Traditional methods used to determine correct IO placement, including needle stability, aspiration of blood, and easy infusion, were used as comparators. Results showed the increased pressure reading at the IO site successfully predicted correct IO placement in all cases; traditional methods did not consistently correctly identify proper IO needle placement.


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.


This abstract describes the results of an observational clinical study that evaluated the use of IO vascular access via the proximal humerus insertion site for administration of contrast media for computed tomography examination. Eight subjects were enrolled into the study, 7 procedures were performed successfully with adequate opacification of the images. One subject experienced extreme pain with the contrast injection, the procedure was terminated and an alternative vascular access route was utilized. There were no serious complications reported. This study was sponsored by Teleflex Incorporated.


A preclinical study comparing the time to onset, time to onset peak, and time to recovery of peripheral intravenous and tibial intraosseous administration of Rocuronium. Study results demonstrated there was no statistical difference front the time of administration to complete neuromuscular blockade between the IO and IV administration of Rocuronium; and the recovery of neuromuscular function was significantly longer after IO administration, however was not deemed clinically significant. The authors concluded that Rocuronium can effectively be used via the IO route without the need for dose adjustments.


This abstract describes an observational study evaluating use of the intraosseous drill (EZ-IO) in 20 patients assisted by EMS and receiving CPR within a 3 year period. The study includes 4 pediatric and 16 adult patients. The authors concluded that IO access is a reliable alternative to peripheral venous access and can be implemented fast and with high success rate of CPR in which drugs and fluids are given.

Spain
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

This abstract describes a practice seminar held at the 32nd annual meeting of the Japanese Society of Reanimatology for establishing intraosseous vascular access in simulation using the EZ-IO and using Doppler ultrasound to confirm placement. The authors concluded the EZ-IO system enables immediate vascular access to the central circulation and the Doppler method enables objective recognition of needle misplacement.

In a series of studies using healthy adult volunteers the objective was to add to available data comparing IO marrow/blood (initial 1 mL aspirate), IO blood (subsequent aspirate), and venous and capillary blood to determine if there is a correlation between samples for serum lactate and PT/INR levels. Two point-of-care analysers were used. Conclusions were lactate levels obtained from IO blood appear comparable to lactate levels from venous blood; the PT/INR levels did not correlate. This study was sponsored by Teleflex Incorporated.

Retrospective study of the Israeli Defense Force (IDF) registry from January 1999 through October 2012 to identify all cases in which IO access was attempted. The Bone Injection Gun (B.I.G.) was the device used for IO access. A total 37 attempts were made in 30 patients. First attempt success was 53% with an overall success rate 49% when factoring subsequent attempts. Most frequent cause for failure related to providers skill level, and due to the device design allowing little room for error. This study prompted the IDF to seek an alternative for the B.I.G.

Israel

This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.

This letter to the editor describes a cadaver study performed by 50 interns who had never performed IO insertion, to determine if there is a learning curve associated with use of the EZ-IO for establishing IO vascular access in the proximal tibia. Following training each intern performed 10 IO insertions and were timed. The results showed a difference between the first and the eighth attempts resulting in a decrease in time to insertion by half. The authors concluded that practice insertions are necessary to become comfortable with the device.

Turkey

This article explores use of IO vascular access in combat and tactical settings through a brief review of the literature describing this practice. A small feasibility study is discussed that evaluated the use of cadavers for training 26 U.S. Air Force Pararescuemen (PJs) on establishing IO access in the humeral head (proximal humerus is the descriptor used by EZ-IO for this site) using the EZ-IO powered driver and needle set system (pictured in the article) and needles inserted with a manual driver without power. First attempt placement success with the EZ-IO powered driver system was achieved in 25 of 26 attempts; first attempt placement success using the manual driver and needle set occurred in 19 of 21 attempts. The authors concluded that the humeral head (proximal humerus) IO site is the most appropriate site within the tactical setting; and that use of a human cadaver model for training is an appropriate model.

A preclinical study comparing the recovery of fibrinogen in a porcine model when fibrinogen concentrate is administered via IV and IO access. The study results suggested intraosseous administration of fibrinogen concentrate results in a recovery of fibrinogen similar to that of intravenous administration.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

This article explores the use of IO access in the prehospital setting to determine if IO access is sufficient for massive fluid resuscitation in trauma patients or if central venous cannulation should be considered. Massive transfusion is defined as 10 units of blood within 24 hours at a rate of more than 150 mL/minute. Through a review of the literature the authors determine that IO access is rapid with a high success rate. IO access allows a bridge to initiate resuscitation while minimizing on scene delays, and has a low complication profile, all benefits over central venous cannulation.

This prospective study sought to evaluate intraosseous flush practices of emergency physicians. Using cadavers, 15 emergency physicians were asked to flush an IO catheter placed in the proximal tibia and proximal humerus IO insertion sites with 10 mL normal saline as they would in clinical practice; IO pressure measurements were recorded using an IO catheter inserted in the diaphysis of the target bones. Results showed the median IO pressure generated was 903 mmHg and the median flush duration was 5.2 seconds. Result showed significant interoperator variability with greater than 35-fold difference in flush forces. The authors concluded that it may be prudent practice for providers to extend the flush over several seconds to limit the maximal pressures.

A prospective study evaluating patient comprehension of and willingness to receive intravenous (IV) access over intraosseous (IO) access based upon the delivery method of the IO information. Patients were randomized to receive IV or IO access using standard text or video information. Results showed there was no difference in patient comprehension based upon education modality (text or video); all groups preferred ultrasound guided peripheral IV access over IO access.

This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).

A questionnaire and interview study evaluating the reasons paramedics do not perform intraosseous (IO) vascular access more frequently. Twelve paramedics in Johannesburg, South Africa were interviewed for the study. Results suggested access to inappropriate equipment (pink hypodermic needles), inadequate training, lack of use in hospital Emergency Departments to which they serve, and the perceived invasiveness of the procedure and pain caused during infusion dissuaded paramedics from performing the procedure.

Abstract reporting on retrospective prehospital study to evaluate the rate of out-of-hospital return of spontaneous circulation (ROSC) in the cardiac arrest patient. The following were assessed and analyzed for direct or indirect correlation on ROSC: dispatch time to arrival, number of intravascular attempts per method (IV versus IO) and rate of success. Conclusions were that ROSC can be achieved more rapidly when IO access is used as the first attempt method in obtaining vascular access in prehospital cardiac arrest. There was a trend in shorter ROSC times among the first attempt IO group compared to the IV group; the difference did not reach statistical significance, most likely due to a lack of power from the smaller sample size of the IO group.

Abstract presented at the Society of Cardiovascular Computed Tomography on preliminary findings of an observational study done after training ER physicians and techs on intraosseous (IO) catheter use and implementation of a policy for IO access use. Authors report high injection rates and excellent computed tomography angiography (CTA) scans safety with use of an IO for power injection of iodinated contrast media (ICM). Authors concluded cardiovascular imaging physicians, surgeons, ER physicians, and CT technologists should be familiar with the techniques of IO needle placement and use for power injection of ICM for CTA. The diagnosis and treatment of critically ill and unstable patients may be hastened by this technique.

This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroplasty. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.
A pre-clinical study that was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated. Results showed that IO pressure was approximately 25% of arterial pressure. A sampling of IO blood gases revealed oxygenation levels of venous blood. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This is a preclinical study comparing the EZ-IO and the Cook manual IO needle when used by 21 resident physicians to establish IO access in anesthetized swine. Results showed the drill-assisted needle was successfully placed 100% of attempts vs 76.2% successful placement with manual; time to placement and user preference also favored the EZ-IO. Technical issues reported included bending of the manual needle 33% of attempts.


A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices.


This article in German explores use of intraosseous access in a dental practice emergency. In a simulation study, dental students attempted to establish standard peripheral IV access and IO access using 3 different devices: EZ-IO, BIG, and manual IO. Results showed the manual was the fastest to insert, however, the EZ-IO had the highest first-attempt success rate as well as the lowest number of total attempts to IO access.


This abstract describes the results of an online survey taken by members of the Obstetric Anaesthetists Association, evaluating use of IO access in obstetric emergencies, and availability of IO equipment on UK labor wards. Results showed many members are trained on IO access, consider it a viable option during emergencies however have limited access to equipment.


This abstract describes a study in which 66 obstetric anesthetists, obstetricians and midwives were training on the EZ-IO and evaluated for successful application of the skill in a mannequin study. The participants also completed a survey following their insertion attempt regarding their perceived ease of use and likeliness to consider IO use in the future. Results showed first attempt success was 95.5%; respondents indicated they found the EZ-IO to be easier than establishing PIV access and 100% indicated they would consider IO use in the future.


Pre-clinical study comparing flow rates acheived after insertion with the EZ-IO in the proximal tibia, distal femur, and proximal humerus in a swine model. IO catheters were placed in each site and normal saline was infused for 10 minutes using a pressure bag at the highest achievable pressures greater than 300mmHg. The flow rates through the proximal humerus were statistically greater than that of the femur or proximal tibia. The femur flow rates were higher than the proximal tibia but similar. Post-mortem histopathologic evaluations done to assess for damage due to the high infusion pressures were consistent with IO catheter placement.


In this preclinical swine study, investigators sought to evaluate whether intraosseous blood samples can be used to measure opioids, and if so, to determine the level of accuracy of those measurements. Blood samples were drawn from bilateral tibial IO catheters and from a central venous catheter for six hours. Authors concluded that IO blood samples can be used for the analysis of opioids if an IV route is not available.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies


Authors described a study in which adult living donor kidney transplantation recipients (N=7) were given mesenchymal stem cells (MSC) derived from the donor bone marrow to evaluate the safety and the feasibility of immunological changes related to the intraosseous injection of MSC into the bone marrow. They concluded that donor MSC injection into the iliac bone at the time of transplant was feasible and safe.


This abstract describes a study in which the investigators sought to determine the approximate patient population in which the 25mm EZ-IO needle set was sufficient length to establish IO access in peripartum patients. Ultrasound was used to determine the tissue depth at four insertion sites. Twenty-six women were recruited with a median gestation of 34 weeks. In 88% of patients with a BMI<40 kg/m² the 25mm needle is sufficient to reach the bone marrow at both tibial sites. For the humeral site, IO placement may be more difficult for patients with a BMI>25 kg/m².


This retrospective study evaluated the number and type of critical procedures, including IO line placement, performed in the ED of a tertiary care pediatric institution over a 12 month period. The authors concluded that critical procedures were rarely performed in a large academic pediatric ED; pediatric emergency medicine faculty are at significant risk for skill deterioration; and fellows are unlikely to achieve competence in performing critical procedures.


A clinical study evaluating the relationship between IO blood and peripheral venous blood lactate levels analyzed using the i-STAT point-of-care analyzer in healthy volunteers. Results showed IO blood lactate levels were comparable to venous blood lactate levels with a positive statistical correlation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This retrospective review of medical records submitted by paramedics identified patients 18 years or younger who had prehospital peripheral IV (PIV) attempts. Over 101 months at least 1 PIV attempt was made on 4188 patients ≤18 years old. The study demonstrated that success rates are significantly associated with patient age and each 1 year increase in age increased the odds of successful PIV placement by 11%. The authors suggest that IO access with the use of a semi-automated IO device (EZ-IO) may be a more efficient first-line method for immediate treatment after 1 PIV failure, especially in younger patients given their higher rate of PIV insertion failure.

Oksan D, Ayfer K. Powered intraosseous device (EZ-IO) for critically ill patients. Indian Pediatr 2013;50(7):689-91

A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 80 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case).


An observational study evaluating use of the EZ-IO by two ground and one air based physician staffed EMS and at a German surgical university hospital between January 1, 2008 and December 31, 2011. The EZ-IO was used to establish IO access 88 times in 87 patients; 83 insertions were performed in the EMS and 5 were performed in the hospital. The proximal tibia was the primary site used (97.7%) and the first attempt success rate was 94%. IO access was the first approach for vascular access in children compared to adults (38.9% vs. 86.2%). There were 5 failures attributed to missed insertions or extravasation and 2 for wrong needle length. There were no serious complications.


A simulation study evaluating if use of a laryngeal mask airways (LMA) and intraosseous (IO) lines established using the EZ-IO leads to improved resuscitation in a simulated cardiac arrest when compared to standard endotracheal intubation and central line placement. Results showed mean time to airway, mean duration of airway attempt, and time to vascular access was shorter in the IO group than the CVL group. Time to defibrillation and percent hand off time was not significantly different between the groups.

An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal tibia was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse, difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.


This is an abstract of a study that analyzed prehospital missions of the Greater Sydney Area Helicopter Emergency Medical Service (GSA-HEMS) involving a blood transfusion, with IO administration recorded as one possible route of administration. The study determined that the carriage and use of blood is both feasible and safe in a physician-led helicopter emergency medical service.


This is an abstract of a study that analyzed the mission profiles and interventions performed during rescues involving the winching of a physician in the Greater Sydney Area Helicopter Emergency Medical Service (GSA-HEMS). A structured case-sheet for a predetermined list of physician-only interventions (POI) was conducted, of which IO access was an intervention. The study showed a high rate of POI thus supporting the winching of physicians.


This study conducted by the Norwegian Navy evaluated the ability of 25 soldiers to perform buddy transfusion by starting phlebotomy, establishing sternal IO access using the FAST1, and infusing 1 unit of whole blood. Physical performance was evaluated pre and post blood donation and lactate levels were recorded. The authors concluded that physical and combat performances are preserved within limits post whole blood donation and that soldiers are able to learn the phlebotomy and sternal reinfusion with only a short lecture on the procedure.


A quality initiative study conducted evaluating use of the EZ-IO needles in pediatric patients and their associated complications rates when placed by EMS/ED staff compared Air Evac Lifeteam placement in 2012. The authors concluded that the powered IO device was appropriately utilized by ED/EMS staff as well as Air Evac staff and that there was no difference in the complication rate when the device was used by the two groups.


This observational pre-hospital study conducted in Madrid, Spain prospectively evaluated use of the EZ-IO Jan 2007- Dec 2009 as an alternative to peripheral IV access. During the study period, 107 patients underwent 114 EZ-IO insertions and all were successful on first attempt. IO access was established in the proximal tibia (49%), distal tibia (25.2%), radius (14.9%), and humerus (10.5%) and all lines were the first form of vascular access established in the patient. There were no adverse events or complications.


A prospective study comparing IO and venous laboratory values obtained from a point-of-care analyzer (i-STAT) in 20 children. IO blood specimens were collected from the iliac crest; 2 ml were discarded before the sample was collected analysis. Results showed differences between venous and IO sample were clinically acceptable for pH, base excess, sodium, ionized calcium and glucose in hemodynamically stable patients. Authors concluded that analysis of IO samples with a bedside point-of-care analyzer is feasible and in emergency situations may be useful to guide treatment.


A study evaluating the use of X-tip intraosseous injection of 2% lidocaine with 1:80,000 epinephrine in dental patients with irreversible pulpitis in whom inferior alveolar nerve block has failed. Thirty patients were included and 93% of X-tip injections were successful. Ninety-six percent of patients had subjective/objective increase in heart rate. Results showed X-tip intraosseous injection of 2% lidocaine was effective in achieving pulpal anesthesia in patients with irreversible pulpitis.

A clinical study comparing Cefazolin concentrations found at the operation site following total knee arthroscopy when prophylactic antibiotics are administered systemically, through IV administration, and regionally, through IO injection directly at the site using the EZ-IO. Subcutaneous fat and bone samples were collected for evaluation from 22 subjects. Authors concluded that regional IO administration of prophylactic antibiotics can achieve tissues levels higher than with systemic administration.

YEAR: 2012


A pre-clinical study that compared the EZ-IO 15 gauge 25mm needle set and the 13 gauge Jamshidi aspiration/biopsy needle when used to obtain core biopsy specimens in canines.


Preclinical study using a porcine model comparing the maximum concentration and time to maximum concentration of epinephrine administered via the tibial IO, sternal IO and IV routes during CPR. The IV route of administration of 1mg of epinephrine resulted in a serum concentration 5.87 and 2.86 times greater than the tibial route and sternal route respectively. The times to peak concentration was similar for IV and sternal IO groups but delayed for the tibial route. Authors conclude that due to limitations of their study the guidelines of administering 1mg of epinephrine via the IO route should not be changed; further studies using larger sample size, larger volume flush, arterial blood samples and the use of a more precise method of measuring serum epinephrine should be done.


Manuscript of a literature review and critical analysis done to develop the Emergency Nurse’s Association (ENA) December 2011 Emergency Nursing Resource (ENR) which focused on the clinical issue of difficult IV access. Graded recommendations and decision options are provided for alternatives to IV access, including IO.


This abstract presented at the 2012 ACEP Research Forum discusses a swine pre-clinical study evaluating CT image opacification when contrast is delivered via IV and proximal humerus IO access. The EZ-IO was used to facilitate IO access. Results showed that under blinded radiology review the IV and IO images were judged adequately opacified to meet diagnostic criteria. Authors concluded that IO administration of contrast material may be a viable alternative if other vascular access is unavailable or if establishing other access will lead to a delay in diagnostic evaluation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Esteo OV. Intraosseous access in prehospital emergency care. Emergencias 2012;24:44-6

A prospective, observational study which evaluated use of the EZ-IO within the prehospital setting over the course of a 3 year period, in Barcelona, Spain. Included patients were in cardiac arrest or with hemodynamic instability, without peripheral venous access after 90 seconds or 3 attempts to establish access. Results showed IO access was attempted in 49 pediatric and adult patients with an overall success rate of 93.9%; complications included extravasation and pain. IO access sites included the proximal tibia (71.4%), proximal humerus (22.4%) and distal tibia (6.1%). The author concluded that IO access is a viable access route for the management of critical patients or those in cardiac arrest in the pre-hospital setting due to the ability to obtain rapid access and the high first attempt success rate.
This article discusses a retrospective review of Japanese prehospital system for intravenous infusion success rates in cardiopulmonary arrest (CPA) patients and a prospective simulation study. A nationwide database was reviewed for CPA records from 1 January 2005 to 31 December 2008 yielding 431,968 cases. Results showed the IV infusion success rate in adults increased annually, however the rate in pediatrics did not; and while the administration of adrenaline increased the 1-month survival rate did not. In the simulation study, 100 EMS technicians used the Bone Injection Gun (BIG) in simulator adult, pediatric and infant legs. There was no difference in the time to establish IO access between the simulation models. The authors concluded that IO access should be considered when IV access is difficult or impossible.


This pre-clinical study sought to compare the flow rates of blood administered through an IO needle in the proximal tibia, distal femur and the proximal humerus in an adult hypovolemic swine at an infusion pressure greater than 300 mmHg. Investigators also evaluated the presence of fat emboli in the lungs. Results showed that the mean rate of IO infusion of blood through the swine humerus (103 mL/min) was greater than the femur (49 mL/min) and tibia (78 mL/min); fat emboli were detected in the lungs of most animals (tibia: 14.14; humerus: 10/11; femur: 8/14).


This abstract presented at the 2012 ACEP Research Forum discusses a literature review of intraosseous access publications since 1985 providing an updated safety profile for IO access. The search resulted in 192 articles describing IO access with 6 cases of osteomyelitis and 6 cases of compartment syndrome secondary to extravasation reported. Of the 192 articles identified, 140 described the EZ-IO. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2012 ACEP Research Forum describes a preclinical swine study evaluating the ability to induce therapeutic hypothermia by infusing chilled saline via IV and IO access. The EZ-IO was used to facilitate IO access. Results showed statistical equivalence between IV and IO routes when used to deliver chilled saline to induce therapeutic hypothermia. Results also showed that use of chilled saline and infusion tubing submerged in an ice water bath provides the most effective means of cooling. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A pre-clinical study evaluating the time to loss of consciousness and effective maintenance of anesthesia following IO and IV administration of propofol in rabbits. The authors concluded that in all evaluated aspects of anesthesia, IO administered propofol was as effective as IV administration in rabbits.

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A pre-clinical study evaluating the systemic bioavailability of antidotes when administered via the intraosseous (IO), intravenous (IV), and intramuscular (IM) routes is described. Results showed rapid and substantial antidote bioavailability after IO administration similar to that of the IV route. Authors concluded that the IO route of antidote administration should be considered when IV access is difficult.


A literature review of articles describing intraosseous vascular access devices used in the pre-hospital setting. Twenty articles met the inclusion criteria and described the manual devices, BIG, Fast-1 and the EZ-IO. The authors concluded that the literature suggests that semi-automated IO devices may be more effective than manual devices.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.

This article describes a post mortem study evaluating a newly developed technique to study the intraosseous vasculature of the humerus involving injection of ink directly into the anterior circumflex humeral artery. This technique allowed visualization of the main nutrient artery to the proximal humerus vasculature until they reached articular cartilage or crossed cortical bone again to enter the rotator cuff tendons.

Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14
The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access.

This pre-clinical study sought to evaluate the various pressure levels obtained by 22 veterinary clinicians when administering a 10ml normal saline flush of an IO catheter. The EZ-IO was used to establish access in an isolated, cadaveric swine femur. The authors found the median peak intraosseous pressure was 615 mmHg with a range of 57 to 1,100 mmHg. Authors concluded that there is a great deal of variability between clinicians and their flush pressure and that a standardized flush protocol may be beneficial.

This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.

This prospective observational study compared flow rates between distal and proximal tibia IO access in adults, with each adult serving as their own control. The EZ-IO was used to facilitate IO access. IO infusion was performed with and without pressure. The authors concluded that infusion flow rates were significantly higher in the proximal tibia as compared to the distal tibia, and that flow rates are significantly higher with pressured infusion vs. non-pressured infusion. This study was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2012 ACEP Research Forum explored the viability of the distal femur as an IO insertion site with a literature review of IO vascular access and brief overview of a post-mortem study of pediatric distal femur insertion success. Authors concluded that clinical literature, clinical studies, and a post-mortem study confirm that the distal femur is a viable option for IO infusion in pediatric patients. This study was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.

This poster presented at the 2012 International Conference of Emergency Medicine described a 4 month review of intraosseous access in UK military operations in Afghanistan. During the timeframe the EZ-IO was used to establish IO access in the proximal humerus and tibia sites; the FAST1 was used to establish sternal IO access. Of the 87 EZ-IO applications there were 12 functional issues and the placement success rate for both sites combined was 86.3%. In 24 FAST1 applications there were 4 functional issues and the placement success rate was 93.4%.

11/9/2019
YEAR: 2011

A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthesia recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anesthesia by IO access was satisfactory without necessity of other infusion access.

Brazil

This abstract reports a literature review using both MEDLINE and Embase databases up to August 2010 to determine feasibility and safety of IO administration during adult cardiac arrest. Authors reported a lack of literature (only two studies met their level of evidence criteria) but concluded IO access in adults appears to be a fast, reliable method to deliver drugs and fluid during CPR allowing adequate drug concentrations and pharmacological response; and should be considered if other medication delivery methods have failed. (Presented at the March 2011 International Symposium on Intensive Care and Emergency Medicine)

This paper summarizes a study comparing first attempt success rates between TIO and HIO insertions during out-of-hospital cardiac arrest (OHCA). Insertions were performed by paramedics using an EZ-IO device. During the first month insertions were first attempted via the HIO route followed by the TIO route if unsuccessful; and vice versa during the second month. The overall TIO insertion success rate was 84.5%. The overall HIO insertion success rate was 40%.

Byars DV, Tsuchitani SN, Erwin E, Anglemyer B, Eastman J. Evaluation of success rate and access time for an adult sternal intraosseous device deployed in the prehospital setting. Prehosp Disaster Med 2011;26(2):127-9
A prospective study evaluating use of the FAST-1 sternal IO device in critically ill or injured patients in cardiac arrest in the pre-hospital setting. In one year, 41 insertion attempts were performed using the FAST-1. Thirty (73%) of attempts were successful and the mean time to placement was 67 seconds from time of opening the packaging to ability to aspirate/infuse without infiltration. Of the 11 insertion failures, 7 were due to failure of the device to deploy; 2 infiltrations after insertion; 1 inability to aspirate; and 1 failure of the catheter to deploy though the needles were inserted.

Dolister M, Miller ST, Borron S, Truemper E, Shah MR. Intraosseous vascular access can be used safely and effectively, and at a lower cost than central venous catheters, for pediatric and adult patients in the hospital setting. Ann Emerg Med 2011;58(4S):S311
This abstract describes the interim results of an observational clinical trial evaluating use of the EZ-IO to establish venous access in patients that would typically receive a central line due to lack of other options. At interim analysis, 50 patients had been enrolled in the study. First attempt IO access success rate was 96%; mean time to IO access was 95.1 seconds. The authors concluded that IO access in place of or as a bridge to central venous catheters is safe, fast, and effective for adult and pediatric patients in the hospital setting with substantial cost savings potential. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This retrospective cohort study evaluated data from 450 California hospitals and emergency departments to determine the rate of IO access use and related complications in the pediatric population from 2005-2007. Results showed 291 children had IO access placed in 90 hospitals out of 6.6 million pediatric ED visits and 2.2 million pediatric admissions; no complications were identified. The most frequent diagnosis related to IO use was cardiac arrest (94%).

This article describes a military study in which post-mortem pautopsy multidetector CT was used to assess placement of tibial IO needles in battlefield trauma deaths where IO was used as part of the medical intervention. Results showed 58 of 61 (95%) tibial IO needles were correctly placed. In this study, the device used for IO placement was not recorded, but may have been the manual device or EZ-IO as the Army has access to both.
This article summarizes the case-based observations made by the Armed Forces Medical Examiner System on soldiers killed in action/died of wounds who had evidence of sternal intraosseous access. The Pyng Fast-1 is noted in the article as the sternal IO device most widely distributed by the department of defense (DOD); the EZ-IO is listed as another device that may be seen in emergency care facilities within the DOD. Of 98 cases, 78 (80%) showed proper placement; 20% were unsuccessful. It should be noted that the article incorrectly states that the EZ-IO using the powered driver is indicated for sternal placement.

Retrospective study describing 3% saline administration during pediatric critical care transports. Primary indications for use included cerebral edema, intracranial bleed with edema and symptomatic hyponatremia. The primary infusion route was peripheral venous with 4 infusions via central line and 2 via the IO route. Most patients received one bolus enroute. No adverse reactions were noted for any route.

This article describes a randomized, single-blind, controlled trial to determine which IO needle can be used best for gaining IO access in patients requiring acute administration of fluids or medication in a prehospital setting. The study was performed at a level 1 trauma center in the Netherlands with a Helicopter Emergency Medical Service (HEMS). Adult and pediatric patients meeting inclusion criteria were randomized between Jamshidi 15G, B.I.G. 15G/18G and F.A.S.T.1. Insertion time, success, aspiration of bone marrow, side effects, medication given, trauma mechanism, and user satisfaction were recorded. In the adult group Jamshidi was placed fastest, significantly faster than the F.A.S.T.1. (p<0.002). Time to insert the B.I.G. 15G did not differ statistically from other devices. In the pediatric group the Jamshidi did not differ statistically from the B.I.G. 18G. On average, the devices (adult and pediatric) did not differ significantly with respect to success rate, complication rates, and user satisfaction. EZ-IO was not included in this study as it was not approved for use in the Netherlands at the time the trial began. Authors recommend comparison with EZ-IO in future research.

Authors report an observational study of 14 children in whom semi-elective IO infusion was performed under anesthesia after peripheral IV had failed. IO infusion was successful for all 14 patients, using the EZ-IO system for 8 patients and the Cook system for 6 patients.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

The authors describe literature that support the use of IO access for administering anesthesia in the ICU, perioperative and operating room, including a study in which IO access was used successfully for providing intraoperative anesthesia for 106 of 109 patients. Among their conclusions, the authors reported that, even though rarely reported in anesthesia literature, IO access is a technique anyone providing care to children should consider when the patient has difficult IV access. They also concluded that IO access should be a part of an algorithm that includes numbers of attempts at peripheral access, feasibility of central access and the need for continued postoperative access; and that considering that IO access may be occasionally used in the perioperative setting in both emergent and nonemergent scenarios, it may be beneficial to have appropriate IO needles in the OR.

This abstract describes a study in which 60 physicians, nurses, and paramedics naïve to IO vascular access were trained on the Arrow EZ-IO system. After lecture and hands-on training, the clinicians attempted to perform the procedure using a bone model and evaluated the device for ease of insertion, number of attempts, time to insertion, and their opinion on the device. The authors concluded use of the EZ-IO system can result in high success rates of insertion with inexperienced device users.

This retrospective study evaluated humeral IO placement success rates, using the EZ-IO, in the out of hospital cardiac arrest patient. Over a 9 month period, humeral placement was attempted in 247 patients. First attempt successful placement was 91%; successful placement within two attempts was 94%. The authors concluded that humeral IO is a reliable method of fluid and drug delivery in the out of hospital cardiac arrest population. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

YEAR: 2009

Prospective study of 246 EMS providers at 14 EMS agencies. Reports successful IO placement in 95% of cases (18 of 19).

This article describes a study conducted at an urban Level I trauma center in Munich, Germany. Ten consecutive patients for whom PIV was difficult or impossible were simultaneously given a central line and an EZ-IO. Procedure times were measured and defined as the time the device package was taken off the shelf until the first drug or solution was administered. First attempt success rate was 90% for EZ-IO and 60% for CVC. The mean procedure times were 2.3 minutes for EZ-IO and 9.9 minutes for CVC, a clinically and statistically significant difference. Investigators concluded, because CVC was slower and less efficacious, IO may improve the safety of patients requiring resuscitation in the ED.

This article describes a cadaver study to determine skill acquisition and performance by use of the EZ-IO system by novices. Overall success rate for the 99 operators was 97%, and mean insertion time was 6 seconds. All operators rated the device faster and easier than using a central line, and 99% expressed willingness to use the device for cardiac arrest patients.

This study sought to determine whether training and previous IO insertion experience influenced a trainee pediatrician's decision on emergency vascular access choice. Multivariate logistic regression analysis showed that previous real life IO insertion experience was the only significant factor to increase the likelihood of choosing IO as the first vascular access choice in an emergency situation. Prior IO insertion experience was more likely to be found among more experienced trainees.

This article describes IO use in general, and the EZ-IO in particular. The author describes its use by the emergency staff at her hospital and how they became advocates for IO access in both emergent adult and pediatric patients. She found that its use improves the quality of our care by providing vascular access to our most critical patients.
This study sought to show that intraosseous hyperpressure plays a role in the pathophysiology of sickle-cell like idiopathic osteonecrosis of the femoral head (ONFH). 10 ONFH patients underwent decompression drilling and pressure measurement resulting in 16 intraosseous pressure (IOP) measurements recorded. Six were sickle-cell patients, 2 were sickle-cell trait carriers with ONFH, and 2 were ONFH patients free of sickle-cell disease. Drilling was performed with a Jamshidi DJ4008X puncture needle. Results displayed elevated predrilling IOP-1 and IOP-2, which was reduced after drilling (IOP-3). IOP-1 and IOP-2 were found to be significantly higher in the sickle-cell disease and sickle-cell trait carrier groups (P<0.05).


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants.

Ong ME, Chan YH, Oh HH, Ngo AS. An observational prospective study comparing tibial and humeral intraosseous access using the EZ-IO. Am J Emerg Med 2008;27:8-15

Comparison of tibial and humeral IO use in 24 adults. Both sites suitable for IO infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants. (Note: This study was also described in an earlier article published in American Journal of Emergency Medicine) This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In this 1,598 patient case series, investigators studied the effects of serial standard of care changes in the EMS system over time. They concluded that IO access is an essential component for a proven algorithm for the management of OOH-CA.


This article describes an observational study performed by the French military air surgical team in Chad. There were 11 patients with no insertion failures. For 7 patients, the insertion site was the proximal tibia and for the remainder the site was the proximal humerus. The authors concluded that the EZ-IO is a device that is simple, reliable and which gives satisfaction for the administration of drugs.


This abstract describes a small study designed to determine if IO line placement improves outcome in adult patients with out-of-hospital cardiac arrest. This 165 patient study did not demonstrate improved survival.

YEAR: 2008


Study comparing manual intraosseous insertion with EZ-IO using adult human cadavers as a model. No significant difference in insertion time between 39 manual insertions and 45 EZ-IO insertions. Found a difference in the success rate (manual, 79.5% vs. EZ-IO 97.8%, p<0.01). The EZ-IO had fewer complications (manual, 15.4% vs. EZ-IO 0.0%, p<0.01) and scored higher on user friendliness (school grading system: manual, 1.9±0.7 vs. EZ-IO 1.2±0.4, p<0.01).


Large retrospective study of patients for whom emergency vascular access was obtained using the Vidacare EZ-IO intraosseous system. Insertion success was 92% and within 10 seconds for 84% of the one-attempt successful cases. Complication rate was low (4.8%), none were serious, and extravasation was the most frequent (0.8%). The device was rated easy to use 72% of the time, and researchers concluded that the powered IO device is safe and effective for achieving vascular access in the resuscitation and stabilization of emergency patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies


A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


The objective of this study was to determine the anesthetic efficacy of repeated intraosseous injections of 2% lidocaine with epinephrine given 30 minutes following a primary injection for pain management for dental procedures. Results found that a repeated injection provided 15 minutes of additional pulpal anesthesia.


Interim report for quasi-controlled prospective study of emergency department patients for whom emergency vascular access using the Vidacare EZ-IO intraosseous (IO) system (n=6) inserted in the proximal humerus was compared to access using central or peripheral intravenous (IV) lines (n=60). Researchers concluded that proximal humerus IO insertion is significantly faster than central or peripheral intravenous (IV) line insertion. Complications and pain profiles were similar for IO and IV techniques. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Three-year study of IO training and use in 28 hospital and ambulance services in Switzerland. Standardized training improved IO success rate to 100%.

Abstract only


This article describes an observational study in which two intraosseous devices were compared: the Pyng Medical F.A.S.T.1 and the Vidacare EZ-IO. For the 117 patients on which the F.A.S.T.1 was used, there was an 84% success; compared to a 97% success rate for the EZ-IO (n=71).


This article describes a prospective cross-over study that evaluated the effects on heart rate of intraosseous administration of 2% lidocaine at various deposition rates in dental practice. Results showed the mean maximum heart rate was statistically higher with the fast intraosseous injection over the two slow injections.

YEAR:  2007


This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study in which the EZ-IO was used to provide emergency vascular access for 95 pediatric patients. Successful insertion and infusion was achieved in 94% of the patients, and insertion time was within 10 seconds for 81% of the placements. There were four minor and no serious complications.


Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

This article describes authors' evaluation of provider performance using two IO devices; the Pyng Medical F.A.S.T.1™ and the Vidacare EZ-IQ®. Of 89 insertions with each device, success rate for 72% for the F.A.S.T.1 and 87% for the EZ-IQ, a significant difference (p=0.009). The time to fluid insertion for the EZ-IQ was also faster (p=0.02). Authors noted that the EZ-IQ is unique and much more useful than the F.A.S.T.1.

This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study done at Boston Medical Center in which the Vidacare EZ-IQ was used to provide emergency vascular access for 50 critically-ill adult patients. Successful insertion was achieved in 92% of the patients; with 90% success on the first attempt. There was one immediate complication—a dislodgement during transport. Investigators concluded that the device is a safe and feasible device for adult patients requiring out-of-hospital vascular care.

In this study, presented at the NAEMSP 2007 annual meeting, authors compared the success rate of conventional IO access with the EZ-IQ during 245 cases in the prehospital setting. They concluded that using EZ-IQ® results in a statistically significant increase in IO success rate, compared to conventional IO methods.

Abstract

Myers BJ, Lewis R. Induced cooling by EMS (ICE): year one in Raleigh/Wake County. JEMS 2007;32;S13-5
This article describes the experience of the Wake County (NC) EMS System in inducing hypothermia for patients with return of spontaneous circulation after cardiac arrest. Authors describe their use of the Vidacare EZ-IQ (now Arrow® EZ-IQ Intraosseous Vascular Access System) for the administration of chilled saline. In this report 56% of vascular access cooling was done utilizing the IO device and an additional 18% utilized a combination of IO and IV induced cooling. The overall EZ-IQ use in this program for all insertions were 414 with an insertion success rate of 94%.

A cadaveric study evaluating the use of ultrasonography visualization of flow within the intraosseous space to confirm proper needle placement. In a sample of 4 freshly frozen, unembalmed cadavers with bilateral distal tibia IO access, ultrasonography accurately detected the flow of crystalloids through the IO space 100%.

The article describes a prospective observational study conducted by several EMS agencies in Portland, OR to determine the safety, efficacy and benefits of using the Vidacare EZ-IQ in the prehospital environment. The IO device was successfully placed in 95% of the 280 cases. In 98% of the cases, placement was made within six seconds.

This paper presents a systematic review that assessed the quality of randomized controlled trials (RCTs) used in teaching undergraduate medical students in Canada surgical and emergency skills. 19 RCTs were assessed, 2 of which involved intraosseous access.

Clinical study of intraosseous antibiotic administration in 87 women with acute pelvic inflammatory disease.

YEAR: 2006

An abstract describing a prehospital study comparing peripheral IV to tibial IO access for placement success, time to access and time to drug delivery. The authors concluded that using IO access on the first attempt results in faster drug administration than if IO access were used as a rescue line after failed IV.

In this study, presented at the NAEMSP 2006 annual meeting, investigators reported the results of a study that evaluated the performance of the EZ-IO® compared to an earlier evaluation of the Pyng F.A.S.T.1 system. There was a statistically significant higher success rate using the EZ-IO® compared to Pyng system, and investigators concluded that the EZ-IO® appears to be a superior device with regard to insertion success.


Prospective observational study evaluating EMT-B ability to provide care in out-of-hospital cardiac arrests. Found that EMT-Bs were able to place the EZ-IO with a 94% success rate. Median time to placement was 72 seconds.

YEAR: 2005


A review of 129 cases comparing the BIG to standard IO needles. Concludes that the BIG is equivalent to manually driven IO needles in effectiveness and likely faster than manual needles in achieving IO access.


Observational study evaluating use of the EZ-IO®. Found 97% success rate for insertion and infusion into the IO space by paramedics, nurses, physicians and other EMS personnel in using the device for emergency vascular access. No serious complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract describes a retrospective study evaluating use of IO access during pediatric critical care transport. From January 1, 2000 to March 31, 2002, 1,792 transports were performed and 47 patients received 58 IO catheter insertions. Insertion took a mean 1.2 attempts for placement and first attempt success was 78%. Most frequently accessed site as the proximal humerus (95%) and access was maintained for a mean 5.2 hours. The authors concluded EMT/paramedics, emergency physicians, and pediatric critical care transport teams should be familiar with IO placement.


Retrospective chart review demonstrating safe and effective IO placement on pediatric patients by EMT-Ps, ED physicians, and members of the transport team in the pediatric critical care transport environment.

Gillum L, Kovar J. Powered intraosseous access in the prehospital setting: MCHD EMS puts the EZ-IO to the test. JEMS 2005;30(10):s24-6

Observational study of initial use of the EZ-IO® in 125 patients by EMS providers. Found 94% success rate for insertion and infusion into the IO space. No complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Preclinical study of one IO device (FAST-1) in cadavers. Design criteria were validated in that 75 out of 77 attempts were successful.


Experimental study of the FAST-1 sternal IO device, with 29 EMT-B’s with minimal training placing the device on mannequins. Authors reported 16 of 29 EMT-B’s placed the device successfully on the first attempt and 27 of 29 on the fourth attempt.


Multicenter, prospective study of cardiopulmonary resuscitation data over 18 months. The study was design to evaluate the impact of survival of IV or IO high-dose epinephrine compared to standard doses in children with cardiorespiratory arrest. Limited conclusions showed that there is no significant difference between the two treatments.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

Retrospective study over a 14-year period examining 129 IO insertions among 23,489 pediatric trauma patients. Patients receiving IO fluids and medications tended to be younger and sicker. Concludes that IO is an essential skill for anyone involved in pediatric trauma resuscitation.

YEAR: 2004

Study compared the VidaPort (now EZ-IO®) and the Bone Injection Gun (B.I.G.). Of 32 cases for each device, insertion rates were 100% for the VidaPort and 88% for the B.I.G. Average insertion times were 16 seconds for the Vidaport and 21 seconds for the B.I.G.

Evaluation of the BIG in a chemical warfare mass casualty scenario. Found 73.4% simulated survival in the IO group and 3.3% in the control group (no IO). Average treatment goals obtained in 3.5 minutes for IO group and 10 minutes for control group. Concludes that IO has great potential for early treatment of chemical.

YEAR: 2003

Prospective radiographic study of 23 children who had received intraosseous infusion via trocar. Found no long-term effect on tibial growth with properly placed trocar.

Dental study finding successful injections of 2% lidocaine with epinephrine in 27 of 33 (82%) X-tip IO injections (82%) for anesthesia in mandibular teeth.

Evaluation of IO models by 40 emergency and critical care physicians. Chicken, turkey bones and plastic IO models received similar scores, pork rib was rated poorly. Emphasizes that bone models should be age appropriate to the expected patient population when using for IO research and training purposes.

YEAR: 2000

Study comparing practitioner experience with IO and umbilical vein catheterization with 42 medical students inexperienced in both techniques. IO was twice as fast as umbilical vein catheterization. Concludes that IO provides easy and rapid vascular access for clinicians who do not regularly perform newborn resuscitation.

Brief review of the discovery and evolution of IO access in emergency care.

Survey on current opinion and practice regarding IO among 332 Accident and Emergency Departments. Found that 75% of respondents were aware of IO use in adult resuscitation.

A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient.

Canada
Spriggs NM, White LJ, Martin SW, Brawley D, Chambers RM. **Comparison of two intraosseous infusion techniques in an EMT training program.** Acad Emerg Med 2000;7:1168

Study comparing B.I.G. and Jamshidi IO needle in an EMS training program. 38 EMT trainees performed the insertion. Time to placement was 12 seconds for the B.I.G. and 17 seconds for the Jamshidi needle. There were no statistical differences in ease-of-use ratings between the devices.

YEAR: **1999**


A retrospective non-comparative study of IO infusion in 41 children. Concludes that IO insertion is an easy technique. Recommends IO for emergency cases when other vascular access techniques have failed in the first 5 minutes of treatment.

Abstract


Retrospective study of 32 cases of IO infusion over a 3 year period. Concludes that IO is rapid, safe and effective and provides an essential alternative vascular route in pediatric resuscitation.

Abstract

Daga SR, Gosavi DV, Verma B. **Intraosseous access using butterfly needle.** Trop Doct 1999;29(3):142-4

Evaluation of the utility of 18-gauge butterfly needles for IO administration of fluids and drugs in 23 children presenting in shock. 22 of 23 children were successfully stabilized after IO infusion.

Abstract


Observational study in 27 newborns, describing 30 intraosseous lines placed after failed IV access. Reports that all patients survived the resuscitation procedures with no long-term side effects.

YEAR: **1998**


This article describes a study to determine the anesthetic efficacy of a supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine in teeth diagnosed with irreversible pulpitis. Patients who did not achieve anesthesia with traditional nerve blocks were given supplemental lidocaine using a Stabident IO injection. This technique was found to be 88% effective in gaining total pulpal anesthesia.

YEAR: **1997**


Preclinical study in 33 piglets of IO infusion during CPR. Found no increase in fat embolism in IO group compared to controls group.


Prospective blinded observational study in 10 subjects finding no difference in tibia length after IO infusion compared to opposite tibia at > 1 year post IO infusion.


A dental study evaluating use of supplemental intraosseous injection of 3% mepivacaine in mandibular posterior teeth following application of an alveolar nerve block. Results showed supplemental injections increased anesthetic effect and a second injection was sometimes necessary.
Intraosseous Vascular Access Bibliography
Clinical, Observational and Other Studies

A dental study comparing the anesthetic effect of 2% lidocaine (1:100,000 epinephrine) and 3% mepivacaine when injected in the mandibular first molars. The results showed the lidocaine to be more successful with a longer duration of pulpal anesthesia than mepivacaine.

Seminal study on the use of the B.I.G. in elective and emergency situations in 50 adult patients. Success rate for IO insertion was 100%. No complications were observed.

YEAR: 1996

This study’s objective was to determine the anesthetic efficacy of the intraosseous injection as a primary technique in human maxillary and mandibular teeth. Forty subjects were enrolled and received 2 sets of intraosseous injections with 1.8ml of 2% lidocaine with 1:100,000 epinephrine on two different occasions. Authors concluded that in 75%-93% of non-inflamed teeth subjects, an intraosseous injection may provide pulpal anesthesia. Authors cautioned that the duration of the anesthesia declines over an hour.

This abstract describes the retrospective study of a German rescue helicopter service and initial experience using intraosseous access in their system. Ten cases presented in which IO puncture of the proximal tibia was required. In all attempts access was established within 60 seconds without complication; in 2 cases general anesthesia was administered via IO access. Authors concluded that IO infusion is simple, fast, and a safe alternative for emergent access.
Article in German

YEAR: 1995

Preclinical study in dog tibias demonstrating that circumferential pressure about an IO infusion site is a rapid method to detect incorrect placement of the IO needle.

YEAR: 1994

Study of IO training for advanced life support providers. Providers were able to establish IO access in 13 of 15 (87%) of pediatric patients (age range 1-24 months) following completion of an 1-hour training course and supervised hands-on simulation. All procedures were performed in less than 10 minutes.

Banerjee S, Singh SC, Singh S, Singh M. The intraosseous route is a suitable alternative to intravenous route for fluid resuscitation in severely dehydrated children. Indian Pediatr 1994;31:1511-20
Study of IO vs. IV for administering fluids for resuscitation in 60 children (age range 3-24 months) with severe dehydration. The IO route was successful in all cases within the first 5 minutes of attempt. The IV line could not be secured in 33% of patients within 5 minutes. Time for successful IV access was 129 seconds, significantly longer than time t for IO cannulation. Fluid infusion through either route was equally effective in stabilizing vital signs and normalizing laboratory values. No significant complications of IO route were noted on short-term follow-up.

Study demonstrating improved performance of pre-hospital endotracheal intubation and vascular access of younger children after introduction of an EMT-P PALS clinical course.
YEAR:  1993

Retrospective analysis of prehospital IO infusion covering 165 attempts on 152 patients over a 5-year period, found a success rate of 73%, with success rates significantly higher in younger children (<2 years old). EMT-Ps maintained proficiency in the technique over time despite infrequent use.

Observational study finding 7 of 27 critically injured patients (ages 3mo-10y) successfully resuscitated using IO. Concluded that IO is a rapid, safe and simple method of obtaining short term vascular access in critically ill and injured children.

Preclinical study of bone perfusion in pigs demonstrating feasibility of inert gas wash-out procedure to study local perfusion rates.

Neufeld JD, Marx JA, Moore EE, Light AI.  Comparison of intraosseous, central, and peripheral routes of crystalloid infusion for resuscitation of hemorrhagic shock in a swine model.  J Trauma 1993;34(3):422-8
Preclinical study finding IO infusion to as effective as central and peripheral venous access for resuscitation with crystalloid infusion in an animal model of hemorrhagic shock.

Preclinical study in 18 piglets finding significant improvement in hemodynamic variables after IO infusion of hyperosmotic saline and IO transfusion of whole blood in an animal model of hemorrhagic shock. Concludes that IO infusion is easy to establish and holds utility for treatment of shock victims.

Study comparing 3 vascular access routes for fluid administration: intravenous (6 patients), intraosseous (6 patients) and/or intraperitoneal routes (4 patients). Concluded that IO and intraperitoneal routes allowed for severely dehydrated children to be resuscitated without significant complications when IV access is difficult to establish. abstract only

Preclinical study comparing infusion rates of IO access sites with IV access under normo- and hypovolemia. Found IV access was most effective for acute volume replacement. IO sites differed in maximum flow rates achievable. The humerus had the greatest flow rate, followed by the femur, malleolus and tibia. Concludes each IO access site is a viable site for short term vascular access.

Preclinical study in goats finding that intraosseous hypertension was associated with a significant increase in periosteal, endocortical, and cancellous new bone formation compared to controls.

Preclinical study in goats examining IO administration of prostaglandin E2 into the proximal metaphysis of the tibia under normotensive and hypertensive conditions within the intraosseous space. Hypertensive PGE2 infusion resulted in significantly more new bone formation.

YEAR:  1992

Preclinical study in nestling rabbits finding that IO infusion of saline and bicarbonate intraosseous infusions did not damage the metaphyseal growth plate but did cause loss of bone trabeculae that support the growth plate.
Preclinical study in pigs comparing IO and IV infusion of hypertonic saline/dextran. Found equivalence in entry of sodium and dextran to the blood stream, plasma volume expansion, and increased cardiac output.

Preclinical study in sheep fetuses and human fetal cadavers finding that IO-derived blood gas parameters (pH, pCO2, and pO2) accurately reflected peripheral venous values and that resuscitation drugs (sodium bicarbonate, glucose, calcium chloride, epinephrine) rapidly entered the fetal circulation.

Veterinary case study finding that an IO implant facilitated vascular access for hyperalimentation and drug therapy over a 72-hour period.

Preclinical study of hemorrhagic shock in dogs treated with IO infusion of hypertonic saline/dextran finding that IO infusion efficacious in the treatment of hemorrhagic shock.

Preclinical study of cardiac arrest in 18 pigs finding IO epinephrine is rapidly transported to the central circulation. Recommends larger doses to produce a significant change in blood pressure.

YEAR: 1991

Clinical study comparing efficacy of IV or IO infusion of 7.5% NaCl/6% dextran compared to Ringer’s lactate in 49 shock patients finding either that sternal IO or IV infusion of 7.5% NaCl/6% dextran is an effective initial treatment of hemorrhagic shock.

Comparison of IO administration in 3 simulated EMS settings: at the scene, in ambulance in steady traffic on curvy road, in ambulance at fast speed in stop and go traffic. Found that 12 EMS participants were successful in establishing IO infusions, with 84.8% of infusions achieved in less than one minute in all settings.

Pollack CV Jr, Pender ES. Intraosseous administration of digoxin: same-dose comparison with intravenous administration in the dog model. J Miss State Med Assoc 1991;32(9):335-8
Preclinical study in dogs finding that IO infusion of digoxin results in similar plasma concentrations of the drug as IV infusion. Abstract only

A pre-clinical study comparing IV and IO blood serum levels of antibiotics: ceftriaxone, cefotaxime, ampicillin and gentamicin in weanling pigs. Blood levels were compared at 15, 30, 45, 60 and 90 minutes and each animal served as their own control. Results showed that IO levels were initially lower than IV levels though the difference became indistinguishable after 30 minutes. Ceftriaxone levels however remained lower throughout the 90 minute sample period. The authors concluded that standard IV doses may be administered intraosseously though further study may suggest higher doses of ceftriaxone may be more beneficial.

YEAR: 1990

Preclinical study in 24 dogs finding that a single IO attempt is preferable to multiple attempts to maintain adequate serum levels of Phenobarbital following IO infusion.
**Intraosseous Vascular Access Bibliography**

**Clinical, Observational and Other Studies**

**Orlowski JP, Gallagher JM, Porembka DT. Endotracheal epinephrine is unreliable. Resuscitation 1990;19(2):103-13**

Preclinical study of the pharmacokinetics of emergency medications in a canine model of shock. Found that endotracheal administration was unreliable, while IO administration was comparable to central and peripheral venous administration.


Preclinical study comparing the pharmacokinetics of 6 emergency medications in dogs. Found that IO administration resulted in similar physiologic effect and/or serum drug levels as central and peripheral venous administration.

**YEAR: 1989**


Preclinical study demonstrating comparable central circulation transit times with IO and IV infusion of a radionuclide tracer.


A pre-clinical study evaluating resultant serum levels when administering phenobarbital and phenytoin via intraosseous infusion as compared to IV administration in domestic swine. Results showed that current IV dosing of phenobarbital 20 mg/kg obtains and maintains therapeutic serum levels when given IO; Phenytoin 15 mg/kg does not maintain therapeutic levels and cannot be recommended for IO administration.


Preclinical study in sheep finding no significant differences between IO and IV infusion of hypertonic saline/Dextran.

**Lathers CM, Jim KF, Spivey WH. A comparison of intraosseous and intravenous routes of administration for antiseizure agents. Epilepsia 1989;30(4):472-9**

Preclinical study in pigs finding equivalence in physiologic response between IO an IV administration of antiepileptic drugs.


This article describes a pre-clinical study comparing bone marrow, venous blood, and arterial blood specimen results when used for blood electrolytes, blood chemistries, blood gases and hemoglobin; and a clinical evaluation of bone marrow and venous blood used for cultures.


Prospective study finding EMS personnel able to successfully establish IO access in 16 of 17 pediatric patients with cardiopulmonary arrest. Observed 13 successful infusions within 1 minute on first attempts at IO access. No significant complications.

**YEAR: 1988**


Retrospective chart review of 33 pediatric patients finding 83% success in establishing IO infusion. IO and percutaneous peripheral catheterization were the quickest methods for vascular access. Observed no major and minimal delayed complications.


Retrospective chart review over a 1-year period finding IO reduced vascular access time in patients with cardiac arrest when standard techniques failed.
Intraosseous Vascular Access Bibliography  
Clinical, Observational and Other Studies


Preclinical study in pigs demonstrating suppression of seizures with both IO and IV administered propranolol. Both IO an IV propranolol reduced basal heart rate by a 32-38% and reduced the transient increase in mean arterial pressure (MAP) elicited by pentylenetetrazol with no effect on the basal MAP.


Preclinical study finding IO infusion of hypertonic glucose and dopamine to be as effective as IV administration.


Anatomical study. Found that IO infusion into the sternum provides direct vascular access via the thoracic veins. Concludes that IO infusion of hypertonic saline dextran may provide paramedics and emergency room physicians with a more rapid and effective method of vascular access and volume expansion than conventional resuscitation regimens.

YEAR: 1987


Preclinical study finding comparable serum drug levels with IO and IV administration.

YEAR: 1985


Preclinical study in pigs examining blood pH during CPR with sodium bicarbonate administered via different vascular access routes. Found that pH pf blood obtained via central venous access and intraosseous access were significantly different from the peripheral group, and that all three groups were significantly different form the control. Pathology studies showed only minor damage to bone with IO sodium bicarbonate administration.

YEAR: 1982


Study finding that 23-gauge needle is less painful and yields purer bone marrow sample from the sternum.

YEAR: 1977


Observational study of 15 patients needing emergency fluids and in whom IV’s were difficult to establish. Patients received drugs and fluids via IO. Concludes that IO therapy is effective with no serious complications.

YEAR: 1956


Study finding sternal puncture superior to iliac crest and spinous process punctures for bone marrow sampling. Cautions that inexperienced practitioners should use iliac crest or spinal process in the absence of training in sternal puncture.

YEAR: 1950


Early review of IO infusion citing complication rate of osteomyelitis (approximately 1 in 150 cases).

YEAR: 1947


Early article on IO puncture and infusion, emphasizing technique. Concludes their technique is safer and more effective than previously described techniques.
**Heinild S, Sondergaard T, Tudvad F.** Bone marrow infusion in childhood: Experiences from a thousand infusions. *J of Pediatrics* 1947; 30: 400-11

Early study on IO. Makes strong distinction between ordinary blood transfusion or infusion of isotonic solutions (generally safe) and continuous infusion or the infusion of hypertonic solutions. The latter carries considerable risk of osteomyelitis and subsequent disturbance in growth of the bone.

**YEAR: 1945**


Abstract describes experience in one institution using tibial IO access to replace fluids, mostly due to dehydration.
The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.


Using a porcine hind leg model authors compared the success rate and ease-of-use ratings of an IO device, the NIO® in comparison to the Arrow® EZ-IO by novice users. NIO success rates were comparable to those of EZ-IO; 54% of the participants preferred using the EZ-IO needles safely in less than 30 seconds.


This study compared success rate, procedure time and user satisfaction of pediatric NIO vs. Pediatric BIG, EZ-IO and Jamshidi intraosseous access devices in pediatric manikins. Study was randomized, crossover trial with 87 paramedics participating. The study evaluated each device on the ease of use in performing their procedures. Results of this study found that paramedics favored the NIO in ease of use of the pediatric manikins.


A retrospective chart review was done to analyze data of three EMS agencies over an 18 month timespan. Analysis was done on charts from adults who suffered OOHCA and received epinephrine through EMS established IV or IO access. An IO first approach was found non-inferior to an IV first approach based on the end point ROSC at time of emergency department arrival.

Iskrzycki L, Smereka J, Szarpak L. Knowledge, skills, and attitudes concerning intraosseous access among hospital physicians. Crit Care Med 2017;45(1):e117

This letter to the editor describes a manikin study that compared use of the Teleflex EZ-IO to the Persys Medical NIO intraosseous vascular access devices. Insertion times were statistically different, favoring the NIO but not considered clinically relevant. The authors concluded that, while hospital physicians' knowledge of intraosseous access was limited, with simple training they could learn the procedure and place IO needles safely in less than 30 seconds.


The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.
Intraosseous Vascular Access Bibliography

Competitor


A study comparing use of the Bone Injection Gun (B.I.G.) and the NIO by paramedics in a manikin model simulation of CPR. Following training, 40 paramedics performed device insertion in the manikin using both devices; and completed a questionnaire regarding their knowledge of indications and contraindications of IO access and experience with each device. Successful insertion was achieved 100% with the NIO and 95% with the B.I.G. Authors concluded that after a short training program, paramedics can perform intraosseous injection with a high degree of efficacy.


A cadaveric study evaluating the function and safety of a manual, screw IO device designed to gain access to the medullary space. Twelve insertions were performed by the same device operator, of which 10 were successful. The 2 failed insertions were due to overshooting of the needle. The authors concluded the new device could successfully penetrate the bone cortex in adult cadaver bones, and that further testing and comparison to commercially available devices is needed.

India


This letter to the editor describes a simulation study evaluating use of the NIO device by 47 firefighters in a simulated anaphylactic shock model. The firefighters were trained on use of the device and standard anaphylactic shock management. An improvement in knowledge of intraosseous vascular access and anaphylactic shock protocol was demonstrated by the group.


This randomized crossover manikin trial compared the NIO and EZ-IO devices for time to placement and ease of use. For both parameters the NIO performed better.

Poland


A manikin study in which 40 paramedics dressed with and without CBRN PPE attempted to establish tibial intraosseous (IO) access using the Jamshidi and BIG devices, time to placement was measured. Results showed that in participants with and without CBRN PPE, BIG access was faster than Jamshidi.


A prospective study comparing use of the NIO device by 84 paramedics to establish proximal humerus and proximal tibia intraosseous (IO) access for first attempt success rate, time to access, and user feedback on ease of use and preference. IO access was established in fresh (within 72 hours of expiration) cadavers. The first attempt success rate with tibial IO access was 89.3% vs 73.8% humeral; procedure time was significantly faster for the tibial IO site; and participants found IO access in the proximal tibia as easier to obtain than the proximal humerus IO site.


This letter to the editor describes a prospective, randomized, cross-over cadaveric study that evaluated use of the EZ-IO and NIO devices by novice paramedic device users. Following a brief in-service on use of both devices and practice insertions using a leg-trainer manikin, each participant attempted to establish IO access using each device in a resuscitation simulation with in an adult cadaver with CPR in progress. Results showed first attempt success rates of 97.4% with the NIO and 100% with the EZ-IO; and mean time to insertion was 16.8 seconds with the NIO and 42 seconds with the EZ-IO.


A simulation study comparing use of peripheral IV access and tibial intraosseous access via the NIO device, by internal medicine specialists. Forty-three participants attempted to establish access using the two methods in a manikin; first attempt success, time to access and ease of procedure were measured. The NIO device was superior to IV access with regard to all endpoints.

YEAR: 2015


A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.
Intraosseous Vascular Access Bibliography

**2014**


A simulation study comparing use of manual (Cook Medical) and mechanical (Arrow EZ-IQ) intraosseous (IO) devices to establish IO access in mannequin bones representing infant, pediatric and adult tibias. Twenty-two anesthesiologists with no prior experience with IO devices participated in the study. The outcome measures were success rate, insertion time and operator reported difficulty of use. Results were in favor of the mechanical device for insertion time in each category, and success rate in the adult tibia group; there was no statistical difference in the difficulty of use evaluation.


A cadaveric study evaluating intraosseous (IO) vascular access insertion sites for attainable flow rates under 300 mmHg. The EZ-IQ was used to establish IO access at the proximal humerus and proximal tibia sites; the FAST1 was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 266 ± 218 mL for the humerus; and 154± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.

**YEAR: 2012**


This was a prospective, randomized controlled clinical pilot study comparing the BIG and EZ-IQ intraosseous (IO) vascular access devices in 52 adult patients admitted to an emergency department with difficult peripheral venous access. Twenty-six patients were randomized to each device; results were first attempt insertion success BIG 92.3%, EZ-IQ 84.6% (P=0.668); procedure time: BIG 2.8 ± 1.2 seconds, EZ-IQ 5.2 ± 2.2 seconds (P<0.001), significant; difficulty of use (with visual analogue scale): BIG 8.6 ± 6.4 mm, EZ-IQ 25.4 ± 12.6 mm (P<0.001), significant. Authors concluded both EZ-IQ and BIG are shown to be reliable and safe methods for insertion of intraosseous access in emergency conditions. There were no adverse events or complications reported.

**Vassallo J, Horne S, Smith JE.** *Intraosseous access in the military operational setting.* *J R Nav Med Serv* 2014; 100(1):36-9

This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IQ and the FAST1 devices (76% EZ-IQ).


A survey study assessing the knowledge of members of emergency medical teams in Poznan about the BIG intraosseous device.
Intraosseous Vascular Access Bibliography

Competitor

YEAR: 2010


This article describes a randomized, single-blind, controlled trial to determine which IO needle can be used best for gaining IO access in patients requiring acute administration of fluids or medication in a prehospital setting. The study was performed at a level 1 trauma center in the Netherlands with a Helicopter Emergency Medical Service (HEMS). Adult and pediatric patients meeting inclusion criteria were randomized between Jamshidi 15G, B.I.G. 15G/18G and F.A.S.T.1. Insertion time, success, aspiration of bone marrow, side effects, medication given, trauma mechanism, and user satisfaction were recorded. In the adult group Jamshidi was placed fastest, significantly faster than the F.A.S.T.1. (p=0.002). Time to insert the B.I.G. 15G did not differ statistically from other devices. In the pediatric group insertion time of the Jamshidi did not differ statistically from the B.I.G. 18G. On average, the devices (adult and pediatric) did not differ significantly with respect to success rate, complication rates, and user satisfaction. EZ-IO was not included in this study as it was not approved for use in the Netherlands at the time the trial began. Authors recommend comparison with EZ-IO in future research.

YEAR: 2009


Case study of a 9-month old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.

YEAR: 2007


A cadaveric study evaluating the use of ultrasonography visualization of flow within the intraosseous space to confirm proper needle placement. In a sample of 4 freshly frozen, unembalmed cadavers with bilateral distal tibia IO access, ultrasonography accurately detected the flow of crystalloids through the IO space 100%.

YEAR: 1998


This article describes a study to determine the anesthetic efficacy of a supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine in teeth diagnosed with irreversible pulpitis. Patients who did not achieve anesthesia with traditional nerve blocks were given supplemental lidocaine using a Stabident IO injection. This technique was found to be 88% effective in gaining total pulpal anesthesia.
Intraosseous Vascular Access Bibliography

Complications

YEAR: 2019

A 75-year-old female presented by EMS to the Emergency Department (ED) after a ventricular fibrillation cardiac arrest. EMS defibrillated the patient and placed a right proximal tibial EZIO intraosseous (IO) catheter which multiple medications (epinephrine, magnesium, amiodarone, and calcium chloride) were administered; and she had return of spontaneous circulation prior to ED arrival. The IO catheter wasn’t patent upon arrival in the ED and was removed. The patient was discharged on day four with ecchymosis near the insertion site. Three weeks post discharge the patient presented with tissue necrosis in an area surrounding the initial proximal tibial IO insertion site. The patient’s leg was debrided and grafting was performed; the author reported “good healing” three months post-event.

YEAR: 2018

This study compared IO insertions with the EZ-IO device (tibial/humeral insertions) to the FAST-R device (sternal insertions only) in a physician-staffed helicopter emergency medical service. Insertion time, insertion site, flow, indication for IO access, and complications were compared. Median insertion time was 15 seconds for EZ-IO and 20 seconds for FAST-R. Overall, 35.1% of EZ-IO insertions resulted in poor flow and required a pressure bag while 85.7% of FAST-R insertions had good or very good flow. EZ-IO complications included extravasation (2.4%), aspiration failure (11.9%), and insertion time >30 seconds (4.8%). Complications associated with FAST-R included user failure (12.5%) and insertion time >30 seconds (12.5%). The authors suggest that although EZ-IO is faster the FAST-R device may be more useful when high-flow infusion rates are required. The authors indicate that a low number of insertions were made with the FAST-R device and many outliers were observed in the data. However, the article does not present the total number of insertions per device.

This case review describes a complication of compartment syndrome post IO placement in a 64 year old male initially unresponsive and hypoglycemic. Approximately 15 minutes post-ED arrival compartment syndrome signs were noted and confirmed with compartment pressures. An ultrasound confirmed lack of flow from the IO needle and x-ray showed the needle set to be inserted 2 mm beyond the posterior tibial cortex. Patient was taken to surgery for fascioto my and four compartment release with subsequent return of pulses. *(Correspondence by the manufacturer 12-2018 with lead author confirmed the tibial placement was lateral and the patient had a full functional recovery).*

This report from France reports a case of tibial osteomyelitis in a 40 year old male that was diagnosed by MRI and biopsy three months post-intraosseous (IO) catheter removal. The patient was given parenteral as well as oral antibiotics and had a good outcome. The initial IO catheter placement was for treatment of overdose after failed IV attempts. The catheter was removed on the first day and the patient was treated with oral antibiotics due to local inflammation at the insertion site. He left against medical advice before a full treatment course was completed.

This case reports a serious compartment syndrome in a 2.5 year old infant which resulted in a left leg partial amputation. The IO device was placed to administer treatment following a respiratory arrest and extravasated.

This article describes a complication of a deformed EZ-IO catheter which was noted following removal of the catheter in an adult patient. The catheter had been placed by a helicopter emergency medical service team following a motor vehicle accident. The cause of the catheter bending was most likely the result of arm positioning for thoracostomy. No difficulties in removing the catheter were noted and it appeared to have been functioning effectively.

This is an article published in a Turkish nursing journal and written in Turkish. From the abstract, the IO route is described as an alternative approach to vascular access when venous access via a peripheral catheter cannot be obtained quickly. Complications of IO access and how to prevent them using nursing interventions are discussed. EZ-IO is discussed in the article.
Intraosseous Vascular Access Bibliography

Complications


This paper describes a case study of a 66 year-old female who presented to an emergency department with symptoms of an acute stroke. After failure of intravenous (IV) placement, humeral intraosseous (IO) access was obtained using the EZ-IO device. Contrast media (CM) for computed tomographic angiography (CTA) was later infused, off label, through the IO line. At the time of the CT scan 20 mL of CM was seen within the glenohumeral joint. The patient did not experience any ill effects from the extravasation following the procedure nor at her 1 week follow-up.

YEAR: 2017

This case report describes a complication of a laceration that occurred in an 85 year old morbidly obese female that presented in septic shock and received a proximal tibial IO placement. A 45 mm needle set was used for the initial insertion, which was completed without any initial problems; no stabilizer was placed. The patient had fluid resuscitation via the IO site with rapidly improved hemodynamics. During transport she developed a 7 cm laceration across the IO insertion site. The catheter was removed and laceration sutured. Authors opined that the lack of use of the EZ-Stabilizer dressing, the amount of soft tissue and thin skin and traction forces on the IO site applied during transport contributed to this complication.

This article describes two cases in which FAST1 intraosseous needle tips were retained in the sternal manubrium of patients following device removal. In each case, there were no long-term complications.

This poster presents a complication and unexpected ultrasound findings associated with IO infusions attributed to fat embolization. At necropsy, lung histology of 35 female swine revealed numerous large fat emboli consisting of bone marrow cellular elements and adipose cells within medium-sized arteries. High IO infusion rates also contributed to fat embolism in the femoral vein. Providers should be aware of the potential for pulmonary embolism.

This report describes a case study of a 19 year-old male who had an IO catheter placement in the left proximal tibia with EZ-IO after sustaining injuries in a motorcycle accident. Upon removal of the IO access, the needle broke at the hub with the retained needle no longer exposed above the skin. Removal at the bedside using Hemostat forceps failed, as well as the use of a sternal needle holder and a wire twister. Under fluoroscopic guidance, a 4 mm Stryker Crown drill bit was used to remove the retained needle by coring it out of the bone. The site was irrigated, bone graft substitute was placed into the defect, and the surgical site was closed. The patient healed well and was discharged with no complications 3 days later.

This paper describes a complication of dermal abrasion with the EZ-IO device in a 1 year old female in Japan who was treated in the emergency department for severe dehydration due to acute gastroenteritis.

Case report of a 64 year old female in critical condition that had bilateral humeral intraosseous (IO) access sites placed for resuscitation. Past medical history included a cloting disorder. IO access was removed within 24 hours after CVC placement. Eight days post-IO catheter removal the patient developed pain, swelling, decreased motion and firmness in the area near the IO site. Conservative management failed and clinicians confirmed elevated deltoid compartment pressures and diagnosed compartment syndrome. She was taken to the operating room for a fasciotomy. Post-operatively the patient had pain relief, improved range of motion and last check-up had no pain and full range of motion.

Case report of a 29 year old that was diagnosed with osteomyelitis in his left tibia after a prehospital IO placement for resuscitation of cardiac arrest. Medications infused included naloxone, epinephrine, and amiodarone. The patient had ROSC and his IO catheter was removed within one hour of ED arrival due to infiltration. Diagnosis of tibial osteomyelitis occurred approximately 8 weeks post-initial placement.
Intraosseous Vascular Access Bibliography

Complications

YEAR: 2016


This case reports one patient in which they found a vascular air embolism via ultrasound when they were assessing the patient’s femoral vessels prior to arterial line placement on the same side as a limb that had an IO device placed. The authors noted that it was possible air was introduced when the patient injected IV heroin to that same leg; but believe it was more likely the IO line or tubing was not flushed or left open for a period of time.


In this letter to the editor authors discuss intraosseous access (IO) via proximal anterior tibia and proximal humerus. Per authors, the tibial site was used more frequently due to ease of identifying the landmarks for insertion and accessibility to this area while proximal humerus intraosseous access (PHIO) site can be more difficult to identify landmarks for insertion. The authors discuss the use of ultrasound to identify structures for PHIO access has the potential to increase the success rate of proper site insertion.


This article discusses the difficulty in defining the time to bone healing after IO access insertion in children. A case study is presented of a 23 month old male with multiple comorbidities that had a tibial and proximal humerus IO placed then 3 weeks post IO placement had tibial swelling. Upon follow-up he was diagnosed with a tibial fracture and incomplete healing of the tibial bone accessed for IO use. Repeated IO access to a limb previously accessed is advised regardless of time after access. Authors emphasize that IO access is a “critically important tool” in pediatric emergency medicine and IO access should be used early and often.


This article includes a case study of an adult patient who received an intraosseous (IO) catheter, that may have extravasated, resulting in vascular compromise. The patient was treated with pharmacologic intervention and the status was reversed. A review of the literature on adult IO complications is also described.


This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access “should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation”.


This article describes a case in which an EZ-IO catheter inserted into the proximal humerus required surgical intervention for removal after traditional removal efforts failed. Authors noted the patient refused an attempt to stabilize the insertion site. Discussion and a brief review of the literature discusses available IO devices and complications. In conclusions authors opined that with education and training, EZ-IO may become the preferred method of achieving rapid vascular access for emergent resuscitation with a low risk for complications.


This reports a case of left lower extremity compartment syndrome in a multi-trauma patient that received bilateral proximal tibia IO catheters. The patient had 1L crystalloid and 2 units of packed red blood cells infused into his left IO tibial site. While in the operating room the team noticed the left leg was tense and swollen. He was diagnosed with compartment syndrome and fasciotomies were done. A left fibula fracture was also discovered but authors do not believe that or the soft tissue injuries present were enough to cause the compartment syndrome. Singapore


This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9.587±2.706mL/hr (n=27); mean PH infusion rate was 6,292 ±3.277mL/hr (n=52). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

Complications

YEAR: 2015


Case report of a prehospital misplaced placement of an IO catheter into the intra-articular space of the knee joint when access was attempted in the field. Upon ED arrival IO placement was noted to be high and intra-articular placement was confirmed by x-ray. A sterile NS lavage was done and patient recovered without complication. Authors note this as a previously unidentified complication of IO placement and advise x-ray confirmation of affected sites with follow-up of intra-articular placements for the septic arthrits. (Picture of site appears to be an EZ-IO).


This single center, prospective, observational clinical study compared use of intraosseous (IO) access to central venous catheter (CVC) access for inpatient medical emergencies, managed by the medical emergency team (MET), within an urban teaching hospital. CVC access training included percutaneous, landmark-guided CVC placement without ultrasound guidance, using the femoral vein as the primary site. For IO access, the proximal tibia was the primary site and proximal humerus was secondary. Results showed IO access was significantly superior to CVC access with regard to first pass success rates, overall success rates, time to placement, and number of attempts for proper placement. On average more CVC kits were used per patient; complications were greater with CVC. There was one serious complication of tissue necrosis secondary to extravasation in the IO group.


This article presents a case report of a 7 month old female who received intraosseous vascular access via the EZ-IO in the distal femur that resulted in a dermal abrasion where the needle hub contacted the skin. The wound healed without significant complication however the scar at the IO site persisted at 11 months post the event. The authors recommend that providers use the minimal force necessary when operating the EZ-IO to avoid similar adverse events.


A retrospective study evaluating attempts to establish intraosseous vascular access in pediatric patients using a manual device and the EZ-IO, in a tertiary care pediatric emergency department. Results showed 35 patients had IO access attempted using manual and EZ-IO devices. In patients greater than and less than 8kg the EZ-IO had a higher success rate but time to placement was longer. Overall success rate including both devices was 64%. There were 2 complications of transient leg swelling after EZ-IO placement in 2 patients.


A retrospective study evaluating the use of pre-hospital and emergency department placed IO access in children before transport to a children’s hospital. Data were extracted from a Level I trauma, tertiary care children’s hospital transport database from 1993-2009. There were 143 eligible patients with an average transport distance of 33 miles; all but 8 catheters were placed by the ED. The most common reasons for IO placement were no IV access (53%) and no perfusion (33.6%); the most commonly reported complication was infiltration (27.3%); 46.9% of patients experienced no complication. The authors concluded IO access plays a significant role in promoting life-saving efforts when IV access is unachievable or no perfusion is determined.


This preclinical study evaluated the occurrence of fat intravasation resulting from intraosseous (IO) flush and infusion in anesthetized swine. Intravasated fat was assessed using a lipophilic fluoroprobe (Nile red) and by vascular ultrasound imaging. Fat intravasation was observed during all IO infusion regimens, with subclinical pulmonary fat emboli persisting 24 hours post infusion. It was noted that initial flush was a significant factor in fat intravasation, low levels of intravasation occurred with infusions ≤300 mmHg, fat intravasation and bone marrow shear-strain increased with IO infusion rates, and intravasation was influenced by cannula insertion site.


This is an abstract of a study that analyzed possible technical and anatomical factors leading to the complication of amputation as a result of IO placement. The study was prompted by a case report of amputation in a neonate after IO access using the EZ-IO device. The study measured medullary diameter of the proximal tibia at the recommended IO access site in three groups: 1-28 day old full term neonates, 1-12 month old infants, and 3-4 year old children. The mean diameter in each group was 7.7 mm, 9.9 mm, and 12.4 mm, respectively. The small size of the IO space, especially in neonates and infants, makes correct placement difficult. As such, complications should be taken into consideration in this patient population.

This case study describes a neonate who suffered a cardiac arrest, had return of spontaneous circulation (ROSC) and was treated with multiple medications and therapeutic hypothermia. The patient had received three IO needle insertions, one in the left tibia that was removed following swelling with bolus injection; one in the left distal femur that dislodged with movement of the patient's legs; and one in the right proximal tibia. Twenty-four hours after initial IO needle placement the child developed pallor and discoloration and was diagnosed with compartment syndrome to the right lower extremity. Five days post-IO insertion a below the knee amputation was performed. Medications infused via the IO access included epinephrine and norepinephrine infusions.


Literature search for complications associated with IO access included 5759 patients with overall complication rate of 2.1%. Two cases involving retained needle fragment discussed; one with a proximal tibial EZ-IO that required surgical removal. Authors concluded IO catheters are reliable tools for fluid and drug delivery to critically ill patients with low complication rates (which can be potentially serious but managed).


This letter to the editor describes a single case of a needle breaking off after a proximal tibial insertion of the EZ-IO into a volunteer (one of the letter's authors) during a training session. "Divergent from manufacturer instructions the sterile steel stylet was put back into place to achieve better grip for a manual pull-out. Under steady pull in strict axial alignment and gentle clockwise turn, the needle broke away from the plastic connector". The needle was extracted using combination pliers and there is no evidence of damage to the leg. Authors acknowledge this can be avoided by adherence to manufacturer's directions for use.

Fowler RL, Lippmann MJ. Benefits vs risks of intraosseous vascular access. Patient Safety Network

This is a discussion of a case study involving a hospitalized woman who had an IO line placed during a code after becoming unresponsive. Several unsuccessful attempts at peripheral venous access were made prior to IO access. The patient was diagnosed 3 hours later with compartment syndrome due to extravasation that required complex ongoing care in the ICU for 2 months.

Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4

Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, "fluids" and calcium. Demarcation of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.


This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).


This article looks at various methods of vascular access including venous, arterial and intraosseous access and their potential to result in air embolism.


Case study of adult multi-trauma patient that had an intraosseous device placed to a fractured left tibia and developed compartment syndrome. Authors concede it is unclear if the fluid infused through the IO device caused the compartment syndrome or if it was due to the multiple-fractures in the tibia. Authors advise against placing an IO line in an injured limb and mention the proximal humerus and sternum as alternative IO sites.
Intraosseous Vascular Access Bibliography

Complications


An observational clinical study evaluating use of the EZ-IO in patients requiring urgent vascular access that would have otherwise received a central venous catheter due to a lack of other options. One hundred five (105) patients were enrolled across five hospitals. The authors concluded that use of IO access in place of CVCs provides time savings, safety, ease of use, and is effective at significant cost savings; IO access may be used as a bridge to CVC placement under optimal conditions; and IO access may be used to replace use of CVCs all together in selective patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A letter to the editor reporting a case study of skin necrosis after IO administration of norepinephrine following resuscitation of a 74 years old in septic shock. The EZ-IO was placed to the proximal tibia; approximately 45 minutes post- norepinephrine administration symptoms of necrosis were evident. Authors cite 3 hypotheses for the cause of necrosis and consider that amines' high level concentration could induce local toxicity in the bone matrix and artery spasm; suggesting it is necessary to define an upper limit of amines' concentration that should be administered through IO vascular access.


A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices.

Denmark


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.

Turkey

Oksan D, Ayfer K. Powered intraosseous device (EZ-IO) for critically ill patients. Indian Pediatr 2013;50(7):689-91

A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 60 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case).

Plancade D, Millot I, Fetissof H, et al.. Sternal perforation with an intraosseous device and hemomediastinum infusion  Ann Fr Anesth Reanim 2013;http://dx.doi.org/10.1016/j.annfar.2013.01.009

A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for sternal use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.


This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.


A quality initiative study conducted evaluating use of the EZ-IO needles in pediatric patients and their associated complications rates when placed by EMS/ED staff compared Air Evac Lifeteam placement in 2012. The authors concluded that the powered IO device was appropriately utilized by ED/EMS staff as well as Air Evac staff and that there was no difference in the complication rate when the device was used by the two groups.
Intraosseous Vascular Access Bibliography

Complications

YEAR: 2012

Cote C, Dumont M, Gagnon JA. Abnormal bone scanning following intraosseous access. Medecine Nucleaire 2012; doi:101016/j.mednuc.2012.02.175

This case study describes a 12 month boy who received IO access for administration of anticonvulsant therapy. Three days post IO infusion sensitivity to the leg was noted and the child returned to the ED. Blood work showed elevated white blood counts and C-reactive protein. A bone scan showed a small round lucency at the site of IO access. Two weeks later, x-rays were normal. The authors suggest that IO access may cause an increased uptake on bone scan in absence of osteomyelitis.


This is a case report of needle sheering associated with the use of the FAST-1 intraosseous infusion system. A soldier successfully placed a FAST-1 needle in the sternum of a healthy volunteer soldier during a training session. Upon completion of the training session, the soldier was unable to remove the needle. The retained needle was later removed surgically at a field hospital.


This pre-clinical study sought to compare the flow rates of blood administered through an IO needle in the proximal tibia, distal femur and the proximal humerus in an adult hypovolemic swine at an infusion pressure greater than 300 mmHg. Investigators also evaluated the presence of fat emboli in the lungs. Results showed that the mean rate of IO infusion of blood through the swine humerus (103 mL/min) was greater than the femur (49 mL/min) and tibia (78 mL/min); fat emboli were detected in the lungs of most animals (tibia: 14.14; humerus: 10/11; femur: 8/14).


This simulation study evaluated the ability of 2 person EMS crews to manage a pediatric emergency and sought to determine root causes of errors made. Participating EMS crews used the BIG for IO access. The authors concluded that cognitive, procedural, affective, teamwork errors and error-producing conditions were identified as root causes for the errors made in the simulation. Authors also concluded that simulation followed by facilitated debriefing is an effective tool for identifying underlying causes of active and latent errors.


This letter to the editor describes a case in which a 53-year-old male in ventricular fibrillation received IO access via the EZ-IO in the ED with suspected massive pulmonary embolism. The patient was successfully resuscitated. Necrosis of the anteromedial side of the leg, at the IO site, presented 48 hrs post IO use. After 18 weeks the patient underwent surgical grafting. The authors linked the necrosis to adrenaline extravasation and local ischaemia. While the authors conclude that thrombolysis or repeated high doses of adrenaline should be given via the IO route when needed, it is not without the risk of complication.


This abstract presented at the 2012 ACEP Research Forum discusses a literature review of intraosseous access publications since 1985 providing an updated safety profile for IO access. The search resulted in 192 articles describing IO access with 6 cases of osteomyelitis and 6 cases of compartment syndrome secondary to extravasation reported. Of the 192 articles identified, 140 described the EZ-IO. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider’s armamentarium.


An article discussing the technique and safety profile of intraosseous access using the EZ-IO device. Needle selection, contraindications, insertion sites and techniques, catheter stabilization and removal are all discussed along with the safety profile of the EZ-IO against other IO devices and central venous catheters. The authors concluded that IO access should be considered whenever immediate vascular access is required. This article was co-written by an employee of Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2nd World Congress on Vascular Access 2012 describes the results of an analysis of published IO complications since 1985. The safety profile of the EZ-IO is also discussed in this abstract. The authors conclude that new devices and techniques have resulted in an approved IO safety profile. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


www.edmedicine.net

This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.


This letter to the editor is written in response to the case report by Landy titled, Complication of intraosseous administration of systemic thrombolysis for a massive pulmonary embolism with cardiac arrest. The author suggests that the tissue necrosis described by Landy may have been due to the removal of the IO needle while there was still significant fibrinolytic activity at the needle insertion site. The author suggests a change in medical care after return of spontaneous circulation (ROSC) in patients following thrombolytic administration through IO access to convert the functioning IO line to a non-flowing saline lock. The EZ-IO was used to provide IO access in the case report by Landy.

Auerhammer J. [Lebensbedrohliche arterielle blutung aus der a. carotis communis: Fallstricke bei der intraossaren punktion]. Notfall Rettungsmedizin 2011;14(2)147-150;doi 10.1007/s10049-010-1380-1. German

This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.

Byars DV, Tsuchitani SN, Erwin E, Anglemyer B, Eastman J. Evaluation of success rate and access time for an adult sternal intraosseous device deployed in the prehospital setting. Prehosp Disaster Med 2011;26(2):127-9

A prospective study evaluating use of the FAST-1 sternal IO device in critically ill or injured patients in cardiac arrest in the pre-hospital setting. In one year, 41 insertion attempts were performed using the FAST-1. Thirty (73%) of attempts were successful and the mean time to placement was 67 seconds from time of opening the packaging to ability to aspirate/infuse without infiltration. Of the 11 insertion failures, 7 were due to failure of the device to deploy; 2 infiltrations after insertion; 1 inability to aspirate; and 1 failure of the catheter to deploy though the needles were inserted.


This article in Spanish describes an IO complication case in which a newborn infant developed tissue necrosis as a result of extravasation during IO infusion.


A case study report in French describing compartment syndrome secondary to intraosseous infusion in a 57-year-old burn patient. IO access was established in the proximal tibia on second attempt; both attempts were made in the same limb though it was noted that the first attempt did not penetrate the cortex. Drug and fluid infusion was initiated; ten hours later the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.


This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK
Intraosseous Vascular Access Bibliography

Complications

Dolister M, Miller ST, Borron S, Truemper E, Shah MR. Intraosseous vascular access can be used safely and effectively, and at a lower cost than central venous catheters, for pediatric and adult patients in the hospital setting. Ann Emerg Med 2011;58(4S):S311

This abstract describes the interim results of an observational clinical trial evaluating use of the EZ-IO to establish venous access in patients that would typically receive a central line due to lack of other options. At interim analysis, 50 patients had been enrolled in the study. First attempt IO access success rate was 96%; mean time to IO access was 95.1 seconds. The authors concluded that IO access in place of or as a bridge to central venous catheters is safe, fast, and effective for adult and pediatric patients in the hospital setting with substantial cost savings potential. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This retrospective cohort study evaluated data from 450 California hospitals and emergency departments to determine the rate of IO access use and related complications in the pediatric population from 2005-2007. Results showed 291 children had IO access placed in 90 hospitals out of 6.6 million pediatric ED visits and 2.2 million pediatric admissions; no complications were identified. The most frequent diagnosis related to IO use was cardiac arrest (54%).


This article summarizes the case-based observations made by the Armed Forces Medical Examiner System on soldiers killed in action/died of wounds who had evidence of sternal intraosseous access. The Pyng Fast-1 is noted in the article as the sternal IO device most widely distributed by the department of defense (DOD); the EZ-IO is listed as another device that may be seen in emergency care facilities within the DOD. Of 98 cases, 78 (80%) showed proper placement: 20% were unsuccessful. It should be noted that the article incorrectly states that the EZ-IO using the powered driver is indicated for sternal placement.


This report describes the case of a 62-year-old man who received emergency tibial IO infusion without complication in the pre-hospital setting and presented to the ED 6 months later complaining of shin pain. MRI and culture findings were diagnostic of subacute osteomyelitis with IO abscess. The patient had a history of multiple chronic health problems including diabetes type II, MGUS, and positive MRSA colonization dating back two years prior. The authors concluded that the occurrence of osteomyelitis with IO abscess may increase as a result of increased pre-hospital use of IO infusion in adult patients with multiple comorbidities.

Khan LAK, Anakwe RE, Murray A, Godwin Y. A severe complication following intraosseous infusion used during resuscitation of a child. Inj Extra 2011;doi:10.1016/j.injury.2011.05.015

This article describes the case of an 11-year-old boy who suffered compartment syndrome of the lower leg following use of the EZ-IO for resuscitation and 24 hours of intraosseous infusion of adrenaline, calcium and potassium. The author concluded that further work is needed to develop recommendations for maximum duration, dose, volume and rates for intraosseous infusion.


This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.


This article describes a pre-hospital clinical study comparing IO first-attempt success between humeral and tibial sites. Of 88 cardiac arrest patients analyzed, 58 and 30 IO access attempts were made in the tibia and humerus, respectively. Of those, there was a 90% first attempt success rate for the tibia, compared to 60% for the humerus. Of successful insertions, 6% of tibial insertions became displaced during transport, compared to 33% of humeral insertions. Investigators concluded that proximal tibial IO needle placement was associated with a significantly higher frequency of first-attempt success and lower incidence of needle dislodgements compared to humeral placements.

Reece A, Cohn A. Safety of power driven devices for intraosseous access in infants. BMJ 2011;343:d4362. doi:10.1136/bmj.d4362

This letter to the editor is regarding the relative safety of using power driven IO devices in infants. Three cases of amputation secondary to compartment syndrome in children under 2 years of age are referenced. The author expressed concern with the weight designations for IO needles stating some of the needles intended for pediatric patients may actually be too long for smaller children and that manually inserted devices may be safer in younger children.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.
Complications

Taylor CC. Amputation and intraosseous access in infants. BMJ 2011;342:d2778. doi:10.1136/bmj.d2778

This article describes two cases of leg amputation after intraosseous infusion in a 5-month-old girl and a 17-month-old boy. The author concluded that fluid extravasation, exacerbated by tibial fracture and needle dislodgement during transportation, caused limb ischemia in these two patients, and that adherence to the principles of careful needle placement, splinting/securing the catheter and limb, limited length of infusion and repeated monitoring of the limb will help avoid this devastating complication.


This article is a response to the Taylor and Clarke 2011 report of two amputations required following development of compartment syndrome after IO infusion. The author notes that complications are possible with all methods of establishing IO access including manual, spring loaded and power driven needles and that it is not accurate to directly relate the adverse events to the power driven device only.


A 7-month-old male infant in septic shock from Neisseria meningitides experienced a complication of bilateral extravasation of noradrenalin at the proximal tibia intraosseous infusion site resulting in severe soft tissue necrosis. Necrosectomy was performed bilaterally and surgical interventions were successfully performed to salvage both limbs. At 19 months the patient was able to crawl without extension deficit.

YEAR: 2010


This veterinary study evaluated 3 IO access devices, impact driven, automatic rotary, and manual, to compare the placement feasibility and amount of bone trauma induced when used in adult feline cadavers. Seventy-two IO insertion locations were used, the 3 devices were equally randomized to the insertion site. The rotary device was found to have shorter time to insertion and better ease of insertion. No statistically significant differences between number of bone fragments, defect diameter, or success rate were found between devices.


Authors reviewed two complications (extravasation and compartment syndrome) associated with IO access in children with meningococcal disease. Authors concluded that IO systems need formal evaluation to assess safety and complication profiles.


This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.


This article describes the vascular access options available to physicians caring for children, including details about each method, placement technique, indication, and complications.


A retrospective chart review in an urban emergency department (ED) was performed to identify central venous catheters placed in the ED and determine the bloodstream infection and duration of catheterization within a one year period. A total of 656 patients (3,622 catheter-days) with CVCs placed in the ED were identified, with 7 bloodstream infections. The mean duration of catheterization was 5.5 days. Within the infected CVC group, the mean duration of catheterization was 8.6 days.


This abstract describes a follow-up swine study to an earlier study done using concentrated doses of Adriamycin over 72 days in which bone complications occurred. Investigators studied different drug administration regimens that might be used to prevent complications. After the study was completed authors concluded that IO delivery of lower dose and diluted concentrations of Adriamycin was determined to be safer and resulted in less tissue abnormality when compared with higher dose/higher concentration; and use of the IO route with rotation of sites may be a feasible option for Adriamycin or other vesicant delivery.
**Intraosseous Vascular Access Bibliography**

**Complications**


This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.


This abstract presented at the 2010 ACEP Research Forum describes a study designed to compare Lidocaine’s effect on pain during fluid infusion through the tibial and humeral IO routes. Authors concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

**Navarro K. Intraosseous infusion. Texas EMS Magazine 2010;Nov/Dec:34-9**

This article provides a brief history of IO infusion and further discusses this vascular access technique in terms of anatomy and physiology, indications and contraindications, performing the manual procedure, and possible complications. A case study is discussed in which a 7-month-old male was treated under emergency circumstances with IO infusion in the lower limb and developed compartment syndrome, resulting in a below the knee amputation.


This article discusses use of IO access within the hospital setting in the emergent and non-emergent patient populations. The history of IO access, clinical situations in which IO access may be considered, devices, contraindications, and complications are discussed. Additionally, pain management, economics, education and training and risk management are explored. This article is co-published in Journal of Infusion Nursing, the Journal of Pediatric Nursing, and Critical Care Nurse and was produced by the Consortium on Intraosseous Vascular Access in Healthcare Practice.


This case report describes a complication of use of a sternal IO device (FAST-1, Pyng Medical Corporation, Richmond, Canada) in a 21-year-old soldier who suffered multiple soft tissue fragmentation injuries, in which the needle tip broke in situ. The author concluded the complication resulted from the IO needle being placed when the patient was lying in a lateral position with the skin over the manubrium displaced from the midline.


This article describes a case in which IO access, using the EZ-IO, was attempted in a patient with osteogenesis imperfecta. In each of 3 attempts, the needle became loose immediately after IO insertion. The author acknowledged that during emergencies it is difficult to assess and consider every possible contraindication for every intervention; and that IO access using the EZ-IO is the author’s choice for emergency vascular access when peripheral access is difficult or has failed.


This article discusses the importance of proper technique, attention to detail, and serial monitoring of limb involved when using IO vascular access to avoid potential compartment syndrome and other complications. The author reports the case of a 2-year-old boy who suffered compartment syndrome of the lower limb following use of IO infusion for resuscitation. Early detection of and response to changes in the affected limb resulted in the patient’s successful recovery.


Large retrospective study of patients for whom emergency vascular access was obtained using the Vidacare EZ-IO intraosseous system. Insertion success was 92% and within 10 seconds for 84% of the one-attempt successful cases. Complication rate was low (4.8%), none were serious, and extravasation was the most frequent (0.8%). The device was rated easy to use 72% of the time, and researchers concluded that the powered IO device is safe and effective for achieving vascular access in the resuscitation and stabilization of emergency patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

Complications

Case reports in which intraosseous (IO) vascular access was successfully used on adults. Summarizes indications for use, complications, and precautions/considerations.

Moen TC, Sarwark JF. Compartment syndrome following intraosseous infusion. Orthopedics 2008; 31: 815
Case report of compartment syndrome in a 6-year old girl after IO infusion during cardiac arrest.

In this case study a 7-month-old female with comorbidities was taken to the ED in cardiopulmonary arrest. IO access was the only vascular access method available for resuscitation. Post mortem CT of the head showed a considerable amount of air within the arterial circulation; the cause of death was listed as undetermined. The authors conclude that considering the details of the patient, the only logical explanation for the cerebral arterial air embolism is that air was introduced into the bloodstream via the IO route.

YEAR:  2007

This case study describes a 4-month-old boy that was found unresponsive. Resuscitation was started and continued through arrival to the ED; IO access at the proximal tibia was established using a 15 gauge aspiration needle as the only vascular access. Post mortem multislice CT examination showed gas in the hepatic veins, the right atrium, right ventricle, the upper pole of the right kidney and the cerebral vessels. Though air embolism was ruled out as the cause this death, it could have caused death in another case. The authors conclude that gas may have entered the body during resuscitation due to IO needle disconnections and that resuscitation with an inserted, disconnected IO needle should be avoided.

YEAR:  2006

Overview article of IO vascular access describes technique, efficacy in medication delivery, utility in pediatric emergencies, use in neonates, complications, and commonly-infused medications.

YEAR:  2005

Review article on IO vascular access in the pediatric patient. Advises that it is not necessary to adjust doses from IV doses, except for hypertonic solutions. Recommends that IO needle be replaced by an IV within 2 hours to avoid complications.
Abstract only. Article in German

YEAR:  2004

Case report of acute osteomyelitis developing 10 days after IO infusion in a 5-month-old infant admitted for sepsis.

Case report of a 31-year old developing left femoral mononeuropathy after bupivacaine is infused for postoperative analgesia into the iliac wound.

Schwartz SB, Kleid DM. Fictitious fracture after infusion of intravenous contrast material via an intraosseous needle. Pediatr Emerg Care 2004;20:829-31
Case report of misdiagnosis of a bone fracture as a result of IO infusion of radiographic contrast material in the involved extremity.
**Intraosseous Vascular Access Bibliography**

**Complications**

**YEAR: 2003**


Case report of IO infusion complicated by iatrogenic fracture at the IO insertion site. Concludes that multiple attempts to achieve IO access weakened the bone cortex and that “considerable force” applied by an anxious 100-kg emergency room doctor led to the fracture.


This article in Spanish discusses general IO principles.


Prospective radiographic study of 23 children who had received intraosseous infusion via trocar. Found no long-term effect on tibial growth with properly placed trocar.


Web article discusses IO cannulation procedure insertion sites, pathophysiology, risks, contraindications and complications.


Case report of a 7-month-old infant who developed severe compartment syndrome associated with popliteal arterial thrombosis following IO fluid infusion resulting in limb amputation.

**YEAR: 2002**


IO infusion of 7.5% hypertonic saline in this model was associated with a high rate of local complications (soft tissue or bone marrow necrosis).


Case report emphasizing that a cortical lesion in the proximal tibia corresponding to the site of IO insertion should not be mistaken for a radiographic sign of child abuse.


Case report of a 3-month-old infant developing osteomyelitis after IO administration of high-dose epinephrine. Speculates that administration of adrenalin in high concentrations may promote the development of osteomyelitis.

**YEAR: 2001**


Review advocating that pathological evidence of a few pulmonary fat emboli should not deter clinicians from using IO because of the many advantages of the technique.


Article implying that the risk of fat emboli is common with IO, but its clinical relevance is unclear.


Study in EMS personnel comparing saphenous vein cutdown to IO access (B.I.G.) in the adult patient. Times to fluid flow were 7.6 minutes for saphenous cutdown and 3.9 minutes for IO. Investigators conclude that use of the B.I.G. was more rapid and successful with fewer complications than saphenous vein cutdown.
Intraosseous Vascular Access Bibliography

Complications


Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.

YEAR: 2000


A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient.

Canada


Brief overview of IO infusion for an anesthesiology audience. Discusses technique, indications, contraindications, equipment, anatomical target sites and potential complications.

YEAR: 1997


Preclinical study in 33 piglets of IO infusion during CPR. Found no increase in fat embolism in IO group compared to controls group.

YEAR: 1996


Preclinical study in pigs examining developmental and histopathologic changes in bone following IO infusion and effect of osmolality and infusion speed. Found that infusion osmolality and speed was not related to physiologic or histologic changes in the bone marrow or in complication.


Preclinical study finding no compartment syndrome with up to 350 ml of IO fluid infusion; however, radio-opaque dye was detected in the soft tissues with compartment pressures increasing to more than 35 mmHg. Calls for a dose and time independent scale for safe intraosseous infusion.


Article describing IO infusion 18 pediatric resuscitative situations. Authors conclude that 11 patients would not have survived without IO access. Complications included a minor fracture, 1 case of compartment syndrome that did not require surgical intervention and a minor fat embolism that was of no clinical significance.


This article describes a malpractice case from the perspective of the prosecution regarding permanent drop foot suffered by a pediatric patient following extravasation from an IO line in the proximal tibia.

YEAR: 1995


Case report describing extravasation of fluids through a previous IO puncture site in the same tibia.


Suggests that intraosseous infusion is reliable alternative to peripheral vein access for rapid infusion of fluids in neonates and infants when venous access is impossible.

Abstract only
Intraosseous Vascular Access Bibliography

Complications


Preclinical study examining hematologic parameters (hemoglobin, schistocytes, free hemoglobin in plasma, bilirubin, lactate dehydrogenase, platelets, fibrinogen, and alveolar-arteriolar O2 gradient) with IO and IV autologous blood transfusions. Found that all hematologic parameters remained within normal limits in both IO and IV groups. Concludes IO blood transfusions to be hematologically safe, i.e. without risk of appreciable hemolysis, DIC or fat embolism syndrome.


Preclinical study in dog tibias demonstrating that circumferential pressure about an IO infusion site is a rapid method to detect incorrect placement of the IO needle.

YEAR: 1994


Case report of unilateral tibial osteomyelitis in a 20-month-old child following bilateral IO infusion. Reviews clinical indications, potential complications, and scan findings.


Case report of compartment systems following improper intraosseous infusion technique.


Long bone fractures should be considered a potential, although rare, complication of intraosseous infusion in children.


This abstract describes clinical use of the SurFast Cook Critical Care IO needle. Thirty-two IO insertion attempts were made, 87.5% were successful on first attempt. Average time to insertion was less than one minute; flow rate for infants and children was 1-2 mL/kg/min; flow rate for adults was 150-200 mL/min. There were two reports of minimal extravasation


Seminal article describing alternatives to intravenous cannulation including intraosseous access, intratracheal drug administration, sublingual and intralingual injection, intra-penile administration, and intracardiac injection. Concludes that the intraosseous method is an effective alternative to intravenous access in emergency situations.


Case report of bilateral osteomyelitis secondary to intraosseous infusion.


Case reports of 2 children with severe complications of IO infusions. One child developed severe tissue necrosis after IO placement. A second child developed compartment syndrome requiring fasciotomy.


Case report of compartment syndrome after prolonged intraosseous infusion (53 hours). Recommends that IO lines be used only temporarily until more permanent vascular access is established.

Review

Page 15 of 19
**Intraosseous Vascular Access Bibliography**

**Complications**

**YEAR: 1993**


Preclinical study in 20 immature rabbits receiving IO infusion of saline, bicarbonate, or dopamine solutions into the tibia. Found no changes in bone growth or epiphyseal injury related to IO infusion.


Case report of a 4-month-old infant developing compartment syndrome after IO infusion. The patient underwent a fasciotomy and had full and normal use of the leg at the 6 month follow up visit.


Preclinical study of IO infusion in 6 foals. Local soft tissue swelling and periosteal reactions observed immediately following the procedure resolved by 2 months.


Case report of fungal osteomyelitis following IO infusion in a child. Cautions that physicians consider both bacterial and fungal sources for infection.


This article presented two case studies in which pediatric patients received emergency IO infusions that ultimately resulted in compartment syndrome. In both cases the patients underwent a four-compartment fasciotomy and recovered without deficit. The authors conclude that though compartment syndrome is a risk of IO infusion, insertion of an IO line in emergency situations is a valuable technique.


Case report outlining precautions to prevent compartment syndrome following IO infusion. Advocates early recognition and aggressive treatment to preserve function in the affected limb.

**YEAR: 1991**

**Christensen DW, Vernon DD, Banner W Jr, Dean JM. Skin necrosis complicating intraosseous infusion. Pediatr Emerg Care 1991;7:289-90**

Case reports of 2 patients with local skin necrosis complicating IO infusion.


Case report of a child with severe compartment syndrome of both lower extremities following IO fluid resuscitation.


Review of intraosseous vascular access targeted for an oncology audience. Describes an implantable IO device with potential to make intraosseous access more convenient for the patient.

**YEAR: 1990**

**Crane RG. Where are the fractures and needles? Ann Emerg Med 1990;19(6):731**

Letter to the editor regarding a previous article, "Iatrogenic Bilateral Tibial Fracture After Intraosseous Infusion Attempts in a 3-Month-Old Infant." Inquires if fractures were caused by questionable technique or an unexplainable complication of a proximally placed needle.


Review of the use of intraosseous infusion in children in the prehospital setting and in the emergency department. Outlines anatomy, indications and contraindications, technique, complications and role of intraosseous infusion in pediatrics.
Intraosseous Vascular Access Bibliography

Complications

This series of 3 letters to the editor are in response to the case report of bilateral fracture of the mid-tibial shaft in a 3-month old child following tibial IO insertion. It is noted that the insertions were made in the mid-tibial shaft rather than at the proximal or distal tibial insertion sites.

Case report of compartment syndrome following IO infusion. Emphasizes IO to be useful for temporary vascular access. Advises that IV lines be placed as soon as possible after IO infusion. Recommends that radiograph be performed after the procedure in very young children to check for bone abnormalities.

This abstract describes a review of the literature on intraosseous pathways and reaches the conclusion that the rate of fluid administered is limited by the size of the marrow cavity and the complication is extravasation of fluids and/or drugs into the soft tissue.

YEAR: 1989

Case report of bone fracture following IO access in an infant.

Preclinical study in dogs examining lung samples for fat and bone marrow emboli following IO infusion. Found no significance difference in embolism formation or density between dogs receiving IO infusion of emergency drugs and control group.

YEAR: 1988

Preclinical study in pigs examining the epiphyseal plate after intentional penetration with IO needle and subsequent fluid infusion. Found no significant growth defects despite injury to the developing growth plate.

Description of IO infusion technique, site selection, procedure, anatomy, physiology, historical perspectives, contemporary research, indications, contraindications, complications, and future direction.

Article for emergency nursing audience describing IO technique, anatomy, absorption rates, clinical indications and contraindications, technique, complications and training in critically ill or injured infants and children.

Nursing article recommending IO early in the treatment of critically ill or injured children with difficult venous access. Highlights speed and ease of IO technique.

YEAR: 1987

Review article on IO infusion, includes historical background, physiology, method, clinical applications and complications of the IO procedure.

YEAR: 1986

Review of medical literature and research on the problem of difficult intravenous access.
Intraosseous Vascular Access Bibliography

Complications

YEAR: 1985

Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.

YEAR: 1984

Outlines problems with conventional vascular access in emergency medicine. Discusses possible resurgence of the "old" technique of intraosseous infusion.

YEAR: 1977

Observational study of 15 patients needing emergency fluids and in whom IV’s were difficult to establish. Patients received drugs and fluids via IO. Concludes that IO therapy is effective with no serious complications.

YEAR: 1956

Study finding sternal puncture superior to iliac crest and spinous process punctures for bone marrow sampling. Cautions that inexperienced practitioners should use iliac crest or spinal process in the absence of training in sternal puncture.

YEAR: 1954

Marill F. Death from sternal puncture. JAMA 1954;155:1276
Case report of death following pericardial rupture with hemorrhage, associated shock, and peripheral circulatory collapse.

YEAR: 1951

Fortner JG, Moss ES. Death following sternal puncture: report of two cases. Annals of Internal Medicine 1951;34:809-15
Case reports of 2 deaths from sternal puncture. Discusses 4 additional cases from the medical literature. Comments of the mechanism of death.

YEAR: 1950

Early review of IO infusion citing complication rate of osteomyelitis (approximately 1 in 150 cases).

YEAR: 1947

Early study on IO. Makes strong distinction between ordinary blood transfusion or infusion of isotonic solutions (generally safe) and continuous infusion or the infusion of hypertonic solutions. The latter carries considerable risk of osteomyelitis and subsequent disturbance in growth of the bone.

YEAR: 1946

Historical article discussing refinements in IO technique and analysis of IO complications. Includes case report of an infant who developed osteomyelitis subsequent to IO infusion.
# Intraosseous Vascular Access Bibliography

## Complications

**YEAR: 1945**


Early article on IO with caveats on use. Includes case report of complication following IO infusion via the sternal marrow of a diabetic. Reviews relevant anatomy, actual and possible technical complications.

**YEAR: 1944**


Early article describes technique for tibial bone marrow infusion. Reports 6 failures and 2 partial failures in 43 attempts on 34 young children. X-ray studies post IO infusion showed small bone defects and periosteal elevation with new bone formation.

**YEAR: 1943**

*Ravitch MM. Suppurative anterior mediastinitis in an infant following intrasternal blood transfusion. Arch Surg 1943;47(3):250-7*

This article provides a brief history of intraosseous infusion beginning in 1903 with supportive literature through the writing of this article in 1943. An overview of mediastinitis, a complication of intrasternal blood transfusion, is also provided followed by a case report of anterior mediastinitis in an infant.

**YEAR: 1922**


Seminal article on blood circulation in the IO space. Demonstrates movement of red blood cells from the bone marrow into the circulating blood by perfusion of the tibia of the dog and by injections into the bone marrow in the rabbit and cat.
This study compared IO insertions with the EZ-IO device (tibial/humeral insertions) to the FAST-R device (sternal insertions only) in a physician-staffed helicopter emergency medical service. Insertion time, insertion site, flow, indication for IO access, and complications were compared. Median insertion time was 15 seconds for EZ-IO and 20 seconds for FAST-R. Overall, 35.1% of EZ-IO insertions resulted in poor flow and required a pressure bag while 85.7% of FAST-R insertions had good or very good flow. EZ-IO complications included extravasation (2.4%), aspiration failure (11.9%), and insertion time >30 seconds (4.8%). Complications associated with FAST-R included user failure (12.5%) and insertion time >30 seconds (12.5%). The authors suggest that although EZ-IO is faster the FAST-R device may be more useful when high-flow infusion rates are required. The authors indicate that a low number of insertions were made with the FAST-R device and many outliers were observed in the data. However, the article does not present the total number of insertions per device.

YEAR: 2018


This case review describes a complication of compartment syndrome post IO placement in a 64 year old male initially unresponsive and hypoglycemic. Approximately 15 minutes post-ED arrival compartment syndrome signs were noted and confirmed with compartment pressures. An ultrasound confirmed lack of flow from the IO needle and an x-ray showed the needle set to be inserted 2 mm beyond the posterior tibial cortex. Patient was taken to surgery for fasciectomy and four compartment release with subsequent return of pulses.

*(Correspondence by the manufacturer 12-2018 with lead author confirmed the tibial placement was lateral and the patient had a full functional recovery).


This article describes a study using prospective sampling of bone marrow (BM) to assess the feasibility of using bone marrow samples for blood group serotype analyses. Peripheral blood (PB) from each subject was used as that subject's control. 71 pairs of BM and PB samples were tested for ABO type, D type, and RBC alloantibody screening. All BM samples were successfully analyzed with no inconclusive results. The study concluded that BM samples collected from IO devices can be utilized for blood group serologic analyses.


This study describes 3 cases in which tissue plasminogen activator (tPA) was administered via intraosseous (IO) access on a mobile stroke unit as part of the BEST-MSU study. IO access was obtained with the EZ-IO device as part of the study protocol.


This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.


This study was a prospective, single-center, observational, cohort study of 10 patients comparing the ventricular enhancement time between humeral intraosseous (HIO) access and brachial intravenous (BIV) access during CPR in adult humans. HIO access was obtained with the EZ-IO device. Endpoints were right and left ventricular enhancement times after administration of a contrast agent. Results indicated that arrival times of medication at the right and left ventricles were significantly lower with HIO than BIV.

Prospective cohort study done by review of video footage which was taken over a 15 month period as part of a quality improvement initiative for patients in extremis (the absence of a palpable pulse or measurable blood pressure) undergoing thoracotomies during trauma resuscitation. Data recorded for vascular access included types intraosseous (IO), peripheral intravenous (PIV), central venous (CVC) and intracardiac (IC)) and site of attempted access, number of attempts and success rates, procedure time, demographics, and mechanism of injury. 145 access attempts were made in 38 patients (median 3.8 (SD 1.4) attempts per patient). Time to access was similar for PIV and IO but longer for CVC and success rates for IO insertion were significantly higher than for PIVs or CVCs (95% vs. 42% vs. 46%, p<0.001). Authors “recommend placement of IO cannulae as a best practice to rapidly establish first line vascular access for resuscitation and as a bridge to additional access.”


This is a case report of a 69 year-old male admitted to an ED in the UK with an extradural hematoma following closed head injury. He was treated with decompression of the hematoma using a 25 mm long EZ-IO intraosseous needle. This is believed to be the first reported use of an EZ-IO device in this manner in the UK. The patient succumbed to his injuries two days later. However, the authors recommend consideration of this technique when transfer to a hospital with a neurosurgery unit for craniostomy is not a feasible option.


This is a prospective registry of data collected in the prehospital setting to evaluate the effect of either intravenous (IV) or intraosseous (IO) vascular access management of non-traumatic, adult, out-of-hospital cardiac arrest (OHCA) cases on patient (pt) outcomes. Results: 28.9% IO patients achieved ROSC vs 38.3% IV; 3.8% IO subjects survived to hospital discharge vs 10.3% IV subjects. The authors concluded that in patients with non-traumatic OHCA, use of IO access is associated with lower survival and poor neurologic outcomes as compared to IV access. Limitations: 560 pts received IO access (5%) and 12,495 received IV access (95%); selection bias by paramedics choosing the vascular access method based upon presenting conditions; and IO access had a higher proportion of non-safe, effective, and attainable in all age groups despite FDA approval only in patients greater than 3 kg.


This paper is a letter to the editor (see Wiles 2018) responding to this author's original work where an IO needle was used (off-label) in an attempt to decompress an acute intracranial hematoma. The authors emphasize that patient safety is their primary concern and that their off-label use of an approved IO device was the best option at the time. They also reiterate that the technique used has not been studied in a clinical trial and they do not advocate its use as standard practice.


This letter to the editor is in response to Nurii et al.’s letter to the editor regarding Kawano et al.’s article on the effect of time to vascular access in out-of-hospital cardiac arrest (OHCA). Kawano et al. performed Nurii et al.’s suggested sensitivity analysis by modifying their multivariable logistic regression model to include duration of out-of-hospital resuscitation among patients with return of spontaneous circulation (ROSC) or termination of resuscitation as measured from the 911 call to either ROSC or termination of resuscitation. The authors conclude that the model continued to demonstrate that IO access, when compared to IV access, was associated with a decreased probability of a favorable neurologic outcome.


This paper is a letter to the editor describing successful insertion of EZ-IO in a neonate weighing less than 2 kg with respiratory failure, signs of sepsis, and shock. After successful insertion the patient was resuscitated and later stabilized. The authors advise that IO access is safe, effective, and attainable in all age groups despite FDA approval only in patients greater than 3 kg.

This letter to the editor is in response to Kawano et al.’s article on the effect of time to vascular access in out-of-hospital cardiac arrest (OHCA). Kawano et al. found an association between intraosseous vascular access and lower survival and worse neurologic outcome in OHCA. Nuri et al. express concern regarding selection bias and confounding factors not being accounted for in the original study. Nuri et al. suggest accounting for time from call to vascular access or return of spontaneous circulation (ROSC). Nuri et al. also suggest considering whether ROSC is an appropriate outcome. Reference: Kawano T, Grunau B, Scheuermeyer FX, et al. Intraosseous vascular access is associated with lower survival and neurologic recovery among patients with out-of-hospital cardiac arrest. (Initial article: Ann Emerg Med. 2016;71:588-596).


Investigators assessed the ability of EMS providers with various skill levels to correctly identify the insertion sites for both the proximal tibia and proximal humerus. Participants were attending a state EMS conference. The distances from the sites identified to correct site was significant. The study concluded the accuracy of landmark identification was low and proper training is important.

Redfield C, Suarez S, Daniels, Sanchez C, Siples H, Landry K. The effect of IV vs. IO access in prehospital cardiac arrest ROSC rates. Prehosp Emerg Care 2018;22(1):38

Retrospective study reviewing data from one EMS service that compared return of spontaneous circulation (ROSC) in cardiac arrests when intraosseous (IO) or intravenous (IV) access was obtained. An IV was placed in 361 patients with a ROSC in 148 (41.1%); and 360 patients had an IO placed with a ROSC in 80 (22.2%). The difference for greater ROSC rates with IV vs. IO use was significant.


This is a learning module for fourth year medical students to learn about fluid management and IO needle placement. The module simulates hypovolemic shock in a 3 year old patient using a child mannequin. An IO kit, including an EZ-IO driver, is supplied for obtaining IO access. A pilot study was conducted in 2017 with 16 subinterns on a pediatric service. Perceived competence in management of volume depletion and procedural skills were high following the training session and students felt the case was a beneficial learning experience.


This article examines emergency vascular access during newborn resuscitation. It discusses the time needed to place an emergency umbilical vein catheter (eUVC) and intraosseous kits (EZ-IO) in a series of simulated newborn resuscitations across 4 studies. In all 4 studies IO placement was significantly faster than eUVC placement. An additional study found eUVC placement to be significantly faster with real human umbilical cords than with simulated umbilical cords as used in the aforementioned studies. While IO access in newborns appears faster then eUVC in simulated models, to date, no randomized trials or large case-cohort studies have systematically evaluated the short and long-term safety of IO placement during newborn resuscitation. Current guidelines still support eUVC as the preferred method of obtaining vascular access during newborn resuscitation. The authors suggest further studies are needed to determine short and long-term safety of IO access in newborns before widespread adoption of the process can be recommended.


This abstract describes interim results of a study in a swine model that discusses the utility of intraosseous blood transfusions for treating hypovolemic battlefield injuries, compares advantages and complications of humeral versus sternal IO access for resuscitation, and identifies flow rates, degree of intravascular hemolysis, and occurrence of coagulopathy in single versus double site intraosseous blood transfusion. The study found that in an animal model of hemorrhagic shock, double site IO transfusion appears to confer a significant advantage in flow rates without significant complications.


This article presents a review of current evidence regarding different routes for the administration of medications during neonatal resuscitation, of which the intraosseous route is included. A table comparing four different intraosseous devices, including EZ-IO, is presented in the document.


This paper describes a project where information was collected using a paper survey from EMS and ED providers in Nebraska. The purpose of the survey was to identify gaps in their skills, knowledge and abilities in order to aid curriculum development for a mobile training unit to be used in rural areas of the state. Intraosseous placement is a clinical skill in which the participants would like further training.


This letter to the editor is a response to Durnford et al. (2018) regarding their off-label surgical procedure utilizing an IO needle in an attempt to decompress an acute intracranial hematoma. Wiles requests confirmation of the regulatory processes in place prior to the undertaking of the IO surgical technique.

This paper is a consensus statement seeking to provide clear guidance for the management of pregnant trauma patients in the pre-hospital setting in the UK. IO access is recommended as an alternative to gain vascular access in pregnant trauma patients when IV access cannot be easily or quickly established. It is recommended that IO access be placed in the right humeral head in order to facilitate left/tilt lateral positioning of the pregnant patient.


This case report describes a CT angiography of the chest and abdomen done via an EZ-IO catheter placed in a critically ill patient’s proximal humerus. The contrast media was infused at a rate of 4 mL/s and the infusion pressure never exceeded 300 mmHg. No immediate or short term complications were observed. The authors describe the overall image quality and vessel contrast observed as excellent.


The author discusses tactical combat casualty (TCC), which has evolved over the past 20 years into a set of evidence-based, best practice prehospital trauma care guidelines for use in combat. TCC has become a standard of trauma care in the US military and many other militaries of our allied nations. The Committee on TCCC and the Joint Trauma System are working with civilian trauma colleagues to advance prehospital trauma care into civilian trauma care in situations such as shooter events, terrorist bombings, motor vehicle accidents, household accidents and criminal violence.


A retrospective chart review was done to analyze data of three EMS agencies over an 18 month timespan. Analysis was done on charts from adults who suffered OOHCA and received epinephrine through EMS established IV or IO access. An IO first approach was found non-inferior to an IV first approach based on the end point ROSC at time of emergency department arrival.


This study reviews current IO administration of antidotes for patients that have presented to the emergency department with serious poisoning and IV access is not available. The study concluded that the evidence supporting the use of IO route for administering antidotes for poisoning patients is rare. Most evidence of IO access administration of antidotes has occurred in animal studies and case reports. Per author, despite lack of evidence, IO access is a potential option for antidotal treatments for resuscitation for patients where IV access is not available.


This study addresses the need for the development of a reliable and validated tool to evaluate technical resuscitation skills in a pediatric simulation setting. The authors created four resuscitation and emergency simulation checklist and evaluation tools were created, (RESCAPE). Study found that use of the RESCAPE tools are reliable and validated tools for evaluation of resuscitation skills in pediatric simulation-based educational programs.


This retrospective cohort study evaluated emergency medical services (EMS) that treated adult patients with out of hospital cardiac arrest (OHCA) in order to compare drug administration via intraosseous(IO) versus intravenous (IV) and the effectiveness. Study endpoints were survival to hospital discharge, return of spontaneous circulation (ROSC), and survival to hospital admission. The study included 1,800 patients, 1,525 of whom received IV access and 275 who received IO access. The practice for OHCA management in the EMS system from which the data was obtained was to attempt tibial IO access after failed IV attempts. The authors concluded that use of IO access was associated with a lower likelihood of ROSC and hospitalization; and acknowledged that further study of how vascular access routes affect OHCA patient outcomes is warranted.

Leutscher SA, Gerritse BM, van der Meer NJ, Schuitemaker FJ, Scohy TV. Need of intraosseous access in advanced life support in the in-hospital setting: Evaluation of difficult vascular access in cardiac arrest. Resuscitation 2017;112:e7

This letter to the editor states the usefulness of intraosseous access devices in out-of-hospital-cardiac-arrest (OHCA) settings.


This paper describes the management of acute hypothermia. In moderate hypothermia (28-32°C) intraosseous access should be considered in patients with difficult peripheral access.
Intraosseous Vascular Access Bibliography

This manuscript provides an overview of CPR physiology, especially as it relates to compression and ventilation. The placement of peripheral and central venous catheters can interfere with compressions. As such, IO access is an alternative that allows drug administration with similar pharmacokinetics and absorption as peripherally administered medications and a higher insertion success rate (>80%).

A prospective study comparing results of intravenous (IV) and intraosseous (IO) blood specimens when analyzed using an EPOC point of care analyzer during resuscitation of non-traumatic cardiac arrest and critically ill patients. Seventeen patients who had IO and IV specimens collected within 5 minutes of each other were included in the study; IO samples were collected before administration through the IO catheter in the proximal tibia or proximal humerus. Results showed that based upon Bland Altman plots, there was reasonable agreement between IV and IO values for PH, bicarbonate, sodium and base excess, and moderate agreement for lactic acid. The intraclass correlation co-efficient was excellent for sodium and reasonable for PH, pO2, bicarbonate and glucose. The primary limitation noted was the small sample size (n=17) and the substantial impact of single outliers in the data.

This article describes a prospective, multicenter, in situ, simulation-based cohort study to describe the frequency of different types of errors between general emergency departments (GEDs) and pediatric emergency department (PEDs) in a simulated pediatric patient case of hypoglycemic seizure. During the debriefing portion of the simulation providers and teams were asked about obtaining vascular access (IV/IO). Questions involved how to obtain vascular access, barriers to obtaining access, assessment of confidence in ability to obtain access, location of access, needle size, time to gain access, who to contact after failed attempts at access, and how to decide which medications or fluids to administer.

This retrospective non-inferiority study examined EMS data extracted from a statewide EMS data system over a two year period. IO insertions performed by advanced EMTs (AEMT) and Paramedics were compared for insertion success rates. The majority of IO placements were with the EZ-IO®. The investigators concluded successful IO access was not different among AEMTs and Paramedics lending evidence in support of expanding the scope of practice of AEMTs to include establishing IO access in adults.

Case report of a 29 year old that was diagnosed with osteomyelitis in his left tibia after a prehospital IO placement for resuscitation of cardiac arrest. Medications infused included naloxone, epinephrine, and amiodarone. The patient had ROSC and his IO catheter was removed within one hour of ED arrival due to infiltration. Diagnosis of tibial osteomyelitis occurred approximately 8 weeks post-initial placement.

YEAR: 2016

Investigators conducted a retrospective prehospital study over a 3 month time period comparing IV vs. IO access for return of spontaneous circulation (ROSC). With approximately 800 cases of out-of-hospital cardiac arrest (OOHCA) they found a significantly greater success rate for IO access but no difference between IO and IV for ROSC or time to first epinephrine.

This journal article literature review was written to provide information about the history, clinical considerations, and devices associated with intraosseous access to administer resuscitative drugs when IV access can’t quickly or easily obtained.

This literature review examined the increase in use of intraosseous access for administration of resuscitative fluids and drugs to patients where intravenous access could not quickly or easily obtained during disasters and mass casualty events. The review also included a comparison of IO route to other routes for establishing vascular access in patients that have been involved in mass casualty or disasters.

The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.

Singapore


This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.


The abstract describes the interim results of an investigational device exemption study evaluating use of EZ-IO in volunteers for a 48 hour dwell time period. At the time of the report, 39 subjects completed the study with no serious adverse event reports. Subjects were randomized to receive IO insertion in the proximal tibia or proximal humerus insertion sites. Pain has been managed using oral hydrocodone/acetaminophen and/or intravenous/intramuscular ketorolac. This study is sponsored by Teleflex Incorporated.


This study examined the attitudes of nurses working with pediatric patients and intraosseous access in pediatric patients. The study was conducted with the use of a diagnostic survey distributed to 200 nurses, with 135 nurses returning the surveys. The study found that there is a need for more training with nurses to increase their level of knowledge of intraosseous access and improve nurses attitudes for use of intraosseous access in pediatric population in emergency situations.


In this letter to the editor authors discuss the difficulties of obtaining vascular access in patients in shock; and make a case for use of intraosseous access (IOA) in shock. Authors note IOA access as a safe, effective alternative to venous access with relatively rare complications.

Poland


This journal article discusses lessons learned from treatment of severe traumatic injury in combat situations and how they can be applied in the civilian environments when treating the same type injuries.


Online article that briefly discusses use of intraosseous access to obtain a CTA study for pulmonary vasculature imaging when intravenous access is difficult.


This study was conducted to determine the level of experience as well as the beliefs and attitudes of trauma practitioners in Canada, Australia and New Zealand using IO devices in adult trauma patients. The study used a web-based survey submitted to 1771 to all members of 4 national emergency and trauma organizations. Surveys were completed by 425 participants and most participants surveyed were comfortable using the IO device in resuscitation of adult trauma patients.


Randomized, prospective preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered vasopressin during cardiac arrest and CPR until ROSC was achieved. No difference was noted for ROSC between TIO and IV delivered vasopressin. Authors concluded the use of IO access could avoid the time delay associated with IV access, and that it is effective for treatment of hypovolemic cardiac arrest and should be first line for rapid vascular access.


This study compared IV to tibial IO administration of amiodarone. Investigators found no significant differences for the endpoints of Cmax, Tmax and time to/rate of ROSC between IO and IV.
This article in German describes a case study of a 3 year old child with a serious heart defect (after total cavopulmonary anastomosis) in which bilateral humeral IO access sites were obtained to manage her condition and the patient was discharged after 30 days without neurological deficits. Key messages include that IO access in children should be a primary access route in emergent and urgent situations, unless a suitable venous access is already available; the humeral head insertion site is an accepted method in emergency situations in adults and children; and IO access is intended for regular emergency administration of drugs. The purely preventive use of an IO is not indicated. Article in German.


In a swine study comparison of the humeral IO and IV amiodarone administration routes investigators found no difference in time to ROSC or rate, time to maximum concentration (Tmax) p = 0.501) or in maximum plasma drug concentration (Cmax) (p = 0.232).


This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access "should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation".


This abstract describes a study designed to describe and compare the use of intraosseous (IO) catheters by military MEDVAC providers during recent conflicts. There were 12 patients that receive IO catheters following failed intravenous cannulation with an 83% success rate, and 74 patients for whom IO access was the first access attempted with an 85% success rate. Researchers concluded that IO access can be used successfully in the combat setting and accounted for approximately 12% of vascular access in the MEDVAC population they studied.


A preclinical study evaluating blood transfusion via IO vascular access in anesthetized swine. Results showed pressurized blood transfusion through IO vascular access resulted in acceptable flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.


This study compared the effects of IO and IV administered resuscitative drugs (vasopressin, amiodarone, and epinephrine) on return of spontaneous circulation (ROSC) in a swine model of sudden cardiac arrest (SCA) with ongoing resuscitation. Swine were randomized to 1 of 5 groups; tibial IO, sternal IO, IV, CPR+defibrillation, and CPR-only. There was no significant difference in ROSC between SIO, TIO, and IV groups. However time to ROSC was significantly less for the SIO group compared to the TIO group (p=0.003). This is possibly related to higher fat content in tibial bone marrow relative to the sternum and the lipophilicity of amiodarone.


This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9.58±2.706mL/hr (n=27); mean PH infusion rate was 6.292±3.277mL/hr (n=52). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.

A study comparing use of the Bone Injection Gun (B.I.G.) and the NIO by paramedics in a manikin model simulation of CPR. Following training, 40 paramedics performed device insertion in the manikin using both devices; and completed a questionnaire regarding their knowledge of indications and contraindications of IO access and experience with each device. Successful insertion was achieved 100% with the NIO and 95% with the B.I.G. Authors concluded that after a short training program, paramedics can perform intraosseous injection with a high degree of efficacy.


This article reviews the best practices for optimal cardiac arrest management, echoing the 2015 ACLS guidelines. Intraosseous vascular access is identified as an access route for delivery of pharmacological agents to aid in patient management.


This retrospective study evaluated 3 years of data in an urban EMS system to determine if out-of-hospital intraosseous (IO) access results in shorter time to epinephrine than peripheral intravenous (IV) access. The proximal humerus was the most common IO access site with a first pass IO success rate of 95.6%; and a significantly lower complication rate when compared to the tibia. Authors reported the time to epinephrine administration was faster in the IO access group; and concluded the out-of-hospital use of IO vascular access for time-dependent medical conditions is recommended.


A retrospective study evaluating vascular access routes used for US military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) use including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. PIV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.


In this letter to the editor, the author calls into question the continued recommended use of the umbilical venous catheter in neonatal resuscitation by the European Resuscitation Council and the lack of intraosseous vascular access recommendation. The author makes the argument that accessing the umbilical vein is difficult for even the most experienced NICU clinicians and that time cannot be spared in these resuscitations; and intraosseous access can provide a viable option for drug delivery.


This letter to the editor describes a simulation study evaluating use of the NIO device by 47 firefighters in a simulated anaphylactic shock model. The firefighters were trained on use of the device and standard anaphylactic shock management. An improvement in knowledge of intraosseous vascular access and anaphylactic shock protocol was demonstrated by the group.


A pre-clinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.


This case study describes the medical management of a 20 year old male post high-speed motor vehicle crash with multitrauma and in shock upon air medical team arrival. Care entailed aggressive airway support, bilateral chest decompressions, management of potential pelvic bleeding with a pelvic binder, one peripheral IV through which packed red blood cells and plasma were given and one proximal humerus IO through which 1 g tranexamic acid (TXA) was given.


A manikin study in which 40 paramedics reasoned with and without CBRN PPE attempted to establish tibial intraosseous (IO) access using the Jamshidi and B.I.G. devices, time to placement was measured. Results showed that in participants with and without CBRN PPE, BIG access was faster than Jamshidi.

This is an abstract of a study conducted in the UK to determine the success rate of the EZ-IO Intraosseous Infusion System on return of spontaneous circulation (ROSC). Patient records were examined for 195 cardiac arrest patients who had an EZ-IO placement attempt. ROSC was achieved for 29% of patients. In patients who received IV administration of medications, 46% achieved ROSC. While IV access appears more favorable in this study, there may be other factors associated with achieving ROSC that were not taken into account.


A preclinical study comparing IV and humeral intraosseous (HIO) access administration of vasopressin in a hypovolemic swine model. Anesthetized swine were put into cardiac arrest, followed by 2 minutes CPR, then 2 minutes of vasopressin administration via IV or HIO route. Return of spontaneous circulation was achieved for 100% of HIO and 92.5% of IV groups. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for return of spontaneous circulation was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV groups for Cmax or Tmax.


Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, followed by 2 minutes CPR, then 2 minutes of vasopressin administration via IV or SIO route. Return of spontaneous circulation was achieved for 90% of IV and 100% of SIO groups. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for return of spontaneous circulation was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the SIO group it was 10 minutes 12 seconds (± 1 minute 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing administration of Hextend via IV and tibial intraosseous (TIO) access routes for time for administration and hemodynamic measures in a hypovolemic swine model. Following exsanguination, 500 mL of Hextend was administered via both routes; a control group received no Hextend. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for administration in the IV group was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the IO group it was 10 minutes 12 seconds (± 1 minute 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, followed by 2 minutes CPR, then 2 minutes of vasopressin administration via IV or SIO route. Return of spontaneous circulation was achieved for 90% of IV and 100% of SIO groups. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for return of spontaneous circulation was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the SIO group it was 10 minutes 12 seconds (± 1 minute 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing administration of Hextend via IV and tibial intraosseous (TIO) access routes for time for administration and hemodynamic measures in a hypovolemic swine model. Following exsanguination, 500 mL of Hextend was administered via both routes; a control group received no Hextend. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for administration in the IV group was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the TIO group it was 10 minutes 12 seconds (± 1 minute 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing IV and humeral intraosseous (HIO) access administration of vasopressin in a hypovolemic swine model in cardiac arrest. Following exsanguination, the swine were placed in cardiac arrest for 2 minutes, then resuscitated for 2 minutes in accordance with ACLS guidelines. Vasopressin was administered. Blood samples were collected at various time points following vasopressin injection and analyzed for maximum concentration (Cmax) and time to maximum concentration (Tmax) between groups; return of spontaneous circulation was also captured. ROSC was achieved for all HIO subjects (n=7) and in seven out of eight IV subjects; mean time to ROSC was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV administration of vasopressin for achievement of ROSC, time to ROSC, Cmax, Tmax, concentration over time, survivability, or odds ratio.


Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.


This is an abstract of a study conducted in the UK to determine the success rate of the EZ-IO Intraosseous Infusion System on return of spontaneous circulation (ROSC). Patient records were examined for 195 cardiac arrest patients who had an EZ-IO placement attempt. ROSC was achieved for 29% of patients. In patients who received IV administration of medications, 46% achieved ROSC. While IV access appears more favorable in this study, there may be other factors associated with achieving ROSC that were not taken into account.
This paper describes a survey of trauma military directors that suggested that military data supporting damage control resuscitation has
2015;158(6):1686-95. doi: 10.1016/j.surg.2015.06.026
This analysis examines the current state of military trauma in high-income countries and how these developments could be applied to
low/middle-income countries to help deliver affordable trauma care there. Intraosseous needles are identified as a key technology
especially when working in a moving environment or on a bumpy road which would likely be encountered in a low/middle-income country.
Under such circumstances normal cannulation would likely fail out, whereas an IO needle would remain in place.
Chico-Fernández M, Terceros-Almanza L, Mudarra-Reche C.  Innovation and new trends in critical trauma disease.  Med Intensiva
This article discusses the need in ongoing innovations in the management of trauma patients in ICUs. In order to achieve more innovations there is
a need for improvement in the following areas: methodology in emergency care medicine, increased knowledge in resuscitation strategies,
study of epidemiology of trauma disease and its effect on patient outcomes, application of methodologies for ensuring correct trauma care
team performance.
This article describes the strategies used at one hospital (Penn Presbyterian Medical Center) to increase the use of intraosseous catheter
to rescue patients in all care settings.
Eriksson M, Strandberg G, Lipsey C, Larsson A.  Troponin I can be determined in intraosseous aspirates in a porcine shock
A preclinical study in which 8 anesthetized swine were put into an induced septic shock state to allow troponin I level measurements to be
compared from serial venous plasma, arterial plasma and intraosseous aspirate specimens collected hourly. Two milliliters of IO aspirate
were wasted before collecting each IO specimen for analysis. The levels of IO troponin I increased during the first 3 hours of shock but then
plateaued at a high level while the venous and arterial levels continued to increase. Authors concluded that troponin I can be analyzed in
bone marrow aspirates in a shock model and that this information may be useful in medical emergencies where cardiac damage is
suspected to be involved.
Ewy G, Bobrow B, Chikani V et al.  The time dependent association of adrenaline administration and survival from out-of-hospital
This article discusses a retrospective analysis of data collected to investigate the possible time-dependent outcomes associated with
adrenaline administration by personnel with Emergency Medical Services (EMS). Primary endpoint was survival to hospital discharge and
positive neurological outcome. The study included 3,469 patients with out of hospital cardiac arrest (OHCA). Study concluded patients with
OHCA that had been treated early with adrenaline and had a shockable rhythm had a survival rate to hospital discharge.
Goldschalt C, Doll S, Ihle B, Kirsch J, Mutzbauer TS.  Peripheral venous or tibial intraosseous access  for medical emergency
This paper describes a cadaver study that evaluated the ability of dental students to successfully place peripheral venous catheters and
tibial intraosseous (IO) catheters using the Vidacare/Teleflex EZ-IO. Success rates, as well as insertion times, were recorded. 29% of
venous and 89% of IO placements were successful. Successful venous access was achieved in an average of 183 seconds and IO access
was achieved in an average of 30 seconds. Investigators concluded that chances to perform successful vascular access for inexperienced
dentist may be higher when using tibial IO for emergency vascular access compared to when using IV catheters.
This paper describes a survey of trauma military directors that suggested that military data supporting damage control resuscitation has
altered civilian practice. Among those practices are the use of intraosseous vascular access
Intraosseous Vascular Access Bibliography
Emergency Care

Retrospective analysis of IO needle insertions performed in all HEMS missions during the first three years (2009-2011) using the EZ-IO® system. Overall success rate of EZ-IO procedures (N=348) was 99.6%, with a first attempt success rate of 85.9%; and high user satisfaction rate of 93%. IO as access was mostly second line overall but first line in children <7, trauma and cardiac arrest. There was one failure and four needle insertion problems noted; no serious complications.

A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, established via the EZ-IO, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.

Prospective preclinical study by to determine the effects of humeral IO (HIO) and IV epinephrine administration during cardiac arrest on pharmacokinetics, ROSC, and odds of survival. There were no significant differences in ROSC, maximum concentration; except at 30 s, and time-to-concentration-maximum between the HIO and IV groups. Significant differences existed between the experimental groups and the control. The HIO delivered a higher concentration of epinephrine than the IV route at 30 s, which they noted may be a survival advantage. Authors suggested clinicians consider using the IO route to administer epinephrine when IV access is unobtainable.

This systematic review compared the reliability, ease of use and speed of insertion of different parenteral access methods with focus on relieving dehydration associated with the Ebola virus disease. Authors found that, compared to the intraosseous group, patients in the intravenous group were more likely to experience an insertion failure.

Lantos D, Goforth D. Intraosseous needles reduce time to first medication for coding inpatients without intravenous access. Crit Care Nurse 2015;35(2):e69
This abstract describes data from a small hospital study after a 2013 policy change which allowed rapid response team nurses to place IO access for in-hospital cardiac arrests. Prior to the change the mean time to first medication was 4.3 minutes with 53.1% patients surviving to ICU. Post-policy change patients that received IO access had a mean time to medication of 1.7 minutes and 85.7% survival to ICU.

This single center, prospective, observational clinical study compared use of intraosseous (IO) access to central venous catheter (CVC) access for inpatient medical emergencies, managed by the medical emergency team (MET), within an urban teaching hospital. CVC access training included percutaneous, landmark-guided CVC placement without ultrasound guidance, using the femoral vein as the primary site. For IO access, the proximal tibia was the primary site and proximal humerus was secondary. Results showed IO access was significantly superior to CVC access with regard to first pass success rates, overall success rates, time to placement, and number of attempts for proper placement. On average more CVC kits were used per patient; complications were greater with CVC. There was one serious complication of tissue necrosis secondary to extravasation in the IO group.

The 2015 updated ACLS guidelines considered a number of issues regarding cardiovascular life support; however there were no changes to those recommendations made in the 2010 guidelines in regard to intraosseous access. The 2010 guidelines stated in regard to IO drug delivery, "it is reasonable for providers to establish IO access if IV access is not readily available (Class Ila, LOE C)."

This paper describes a case study of a 64 year old man who presented to the ED with symptoms of bleeding related to rivaroxaban and clopidogrel. Due to concern for bleeding, low BP, and perceived difficulty in IV access, IO access was obtained. After access the patient experienced significant pain and was unable to tolerate large volume administration through the IO site. The patient was successfully treated with prothrombin complex concentrate (PCC), which has a smaller volume when compared to blood products. This was the first reported case of IO PCC administration.
This article summarizes the main updates to the 2015 ERC Guidelines for Resuscitation of adults and pediatric patients. In reference to intraosseous (IO) vascular access, the guidelines state: "IO access is a "rapid, safe, and effective route to give drugs, fluids and blood products"; and recommend consideration of the IO route when peripheral venous access is difficult.


In a healthy adult volunteer study contrast media was injected through the proximal humerus site and captured under fluoroscopy as it entered the heart. The mean time it took from injection at the insertion site to visualize contrast entry into the superior vena cava and the right atrium was 2.42 seconds. Abstract presented at ACEP 2015. This study was sponsored by Teleflex Incorporated.


This is a case report of a 34 year old female with bilateral peripheral pulmonary emboli with bibasal consolidation and pleural effusions. Due to difficulty with establishing peripheral access, IO access was established in the proximal tibia and Alteplase was administered along the line. Central venous and arterial access were ultimately obtained, and extracorporeal membrane oxygenation (ECMO) was initiated. The patient ultimately recovered and was discharged from the hospital after 36 days. The authors noted that the combination of IO thrombolysis and ECMO for treatment of acute massive PE has not been previously reported and highlights the importance of appropriate access for administration of pharmacotherapy in the critically ill patient.


Abstract describing preliminary results for the first 24 subjects of an EZ-IO study evaluating catheter dwell times for 48 hours. Initial data indicate that IO vascular access can be safely maintained for a period up to 48 hours without risk of osteomyelitis or other serious adverse events. Authors also noted that additional analgesics for IO infusion pain management may be more effective than the current solely administering lidocaine into the IO space. This study was sponsored by Teleflex Incorporated.


This article presents a case report of a 7 month old female who received intraosseous vascular access via the EZ-IO in the distal femur that resulted in a dermal abrasion where the needle hub contacted the skin. The wound healed without significant complication however the scar at the IO site persisted at 11 months post the event. The authors recommend that providers use the minimal force necessary when operating the EZ-IO to avoid similar adverse events.


Case study of 9-month-old patient (approximate weight 7 kg) presented with Ebola Virus Disease (EVD) and severe dehydration. IO access was obtained using a 15 g Jamshidi device to the right proximal tibia. A total bolus of 280 mL of lactated ringers solution was infused; then the IO infusion continued for 12 hours until an IV could be established. Authors stated it is important for emergency disaster responders, as well as their responding organizations, to know and understand that IO access is an important and safe modality to use in patients with EVD, and in the austere settings often found in disaster settings.


This abstract describes pilot data regarding initial vascular access device use in emergency department management of patients with out-of-hospital cardiac arrest. Twenty-six patients were included, and only 10 arrived to the ED with venous access established in the field: 4 via intraosseous and 6 via peripheral IV. Of the 16 subjects without access upon ED arrival, PIV was selected for 12 and IO was selected for 4. Nine patients experienced a delay in obtaining access attributed to the selection of PIV as the initial mode of gaining access. Median time required for access was reported as: 50 seconds for IO; 95 seconds for PIV and 780 seconds for CVC. The authors concluded that selection of PIV as the initial access method may be associated with delayed vascular access in the ED.


This abstract describes a pilot observational study of vascular access devices (VAD) and their use in management of 20 out of hospital cardiac arrest patients. VAD selected, number of attempts for successful placement and time to insertion were recorded. Twenty patients were included in this study, 10 of whom received IO access upon ED arrival.
Intraosseous Vascular Access Bibliography
Emergency Care


An abstract describing preliminary data evaluating the effect of initial vascular access device selection on the management of out-of-hospital cardiac arrest (OOHCA) patients by the ED. Twenty patients were included. Success rate by vascular access device selected was: 66% IO lines (2/3); 25% for PIV lines (3/12); and 100% for CVC (1/1). Eight patients experienced a delay in access due to initial method selected, 7 were attributed to PIV and 1 to IO. The authors concluded that the results suggest use of PIV as the initial mode of access may be associated with delays in access when compared to IO access in patients with OOHCA.


A retrospective study evaluating attempts to establish intraosseous vascular access in pediatric patients using a manual device and the EZ-IO, in a tertiary care pediatric emergency department. Results showed 35 patients had IO access attempted using manual and EZ-IO devices. In patients greater than and less than 8kg the EZ-IO had a higher success rate but time to placement was longer. Overall success rate including both devices was 64%. There were 2 complications of transient leg swelling after EZ-IO placement in 2 patients.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating the use of pre-hospital and emergency department placed IO access in children before transport to a children’s hospital. Data were extracted from a Level 1 trauma, tertiary care children’s hospital transport database from 1993-2009. There were 143 eligible patients with an average transport distance of 33 miles; all but 8 catheters were placed by the ED. The most common reasons for IO placement were no IV access (53%) and no perfusion (33%); the most commonly reported complication was infiltration (27.3%); 46.9% of patients experienced no complication. The authors concluded IO access plays a significant role in promoting life-saving efforts when IV access is unachievable or no perfusion is determined.


Case report of a 13 year old girl suffering from severe hemorrhagic shock due to blast injuries and gun shot wounds that received freeze-dried plasma via IO access as part of prehospital resuscitative efforts. Her vital signs improved upon arrival to the hospital; and she was released after 3 weeks of hospitalization.


A pilot study evaluating the relationship between intraosseous (IO) pressure measurements and blood pressure obtained via external blood pressure cuff in ICU patients. Patients with IO access established by EMS or in the emergency department with planned admission to the ICU or surgical ICU were included in the study. External pressures were recorded every 15 minutes and IO pressure was monitored via a transducer for 12 continuous hours. Results showed IO pressures were approximately 30% of external blood pressure cuff readings.


A case study report of a 24-year old female who presented to the emergency department after consuming an over dose amount of verapamil. Central and peripheral venous access were obtained for delivery of vasopressors and intravenous fat emulsion 20% (IFE). IFE was initiated via peripheral IV (PIV) access but access was lost; administration through central access was not possible due to the potential drug interaction. Intraosseous (IO) access was established using the Arrow EZ-IO system in the proximal tibia without complication and IFE administration was resumed. The patient reported some pain with infusion. After half the bolus administration was delivered, the infusion pump alarmed due to inadequate flow. PIV access was obtained and IFE administration was resumed using the newly obtained access route. The authors suggested that the viscosity of the medication may have caused the delivery failure by infusion pump through the IO route and recommend slowing down the bolus rate of infusion for clinicians attempting this route for IFE administration in the future.


This review article describes various protocols for haemorrhage control, specifying routes of access, including intraosseous vascular access infusion rates and volumes of various transfusion fluids.
Intraosseous Vascular Access Bibliography

Emergency Care


This abstract describes a study (SAFER) reporting initial emergency department efforts in obtaining adequate vascular access (AVA) and initiating appropriate fluid resuscitation for hypovolemic patients with undifferentiated hypotension within the first 60 minutes following ED arrival. AVA was defined as any two of the following: PIV, IO, or CVC catheter. No data was given regarding time to IO access in the results.


This case study describes a neonate who suffered a cardiac arrest, had return of spontaneous circulation (ROSC) and was treated with multiple medications and therapeutic hypothermia. The patient had received three IO needle insertions, one in the left tibia that was removed following swelling with bolus injection; one in the left distal femur that dislodged with movement of the patient's legs; and one in the right proximal tibia. Twenty-four hours after initial IO needle placement the child developed pallor and discoloration and was diagnosed with compartment syndrome to the right lower extremity. Five days post-IO insertion a below the knee amputation was performed. Medications infused via the IO access included epinephrine and norepinephrine infusions.


This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive drug in pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.

YEAR: 2014


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.


Randomized comparative study of adult pigs infused intraosseously with either: 7.5% hypertonic solution (HTS), 3% HTS or normal 0.9% isotonic saline. The animals were observed daily for infection, necrosis and gait up to 5 days, then necropsy and histological analysis was performed for tissue necrosis. Observations included regular tissue morphology and normal gait scores over the 5 day observation period; and absence of gross tissue necrosis and microscopic ischemia post IO HTS infusion in this swine model. Authors concluded this study confirms the clinical safety of IO HTS infusion and its use as an alternative lifesaving treatment.


This article describes a case study of a 31-month old infant that suffered hypovolemic shock due to severe epistaxis. After several failed peripheral and central line attempts an 18g needle was inserted intraosseously through the proximal tibia. The child received 300 mL of Ringer’s Lactate in one hour then 200 mL of blood via the IO route by syringe boluses resulting in improvement. Cl oxacin ill was also administered IO as prophylaxis for infection. Authors conclude an IO blood transfusion should be the immediate intervention in similar life-threatening situations.

Zambia

Cheung WJ, Rosenberg H, Vaillancourt C. Barriers and facilitators to intraosseous access in adult resuscitations when peripheral intravenous access is not achievable. Acad Emerg Med 2014;21:250-6. doi:10.1111/acem.12329

This survey study sought to identify the barriers and facilitators to use of intraosseous vascular access for adult resuscitations when peripheral IV (PIV) access is not available, among physicians from various clinical care settings in 3 teaching hospitals in Ottawa, Ontario. Completed survey responses were received from 205 physicians; results suggest that to increase IO use educational interventions need to address their attitudinal, normative, and control beliefs. Specific beliefs that act as barriers are described.

Canada

The focus for the article is the need for early recognition and stabilization of a critically ill child presenting to local hospital and how hospitals admitting critically ill children must be able to resuscitate and stabilize the child prior to transferring to another hospital. The article discusses the initial assessment and resuscitation when a critically ill child presents to a local hospital and the pediatric transport process and the importance of communication between all teams. The article also discusses the need for clinicians working with critically ill children need to be properly trained and be able to maintain those skills.


This article identifies new concepts and changes in neonatal resuscitation discussed at the Egyptian Pediatric Association national conference. Intraosseous vascular access is included stating, "temporary intraosseous access to provide fluids and medication to resuscitate critically ill neonates may be indicated following unsuccessful attempts to establish intravenous vascular access or when caregivers are more skilled at securing intraosseous access."


The objective of this study was to use a competency exam to compare different emergency skills and knowledge between out of hospital emergency physicians (OOHEP) and those who are not OOHEP at the time of their mandatory biannual refresher courses. Results from 836 respondents suggested that OOHEP are significantly more likely to initiate intraosseous access, initiate mild-therapeutic hypothermia, and had higher knowledge about the used defibrillator.


A preclinical study comparing intraosseous (IO) and intravenous (IV) administration of Hextend in 27 swine for time of administration and hemodynamics. IO access was established in the proximal humerus using the EZ-IO. Results showed time for administration was not significant; there were no significant differences between IO and IV relative to hemodynamics. The author concluded that the IO route is an effective method of administering Hextend.


This article identifies new concepts and changes in neonatal resuscitation discussed at the Egyptian Pediatric Association national conference. Intraosseous vascular access is included stating, "temporary intraosseous access to provide fluids and medication to resuscitate critically ill neonates may be indicated following unsuccessful attempts to establish intravenous vascular access or when caregivers are more skilled at securing intraosseous access."


Manikin study conducted in Poland with 107 paramedic operators designed to investigate the success rate, time of insertion and perceived difficulty of intraosseous access devices during simulated resuscitation using the EZ-IO. Bone Injection Gun and Jamshidi needles. Results were first attempt success: B.I.G.: 91.59%; EZ-IO: 82.66%; Jamshidi: 47.66%; mean procedure time: B.I.G.: 2.0 min ± 0.7; EZ-IO: 3.1 min ± 0.9; Jamshidi: 4.2 min ± 1.0; and ease of use (1-best to 5-worst): B.I.G.: 1.83; EZ-IO: 2.92; Jamshidi: 4.68.

Poland


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.


Case study of 36 year-old in septic shock with co-morbidities of IV drug abuse, endocarditis, tricuspid valve insufficiency and pulmonary embolism. Initially impossible to obtain PIV or CVC access; then unable to give desired fluids through 22 gauge PIV when finally placed. Proximal humerus IO access was established with the EZ-IO 45 mm needle set and the patient was resuscitated with 30 mL/kg fluids and multiple medications given in first hour. Conclusions included that CVCs are not always possible and volume treatment with an IO placed sooner rather than later, especially in children but also in adults, can be lifesaving. IO systems should be extensively available throughout the clinical setting. Article in German.

Germany

This abstract describes the results of an observational clinical study that evaluated the use of IO vascular access via the proximal humerus insertion site for administration of contrast media for computed tomography examination. Eight subjects were enrolled into the study, 7 procedures were performed successfully with adequate opacification of the images. One subject experienced extreme pain with the contrast injection, the procedure was terminated and an alternative vascular access route was utilized. There were no serious complications reported. This study was sponsored by Teleflex Incorporated.


A preclinical study comparing the time to onset, time to onset peak, and time to recovery of peripheral intravenous and tibial intraosseous administration of Rocuronium. Study results demonstrated there was no statistical difference between the time of administration to complete neuromuscular blockade between the IO and IV administration of Rocuronium; and the recovery of neuromuscular function was significantly longer after IO administration, however was not deemed clinically significant. The authors concluded that Rocuronium can effectively be used via the IO route without the need for dose adjustments.


This abstract describes an observational study evaluating use of the intraosseous drill (EZ-IO) in 20 patients assisted by EMS and receiving CPR within a 3 year period. The study includes 4 pediatric and 16 adult patients. The authors concluded that IO access is a reliable alternative to peripheral venous access and can be implemented fast and with high success rate of CPR in which drugs and fluids are given.


In a series of studies using healthy adult volunteers the objective was to add to available data comparing IO marrow/blood (initial 1 mL aspirate), IO blood (subsequent aspirate), and venous and capillary blood to determine if there is a correlation between samples for serum lactate and PT/INR levels. Two point-of-care analysers were used. Conclusions were lactate levels obtained from IO blood appear comparable to lactate levels from venous blood; the PT/INR levels did not correlate. This study was sponsored by Teleflex Incorporated.

Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4

Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, “fluids” and calcium. Decaration of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.


In this pre-clinical study, 18 units of blood were transfused into 10 anesthetized swine via intraosseous (IO) access. Venous specimens were collected to evaluate free hemoglobin levels as an indicator of hemolysis. Seventeen transfusions were given via the proximal humerus site and 1 via the proximal tibia, using a pressure bag set to 300 mmHg. Mean transfusion flow rate was 61.6 ± 37.3 mL/min and the mean blood volume transfused was 266 ± 74 mL (n=18). The authors concluded that blood transfusion via IO access resulted in high flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.


This article explores use of IO vascular access in combat and tactical settings through a brief review of the literature describing this practice. A small feasibility study is discussed that evaluated the use of cadavers for training 26 U.S. Air Force Pararescuemen (PJs) on establishing IO access in the humeral head (proximal humerus is the descriptor used by EZ-IO for this site) using the EZ-IO powered driver and needle set system (pictured in the article) and needles inserted with a manual driver without power. First attempt placement success with the EZ-IO powered driver system was achieved in 25 of 26 attempts; first attempt placement success using the manual driver and needle set occurred in 19 of 21 attempts. The authors concluded that the humeral head (proximal humerus) IO site is the most appropriate site within the tactical setting; and that use of a human cadaver model for training is an appropriate model.


A preclinical study comparing the recovery of fibrinogen in a porcine model when fibrinogen concentrate is administered via IV and IO access. The study results suggested intraosseous administration of fibrinogen concentrate results in a recovery of fibrinogen similar to that of intravenous administration.
Intraosseous Vascular Access Bibliography

Emergency Care

This article explores the use of IO access in the prehospital setting to determine if IO access is sufficient for massive fluid resuscitation in trauma patients or if central venous cannulation should be considered. Massive transfusion is defined as 10 units of blood within 24 hours at a rate of more than 150 mL/minute. Through a review of the literature the authors determine that IO access is rapid with a high success rate, IO access allows a bridge to initiate resuscitation while minimizing on scene delays, and has a low complication profile, all benefits over central venous cannulation.

Australia

A case study report describing a 12-year-old male who expired following a fatal myocardial ischemia. The patient complained of severe chest pains within the week prior to the event and was misdiagnosed as having GERD. ECG by first responders showed STEMI; IO access was established in the PT for vascular access.

This prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).

A questionnaire and interview study evaluating the reasons paramedics do not perform intraosseous (IO) vascular access more frequently. Twelve paramedics in Johannesburg, South Africa were interviewed for the study. Results suggested access to inappropriate equipment (pink hypodermic needles), inadequate training, lack of use in hospital Emergency Departments to which they serve, and the perceived invasiveness of the procedure and pain caused during infusion dissuaded paramedics from performing the procedure.

Abstract reporting on retrospective prehospital study to evaluate the rate of out-of hospital return of spontaneous circulation (ROSC) in the cardiac arrest patient. The following were assessed and analyzed for direct or indirect correlation on ROSC: dispatch time to arrival, number of intravascular attempts per method (IV versus IO) and rate of success. Conclusions were that ROSC can be achieved more rapidly when IO access is used as the first attempt method in obtaining vascular access in prehospital cardiac arrest. There was a trend in shorter ROSC times among the first attempt IO group compared to the IV group; the difference did not reach statistical significance, most likely due to a lack of power from the smaller sample size of the IO group.

Abstract presented at the Society of Cardiovascular Computed Tomography on preliminary findings of an observational study done after training ER physicians and techs on intraosseous (IO) catheter use and implementation of a policy for IO access use. Authors report high injection rates and excellent computed tomography angiography (CTA) scans safety with use of an IO for power injection of iodinated contrast media (ICM). Authors concluded cardiovascular imaging physicians, surgeons, ER physicians, and CT technologists should be familiar with the techniques of IO needle placement and use for power injection of ICM for CTA. The diagnosis and treatment of critically ill and unstable patients may be hastened by this technique.

This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.

YEAR: 2013

Case report of 54-year-old male obtunded patient requiring a CT angiogram to diagnosis a suspected massive pulmonary embolism. After several failed attempts to reestablish PIV access, 150mL of contrast were injected through the proximal tibia IO catheter placed by EMS. Excellent opacification of the pulmonary arteries was achieved and there were no immediate complications from the injection noted.
Intraosseous Vascular Access Bibliography

**Emergency Care**


Reprint article of policy statement originally published 2009, endorsed by multiple professional societies providing guidelines for care of children in the emergency department. A recommendation for IO equipment in adult and pediatric sizes is included.


In a letter to the editor this study reports data collected (during a survey of one third of academic emergency medicine programs in the U.S.) regarding IO use in adults and comparing IO access with other vascular access techniques through simulation. Data suggest that IOs were used less than 5% of the time patients needed emergent access and a peripheral line was unobtainable. The EZ-I0 was most often used IO device. Authors conclude IO use should be considered more frequently in critical, unstable patients. (This research was presented at the ACEP Research Forum in 2010).


This letter to the editor describes a prospective, observational, trial that evaluated use of the EZ-I0 in critically ill and injured patients (adult and pediatric) in a multijurisdictional prehospital setting; 9 EMS agencies were included. The 25mm needle set was the only needle size allowed for the study. One-hundred-eleven EZ-I0 placements were performed by EMT-Intermediates and EMT-Paramedics with 96 successful placements (86.5%); the most common cause for failure reported by the author was thought to be patient obesity and inadequate needle length. Cardiac arrest patients made up 74.7% of the study population and the most common site accessed was the proximal tibia. Device operators rated the ease of use 7.87 using a 0 to 10 scale where 10=extremely easy.

**Cleugh FM, Macaonochie IK. Management of the multiply injured child. Paediatrics and Child Health 2013;23(5):194-9**

General overview of care of a child with multiple trauma. IO vascular access is mentioned as a treatment option after 90 seconds or 3 failed PIV attempts. The B.I.G. is cited as an option along with the manual needles.


Case study of adult multi-trauma patient that had an intraosseous device placed to a fractured left tibia and developed compartment syndrome. Authors concede it is unclear if the fluid infused through the IO device caused the compartment syndrome or if it was due to the multiple-fractures in the tibia. Authors advise against placing an IO line in an injured limb and mention the proximal humerus and sternum as alternative IO sites.


An observational clinical study evaluating use of the EZ-I0 in patients requiring urgent vascular access that would have otherwise received a central venous catheter due to a lack of other options. One hundred five (105) patients were enrolled across five hospitals. The authors concluded that use of IO access in place of CVC's provides time savings, safety, ease of use, and is effective at significant cost savings; IO access may be used as a bridge to CVC placement under optimal conditions; and IO access may be used to replace use of CVCs all together in selective patients. This study was sponsored by Vidacare Corporation, acquired by Teledex Incorporated.


This article describes a mannequin and cadaver study that evaluated use of the EZ-I0 sternal device and the Illinois needle to establish sternal IO vascular access by dental students. Results of the cadaver study showed two cases of perforation of the posterior sternal cortex when the Illinois needle was used and one EZ-I0 insertion in the soft tissue without entering the IO space. The authors concluded use of the EZ-I0 sternal device with the insertion site template and scalpel incision may be more efficient and less predisposed to complication than use of the Illinois needle.


A retrospective study that evaluated use of IO access by one EMS system whose patients were transported to a level 1 trauma center over a period of 64 months. Results showed 140 IO attempts were made with 130 successful placements (92.9%); there were no long term complications.


A letter to the editor reporting a case study of skin necrosis after IO administration of norepinephrine following resuscitation of a 74 years old in septic shock. The EZ-I0 was placed to the proximal tibia; approximately 45 minutes post- norepinephrine administration symptoms of necrosis were evident. Authors cite 3 hypotheses for the cause of necrosis and consider that amines’ high level concentration could induce local toxicity in the bone matrix and artery spasm; suggesting it is necessary to define an upper limit of amines’ concentration that should be administered through IO vascular access.
Intraosseous Vascular Access Bibliography

Emergency Care

A pre-clinical study that evaluated use of intraosseous (IO) pressure as an indicator of changes in fluid volume status during a hemorrhagic shock protocol. Central venous and arterial pressures were used as comparators. Results showed IO pressure decreased consistently during the controlled shock protocol. Authors concluded IO pressure appears to be equivalent to CVP as an indicator of fluid volume status. This study was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.

A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measurable blood pressure and it correlates with pressure obtained through conventional techniques.

General discussion on use of the intraosseous vascular access route for infusion of CT contrast, with attention to clinical considerations pertinent to nurses working in the imaging suite. Author also reviews general IO principles and IO devices.

This is a preclinical study comparing the EZ-IO and the Cook manual IO needle when used by 21 resident physicians to establish IO access in anesthetized swine. Results showed the drill-assisted needle was successfully placed 100% of attempts vs 76.2% successful placement with manual; time to placement and user preference also favored the EZ-IO. Technical issues reported included bending of the manual needle 33% of attempts.

A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices.

This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handheld IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult.

This article explores the use of IO access for blood product administration and whether or not it is clinically effective. Based upon lack of clinical evidence and physics principles, the author argues that maximum flow rates attainable for IO blood infusion are not adequate for resuscitation.

This article in German explores use of intraosseous access in a dental practice emergency. In a simulation study, dental students attempted to establish standard peripheral IV access and IO access using 3 different devices: EZ-IO, BIG, and manual IO. Results showed the manual was the fastest to insert, however, the EZ-IO had the highest first-attempt success rate as well as the lowest number of total attempts to IO access.

German

11/19/2019
This abstract describes a study in which 66 obstetric anesthetists, obstetricians and midwives were training on the EZ-IO and evaluated for successful application of the skill in a mannequin study. The participants also completed a survey following their insertion attempt regarding their perceived ease of use and likeliness to consider IO use in the future. Results showed first attempt success was 95.5%; respondents indicated they found the EZ-IO to be easier than establishing PIV access and 100% indicated they would consider IO use in the future.

UK

This article describes the role of the casualty evacuation nurse role within the military. One case study briefly notes the use of proximal tibia IO access and the administration of packed red blood cells in a 22-year-old woman. No further follow up is provided other than noting the patients were expected to survive.
Intraosseous Vascular Access Bibliography

Emergency Care


This retrospective review of medical records submitted by paramedics identified patients 18 years or younger who had prehospital peripheral IV (PIV) attempts. Over 101 months at least 1 PIV attempt was made on 4188 patients ≤18 years old. The study demonstrated that success rates are significantly associated with patient age and each 1 year increase in age increased the odds of successful PIV placement by 11%. The authors suggest that IO access with the use of a semiautomatic IO device (EZ-IO) may be a more efficient first-line method for immediate treatment after 1 PIV access failure, especially in younger patients given their higher rate of PIV insertion failure.

Oksan D, Ayfer K. Powered intraosseous device (EZ-IO) for critically ill patients. Indian Pediatr 2013;50(7):689-91

A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 60 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case). Turkey


A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for IO use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.


A case study describing use of the EZ-IO in Afghanistan by US military on 5 patients with traumatic injury including one pediatric patient. Access was obtained in the proximal tibia on first attempt and was used to administer crystalloids in all patients along with opioids, analgesics and antibiotics. All ultimately received central venous access and peripheral access was established in one patient. There were no IO complications.


An observational study evaluating use of the EZ-IO by two ground and one air based physician staffed EMS and at a German surgical university hospital between January 1, 2008 and December 31, 2011. The EZ-IO was used to establish IO access 88 times in 87 patients; 83 insertions were performed in the EMS and 5 were performed in the hospital. The proximal tibia was the primary site used (97.7%) and the first attempt success rate was 94%. IO access was the first approach for vascular access in children compared to adults (38.9% vs. 86.2%). There were 5 failures attributed to missed insertions or extravasation and 2 for wrong needle length. There were no serious complications.


A simulation study evaluating if use of a laryngeal mask airways (LMA) and intraosseous (IO) lines established using the EZ-IO leads to improved resuscitation in a simulated cardiac arrest when compared to standard endotracheal intubation and central line placement. Results showed mean time to airway, mean duration of airway attempt, and time to vascular access was shorter in the IO group than the CVL group. Time to defibrillation and percent hand off time was not significantly different between the groups.


An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal tibia was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse, difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.


This is an abstract of a study that analyzed prehospital missions of the Greater Sydney Area Helicopter Emergency Medical Service (GSA-HEMS) involving a blood transfusion, with ID administration recorded as one possible route of administration. The study determined that the carriage and use of blood is both feasible and safe in a physician-led helicopter emergency medical service.
Intraosseous Vascular Access Bibliography

Emergency Care


This is an abstract of a study that analyzed the mission profiles and interventions performed during rescues involving the winching of a physician in the Greater Sydney Area Helicopter Emergency Medical Service (GSA-HEMS). A structured case-sheet for a predetermined list of physician-only interventions (POI) was conducted, of which IO access was an intervention. The study showed a high rate of POI thus supporting the winching of physicians.


An overview of pediatric emergency medicine and critical procedures. One of the key points noted: intraosseous vascular access can be used in all ages.


This article reviews the clinical effects of both high-quality chest compressions and the effects that interruptions during chest compressions have clinically on patient outcomes. The authors indicate intraosseous vascular access should be heavily considered as the first or at least second-line method used to help prevent prolonged compression interruptions for the purpose of establishing vascular access. The authors note that when using the EZ-IO this method of access is fast, effective, can handle all resuscitation fluids, and can minimize no flow time when used properly.


A case report describing administration of thrombolytics via tibial IO vascular access for pulmonary embolism in a 36-year-old woman. Due to the emergent nature of the situation, IO access was determined to be the best option for immediate vascular access. Alteplase was administered through the IO line at 100 mg over 2 hours without complication. The patient successfully recovered and was discharged from the hospital on day 7 without long-term disability. The author concluded that this case study raised the potential use of IO lines to deliver thrombolytics in patients with massive pulmonary embolism and that further evaluation is needed to compare the risk and benefits of the alternative method of administration.


This study conducted by the Norwegian Navy evaluated the ability of 25 soldiers to perform buddy transfusion by starting phlebotomy, establishing sternal IO access using the FAST1, and infusing 1 unit of whole blood. Physical performance was evaluated pre and post blood donation and lactate levels were recorded. The authors concluded that physical and combat performances are preserved within limits post whole blood donation and that soldiers are able to learn the phlebotomy and sternal reinfusion with only a short lecture on the procedure.


A quality initiative study conducted evaluating use of the EZ-IO needles in pediatric patients and their associated complications rates when placed by EMS/ED staff compared Air Evac Lifeteam placement in 2012. The authors concluded that the powered IO device was appropriately utilized by ED/EMS staff as well as Air Evac staff and that there was no difference in the complication rate when the device was used by the two groups.


This observational pre-hospital study conducted in Madrid, Spain prospectively evaluated use of the EZ-IO Jan 2007- Dec 2009 as an alternative to peripheral IV access. During the study period, 107 patients underwent 114 EZ-IO insertions and all were successful on first attempt. IO access was established in the proximal tibia (48%), distal tibia (25.2%), radius (14.9%), and humerus (10.5%) and all lines were the first form of vascular access established in the patient. There were no adverse events or complications.


A prospective study comparing IO and venous laboratory values obtained from a point-of-care analyzer (i-STAT) in 20 children. IO blood specimens were collected from the iliac crest; 2 ml were discarded before the sample was collected analysis. Results showed differences between venous and IO sample were clinically acceptable for pH, base excess, sodium, ionized calcium and glucose in hemodynamically stable patients. Authors concluded that analysis of IO samples with a bedside point-of-care analyzer is feasible and in emergency situations may be useful to guide treatment.

This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 mL of red blood cells via the EZ-IO in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock; and RBC infusions via the IO route are feasible in this age group.

YEAR: 2012

Barker LT. In the child with gastroenteritis who is unable to tolerate oral fluids, are there effective alternatives to intravenous hydration? Ann Emerg Med 2012;60(5):607-8. doi: 10.1016/j.annemergmed.2012.04.003

This article, part of a Review Snapshot series in Annals summarizes a literature review (Rouhani et al in Pediatrics 2011) for evidence of alternatives to traditional IV hydration in a dehydrated child. Thirty-eight articles were included for the analysis with five of them randomized controlled trials; and one of those comparing IO to IV rehydration. (Banerjee et al, which found IO placement faster with no therapeutic outcome differences). The focus of this review was on nasogastric tube rehydration as effective when IV fails and as less invasive than IO or CVC placement.


This article takes a look at the emergency medicine advances that result from war, including intraosseous resuscitation.


This article discusses how IO access can be used to improve advanced life support therapy. The EZ-IO is described in this article; published comparative studies between other IO devices and peripheral IV access are cited, leading the author to conclude the EZ-IO is user friendly, and establishes intravascular access more quickly and more often on first attempt than other devices.


This pre-clinical study evaluated IO flow rates obtainable with infusion of lactated Ringer’s and hetastarch 6% through the proximal tibia and sternum IO insertion sites, using a swine model. The EZ-IO 25mm was used to facilitate tibial IO access; sternal access was established using a Jamshidi needle. Results showed that hetastarch flow rates were lower than lactated Ringer’s flow rates at both insertion sites; sternal infusion of hetastarch is likely to provide greater estimated intravascular volume expansion than lactated Ringer’s, despite the lower infusion rates; resuscitation using the IO rate is likely to benefit from pressure bag or high-pressure pump delivery. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Spanish

This article in Spanish describes a study in which the management of simulated pediatric multiple trauma cases was compared to the 8 tasks validated in a polytrauma training program from Cincinnati Children’s Hospital. The authors concluded that primary care pediatricians have difficulty applying the sequence of trauma and cervical screening maneuvers in a simulated setting and that pediatric training programs should strengthen practical initial care for trauma.


Manuscript of a literature review and critical analysis done to develop the Emergency Nurse’s Association (ENA) December 2011 Emergency Nursing Resource (ENR) which focused on the clinical issue of difficult IV access. Graded recommendations and decision options are provided for alternatives to IV access, including IO.


Review article citing evidence supporting uninterrupted CPR for cardiac arrest. Interventions that reduce interruptions in compressions are discussed including intraosseous (IO) vascular access as an alternative to peripheral intravenous (PIV) access especially for difficult PIV cases. Although PIV access is cited as preferred authors cite speed, high success rates, safety and ease of use of IO access with several studies as evidence. Important points made include that for multiple access sites a small time advantage for IO access is magnified; providers should have low threshold for choosing IO vs. PIV (go IO faster); and central venous placement (CVC) is likely not indicated in most arrest scenarios. IO placement is strongly encouraged.


PALS 2012 guidelines on pharmacotherapy and toxicological emergencies.
Davis DP. *The use of intraosseous devices during cardiopulmonary resuscitation: Is this the answer for which we have been searching?* Resuscitation 2012;83(1):7-8. doi:10.1016/j.resuscitation.2011.11.017

This editorial discussed the numerous changes in practice with regard to cardiopulmonary resuscitation, and explored the scientific basis upon which the changes were made. Changes in drug administration and vascular access methods, including IO, are discussed. The author's overall view was that perhaps clinical practice in cardiopulmonary resuscitation is too quickly changed with the presentation of minimal scientific data.


This abstract presented at the 2012 ACEP Research Forum discusses a swine pre-clinical study evaluating CT image opacification when contrast is delivered via IV and proximal humerus IO access. The EZ-IO was used to facilitate IO access. Results showed that under blinded radiology review the IV and IO images were judged adequately opacified to meet diagnostic criteria. Authors concluded that IO administration of contrast material may be a viable alternative if other vascular access is unavailable or if establishing other access will lead to a delay in diagnostic evaluation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Esteo OV. *Intraosseous access in prehospital emergency care.* Emergencias 2012;24:44-6

A prospective, observational study which evaluated use of the EZ-IO within the prehospital setting over the course of a 3 year period, in Barcelona, Spain. Included patients were in cardiac arrest or with hemodynamic instability, without peripheral venous access after 90 seconds or 3 attempts to establish access. Results showed IO access was attempted in 49 pediatric and adult patients with an overall success rate of 93.9%; complications included extravasation and pain. IO access sites included the proximal tibia (74.4%), proximal humerus (22.4%) and distal tibia (6.1%). The author concluded that IO access is a viable access route for the management of critical patients or those in cardiac arrest in the pre-hospital setting due to the ability to obtain rapid access and the high first attempt success rate.


Physicians from two different emergency department settings reported 2 cases of supraventricular tachycardia (SVT) in infants (2 and 4 month old) in which IO administration of adenosine failed to convert SVT to a normal rhythm.


This article is a review of techniques and available evidence for establishing intravenous access, rational approaches to fluid resuscitation, and blood product transfusion in the pediatric trauma patient. IO needle systems are available for integration into pre-existing trauma care systems for pediatric patients.


Pharmacokinetics of IO drug delivery was compared using the tibia or sternum, versus central venous delivery during CPR. Anesthetized swine with KCl arrest were used for this study, CPR was initiated 8 minutes post arrest. Using 2 study groups, dye was injected as a bolus with adrenaline through either the IO sternal and tibial needles or through the IO sternal and IV central venous needles. Results showed peak arterial blood concentrations were faster for sternal IO vs tibial IO administration. Tibial IO delivered 65% of the total dose delivered with sternal administration. Peak blood concentrations were similar for sternal IO and central venous administration. Sternal IO delivered 86% of the total dose delivered by central venous administration. The EZ-IO and Jamshidi were used to facilitate IO access. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Ibrahim M, Cairney K. *Intraosseous (IO) infusion as a means of vascular access.* Br J Resuscitation 2012;Autumn:23-6

This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access.


This article discusses a retrospective review of Japanese prehospital system for intravenous infusion success rates in cardiopulmonary arrest (CPA) patients and a prospective simulation study. A nationwide database was reviewed for CPA records from 1 January 2005 to 31 December 2008 yielding 431,968 cases. Results showed the IV infusion success rate in adults increased annually, however the rate in pediatrics did not; and while the administration of adrenaline increased the 1-month survival rate did not. In the simulation study, 100 EMS technicians used the Bone Injection Gun (BIG) in simulator adult, pediatric and infant legs. There was no difference in the time to establish access in the prehospital setting in Japan and a proposal for intraosseous infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


An overview of pre-hospital trauma care. Endotracheal intubation, use of tourniquets, identification of shock, and clinical research in the pre-hospital setting are specifically addressed. Intraosseous vascular access is generally mentioned in relation to resuscitation.
**Intraosseous Vascular Access Bibliography**

**Emergency Care**


This simulation study evaluated the ability of 2 person EMS crews to manage a pediatric emergency and sought to determine root causes of errors made. Participating EMS crews used the BIG for IO access. The authors concluded that cognitive, procedural, affective, teamwork errors and error-producing conditions were identified as root causes for the errors made in the simulation. Authors also concluded that simulation followed by facilitated debriefing is an effective tool for identifying underlying causes of active and latent errors.


This clinical trial evaluated the time required to establish IO access versus central venous catheter (CVC) in adults undergoing resuscitation, who had failed peripheral IV access (PIV) attempts. IO and CVC placement were performed simultaneously; two IO devices, the EZ-IO and the BIG, were used to facilitate IO access in randomized format. Forty (40) patients were enrolled, first attempt success for IO was 85% vs 60% for CVC placement; median procedure time was 2 minutes for IO vs 8 minutes for CVC. The author concluded that though IO access is safe, reliable and rapid during resuscitation, it cannot replace CVC but should be considered as a valuable bridging technique.

**Miller L, Montez DF, Philbeck TE, Puga TA, Morgan J.** Infusing chilled saline via the Intraosseous route is equivalent to infusion via the intravenous route in reducing the core temperature in swine. *Prehosp Emerg Care 2012;16(1):152. doi:10.3109/10903127.2011.624676*

This abstract presented at the 2012 NAEMSP scientific assembly described a randomized, cross-over study in which 8 swine were administered chilled saline via IV and IO routes to determine if the two routes were equivalent. The results suggested no clinical or statistical difference between IV and IO routes for infusion of chilled saline for therapeutic hypothermia. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2012 ACEP Research Forum describes a preclinical swine study evaluating the ability to induce therapeutic hypothermia by infusing chilled saline via IV and IO access. The EZ-IO was used to facilitate IO access. Results showed statistical equivalence between IV and IO routes when used to deliver chilled saline to induce therapeutic hypothermia. Results also showed that use of chilled saline and infusion tubing submerged in an ice water bath provides the most effective means of cooling. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A pre-clinical study evaluating the systemic bioavailability of antidotes when administered via the intraosseous (IO), intravenous (IV), and intramuscular (IM) routes is described. Results showed rapid and substantial antidote bioavailability after IO administration similar to that of the IV route. Authors concluded that the IO route of antidote administration should be considered when IV access is difficult.


This abstract presented at 2012 NAEMSP scientific assembly described a retrospective study that evaluated success rates and features of prehospital IO placement in adults following implementation of the EZ-IO, over a 2 year period. First attempt success rate in 281 patients was 89.7%; overall placement success was achieved for 91.8%.


A literature review of articles describing intraosseous vascular access devices used in the pre-hospital setting. Twenty articles met the inclusion criteria and described the manual devices, BIG, Fast-1 and the EZ-IO. The authors concluded that the literature suggests that semi-automated IO devices may be more effective than manual devices.

**Page D.** Intraosseous intrigue: Studies examine success rates on pediatric, adult & obese patients. *JEMS January 2012;32-3*

In this article, the author discussed five recent studies on intraosseous access providing his opinion about the quality of each study.

**Pallin DJ.** Intraosseous vs intravenous access for adults with out-of-hospital cardiac arrest. *Journal Watch Emergency Medicine 2012; http://emergency-medicine.jwatch.org/cgi/content/full/2012/106/1?q=etoc_jwca*

This editorial discussed a prior publication by Reades, et al that evaluated first attempt placement success rates for tibial IO, humeral IO, and peripheral IV in the prehospital setting. The author concluded that the research shows tibial IO access is the best route for adults with out-of-hospital cardiac arrest.
Intraosseous Vascular Access Bibliography
Emergency Care

An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.

This letter to the editor describes a case in which sternal IO access was established using a Jamshidi needle to administer iodinated contrast for a thoraco abdominal CT on a 61-year old male who presented to the ED with respiratory distress. Picture quality was deemed excellent by the radiologists. The authors conclude that the sternal IO route can be used with excellent picture quality but it should be used only in exceptional cases due to the potential risks of a high-power injection through the bone. EZ-IO is mentioned as an alternative IO device available.

Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14
The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access.

Brazil

This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.

This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.

This letter to the editor is written in response to the case report by Landy titled, Complication of intraosseous administration of systemic thrombolysis for a massive pulmonary embolism with cardiac arrest. The author suggests that the tissue necrosis described by Landy may have been due to the removal of the IO needle while there was still significant fibrinolytic activity at the needle insertion site. The author suggests a change in medical care after return of spontaneous circulation (ROSC) in patients following thrombolytic administration through IO access to convert the functioning IO line to a non-flowing saline lock. The EZ-IO was used to provide IO access in the case report by Landy.

This abstract presented at the 2012 NAEMSP scientific assembly described a study in which the comfort level of paramedics was evaluated as it related to establishing vascular access in out of hospital cardiac arrest resuscitation, using a predetermined method (PIV, humeral IO, tibial IO). Results showed that paramedics were typically comfortable with the method assigned.

This abstract presented at the 2012 ACEP Research Forum explored the viability of the distal femur as an IO insertion site with a literature review of IO vascular access and brief overview of a post-mortem study of pediatric distal femur insertion success. Authors concluded that clinical literature, clinical studies, and a post-mortem study confirm that the distal femur is a viable option for IO infusion in pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO.
Intraosseous Vascular Access Bibliography
Emergency Care


This abstract presented at the 2012 NAEMSP scientific assembly evaluated end-tidal carbon dioxide (ETCO2) levels under initial induction of hypothermia, rewarming, and a second induction of hypothermia, via IO and IV infusion in the swine model. The authors concluded that there was no demonstrated association of ETCO2 with brain temperature during the initial induction. However, during rewarming and second induction of hypothermia the association of ETCO2 and brain temperature had a direct and proportional association. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This study conducted by the San Antonio Fire Department evaluated the first-attempt success rate for humeral EZ-IO placement by paramedics in prehospital adult cardiac arrest patients. Humeral placement was attempted in 247 cardiac arrest patients; first attempt placement success rate was 91%. Authors concluded that humeral IO placement is a reliable method for vascular access in this patient population. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article is making a case for pediatric anesthesiologists to have IO access equipment readily available wherever children are anesthetized; and for anesthesiologists to consider IO access not only as a last resort but as the route of choice in children requiring urgent vascular access.


A critical care literature review article that addressed cardiac arrest, trauma, ultrasound, pediatrics, and boarding. Intraosseous vascular access is noted as a method for obtaining vascular access.

YEAR: 2011


This abstract reports a literature review using both MEDLINE and Embase databases up to August 2010 to determine feasibility and safety of IO administration during adult cardiac arrest. Authors reported a lack of literature (only two studies met their level of evidence criteria) but concluded IO access in adults appears to be a fast, reliable method to deliver drugs and fluid during CPR allowing adequate drug concentrations and pharmacological response; and should be considered if other medication delivery methods have failed. (Presented at the March 2011 International Symposium on Intensive Care and Emergency Medicine)


This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first responders to place IO lines for antidote administration using the EZ-IO device. First responders placed IO lines successfully in 100% of cases, and first responders placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.


This paper summarizes a study comparing first attempt success rates between TIO and HIO insertions during out-of-hospital cardiac arrest (OHCA). Insertions were performed by paramedics using an EZ-IO device. During the first month insertions were first attempted via the HIO route followed by the TIO route if unsuccessful; and vice versa during the second month. The overall TIO insertion success rate was 84.5%. The overall HIO insertion success rate was 40%.

Brisson M. Trauma and the military medic. EMS1.com 12/01/2011

This article describes use of IO access along with other prehospital interventions in a traumatically wounded soldier in a combat zone. The IO site used was the proximal humerus as the patient had 3 of 4 limbs traumatically amputated.

Byars DV, Tsuchitani SN, Erwin E, Anglemyer B, Eastman J. Evaluation of success rate and access time for an adult sternal intraosseous device deployed in the prehospital setting. Prehosp Disaster Med 2011;26(2):127-9

A prospective study evaluating use of the FAST-1 sternal IO device in critically ill or injured patients in cardiac arrest in the pre-hospital setting. In one year, 41 insertion attempts were performed using the FAST-1. Thirty (73%) of attempts were successful and the mean time to placement was 67 seconds from time of opening the packaging to ability to aspirate/infuse without infiltration. Of the 11 insertion failures, 7 were due to failure of the device to deploy; 2 infiltrations after insertion; 1 inability to aspirate; and 1 failure of the catheter to deploy though the needles were inserted.
Intraosseous Vascular Access Bibliography
Emergency Care


The case report describes a woman experiencing massive hemorrhaging following emergency caesarean delivery. Though the patient possessed a peripheral IV catheter, additional IV access was needed and gained through the proximal humerus IO space using an EZ-IO. This vascular stabilization and additional filling of the central volume through the IO route allowed placement of a subclavian central line. Authors concluded that a key to the resuscitation process was the rapid utilization of the IO.


A case study report in French describing compartment syndrome secondary to intraosseous infusion in a 57-year-old burn patient. IO access was established in the proximal tibia on second attempt; both attempts were made in the same limb though it was noted that the first attempt did not penetrate the cortex. Drug and fluid infusion was initiated; ten hours after infusion the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.

Day MW. Intraosseous devices for intravascular access in adult trauma patients. Crit Care Nurs 2011;31:76-90. doi: 10.4037/ccn2011165

An overview of available intraosseous vascular access devices, including the EZ-IO.


Case study of a 42-year-old woman with massive obstetric hemorrhage ultimately resulting in postpartum hysterectomy. Massive blood loss and inability to stop bleed prevented sufficient resuscitation via established PIV lines. IO access was established with the EZ-IO and used for fluid replacement and administration of cardiac resuscitation drugs. Fluid administered through IO access was 75% of the total infusion volume.

Dolister M, Miller ST, Borron S, Truemper E, Shah MR. Intraosseous vascular access can be used safely and effectively, and at a lower cost than central venous catheters, for pediatric and adult patients in the hospital setting. Ann Emerg Med 2011;58(4S):S311

This abstract describes the interim results of an observational clinical trial evaluating use of the EZ-IO to establish venous access in patients that would typically receive a central line due to lack of other options. At interim analysis, 50 patients had been enrolled in the study. First attempt IO access success rate was 96%; mean time to IO access was 95.1 seconds. The authors concluded that IO access in place of or as a bridge to central venous catheters is safe, fast, and effective for adult and pediatric patients in the hospital setting with substantial cost savings potential. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


The Emergency Nurse’s Association (ENA) published a series of Emergency Nursing Resources with emphasis on clinical or practice based issues. This issue focused on difficult IV access and provides a summary of the literature review, with graded recommendations and decision options for practice for IO access, ultrasound guidance, subcutaneous rehydration therapy and several other alternatives. IO access is graded as having a high level of evidence supporting use of IO access when difficult IV access is known or suspected for high success rates and rapid time to insertion.

Friedman JN. Emergency management of the paediatric patient with generalized convulsive status epilepticus. Paediatr Child Health 2011;16(2):91-97

This Canadian Paediatric Society paper provides guidelines for the “emergency management of generalized convulsive status epilepticus (GSE) in children and infants older than one month of age”. Use of IO access is included for medication administration when IV access is not possible.


This article describes an observational study to assess the safety and efficacy of the EZ-IO when using a management algorithm for difficult vascular access in an out-of-hospital setting. Over a one-year period, the device was used in 30 cardiac arrest and 9 other cases. Overall success rate was 97% and first attempt success was 84%. There was one complication—transient local inflammation. Investigators concluded that the device is suitable as a first-line option for difficult vascular access in the out-of-hospital setting.


This retrospective cohort study evaluated data from 450 California hospitals and emergency departments to determine the rate of IO access use and related complications in the pediatric population from 2005-2007. Results showed 291 children had IO access placed in 90 hospitals out of 6.6 million pediatric ED visits and 2.2 million pediatric admissions; no complications were identified. The most frequent diagnosis related to IO use was cardiac arrest (34%).
This study compared the effectiveness of infusing ice cold saline via IO and IV to induce mild therapeutic hypothermia (temperature drop to ³C) within a 30 minute timeframe, in a swine model of cardiac arrest. Five swine were evaluated in each the IV and IO groups. Goal temperature was reached in 4/5 animals in the IV group and 0/5 animals in the IO group in the allotted time frame; IV was superior in terms of rate of infusion, rate of temperature change, and time to achieve target temperature.

This abstract describes an evaluation performed in the goat model, using the EZ-Io, to determine the ability of IO access to accommodate a typical contrast dye infusion and withstand the power injection pressure. Bench testing was done to determine the max pressure deliverable through the EZ-Io using the power injector; various injection occlusion scenarios were established. Results showed the mean pressure through the humerus was 56.5psi; through the tibia was 163.5psi. There were 2 tibial extraosseous distal venous ruptures visible by fluoroscopy but not on gross examination. Under bench testing, for all tests, at pressures up to 750psi no failure or leakage was observed in the IO catheter. The EZ-Io extension tubing should not be used for power injection, particularly if the IO is in the tibia. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes the changes in practice experienced when a 12-site statewide ambulance service changed from the manual to the semi-automatic IO device (EZ-Io). There was no statistically significant change in first-attempt success or the number of successes per attempt. However, the use of IO access more than tripled when changing from the manual to the semi-automatic device and PIV access attempts before IO access went from occurring in 35.5% of patients to 1.7% of patients.

Myers LA, Russi CS, Arteaga GM. The introduction of a semiautomated (EZ-Io) device in pediatric prehospital care replacing a manual intraosseous (IO) device improves the success rate for attempts at vascular access. Prehosp Emerg Care 2011;15(1):110

This abstract describes a 93 patient study presented at the 2011 National Association of EMS Physicians Annual Conference that examined the characteristics of pediatric patients receiving IO infusions and the primary EMS clinical impressions, success rates, and subsequent treatments delivered via manual IO vs. the powered EZ-Io device. Investigators concluded that for the pediatric cohort use of the powered device offered a marginally higher first-attempt success rate compared to the manual device; and that the rate of IO access utilization by EMS more than tripled after adoption of the powered device.


This article in Spanish describes the Spanish military medical staff’s experience with the use of intraosseous lines for fluid therapy in a combat zone from March 2007 to June 2008. Twenty-five patients had an IO placed with the Bone Injection Gun (BIG). Placement success rates were 76% for the 19 pre-hospital placements and 100% for the 6 in-hospital placements. There were no complications during insertion. Conclusion was intraosseous access can provide an alternative to venous access for treating trauma patients in combat zones.


This article in German discusses use of IO access and its multiple applications, focusing on the EZ-Io Infusion System.


This article describes a literature review study with the objective of establishing which intraosseous device is best for prehospital use. This short review searched Medline 1950-2010, CINAHL 1982-2010 and EMBASE 1980-2010 and identified two studies meeting their evidence search criteria, one study compared the BIG vs. manual; the second compared EZ-Io vs. FAST-1. The clinical bottom line asserted by the author was traditional manual IO devices have faster, better success rates in the pre-hospital setting; but that more randomized trials are needed to determine the best device.

Australia


This study compared time to placement, errors in placement and perceived ease of use for healthcare providers placing umbilical venous catheters (UVC) and intraosseous needles in a simulated delivery room, responding to persistent bradycardia. Results showed mean IO placement time was 46 seconds faster than UVC placement; there was no significant difference in the number of errors and the perceived ease of use between UVC and IO.


This article describes a pre-hospital clinical study comparing IO first-attempt success between humeral and tibial sites. Of 88 cardiac arrest patients analyzed, 58 and 30 IO access attempts were made in the tibia and humerus, respectively. Of those, there was a 90% first attempt success rate for the tibia, compared to 60% for the humerus. Of successful insertions, 6% of tibial insertions became displaced during transport, compared to 33% of humeral insertions. Investigators concluded that proximal tibial IO needle placement was associated with a significantly higher frequency of first-attempt success and lower incidence of needle dislodgements compared to humeral placements.
Intraosseous Vascular Access Bibliography

Emergency Care


The objective of this study was to determine the frequency of first-attempt success of humeral IO, tibial IO, and peripheral IV (PIV) insertions during out-of-hospital cardiac arrest. Patients were randomized to receive one of the 3 methods. There were 182 patients enrolled, 64 were assigned to tibial IO, 51 to humeral IO and 67 to PIV. Of all patients 130 (71%) were successful on first attempt with 17 (9%) needles dislodged. First attempt success within the treatment groups was 91% for tibial IO, 51% for humeral IO, and 43% for PIV.


This study conducted in Germany and Switzerland evaluated use of the EZ-IO in the prehospital setting over a 24 month period. The decision to use IO access was left to the discretion of the onsite clinician, a paramedic or an emergency physician. Results showed IO access was attempted in 77 patients, and was successful on first attempt in 75 patients. Significant pain with infusion was reported in the majority of responsive patients.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.


This article discusses the use of IO access for neonatal and newborn resuscitation by the national park service and provides information as to how the decision was made to make IO access a standard of care for those patients.


This article in German concludes that the introduction of IO in pre-hospital pediatric emergency system has markedly reduced the number of critically ill or severely injured pediatric patients without vascular access or with less reliable alternative administration routes in the last 20 years.


In this pre-clinical study, IO and arterial blood samples were collected over a 6-hour timeframe from the tibia of anesthetized swine, analyzed using an iStat and compared. Results showed compliant values between IO and arterial blood for electrolytes, hemoglobin, pH, and pCO2. Lactate, BE, PO2 and SO2 were less compliant. There were high correlations between SO2 and PO2 although the levels in arterial blood were higher.


In this preclinical study, 30 swine in ventricular fibrillation received IO epinephrine, IV epinephrine, or placebo. Return of spontaneous circulation, 24-hour survival, and 24-hour survival with good neurological outcome was evaluated. Results showed ROSC to be nearly universal for the IV and IO groups with no differences between rates; 24-hour survival was substantially more likely in the IO group than the IV group; survival with good neurological outcome was more likely in the IO group than the IV group.

YEAR: 2010


This article explores the use of epinephrine during cardiac arrest to evaluate the lack of demonstrated efficacy in human trials of out-of-hospital cardiac arrest as compared to the laboratory animal model. The author concluded that the value of epinephrine as an adjust to resuscitation of cardiac arrest depends on the dosage, timing of administration and the initiating factor the cardiac arrest, and suggests that IO administration of epinephrine may help address the issue of timing of administration.


This abstract, which was presented at the 2010 ACEP Research Forum, describes a study conducted by investigators from the Medical College of Georgia to determine the frequency of intraosseous vascular access use in adult emergency patients. They surveyed academic emergency departments across the country and, at their own facility, compared ease and speed of standard emergency vascular access methods—including intraosseous. They concluded that IO access is underutilized and generally not the second-line choice of vascular access in unstable adult patients in academic institutions. Their simulation showed IO placement was considerably faster than both central lines and ultrasound guided peripheral IV. They opined that IO should be considered more frequently in critical unstable adult emergency department patients.

This abstract describes a retrospective case-series analysis of pediatric IO recipients from 1998-2009. Seventy-two (72) patients were included in the study; IO access was established in the proximal tibia (n=61), medial tibia (n=8), distal tibia (n=1), sternum (n=1), and iliac crest (n=1). IO access devices used in the proximal tibia included the Cook Critical Care needle (n=4), the Jamshidi needle (n=2), the BIG (n=1), and an 18 gauge spinal needle (n=54). The authors concluded that a spinal needle can be used to provide IO vascular access in children.


Authors reviewed two complications (extravasation and compartment syndrome) associated with IO access in children with meningococcal disease. Authors concluded that IO systems need formal evaluation to assess safety and complication profiles.


This article discusses training methodology and applies the concept to the implementation of the EZ-IO in the Montgomery County Hospital District EMS, a participant in the EZ-IO beta test.


This article describes a randomized, single-blind, controlled trial to determine which IO needle can be used best for gaining IO access in patients requiring acute administration of fluids or medication in a prehospital setting. The study was performed at a level 1 trauma center in the Netherlands with a Helicopter Emergency Medical Service (HEMS). Adult and pediatric patients meeting inclusion criteria were randomized between Jamshidi 15G, B.I.G. 15G/18G and F.A.S.T.1. Insertion time, success, aspiration of bone marrow, side effects, medication given, trauma mechanism, and user satisfaction were recorded. In the adult group Jamshidi was placed fastest, significantly faster than the F.A.S.T.1. (p=0.002). Time to insert the B.I.G. 15G did not differ statistically from other devices. In the pediatric group insertion time of the Jamshidi did not differ statistically from the B.I.G. 18G. On average, the device (adult and pediatric) did not differ significantly with respect to success rate, complication rates, and user satisfaction. EZ-IO was not included in this study as it was not approved for use in the Netherlands at the time the trial began. Authors recommend comparison with EZ-IO in future research.


This letter to the editor describes 2 cases in which IV administration of antivenom was not possible and was thereby administered via IO route, and in one case via the intramuscular route as well. In both cases the patients recovered.


This article evaluates various methods of obtaining vascular access in the management of 21st century battlefield trauma including, peripheral IV access, intraosseous access, venous cut-down, and central venous access. The authors conclude that IO access should be the first line vascular access in casualties with severe trauma to avoid delay initiating resuscitation in pre-hospital or hospital setting.


This article in German describes the results of a survey of rescue assistants and physicians, in which they found that IO use was still a rarity in the Berlin emergency medical service and, therefore, presumably nationwide.


Authors describe a randomized, controlled trial comparing two different IO access devices in adults in the hospital setting. Twenty patients received the BIG and 20 received the EZ-IO. Success rate on first attempt was 80% for the BIG and 90% for the EZ-IO. Mean procedure time was 2.2 minutes for the BIG vs. 1.8 minutes for the EZ-IO. Differences in success rate and procedure time were not statistically significant, and there were no significant complications for any patients. Investigators concluded that IO access is a reliable and safe method for rapid vascular access for in-hospital adult patients under resuscitation.


In this letter to the editor, the author discusses the use of IO access concluding that a change in practice should be made in which immediate IO access should be established for initial emergency resuscitation and serve as a bridging technique when peripheral IV access has been unsuccessful 3 times over a maximum duration of 2 minutes.
A case study describing administration of scorpion antivenom via intraosseous (IO) vascular access in a 16-month old female. Following failure to obtain IV access in pre-hospital and upon arrival at the ED, IO vascular access was established in the proximal tibia and 3 vials of antivenom in 50 mL saline were administered over 10 minutes. Within 5 minutes, the patient's respiratory status improved, intubation was averted, and vital signs stabilized immediately; nystagmus and writhing resolved. The patient was discharged home after a short observation period. The authors concluded that when IV access is difficult, IO access may be a rapid and reasonable rescue maneuver for patients requiring scorpion antivenom.

The 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. IO access is discussed as a preferred route when IV access cannot be established. The guidelines however do address the lack of clinical information regarding IO drug delivery during CPR but affirm it is reasonable for providers to establish IO access if IV access is not readily available.

2010 updated guidelines for resuscitation by the European Resuscitation Council. This update notes IO access as the preferred mode of vascular access for drug administration, over endotracheal administration, when IV access is unavailable. IO blood is also noted as useful for typing and evaluating laboratory values.

This paper describes experiences with the EZ-IO device in Japan in 24 adult patients during CPR. The device is not sold in Japan. Article in Japanese

This article discusses use of IO access within the hospital setting in the emergent and non-emergent patient populations. The history of IO access, clinical situations in which IO access may be considered, devices, contraindications, and complications are discussed. Additionally, pain management, economics, education and training and risk management are explored. This article is co-published in Journal of Infusion Nursing, the Journal of Pediatric Nursing, and Critical Care Nurse and was produced by the Consortium on Intraosseous Vascular Access in Healthcare Practice.

This article provides an overview of pediatric trauma care in the pre-hospital setting by using a literature review to evaluate the risks and benefits of various aspects of care. Topics discussed include: pre-hospital care time, pre-hospital triage and transport, airway management, intravenous (IV) and intraosseous (IO) vascular access and infusions, cervical spine immobilization, traumatic brain injury, and pain assessment and management.

This article describes a longitudinal study of intraosseous vascular access in pre-hospital emergency medicine handled by helicopter emergency medical services. Of the 78 IO insertion attempts made on 70 patients, overall success rates were 50% using manual needles, 55% using the Bone Injection Gun, and 96% using the EZ-IO. Investigators concluded that newer IO techniques may enable faster and more reliable vascular access; and that all emergency services should be familiar with IO techniques.

This case study describes a 25 year-old woman who had a massive pulmonary thromboembolism and was administered thrombolysis via IO route (internal tibial malleolus) in the air-transfer pre-hospital setting. The patient recovered.

Vegunta RK. Chapter 8-Vascular access. Ashcraft's Pediatric Surgery 2010;5th ed:110-6
This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.
Intraosseous Vascular Access Bibliography

Emergency Care


This retrospective study evaluated humeral IO placement success rates, using the EZ-IO, in the out of hospital cardiac arrest patient. Over a 9 month period, humeral placement was attempted in 247 patients. First attempt successful placement was 91%; successful placement within two attempts was 94%. The authors concluded that humeral IO is a reliable method of fluid and drug delivery in the out of hospital cardiac arrest population. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article in Chinese, describes a study that evaluated the effects to the bone marrow following IO infusion of hypertonic saline-hydroxyethyl (HSH) in the dog model; using a normal saline group (NS) and a non-infusion group. The test subjects were put into shock and resuscitated. Results showed that at 48 hours post infusion and 1 week post infusion changes were seen in the bone marrow and peripheral blood in the HSH and NS groups as compared to the non-infusion group. At 4 weeks post infusion, the NS group and HSH group recovered to normal level. Bone marrow morphology changed slightly but no bone necrosis occurred. The author concluded that HSH in small amounts via IO is safe and effective as a fluid resuscitation measure for shock, and little change in bone marrow has been found after infusion.

YEAR: 2009


This study was designed to evaluate the effect of education on knowledge, attitudes and skill performance of IO access by Level 1 EMTs in Korea. After a two-hour program, the knowledge and attitude of IO access improved significantly.


Assessment of PALS training on EMS personnel. PALS-trained personnel had 100% success rate in IO placement (55% non-trained).

Barrett J. Adult Intraosseous infusion: “Good to the bone!” Response 2009;36(3):19-21

This article addresses adult IO infusion, primarily in the pre-hospital setting, with regard to the history of IO, anatomy and physiology, training considerations, clinical guidelines and contraindications, and financial considerations.


This letter to the editor discussed the experience of one ground emergency rescue service in Germany and their trial implementation of the EZ-IO, as compared to the David et al evaluation of the BIG by emergency physicians in which the rate of failure was 55%. Over a one year evaluation of the EZ-IO in the field, it was used in 20 patients, of which 19 were successfully placed (95%). The success of the field evaluation and a human cadaver study resulted in the addition of the EZ-IO to the receiving University Hospital emergency department.


Guidelines for prehospital fluid resuscitation addressing when vascular access should be attempted and how; and if fluids should be administered, which should be given and at what rate.


This letter to the editor discusses the experience of a mobile intensive care unit use of the Bone Injection Gun (B.I.G.) from January 1, 2005 - December 31, 2006. Following two failed attempts to establish peripheral IV access, IO access was attempted at the proximal tibia insertion site. IO access was attempted in 11 patients and was successful in 5. The authors attributed the failures to an inability to control the path of the catheter, resulting in too shallow of attempts or complete transfixion of the bone.


This article provides a general overview of intraosseous access and its use in emergency situations. A description of available IO access devices is provided.


Case study of a 9- month old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.

Prospective study of 246 EMS providers at 14 EMS agencies. Reports successful IO placement in 95% of cases (18 of 19).


Dutch study of IO use with the Bone Injection Gun by helicopter EMS teams. Reports 71% success rate for pediatric patients and 73% success rate for adults.


This article describes a cadaver study to determine skill acquisition and performance by use of the EZ-IO system by novices. Overall success rate for the 99 operators was 97%, and mean insertion time was 6 seconds. All operators rated the device faster and easier than using a central line, and 99% expressed willingness to use the device for cardiac arrest patients.


This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study designed to determine the feasibility of inducing therapeutic hypothermia (TH) after resuscitation by giving an IO infusion of iced saline. Researchers concluded that rapid, large volume IO infusion of iced saline is as effective for lowering core body temperature after resuscitation as central access and peripheral IV. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract describes a retrospective study to determine the time from EMS dispatch to IV or IO drug delivery, time savings to drug delivery if vascular access preceded intubation, the internal validity of that point estimate using matched cases in which IV/IO was performed first, and the theoretical increase in rate of return to spontaneous circulation. Investigators concluded that time from dispatch to IV/IO delivery could be reduced by 4 minutes if vascular access preceded intubation and could, potentially double ROSC.


This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study that evaluated crystalloid fluid flow through an IO needle following nitroglycerin infusion in a swine model. Investigators concluded there was not a significant increase in flow rate after administration of IO nitroglycerin.


This abstract for a presentation at the 2009 ACEP Research Forum describes a volunteer study that examined the relationships between IO and venous blood samples when analyzed for complete blood count and chemistry profile. Researchers concluded that the IO space is a reliable source for blood used for CBC and chemistry profile. Results may be moderately reliable for carbon dioxide, but unreliable for WBC counts that appear to be elevated and platelet counts that appear lower. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Miller LJ, Philbeck TE, Montez DF, Spadaccini CJ. A new study of intraosseous blood for laboratory analysis. Arch Pathol Lab Med 2009;133:1628

This abstract for a presentation at the College of American Pathology 2009 meeting describes a volunteer study that examined the relationships between IO and venous blood samples when analyzed for complete blood count and chemistry profile. Researchers concluded that the IO space is a reliable source for blood used for CBC and chemistry profile. Results may be moderately reliable for carbon dioxide, but unreliable for WBC counts that appear to be elevated and platelet counts that appear lower.


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants.

This article describes a case in which IO access, using the EZ-IO, was attempted in a patient with osteogenesis imperfecta. In each of 3 attempts, the needle became loose immediately after IO insertion. The author acknowledged that during emergencies it is difficult to assess and consider every possible contraindication for every intervention; and that IO access using the EZ-IO is the author's choice for emergency vascular access when peripheral access is difficult or has failed.


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants. (Note: This study was also described in an earlier article published in American Journal of Emergency Medicine) This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In this 1,598 patient case series, investigators studied the effects of serial standard of care changes in the EMS system over time. They concluded that IO access is an essential component for a proven algorithm for the management of OOH-CA.


This article describes the first clinical study that focuses on the proximal humerus as an IO site. It is also the first article describing a comparison between IO access and peripheral IV (PIV) and central venous catheters (CVC). They found that IO catheter placement was significantly faster than PIV or CVC placement, and concluded that IO access is life-saving when PIV or CVC is difficult or impossible. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract for a presentation at the 2009 ACEP Research Forum describes a volunteer study to determine the optimal Lidocaine dosing and sequencing for patients receiving fluids through the IO route and to determine if adequate fluid flow rates can be delivered through the proximal humerus IO site. Researchers concluded that for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed, followed by a rapid normal saline flush of 10ml. Additional dosing and flushing may be required. For humeral insertion, a longer IO needleset should be considered. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes an observational study performed by the French military air surgical team in Chad. There were 11 patients with no insertion failures. For 7 patients, the insertion site was the proximal tibia and for the remainder the site was the proximal humerus. The authors concluded that the EZ-IO is a device that is simple, reliable and which gives satisfaction for the administration of drugs.


This abstract describes a small study designed to determine if IO line placement improves outcome in adult patients with out-of-hospital cardiac arrest. This 165 patient study did not demonstrate improved survival.


This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.


This letter to the editor describes the first case reported in the clinical literature in which therapeutic hypothermia was administered using the intraosseous route. The patient, a 2-year-old boy who was found submerged in a cesspool and had been asystolic for 5-10 minutes, survived without neurological complications.


This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.
Intraosseous Vascular Access Bibliography

Emergency Care

YEAR: 2008


No abstract available.


Animal (goat) study to determine if IO administration of hydroxocobalamin for antidotal treatment for exposure to cyanide and other poison agents would be faster and require less fine motor coordination and sensitivity; and would result in similar hemodynamic changes compared to IV administration. Using the EZ-IO device, researchers concluded that hemodynamic effects of hydroxocobalamin given by the IO route in non-poisoned goats are mild and similar in magnitude to those of saline control animals.


Animal (goat) study to determine the capacity and time required for protected hazardous materials responders and receivers to accomplish vascular access and hydroxocobalamin administration for antidotal treatment for exposure to cyanide and other poison agents. Using the EZ-IO device, researchers concluded that the time required for IO administration of the drug was shorter than intravenous administration; and that IO placement is readily accomplished wearing all levels of chemical protective garments and equipment.


Study comparing manual intraosseous insertion with EZ-IO using adult human cadavers as a model. No significant difference in insertion time between 39 manual insertions and 45 EZ-IO insertions. Found a difference in the success rate (manual, 79.5% vs. EZ-IO 97.8%, p<0.01). The EZ-IO had fewer complications (manual, 15.4% vs. EZ-IO 0.0%, p<0.01) and scored higher on user friendliness (school grading system: manual, 1.9±0.7 vs. EZ-IO 1.2±0.4, p<0.01).


Large retrospective study of patients for whom emergency vascular access was obtained using the Vidacare EZ-IO intraosseous system. Insertion success was 92% and within 10 seconds for 84% of the one-attempt successful cases. Complication rate was low (4.8%), none were serious, and extravasation was the most frequent (0.8%). The device was rated easy to use 72% of the time, and researchers concluded that the powered IO device is safe and effective for achieving vascular access in the resuscitation and stabilization of emergency patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Interim report for quasi-controlled prospective study of emergency department patients for whom emergency vascular access using the Vidacare EZ IO intraosseous (IO) system (n=6) inserted in the proximal humerus was compared to access using central or peripheral intravenous (IV) lines (n=60). Researchers concluded that proximal humerus IO insertion is significantly faster than central or peripheral intravenous (IV) line insertion. Complications and pain profiles were similar for IO and IV techniques. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Three-year study of IO training and use in 28 hospital and ambulance services in Switzerland. Standardized training improved IO success rate to 100%.

Abstract only


This article describes an observational study in which two intraosseous devices were compared: the Pyng Medical F.A.S.T.1 and the Vidacare EZ-IO. For the 117 patients on which the F.A.S.T.1 was used, there was an 84% success; compared to a 97% success rate for the EZ-IO (n=71).


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Intraosseous Vascular Access Bibliography

Emergency Care


Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter by S. Nicoll and S. Rochester states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation. The second by R. Salter notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.

UK


Prospective observational study of the use of the Bone Injection Gun in Israel from 2000 to 2004. Of the 189 patients enrolled in the study, successful insertion on first attempt was accomplished in 91% of cases.


This article describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine sulfate for nearly all pharmacokinetic parameters. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.


This article describes thoracic trauma in the pediatric population. Includes a review of the assessment of pediatric patients. Circulation section of the article strongly recommends rapid intravascular volume expansion by the intraosseous route, and recommends the EZ-IO for “...quick and reliable vascular access during resuscitation ...”.

YEAR: 2007


This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study in which the EZ-IO was used to provide emergency vascular access for 95 pediatric patients. Successful insertion and infusion was achieved in 94% of the patients, and insertion time was within 10 seconds for 81% of the placements. There were four minor and no serious complications.


Data from the largest combat trauma database was analyzed to identify how new or improved devices, dressings or drugs have impacted prehospital casualty care, how guidelines and resuscitation strategy have changed, and discusses lessons learned and how concepts have crossed back into the civilian practice. Intraosseous access, particularly the sternal site, is identified as one of the advances for vascular access in combat medicine.


This article reviews and assesses the literature on the use of IO drug administration during cardiopulmonary resuscitation. It addresses the risks and benefits of using IO in adults and children. The article describes the FDA-cleared devices available for use including the Pyng F.A.S.T.1, Waismed Bone Injection Gun and the Vidacare EZ-IO®.


Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.

de Caen A. Venous access in the critically ill child. Pediat Emerg Care 2007;23:422-4

This review article states the availability of intraosseous (IO) needles for pediatric patients, outlines the limitations of traditional venous access, and discusses the various IO devices currently available, including the Vidacare EZ-IO®.


This article summarized the challenges and methods of providing vascular access for infants. It describes IO techniques and devices, including the Jamshidi, Cook, EZ-IO® and Bone Injection Gun (BIG) devices.


Fowler RL. Prehospital intraosseous access: elemental to the field? JEMS 2007; doi:http://jems.com/print/9198

Discussion of the role intraosseous vascular access can play in the prehospital setting where vascular access is often difficult or impossible to establish. The EZ-IO is named as a new IO device along with descriptions of Jamshidi, Pyng Fast 1, and BIG needles.


This article describes authors’ evaluation of provider performance using two IO devices; the Pyng Medical F.A.S.T.1™ and the Vidacare EZ-IO®. Of 89 insertions with each device, success rate for 72% for the F.A.S.T.1 and 87% for the EZ-IO, a significant difference (p=0.009). The time to fluid insertion for the EZ-IO was also faster (p=0.02). Authors noted that the EZ-IO is unique and much more useful than the F.A.S.T.1.

Gagliardi P, Purrone G. [Il potere di salvare vite: l'infusione di liquidi e farmaci in emergenza con accesso veneso non reperibile]. N & A Mensile Italiano del Soccorso 2007; 177: 20-3. Italian

Article in Italian describing IO access and EZ-IO


This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study done at Boston Medical Center in which the Vidacare EZ-IO was used to provide emergency vascular access for 50 critically-ill adult patients. Successful insertion was achieved in 92% of the patients; with 90% success on the first attempt. There was one immediate complication—a dislodgement during transport. Investigators concluded that the device is a safe and feasible device for adult patients requiring out-of-hospital vascular care.


This case study describes a 4-month-old boy that was found unresponsive. Resuscitation was started and continued through arrival to the ED; IO access at the proximal tibia was established using a 15 gauge aspiration needle as the only vascular access. Post mortem multislice CT examination showed gas in the hepatic veins, the right atrium, right ventricle, the upper pole of the right kidney and the cerebral vessels. Though air embolism was ruled out as the cause this death, it could have caused death in another case. The authors conclude that gas may have entered the body during resuscitation due to IO needle disconnections and that resuscitation with an inserted, disconnected IO needle should be avoided.

Landes AH. Intra-osseous infusions: the current status. Care of the Critically Ill 2007; 23: 53-8

Overview of IO access. Includes historical aspects, current status, indications for use, advantages and disadvantages, IO kinetics, insertion sites, complications and contraindications and description of available IO devices, including EZ-IO®.


In this study, presented at the NAEMSP 2007 annual meeting, authors compared the success rate of conventional IO access with the EZ-IO during 245 cases in the prehospital setting. They concluded that using EZ-IO® results in a statistically significant increase in IO success rate, compared to conventional IO methods.

Abstract

Myers BJ, Lewis R. Induced cooling by EMS (ICE): year one in Raleigh/Wake County. JEMS 2007;32:s13-5

This article describes the experience of the Wake County (NC) EMS System in inducing hypothermia for patients with return of spontaneous circulation after cardiac arrest. Authors describe their use of the Vidacare EZ-IO (now Arrow® EZ-IO Intraosseous Vascular Access System) for the administration of chilled saline. In this report 56% of vascular access cooling was done utilizing the IO device and an additional 18% utilized a combination of IO and IV induced cooling. The overall EZ-IO use in this program for all insertions were 414 with an insertion success rate of 94%.

Potyka JS, Gordon DJ. Stories behind the numbers: IO experiences in providers’ own words. JEMS 2007;32:s30-1

Qualitative study focuses on EMS caregivers’ experiences with Vidacare’s EZ-IO device and personal opinions. The study used a narrative approach to gain insight from EMS practitioners working with an IO access device under real field conditions.
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<td>Intraosseous vascular access: devices, sites and rationale for IO use.</td>
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This article in JEMS discusses an EMS system in New York following their adoption of the EZ-IO, and the advantages.

Article in Dutch describing IO access and EZ-IO.

The article describes a prospective observational study conducted by several EMS agencies in Portland, OR to determine the safety, efficacy and benefits of using the Vidacare EZ-IO in the prehospital environment. The IO device was successfully placed in 95% of the 280 cases. In 98% of the cases, placement was made within six seconds.

Study investigating time difference in obtaining IO vs. IV access while wearing personal protective equipment (PPE) in simulated HazMat scenarios. With provider in PPE and mannequin not in PPE, vascular access was faster with IO (14 seconds vs. 46 seconds; p<0.001); also, fluid infusion time (28 seconds vs. 46 seconds; p<0.001). With provider and mannequin in PPE, all the following favored IO: needle to skin time (13 seconds vs. 25 seconds; p<0.001), vascular access time (17 seconds vs. 63 seconds; p<0.001), and fluid infusion time (30 seconds vs. 66 seconds; p<0.001). Investigators conclude that EZ-IO under HazMat conditions provides vascular access and fluid more quickly than IV access.

Article describes a controlled study in which the time difference between IV and IO access was compared while providers and simulated patients (mannequins) were wearing personal protective equipment (PPE). Twenty-two EMT-P providers measured the times to skin access, vascular access and fluid infusion in three scenarios: no PPE for providers or mannequins; providers only in PPE; and both providers and mannequins in PPE. In all scenarios, there was a statistically significant difference in vascular access and fluid infusion time, in favor of the EZ-IO. Investigators concluded that, overall, the EZ-IO provides vascular access and fluid more quickly than standard IV access, and that donning PPE does not hinder providers' use of the EZ-IO.

This article reviews intraosseous vascular access in general, and summarizes the various devices available. These include the Waismed B.I.G., the Vidacare EZ-IO, and Pyng F.A.S.T.1.

This article in German (with abstract in English) describes IO infusion in detail. It includes techniques, indications, complications, and recommendations. Also describes the various devices available, including Cook, Bone Injection Gun (BIG), First Access for Shock and Trauma (F.A.S.T.1), and the EZ-IO®.

Overview article of IO vascular access describes technique, efficacy in medication delivery, utility in pediatric emergencies, use in neonates, complications, and commonly-infused medications.

An abstract describing a prehospital study comparing peripheral IV to tibial IO access for placement success, time to access and time to drug delivery. The authors concluded that using IO access on the first attempt results in faster drug administration than if IO access were used as a rescue line after failed IV.

Evaluation of the Pyng Medical F.A.S.T.1 intraosseous device in simulated prehospital scenarios. Mean procedure time for initiation of fluid flow was 92 ± 32 seconds. Concludes that the F.A.S.T.1 is fast, accurate and easy to use.
Intraosseous Vascular Access Bibliography

Emergency Care

In this study, presented at the NAEMSP 2006 annual meeting, investigators reported the results of a study that evaluated the performance of the EZ-IO® compared to an earlier evaluation of the Pyng F.A.S.T.1 system. There was a statistically significant higher success rate using the EZ-IO® compared to Pyng system, and investigators concluded that the EZ-IO® appears to be a superior device with regard to insertion success.

Prospective observational study evaluating EMT-B ability to provide care in out-of-hospital cardiac arrests. Found that EMT-Bs were able to place the EZ-IO with a 94% success rate. Median time to placement was 72 seconds.

Hoskins SL, Kramer GC, Stephens CT, Zachariah BS. Abstract 79: Efficacy of epinephrine delivery via the intraosseous humeral head route during CPR. Circulation 2006;114:II_1204
Results from this study which sought to determine the efficacy of intraosseous drug delivery using the proximal humerus during CPR in swine showed that the humeral route generated higher mean arterial pressures than central venous or endotracheal delivery.

La May G, Fries G. Pediatric fluid resuscitation and airway management - a primer on volume replacement in pediatric patients. EMS 2006;May:65-72
An overview of managing pediatric fluid resuscitation and airway management in the pre-hospital setting.

An overview of intraosseous cannulation in the pediatric population. Anatomy, technique, contraindications, complications and laboratory investigations are all discussed.

Two case studies of neonates that successfully received IO infusion.

Article in French describes IO access and IO devices, including B.I.G., F.A.S.T.1 and EZ-IO®.

YEAR: 2005

Observational study evaluating use of the EZ-IO®. Found 97% success rate for insertion and infusion into the IO space by paramedics, nurses, physicians and other EMS personnel in using the device for emergency vascular access. No serious complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Article describes intraosseous access for adults and pediatrics. Describes and discusses IO devices available including Jamshidi, Bone Injection Gun, F.A.S.T.1, and EZ-IO®.

This abstract describes a retrospective study evaluating use of IO access during pediatric critical care transport. From January 1, 2000 to March 31, 2002, 1.792 transports were performed and 47 patients received 58 IO catheter insertions. Insertion took a mean 1.2 attempts for placement and first attempt success was 78%. Most frequently accessed site as the proximal humerus (95%) and access was maintained for a mean 5.2 hours. The authors concluded EMT/paramedics, emergency physicians, and pediatric critical care transport teams should be familiar with IO placement.

Retrospective chart review demonstrating safe and effective IO placement on pediatric patients by EMT-Ps, ED physicians, and members of the transport team in the pediatric critical care transport environment.

Gillum L, Kovar J. Powered intraosseous access in the prehospital setting: MCHD EMS puts the EZ-IO to the test. JEMS 2005;30(10):s24-6
Observational study of initial use of the EZ-IO® in 125 patients by EMS providers. Found 94% success rate for insertion and infusion into the IO space. No complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

Emergency Care

This animal study compared IO drug delivery in the tibia versus the sternum during CPR. Researchers concluded that during CPR IO infusions delivered via both sites were effective—although sternal delivery was faster; and that IO sternum access is comparable to IV access for drug delivery during CPR.

This study abstract discusses use of the EZ-IO to determine the pharmacokinetics (PK) and efficacy of tibial IO drug delivery during treatment of cardiac arrest in the swine model, as compared to IV access. Results showed that PK analysis of IO drug delivery via the tibial route showed a delay of 20-50 seconds compared to IV; however, physiologically significant levels of epinephrine were reached as MAP. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Nursing article discussing the utility of the sternum as a site for IO infusion. Includes clinical indications, insertions techniques, contraindications, potential complications, post-insertion care and considerations for discontinuing the sternal device.

Animal study compared the sternal and tibial routes for IO drug delivery during CPR. Investigators concluded that both the sternal and tibial routes can effectively deliver near equivalent doses during CPR in swine. http://www.aemj.org/cgi/content/abstract/12/5_suppl_1/67

Case report. Finds more positive outcomes with fluid restriction (permissive hypotension) in patients with uncontrolled hemorrhagic shock.

Miller LJ, Kramer GC, Bolleter S. Rescue access made easy: Intraosseous infusion, once limited to use in children, is now becoming a reliable access site for adults. JEMS 2005;30(10):Suppl 8-18
Overview of IO therapy. Includes 10 Myths about Adult IO and description of available IO devices, including the EZ-IO®.

Retrospective study over a 14-year period examining 129 IO insertions among 23,489 pediatric trauma patients. Patients receiving IO fluids and medications tended to be younger and sicker. Concludes that IO is an essential skill for anyone involved in pediatric trauma resuscitation.

YEAR: 2004

This article discusses different aspects of burn care in the EMS setting, noting IO access as possibly your best when fluid resuscitation is necessary in burn victims.

Review article describing how IO has replaced saphenous venous cutdowns in pediatric emergencies and decreased need for immediate central venous access.

Miller LJ, Morissette C. VidaPort-an advanced easy IO device. Prehosp Emerg Care 2004;8(1):110-1
Study compared the VidaPort (now EZ-IO®) and the Bone Injection Gun (B.I.G.). Of 32 cases for each device, insertion rates were 100% for the VidaPort and 88% for the B.I.G. Average insertion times were 16 seconds for the VidaPort and 21 seconds for the B.I.G.

YEAR: 2003

Study evaluating the ability of physicians to establish IO access in patients while wearing full protective gear. Concludes that IO insertion of the BIG needle is rapid, but the protective gear increased insertion time 50%.

Review article asserting that IO administration of hypertonic saline dextran is consistent with the concept of permissive hypotension. Calls for innovative techniques in resuscitating patients from severe hemorrhage.
Intraosseous Vascular Access Bibliography

Emergency Care


Case report of a patient in asystolic arrest successfully resuscitated with an IO line inserted through deeply burned skin without complication. After multiple failed IV attempts, IO access was the only viable method of vascular access.

YEAR: 2002

Dries DJ, Sample MA. Recent advances in emergency life support. Nurs Clin North Am 2002; 37:1-10

Review article for a nursing audience outlining recent changes in emergency life support in the most recent Advanced Cardiac Life Support (ACLS) guidelines from the American Heart Association with specific emphasis on new technologies for vascular access and emergency airway management.

YEAR: 2001


Results of a literature search to determine if a standard bone marrow needle can be used to establish IO access in a pediatric patient. Results showed only one article addressing the issue that indicated standard bone marrow aspiration needles can be used for IO infusion.

Donati F, Guay J. The substitute for the intravenous route. Anesthesiology 2001;95(4):1041

This letter is in response to an editorial on management of laryngospasms without previous intravenous access. The authors debate the use of intramuscular succinylcholine vs. intraosseous administration.


Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.

Weiss M, Gerber A. The substitute for the intravenous route. Anesthesiology 2001;95(4):1040

In this letter to the editor the author responded to an editorial by Donati and Guay in which they suggested that every effort should be focused on a search for intravenous access including the femoral route. The authors suggest that the IO route is the safe alternative to unobtainable peripheral venous access.

YEAR: 2000


Nursing article discussing the role of IO infusion when peripheral veins are collapsed. Describes advantages of IO, including ready availability, ability to establish vascular access without interrupting CPR.


Brief review of the discovery and evolution of IO access in emergency care.


Survey on current opinion and practice regarding IO among 332 Accident and Emergency Departments. Found that 75% of respondents were aware of IO use in adult resuscitation.


This article reports the first 50 uses of the Pyng F.A.S.T.1 sternal IO infusion system in adults. Six emergency departments and 5 EMS systems participated. Results showed the overall success rate for the system was 84%. Success rates were 74% for first-time users and 96% for experienced users. Mean time to vascular access was 77 seconds.


Overview of pediatric IO infusion targeted for an EMS/paramedic audience. Discusses anatomy of long bones, indications, advantages, contraindications, steps for insertion, fluid administration and ongoing assessment and documentation.
Intraosseous Vascular Access Bibliography

Emergency Care


A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient.


Study comparing B.I.G. and Jamshidi IO needle in an EMS training program. 38 EMT trainees performed the insertion. Time to placement was 12 seconds for the B.I.G. and 17 seconds for the Jamshidi needle. There were no statistical differences in ease-of-use ratings between the devices.


This article discusses the basic steps of performing rapid sequence intubation in children with a referenced case study and literature review. The authors stated that based upon the evidence, when emergency intubation is needed, IO access can be an acceptable route for RSI in the absence of peripheral venous access.

Lavis M. Prehospital adult intraosseous infusion. Prehospital Immediate Care 1999; 3: 89-92

Review article describing IO vascular access in adult patients in critical prehospital situations. The technique is easy to teach and skills are maintained.


A 3-year old male presented at the emergency department with rapidly progressing circulatory collapse clinically aligned with meningococcal septicemia. Attempts at peripheral and central venous access were unsuccessful. Attempts at tibial IO insertion were unsuccessful with a number of needles bending when cortical penetration was attempted. IO insertion was successfully achieved at the medial aspect of the calcaneum. IO infusion was continued for 6 hours and removed when no longer needed. The patient fully recovered and the calcaneal site healed without complication.

Manley L. Pediatric hypovolemia: back to the basics. Int J Trauma Nurs 1997; 3:93-8

Review article for trauma nursing audience describing advances in trauma care.


Case report of an 18-month-old boy with cardiopulmonary arrest secondary to penicillin anaphylaxis successfully resuscitated by IO administration of emergency medications.


Clinical study finding that prehospital IO did not improve outcome in pediatric patients with cardiac arrest. Cautions that the sample size was too small to reach a statistically significant conclusion.


Describes a miniature C-arm imaging device to accurately confirm proper needle placement in intraosseous infusions.
Intraosseous Vascular Access Bibliography
Emergency Care

Discusses research directions for resuscitation from trauma-induced acute hemorrhagic shock, particularly uncontrolled hemorrhagic shock, with emphasis on fluid resuscitation.

YEAR: 1995

Evans RJ, Jewkes F, Owen G, McCabe M, Palmer D.  Intraosseous infusion--a technique available for intravascular administration of drugs and fluids in the child with burns.  Burns 1995; 21; 552-3
Case report finding IO a viable method of venous access in a child with burns.

Describes 2 cases of resuscitation of a scalded child by IO infusion following failed IV attempts.  Reviews IO techniques.

Nursing article on pharmacologic management of cardiac arrest discussing administration routes for cardiac medications.

Article in French.  
No abstract available

YEAR: 1994

Study of IO training for advanced life support providers. Providers were able to establish IO access in 13 of 15 (87%) of pediatric patients (age range 1-24 months) following completion of an 1-hour training course and supervised hands-on simulation. All procedures were performed in less than 10 minutes.

Comparison of flow rates for IO infusion through the clavicle and subclavian venous infusion.  Found no significant differences between the two infusion routes.  
Abstract only

Preclinical study in 86 injured dogs with hemostasis disorders. Plasma and platelet disorders normalized 3 hours after the onset of infusion therapy.  The response was enhanced by IO infusion of isotonic saline.  
Article in Russian-abstract only

Study demonstrating improved performance of pre-hospital endotracheal intubation and vascular access of younger children after introduction of an EMT-P PALS clinical course.

Describes frustration associated with difficult venous access.  Recommends intraosseous infusion technique as a non-collapsible vein for parenteral infusions.

Seminal article describing alternatives to intravenous cannulation including intraosseous access, intratracheal drug administration, sublingual and intralingual injection, intra-penile administration, and intracardiac injection. Concludes that the intraosseous method is an effective alternative to intravenous access in emergency situations.  
Review
Rieger A, Berman JM, Striebel HW. Initial resuscitation and vascular access. Int Anesthesiol Clin 1994;32:47-77
Discussion of the role of the trauma anesthesiologist/critical care specialist (TA/CCS) in field airway resuscitation, management and reversal of shock are covered in this chapter.

Preclinical study demonstrating IO infusion of a saturated salt-dextran solution restored cardiac output in a pig model of hemorrhage. Suggests that IO-administered concentrated salt-dextran solution is a viable alternative during harsh field conditions where conventional resuscitation techniques may be impractical.
Abstract only

A brief overview on establishing intraosseous vascular access in the neonatal patient population. Discusses insertion techniques, anatomy and physiology, absorption rates, indications and contraindications.

YEAR: 1993

Retrospective analysis of prehospital IO infusion covering 165 attempts on 152 patients over a 5-year period, found a success rate of 73%, with success rates significantly higher in younger children (<2 years old). EMT-Ps maintained proficiency in the technique over time despite infrequent use.

Observational study finding 7 of 27 critically injured patients (ages 3mo-10y) successfully resuscitated using IO. Concluded that IO is a rapid, safe and simple method of obtaining short term vascular access in critically ill and injured children.

Preclinical study in 18 piglets finding significant improvement in hemodynamic variables after IO infusion of hyperosmotic saline and IO transfusion of whole blood in an animal model of hemorrhagic shock. Concludes that IO infusion is easy to establish and holds utility for treatment of shock victims.

YEAR: 1992

Evaluation of the chain of survival from cardiac arrest using standard measurements of performance.

Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure.
Abstract only

A review of intraosseous infusion and the possible applications in pediatric emergency medicine.
Abstract only

Descriptive comparison of the 4 available routes to provide drugs to adult patients during cardiopulmonary resuscitation.
Intraosseous Vascular Access Bibliography

Emergency Care

YEAR: 1991

Discussion of case reports of IO infusion, as well as physiology of IO and technique for IO access. Concludes that IO infusion is simple and safe. The technique can be successfully performed under field conditions by paramedical personnel, even by untrained personnel.
Abstract only

Review article discussing aspects of intraosseous infusion, including indications, technique, and pharmacokinetic factors. Concludes that multiple drugs and fluids can be safely administered through the intraosseous route.

Comparison of IO administration in 3 simulated EMS settings: at the scene, in ambulance in steady traffic on curvy road, in ambulance at fast speed in stop and go traffic. Found that 12 EMS participants were successful in establishing IO infusions, with 84.8% of infusions achieved in less than one minute in all settings.

Review of indications and benefits of intraosseous infusion. Concludes IO access may be especially valuable for medical personnel who rarely care for critically ill children because the IO technique is easily mastered even with limited practice.

Case report of an 11-week old infant in cardiac arrest due to haemorrhage successfully treated using IO infusion. The child was discharged with no apparent neurological deficit.

Preclinical study in 39 puppies comparing IO treatment with Ringer’s lactate with antishock trousers and control group receiving no treatment. Concludes that emergency administration of IO fluids is safe and effective for the initial resuscitation of hypovolemic shock.

YEAR: 1990

Textbook chapter on IO.

Case report of a critically ill preterm neonate who received needed emergency fluids via IO infusion.

Review of the use of intraosseous infusion in children in the prehospital setting and in the emergency department. Outlines anatomy, indications and contraindications, technique, complications and role of intraosseous infusion in pediatrics.

Case report of a 6-month-old infant in cardiac arrest successfully resuscitated with IO epinephrine.
Abstract

Case report of 2 severely burned children saved after IO was used to establish IV access.

Preclinical study comparing a sternal IO infusion device to IV fluids for resuscitation. Blood pressure and cardiac output were normalized at 10 minute post infusion in both groups. Advocates use of IO infusion as a way for pre-hospital rescuers to consistently incorporate fluid therapy in their scoop and run policies.
Intraosseous Vascular Access Bibliography
Emergency Care

Nursing article describing intraosseous infusion techniques and benefits.

Preclinical study comparing the pharmacokinetics of 6 emergency medications in dogs. Found that IO administration resulted in similar physiologic effect and/or serum drug levels as central and peripheral venous administration.

Discusses current limited pre-hospital use of intraosseous infusion. Stresses need for a concerted effort to promote broad adoption.

This article describes two cases of IO administration of succinylcholine for emergency airway management in children that resulted in adequate intubating conditions within 45 seconds for both cases.

A 15mg/kg dose of phenytoin was administered over 15 minutes to 6 pigs using the IV route and 6 pigs using the tibial IO route. Blood samples were taken every 5 minutes for 35 minutes to determine phenytoin levels. There was no statistical difference between the two groups. Bone cortex and marrow were microscopically examined and were normal after 5 weeks. Authors concluded the IO route is an effective alternative to the IV route for administering phenytoin without permanent damage to the marrow.

YEAR: 1989

Preclinical study in pigs and mathematical model using mean frequency of the ECG during ventricular fibrillation to predict downtime.

Study of 22 cardiac arrest patients arriving at the Emergency Department with no or insufficient intravenous access. Intraosseous needle placed and flow established in less than 1 minute in all patients. Observed flow rates of 5 to 12 mL/min with pressure bag attached. IO needle placed in the medial supramalleolous.

Study of IO infusion by paramedics on pediatric patients (>5 years of age) in cardiac arrest. Paramedics completed a training program in IO technique. Observed 85% success rate (10 of 12 IO attempts). Discusses training methods, limitations and implications for future use.

This article describes a pre-clinical study comparing bone marrow, venous blood, and arterial blood specimen results when used for blood electrolytes, blood chemistries, blood gases and hemoglobin; and a clinical evaluation of bone marrow and venous blood used for cultures.

Prospective study finding EMS personnel able to successfully establish IO access in 16 of 17 pediatric patients with cardiopulmonary arrest. Observed 13 successful infusions within 1 minute on first attempts at IO access. No significant complications.

Review article for a nursing audience presenting a brief historical overview of IO technique and insertion methods, with discussion of clinical applications and nursing management aspects.

Observational study finding nearly 70% of aeromedical transport programs do not use IO infusion. Concludes IO to be grossly under-utilized. Calls for further consideration.
YEAR: 1988

Description of IO infusion technique, site selection, procedure, anatomy, physiology, historical perspectives, contemporary research, indications, contraindications, complications, and future direction.

Retrospective chart review of 33 pediatric patients finding 83% success in establishing IO infusion. IO and percutaneous peripheral catheterization were the quickest methods for vascular access. Observed no major and minimal delayed complications.

Retrospective chart review over a 1-year period finding IO reduced vascular access time in patients with cardiac arrest when standard techniques failed.

Preclinical study finding IO infusion of hypertonic glucose and dopamine to be as effective as IV administration.

Concludes intraosseous infusion to be a safe and viable technique in the pre-hospital setting, especially in the aeromedical area.

YEAR: 1987

Brillman JC. Intraosseous infusion for emergency vascular access. West J Med 1987;146(5):603
A brief overview of intraosseous vascular access. The author concluded that IO vascular access is a firmly established practice based on scientific fact and clinical significance.

Preclinical study of IO flow rates during hypovolemia. Concludes that IO flow rates may be insufficient for definitive treatment of severe hypovolemic or hemorrhagic shock.

Several case reports illustrating the utility of IO in the emergency department. Includes discussion of IO administration of diazepam in succinylycholine.

YEAR: 1986

Evaluation of a sequential protocol comparing femoral vein catheterization, saphenous vein cutdown, and IO (in order) when conventional IV access was impossible in a pediatric patient population. Found that IV access was attained in 4.5 minutes when the protocol was followed, compared to 10 minutes when protocol was not followed. Suggests that IV access should always be attained in 5 minutes or less.

Discusses rediscovery of intraosseous infusion as a straightforward technique for an extremely difficult clinical problem. Suggests that many fluids and medications can be administered via the IO route.

Discusses IO route as a safe, proven, and technically easy method for administration of replacement fluids, blood products, and resuscitative drugs. Presents value, historical context, technique, and complications of the IO infusion.

Case report of child with status epilepticus. IO phenytoin resulted in seizure resolution and therapeutic serum levels of drug.
Intraosseous Vascular Access Bibliography
Emergency Care

YEAR: 1985

Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.

Preclinical study in pigs examining blood pH during CPR with sodium bicarbonate administered via different vascular access routes. Found that pH pf blood obtained via central venous access and intraosseous access were significantly different from the peripheral group, and that all three groups were significantly different form the control. Pathology studies showed only minor damage to bone with IO sodium bicarbonate administration.

Letter to the editor asserting that while the Turkel trephine technique may stabilize the IO needle better and minimize fluid leakage into the subcutaneous tissue, few physicians are familiar with the technique and it is more time-consuming than using a standard bone marrow needle or standard hypodermic needle.

YEAR: 1984

Case report of continuous IO infusion of dopamine hydrochloride and dobutamine hydrochloride in a 6 month old infant. Concludes that IO infusion is efficacious and complications rare.

Seminal article on IO infusion by the “Father of IO.” Drugs and fluids infused through the IO space enter the central circulation as rapidly as through IV routes. Unlike peripheral veins, the intramedullary blood vessels will not collapse in shock.

Outlines problems with conventional vascular access in emergency medicine. Discusses possible resurgence of the “old” technique of intraosseous infusion.

Turkel H. Emergency infusion through the bone. Military Medicine 1984;149:349-50
Article for military medicine audience concluding that the intraosseous route is more safe and effective than the intravenous route for several clinical indications, including burns and shock, circulatory collapse, uncooperative patients, patients in transit, shortage of physicians, especially under emergency conditions. States that IO infusion is an established alternative to intravenous infusion.

YEAR: 1983

Recommends IO infusion of fluids in cases of shock, burns, mass casualties, and also for long term parenteral nutrition whenever peripheral veins cannot or should not be used.

YEAR: 1977

Observational study of 15 patients needing emergency fluids and in whom IV’s were difficult to establish. Patients received drugs and fluids via IO. Concludes that IO therapy is effective with no serious complications.

YEAR: 1954

Marill F. Death from sternal puncture. JAMA 1954;155:1276
Case report of death following pericardial rupture with hemorrhage, associated shock, and peripheral circulatory collapse.

YEAR: 1941

Tocantins LM, O’Neill JF, Jones H. Infusion of blood and other fluids via the bone marrow: Application in pediatrics. JAMA 1941a; 117(5):1229-34
Describes emergency IO infusion of citrated blood and saline into the tibia or femur of 9 infants. IV access was impossible. Found no complications upon clinical or x-ray examination post-infusion.

Early study of 4 patients with acute failure of the peripheral circulation. IO infusion of blood, fluids, or drugs via the bone marrow resulted in a prompt recovery from the state of collapse. Recommends IO route when peripheral veins are not available and fluids are urgently needed.
Intraosseous Vascular Access Bibliography
Arrow® EZ-IO®

YEAR: 2019

This pre-clinical study compared various PK parameters, return of spontaneous circulation (ROSC), time to ROSC, and odds of ROSC after epinephrine was administered via endotracheal (ETT), IO, and IV routes in a swine traumatic cardiac arrest model (TCA). IO groups included sternal IO (SIO), humeral IO (HIO), and tibial IO (TIO). CPR only and CPR plus defibrillation (CPRD) groups were included for analyzing ROSC. The Cmax of the IV epinephrine group was significantly higher than that of the IO group (p=0.049). The tmax of the TIO group was significantly longer than that of all other groups (p=0.008). There were significant differences in mean plasma concentrations over time between the IV and TIO groups at 90, 120, 150, and 180 seconds (p<0.05) with the TIO group having an unexpectedly prolonged absorption phase. There was no difference in the rate of ROSC between ETT, TIO, HIO, SIO, IV and CPRD groups. The PK findings relative to ROSC support the concept that neither epinephrine nor the route of administration influenced the outcome. All IO insertions were performed using the EZ-IO device.

Retrospective case report of six patients describing the use of intraosseous (IO) administration for 23.4% saline administration to treat intracranial hypertension. In all six cases sodium levels were increased and there were no IO complications.

This article describes a study comparing medical students’ comfort level in performing IO needle placement and defibrillator use in a pediatric ED before and after just-in-time training (JITT). JITT sessions were facilitated by ED attending physicians. Sessions for IO placement included group discussion of the location of IO needle set, indications, contraindications, locations on the body for placement, confirmation of placement, and selection of appropriate needle size. Participants then had hands-on practice using the EZ-IO task trainer for the humerus and tibia. The comfort level increased from pre survey 0% to post survey 48% (P<0.0001).

Investigators conducted a prospective, observational study to compare intraosseous (IO) blood samples to arterial samples obtained from 35 patients in the prehospital setting. Blood gases, acid-base balance, electrolytes, glucose and hemoglobin results were obtained using an i-STAT® POC analyser. The analysis was successful for 23 of the 33 patients with 7 failures due to technical problems (clotting, inability pf device to analyse). For the parameters of BE, pH, HCO₃, Gluc, iCa and Na the IO and arterial agreement was deemed acceptable enough that it may be useful for emergency patients until venous or arterial samples can be obtained; and limitations of IO sample use must be considered.

This pre-clinical study compared IO, arterial, and venous point-of-care blood samples taken during cardiac arrest and CPR pertaining to the source of the sample. The authors suggest that if arterial or venous samples are not available then IO samples can be considered.

This is a case report of IO access for palliative sedation with propofol in a 56-year-old man with no venous access. IO access was gained using an EZ-IO driver and the patient was successfully treated with propofol for 4 days to manage intractable pain and agitation.

A 75-year old female presented by EMS to the Emergency Department (ED) after a ventricular fibrillation cardiac arrest. EMS defibrillated the patient and placed a right proximal tibial EZIO intraosseous (IO) catheter which multiple medications (epinephrine, magnesium, amiodarone, and calcium chloride) were administered; and she had return of spontaneous circulation prior to ED arrival. The IO catheter wasn’t patent upon arrival in the ED and was removed. The patient was discharged on day four with ecchymosis near the insertion site. Three weeks post discharge the patient presented with tissue necrosis in an area surrounding the initial proximal tibial IO insertion site. The patient’s leg was debrided and grafting was performed; the author reported “good healing” three months post-event.
This study compared IO insertions with the EZ-IO device (tibial/humeral insertions) to the FAST-R device (sternal insertions only) in a physician-staffed helicopter emergency medical service. Insertion time, insertion site, flow, indication for IO access, and complications were compared. Median insertion time was 15 seconds for EZ-IO and 20 seconds for FAST-R. Overall, 35.1% of EZ-IO insertions resulted in poor flow and required a pressure bag while 85.7% of FAST-R insertions had good or very good flow. EZ-IO complications included extravasation (2.4%), aspiration failure (11.9%), and insertion time >30 seconds (4.8%). Complications associated with FAST-R included user failure (12.5%) and insertion time >30 seconds (12.5%). The authors suggest that although EZ-IO is faster the FAST-R device may be more useful when high-flow infusion rates are required. The authors indicate that a low number of insertions were made with the FAST-R device and many outliers were observed in the data. However, the article does not present the total number of insertions per device.


This study sought to investigate the reliability of ROTE M parameters in IO blood for the purpose of allowing a target-oriented administration of procoagulant agents in patients with IO access only. Healthy subjects and subjects undergoing minor surgery under anaesthesia were enrolled. The EZ-IO device was used to obtain IO samples. Tibial and humeral sites were used. Due to clotting in a majority of samples, only 9/23 samples were evaluable and ROTE M was feasible in only 3/23. The authors conclude that ROTE M measurements from IO samples are not reliable and should not be used for guidance of procoagulant therapy in the emergency setting.

YEAR: 2018


This case review describes a complication of compartment syndrome post IO placement in a 64 year old male initially unresponsive and hypoglycemic. Approximately 15 minutes post-ED arrival compartment syndrome signs were noted and confirmed with compartment pressures. An ultrasound confirmed lack of flow from the IO needle and x-ray showed the needle set to be inserted 2 mm beyond the posterior tibial cortex. Patient was taken to surgery for fasciectomy and four compartment release with subsequent return of pulses.


This study compared the efficacy and safety of IO versus IV idarucizumab for dabigatran reversal in a porcine polytrauma model. Twenty-one male pigs received oral dabigatran for 3 days and on the 4th day received dabigatran infusion while another 7 received a sham treatment. The treated pigs were then randomized to one of three groups: IO saline, IV idarucizumab, IO idarucizumab while the other 7 comprised the sham group. The pigs were subjected to polytrauma (femur fracture and blunt liver injury). Blood loss, hemodynamic values, and blood samples were measured and recorded. Blood loss was highest in the control group, followed by the two idarucizumab groups, and lowest in the sham group. Survival to 240 minutes was 100% in the sham group and both idarucizumab groups, and 14% in the control group. IO and IV idarucizumab promptly normalized global coagulation assays and thrombin generation and were comparable for reversing dabigatran.


This pilot study compares four different IO blood transfusion strategies with varying degrees of transfusion pressure in a swine model with similar bone density to that of an adult military servicemember. Animals were randomly assigned to one of four transfusion strategies: 1) gravity, 2) pressure-bag, 3) rapid-transfusion device, or 4) manual push-pull. Hemorrhage was simulated then IO access was obtained with the EZ-IO device. Gravity transfusion was the slowest with a flow rate 5 mL/min, followed by rapid transfusion device (31 mL/min), single site pressure bag (78 mL/min), double site pressure bag (103 mL/min), and push-pull technique (109 mL/min). Single site or double site pressure bag was determined to be the best option for IO infusion because of the high flow rate and no associated incidences of overpressure or death.


This article describes a prospective, comparative, nonrandomized study to compare flow rates using the sternal IO route with two different devices (EZ-IO and Fast1) when transfusing warm fresh whole blood as well as measuring post-infusion hemolysis when compared to IV infusion. Post procedure blood samples from all patients were within normal ranges with no statistically significant differences between groups. This study had a high catheter insertion failure rate in the IO groups. This was most likely due to subjects, healthy Norwegian military volunteers, performing the procedures on each other. The results suggest that infusion of fresh whole blood via the IO route is safe and reliable.
This study describes 3 cases in which tissue plasminogen activator (TPA) was administered via intraosseous (IO) access on a mobile stroke unit as part of the BEST-MSU study. IO access was obtained with the EZ-IO device as part of the study protocol.


This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.


This report from France reports a case of tibial osteomyelitis in a 40 year old male that was diagnosed by MRI and biopsy three months post-intraosseous (IO) catheter removal. The patient was given parenteral as well as oral antibiotics and had a good outcome. The initial IO catheter placement was for treatment of overdose after failed IV attempts. The catheter was removed on the first day and the patient was treated with oral antibiotics due to local inflammation at the insertion site. He left against medical advice before a full treatment course was completed.


This study compared tissue concentrations of low-dose vancomycin via intraosseous regional administration (IORA) vs actual body weight-adjusted IV dosing in total knee arthroplasty (TKA) in obese patients (BMI>35). The obese patient population has an increased risk of periartificial joint infection after TKA. 22 patients were randomized to receive either 15mg/kg (max 2 g) of systemic vancomycin or 500 mg vancomycin via IORA. Fat and bone samples were taken and antibiotic concentrations measured. The overall mean tissue concentration in the subcutaneous fat was 39.3 µg/g in the IORA group vs 4.4 µg/g in the IV group (P<0.01). Mean tissue concentrations in bones were 34.4 µg/g in the IORA group vs 6.1 µg/g in the IV group (P<0.01). Low-dose IORA vancomycin was effective in providing tissue concentrations 5-9 times higher than IV administration in this high risk patient population.


This study was a prospective, single-center, observational, cohort study of 10 patients comparing the ventricular enhancement time between humeral intraosseous (HIO) access and brachial intravenous (BIV) access during CPR in adult humans. HIO access was obtained with the EZ-IO device. Endpoints were right and left ventricular enhancement times after administration of a contrast agent. Results indicated that arrival times of medication at the right and left ventricles were significantly lower with HIO than BIV.


The objective of this study was to evaluate success and ease-of-use ratings when experienced paramedics attempted EZ-IO intraosseous (IO) access in a cadaveric model when wearing their standard uniform and wearing Chemical, Biological, Radiation and Nuclear (CBRN) personal protective equipment. There was no significant difference for the tasks of land marking, humeral site insertion, saline flush, holding and manipulating driver and catheter removal. Insertion times were statistically longer (by 9.4 seconds) wearing CBRN. Investigator concluded IO access can be effectively and promptly achieved while wearing CBRN.


This case study discusses the use of an IO vascular access device (EZ-IO) as a substitute for k-wire stabilization of mallet finger in a patient with distal fracture and tendon exposure of the third and fourth phalange. The needle driver of the EZ-IO was placed in a sterile glove and was then used to place the inner stylet of the device through the tip of the finger to achieve splint fixation in extension. The patient had a favorable outcome.

This paper provides a brief overview of the following IO needles and devices: the Dieckmann Modified Needle, the EZ-IO Manual Needle Set, the EZ-IO T.A.L.O.N Needle Set, the Jamshidi Needle, the Bone Injection Gun (BIG), the New Intraosseous Device (NIO), the FAST Responder Sternal Intraosseous Device, and the EZ-IO Intraosseous Vascular Access System.


This is a case report of a 69 year-old male admitted to an ED in the UK with an extradural hematoma following closed head injury. He was treated with decompression of the hematoma using a 25 mm long EZ-IO intraosseous needle. This is believed to be the first reported use of an EZ-IO device in this manner in the UK. The patient succumbed to his injuries two days later. However, the authors recommend consideration of this technique when transfer to a hospital with a neurosurgery unit for craniostomy is not a feasible option.


Prospective randomized clinical trial in which IO access was compared to peripheral intravenous access (PIV)in pediatric patients with septic shock. Children’s ages ranged from 1 month to 36 months old and weights ranged from 4 to 14 kg with similar characteristics in both groups; 30 patients in each subset. The IO group had significantly shorter vascular access insertion times, shorter length of stay and reduced mortality. IO access was achieved in the proximal tibia on first attempt for all insertions; 50% of PIV attempts failed on first attempt. There were no complications for the IO subset compared to 26.7 % for PIV. There was a reduced ability to aspirate for labwork via the IO access. This study supports existing literature that early use of IO insertion is safe and effective with minimal complications.


This study evaluated emergency department (ED) nurses’ success rate, compared with paramedics, in establishing pediatric IO access using semiautomatic devices. The NIO and EZ-IO devices were used by both nurses and paramedics on uncooked bones of 8- to 12-week old piglets. A total of 30 and 31 insertion attempts were performed by 17 ED nurses and 15 paramedics, respectively. First attempt success rates were 79.4% for nurses and 83.3% for paramedics. 82.3% of nurses and 73.3% of paramedics recorded the EZ-IO as their “first choice device”. The findings of this study suggest that ED nurses have the competence to perform IO insertions and this technique should be used in nursing school curriculum.

Fenwick R, Nutbeam T, Lowther A, Mann T. Maximising flow in intraosseous: An in vitro study. Poster presented at: Trauma Care Conference; April 15, 2018; Staffordshire, United Kingdom

This poster presents the findings of an in-vitro study to measure the time taken to administer 500 mL of saline via the intraosseous (IO) route using three different methods of administration: fluid giving set placed directly on the IO needle hub (DTO), fluid giving set connected to the EZ-IO device extension set (EZS), and fluid giving set connected to a simple 3-way extension set (TWS). The EZS set produced the slowest administration times. The authors concluded that clinicians may be able to increase IO flow rates by replacing the extension set that is supplied with the EZ-IO.


This article investigates the success rate of IO access in preterm and term stillborns using two different needles (21G butterfly and 15G EZ-IO) inserted manually and one battery-powered semi-automatic drill (EZ-IO). All insertions were performed on the tibia. Estimated success rates were 61.1% for the butterfly needle, 43.0% for the hand twisted EZ-IO, and 39.7% for the EZ-IO drill. The authors conclude that IO access in premature and term neonates is best achieved by manual access with a twisted butterfly needle.


Randomized crossover prospective study in which 77 of U.S. Army Combat Medics naive to the EZ-IO system were trained and then attempted IO access using the EZ-IO in bone models of the proximal tibial (PT) and proximal humerus (PH) sites. Success rate was the primary outcome with no significant differences in results between sites; and no significant learning or design confounding effects. Secondary outcomes of mean procedural time demonstrated a significant mean time advantage of 17.1 s (p < 0.05) in PT placement. There was no significant difference between sites for mean participant comfort level utilizing the EZ-IO® System. Authors concluded the overall first-attempt success rates with the EZ-IO® System are similar to the success rates of the FAST1® device.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


This paper is a letter to the editor describing successful insertion of EZ-IO in a neonate weighing less than 2 kg with respiratory failure, signs of sepsis, and shock. After successful insertion the patient was resuscitated and later stabilized. The authors advise that IO access is safe, effective, and attainable in all age groups despite FDA approval only in patients greater than 3 kg.


This abstract describes a new technique for splitting the rib cage after a trauma resulting in flail chest using a pediatric EZ-IO needle driven through splint material and skin then into the ribs to achieve rapid fixation.


This study compared the success rates and time to placement for Manual IO versus EZ-IO needles in pediatric emergency department (PED) patients ≤8 kg and >8 kg at a single institution. It was a retrospective, cross-sectional, descriptive study. All identified patients with an IO attempted in the PED were included. Fifty patients were identified. In patients ≤8 kg, overall success rates were 55% (17/31) for Manual IO and 47% (8/17) for EZ-IO. In patients >8 kg, Manual IO success rates were 100% (2/2) and EZ-IO success rates were 93% (14/15) for overall attempts. Time (minutes) to successful placement in patients ≤8 kg was 4.5 for Manual IO vs 12.8 for EZ-IO (P=0.02). In patients >8 kg, time to successful placement was 8.5 for Manual IO vs 10.2 for EZ-IO (P=0.70). Overall success rates in this study were poor in both groups, most likely due to lack of experience at IO insertion or inadequate device training. Access in smaller patients was more difficult and required greater time to insertion.


This article describes a complication of a deformed EZ-IO catheter which was noted following removal of the catheter in an adult patient. The catheter had been placed by a helicopter emergency medical service team following a motor vehicle accident. The cause of the catheter bending was most likely the result of arm positioning for thoracostomy. No difficulties in removing the catheter were noted and it appeared to have been functioning effectively.


This is a learning module for fourth year medical students to learn about fluid management and IO needle placement. The module simulates hypovolemic shock in a 3 year old patient using a child mannequin. An IO kit, including an EZ-IO driver, is supplied for obtaining IO access. A pilot study was conducted in 2017 with 16 subinterns on a pediatric service. Perceived competence in management of volume depletion and procedural skills were high following the training session and students felt the case was a beneficial learning experience.


This article investigates intraosseous fluid (IOF) as an alternative matrix for drug testing in deceased patients, especially in cases where the cadaver is severely compromised following death. IO access was obtained at 4 sites, bilateral proximal tibia and bilateral proximal humerus, using the EZ-IO device. Samples in 29 subjects were collected and screened for a host of illicit substances. Study results support the possible use of IOF as an alternative postmortem specimen for toxicological investigations when necessary.


This article examines emergency vascular access during newborn resuscitation. It discusses the time needed to place an emergency umbilical vein catheter (eUVC) and intraosseous kits (EZ-IO) in a series of simulated newborn resuscitations across 4 studies. In all 4 studies IO placement was significantly faster than eUVC placement. An additional study found eUVC placement to be significantly faster with real human umbilical cords than with simulated umbilical cords as used in the aforementioned studies. While IO access in newborns appears faster then eUVC in simulated models, to date, no randomized trials or large case-cohort studies have systematically evaluated the short and long-term safety of IO placement during newborn resuscitation. Current guidelines still support eUVC as the preferred method of obtaining vascular access during newborn resuscitation. The authors suggest further studies are needed to determine short and long-term safety of IO access in newborns before widespread adoption of the process can be recommended.


In neonatal training events in 16 hospitals over two years, clinicians with neonatal experience simulated resuscitation of an asphyxiated newborn and were recorded for retrospective analysis. Clinicians could choose either umbilical venous catheter (UVC) or intraosseous access (IO), using the EZ-IO device for vascular access. Delays for both procedures were related to equipment availability and lack of familiarity; training and prepackaged kits may decrease this variable. IO access was more than twice as fast to obtain than eUVC access.
Intraosseous Vascular Access Bibliography

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This is an article published in a Turkish nursing journal and written in Turkish. From the abstract, the IO route is described as an alternative approach to vascular access when venous access via a peripheral catheter cannot be obtained quickly. Complications of IO access and how to prevent them using nursing interventions are discussed. EZ-IO is discussed in the article.


This study aimed to compare the success rates of 4 commonly used IO devices (NIO Pediatric, BIG Pediatric, EZ-IO, and a manual Jamshidi IO needle) in a pediatric model. Speed of insertion, ease of use, and complications were secondary outcomes. Seventy-five novice physicians from Warsaw, Poland participated in this study; none of whom had prior experience with IO devices. First attempt success rates were 43% (Jamshidi), 90% (BIG), 97% (EZ-IO), and 100% (NIO-P). Median time to achieve IO access was 18 seconds (NIO), 23 seconds (EZ-IO and BIG), and 34 seconds (Jamshidi). 39/68 participants preferred the NIO device, 18/68 preferred the EZ-IO device, 11/68 preferred the BIG device, and none of the participants preferred the Jamshidi needle.


This article presents a review of current evidence regarding different routes for the administration of medications during neonatal resuscitation, of which the intraosseous route is included. A table comparing four different intraosseous devices, including EZ-IO, is presented in the document.


This paper describes a case study of a 66 year-old female who presented to an emergency department with symptoms of an acute stroke. After failure of intravenous (IV) placement, humeral intraosseous (IO) access was obtained using the EZ-IO device. Contrast media (CM) for computed tomographic angiography (CTA) was later infused, off label, through the IO line. At the time of the CT scan 20 mL of CM was seen within the glenohumeral joint. The patient did not experience any ill effects from the extravasation following the procedure nor at her 1 week follow-up.


This is a prospective, randomized, controlled trial of patients undergoing revision total knee arthroplasty (TKA). Twenty patients were randomized to receive systemic IV or IO regional administration (IORA) of vancomycin as prophylaxis. Higher tissue and bone concentrations were consistently achieved in the IORA group with tissue concentrations during the procedure 5 to 20 times higher in the IORA group than in the IV group. The EZ-IO device was used to gain IO access in this study.

**YEAR: 2017**

**Afzali M, Kvissegaard AD, Lyngeraa TS, Viggers S.** Intraosseous access can be taught to medical students using the four-step approach. BMC Medical Education 2017;17(50):doi:10.1186/s12909-017-0882-7. (Denmark)

This study evaluated the ability to teach the skill of IO access in a four hour timeframe to medical students using a modified Walker and Peyton’s four-step approach teaching method and a cadaveric model. The learner’s competencies were evaluated with an objective structured clinical examination checklist. This study found the teaching method was successful. Authors recommend repetitive training to be integrated to medical curriculum for maximal skill retention.


This article describes the anatomy and physiology of IO cannula insertion as well as indications and contraindications of IO use. Devices and techniques as applied to the pediatric population are discussed, including EZ-IO.


This study compared success rate, procedure time and user satisfaction of pediatric NIO vs. Pediatric BIG, EZ-IO and Jamshidi intraosseous access devices in pediatric manikins. Study was randomized, crossover trial with 87 paramedics participating. The study evaluated each device on the ease of use in performing their procedures. Results of this study found that paramedics favored the NIO in ease of use in the pediatric manikins.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


Swine study comparing pharmacokinetic (pK) parameters of TXA given by the IO vs IV route. For the 4 min and 5 min results Cmax plasma concentrations were higher in the IV group but similar from injection completion onwards. Other pK parameters were not significantly different. Limitations included swine model, normotensive animals and proximity of sampling site (jugular vein) to the IV infusion site (auricular). Investigators concluded this study supports the pharmacokinetic bioequivalence of IO and IV administration of TXA in this animal model.


This case report describes a complication of a laceration that occurred in an 85 year old morbidly obese female that presented in septic shock and received a proximal tibial IO placement. A 45 mm needle set was used for the initial insertion, which was completed without any initial problems; no stabilizer was placed. The patient had fluid resuscitation via the IO site with rapidly improved hemodynamics. During transport she developed a 7 cm laceration across the IO insertion site. The catheter was removed and laceration sutured. Authors opined that the lack of use of the EZ-Stabilizer dressing, the amount of soft tissue and thin skin and traction forces on the IO site applied during transport contributed to this complication.


This case report describes a CT angiography of the chest and abdomen done via an EZ-IO catheter placed in a critically ill patient’s proximal humerus. The contrast media was infused at a rate of 4 mL/s and the infusion pressure never exceeded 300 mmHg. No immediate or short term complications were observed. The authors describe the overall image quality and vessel contrast observed as excellent.


This case report describes use of an intraosseous needle for initial management of increased intracranial pressure from an extradural bleed in a 43 year old female with a traumatic head injury. The patient was taken to surgery for a craniotomy and recovered without deficit.


This preclinical study reported data evaluating the pharmacokinetics of HIO and IV vasopressin and the ROSC in a swine model of ventricular fibrillation cardiac arrest. For the parameters of occurrence of ROSC, odds of ROSC, time to ROSC, Cmax, Tmax, and plasma concentrations over time, the IO and IV routes results were comparable.


This is an abstract of a cross-over study comparing the ease-of-use and success rates of cadaver IO insertions performed by paramedics while wearing their standard pre-hospital clothing or Chemical, Biological, Radiation and Nuclear (CBRN) personal protective equipment. There were no statistically significant differences between groups for ease-of-use scores, however, scores were generally lower in the CBRN group. Insertion times were significantly longer while wearing CBRN (25 seconds vs 34.38 seconds). IO access was obtained using the EZ-IO device.

Iskrzycki L, Smereka J, Szarpak L. Knowledge, skills, and attitudes concerning intraosseous access among hospital physicians. Crit Care Med 2017;45(1):e117

This letter to the editor describes a manikin study that compared use of the Teleflex EZ-IO to the Persys Medical NIO intraosseous vascular access devices. Insertion times were statistically different, favoring the NIO but not considered clinically relevant. The authors concluded that, while hospital physicians’ knowledge of intraosseous access was limited, with simple training they could learn the procedure and place IO needles safely in less than 30 seconds.


This article describes a retrospective, CT-assisted evaluation of IO cannula placement. Over a 5 year period all multislice-CT trauma scans performed in a trauma center were monitored for intraosseous devices in situ. 982 patients were evaluated and 13 IO cannulas were found in 11 patients. In all cases, the EZ-IO device was used. Evaluation of placement found that all applications were placed correctly, but none were according to current guidelines. The site of puncture deviated in all cases with the most common error of overshooting during needle introduction. (Article in German)
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


Study using 31 healthy volunteers to evaluate IO blood samples drawn from the proximal tibia compared to arterial and venous samples using a POC lab device. Two samples were drawn from each site with no significant difference observed in the results with or without waste blood. Results varied particularly between the arterial and IO samples; and for several parameters. Authors concluded that IO blood samples may be evaluated using the i-STAT® point-of-care analyser; and results should be interpreted with care in the clinical situation context.


This case study describes a resident’s experience treating an infant in respiratory arrest. Among the interventions were tibial intraosseous vascular access using the Arrow® EZ-IO and administration of epinephrine. The baby did not survive.


This abstract describes a preclinical study conducted to determine how long an infusion must be stopped before drawing an IO specimen for analysis; to determine if there is a difference between IO specimen results when the first 2 mL of IO blood were discarded and not discarded; and add to existing data comparing lab results from IO vs. CVC access. Lab specimens were drawn following infusion of 0.9% NS and analyzed using a point-of-care analyzer and cartridge system. Results indicated the initial specimen drawn from the IO catheter for tested analytes may be considered for sampling, if those values are needed, and IO infusion is occurring, a wait time of two minutes post-stopping the infusion may be adequate for analysis; and IO specimen values are comparable to CVC values. This study was sponsored by Teleflex Incorporated.


This article describes a prospective, observational study that attempted to establish baseline values of IO pressure (IOP) in a healthy human population. Subjects had an IO device placed in the tibia and humerus. IO pressures, vital signs, and pain scores were monitored for 60 minutes. Absolute IOP values were not consistent between subjects. Future research is needed to determine how IO pressure can be used to guide therapy in ill and injured patients.


This report describes a case study of a 19 year-old male who had an IO catheter placement in the left proximal tibia with EZ-IO after sustaining injuries in a motorcycle accident. Upon removal of the IO access, the needle broke at the hub with the retained needle no longer exposed above the skin. Removal at the bedside using Hemostat forceps failed, as well as the use of a sternal needle holder and a wire twister. Under fluoroscopic guidance, a 4 mm Stryker Crown drill bit was used to remove the retained needle by coring it out of the bone. The site was irrigated, bone graft substitute was placed into the defect, and the surgical site was closed. The patient healed well and was discharged with no complications 3 days later.


Using a porcine hind leg model authors compared the success rate and ease-of-use ratings of an IO device, the NIO® in comparison to the Arrow® EZ-IO by novice users. NIO success rates were comparable to those of EZ-IO; 54% of the participants preferred using the EZ-IO over the NIO.


This article assesses the usability of the Partial Task Trainer (PTT) to train certain military medical providers on the technique of humeral head intraosseous infusion (HHIO). The PTT consists of an arm with functional structures and characteristics that allow trainees hands on practice locating anatomical landmarks, inserting the IO needle, and introducing the catheter into the humerus. Currently the US Army utilizes the EZ-IO Intraosseous Infusion System for HHIO infusions.


This paper describes a complication of dermal abrasion with the EZ-IO device in a 1 year old female in Japan who was treated in the emergency department for severe dehydration due to acute gastroenteritis.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


Case report of a 64 year old female in critical condition that had bilateral humeral intraosseous (IO) access sites placed for resuscitation. Past medical history included a clotting disorder. IO access was removed within 24 hours after CVC placement. Eight days post-IO catheter removal the patient developed pain, swelling, decreased motion and firmness in the area near the IO site. Conservative management failed and clinicians confirmed elevated deltoid compartment pressures and diagnosed compartment syndrome. She was taken to the operating room for a fasciotomy. Post-operatively the patient had pain relief, improved range of motion and last check-up had no pain and full range of motion.


The CoTCCC handbook was created as a guide to best practices created by the Committee on Tactical Combat Casualty Care (CoTCCC) which includes representatives from all the U.S. Armed Services that are part of the Tactical Combat Casualty Care (TCCC) Working Group. The recommendations are based on input from the battlefield as well as evidence in the civilian literature, examined and put together to provide guidelines for care. The recommendations and required skill sets include IO access as an alternative to IV access in multiple sections. The TCCC Medical provider skill set specifically includes the ability to demonstrate the use of IV/IO blood product administration (medical officers and operating room special operations medics) and the use of IV/IO tranexamic acid (TXA).


This retrospective study of a quality and safety database compared procedures performed by use of intraosseous vascular access for contrast media infusion to a control group of the studies in the database performed with antecubital intravenous access. The quality metrics of the two groups were similar, with the intraosseous needle group being slightly better. There were no complications related to IO use in general or specifically associated with the procedures. Limitations included this was a single-center study with small sample size and possible selection bias due to unfamiliarity with IO access.


This retrospective non-inferiority study examined EMS data extracted from a statewide EMS data system over a two year period. IO insertions performed by advanced EMTs (AEMT) and Paramedics were compared for insertion success rates. The majority of IO placements were with the EZ-IO®. The investigators concluded successful IO access was not different among AEMTs and Paramedics lending evidence in support of expanding the scope of practice of AEMTs to include establishing IO access in adults.


Case report of a 29 year old that was diagnosed with osteomyelitis in his left tibia after a prehospital IO placement for resuscitation of cardiac arrest. Medications infused included naloxone, epinephrine, and amiodarone. The patient had ROSC and his IO catheter was removed within one hour of ED arrival due to infiltration. Diagnosis of tibial osteomyelitis occurred approximately 8 weeks post-initial placement.


This is an abstract of a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Overall geometric mean tissue concentrations in fat samples were 3.7 µg/g in the IV group vs 49.3 µg/g in the IORA group (P<0.001) while mean tissue concentrations in the femoral bone were 6.4 µg/g in the IV group vs 77.1 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

Young SW, Clarke HD, Moore GA, Zhang M, Spangehl MJ. Higher tissue concentrations of vancomycin are achieved with intraosseous versus intravenous administration in revision TKA. The Knee 2017;24(6):XIV (Abstract 0018).

https://doi.org/10.1016/j.knee.2017.08.045.

This abstract describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Mean tissue concentrations in fat samples were 4.1µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.
Young SW, Clarke HD, Pitto R, et al. Higher tissue concentrations of vancomycin with low-dose intraosseous regional versus intravenous systemic prophylaxis in revision TKA. ePoster presented at: International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine Biennial Congress; June 4-8, 2017; Shanghai, China. ePoster 1230

This e-poster describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty-two patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin with 20 patients analyzed. Mean tissue concentrations in fat samples were 4.1 µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

Young SW, Zhang M, Moore GA, Pitto RP, Clarke HD, Spanghel MJ. Higher tissue concentrations of vancomycin with intraosseous regional prophylaxis in revision TKA- A randomized controlled trial. Manuscript submitted for publication

A randomized controlled study comparing antibiotic tissue concentrations when vancomycin is administered for total knee arthroscopy via IO and IV access. Ten subjects were randomized to each group. The IO group received 500 mg vancomycin injected directly into the proximal tibia IO insertion site below an inflated thigh tunicate, and the IV group received 1 gram vancomycin, both were given before skin incision. Results showed IO tissue concentrations of vancomycin were 5-20 times higher than systemic IV despite the lower dose. This study was sponsored by Teleflex Incorporated.

YEAR: 2016


This article provides a brief overview of intraosseous access for radiologists followed by a discussion of the use of IO access devices in the radiology suite, particularly for CT imaging. The protocol established at the authors’ institution for use of the EZ-IO system is described which emphasizes obtaining confirmation of proper IO catheter placement by use of imagery prior to full infusion of contrast medium.


Preclinical RCT evaluating the relationships between the anatomical distance of IO epinephrine and measures of resuscitative outcome in an adult swine model of ventricular fibrillation (VF). There were no significant differences between the HIO, TIO, and IV groups relative to the occurrence of ROSC, 30-minute post-ROSC survival, and time to ROSC. The anatomical distance of IO epinephrine injection from the heart did not affect short-term measures of resuscitative outcome in an adult swine model of VF including the occurrence of ROSC, 30 minute post-ROSC survival, and time to ROSC. Rapidly administered epinephrine, irrespective of route of administration, increased the chance of ROSC and survival to 30 minutes post-ROSC in this study.


This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.


The abstract describes the interim results of an investigational device exemption study evaluating use of EZ-IO in volunteers for a 48 hour dwell time period. At the time of the report, 39 subjects completed the study with no serious adverse event reports. Subjects were randomized to receive IO insertion in the proximal tibia or proximal humerus insertion sites. Pain has been managed using oral hydrocodone/acetaminophen and/or intravenous/intramuscular ketorolac. This study is sponsored by Teleflex Incorporated.


This study conducted as an IDE was conducted to evaluate the safety of IO access for a period up to 48 hours, in healthy or stable health-compromised (with diabetes or renal failure stage 2) adult volunteer subjects. The IO site was randomized to the proximal humerus or proximal tibia, and once placed the catheter was left in place with an infusion of 0.9% sodium chloride for 48 hours. 120 subjects completed the study with no serious complications. Investigators also found infusion pain can be managed with oral analgesics and an infusion of 30 mL/ hour maintained patency. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography


In this letter to the editor authors discuss the difficulties of obtaining vascular access in patients in shock; and make a case for use of intraosseous access (IOA) in shock. Authors note IOA access as a safe, effective alternative to venous access with relatively rare complications.

Poland


This paper provides a brief overview of IO access and discusses advantages and disadvantages of IO use. Validation of IO blood gases by point-of-care technology, IO administration of antibiotics, IO monitoring of renal function, and IO access in acute cardiac care are also discussed.


This preclinical study compared arterial and intraosseous derived biomarkers to determine if the results would correlate well enough over a period of 6 hours to consider use of IO derived blood when traditional samples are difficult to obtain. Authors noted there were no clinically relevant average differences between alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase, creatinine kinase and gamma-glutamyl transferase values which may be good enough for initial estimates of these markers analyzed in intraosseous and arterial samples. However the lactate dehydrogenase levels showed less correlation; and the precision of IO samples may be limited.


Randomized, prospective preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered vasopressin during cardiac arrest and CPR until ROSC was achieved. No difference was noted for ROSC between TIO and IV delivered vasopressin. Authors concluded the use of IO access could avoid the time delay associated with IV access, and that it is effective for treatment of hypovolemic cardiac arrest and should be first line for rapid vascular access.


Literature review on contemporary practices of intraosseous (IO) vascular access in adult patients.

Great Britain


This article discusses the difficulty in defining the time to bone healing after IO access insertion in children. A case study is presented of a 23 month old male with multiple comorbidities that had a tibial and proximal humerus IO placed then 3 weeks post IO placement had tibial swelling. Upon follow-up he was diagnosed with a tibial fracture and incomplete healing of the tibial bone accessed for IO use. Repeated IO access to a limb previously accessed is advised regardless of time after access. Authors emphasize that IO access is a "critically important tool" in pediatric emergency medicine and IO access should be used early and often.


This article includes a case study of an adult patient who received an intraosseous (IO) catheter, that may have extravasated, resulting in vascular compromise. The patient was treated with pharmacologic intervention and the status was reversed. A review of the literature on adult IO complications is also described.


This article in German describes a case study of a 3 year old child with a serious heart defect (after total cavopulmonary anastomosis) in which bilateral humeral IO access sites were obtained to manage her condition and the patient was discharged after 30 days without neurological deficits. Key messages include that IO access in children should be a primary access route in emergent and urgent situations, unless a suitable venous access is already available; the humeral head insertion site is an accepted method in emergency situations in adults and children; and IO access is intended for regular emergency administration of drugs. The purely preventive use of an IO is not indicated. Article in German.
This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access “should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation”.

This study examined the relationship between body mass index (BMI), the ability to palpate the tibial tuberosity (TT), and soft tissue depth at recommended IO insertion sites in obese patients using ultrasound. Authors concluded in obese adults with a palpable TT or BMI ≤ 43, a 25 mm IO needle is likely acceptable at the proximal bone mass index and distal tibial insertion sites; and at the proximal humerus site a 45 mm is recommended.

This article describes a case in which an EZ-IO catheter inserted into the proximal humerus required surgical intervention for removal after traditional removal efforts failed. Authors noted the patient refused an attempt to stabilize the insertion site. Discussion and a brief review of the literature discusses available IO devices and complications. In conclusions authors opined that with education and training, EZ-IO may become the preferred method of achieving rapid vascular access for emergent resuscitation with a low risk for complications.

This veterinary care article describes vascular access methods and devices used for small animal emergencies, including intraosseous devices.

A prospective study with 30 evaluable healthy volunteers receiving PH and sternal IO access (Arrow® EZ-IO® Vascular Access System and T.A.L.O.N.™, Teleflex, Wayne, PA) was conducted to determine if there is a significant difference between pain after a total of 60mg or 40mg of 2% preservative-free and epinephrine-free lidocaine. Endpoints were subject reported pain scores during 5 minutes of rapid infusion at 300 mmHg and 15 and 30 minutes at a rate of 125 mL/hour per pump. Authors concluded infusion pain through a PH IO may be managed with a single 40mg lidocaine prior to infusion, but a total of 60mg may be considered for sternal IO infusion. This study was sponsored by Teleflex Incorporated.

A preclinical study evaluating blood transfusion via IO vascular access in anesthetized swine. Results showed pressurized blood transfusion through IO vascular access resulted in acceptable flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.

This pre-clinical study compared the performance of IO and IV administered albumin. IO access was obtained via the tibia using an EZ-IO device. Mean infusion time for TIO was 7 minutes, 35 seconds. Mean infusion time for IV was 4 minutes, 32 seconds. There were no significant differences between groups relative to mean arterial pressure, cardiac output, heart rate, or stroke volume. Hemodynamic parameters were measured for only 3 minutes.

This study compared the effects of IO and IV administered resuscitative drugs (vasopressin, amiodarone, and epinephrine) on return of spontaneous circulation (ROSC) in a swine model of sudden cardiac arrest (SCA) with ongoing resuscitation. Swine were randomized to 1 of 5 groups; tibial IO, sternal IO, IV, CPR-defibrillation, and CPR-only. There was no significant difference in ROSC between SIO, TIO, and IV groups. However time to ROSC was significantly less for the SIO group compared to the TIO group (p=0.003). This is possibly related to higher fat content in tibial bone marrow relative to the sternum and the lipophilicity of amiodarone.
This letter to the editor describes a novel training technique employed to provide training to clinicians on use of the EZ-IO system, in 15-minute sessions. Implementation of this program has resulted in 97% of participants reporting an increase in confidence using the EZ-IO system and 100% were able to correctly identify the locations of the devices for their clinical areas.

This article reports the results of a systematic review using PubMed for current evidence through 2015 for intraosseous (IO) vascular access use in adults requiring resuscitative procedures. General anatomy, indications and contraindications and available devices are discussed. Authors determined IO infusion is indicated in all critical situations with difficult vascular access; contraindications are few; and serious complications uncommon.

This abstract describes the results of a healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used safely and successfully in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.

This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9.58±2.706mL/h (n=27); mean PH infusion rate was 6.29±3.277mL/h (n=52). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.

A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.

A retrospective study evaluating vascular access routes used for US Military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) access including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. IV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.

A pre-clinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.

This randomized crossover manikin trial compared the NIO and EZ-IO devices for time to placement and ease of use. For both parameters the NIO performed better.

Poland


This letter to the editor describes a prospective, randomized, cross-over cadaveric study that evaluated use of the EZ-IO and NIO devices by novice paramedic device users. Following a brief in-service on use of both devices and practice insertions using a leg-trainer manikin, each participant attempted to establish IO access using each device in a resuscitation simulation with an adult cadaver with CPR in progress. Results showed first attempt success rates of 97.4% with the NIO and 100% with the EZ-IO; and mean time to insertion was 16.8 seconds with the NIO and 42 seconds with the EZ-IO.


A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, after 2 minutes CPR was initiated for 2 minutes, then 40 units of vasopressin was administered via IV or SIO route. Results showed no significant difference in SIO and IV groups for Cmax or Tmax.


A preclinical study comparing administration of Hextend via IV and tibial intraosseous (SIO) access routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


A preclinical study comparing IV and humeral intraosseous (IO) access routes for administration of vasopressin in a hypovolemic swine model in cardiac arrest. Following exsanguination, the swine were placed in cardiac arrest for 2 minutes, then resuscitated for 2 minutes in accordance with ACLS guidelines. Vasopressin was administered. Blood samples were collected at various time points following vasopressin injection and analyzed for maximum concentration (Cmax) and time to maximum concentration (Tmax) between groups; return of spontaneous circulation was also captured. ROSC was achieved for all HIO subjects (n=7) and in seven out of eight IV subjects; mean time to ROSC was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV administration of vasopressin for achievement of ROSC, time to ROSC, Cmax, Tmax, concentration over time, survivability, or odds ratio.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.


This is an abstract of a study conducted in the UK to determine the success rate of the EZ-IO Intraosseous Infusion System on return of spontaneous circulation (ROSC). Patient records were examined for 195 cardiac arrest patients who had an EZ-IO placement attempt. ROSC was achieved for 29% of patients. In patients who received IV administration of medications, 46% achieved ROSC. While IV access appears more favorable in this study, there may be other factors associated with achieving ROSC that were not taken into account.

YEAR: 2015


This article presents a 5-case series describing use of IO vascular access by anesthesiologists in the perioperative and critical care settings. All insertions were made in the proximal tibia and there were no adverse events reported. The devices cited as being used were the EZ-IO and the Cook Surfast manual needle. A proposed perioperative vascular access algorithm incorporating IO access is presented. The authors address key topics around IO access including use of same drug dosing as IV administered drugs, frequent palpation and monitoring of the insertion site for extravasation, low complication rate and actual risks associated with fat emboli and bone injury, pain and anxiety management in the awake patient and clinician-perceived pain. Administration of blood products, ACLS drugs, Lactated Ringer’s solution and anesthetics are noted without complication. Use of IO aspirate for laboratory testing is noted, however use of the initial aspirate is indicated. Several patients in the case series were found to not have significant levels of IO insertion preferable to multiple intravenous attempts. The authors concluded: IO lines can be placed quickly and safely in emergency situations or in elective surgical patients with difficult intravenous access; IO access can be useful in a wide variety of clinical settings; and is an important skill for anesthesiologist to learn.


This article describes the strategies used at one hospital (Penn Presbyterian Medical Center) to increase the use of intraosseous catheter to rescue patients in all care settings.


This article in Swedish describes a study evaluating use of aspirate obtained from the IO space for laboratory analysis. The authors note that point-of-care equipment should be used for analysis. Creatinine, morphine and troponin was successfully analyzed; leucocytes and platelets were noted to possibly cause falsely elevated values.


A preclinical study in which 8 anesthetized swine were put into an induced septic shock state to allow troponin I level measurements to be compared from serial venous plasma, arterial plasma and intraosseous aspirate specimens collected hourly. Two milliliters of IO aspirate were wasted before collecting each IO specimen for analysis. The levels of IO troponin I increased during the first 3 hours of shock but then plateaued at a high level while the venous and arterial levels continued to increase. Authors concluded that troponin I can be analyzed in bone marrow aspirates in a shock model and that this information may be useful in medical emergencies where cardiac damage is suspected to be involved.


Preclinical study to determine whether intraosseous pressure (IOP) could be consistently recorded and similarity of IOP to central venous and arterial pressure in a porcine hemorrhagic shock model. IOP tracings were tracked reliably from the proximal humerus, distal femur, and proximal tibia. Baseline IOP ranged from 16-18 mm Hg among the three sites, which was approximately 23% of arterial pressure. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
This paper describes a cadaver study that evaluated the ability of dental students to successfully place peripheral venous catheters and tibial intraosseous (IO) catheters using the Vidacare/Teleflex EZ-IO. Success rates, as well as insertion times, were recorded. 29% of venous and 83% of IO placements were successful. Successful venous access was achieved in an average of 163 seconds and IO access was achieved in an average of 30 seconds. Investigators concluded that chances to perform successful vascular access for inexperienced dentist may be higher when using tibial IO for emergency vascular access compared to when using IV catheters.

Case report of a prehospital misplacement of an IO catheter into the intra-articular space of the knee joint when access was attempted in the field. Upon ED arrival IO placement was noted to be high and intra-articular placement was confirmed by xray. A sterile NS lavage was done and patient recovered without complication. Authors note this as a previously unidentified complication of IO placement and advise xray confirmation of affected sites with follow-up of intra-articular placements for the septic arthritis. (Picture of site appears to be an EZ-IO).

A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.

Retrospective analysis of IO needle insertions performed in all HEMS missions during the first three years (2009-2011) using the EZ-IO system. Overall success rate of EZ-IO procedures (N=348) was 99.6%, with a first attempt success rate of 85.9%; and high user satisfaction rate of 93%. IO access was mostly second line overall but first line in children <7, trauma and cardiac arrest. There was one failure and four needle insertion problems noted; no serious complications.

German

A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, established via the EZ-IO, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.

This systematic review compared the reliability, ease of use and speed of insertion of different parenteral access methods with focus on relieving dehydration associated with the Ebola virus disease. Authors found that, compared to the intraosseous group, patients in the intravenous group were more likely to experience an insertion failure.

This single center, prospective, observational clinical study compared use of intraosseous (IO) access to central venous catheter (CVC) access for inpatient medical emergencies, managed by the medical emergency team (MET), within an urban teaching hospital. CVC access training included percutaneous, landmark-guided CVC placement without ultrasound guidance, using the femoral vein as the primary site. For IO access, the proximal tibia was the primary site and proximal humerus was secondary. Results showed IO access was significantly superior to CVC access with regard to first pass success rates, overall success rates, time to placement, and number of attempts for proper placement. On average more CVC kits were used per patient; complications were greater with CVC. There was one serious complication of tissue necrosis secondary to extravasation in the IO group.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

This paper describes a case study of a 64 year old man who presented to the ED with symptoms of bleeding related to rivaroxaban and clopidogrel. Due to concern for bleeding, low BP, and perceived difficulty in IV access, IO access was obtained. After access the patient experienced significant pain and was unable to tolerate large volume administration through the IO site. The patient was successfully treated with prothrombin complex concentrate (PCC), which has a smaller volume when compared to blood products. This was the first reported case of IO PCC administration.

In a healthy adult volunteer study contrast media was injected through the proximal humerus site and captured under fluoroscopy as it entered the heart. The mean time it took from injection at the insertion site to visualize contrast entry into the superior vena cava and the right atrium was 2.42 seconds. Abstract presented at ACEP 2015. This study was sponsored by Teleflex Incorporated.

A simulation study comparing use of manual (Cook Medical) and mechanical (Arrow EZ-IO) intraosseous (IO) devices to establish IO access in mannequin bones representing infant, pediatric and adult tibias. Twenty-two anesthesiologists with no prior experience with IO devices participated in the study. The outcome measures were success rate, insertion time and operator reported difficulty of use. Results were in favor of the mechanical device for insertion time in each category, and success rate in the adult tibia group; there was no statistical difference in the difficulty of use evaluation.

Abstract describing preliminary results for the first 24 subjects of an EZ-IO study evaluating catheter dwell times for 48 hours. Initial data indicate that IO vascular access can be safely maintained for a period up to 48 hours without risk of osteomyelitis or other serious adverse events. Authors also noted that additional analgesics for IO infusion pain management may be more effective than the current solely administering lidocaine into the IO space. This study was sponsored by Teleflex Incorporated.

This article presents a case report of a 7 month old female who received intraosseous vascular access via the EZ-IO in the distal femur that resulted in a dermal abrasion where the needle hub contacted the skin. The wound healed without significant complication however the scar at the IO site persisted at 11 months post the event. The authors recommend that providers use the minimal force necessary when operating the EZ-IO to avoid similar adverse events.

A cadaveric study evaluating intraosseous (IO) vascular access insertion sites for attainable flow rates under 300 mmHg. The EZ-IO was used to establish IO access at the proximal humerus and proximal tibia sites; the FAST1 was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 286 ± 218 mL for the humerus; and 154± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.

This abstract describes pilot data regarding initial vascular access device use in emergency department management of patients with out-of-hospital cardiac arrest. Twenty-six patients were included, and only 10 arrived to the ED with venous access established in the field: 4 via intraosseous and 6 via peripheral IV. Of the 16 subjects without access upon ED arrival, PIV was selected for 12 and IO was selected for 4. Nine patients experienced a delay in obtaining access attributed to the selection of PIV as the initial mode of gaining access. Median time required for access was reported as: 50 seconds for IO; 95 seconds for PIV and 780 seconds for CVC. The authors concluded that selection of PIV as the initial access method may be associated with delayed vascular access in the ED.

An abstract describing preliminary data evaluating the effect of initial vascular access device selection on the management of out-of-hospital cardiac arrest (OOHCA) patients by the ED. Twenty-six patients were included. Success rate by vascular access device selected was: 66% IO lines (2/3); 25% for PIV lines (3/12); and 100% for CVC (1/1). Eight patients experienced a delay in access due to initial method selected, 7 were attributed to PIV and 1 to IO. The authors concluded that the results suggest use of PIV as the initial mode of access may be associated with delays in access when compared to IO access in patients with OOHCA.
Intraosseous Vascular Access Bibliography

**Arrow® EZ-IO®**


This abstract describes a pilot observational study of vascular access devices (VAD) and their use in management of 20 out of hospital cardiac arrest patients. VAD selected, number of attempts for successful placement and time to insertion were recorded. Twenty patients were included in this study, 10 of whom received IO access upon ED arrival.


A healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. Military trained medics performed all device insertions. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used by military and tactical medicine personnel to safely and successfully establish IO access in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating attempts to establish intraosseous vascular access in pediatric patients using a manual device and the EZ-IO, in a tertiary care pediatric emergency department. Results showed 35 patients had IO access attempted using manual and EZ-IO devices. In patients greater than and less than 8kg the EZ-IO had a higher success rate but time to placement was longer. Overall success rate including both devices was 64%. There were 2 complications of transient leg swelling after EZ-IO placement in 2 patients.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.


This preclinical study evaluated the occurrence of fat intravasation resulting from intraosseous (IO) flush and infusion in anesthetized swine. Intravasated fat was assessed using a lipophilic fluoroprobe (Nile red) and by vascular ultrasound imaging. Fat intravasation was observed during all IO infusion regimens, with subclinical pulmonary fat emboli persisting 24 hours post infusion. It was noted that initial flush was a significant factor in fat intravasation, low levels of intravasation occurred with infusions ≤300 mmHg, fat intravasation and bone marrow shear-strain increased with IO infusion rates, and intravasation was influenced by cannula insertion site.


A pilot study evaluating the relationship between intraosseous (IO) pressure measurements and blood pressure obtained via external blood pressure cuff in ICU patients. Patients with IO access established by EMS or in the emergency department with planned admission to the ICU or surgical ICU were included in the study. External pressures were recorded every 15 minutes and IO pressure was monitored via a transducer for 12 continuous hours. Results showed IO pressures were approximately 30% of external blood pressure cuff readings.


The authors described a proof of concept pilot study conducted to determine intraosseous (IO) pressure measures and their relationship to blood pressure obtained using an external blood pressure cuff in ICU patients. The average IO systolic blood pressure, IO diastolic blood pressure, and IO mean were 39.5±12.7 mm Hg, 31.5±7.6 mmHg, and 35.0±8.8 mm Hg respectively. The ratio of IO systolic blood pressure to cuff systolic blood pressure, IO diastolic blood pressure to cuff diastolic blood pressure, and IO mean to cuff mean are 34.5±13.4%, 40.5±22.3%, and 40.1±17.1% respectively. There were no adverse events reported. Investigators concluded that in their convenience sample of severely ill and injured patients, IO pressure was reliably obtained and appeared to be 35% to 40% of blood pressure readings obtained via external blood pressure cuff; and that this method of pressure monitoring may be an appropriate alternative to invasive monitoring option in the future. This study was sponsored by Teleflex Incorporated.
A case study report of a 24-year-old female who presented to the emergency department after consuming an overdose amount of verapamil. Central and peripheral venous access were obtained for delivery of vasopressors and intravenous fat emulsion 20% (IFE). IFE was initiated via peripheral IV (PIV) access but access was lost; administration through central access was not possible due to the potential drug interaction. Intraosseous (IO) access was established using the Arrow EZ-IO system in the proximal tibia without complication and IFE administration was resumed. The patient reported some pain with infusion. After half the bolus administration was delivered, the infusion pump alarmed due to inadequate flow. PIV access was obtained and IFE administration was resumed using the newly obtained access route. The authors suggested that the viscosity of the medication may have caused the delivery failure by infusion pump through the IO route and recommend slowing down the bolus rate of infusion for clinicians attempting this route for IFE administration in the future.

This abstract describes a study (SAFER) reporting initial emergency department efforts in obtaining adequate vascular access (AVA) and initiating appropriate fluid resuscitation for hypovolemic patients with undifferentiated hypotension within the first 60 minutes following ED arrival. AVA was defined as any two of the following: PIV, IO, or CVC catheter. No data was given regarding time to IO access in the results. An overview of IO vascular access with a focus on the proximal humerus IO insertion site.

Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) antibiotic (cefotaxime and gentamicin) concentrations during septic shock. Both methods of administration yielded comparable concentrations. Authors concluded in an emergency, IO administration of these antibiotics may be considered in severe infections when venous access is difficult.

This is an abstract of a study that analyzed possible technical and anatomical factors leading to the complication of amputation as a result of IO placement. The study was prompted by a case report of amputation in a neonate after IO access using the EZ-IO device. The study measured medullary diameter of the proximal tibia at the recommended IO access site in three groups: 1-28 day old full term neonates, 1-12 month old infants, and 3-4 year old children. The mean diameter in each group was 7.7 mm, 9.9 mm, and 12.4 mm, respectively. The small size of the IO space, especially in neonates and infants, makes correct placement difficult. As such, complications should be taken into consideration in this patient population.

This case study describes a neonate who suffered a cardiac arrest, had return of spontaneous circulation (ROSC) and was treated with multiple medications and therapeutic hypothermia. The patient had received three IO needle insertions, one in the left tibia that was removed following swelling with bolus injection; one in the left distal femur that dislodged with movement of the patient's legs; and one in the right proximal tibia. Twenty-four hours after initial IO needle placement the child developed pallor and discoloration and was diagnosed with compartment syndrome to the right lower extremity. Five days post-IO insertion a below the knee amputation was performed.

This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive drug in pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.

This is a review article written in the Chinese language describing intraosseous vascular access.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

YEAR: 2014


This article in French is a survey of residents and doctors in France that practice in ED, ICU and anesthesiologists units seeking their opinions and practice habits in regard to IO access. Only 29% had ever used an IO kit; with a correlation between years of experience in practice and use of IO access. 55% had received some IO access training; 90% of untrained doctors believed training was necessary. The powered system was the most utilized (EZ-IO).

France


Literature search for complications associated with IO access included 5759 patients with overall complication rate of 2.1%. Two cases involving retained needle fragment discussed; one with a proximal tibial EZ-IO that required surgical removal. Authors concluded IO catheters are reliable tools for fluid and drug delivery to critically ill patients with low complication rates (which can be potentially serious but managed).


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.


Randomized swine study with the objective to compare the efficacy of IO delivery of hydroxocobalamin to intravenous (IV) injection for the management of acute cyanide toxicity. The survival rate, physiologic parameters such as reversal of hypotension, and pharmacokinetic results were similar between the IV and IO group. The primary limitation was use of a swine model. Investigators concluded intraosseous hydroxocobalamin may be as effective as the intravenous route in treatment of cyanide toxicity.


Randomized comparative study of adult pigs infused intraosseously with either: 7.5% hypertonic solution (HTS), 3% HTS or normal 0.9% isotonic saline. The animals were observed daily for infection, necrosis and gait up to 5 days, then necropsy and histological analysis was performed for tissue necrosis. Observations included regular tissue morphology and normal gait scores over the 5 day observation period; and absence of gross tissue necrosis and microscopic ischemia post IO HTS infusion in this swine model. Authors concluded this study confirms the clinical safety of IO HTS infusion and its use as an alternative lifesaving treatment.


Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) whole blood transfusion relative to hemolysis and transfusion time. IO transfusion does not significantly increase hemolysis (using free hemoglobin as outcome measure) or transfusion time compared with IV transfusion. Authors concluded transfusion of whole blood through an IO device is an effective transfusion method that may be used until other vascular access is obtained.

Craiu M, Stan V, Cochino AV. Intraosseous access-A classical method for vascular access that regains an important role as resuscitation tool. Ro J Pediatr 2014;68(3):233-7. Romanian

This article reviews the initial development of IO access and provides an overview of IO use in pediatric populations including insertion technique, side effects, and contraindications.

English and Romanian article


This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK
Intraosseous Vascular Access Bibliography

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This letter to the editor describes a single case of a needle breaking off after a proximal tibial insertion of the EZ-IO into a volunteer (one of the letter’s authors) during a training session. “Divergent from manufacturer instructions the sterile steel styllet was put back into place to achieve better grip for a manual pull-out. Under steady pull in strict axial alignment and gentle clockwise turn, the needle broke away from the plastic connector”. The needle was extracted using combination pliers and there is no evidence of damage to the leg. Authors acknowledge this can be avoided by adherence to manufacturer’s directions for use.

Germany


This was a prospective, randomized controlled clinical pilot study comparing the BIG and EZ-IO intraosseous (IO) vascular access devices in 52 adult patients admitted to an emergency department with difficult peripheral venous access. Twenty-six patients were randomized to each device; results were first attempt insertion success BIG 92.3%, EZ-IO 84.6% (P=0.668); procedure time: BIG 2.8 ± 1.2 seconds, EZ-IO 5.2 ± 2.2 seconds (P<0.001), significant; difficulty of use (with visual analogue scale): BIG 8.6 ± 6.4 mm, EZ-IO 25.4 ± 12.6 mm (P<0.001), significant. Authors concluded both EZ-IO and BIG are shown to be reliable and safe methods for insertion of intravascular access in emergency conditions. There were no adverse events or complications reported.

Turkey

Derikx HJGM, Gerritse BM, Gans R, vander Meer NJM. A randomized trial comparing two intraosseous access devices in intrahospital healthcare providers with a focus on retention of knowledge, skill, and self-efficacy. Eur J Trauma and Emerg Surg 2014; DOI:10.1007/s00068-014-0385-8

This article describes a randomized trial comparing the retention knowledge, skill and self-efficacy among anesthesiologists and registered nurses of anesthesia with use of the EZ-IO and Bone Injection Gun (B.I.G.). Participants were randomized to be trained on one device and were tested at 0, 3, and 12 months post training. The authors concluded that training anesthesiologists on use of the EZ-IO with the educational tools provided by the manufacturer will ensure optimal performance for a period of one year.

The Netherlands


Text article that accompanies video featured in The New England Journal of Medicine on intraosseous access which provides a general overview of IO access and demonstration of IO insertion using the EZ-IO and one manual IO needle set.


A cadaveric study performed by dentistry and medical students evaluating the feasibility of gaining vascular access via the anterior mandible bone.


This review provides a comprehensive summary of pharmacologic therapies that utilize prefilled devices as a delivery mechanism for parenteral application. Six categories are described: endocrine, neurological, pain management, immune disorders, anaphylaxis, and emergency medicine. Within emergency medicine IO access is recommended as an alternative to IV access when IV access cannot be obtained. Various devices for IO access, including the EZ-IO device, are listed.


A preclinical study comparing intraosseous (IO) and intravenous (IV) administration of Hextend in 27 swine for time of administration and hemodynamics. IO access was established in the proximal humerus using the EZ-IO. Results showed time for administration was not significant; there were no significant differences between IV and IO relative to hemodynamics. The author concluded that the IO route is an effective method of administering Hextend


Manikin study conducted in Poland with 107 paramedic operators designed to investigate the success rate, time of insertion and perceived difficulty of intraosseous access devices during simulated resuscitation using the EZ-IO, Bone Injection Gun and Jamshidi needles. Results were first attempt success: B.I.G.: 91.59%; EZ-IO: 82.96%; Jamshidi: 47.66%; mean procedure time: B.I.G.: 2.0 min ± 0.7; EZ-IO: 3.1 min ± 0.9; Jamshidi: 4.2 min ± 1.0; and ease of use (1-very easy to 5-very hard): B.I.G.: 1.83; EZ-IO: 2.92; Jamshidi: 4.68.

Poland
The objective of this study was to evaluate inclusion of IO access in Korean medical education with a selected group of 50 medical students. Students received 1 hour of didactic lecture and a 1 hour hands on session using the EZ-IO and artificial tibias and were tested. Results showed an insertion success rate of 88%. The authors concluded IO access was adequate for medical education in Korea.


In this pre-clinical study, investigators sought to determine if the pressure readings at the proximal tibia IO site served as a good indicator of proper IO placement when the foot of the limb was squeezed. Traditional methods used to determine correct IO placement, including needle stabiliy, aspiration of blood, and easy infusion, were used as comparators. Results showed the increased pressure reading at the IO site successfully predicted correct IO placement in all cases; traditional methods did not consistently correctly identify proper IO needle placement.


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FASTI IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.


Case study of 36 year-old in septic shock with co-morbidities of IV drug abuse, endocarditis, tricuspid valve insufficiency and pulmonary embolism. Initially impossible to obtain PIV or CVC access; then unable to give desired fluids through 22 gauge PIV when finally placed. Proximal humerus IO access was established with the EZ-IO 45 mm needle set and the patient was resuscitated with 30 mL/kg fluids and multiple medications given in first hour. Conclusions included that CVCs are not always possible and volume treatment with an IO placed sooner rather than later, especially in children but also in adults, can be lifesaving. IO systems should be extensively available throughout the clinical setting. Article in German.


This abstract describes the results of an observational clinical study that evaluated the use of IO vascular access via the proximal humerus insertion site for administration of contrast media for computed tomography examination. Eight subjects were enrolled into the study, 7 procedures were performed successfully with adequate opacification of the images. One subject experienced extreme pain with the contrast injection, the procedure was terminated and an alternative vascular access route was utilized. There were no serious complications reported. This study was sponsored by Teleflex Incorporated.


A preclinical study comparing the time to onset, time to onset peak, and time to recovery of peripheral intravenous and tibial intraosseous administration of Rocuronium. Study results demonstrated there was no statistical difference front the time of administration to complete neuromuscular blockade between the IO and IV administration of Rocuronium; and the recovery of neuromuscular function was significantly longer after IO administration, however was not deemed clinically significant. The authors concluded that Rocuronium can effectively be used via the IO route without the need for dose adjustments.


This abstract describes an observational study evaluating use of the intraosseous drill (EZ-IO) in 20 patients assisted by EMS and receiving CPR within a 3 year period. The study includes 4 pediatric and 16 adult patients. The authors concluded that IO access is a reliable alternative to peripheral venous access and can be implemented fast and with high success rate of CPR in which drugs and fluids are given.

This abstract describes a practice seminar held at the 32nd annual meeting of the Japanese Society of Reanimatology for establishing intraosseous vascular access in simulation using the EZ-IO and using Doppler ultrasound to confirm placement. The authors concluded the EZ-IO system enables immediate vascular access to the central circulation and the Doppler method enables objective recognition of needle misplacement.


In a series of studies using healthy adult volunteers the objective was to add to available data comparing IO marrow/blood (initial 1 mL aspirate), IO blood (subsequent aspirate), and venous and capillary blood to determine if there is a correlation between samples for serum lactate and PT/INR levels. Two point-of-care analysers were used. Conclusions were lactate levels obtained from IO blood appear comparable to lactate levels from venous blood; the PT/INR levels did not correlate. This study was sponsored by Teleflex Incorporated.


Retrospective study of the Israeli Defense Force (IDF) registry from January 1999 through October 2012 to identify all cases in which IO access was attempted. The Bone Injection Gun (B.I.G.) was the device used for IO access. A total 37 attempts were made in 30 patients. First attempt success was 53% with an overall success rate 49% when factoring subsequent attempts. Most frequent cause for failure related to providers skill level, and due to the device design allowing little room for error. This study prompted the IDF to seek an alternative for the B.I.G.

Neuhaus D. Intraosseous Infusion in elective and emergency pediatric anesthesia: when should we use it? Curr Opin Anaesthesiol 2014;27(3):282-7. DOI: 10.1097/ACO.0000000000000069

General review of IO access, with particular attention to perioperative setting and includes published guidelines of the German Scientific Working Group for Pediatric Anesthesia for use of intraosseous access. The author recommends that for children with known difficult venous access physicians discuss the possibility of IO access preoperatively with the family.

Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4

Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, “fluids” and calcium. Demarcation of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.


This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.


This letter to the editor describes a cadaver study performed by 50 interns who had never performed IO insertion, to determine if there is a learning curve associated with use of the EZ-IO for establishing IO vascular access in the proximal tibia. Following training each intern performed 10 IO insertions and were timed. The results showed a difference between the first and the eighth attempts resulting in a decrease in time to insertion by half. The authors concluded that practice insertions are necessary to become comfortable with the device.
In this pre-clinical study, 18 units of blood were transfused into 10 anesthetized swine via intraosseous (IO) access. Venous specimens were collected to evaluate free hemoglobin levels as an indicator of hemolysis. Seventeen transfusions were given via the proximal humerus site and 1 via the proximal tibia, using a pressure bag set to 300 mmHg. Mean transfusion flow rate was 61.6 ± 37.3 mL/min and the mean blood volume transfused was 266 ± 74 mL (n=18). The authors concluded that blood transfusion via IO access resulted in high flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.

This article explores use of IO vascular access in combat and tactical settings through a brief review of the literature describing this practice. A small feasibility study is discussed that evaluated the use of cadavers for training 26 U.S. Air Force Pararescuemen (PJs) on establishing IO access in the humeral head (proximal humerus) is the descriptor used by EZ-IO for this site) using the EZ-IO powered driver and needle set system (pictured in the article) and needles inserted with a manual driver without power. First attempt placement success with the EZ-IO powered driver system was achieved in 25 of 26 attempts; first attempt placement success using the manual driver and needle set occurred in 19 of 21 attempts. The authors concluded that the humeral head (proximal humerus) IO site is the most appropriate site within the tactical setting; and that use of a human cadaver model for training is an appropriate model.

A preclinical study comparing the recovery of fibrinogen in a porcine model when fibrinogen concentrate is administered via IV and IO access. The study results suggested intraosseous administration of fibrinogen concentrate results in a recovery of fibrinogen similar to that of intravenous administration.

This prospective study sought to evaluate intraosseous flush practices of emergency physicians. Using cadavers, 15 emergency physicians were asked to flush an IO catheter placed in the proximal tibia and proximal humerus IO insertion sites with 10 mL normal saline as they would in clinical practice; IO pressure measurements were recorded using an IO catheter inserted in the diaphysis of the target bones. Results showed the median IO pressure generated was 903 mmHg and the median flush duration was 5.2 seconds. Result showed significant interoperator variability with greater than 35-fold difference in flush forces. The authors concluded that it may be prudent practice for providers to extend the flush over several seconds to limit the maximal pressures.

This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).

A questionnaire and interview study evaluating the reasons paramedics do not perform intraosseous (IO) vascular access more frequently. Twelve paramedics in Johannesburg, South Africa were interviewed for the study. Results suggested access to inappropriate equipment (pink hypodermic needles), inadequate training, lack of use in hospital Emergency Departments to which they serve, and the perceived invasiveness of the procedure and pain caused during infusion dissuaded paramedics from performing the procedure.

Abstract presented at the Society of Cardiovascular Computed Tomography on preliminary findings of an observational study done after training ER physicians and techs on intraosseous (IO) catheter use and implementation of a policy for IO access use. Authors report high injection rates and excellent computed tomography angiography (CTA) scans safety with use of an IO for power injection of iodinated contrast media (ICM). Authors concluded cardiovascular imaging physicians, surgeons, ER physicians, and CT technologists should be familiar with the techniques of IO needle placement and use for power injection of ICM for CTA. The diagnosis and treatment of critically ill and unstable patients may be hastened by this technique.
Intraosseous Vascular Access Bibliography
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This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.

YEAR: 2013


Case report of 54-year-old male obtunded patient requiring a CT angiogram to diagnosis a suspected massive pulmonary embolism. After several failed attempts to reestablish PIV access, 150mL of contrast were injected through the proximal tibia IO catheter placed by EMS. Excellent opacification of the pulmonary arteries was achieved and there were no immediate complications from the injection noted.


This article describes a questionnaire study that was given to UK Role One military clinicians deployed to Afghanistan to assess the level of experience and confidence rating with use of IO access, using the FAST-1 and EZ-IO, and IV access. Thirty-three responses were received; clinicians felt more confident with IV access over IO access; clinicians felt more confident with FAST-1 IO access than EZ-IO IO access.


In a letter to the editor this study reports data collected (during a survey of one third of academic emergency medicine programs in the U.S.) regarding IO use in adults and comparing IO access with other vascular access techniques through simulation. Data suggest that IOs were used less than 5% of the time patients needed emergent access and a peripheral line was unobtainable. The EZ-IO was most often used IO device. Authors conclude IO use should be considered more frequently in critical, unstable patients. (This research was presented at the ACEP Research Forum in 2010).


This letter to the editor describes a prospective, observational, trial that evaluated use of the EZ-IO in critically ill and injured patients (adult and pediatric) in a multijurisdictional prehospital setting: 9 EMS agencies were included. The 25mm needle set was the only needle size allowed for the study. One-hundred-eleven EZ-IO placements were performed by EMT-Intermediates and EMT-Paramedics with 96 successful placements (86.5%); the most common cause for failure reported by the author was thought to be patient obesity and inadequate needle length. Cardiac arrest patients made up 74.7% of the study population and the most common site accessed was the proximal tibia. Device operators rated the ease of use 7.87 using a 0 to 10 scale where 10=extremely easy.


An observational clinical study evaluating use of the EZ-IO in patients requiring urgent vascular access that would have otherwise received a central venous catheter due to a lack of other options. One hundred five (105) patients were enrolled across five hospitals. The authors concluded that use of IO access in place of CVCs provides time savings, safety, ease of use, and is effective at significant cost savings; IO access may be used as a bridge to CVC placement under optimal conditions; and IO access may be used to replace use of CVCs all together in selective patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes a mannequin and cadaver study that evaluated use of the EZ-IO sternal device and the Illinois needle to establish sternal IO vascular access by dental students. Results of the cadaver study showed two cases of perforation of the posterior sternal cortex when the Illinois needle was used and one EZ-IO insertion in the soft tissue without entering the IO space. The authors concluded use of the EZ-IO sternal device with the insertion site template and scalpel incision may be more efficient and less predisposed to complication than use of the Illinois needle.
A letter to the editor reporting a case study of skin necrosis after IO administration of norepinephrine following resuscitation of a 74 years old in septic shock. The EZ-IO was placed to the proximal tibia; approximately 45 minutes post- norepinephrine administration symptoms of necrosis were evident. Authors cite 3 hypotheses for the cause of necrosis and consider that amines' high level concentration could induce local toxicity in the bone matrix and artery spasm; suggesting it is necessary to define an upper limit of amines' concentration that should be administered through IO vascular access.


A pre-clinical study that evaluated use of intraosseous (IO) pressure as an indicator of changes in fluid volume status during a hemorrhagic shock protocol. Central venous and arterial pressures were used as comparators. Results showed IO pressure decreased consistently during the controlled shock protocol. Authors concluded IO pressure appears to be equivalent to CVP as an indicator of fluid volume status. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A pre-clinical study that compared intraosseous (IO), central venous and arterial pressure tracings in a porcine model. Results showed that IO pressure was approximately 25% of arterial pressure. A sampling of IO blood gases revealed oxygenation levels of venous blood. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measureable blood pressure and it correlates with pressure obtained through conventional techniques.


General discussion on use of the intraosseous vascular access route for infusion of CT contrast, with attention to clinical considerations pertinent to nurses working in the imaging suite. Author also reviews general IO principles and IO devices.


This is a preclinical study comparing the EZ-IO and the Cook manual IO needle when used by 21 resident physicians to establish IO access in anesthetized swine. Results showed the drill-assisted needle was successfully placed 100% of attempts vs 76.2% successful placement with manual; time to placement and user preference also favored the EZ-IO. Technical issues reported included bending of the manual needle 33% of attempts.


A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices.
Intraosseous Vascular Access Bibliography

**Hunsaker S, Hillis D. Intraosseous vascular access for alert patients.** Am J Nurs 2013;113(11):34-9

This article presents an overview of IO access focused on nurses’ use of the technique. A list of available devices, history and support for use and possible complications are included.


This abstract describes a study in which 66 obstetric anesthetists, obstetricians and midwives were training on the EZ-IO and evaluated for successful application of the skill in a mannequin study. The participants also completed a survey following their insertion attempt regarding their perceived ease of use and likeliness to consider IO use in the future. Results showed first attempt success was 95.5%; respondents indicated they found the EZ-IO to be easier than establishing PIV access and 100% indicated they would consider IO use in the future.

**UK**


This abstract describes the results of an online survey taken by members of the Obstetric Anaesthetists’ Association, evaluating use of IO access in obstetric emergencies, and availability of IO equipment on UK labor wards. Results showed many members are trained on IO access, consider it a viable option during emergencies however have limited access to equipment.

**UK**

**Kim S. Intraosseous access: an important clinical procedure for emergency physicians.** Lifeline 2013;June:12-3

Article featured in June 2013 issue of California’s ACEP monthly newsletter. This article discusses general IO principles with examples of several short case reviews and highlights the EZ-IO.


Pre-clinical study comparing flow rates achieved after insertion with the EZ-IO in the proximal tibia, distal femur, and proximal humerus in a swine model. IO catheters were placed in each site and normal saline was infused for 10 minutes using a pressure bag at the highest achievable pressures greater than 300mmHg. The flow rates through the proximal humerus were statistically greater than that of the femur or proximal tibia. The femur flow rates were higher than the proximal tibia but similar. Post-mortem histopathologic evaluations done to assess for damage due to the high infusion pressures were consistent with IO catheter placement.


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.

**Lyon RM, Donald M. Intraosseous access in the prehospital setting-Ideal first-line option or best bailout?** Resuscitation 2013;84:405-406. http://dx.doi.org/10.1016/j.resuscitation.2013.01.027

Editorial reviewing a case series of EZ-IO use in the pre-hospital setting in Switzerland by Santos et al., combined with a literature review. The authors conclude IO access should probably be used selectively and training on its use improved, insertion sites should be compared and further investigation of use of the EZ-IO in major trauma patients, infusing blood components, use in infants, and application of training warrant further investigation.


This abstract describes a study in which the investigators sought to determine the approximate patient population in which the 25mm EZ-IO needle set was sufficient length to establish IO access in peripartum patients. Ultrasound was used to determine the tissue depth at four insertion sites. Twenty-six women were recruited with a median gestation of 34 weeks. In 88% of patients with a BMI<40 kg/m² the 25mm needle is sufficient to reach the bone marrow at both tibial sites. For the humeral site, IO placement may be more difficult for patients with a BMI>25 kg/m².

**UK**
A clinical study evaluating the relationship between IO blood and peripheral venous blood lactate levels analyzed using the i-STAT point-of-care analyzer in healthy volunteers. Results showed IO blood lactate levels were comparable to venous blood lactate levels with a positive statistical correlation. This study was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.

This retrospective review of medical records submitted by paramedics identified patients 18 years or younger who had prehospital peripheral IV (PIV) attempts. Over 101 months at least 1 PIV attempt was made on 4188 patients ≤18 years old. The study demonstrated that success rates are significantly associated with patient age and each 1 year increase in age increased the odds of successful PIV placement by 11%. The authors suggest that IO access with the use of a semiautomatic IO device (EZ-IO) may be a more efficient first-line method for immediate treatment after 1 PIV access failure, especially in younger patients given their higher rate of PIV insertion failure.

Oksan D, Ayfer K. Powered intraosseous device (EZ-IO) for critically ill patients. Indian Pediatr 2013;50(7):689-91
A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 60 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case). Turkey

This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.

A case study describing use of the EZ-IO in Afghanistan by US military on 5 patients with traumatic injury including one pediatric patient. Access was obtained in the proximal tibia on first attempt and was used to administer crystalloids in all patients along with opioids, analgesics and antibiotics. All ultimately received central venous access and peripheral access was established in one patient. There were no IO complications.

An observational study evaluating use of the EZ-IO by two ground and one air based physician staffed EMS and at a German surgical university hospital between January 1, 2008 and December 31, 2011. The EZ-IO was used to establish IO access 88 times in 87 patients; 83 insertions were performed in the EMS and 5 were performed in the hospital. The proximal tibia was the primary site used (97.7%) and the first attempt success rate was 94%. IO access was the first approach for vascular access in children compared to adults (38.9% vs. 86.2%). There were 5 failures attributed to missed insertions or extravasation and 2 for wrong needle length. There were no serious complications.

A simulation study evaluating if use of a laryngeal mask airways (LMA) and intraosseous (IO) lines established using the EZ-IO leads to improved resuscitation in a simulated cardiac arrest when compared to standard endotracheal intubation and central line placement. Results showed mean time to airway, mean duration of airway attempt, and time to vascular access was shorter in the IO group than the CVL group. Time to defibrillation and percent hand off time was not significantly different between the groups.

An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal humerus was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.

This article reviews the clinical effects of both high-quality chest compressions and the effects that interruptions during chest compressions have clinically on patient outcomes. The authors indicate intraosseous vascular access should be heavily considered as the first or at least second-line method used to help prevent prolonged compression interruptions for the purpose of establishing vascular access. The authors note that when using the EZ-IO this method of access is fast, effective, can handle all resuscitation fluids, and can minimize no flow time when used properly.


A quality initiative study conducted evaluating use of the EZ-IO needles in pediatric patients and their associated complications rates when placed by EMS/ED staff compared Air Evac Lifeteam placement in 2012. The authors concluded that the powered IO device was appropriately utilized by ED/EMS staff as well as Air Evac staff and that there was no difference in the complication rate when the device was used by the two groups.


This observational pre-hospital study conducted in Madrid, Spain prospectively evaluated use of the EZ-IO Jan 2007-Dec 2009 as an alternative to peripheral IV access. During the study period, 107 patients underwent 114 EZ-IO insertions and all were successful on first attempt. IO access was established in the proximal tibia (49%), distal tibia (25.2%), radius (14.9%), and humerus (10.5%) and all lines were the first form of vascular access established in the patient. There were no adverse events or complications.


This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 mL of red blood cells via the EZ-IO in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock; and RBC infusions via the IO route are feasible in this age group.


A clinical study comparing Cefazolin concentrations found at the operation site following total knee arthroscopy when prophylactic antibiotics are administered systemically, through IV administration, and regionally, through IO injection directly at the site using the EZ-IO. Subcutaneous fat and bone samples were collected for evaluation from 22 subjects. Authors concluded that regional IO administration of prophylactic antibiotics can achieve tissues levels higher than with systemic administration.

YEAR: 2012


A pre-clinical study that compared the EZ-IO 15 gauge 25mm needle set and the 13 gauge Jamshidi aspiration/biopsy needle when used to obtain core biopsy specimens in canines.

Canada


Preclinical study using a porcine model comparing the maximum concentration and time to maximum concentration of epinephrine administered via the tibial IO, sternal IO and IV routes during CPR. The IV route of administration of 1mg of epinephrine resulted in a serum concentration 5.87 and 2.86 times greater than the access route and sternal route respectively. The times to peak concentration was similar for IV and sternal IO groups but delayed for the tibial route. Authors conclude that due to limitations of their study the guidelines of administering 1mg of epinephrine via the IO route should not be changed; further studies using larger sample size, larger volume flush, arterial blood samples and the use of a more precise method of measuring serum epinephrine should be done.
Intraosseous Vascular Access Bibliography

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This article discusses how IO access can be used to improve advanced life support therapy. The EZ-IO is described in this article; published comparative studies between other IO devices and peripheral IV access are cited, leading the author to conclude the EZ-IO is user friendly, and establishes intravascular access more quickly and more often on first attempt than other devices.

This pre-clinical study evaluated IO flow rates obtainable with infusion of lactated Ringer's and hetastarch 6% through the proximal tibia and sternum IO insertion sites, using a swine model. The EZ-IO 25mm was used to facilitate tibial IO access; sternal access was established using a Jamshidi needle. Results showed that hetastarch flow rates were lower than lactated Ringer’s flow rates at both insertion sites; sternal infusion of hetastarch is likely to provide greater estimated intravascular volume expansion than lactated Ringer’s, despite the lower infusion rates; resuscitation using the IO rate is likely to benefit from pressure bag or high-pressure pump delivery. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2nd World Congress on Vascular Access 2012 reports data collected on the knowledge gaps and barriers to IO vascular access use. Two focus group discussions were held at professional conferences (American College of Emergency Physicians and the Emergency Nurses Association) and facilitated by clinical researchers. Data was qualitatively evaluated and researchers identified several main areas of concern for clinicians in both implementation and knowledge gap areas. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract presented at the 2012 ACEP Research Forum discusses a swine pre-clinical study evaluating CT image opacification when contrast is delivered via IV and proximal humerus IO access. The EZ-IO was used to facilitate IO access. Results showed that under blinded radiology review the IV and IO images were judged adequately opacified to meet diagnostic criteria. Authors concluded that IO administration of contrast material may be a viable alternative if other vascular access is unavailable or if establishing other access will lead to a delay in diagnostic evaluation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Esteo OV. Intraosseous access in prehospital emergency care. Emergencias 2012;24:44-6
A prospective, observational study which evaluated use of the EZ-IO within the prehospital setting over the course of a 3 year period, in Barcelona, Spain. Included patients were in cardiac arrest or with hemodynamic instability, without peripheral venous access after 90 seconds or 3 attempts to establish access. Results showed IO access was attempted in 49 pediatric and adult patients with an overall success rate of 93.9%; complications included extravasation and pain. IO access sites included the proximal tibia (71.4%), proximal humerus (22.4%) and distal tibia (6.1%). The author concluded that IO access is a viable access route for the management of critical patients or those in cardiac arrest in the pre-hospital setting due to the ability to obtain rapid access and the high first attempt success rate.

This article is a review of techniques and available evidence for establishing intravenous access, rational approaches to fluid resuscitation, and blood product transfusion in the pediatric trauma patient. IO needle systems are available for integration into pre-existing trauma care systems for pediatric patients.

Pharmacokinetics of IO drug delivery was compared using the tibia or sternum, versus central venous delivery during CPR. Anesthetized swine with KCl arrest were used for this study, CPR was initiated 8 minutes post arrest. Using 2 study groups, dye was injected as a bolus with adrenaline through either the IO sternal and tibial needles or through the IO sternal and IV central venous needles. Results showed peak arterial blood concentrations were faster for sternal IO vs tibial IO administration. Tibial IO delivered 65% of the total dose delivered by central venous administration. The EZ-IO and Jamshidi were used to facilitate IO access. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Ibrahim M, Cairney K. Intraosseous (IO) infusion as a means of vascular access. Br J Resuscitation 2012;Autumn:23-6
This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access.
Intraosseous Vascular Access Bibliography

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This article describes a study evaluating a new manual needle insertion device, the Near Needle Holder, which uses hollow-bore needles to establish IO access. In a comparative study, healthcare professionals attempted IO insertion in the proximal tibia insertion site of a mannequin using the NNH and a standard Cook manual IO needle. Participants then completed a questionnaire regarding their experience. The most reported complication was the plunging of the needle into the medullary space from the decrease in resistance once the cortex was penetrated. Other IO devices on the market are mentioned, including the EZ-IO.


This letter to the editor describes a case in which a 53-year-old male in ventricular fibrillation received IO access via the EZ-IO in the ED with suspected massive pulmonary embolism. The patient was successfully resuscitated. Necrosis of the anteromedial side of the leg, at the IO site, presented 48 hrs post IO use. After 18 weeks the patient underwent surgical grafting. The authors linked the necrosis to adenolysis extravasation and local ischaemia. While the authors conclude that thrombolysis or repeated high doses of adrenaline should be given via the IO route when needed, it is not without the risk of complication.


This clinical trial evaluated the time required to establish IO access versus central venous catheter (CVC) in adults undergoing resuscitation, who had failed peripheral IV access (PIV) attempts. IO and CVC placement were performed simultaneously; two IO devices, the EZ-IO and the BIG, were used to facilitate IO access in randomized format. Forty (40) patients were enrolled, first attempt success for IO was 85% vs 80% for CVC placement; median procedure time was 2 minutes for IO vs 8 minutes for CVC. The author concluded that though IO access is safe, reliable and rapid during resuscitation, it cannot replace CVC but should be considered as a valuable bridging technique.


This abstract presented at the 2012 NAEMSP scientific assembly described a randomized, cross-over study in which 8 swine were administered chilled saline via IV and IO routes to determine if the two routes were equivalent. The results suggested no clinical or statistical difference between IV and IO routes for infusion of chilled saline for therapeutic hypothermia. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2012 ACEP Research Forum discusses a literature review of intraosseous access publications since 1985 providing an updated safety profile for IO access. The search resulted in 192 articles describing IO access with 6 cases of osteomyelitis and 6 cases of compartment syndrome secondary to extravasation reported. Of the 192 articles identified, 140 described the EZ-IO. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2012 ACEP Research Forum describes a preclinical swine study evaluating the ability to induce therapeutic hypothermia by infusing chilled saline via IV and IO access. The EZ-IO was used to facilitate IO access. Results showed statistical equivalence between IV and IO routes when used to deliver chilled saline to induce therapeutic hypothermia. Results also showed that use of chilled saline and infusion tubing submerged in an ice water bath provides the most effective means of cooling. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at 2012 NAEMSP scientific assembly described a retrospective study that evaluated success rates and features of prehospital IO placement in adults following implementation of the EZ-IO, over a 2 year period. First attempt success rate in 281 patients was 89.7%; overall placement success was achieved for 91.8%.


A literature review of articles describing intraosseous vascular access devices used in the pre-hospital setting. Twenty articles met the inclusion criteria and described the manual devices, BIG, Fast-1 and the EZ-IO. The authors concluded that the literature suggests that semiautomatic IO devices may be more effective than manual devices.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

Page D. Intraosseous intrigue: Studies examine success rates on pediatric, adult & obese patients. JEMS January 2012;32-3

In this article, the author discussed five recent studies on intraosseous access providing his opinion about the quality of each study.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.


This letter to the editor describes a case in which sternal IO access was established using a Jamshidi needle to administer iodinated contrast for a thoraco abdominal CT on a 61-year old male who presented to the ED with respiratory distress. Picture quality was deemed excellent by the radiologists. The authors conclude that the sternal IO route can be used with excellent picture quality but it should be used only in exceptional cases due to the potential risks of a high-power injection through the bone. EZ-IO is mentioned as an alternative IO device available.


An article discussing the technique and safety profile of intraosseous access using the EZ-IO device. Needle selection, contraindications, insertion sites and techniques, catheter stabilization and removal are all discussed along with the safety profile of the EZ-IO against other IO devices and central venous catheters. The authors concluded that IO access should be considered whenever immediate vascular access is required. This article was co-written by an employee of Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2nd World Congress on Vascular Access 2012 describes the results of an analysis of published IO complications since 1985. The safety profile of the EZ-IO is also discussed in this abstract. The authors conclude that new devices and techniques have resulted in an approved IO safety profile. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.


This pre-clinical study sought to evaluate the various pressure levels obtained by 22 veterinary clinicians when administering a 10ml normal saline flush of an IO catheter. The EZ-IO was used to establish access in an isolated, cadaveric swine femur. The authors found the median peak intraosseous pressure was 615 mmHg with a range of 57 to 1,100 mmHg. Authors concluded that there is a great deal of variability between clinicians and their flush pressure and that a standardized flush protocol may be beneficial.


This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.
Intraosseous Vascular Access Bibliography

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This letter to the editor is written in response to the case report by Landy titled, Complication of intraosseous administration of systemic thrombolysis for a massive pulmonary embolism with cardiac arrest. The author suggests that the tissue necrosis described by Landy may have been due to the removal of the IO needle while there was still significant fibrinolytic activity at the needle insertion site. The author suggests a change in medical care after return of spontaneous circulation (ROSC) in patients following thrombolytic administration through IO access to convert the functioning IO line to a non-flowing saline lock. The EZ-IO was used to provide IO access in the case report by Landy.


This prospective observational study compared flow rates between distal and proximal tibia IO access in adults, with each adult serving as their own control. The EZ-IO was used to facilitate IO access. IO infusion was performed with and without pressure. The authors concluded that infusion flow rates were significantly higher in the proximal tibia as compared to the distal tibia, and that flow rates are significantly higher with pressured infusion vs. non-pressured infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2012 ACEP Research Forum explored the viability of the distal femur as an IO insertion site with a literature review of IO vascular access and brief overview of a post-mortem study of pediatric distal femur insertion success. Authors concluded that clinical literature, clinical studies, and a post-mortem study confirm that the distal femur is a viable option for IO infusion in pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This poster presented at the 2012 International Conference of Emergency Medicine described a 4 month review of intraosseous access in UK military operations in Afghanistan. During the timeframe the EZ-IO was used to establish IO access in the proximal humerus and tibia sites; the FAST1 was used to establish sternal IO access. Of the 87 EZ-IO applications there were 12 functional issues and the placement success rate for both sites combined was 86.3%. In 24 FAST1 applications there were 4 functional issues and the placement success rate was 93.4%.


In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO


This study conducted by the San Antonio Fire Department evaluated the first-attempt success rate for humeral EZ-IO placement by paramedics in prehospital adult cardiac arrest patients. Humeral placement was attempted in 247 cardiac arrest patients; first attempt placement success rate was 91%. Authors concluded that humeral IO placement is a reliable method for vascular access in this patient population. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A literary search of electronic databases was performed to identify publications comparing IO access devices. Publications qualifying for study evaluation must have compared two or more semi-automatic IO devices or at least one semi-automatic device and a manual device. Reviews, editorials, surveys, and case reports were excluded. Ten comparative studies met the qualifications for inclusion and are briefly discussed. The studies evaluated suggested superiority of the battery powered IO driver over manual needles and other semi-automatic IO infusion devices.

YEAR: 2011


This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.

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**Intraosseous Vascular Access Bibliography**

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This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first receivers to place IO lines for antidote administration using the EZ-IO device. First responders placed IO lines successfully in 100% of cases, and first receivers placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.

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This paper summarizes a study comparing first attempt success rates between TIO and HIO insertions during out-of-hospital cardiac arrest (OHCA). Insertions were performed by paramedics using an EZ-IO device. During the first month insertions were first attempted via the HIO route followed by the TIO route if unsuccessful; and vice versa during the second month. The overall TIO insertion success rate was 84.5%. The overall HIO insertion success rate was 40%.

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The case report describes a woman experiencing massive hemorrhaging following emergency caesarean delivery. Though the patient possessed a peripheral IV catheter, additional IV access was needed and gained through the proximal humerus IO space using an EZ-IO. This vascular stabilization and additional filling of the central volume through the IO route allowed placement of a subclavian central line. Authors concluded that a key to the resuscitation process was the rapid utilization of the IO.

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A case study report in French describing compartment syndrome secondary to intraosseous infusion in a 57-year-old burn patient. IO access was established in the proximal tibia on second attempt; both attempts were made in the same limb though it was noted that the first attempt did not penetrate the cortex. Drug and fluid infusion was initiated; ten hours later the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.

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**Coutry L, Hssain I, Joshi G, Diemunsch P. Intraosseous access for fluid administration in a simulation setting: Comparison with intravenous access.** American Society of Anesthesiologists (ASA) Annual Meeting 2012; abstract number A855.

This simulation study compared intraosseous (IO) vascular access, via EZ-IO, with peripheral venous (PIV) access for time to access, perceived ease of placement, rapidity, and safety, and which will be first choice in life threatening situation among 73 prehospital care providers with no prior experience with IO access. Results showed time to placement for IO access was significantly faster than that of PIV; the majority of device operators graded the device superior to PIV for ease of placement, rapidity and safety.

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**Cullen PM. Intraosseous cannulation in children.** Paediatric Critical Care 2011;13(1):28-30

This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

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**Day MW. Intraosseous devices for intravascular access in adult trauma patients.** Crit Care Nurs 2011;31:76-90. doi: 10.4037/ccn2011165

An overview of available intraosseous vascular access devices, including the EZ-IO.

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Case study of a 42 year-old woman with massive obstetric hemorrhage ultimately resulting in postpartum hysterectomy. Massive blood loss and inability to stop bleed prevented sufficient resuscitation via established PIV lines. IO access was established with the EZ-IO and used for fluid replacement and administration of cardiac resuscitation drugs. Fluid administered through IO access was 75% of the total infusion volume.
Heyder-Musolf J, Giest J, Straub J. Kasuistik-Intraossärer Zugang bei einem 1300 adult septic shock cases in which IO access was used for rapid IV fluid replacement as well as IV antibiotics and inotrope support.

In this article, the author makes a supporting case for remote emergency departments to stock adult intraosseous kits by referencing two 2011;40(7):510-1

Howarth D. Adult intraosseous access: experiences in a remote emergency department. Australian Family Physician 2011;40(7):510-1

In this article, the author makes a supporting case for remote emergency departments to stock adult intraosseous kits by referencing two adult septic shock cases in which IO access was used for rapid IV fluid replacement as well as IV antibiotics and inotrope support.
Intraosseous Vascular Access Bibliography

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This manuscript describes two studies conducted to assess the function and longevity of EZ-IO catheter when placed in the goat model. The authors concluded that the EZ-IO catheter can be left in place for more than 24 hours in animals and can be used in many different veterinary settings when IV access is not immediately available. They also concluded that the EZ-IO system is useful in larger or adult bones.

Khan LAK, Anakwe RE, Murray A, Godwin Y. A severe complication following intraosseous infusion used during resuscitation of a child. Inj Extra 2011;doi:10.1016/j.injury.2011.05.015

This article describes the case of a 11-year-old boy who suffered compartment syndrome of the lower leg following use of the EZ-IO for resuscitation and 24 hours of intraosseous infusion of adrenaline, calcium and potassium. The author concluded that further work is needed to develop recommendations for maximum duration, dose, volume and rates for intraosseous infusion.


This article reports a case in which IO access was used to deliver intravenous contrast agent in an adult blunt trauma patient. After placement in the proximal humerus, contrast agent was administered via the IO route, and clinicians found the CT scans of the thorax, abdomen, and pelvis to be adequate for diagnostic purposes and subjectively equivalent to those of studies using central venous access. There were no complications and the authors concluded that IO access appeared to be an effective alternative to traditional venous access for administering contrast agents for CT evaluation in adult blunt trauma patients.


This abstract describes a swine study presented at the 2011 National Association of EMS Physicians Annual Conference that examined infusion rates through 3 anatomical sites via the powered EZ-IO device. Investigators concluded that the infusion rate was greater via the humerus compared to the tibia and femur.


This study compared the effectiveness of infusing ice cold saline via IO and IV to induce mild therapeutic hypothermia (temperature drop to 34°C) within a 30 minute timeframe, in a swine model of cardiac arrest. Five swine were evaluated in each the IV and IO groups. Goal temperature was reached in 4/5 animals in the IV group and 0/5 animals in the IO group in the allotted time frame; IV was superior in terms of rate of infusion, rate of temperature change, and time to achieve target temperature.

Lowther A. Intraosseous access and adults in the emergency department. Nurs Stand 2011;25(48):35-8

This is a review article describing intraosseous vascular access, including techniques and device used, and contraindications.


This study evaluated the use of telesimulation by Canadian pediatricians to teach a relatively new IO insertion technique (EZ-IO System) to physicians in Africa. Self-assessment questionnaires were completed before and after training, multiple-choice tests were given and a demonstration of competency was done within 3 training sessions. Twenty-two physicians participated; the sessions improved physicians’ knowledge, self-reported confidence, and comfort level in inserting the IO needle. The author concluded that telesimulation offers potential for teaching other procedural skills over distances.


This abstract describes an evaluation performed in the goat model, using the EZ-IO, to determine the ability of IO access to accommodate a typical contrast dye infusion and withstand the power injection pressure. Bench testing was done to determine the max pressure deliverable through the EZ-IO using the power injector; various injection occlusion scenarios were established. Results showed the mean pressure through the humerus was 56.5psi; through the tibia was 163.5psi. There were 2 tibial extraosseous distal venous ruptures visible by fluoroscopy but not on gross examination. Under bench testing, for all tests, at pressures up to 750psi no failure or leakage was observed in the IO catheter. The EZ-IO extension tubing should not be used for power injection, particularly if the IO is in the tibia. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
The objectives of this study were to evaluate the amount of time necessary following IO insertion and infusion for the bone to heal such that a second IO catheter can be placed in the same bone without the risk of extravasation from the first hole; and to determine the length of time required to show radiological evidence of closure. Four anesthetized goats were used for the study. Twenty-four hours post insertion, extravasation was observed in 2 of 4 tibial sites with no extravasation in 4 humeral sites. Forty-eight hours post insertion, no extravasation was observed in tibial or humeral sites. Authors concluded that IO infusion should not be attempted in the same bone as a previous IO insertion within 48 hours of removal of the first IO catheter. Radiological examination showed evidence of bone healing as early as 6 days post IO placement. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes the changes in practice experienced when a 12-site statewide ambulance service changed from the manual to the semi-automatic IO device (EZ-IO). There was no statistically significant change in first-attempt success or the number of successes per attempt. However, the use of IO access more than tripled when changing from the manual to the semi-automatic device and PIV access attempts before IO access went from occurring in 35.5% of patients to 1.7% of patients.


This abstract describes a 93 patient study presented at the 2011 National Association of EMS Physicians Annual Conference that examined the characteristics of pediatric patients receiving IO infusions and the primary EMS clinical impressions, success rates, and subsequent treatments delivered via manual IO vs. the powered EZ-IO device. Investigators concluded that for the pediatric cohort use of the powered device offered a marginally higher first-attempt success rate compared to the manual device; and that the rate of IO access utilization by EMS more than tripled after adoption of the powered device.


This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.


This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.


This article describes a literature review study with the objective of establishing which intraosseous device is best for prehospital use. This short review searched Medline 1950-2010, CINAHL 1982-2010 and EMBASE 1980-2010 and identified two studies meeting their evidence search criteria, one study compared the BIG vs. manual; the second compared EZ-IO vs. FAST-1. The clinical bottom line asserted by the author was traditional manual IO devices have faster, better success rates in the pre-hospital setting; but that more randomized trials are needed to determine the best device.

Australia


This article describes a pre-hospital clinical study comparing IO first-attempt success between humeral and tibial sites. Of 88 cardiac arrest patients analyzed, 58 and 30 IO access attempts were made in the tibia and humerus, respectively. Of those, there was a 90% first attempt success rate for the tibia, compared to 60% for the humerus. Of successful insertions, 6% of tibial insertions became displaced during transport, compared to 33% of humeral insertions. Investigators concluded that proximal tibial IO needle placement was associated with a significantly higher frequency of first-attempt success and lower incidence of needle dislodgements compared to humeral placements.


The objective of this study was to determine the frequency of first-attempt success of humeral IO, tibial IO, and peripheral IV (PIV) insertions during out-of-hospital cardiac arrest. Patients were randomized to receive one of the 3 methods. There were 182 patients enrolled, 64 were assigned to tibial IO, 51 to humeral IO and 67 to PIV. Of all patients 130 (71%) were successful on first attempt with 17 (9%) needles dislodged. First attempt success within the treatment groups was 91% for tibial IO, 51% for humeral IO, and 43% for PIV.
**Intraosseous Vascular Access Bibliography**

**Arrow® EZ-IO®**


This article describes a case in which systemic fibrinolysis was administered through the intraosseous route in a patient with ST-segment elevation myocardial infarction. Fibrinolytics and antiarrhythmic drugs were administered though the IO line, resulting in resolution of coronary ischemia and electrical instability, without complications. Authors concluded that intraosseous cannulation represents a novel route for administration of systemic fibrinolysis in cases of difficult peripheral venous access in the out-of-hospital setting.


This study conducted in Germany and Switzerland evaluated use of the EZ-IO in the prehospital setting over a 24 month period. The decision to use IO access was left to the discretion of the onsite clinician, a paramedic or an emergency physician. Results showed IO access was attempted in 77 patients, and was successful on first attempt in 75 patients. Significant pain with infusion was reported in the majority of responsive patients.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.


This article discusses how a group of obstetricians and anesthesiologists prepared for what they expected to be a difficult delivery with limited venous access. The EZ-IO was brought into the delivery suite as a back-up option if they were unable to achieve venous access in an emergency situation. The authors did note their concern with the pain associated with IO infusion. Ultimately, the IO device was not needed for the delivery in question, but it has been added to their resuscitation kit within the delivery suites.


This article describes IO access in terms of efficacy, indications/contraindications for use, and the IO procedure and comparison of devices to make a case for IO use in oral and maxillofacial surgical practice. In discussing IO devices citing published data, the author identified the EZ-IO device as the most accurate, efficacious, and precise system when trying to achieve IO access.


This article in German concludes that the introduction of IO in pre-hospital pediatric emergency system has markedly reduced the number of critically ill or severely injured pediatric patients without vascular access or with less reliable alternative administration routes in the last 20 years.

**Taylor CC.** Amputation and intraosseous access in infants. BMJ 2011;342:d2778. doi:10.1136/bmj.d2778

This article describes two cases of leg amputation after intraosseous infusion in a 5-month-old girl and a 17-month-old boy. The author concluded that fluid extravasation, exacerbated by tibial fracture and needle dislodgement during transportation, caused limb ischemia in these two patients, and that adherence to the principles of careful needle placement, splinting/securing the catheter and limb, limited length of infusion and repeated monitoring of the limb will help avoid this devastating complication.


This article in Danish discusses use of the IO route for second line vascular access when peripheral IV access is difficult or impossible.

**Waltzman ML.** Amputation and intraosseous access in infants-Intraosseous access: It’s the operator and not the device. BMJ 2011; http://www.bmj.com/rapid-response/2011/11/03/intraossesous-access-its-operator-and-not-device

This article is a response to the Taylor and Clarke 2011 report of two amputations required following development of compartment syndrome after IO infusion. The author notes that complications are possible with all methods of establishing IO access including manual, spring loaded and power driven needles and that it is not accurate to directly relate the adverse events to the power driven device only.
Intraosseous Vascular Access Bibliography

**Year: 2010**


This abstract, which was presented at the 2010 ACEP Research Forum, describes a study conducted by investigators from the Medical College of Georgia to determine the frequency of intraosseous vascular access use in adult emergency patients. They surveyed academic emergency departments across the country and, at their own facility, compared ease and speed of standard emergency vascular access methods—including intraosseous. They concluded that IO access is underutilized and generally not the second-line choice of vascular access in unstable adult patients in academic institutions. Their simulation showed IO placement was considerably faster than both central lines and ultrasound guided peripheral IV. They opined that IO should be considered more frequently in critical unstable adult emergency department patients.


This veterinary study evaluated 3 IO access devices, impact driven, automatic rotary, and manual, to compare the placement feasibility and amount of bone trauma induced when used in adult feline cadavers. Seventy-two IO insertion locations were used, the 3 devices were equally randomized to the insertion site. The rotary device was found to have shorter time to insertion and better ease of insertion. No statistically significant differences between number of bone fragments, defect diameter, or success rate were found between devices.


This article, written in German, gives an overview of intraosseous access in pediatric patients especially with regard to particularly difficult vascular access in the areas of pediatric anesthesia and perioperative care. The article also gives an overview of various devices available to gain IO access, including the Cook needle and the EZ-IO device.


This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.


This article discusses training methodology and applies the concept to the implementation of the EZ-IO in the Montgomery County Hospital District EMS, a participant in the EZ-IO beta test.


An article evaluating various methods of obtaining vascular access in the management of 21st century battlefield trauma including, peripheral IV access, intraosseous access, venous cut-down, and central venous access. The authors conclude that IO access should be the first line vascular access in casualties with severe trauma to avoid delay initiating resuscitation in pre-hospital or hospital setting.

**Kellner P, Eggers M, Rachut B.** [Der Einsatz des intraossaren zugangs im praklinischen notarztdienst: Diskrepanzzwischen leitlinien-empfehlungen und realitat!] *Notfall Rettungsmedizin* 2010; doi:10.1007/s10049-010-1381-0. German

This article in German describes the results of a survey of rescue assistants and physicians, in which they found that IO use was still a rarity in the Berlin emergency medical service and, therefore, presumably nationwide.

**Kovar J, Gillum L.** Alternate route: the humerus bone - a viable option for IO access. *JEMS* 2010;35(8):52-59

Authors describe an early observational study (N=120) comparing intraosseous access in the humerus and the tibia, using the EZ-IO. Investigators concluded that the humerus is an acceptable IO site, which may be preferable under certain clinical conditions. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In an abstract presented at the 2010 ACEP Research Forum, investigators describe a swine study designed to compare IO infusion rates using the Belmont FMS 2000 rapid infusion device and a pressure bag through the proximal tibia and proximal humerus. Investigators concluded that infusion rates were highest using the pressure bag via the proximal humerus.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®


Training study with nurses and physicians comparing EZ-IO to IV lines under Hazmat conditions. IO procedure significantly shorter.


Authors describe a randomized, controlled trial comparing two different IO access devices in adults in the hospital setting. Twenty patients received the BIG and 20 received the EZ-IO. Success rate on first attempt was 80% for the BIG and 90% for the EZ-IO. Mean procedure time was 2.2 minutes for the BIG vs. 1.8 minutes for the EZ-IO. Differences in success rate and procedure time were not statistically significant, and there were no significant complications for any patients. Investigators concluded that IO access is a reliable and safe method for rapid vascular access for in-hospital adult patients under resuscitation.


This abstract describes a follow-up swine study to an earlier study done using concentrated doses of Adriamycin over 72 days in which bone complications occurred. Investigators studied different drug administration regimens that might be used to prevent complications. After the study was completed authors concluded that IO delivery of lower dose and diluted concentrations of Adriamycin was determined to be safer and resulted in less tissue abnormality when compared with higher dose/higher concentration; and use of the IO route with rotation of sites may be a feasible option for Adriamycin or other vesicant delivery.


This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.


In this study, using a swine model, investigators concluded that mild therapeutic hypothermia can be effectively induced after successful resuscitation of prolonged ventricular fibrillation through infusion of chilled saline via the IO catheter.


This abstract, presented at the 2010 ACEP Research Forum, describes study designed to determine the relative precision of intraosseous needle placement using only tactile feedback. The study also assessed the ability to access simulated osteoporotic bone without damage using the 3 methods. Investigators concluded that, using tactile feedback only, rotary power may allow precise IO catheter placement with greater success and confidence than manual or hammer-assisted devices. Powered insertion may facilitate penetration into fragile bone without damage. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract, presented at the 2010 ACEP Research Forum, describes a study designed to determine infusion flow rates through the proximal humerus and proximal tibia. Researchers found that, at all infusion pressure levels, the humerus provided substantially greater flow rates than the tibia. They concluded that, for most situations, adequate IO infusion rates can be achieved using the tibial site, but the proximal humerus site should be strongly considered when greater infusion flow rates are required. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2010 ACEP Research Forum describes a study designed to compare Lidocaine's effect on pain during fluid infusion through the tibial and humeral IO routes. Investigators concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Authors describe a 10 subject volunteer study that compared intraosseous (IO) blood samples to venous blood samples for complete blood count (CBC) and chemistry profile testing. They concluded that IO blood may serve as a reliable alternate for hemoglobin and hematocrit levels, as well as for most analytes in a basic blood chemistry profile. Exceptions are CO₂ levels, platelets, and WBC. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In this abstract of a study presented at the 2010 National Association of EMS Physicians Meeting, researchers describe a study in which sternal and tibial IO devices were evaluated with and without chemical protective equipment. Researchers concluded that the use of the protective equipment did not affect the success rate or time to placement for the two IO devices.


This article describes an online questionnaire study in which the Heads of Department of 20 EDs in Denmark were asked about IO infusion within their institution. Nineteen responses were received; 14 hospitals (74%) reported having IO devices available with the median number of IO procedures performed as 5. In 9 departments training had not been provided and 8 departments didn’t have IO guidelines. The favored device was the EZ-IO found in 18 of the EDs, 2 had EZ-IO and Cook Surfast and 1 had the BIG.


Authors report an observational study of 14 children in whom semi-elective IO infusion was performed under anesthesia after peripheral IV had failed. IO infusion was successful for all 14 patients, using the EZ-IO system for 8 patients and the Cook system for 6 patients.


This paper describes experiences with the EZ-IO device in Japan in 24 adult patients during CPR. The device is not sold in Japan. Article in Japanese

Philbeck TE, Miller LJ, Montez D, Puga T. Hurts so good; easing IO pain and pressure. JEMS 2010;35(9):58-69

This article describes two studies designed to compare Lidocaine’s effect on pain during fluid infusion through the tibial and humeral IO routes and to determine infusion flow rates. Authors concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract describes an animal study, presented at the 2010 ACEP Research Forum, that examined shear and pressure changes within the medullary space during intraosseous infusion. Results suggest that resistance to flow depends of cannula placement site, IO pressure rises rapidly with infusion rates, and medullary compression and axial shear are present at high infusion rates.


This article describes a longitudinal study of intraosseous vascular access in pre-hospital emergency medicine handled by helicopter emergency medical services. Of the 78 IO insertion attempts made on 70 patients, overall success rates were 50% using manual needles, 55% using the Bone Injection Gun, and 96% using the EZ-IO. Investigators concluded that newer IO techniques may enable faster and more reliable vascular access; and that all emergency services should be familiar with IO techniques.


The authors describe literature that support the use of IO access for administering anesthesia in the ICU, perioperative and operating room, including a study in which IO access was used successfully for providing intraoperative anesthesia for 106 of 109 patients. Among their conclusions, the authors reported that, even though rarely reported in anesthesia literature, IO access is a technique anyone providing care to children should consider when the patient has difficult IV access. They also concluded that IO access should be a part of an algorithm that includes numbers of attempts at peripheral access, feasibility of central access and the need for continued postoperative access; and that considering that IO access may be occasionally used in the perioperative setting in both emergent and nonemergent scenarios, it may be beneficial to have appropriate IO needles in the OR.
This abstract describes a study in which 60 physicians, nurses, and paramedics naïve to IO vascular access were trained on the Arrow EZ-IO system. After lecture and hands-on training, the clinicians attempted to perform the procedure using a bone model and evaluated the device for ease of insertion, number of attempts, time to insertion, and their opinion on the device. The authors concluded use of the EZ-IO system can result in high success rates of insertion with inexperienced device users.

Vegunta RK. Chapter 8-Vascular access. Ashcraft’s Pediatric Surgery 2010;5th ed:110-6
This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.

This article provides an overview of IO anatomy and physiology, IO access indications, care, and management; describes therapies administered via IO access; and discusses the expanding use of IO access into areas within hospitals during nonemergency clinical situations. It also includes a table addressing indications for IO access in the hospital, as well as a table addressing the general insertion procedure for IO access.

This retrospective study evaluated humeral IO placement success rates, using the EZ-IO, in the out of hospital cardiac arrest patient. Over a 9 month period, humeral placement was attempted in 247 patients. First attempt successful placement was 91%; successful placement within two attempts was 94%. The authors concluded that humeral IO is a reliable method of fluid and drug delivery in the out of hospital cardiac arrest population. This research was sponsored by Viascare Corporation, acquired by Teleflex Incorporated.

YEAR: 2009

This study was designed to evaluate the effect of education on knowledge, attitudes and skill performance of IO access by Level 1 EMTs in Korea. After a two-hour program, the knowledge and attitude of IO access improved significantly.

In a preclinical study using a caprine model, researchers assessed the hemodynamics of hydroxocobalamin (OHCo) compared to normal saline (NS) by the intraosseous (IO) route and concluded that the effects of OHCo given by the IO route in non-CN-poisoned goats are mild and well tolerated. Investigators concluded that IO administration of OHCo may “find a role in the settings of individual patients with cyanide-induced cardiovascular collapse or mass cyanide casualties”.

This letter to the editor discussed the experience of one ground emergency rescue service in Germany and their trial implementation of the EZ-IO, as compared to the David et al evaluation of the BIG by emergency physicians in which the rate of failure was 55%. Over a one year evaluation of the EZ-IO in the field, it was used in 20 patients, of which 19 were successfully placed (95%). The success of the field evaluation and a human cadaver study resulted in the addition of the EZ-IO to the receiving University Hospital emergency department.

Burgert JM. Intraosseous infusion of blood products and epinephrine in an adult patient in hemorrhagic shock. AANA J 2009; 77:359-63
Case report of IO infusion in 79-year old woman with hematemesis after intestinal surgery.

This article provides a general overview of intraosseous access and its use in emergency situations. A description of available IO access devices is provided.
Intraosseous Vascular Access Bibliography

Prospective study of 246 EMS providers at 14 EMS agencies. Reports successful IO placement in 95% of cases (18 of 19).

This article describes a study conducted at an urban Level I trauma center in Munich, Germany. Ten consecutive patients for whom PIV was difficult or impossible were simultaneously given a central line and an EZ-IO. Procedure times were measured and defined as the time the device package was taken off the shelf until the first drug or solution was administered. First attempt success rate was 90% for EZ-IO and 60% for CVC. The mean procedure times were 2.3 minutes for EZ-IO and 9.9 minutes for CVC, a clinically and statistically significant difference. Investigators concluded, because CVC was slower and less efficacious, IO may improve the safety of patients requiring resuscitation in the ED.

This article describes a cadaver study to determine skill acquisition and performance by use of the EZ-IO system by novices. Overall success rate for the 99 operators was 97%, and mean insertion time was 6 seconds. All operators rated the device faster and easier than using a central line, and 99% expressed willingness to use the device for cardiac arrest patients.

This article describes IO use in general, and the EZ-IO in particular. The author describes its use by the emergency staff at her hospital and how they became advocates for IO access in both emergent adult and pediatric patients. She found that its use improves the quality of our care by providing vascular access to our most critical patients.

This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study designed to determine the feasibility of inducing therapeutic hypothermia (TH) after resuscitation by giving an IO infusion of iced saline. Researchers concluded that rapid, large volume IO infusion of iced saline is as effective for lowering core body temperature after resuscitation as central access and peripheral IV. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract describes a retrospective study to determine the time from EMS dispatch to IV or IO drug delivery, time savings to drug delivery if vascular access preceded intubation, the internal validity of that point estimate using matched cases in which IV/IO was performed first, and the theoretical increase in rate of return to spontaneous circulation. Investigators concluded that time from dispatch to IV/IO delivery could be reduced by 4 minutes if vascular access preceded intubation and could, potentially double ROSC.

This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study that evaluated crystalloid fluid flow through an IO needle following nitroglycerin infusion in a swine model. Investigators concluded there was not a significant increase in flow rate after administration of IO nitroglycerin.

This abstract for a presentation at the 2009 ACEP Research Forum describes a volunteer study that examined the relationships between IO and venous blood samples when analyzed for complete blood count and chemistry profile. Researchers concluded that the IO space is a reliable source for blood used for CBC and chemistry profile. Results may be moderately reliable for carbon dioxide, but unreliable for WBC counts that appear to be elevated and platelet counts that appear lower. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

Miller Ll, Philbeck TE, Montez DF, Spadaccini CJ. A new study of intraosseous blood for laboratory analysis. Arch Pathol Lab Med 2009;133:1628

This abstract for a presentation at the College of American Pathology 2009 meeting describes a volunteer study that examined the relationships between IO and venous blood samples when analyzed for complete blood count and chemistry profile. Researchers concluded that the IO space is a reliable source for blood used for CBC and chemistry profile. Results may be moderately reliable for carbon dioxide, but unreliable for WBC counts that appear to be elevated and platelet counts that appear lower.


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants.


This article describes a case in which IO access, using the EZ-IO, was attempted in a patient with osteogenesis imperfecta. In each of 3 attempts, the needle became loose immediately after IO insertion. The author acknowledged that during emergencies it is difficult to assess and consider every possible contraindication for every intervention; and that IO access using the EZ-IO is the author's choice for emergency vascular access when peripheral access is difficult or has failed.

Ong ME, Chan YH, Oh HH, Ngo AS. An observational prospective study comparing tibial and humeral intraosseous access using the EZ-IO. Am J Emerg Med 2009;27:8-15

Comparison of tibial and humeral IO use in 24 adults. Both sites suitable for IO infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants. (Note: This study was also described in an earlier article published in American Journal of Emergency Medicine) This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In this 1,596 patient case series, investigators studied the effects of serial standard of care changes in the EMS system over time. They concluded that IO access is an essential component for a proven algorithm for the management of OOH-CA.


This article describes the first clinical study that focuses on the proximal humerus as an IO site. It is also the first article describing a comparison between IO access and peripheral IV (PIV) and central venous catheters (CVC). They found that IO catheter placement was significantly faster than PIV or CVC placement, and concluded that IO access is life-saving when PIV or CVC is difficult or impossible. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract for a presentation at the 2009 ACEP Research Forum describes a volunteer study to determine the optimal Lidocaine dosing and sequencing for patients receiving fluids through the IO route and to determine if adequate fluid flow rates can be delivered through the proximal humerus IO site. Researchers concluded that for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed, followed by a rapid normal saline flush of 10ml. Additional dosing and flushing may be required. For humeral insertion, a longer IO needleset should be considered. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes an observational study performed by the French military air surgical team in Chad. There were 11 patients with no insertion failures. For 7 patients, the insertion site was the proximal tibia and for the remainder the site was the proximal humerus. The authors concluded that the EZ-IO is a device that is simple, reliable and which gives satisfaction for the administration of drugs.
This case study describes injuries sustained in Iraq by an American soldier, and the concurrent use of 4 IO devices to resuscitate and stabilize him.

This abstract describes a small study designed to determine if IO line placement improves outcome in adult patients with out-of-hospital cardiac arrest. This 165 patient study did not demonstrate improved survival.

Authors of this article describe a pilot study designed to compare the success rate for insertion and ease-of-use of the Bone Injection Gun (BIG) spring-loaded device and the EZ-IO battery-powered device on a turkey bone model. Investigators concluded that the EZ-IO demonstrated higher success rates than the BIG (28/29 vs. 19/29, p=0.016), and the EZ-IO was the preferred device.

This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.

This review article in German describes intraosseous vascular access, and includes descriptions of the Waismed Bone Injection Gun, Vidacare EZ-IO, Jamshidi and Cook Medical IO devices.

This letter to the editor describes the first case reported in the clinical literature in which therapeutic hypothermia was administered using the intraosseous route. The patient, a 2-year-old boy who was found submerged in a cesspool and had been asystolic for 5-10 minutes, survived without neurological complications.

Von Hoff DD, Kuhn JG, Burris HA, Miller LJ. *La perfusion intraosseuse est-elle equivalente a la perfusion intraveineuse?* *Urgence Pratique* 2009;36:36-40
This French version of an article previously published in American Journal of Emergency Medicine describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous using the Vidaport (a predecessor of the Vidacare EZ-IO) vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine for nearly all pharmacokinetic parameters, including maximum plasma concentration, time to maximum plasma concentration, and area under plasma concentration-time curve. There was a significant difference in the volume of distribution in the central compartment, which investigators attributed to a minor deposition effect near the IO port or in the bone marrow. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.

This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.

This swine study was designed to determine if intraosseous infusion is suitable to delivery recombinant human factor VIIa (rFVIIa) during hemorrhagic shock. Investigators concluded that administration of rFVIIa via IO infusion is a safe route for delivery and is likely to produce blood levels required to improve hemostasis during shock.

This article discusses the importance of proper technique, attention to detail, and serial monitoring of limb involved when using IO vascular access to avoid potential compartment syndrome and other complications. The author reports the case of a 2-year-old boy who suffered compartment syndrome of the lower limb following use of IO infusion for resuscitation. Early detection of and response to changes in the affected limb resulted in the patient’s successful recovery.


Animal (goat) study to determine if IO administration of hydroxocobalamin for antidotal treatment for exposure to cyanide and other poison agents would be faster and require less fine motor coordination and sensitivity; and would result in similar hemodynamic changes compared to IV administration. Using the EZ-IO device, researchers concluded that hemodynamic effects of hydroxocobalamin given by the IO route in non-poisoned goats are mild and similar in magnitude to those of saline control animals.


Animal (goat) study to determine the capacity and time required for protected hazardous materials responders and receivers to accomplish vascular access and hydroxocobalamin administration for antidotal treatment for exposure to cyanide and other poison agents. Using the EZ-IO device, researchers concluded that the time required for IO administration of the drug was shorter than intravenous administration; and that IO placement is readily accomplished wearing all levels of chemical protective garments and equipment.


Study comparing manual intraosseous insertion with EZ-IO using adult human cadavers as a model. No significant difference in insertion time between 39 manual insertions and 45 EZ-IO insertions. Found a difference in the success rate (manual, 79.5% vs. EZ-IO 97.8%, p<0.01). The EZ-IO had fewer complications (manual, 15.4% vs. EZ-IO 0.0%, p<0.01) and scored higher on user friendliness (school grading system: manual, 1.9±0.7 vs. EZ-IO 1.2±0.4, p<0.01).


Describes common drugs used in pediatric resuscitation and evidence supporting their use. Also describes routes of administration including intravenous, intraosseous, and intratracheal. Describes IO systems including Bone Injection Gun, FAST-1, and EZ-IO.


This article describes IO infusion devices - including Jamshidi, Cook, WaisMed, and Vidacare devices - and placement sites. It also addresses assessment and care of the infant receiving fluids and medications through the IO route.


Large retrospective study of patients for whom emergency vascular access was obtained using the Vidacare EZ-IO intraosseous system. Insertion success was 92% and within 10 seconds for 84% of the one-attempt successful cases. Complication rate was low (4.8%), none were serious, and extravasation was the most frequent (0.8%). The device was rated easy to use 72% of the time, and researchers concluded that the powered IO device is safe and effective for achieving vascular access in the resuscitation and stabilization of emergency patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Arrow® EZ-IO®

Article describing IO access.

Interim report for quasi-controlled prospective study of emergency department patients for whom emergency vascular access using the Vidacare EZ-IO intraosseous (IO) system (n=6) inserted in the proximal humerus was compared to access using central or peripheral intravenous (IV) lines (n=60). Researchers concluded that proximal humerus IO insertion is significantly faster than central or peripheral intravenous (IV) line insertion. Complications and pain profiles were similar for IO and IV techniques. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article describes an observational study in which two intraosseous devices were compared: the Pyng Medical F.A.S.T.1 and the Vidacare EZ-IO. For the 117 patients on which the F.A.S.T.1 was used, there was an 84% success; compared to a 97% success rate for the EZ-IO (n=71).

This article describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine sulfate for nearly all pharmacokinetic parameters. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.

This article describes thoracic trauma in the pediatric population. Includes a review of the assessment of pediatric patients. Circulation section of the article strongly recommends rapid intravascular volume expansion by the intraosseous route, and recommends the EZ-IO for "...quick and reliable vascular access during resuscitation ...".

YEAR: 2007

This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study in which the EZ-IO was used to provide emergency vascular access for 95 pediatric patients. Successful insertion and infusion was achieved in 94% of the patients, and insertion time was within 10 seconds for 81% of the placements. There were four minor and no serious complications.

This article reviews and assesses the literature on the use of IO drug administration during cardiopulmonary resuscitation. It addresses the risks and benefits of using IO in adults and children. The article describes the FDA-cleared devices available for use including the Pyng F.A.S.T.1, Waismed Bone Injection Gun and the Vidacare EZ-IO.

Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.

de Caen A. Venous access in the critically ill child. Pediatr Emerg Care 2007;23:422-4
This review article states the availability of intraosseous (IO) needles for pediatric patients, outlines the limitations of traditional venous access, and discusses the various IO devices currently available, including the Vidacare EZ-IO®.

11/19/2019
This article summarized the challenges and methods of providing vascular access for infants. It describes IO techniques and devices, including the Jamshidi, Cook, EZ-IO® and Bone Injection Gun (BIG) devices.

Article calls for EMS medical directors to consider and use the intraosseous route for adult patients requiring immediate vascular access. Provides evidence in support of position statement by the National Association of EMS Physicians on IO use.

Fowler RL. Prehospital intraosseous access: elemental to the field? JEMS 2007; doi:http://jems.com/print/9198
Discussion of the role intraosseous vascular access can play in the prehospital setting where vascular access is often difficult or impossible to establish. The EZ-IO is named as a new IO device along with descriptions of Jamshidi, Pyng Fast 1, and BIG needles.

This article describes authors’ evaluation of provider performance using two IO devices; the Pyng Medical F.A.S.T.1™ and the Vidacare EZ-IO®. Of 89 insertions with each device, success rate for 72% for the F.A.S.T.1 and 87% for the EZ-IO, a significant difference (p=0.009). The time to fluid insertion for the EZ-IO was also faster (p=0.02). Authors noted that the EZ-IO is unique and much more useful than the F.A.S.T.1.

Gagliardi P, Purrone G. [Il potere di salvare vite: l'infusione di liquidi e farmaci in emergenza con accesso venoso non reperibile]. N & A Mensile Italiano del Soccorso 2007; 177: 20-3. Italian
Article in Italian describing IO access and EZ-IO

This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study done at Boston Medical Center in which the Vidacare EZ-IO was used to provide emergency vascular access for 50 critically-ill adult patients. Successful insertion was achieved in 92% of the patients; with 90% success on the first attempt. There was one immediate complication—a dislodgement during transport. Investigators concluded that the device is a safe and feasible device for adult patients requiring out-of-hospital vascular care.

Hoskins SL, Zachariah BS, Copper N, Kramer GC. Comparison of intraosseous proximal humerus and sternal routes for drug delivery during CPR. Circulation 2007;116:II_993
Results from this, study which sought to compare drug delivery time using the proximal humerus IO route to delivery time using the sternal IO route, suggest that IO proximal humerus is comparable to IO sternal for prompt drug delivery during CPR.

Landes AH. Intra-osseous infusions: the current status. Care of the Critically Ill 2007; 23: 53-8
Overview of IO access. Includes historical aspects, current status, indications for use, advantages and disadvantages, IO kinetics, insertion sites, complications and contraindications and description of available IO devices, including EZ-IO®.

In this study, presented at the NAEMSP 2007 annual meeting, authors compared the success rate of conventional IO access with the EZ-IO during 245 cases in the prehospital setting. They concluded that using EZ-IO® results in a statistically significant increase in IO success rate, compared to conventional IO methods.
Abstract
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

Myers BJ, Lewis R. Induced cooling by EMS (ICE): year one in Raleigh/Wake County. JEMS 2007;32:s13-5
This article describes the experience of the Wake County (NC) EMS System in inducing hypothermia for patients with return of spontaneous circulation after cardiac arrest. Authors describe their use of the Vidacare EZ-IO (now Arrow® EZ-IO Intraosseous Vascular Access System) for the administration of chilled saline. In this report 56% of vascular access cooling was done utilizing the IO device and an additional 18 % utilized a combination of IO and IV induced cooling. The overall EZ-IO use in this program for all insertions were 414 with an insertion success rate of 94%.

Potyka JS, Gordon DJ. Stories behind the numbers: IO experiences in providers’ own words. JEMS 2007;32:s30-1
Qualitative study focuses on EMS caregivers’ experiences with Vidacare’s EZ-IO device and personal opinions. The study used a narrative approach to gain insight from EMS practitioners working with an IO access device under real field conditions.

Pye D. NY Paramedics get the EZ-IO. JEMS 2007; doi: http://www.jems.com/print/5184
This article in JEMS discusses an EMS system in New York following their adoption of the EZ-IO, and the advantages.

Article in Dutch describing IO access and EZ-IO.

The article describes a prospective observational study conducted by several EMS agencies in Portland, OR to determine the safety, efficacy and benefits of using the Vidacare EZ-IO in the prehospital environment. The IO device was successfully placed in 95% of the 280 cases. In 98% of the cases, placement was made within six seconds.

Study investigating time difference in obtaining IO vs. IV access while wearing personal protective equipment (PPE) in simulated HazMat scenarios. With provider in PPE and mannequin not in PPE, vascular access was faster with IO (14 seconds vs. 46 seconds; p<0.001); also, fluid infusion time (28 seconds vs. 46 seconds; p<0.001). With provider and mannequin in PPE, all the following favored IO: needle to skin time (13 seconds vs. 25 seconds, p<0.001), vascular access time (17 seconds vs. 63 seconds; p<0.001), and fluid infusion time (30 seconds vs. 66 seconds; p<0.001). Investigators conclude that EZ-IO under HazMat conditions provides vascular access and fluid more quickly than IV access.

Wayne MA. Intraosseous vascular access: devices, sites and rationale for IO use. JEMS 2007;32:s23-5
This article reviews intraosseous vascular access in general, and summarizes the various devices available. These include the Waismid B.I.G., the Vidacare EZ-IO, and Pyng F.A.S.T.1.

This article in German (with abstract in English) describes IO infusion in detail. It includes techniques, indications, complications, and recommendations. Also describes the various devices available, including Cook, Bone Injection Gun (BIG), First Access for Shock and Trauma (F.A.S.T.1), and the EZ-IO®.
Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

YEAR: 2006

In this study, presented at the NAEMSP 2006 annual meeting, investigators reported the results of a study that evaluated the performance of the EZ-IO® compared to an earlier evaluation of the Pyng F.A.S.T.1 system. There was a statistically significant higher success rate using the EZ-IO® compared to Pyng system, and investigators concluded that the EZ-IO® appears to be a superior device with regard to insertion success.

Prospective observational study evaluating EMT-B ability to provide care in out-of-hospital cardiac arrests. Found that EMT-Bs were able to place the EZ-IO with a 94% success rate. Median time to placement was 72 seconds.

Hoskins SL, Kramer GC, Stephens CT, Zachariah BS. Abstract 79: Efficacy of epinephrine delivery via the intraosseous humeral head route during CPR. Circulation 2006;114:I_1204
Results from this study which sought to determine the efficacy of intraosseous drug delivery using the proximal humerus during CPR in swine showed that the humeral route generated higher mean arterial pressures than central venous or endotracheal delivery.

Article in French describes IO access and IO devices, including B.I.G., F.A.S.T.1 and EZ-IO®.

YEAR: 2005

Observational study evaluating use of the EZ-IO®. Found 97% success rate for insertion and infusion into the IO space by paramedics, nurses, physicians and other EMS personnel in using the device for emergency vascular access. No serious complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Article describes intraosseous access for adults and pediatrics. Describes and discusses IO devices available including Jamshidi, Bone Injection Gun, F.A.S.T.1, and EZ-IO®.

Gillum L, Kovar J. Powered intraosseous access in the prehospital setting: MCHD EMS puts the EZ-IO to the test. JEMS 2005;30(10):s24-6
Observational study of initial use of the EZ-IO® in 125 patients by EMS providers. Found 94% success rate for insertion and infusion into the IO space. No complications reported. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Heightman AJ. The rebirth of adult IO: a first-hand account of recent advances in intraosseous infusion for adults, drawn from a scientific workshop and practical lab experience. JEMS 2005;30(10):s4-7
Editorial article highlighting recent advances in intraosseous (IO) infusion and IO devices based on the author’s experience at a scientific seminar hosted by Vidacare. Makes recommendations on the efficiency and safety of the devices.

This animal study compared IO drug delivery in the tibia versus the sternum during CPR. Researchers concluded that during CPR IO infusions delivered via both sites were effective—although sternal delivery was faster; and that IO sternum access is comparable to IV access for drug delivery during CPR.

This study abstract discusses use of the EZ-IO to determine the pharmacokinetics (PK) and efficacy of tibial IO drug delivery during treatment of cardiac arrest in the swine model, as compared to IV access. Results showed that PK analysis of IO drug delivery via the tibial route showed a delay of 20-50 seconds compared to IV; however, physiologically significant levels of epinephrine were reached as MAP. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Animal study compared the sternal and tibial routes for IO drug delivery during CPR. Investigators concluded that both the sternal and tibial routes can effectively deliver near equivalent doses during CPR in swine. http://www.aemj.org/cgi/content/abstract/12/5_suppl_1/67

Miller LJ, Kramer GC, Bolleter S. Rescue access made easy: Intraosseous infusion, once limited to use in children, is now becoming a reliable access site for adults. JEMS 2005;30(10):Suppl 8-18

Overview of IO therapy. Includes 10 Myths about Adult IO and description of available IO devices, including the EZ-IO®.

YEAR: 1922


Seminal article on blood circulation in the IO space. Demonstrates movement of red blood cells from the bone marrow into the circulating blood by perfusion of the tibia of the dog and by injections into the bone marrow in the rabbit and cat.
Intraosseous Vascular Access Bibliography

Guidelines

YEAR: 2018


These guidelines are a Japanese-specific set of guidelines for sepsis and septic shock created by the Japanese Society of Intensive Care Medicine and the Japanese Association for Acute Medicine. The IO route for administration of fluid resuscitation and circulatory inotropes when treating septic shock in pediatric patients is discussed. The authors conclude there is insufficient evidence to make a recommendation for this use.

YEAR: 2017


This paper is a consensus statement seeking to provide clear guidance for the management of pregnant trauma patients in the pre-hospital setting in the UK. IO access is recommended as an alternative to gain vascular access in pregnant trauma patients when IV access cannot be easily or quickly established. If possible, it is recommended that IO access be placed in the right humeral head in order to facilitate left tilt/left lateral positioning of the pregnant patient.


This study addresses the need for the development of a reliable and validated tool to evaluate technical resuscitation skills in a pediatric simulation setting. The authors created four resuscitation and emergency simulation checklist and evaluation tools were created, (RESCAPE). Study found that use of the RESCAPE tools are reliable and validated tools for evaluation of resuscitation skills in pediatric simulation-based educational programs.


These are guidelines for prolonged field care (PFC) intended to be used after Tactical Combat Casualty Care (TCCC) when evacuation to higher level of care is not immediately possible. The intent of these guidelines is to identify potential issues to consider when providing analgesia with or without sedation for an extended time period (4-72 hours). IO is listed as an optional route of administration.


Within the updated 2016 Surviving Sepsis Campaign Guidelines noted that intraosseous (IO) access can be "quickly and reliably established" which will make following the guidelines for fluid therapy and early antibiotics an easier task.


The CoTCCC handbook was created as a guide to best practices created by the Committee on Tactical Combat Casualty Care (CoTCCC) which includes representatives from all the U.S. Armed Services that are part of the Tactical Combat Casualty Care (TCCC) Working Group. The recommendations are based on input from the battlefield as well as evidence in the civilian literature, examined and put together to provide guidelines for care. The recommendations and required skill sets include IO access as an alternative to IV access in multiple sections. The TCCC- Medical provider skill set specifically includes the ability to demonstrate the use of IV/IO blood product administration (medical officers and operating room special operations medics) and the use of IV/IO tranexamic acid (TXA).

YEAR: 2016


This consensus document was created by a working group of the Association of Anaesthetists of Great Britain and Ireland and based upon an up to date review of the literature, practice and expert opinion. The recommendations focus on safety in relation to insertion, care and removal of vascular access devices. IO access is recommended as useful for emergencies in cases of difficult vascular access; and clinicians providing acute care should have IO devices accessible and be trained in IO access techniques.


This 2016 publication by the Royal College of Nursing (RCN) was intended to support clinical practice for adult patients undergoing infusion therapies, including intraosseous (IO) access. The chapters begin with a general statement followed by the "standard" set by RCN and then guidelines relating to that intervention. The section on IO access states IO access "should be obtained for emergency or short-term treatment when access by the vascular route is difficult" and the "patient's condition is considered life-threatening".
This section of the 2016 National Institute for Health and Care Excellence (NICE) guidelines addressed assessment and initial management of trauma patients. In the prehospital setting for major trauma, intraosseous (IO) access is recommended if intravenous access fails; and should be considered for first line access in patients ≤ 16 years old. In the hospital setting, if peripheral intravenous access fails, consider IO access while central venous access is being achieved.

YEAR: 2015


This publication was created for providers and instructors to summarize the key issues and changes affecting practice in the 2015 American Heart Association (AHA) Guidelines Update for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC). No changes specific to intraosseous access were mentioned. Intranasal administration of naloxone for overdose management was added as a reasonable intervention.


The 2015 updated ACLS guidelines considered a number of issues regarding cardiovascular life support; however there were no changes to those recommendations made in the 2010 guidelines in regard to intraosseous access. The 2010 guidelines stated in regard to IO drug delivery, "it is reasonable for providers to establish IO access if IV access is not readily available (Class IIa, LOE C)."


This article summarizes the main updates to the 2015 ERC Guidelines for Resuscitation of adults and pediatric patients. In reference to intraosseous (IO) vascular access, the guidelines state: IO access is a “rapid, safe, and effective route to give drugs, fluids and blood products”; and recommend consideration of the IO route when peripheral venous access is difficult.


This review article describes various protocols for haemorrhage control, specifying routes of access, including intraosseous vascular access infusion rates and volumes of various transfusion fluids.


This publication was created for providers and instructors to summarize the key issues and changes affecting practice in the 2015 American Heart Association (AHA) Guidelines Update for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC). No changes specific to intraosseous access were mentioned. Intranasal administration of naloxone for overdose management was added as a reasonable intervention.

YEAR: 2014

Cheung WJ, Rosenberg H, Vaillancourt C. Barriers and facilitators to intraosseous access in adult resuscitations when peripheral intravenous access is not achievable. Acad Emerg Med 2014;21:250-6. doi:10.111/acem.12329

This survey study sought to identify the barriers and facilitators to use of intraosseous vascular access for adult resuscitations when peripheral IV (PIV) access is not available, among physicians from various clinical care settings in 3 teaching hospitals in Ottawa, Ontario. Completed survey responses were received from 205 physicians; results suggest that to increase IO use educational interventions need to address their attitudinal, normative, and control beliefs. Specific beliefs that act as barriers are described.

Canada


This article identifies new concepts and changes in neonatal resuscitation discussed at the Egyptian Pediatric Association national conference. Intraosseous vascular access is included stating, "temporary intraosseous access to provide fluids and medication to resuscitate critically ill neonates may be indicated following unsuccessful attempts to establish intravenous vascular access or when caregivers are more skilled at securing intraosseous access.”

Egypt
Intraosseous Vascular Access Bibliography

Guidelines

This discussion of pediatric sepsis focuses on the "global setting" making note of inherent differences in policies, diagnostics, causes and management approach between regions. A review of basic assessment, treatment, follow-up and prevention strategies applicable regardless of resources is offered. Goal directed therapy within the first 5 minutes includes establishment of IV/IO access.

This retrospective study reports IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.

Neuhaus D. Intraosseous Infusion in elective and emergency pediatric anesthesia: when should we use it? Curr Opin Anaesth 2014;27(3):282-7. DOI: 10.1097/ACO.0000000000000069
General review of IO access, with particular attention to perioperative setting and includes published guidelines of the German Scientific Working Group for Pediatric Anesthesia for use of intraosseous access. The author recommends that for children with known difficult venous access physicians discuss the possibility of IO access preoperatively with the family.

This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.

This letter to the editor describes a cadaver study performed by 50 interns who had never performed IO insertion, to determine if there is a learning curve associated with use of the EZ-IO for establishing IO vascular access in the proximal tibia. Following training each intern performed 10 IO insertions and were timed. The results showed a difference between the first and the eighth attempts resulting in a decrease in time to insertion by half. The authors concluded that practice insertions are necessary to become comfortable with the device.

This article explores use of IO vascular access in combat and tactical settings through a brief review of the literature describing this practice. A small feasibility study is discussed that evaluated the use of cadavers for training 26 U.S. Air Force Pararescuemen (PJs) on establishing IO access in the humeral head (proximal humerus is the descriptor used by EZ-IO for this site) using the EZ-IO powered driver and needle set system (pictured in the article) and needles inserted with a manual driver without power. First attempt placement success with the EZ-IO powered driver system was achieved in 25 of 26 attempts; first attempt placement success using the manual driver and needle set occurred in 19 of 21 attempts. The authors concluded that the humeral head (proximal humerus) IO site is the most appropriate site within the tactical setting; and that use of a human cadaver model for training is an appropriate model.

YEAR: 2013

Reprint article of policy statement originally published 2009, endorsed by multiple professional societies providing guidelines for care of children in the emergency department. A recommendation for IO equipment in adult and pediatric sizes is included.

Cleugh FM, Maconochie IK. Management of the multiply injured child. Paediatrics and Child Health 2013;23(5):194-9
General overview of care of a child with multiple trauma. IO vascular access is mentioned as a treatment option after 90 seconds or 3 failed PIV attempts. The B.I.G. is cited as an option along with the manual needles.
Intraosseous Vascular Access Bibliography

Guidelines


This article presents an overview of IO access focused on nurses’ use of the technique. A list of available devices, history and support for use and possible complications are included.


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.

**Lyon RM, Donald M. Intraosseous access in the prehospital setting-Ideal first-line option or best bailout? Resuscitation 2013;84:405-406. http://dx.doi.org/10.1016/j.resuscitation.2013.01.027**

Editorial reviewing a case series of EZ-IO use in the pre-hospital setting in Switzerland by Santos et al., combined with a literature review. The authors conclude IO access should probably be used selectively and training on its use improved, insertion sites should be compared and further investigation of use of the EZ-IO in major trauma patients, infusing blood components, use in infants, and application of training warrant further investigation.


This article in Spanish provides an overview of intraosseous vascular access. Article in Spanish


This abstract describes a study in which the investigators sought to determine the approximate patient population in which the 25mm EZ-IO needle set was sufficient length to establish IO access in peripartum patients. Ultrasound was used to determine the tissue depth at four insertion sites. Twenty-six women were recruited with a median gestation of 34 weeks. In 88% of patients with a BMI<40 kg/m² the 25mm needle is sufficient to reach the bone marrow at both tibial sites. For the humeral site, IO placement may be more difficult for patients with a BMI>25 kg/m².


This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.


An overview of pediatric emergency medicine and critical procedures. One of the key points noted: intraosseous vascular access can be used in all ages.


This article reviews the clinical effects of both high-quality chest compressions and the effects that interruptions during chest compressions have clinically on patient outcomes. The authors indicate intraosseous vascular access should be heavily considered as the first or at least second-line method used to help prevent prolonged compression interruptions for the purpose of establishing vascular access. The authors note that when using the EZ-IO this method of access is fast, effective, can handle all resuscitation fluids, and can minimize no flow time when used properly.

**YEAR: 2012**


Manuscript of a literature review and critical analysis done to develop the Emergency Nurse’s Association (ENA) December 2011 Emergency Nursing Resource (ENR) which focused on the clinical issue of difficult IV access. Graded recommendations and decision options are provided for alternatives to IV access, including IO.


PALS 2012 guidelines on pharmacotherapy and toxicological emergencies.
Intraosseous Vascular Access Bibliography
Guidelines


This article describes a questionnaire study in which members of selected Scandinavian medical societies were surveyed to identify reasons for not using IO access during resuscitation when IV access is difficult. There were 759 evaluable responses from doctors, nurses, and ambulance staff. Of the respondents, 178 (23.5%) had experienced at least one situation where there was an indication for IO but it was not attempted. The most common reason for not using IO was unavailability of equipment (n=86) and lack of training. The author concluded that increased training in IO use and greater availability of IO equipment for front-line staff should be implemented.

*Ibrahim M, Cairney K. Intraosseous (IO) infusion as a means of vascular access. Br J Resuscitation 2012;Autumn:23-6*

This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access.


An overview of pre-hospital trauma care. Endotracheal intubation, use of tourniquets, identification of shock, and clinical research in the pre-hospital setting are specifically addressed. Intraosseous vascular access is generally mentioned in relation to resuscitation.


This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.

*Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14*

The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access.


An overview of pre-hospital trauma care. Endotracheal intubation, use of tourniquets, identification of shock, and clinical research in the pre-hospital setting are specifically addressed. Intraosseous vascular access is generally mentioned in relation to resuscitation.


In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO


A critical care literature review article that addressed cardiac arrest, trauma, ultrasound, pediatrics, and boarding. Intraosseous vascular access is noted as a method for obtaining vascular access.

**YEAR: 2011**


Case study of a 42 year-old woman with massive obstetric hemorrhage ultimately resulting in postpartum hysterectomy. Massive blood loss and inability to stop bleed prevented sufficient resuscitation via established PIV lines. IO access was established with the EZ-IO and used for fluid replacement and administration of cardiac resuscitation drugs. Fluid administered through IO access was 75% of the total infusion volume.

German Society of Anaesthesiology and Intensivmedizin eV (DGAI), includes a general discussion of intraosseous (IO) as vascular access, overview of devices and recommendations for pediatric anesthesia with indications for intraosseous infusion in pediatric anesthesia and perioperative care in children. Early or primary IO indications are respiratory and circulatory arrest; critical hemodynamic instability before or during anesthesia introduction; severe laryngospasm; anesthesia induction in respiratory bleeding. Urgent indications (decision based on each case is necessary) include urgent induction of anesthesia in non-fasted children (ileus, RSI); induction of anesthesia in children with unstable circulation or severe cardiac insufficiency. Semi-elective indications (decision based on each case is necessary) after mask induction of anesthesia (if vascular access required); mandatory induction of “intraosseous” anesthesia (as in malignant hyperthermia). This article is in German.


The Emergency Nurse’s Association (ENA) published a series of Emergency Nursing Resources with emphasis on clinical or practice based issues. This issue focused on difficult IV access and provides a summary of the literature review, with graded recommendations and decision options for practice for IO access, ultrasound guidance, subcutaneous rehydration therapy and several other alternatives. IO access is graded as having a high level of evidence supporting use of IO access when difficult IV access is known or suspected for high success rates and rapid time to insertion.

Friedman JN. Emergency management of the paediatric patient with generalized convulsive status epilepticus. Paediatr Child Health 2011;16(2):91-97

This Canadian Paediatric Society paper provides guidelines for the “emergency management of generalized convulsive status epilepticus (CSE) in children and infants older than one month of age”. Use of IO access is included for medication administration when IV access is not possible.


General overview of PALS updates. Various IO devices were specifically mentioned in the vascular access section, including the EZ-IO.


An online questionnaire was distributed to members of emergency medicine, pediatric and anesthesiology societies in Scandinavia regarding the amount of training they have received on IO vascular access and evaluate their level of confidence. A total of 322 responses were received and categorized as confident or not confident. The author concluded that confidence with IO increases with the number of learning modalities, and that hands-on experience as a single training modality seems as effective as having a combination of two non-hands-on modalities.


In this abstract the authors attempted to establish a relationship in obese patients (BMI >30) between BMI, ability to palpate the tibial tubercle, and tissue depth at the IO insertion sites. Results showed that in obese patients, IO placement with a 25mm catheter is feasible at the proximal and distal tibial sites if the tibial tubercle is palpable and that insertion into the proximal humerus in this population is not recommended.

Khan LAK, Anakwe RE, Murray A, Godwin Y. A severe complication following intraosseous infusion used during resuscitation of a child. Inj Extra 2011;doi:10.1016/j.injury.2011.05.015

This article describes the case of an 11-year-old boy who suffered compartment syndrome of the lower leg following use of the EZ-IO for resuscitation and 24 hours of intraosseous infusion of adrenaline, calcium and potassium. The author concluded that further work is needed to develop recommendations for maximum duration, dose, volume and rates for intraosseous infusion.


This study evaluated the use of telesimulation by Canadian pediatricians to teach a relatively new IO insertion technique (EZ-IO System) to physicians in Africa. Self-assessment questionnaires were completed before and after training, multiple-choice tests were given and a demonstration of competency was done within 3 training sessions. Twenty-two physicians participated; the sessions improved physicians’ knowledge, self-reported confidence, and comfort level in inserting the IO needle. The author concluded that telesimulation offers potential for teaching other procedural skills over distances.
Miller LJ, Philbeck TE, Puga TA, Montez DF, Escobar GP. A pre-clinical study to determine the time to bone sealing and healing following intraosseous vascular access. Ann Emerg Med 2011;58(4S):S240

The objectives of this study were to evaluate the amount of time necessary following IO insertion and infusion for the bone to heal such that a second IO catheter can be placed in the same bone without the risk of extravasation from the first hole; and to determine the length of time required to show radiological evidence of closure. Four anesthetized goats were used for the study. Twenty-four hours post insertion, extravasation was observed in 2 of 4 tibial sites with no extravasation in 4 humeral sites. Forty-eight hours post insertion, no extravasation was observed in tibial or humeral sites. Authors concluded that IO infusion should not be attempted in the same bone as a previous IO insertion within 48 hours of removal of the first IO catheter. Radiological examination showed evidence of bone healing as early as 8 days post IO placement. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.

Taylor CC. Amputation and intraosseous access in infants. BMJ 2011;342:d2778. doi:10.1136/bmj.d2778

This article describes two cases of leg amputation after intraosseous infusion in a 5-month-old girl and a 17-month-old boy. The author concluded that fluid extravasation, exacerbated by tibial fracture and needle dislodgement during transportation, caused limb ischemia in these two patients, and that adherence to the principles of careful needle placement, splinting/securing the catheter and limb, limited length of infusion and repeated monitoring of the limb will help avoid this devastating complication.

YEAR: 2010


This paper describes the process of establishing a nurse-led central venous catheter insertion service in a university affiliated hospital using a process evaluation method. Introduction discusses CVC adverse events rate and mortality.


This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.


This article discusses training methodology and applies the concept to the implementation of the EZ-IO in the Montgomery County Hospital District EMS; a participant in the EZ-IO beta test.


Part 14 of the 2010 PALS update supports IO vascular access as easy and quick to establish, useful for first line access in cardiac arrest and equivalent for many medications.


This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.


This abstract presented at the 2010 ACEP Research Forum describes a study designed to compare Lidocaine’s effect on pain during fluid infusion through the tibial and humeral IO routes. Authors concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography


The 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. IO access is discussed as a preferred route when IV access cannot be established. The guidelines however do address the lack of clinical information regarding IO drug delivery during CPR but affirm it is reasonable for providers to establish IO access if IV access is not readily available.


2010 updated guidelines for resuscitation by the European Resuscitation Council. This update notes IO access as the preferred mode of vascular access for drug administration, over endotracheal administration, when IV access is unavailable. IO blood is also noted as useful for typing and evaluating laboratory values.


This article discusses use of IO access within the hospital setting in the emergent and non-emergent patient populations. The history of IO access, clinical situations in which IO access may be considered, devices, contraindications, and complications are discussed. Additionally, pain management, economics, education and training and risk management are explored. This article is co-published in Journal of Infusion Nursing, the Journal of Pediatric Nursing, and Critical Care Nurse and was produced by the Consortium on Intraosseous Vascular Access in Healthcare Practice.


This article provides an overview of pediatric trauma care in the pre-hospital setting by using a literature review to evaluate the risks and benefits of various aspects of care. Topics discussed include: pre-hospital care time, pre-hospital triage and transport, airway management, intravenous (IV) and intraosseous (IO) vascular access and infusions, cervical spine immobilization, traumatic brain injury, and pain assessment and management.

Vegunta RK. Chapter 8-Vascular access. Ashcraft’s Pediatric Surgery 2010;5th ed:110-6

This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.


This article provides an overview of IO anatomy and physiology, IO access indications, care, and management; describes therapies administered via IO access; and discusses the expanding use of IO access into areas within hospitals during nonemergency clinical situations. It also includes a table addressing indications for IO access in the hospital, as well as a table addressing the general insertion procedure for IO access.


These are the WHO guidelines for the prevention and clinical management of snakebite in Africa. Intraosseous access is presented as an option for volume resuscitation in the event of circulatory failure or shock. Intraosseous injection of antivenom in children is acceptable when intravenous administration is not possible

YEAR: 2009

Barrett J. Adult Intraosseous infusion: “Good to the bone!” Response 2009;36(3):19-21

This article addresses adult IO infusion, primarily in the pre-hospital setting, with regard to the history of IO, anatomy and physiology, training considerations, clinical guidelines and contraindications, and financial considerations.


This is a continuing medical education (CME) document discussing pediatric advanced life support guidelines. It is geared toward pediatric emergency medicine physicians. IO is a preferred route of drug administration.


Instructional program on IO.
Intraosseous Vascular Access Bibliography

Guidelines

Guidelines for prehospital fluid resuscitation addressing when vascular access should be attempted and how; and if fluids should be administered, which should be given and at what rate.

Report from task force from Infusion Nurses Society advocating role for properly trained nurses in IO use.

YEAR: 2008

This article discusses the importance of proper technique, attention to detail, and serial monitoring of limb involved when using IO vascular access to avoid potential compartment syndrome and other complications. The author reports the case of a 2-year-old boy who suffered compartment syndrome of the lower limb following use of IO infusion for resuscitation. Early detection of and response to changes in the affected limb resulted in the patient’s successful recovery

Infusion Nurses Society’s guidelines and standards for using IO devices.

A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Three-year study of IO training and use in 28 hospital and ambulance services in Switzerland. Standardized training improved IO success rate to 100%. Abstract only

YEAR: 2007

Data from the largest combat trauma database was analyzed to identify how new or improved devices, dressings or drugs have impacted prehospital casualty care, how guidelines and resuscitation strategy have changed, and discusses lessons learned and how concepts have crossed back into the civilian practice. Intraosseous access, particularly the sternal site, is identified as one of the advances for vascular access in combat medicine.

Article calls for EMS medical directors to consider and use the intraosseous route for adult patients requiring immediate vascular access. Provides evidence in support of position statement by the National Association of EMS Physicians on IO use.

YEAR: 2006

King Edward Memorial/Princess Margaret Hospitals. Venous and arterial access and line management. King Edward Memorial/Princess Margaret Hospitals NCCU Clinical Guidelines Section: 5 2006;1-3
Includes section on “Insertion of Intraosseous Needles and Care.” Provides guidelines including Key Points, Equipment, Complications, Procedure, and Documentation.
Intraosseous Vascular Access Bibliography

Guidelines

La May G, Friese G. Pediatric fluid resuscitation and airway management - a primer on volume replacement in pediatric patients. EMS 2006;May:65-72
An overview of managing pediatric fluid resuscitation and airway management in the pre-hospital setting.

YEAR: 2005

AHA guidelines for cardiac arrest recommending IO as first line alternative to IV access in adult cardiac arrest patients. Affirms that IO is a safe and effective way to access the central vascular system. Maintains that IO access is similar to central line access and results in fewer complications.
http://circ.ahajournals.org/cgi/content/full/112/24_suppl/IV-58

This is a continuing medical education (CME) document that provides an overview of shock and discusses management of shock in the pediatric patient. It is geared toward pediatric emergency medicine physicians. IO is a supported route for obtaining vascular access.

YEAR: 2002

Dries DJ, Sample MA. Recent advances in emergency life support. Nurs Clin North Am 2002; 37:1-10
Review article for a nursing audience outlining recent changes in emergency life support in the most recent Advanced Cardiac Life Support (ACLS) guidelines from the American Heart Association with specific emphasis on new technologies for vascular access and emergency airway management.

YEAR: 2001


Cain BS, Shannon-Cain J. Vasopressin in advanced cardiac life support? Crit Care Med 2001; 29: 1649
Critical care article advocating use of vasopressin when standard or high dose epinephrine fails in a salvageable patient.

YEAR: 1996

Article in German

YEAR: 1992

Evaluation of the chain of survival from cardiac arrest using standard measurements of performance.

YEAR: 1988

Guidelines for IO in pediatric patients.
**Intraosseous Vascular Access Bibliography**

**Guidelines**

**YEAR: 1986**


Letter to the editor discussing guidelines for IO in Standards and Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiac Care, and in the chapter on Intravenous and Intra-arterial Techniques for the Pediatric Advanced Life Support (Pals) textbook being completed by the Working Group on Pediatric Resuscitation of the American Heart Association.


This preclinical study compared CBCs and routine blood chemistries drawn from IO and IV blood. The authors concluded that IO blood chemistries reflected venous blood chemistries and may be used if venous blood cannot be obtained; CBC cannot be reliably obtained from IO blood.

**YEAR: 1985**


Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.
Intraosseous Vascular Access Bibliography

Infusion Devices

YEAR: 2018

This article describes a prospective, comparative, nonrandomized study to compare flow rates using the sternal IO route with two different devices (EZ-IO and Fast1) when transfusing warm fresh whole blood as well as measuring post-infusion hemolysis when compared to IV infusion. Post procedure blood samples from all patients were within normal ranges with no statistically significant differences between groups. This study had a high catheter insertion failure rate in the IO groups. This was most likely due to subjects, healthy Norwegian military volunteers, performing the procedures on each other. The results suggest that infusion of fresh whole blood via the IO route is safe and reliable.

This paper provides a brief overview of the following IO needles and devices: the Dieckmann Modified Needle, the EZ-IO Manual Needle Set, the EZ-IO T.A.L.O.N Needle Set, the Jamshidi Needle, the Bone Injection Gun (BIG), the New Intraosseous Device (NIO), the FAST Responder Sternal Intraosseous Device, and the EZ-IO Intraosseous Vascular Access System.

This article investigates the success rate of IO access in preterm and term stillborns using two different needles (21G butterfly and 15G EZ-IO) inserted manually and one battery-powered semi-automatic drill (EZ-IO). All insertions were performed on the tibia. Estimated success rates were 61.1% for the butterfly needle, 43.0% for the hand twisted EZ-IO, and 39.7% for the EZ-IO drill. The authors conclude that IO access in premature and term neonates is best achieved by manual access with a twisted butterfly needle.

YEAR: 2017

This study reviews current IO administration of antidotes for patients that have presented to the emergency department with serious poisoning and IV access is not available. The study concluded that the evidence supporting the use of IO route for administering antidotes for poisoning patients is rare. Most evidence of IO access administration of antidotes has occurred in animal studies and case reports. Per author, despite lack of evidence, IO access is a potential option for antidotal treatments for resuscitation for patients where IV access is not available.

This retrospective cohort study evaluated emergency medical services (EMS) that treated adult patients with atraumatic out of hospital cardiac arrest (OHCA) in order to compare drug administration via intraosseous (IO) versus intravenous (IV) and the effectiveness. Study endpoints were survival to hospital discharge, return of spontaneous circulation (ROSC), and survival to hospital admission. The study included 1,800 patients, 1,525 of whom received IV access and 275 who received IO access. The practice for OHCA management in the EMS system from which the data was obtained was to attempt tibial IO access after failed IV attempts. The authors concluded that use of IO access was associated with a lower likelihood of ROSC and hospitalization; and acknowledged that further study of how vascular access routes affect OHCA patient outcomes is warranted.
Leutscher SA, Gerritse BM, van der Meer NJ, Schuitemaker FJ, Scohy TV. Need of intraosseous access in advanced life support in the in-hospital setting: Evaluation of difficult vascular access in cardiac arrest. Resuscitation 2017;112:e7
This letter to the editor states the usefulness of intraosseous access devices in out-of-hospital-cardiac-arrest (OHCA) settings.

YEAR: 2016

This study compared maximum concentration time (Cmax) to maximum concentration mean (Tmax) of mean serum concentration of vasopressin, return of spontaneous circulation (ROSC), time to ROSC, with odds of survival to vasopressin administration by tibial intraosseous, proximal humerus intraosseous (PHIO), and intravenous (IV) routes in a cardiac arrest model. Authors concluded TIO and PHIO provide rapid and reliable access in administration of life-saving medications during cardiac arrest and may be faster due to IV difficulty.

This study examined the differences of pharmacokinetics and pharmacodynamics of epinephrine via of tibial intraosseous access and IV access. Interruptions in CPR in order to obtain vascular access reduces the flow of blood to vital organs. Study results showed that TIO access may be a faster alternative to IV access for delivery of vasoactive medications.

This study was to determine if there were any significant differences between humerus intraosseous (PHIO), sternal intraosseous(SIO) and intravenous (IV) administration of Hextend on the hemodynamics or administration time in a hypovolemic swine model. Time of administration of the Hextend on effects on systolic and diastolic blood pressure, mean arterial pressure, heart rate, cardiac output and stroke volume. After administration of Hextend, data was collected every 2 minutes for 8 minutes total. Results found no significant difference in these measures among the PHIO, SIO or IV groups.

This journal article literature review was written to provide information about the history, clinical considerations, and devices associated with intraosseous access to administer resuscitative drugs when IV access can’t quickly or easily obtained.

This literature review examined the increase in use of intraosseous access for administration of resuscitative fluids and drugs to patients where intravenous access could not quickly or easily obtained during disasters and mass casualty events. The review also included a comparison of IO route to other routes for establishing vascular access in patients that have been involved in mass casualty or disasters.

In this letter to the editor authors discuss the importance of establishing access to circulatory system during CPR. The authors referenced the study "The effects of proximal and distal routes of intraosseous epinephrine administration on short-term resuscitative outcome measures in an adult swine model of ventricular fibrillation: a randomized controlled study" and the study "Intraosseous versus intravenous vascular access during out-of-hospital cardiac arrest: a randomized controlled trial". Authors concluded that intraosseous access seems reasonable for patients in cardiopulmonary arrest or severe shock that do not have available and quick IV access for administration of medications and fluids.

This veterinary care article describes vascular access methods and devices used for small animal emergencies, including intraosseous devices.

This randomized crossover manikin trial compared the NIO and EZ-IO devices for time to placement and ease of use. For both parameters the NIO performed better.

Poland
This letter to the editor describes a prospective, randomized, cross-over cadaveric study that evaluated use of the EZ-IO and NIO devices by novice paramedic device users. Following a brief in-service on use of both devices and practice insertions using a leg-trainer manikin, each participant attempted to establish IO access using each device in a resuscitation simulation with an adult cadaver with CPR in progress. Results showed first attempt success rates of 97.4% with the NIO and 100% with the EZ-IO; and mean time to insertion was 16.8 seconds with the NIO and 42 seconds with the EZ-IO.

YEAR: 2015


This article presents a 5-case series describing use of IO vascular access by anesthesiologists in the perioperative and critical care settings. All insertions were made in the proximal tibia and there were no adverse events reported. The devices cited as being used were the EZ-IO and the Cook Surfast manual needle. A proposed perioperative vascular access algorithm incorporating IO access is presented. The authors address key topics around IO access including use of same drug dosing as IV administered drugs, frequent palpation and monitoring of the insertion site for extravasation, low complication rate and actual risks associated with fat emboli and bone injury, pain and anxiety management in the awake patient and clinician-perceived pain. Administration of blood products, ACLS drugs, Lactated Ringer’s solution and anesthetics are noted without complication. Use of IO aspirate for laboratory testing is noted, however use of the initial aspirate is indicated. Several patients in the case series were reported to find the discomfort of IO insertion preferable to multiple intravenous attempts. The authors concluded: IO lines can be placed quickly and safely in emergency situations or in elective surgical patients with difficult intravenous access; IO access can be useful in a wide variety of clinical settings; and is an important skill for anesthesiologist to learn.


This document is a tutorial provided by the World Federation of Anaesthesiologists geared at understanding and establishing intraosseous access. It provides an overview of venous blood drainage from bones as well as indications, contraindications, common access sites, advice for establishing access, an overview of device types, insertion techniques, and complications.


A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.


A cadaveric study evaluating intraosseous (IO) vascular access insertion sites for attainable flow rates under 300 mmHg. The EZ-IO was used to establish IO access at the proximal humerus and proximal tibia sites; the FASTR was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 286 ± 218 mL for the humerus; and 154± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.

YEAR: 2014

Anson JA. Vascular access in resuscitation: Is there a role for the intraosseous route? Anesthesiology 2014;120(4):1015-31

Literature review through August 1, 2013 with primary aim to determine whether there is a role for intraosseous vascular access in the resuscitation of critically ill patients. Secondary aims were to investigate the evidence regarding clinical use, drug administration, and complications of IO access. The authors concluded that IO access can be achieved quickly and accurately in emergency situations and there is clearly a role for it in resuscitation of ill patients; anesthesiologists should become familiar with IO access.


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the E-BRIO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.
Intraosseous Vascular Access Bibliography

**Infusion Devices**


This article describes a case study of a 31-month old infant that suffered hypovolemic shock due to severe epistaxis. After several failed peripheral and central line attempts an 18g needle was inserted intraosseously through the proximal tibia. The child received 300 mL of Ringer’s Lactate in one hour then 200 mL of blood via the IO route by syringe boluses resulting in improvement. Cloxacillin was also administered IO as prophylaxis for infection. Authors conclude an IO blood transfusion should be the immediate intervention in similar life-threatening situations.

Zambia


This was a prospective, randomized controlled clinical pilot study comparing the BIG and EZ-IO intraosseous (IO) vascular access devices in 52 adult patients admitted to an emergency department with difficult peripheral venous access. Twenty-six patients were randomized to each device; results were first attempt insertion success BIG 92.3%, EZ-IO 84.6% (P=0.668); procedure time: BIG 2.8 ± 1.2 seconds, EZ-IO 5.2 ± 2.2 seconds (P<0.001), significant; difficulty of use (with visual analogue scale): BIG 6.6 ± 6.4 mm, EZ-IO 25.4 ± 12.6 mm (P<0.001), significant. Authors concluded both EZ-IO and BIG are shown to be reliable and safe methods for insertion of intravascular access in emergency conditions. There were no adverse events or complications reported.

Turkey

Derikx HJGM, Gerritse BM, Gans R, vander Meer NJM. A randomized trial comparing two intraosseous access devices in intrahospital healthcare providers with a focus on retention of knowledge, skill, and self-efficacy. Eur J Trauma and Emerg Surg 2014;doi:10.1007/s00068-014-0385-8

This article describes a randomized trial comparing the retention knowledge, skill and self-efficacy among anesthesiologists and registered nurses of anesthesia with use of the EZ-IO and Bone Injection Gun (B.I.G.). Participants were randomized to be trained on one device and were tested at 0, 3, and 12 months post training. The authors concluded that training anesthesiologists on use of the EZ-IO with the educational tools provided by the manufacturer will ensure optimal performance for a period of one year.

The Netherlands


Text article that accompanies video featured in The New England Journal of Medicine on intraosseous access which provides a general overview of IO access and demonstration of IO insertion using the EZ-IO and one manual IO needle set.


This review provides a comprehensive summary of pharmacologic therapies that utilize prefilled devices as a delivery mechanism for parenteral application. Six categories are described: endocrine, neurological, pain management, immune disorders, anaphylaxis, and emergency medicine. Within emergency medicine IO access is recommended as an alternative to IV access when IV access cannot be obtained. Various devices for IO access, including the EZ-IO device, are listed.


Manikin study conducted in Poland with 107 paramedic operators designed to investigate the success rate, time of insertion and perceived difficulty of intraosseous access devices during simulated resuscitation using the EZ-IO, Bone Injection Gun and Jamshidi needles. Results were first attempt success: B.I.G.: 91.59%; EZ-IO: 82.66%; Jamshidi: 47.66%; mean procedure time: B.I.G.: 2.0 min ± 0.7; EZ-IO: 3.1 min ± 0.9; Jamshidi: 4.2 min ± 1.0; and ease of use (1-very easy to 5-very hard): B.I.G.: 1.83; EZ-IO: 2.92; Jamshidi: 4.68.

Poland


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use, IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.

Retrospective study of the Israeli Defense Force (IDF) registry from January 1999 through October 2012 to identify all cases in which IO access was attempted. The Bone Injection Gun (B.I.G.) was the device used for IO access. A total 37 attempts were made in 30 patients. First attempt success was 53% with an overall success rate 49% when factoring subsequent attempts. Most frequent cause for failure related to providers skill level, and due to the device design allowing little room for error. This study prompted the IDF to seek an alternative for the B.I.G.


This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.


This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).


Abstract reporting on retrospective prehospital study to evaluate the rate of out-of hospital return of spontaneous circulation (ROSC) in the cardiac arrest patient. The following were assessed and analyzed for direct or indirect correlation on ROSC; dispatch time to arrival, number of intravascular attempts per method (IV versus IO) and rate of success. Conclusions were that ROSC can be achieved more rapidly when IO access is used as the first attempt method in obtaining vascular access in prehospital cardiac arrest. There was a trend in shorter ROSC times among the first attempt IO group compared to the IV group; the difference did not reach statistical significance, most likely due to a lack of power from the smaller sample size of the IO group.

YEAR: 2013


This article describes a questionnaire study that was given to UK Role One military clinicians deployed to Afghanistan to assess the level of experience and confidence rating with use of IO access, using the FAST-1 and EZ-IO, and IV access. Thirty-three responses were received; clinicians felt more confident with IV access over IO access; clinicians felt more confident with FAST-1 IO access than EZ-IO IO access.


In a letter to the editor this study reports data collected (during a survey of one third of academic emergency medicine programs in the U.S.) regarding IO use in adults and comparing IO access with other vascular access techniques through simulation. Data suggest that IOs were used less than 5% of the time patients needed emergent access and a peripheral line was unobtainable. The EZ-IO was most often used IO device. Authors conclude IO use should be considered more frequently in critical, unstable patients. (This research was presented at the ACEP Research Forum in 2010).

Cleugh FM, Maconochie IK. Management of the multiply injured child. Paediatrics and Child Health 2013;23(5):194-9

General overview of care of a child with multiple trauma. IO vascular access is mentioned as a treatment option after 90 seconds or 3 failed PIV attempts. The B.I.G. is cited as an option along with the manual needles.


This article looks at various methods of vascular access including venous, arterial and intraosseous access and their potential to result in air embolism.
Intraosseous Vascular Access Bibliography
Infusion Devices


An observational clinical study evaluating use of the EZ-IO in patients requiring urgent vascular access that would have otherwise received a central venous catheter due to a lack of other options. One hundred five (105) patients were enrolled across five hospitals. The authors concluded that use of IO access in place of CVCs provides time savings, safety, ease of use, and is effective at significant cost savings; IO access may be used as a bridge to CVC placement under optimal conditions; and IO access may be used to replace use of CVCs all together in selective patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes a mannequin and cadaver study that evaluated use of the EZ-IO sternal device and the Illinois needle to establish sternal IO vascular access by dental students. Results of the cadaver study showed two cases of perforation of the posterior sternal cortex when the Illinois needle was used and one EZ-IO insertion in the soft tissue without entering the IO space. The authors concluded use of the EZ-IO sternal device with the insertion site template and scalpel incision may be more efficient and less predisposed to complication than use of the Illinois needle.


General discussion on use of the intraosseous vascular access route for infusion of CT contrast, with attention to clinical considerations pertinent to nurses working in the imaging suite. Author also reviews general IO principles and IO devices.


This is a preclinical study comparing the EZ-IO and the Cook manual IO needle when used by 21 resident physicians to establish IO access in anesthetized swine. Results showed the drill-assisted needle was successfully placed 100% of attempts vs 78.2% successful placement with manual; time to placement and user preference also favored the EZ-IO. Technical issues reported included bending of the manual needle 33% of attempts.


A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices. Denmark


This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handmade IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult. Iraq


This article in German explores use of intraosseous access in a dental practice emergency. In a simulation study, dental students attempted to establish standard peripheral IV access and IO access using 3 different devices: EZ-IO, BIG, and manual IO. Results showed the manual was the fastest to insert, however, the EZ-IO had the highest first-attempt success rate as well as the lowest number of total attempts to IO access. Germany
Intraosseous Vascular Access Bibliography

Infusion Devices


This article presents an overview of IO access focused on nurses’ use of the technique. A list of available devices, history and support for use and possible complications are included.


This abstract describes the results of an online survey taken by members of the Obstetric Anaesthetists’ Association, evaluating use of IO access in obstetric emergencies, and availability of IO devices on UK labor wards. Results showed many members are trained on IO access, consider it a viable option during emergencies however have limited access to equipment.

UK


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.

Plancade D, Millot I, Fetissof H, et al.. Sternal perforation with an intraosseous device and hemomediastinum infusion Ann Fr Anesth Reanim 2013;http://dx.doi.org/10.1016/j.annfar.2013.01.009

A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for sternal use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.


This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.


This study conducted by the Norwegian Navy evaluated the ability of 25 soldiers to perform buddy transfusion by starting phlebotomy, establishing sternal IO access using the FAST1, and infusing 1 unit of whole blood. Physical performance was evaluated pre and post blood donation and lactate levels were recorded. The authors concluded that physical and combat performances are preserved within limits post whole blood donation and that soldiers are able to learn the phlebotomy and sternal reinfusion with only a short lecture on the procedure.

YEAR: 2012


This article discusses how IO access can be used to improve advanced life support therapy. The EZ-IO is described in this article; published comparative studies between other IO devices and peripheral IV access are cited, leading the author to conclude the EZ-IO is user friendly, and establishes intravascular access more quickly and more often on first attempt than other devices.


This pre-clinical study evaluated IO flow rates obtainable with infusion of lactated Ringer’s and hetastarch 6% through the proximal tibia and sternum IO insertion sites, using a swine model. The EZ-IO 25mm was used to facilitate tibial IO access; sternal access was established using a Jamshidi needle. Results showed that hetastarch flow rates were lower than lactated Ringer’s flow rates at both insertion sites; sternal infusion of hetastarch is likely to provide greater estimated intravascular volume expansion than lactated Ringer’s, despite the lower infusion rates; resuscitation using the IO rate is likely to benefit from pressure bag or high-pressure pump delivery. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

**Infusion Devices**


This article discusses a retrospective review of Japanese prehospital system for intravenous infusion success rates in cardiopulmonary arrest (CPA) patients and a prospective simulation study. A nationwide database was reviewed for CPA records from 1 January 2005 to 31 December 2008 yielding 431,968 cases. Results showed the IV infusion success rate in adults increased annually, however the rate in pediatrics did not; and while the administration of adrenaline increased the 1-month survival rate did not. In the simulation study, 100 EMS technicians used the Bone Injection Gun (BIG) in simulator adult, pediatric and infant legs. There was no difference in the time to establish IO access between the simulation models. The authors concluded that IO access should be considered when IV access is difficult or impossible.


This article describes a study evaluating a new manual needle insertion device, the Near Needle Holder, which uses hollow-bore needles to establish IO access. In a comparative study, healthcare professionals attempted IO insertion in the proximal tibia insertion site of a mannequin using the NNH and a standard Cook manual IO needle. Participants then completed a questionnaire regarding their experience. The most reported complication was the plunging of the needle into the medullary space from the decrease in resistance once the cortex was penetrated. Other IO devices on the market are mentioned, including the EZ-IO.


This simulation study evaluated the ability of 2 person EMS crews to manage a pediatric emergency and sought to determine root causes of errors made. Participating EMS crews used the BIG for IO access. The authors concluded that cognitive, procedural, affective, teamwork errors and error-producing conditions were identified as root causes for the errors made in the simulation. Authors also concluded that simulation followed by facilitated debriefing is an effective tool for identifying underlying causes of active and latent errors.


This clinical trial evaluated the time required to establish IO access versus central venous catheter (CVC) in adults undergoing resuscitation, who had failed peripheral IV access (PIV) attempts. IO and CVC placement were performed simultaneously; two IO devices, the EZ-IO and the BIG, were used to facilitate IO access in randomized format. Forty (40) patients were enrolled, first attempt success for IO was 85% vs 60% for CVC placement; median procedure time was 2 minutes for IO vs 8 minutes for CVC. The author concluded that though IO access is safe, reliable and rapid during resuscitation, it cannot replace CVC but should be considered as a valuable bridging technique.


This abstract presented at the 2012 ACEP Research Forum discusses a literature review of intraosseous access publications since 1985 providing an updated safety profile for IO access. The search resulted in 192 articles describing IO access with 6 cases of osteomyelitis and 6 cases of compartment syndrome secondary to extravasation reported. Of the 192 articles identified, 140 described the EZ-IO. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article highlights the FAST Combat™ IO device with improvements and as a replacement for the FAST1®. Anticipated FDA clearance: Spring 2013.


A literature review of articles describing intraosseous vascular access devices used in the pre-hospital setting. Twenty articles met the inclusion criteria and described the manual devices, BIG, Fast-1 and the EZ-IO. The authors concluded that the literature suggests that semiautomatic IO devices may be more effective than manual devices.


This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.
Intraosseous Vascular Access Bibliography
Infusion Devices

Page D. Intraosseous intrigue: Studies examine success rates on pediatric, adult & obese patients. JEMS January 2012;32-3
In this article, the author discussed five recent studies on intraosseous access providing his opinion about the quality of each study.

An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.

This letter to the editor describes a case in which sternal IO access was established using a Jamshidi needle to administer iodinated contrast for a thoraco abdominal CT on a 61-year old male who presented to the ED with respiratory distress. Picture quality was deemed excellent by the radiologists. The authors conclude that the sternal IO route can be used with excellent picture quality but it should be used only in exceptional cases due to the potential risks of a high-power injection through the bone. EZ-IO is mentioned as an alternative IO device available.

An article discussing the technique and safety profile of intraosseous access using the EZ-IO device. Needle selection, contraindications, insertion sites and techniques, catheter stabilization and removal are all discussed along with the safety profile of the EZ-IO against other IO devices and central venous catheters. The authors concluded that IO access should be considered whenever immediate vascular access is required. This article was co-written by an employee of Vidacare Corporation, acquired by Teleflex Incorporated.

This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.

The objective of this study was to retrospectively evaluate the relationship between out-of-hospital IV access and mortality among non-injured, non-cardiac arrest patients transported by 4 advanced life support agencies between January 1, 2002 and December 31, 2006. A total of 56,332 patients were included in the study. The author concludes that efforts to establish IV access in the out-of-hospital setting is was associated with reduction in hospital mortality among non-injured, non-cardiac arrest patients.

This poster presented at the 2012 International Conference of Emergency Medicine described a 4 month review of intraosseous access in UK military operations in Afghanistan. During the timeframe the EZ-IO was used to establish IO access in the proximal humerus and tibia sites; the FAST1 was used to establish sternal IO access. Of the 87 EZ-IO applications there were 12 functional issues and the placement success rate for both sites combined was 86.3%. In 24 FAST1 applications there were 4 functional issues and the placement success rate was 83.4%.

In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO

A literary search of electronic databases was performed to identify publications comparing IO access devices. Publications qualifying for study evaluation must have compared two or more semi-automatic IO devices or at least one semi-automatic device and a manual device. Reviews, editorials, surveys, and case reports were excluded. Ten comparative studies met the qualifications for inclusion and are briefly discussed. The studies evaluated suggested superiority of the battery powered IO driver over manual needles and other semi-automatic IO infusion devices.
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YEAR: 2011

A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthetics recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anesthesia by IO access was satisfactory without necessity of other infusion access.

Brazil

This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.

This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first receivers to place IO lines for antidote administration using the EZ-IO device. First responders placed IO lines successfully in 100% of cases, and first receivers placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.

Byars DV, Tsuchitani SN, Erwin E, Anglemyer B, Eastman J. Evaluation of success rate and access time for an adult sternal intraosseous device deployed in the prehospital setting. Prehosp Disaster Med 2011;26(2):127-9
A prospective study evaluating use of the FAST-1 sternal IO device in critically ill patients in cardiac arrest in the pre-hospital setting. In one year, 41 insertion attempts were performed using the FAST-1. Thirty (73%) of attempts were successful and the mean time to placement was 67 seconds from time of opening the packaging to ability to aspirate/infuse without infiltration. Of the 11 insertion failures, 7 were due to failure of the device to deploy; 2 infiltrations after insertion; 1 inability to aspirate; and 1 failure of the catheter to deploy though the needles were inserted.

This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK

Day MW. Intraosseous devices for intravascular access in adult trauma patients. Crit Care Nurs 2011;31:76-90. doi: 10.4037/ccn2011615
An overview of available intraosseous vascular access devices, including the EZ-IO.

The Emergency Nurse’s Association (ENA) published a series of Emergency Nursing Resources with emphasis on clinical or practice based issues. This issue focused on difficult IV access and provides a summary of the literature review, with graded recommendations and decision options for practice for IO access, ultrasound guidance, subcutaneous rehydration therapy and several other alternatives. IO access is graded as having a high level of evidence supporting use of IO access when difficult IV access is known or suspected for high success rates and rapid time to insertion.

General overview of PALS updates. Various IO devices were specifically mentioned in the vascular access section, including the EZ-IO.

This article summarizes the case-based observations made by the Armed Forces Medical Examiner System on soldiers killed in action/died of wounds who had evidence of sternal intraosseous access. The Pyng Fast-1 is noted in the article as the sternal IO device most widely distributed by the department of defense (DOD); the EZ-IO is listed as another device that may be seen in emergency care facilities within the DOD. Of 98 cases, 78 (80%) showed proper placement; 20% were unsuccessful. It should be noted that the article incorrectly states that the EZ-IO using the powered driver is indicated for sternal placement.

In this abstract the authors attempted to establish a relationship in obese patients (BMI >30) between BMI, ability to palpate the tibial tubercle, and tissue depth at the IO insertion sites. Results showed that in obese patients, IO placement with a 25mm catheter is feasible at the proximal and distal tibial sites if the tibial tubercle is palpable and that insertion into the proximal humerus in this population is not recommended.

**Abstract only**


This study compared the effectiveness of infusing ice cold saline via IO and IV to induce mild therapeutic hypothermia (temperature drop to 34°C) within a 30 minute timeframe, in a swine model of cardiac arrest. Five swine were evaluated in each the IV and IO groups. Goal temperature was reached in 4/5 animals in the IV group and 0/5 animals in the IO group in the allotted time frame; IV was superior in terms of rate of infusion, rate of temperature change, and time to achieve target temperature.


This article describes the changes in practice experienced when a 12-site statewide ambulance service changed from the manual to the semi-automatic IO device (EZ-IO). There was no statistically significant change in first-attempt success or the number of successes per attempt. However, the use of IO access more than tripled when changing from the manual to the semi-automatic device and PIV access attempts before IO access went from occurring in 35.5% of patients to 1.7% of patients.

**Myers LA, Russi CS, Arteaga GM.** The introduction of a semiautomated (EZ-IO) device in pediatric prehospital care replacing a manual intraosseous (IO) device improves the success rate for attempts at vascular access. *Prehosp Emerg Care* 2011;15(1):110

This abstract describes a 93 patient study presented at the 2011 National Association of EMS Physicians Annual Conference that examined the characteristics of pediatric patients receiving IO infusions and the primary EMS clinical impressions, success rates, and subsequent treatments delivered via manual IO vs. the powered EZ-IO device. Investigators concluded that for the pediatric cohort use of the powered device offered a marginally higher first-attempt success rate compared to the manual device; and that the rate of IO access utilization by EMS more than tripled after adoption of the powered device.


This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.


This article in Spanish describes the Spanish military medical staff’s experience with the use of intraosseous lines for fluid therapy in a combat zone from March 2007 to June 2008. Twenty-five patients had an IO placed with the Bone Injection Gun (BIG). Placement success rates were 76% for the 19 pre-hospital placements and 100% for the 6 in-hospital placements. There were no complications during insertion. Conclusion was intraosseous access can provide an alternative to venous access for treating trauma patients in combat zones.


This article describes a literature review study with the objective of establishing which intraosseous device is best for prehospital use. This short review searched Medline 1950-2010, CINAHL 1982-2010 and EMBASE 1980-2010 and identified two studies meeting their evidence search criteria, one study compared the BIG vs. manual; the second compared EZ-IO vs. FAST-1. The clinical bottom line asserted by the author was traditional manual IO devices have faster, better success rates in the pre-hospital setting; but that more randomized trials are needed to determine the best device.


This study compared time to placement, errors in placement and perceived ease of use for healthcare providers placing umbilical venous catheters (UVC) and intraosseous needles in a simulated delivery room, responding to persistent bradycardia. Results showed mean IO placement time was 46 seconds faster than UVC placement; there was no significant difference in the number of errors and the perceived ease of use between UVC and IO.

The objective of this study was to determine the frequency of first-attempt success of humeral IO, tibial IO, and peripheral IV (PIV) insertions during out-of-hospital cardiac arrest. Patients were randomized to receive one of the 3 methods. There were 182 patients enrolled, 64 were assigned to tibial IO, 51 to humeral IO and 67 to PIV. Of all patients 130 (71%) were successful on first attempt with 17 (9%) needles dislodged. First attempt success within the treatment groups was 91% for tibial IO, 51% for humeral IO, and 43% for PIV.


This article describes a case in which systemic fibrinolysis was administered through the intraosseous route in a patient with ST-segment elevation myocardial infarction. Fibrinolytics and antiarrhythmic drugs were administered through the IO line, resulting in resolution of coronary ischemia and electrical instability, without complications. Authors concluded that intraosseous cannulation represents a novel route for administration of systemic fibrinolysis in cases of difficult peripheral venous access in the out-of-hospital setting.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.


This article describes IO access in terms of efficacy, indications/contraindications for use, and the IO procedure and comparison of devices to make a case for IO use in oral and maxillofacial surgical practice. In discussing IO devices cited publishing data, the author identified the EZ-IO device as the most accurate, efficacious, and precise system when trying to achieve IO access.


This article is a response to the Taylor and Clarke 2011 report of two amputations required following development of compartment syndrome after IO infusion. The author notes that complications are possible with all methods of establishing IO access including manual, spring loaded and power driven needles and that it is not accurate to directly relate the adverse events to the power driven device only.

YEAR: 2010


This paper describes the process of establishing a nurse-led central venous catheter insertion service in a university affiliated hospital using a process evaluation method. Introduction discusses CVC adverse events rate and mortality.


This veterinary study evaluated 3 IO access devices, impact driven, automatic rotary, and manual, to compare the placement feasibility and amount of bone trauma induced when used in adult feline cadavers. Seventy-two IO insertion locations were used, the 3 devices were equally randomized to the insertion site. The rotary device was found to have shorter time to insertion and better ease of insertion. No statistically significant differences between number of bone fragments, defect diameter, or success rate were found between devices.


This abstract describes a retrospective case-series analysis of pediatric IO recipients from 1998-2009. Seventy-two (72) patients were included in the study; IO access was established in the proximal tibia (n=61), medial tibia (n=8), distal tibia (n=1), sternum (n=1), and iliac crest (n=1). IO access devices used in the proximal tibia included the Cook Critical Care needle (n=4), the Jamshidi needle (n=2), the BIG (n=1), and an 18 gauge spinal needle (n=54). The authors concluded that a spinal needle can be used to provide IO vascular access in children.


Authors reviewed two complications (extravasation and compartment syndrome) associated with IO access in children with meningococcal disease. Authors concluded that IO systems need formal evaluation to assess safety and complication profiles.
Intraosseous Vascular Access Bibliography

Infusion Devices


This article discusses the challenges of gaining vascular access in small infants and neonates and how new equipment such as ultrasound machines with pediatric probes can provide better guidance and improve safety and efficacy. The article also addresses the importance of education and training in ultrasound use. This article was based on literature research as well as authors' experience.


This article, written in German, gives an overview of intraosseous access in pediatric patients especially with regard to particularly difficult vascular access in the areas of pediatric anesthesia and perioperative care. The article also gives an overview of various devices available to gain IO access, including the Cook needle and the EZ-IO device.


This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.


This article describes a randomized, single-blind, controlled trial to determine which IO needle can be used best for gaining IO access in patients requiring acute administration of fluids or medication in a prehospital setting. The study was performed at a level 1 trauma center in the Netherlands with a Helicopter Emergency Medical Service (HEMS). Adult and pediatric patients meeting inclusion criteria were randomized between Jamshidi 15G, B.I.G. 15G/18G and F.A.S.T. Insertion time, success, aspiration of bone marrow, side effects, medication given, trauma mechanism, and user satisfaction were recorded. In the adult group Jamshidi was placed fastest, significantly faster than the F.A.S.T.1. (p=0.002). Time to insert the B.I.G. 15G did not differ statistically from other devices. In the pediatric group insertion time of the Jamshidi did not differ statistically from the B.I.G. 18G. On average, the devices (adult and pediatric) did not differ significantly with respect to success rate, complication rates, and user satisfaction. EZ-IO was not included in this study as it was not approved for use in the Netherlands at the time the trial began. Authors recommend comparison with EZ-IO in future research.


An article evaluating various methods of obtaining vascular access in the management of 21st century battlefield trauma including, peripheral IV access, intraosseous access, venous cut-down, and central venous access. The authors conclude that IO access should be the first line vascular access in casualties with severe trauma to avoid delay initiating resuscitation in pre-hospital or hospital setting.


In an abstract presented at the 2010 ACEP Research Forum, investigators describe a swine study designed to compare IO infusion rates using the Belmont FMS 2000 rapid infusion device and a pressure bag through the proximal tibia and proximal humerus. Investigators concluded that infusion rates were highest using the pressure bag via the proximal humerus.


Training study with nurses and physicians comparing EZ-IO to IV lines under Hazmat conditions. IO procedure significantly shorter.


This article describes the vascular access options available to physicians caring for children, including details about each method, placement technique, indication, and complications.


Authors describe a randomized, controlled trial comparing two different IO access devices in adults in the hospital setting. Twenty patients received the BIG and 20 received the EZ-IO. Success rate on first attempt was 80% for the BIG and 90% for the EZ-IO. Mean procedure time was 2.2 minutes for the BIG vs. 1.8 minutes for the EZ-IO. Differences in success rate and procedure time were not statistically significant, and there were no significant complications for any patients. Investigators concluded that IO access is a reliable and safe method for rapid vascular access in in-hospital adult patients under resuscitation.
Intraosseous Vascular Access Bibliography
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A retrospective chart review in an urban emergency department (ED) was performed to identify central venous catheters placed in the ED and determine the bloodstream infection and duration of catheterization within a one year period. A total of 656 patients (3,622 catheter-days) with CVCs placed in the ED were identified, with 7 bloodstream infections. The mean duration of catheterization was 5.5 days. Within the infected CVC group, the mean duration of catheterization was 8.6 days


This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.


In this letter to the editor, the author discusses the use of IO access concluding that a change in practice should be made in which immediate IO access should be established for initial emergency resuscitation and serve as a bridging technique when peripheral IV access has been unsuccessful 3 times over a maximum duration of 2 minutes.


In this abstract of a study presented at the 2010 National Association of EMS Physicians Meeting, researchers describe a study in which sternal and tibial IO devices were evaluated with and without chemical protective equipment. Researchers concluded that the use of the protective equipment did not affect the success rate or time to placement for the two IO devices.


Authors report an observational study of 14 children in whom semi-elective IO infusion was performed under anesthesia after peripheral IV had failed. IO infusion was successful for all 14 patients, using the EZ-IO system for 8 patients and the Cook system for 6 patients.


This article discusses vascular access procedures in critically ill obese patients. Anatomic considerations, general procedural considerations such as location of the procedure and patient positioning, catheter insertion technique, ultrasound guided insertion, intraosseous insertion, and other various considerations are evaluated.


This article describes a longitudinal study of intraosseous vascular access in pre-hospital emergency medical service handled by helicopter emergency medical services. Of the 78 IO insertion attempts made on 70 patients, overall success rates were 50% using manual needles, 55% using the Bone Injection Gun, and 96% using the EZ-IO. Investigators concluded that newer IO techniques may enable faster and more reliable vascular access; and that all emergency services should be familiar with IO techniques.

Vegunta RK. Chapter 8-Vascular access. Ashcraft's Pediatric Surgery 2010;5th ed:110-6

This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.

YEAR: 2009


This letter to the editor discussed the experience of one ground emergency rescue service in Germany and their trial implementation of the EZ-IO, as compared to the David et al evaluation of the BIG by emergency physicians in which the rate of failure was 55%. Over a one year evaluation of the EZ-IO in the field, it was used in 20 patients, of which 19 were successfully placed (95%). The success of the field evaluation and a human cadaver study resulted in the addition of the EZ-IO to the receiving University Hospital emergency department.


This letter to the editor discusses the experience of a mobile intensive care unit use of the Bone Injection Gun (B.I.G.) from January 1, 2005 - December 31, 2006. Following two failed attempts to establish peripheral IV access, IO access was attempted at the proximal tibia insertion site. IO access was attempted in 11 patients and was successful in 5. The authors attributed the failures to an inability to control the path of the catheter, resulting in too shallow of attempts or complete transfixon of the bone.
This article provides a general overview of intraosseous access and its use in emergency situations. A description of available IO access devices is provided.

This case report describes a complication of use of a sternal IO device (FAST-1, Pyng Medical Corporation, Richmond, Canada) in a 21-year-old soldier who suffered multiple soft tissue fragmentation injuries, in which the needle tip broke in situ. The author concluded the complication resulted from the IO needle being placed when the patient was lying in a lateral position with the skin over the manubrium displaced from the midline.

Prospective study of 246 EMS providers at 14 EMS agencies. Reports successful IO placement in 95% of cases (18 of 19).

Dutch study of IO use with the Bone Injection Gun by helicopter EMS teams. Reports 71% success rate for pediatric patients and 73% success rate for adults.
Abstract only

This article describes a study conducted at an urban Level I trauma center in Munich, Germany. Ten consecutive patients for whom PIV was difficult or impossible were simultaneously given a central line and an EZ-IO. Procedure times were measured and defined as the time the device package was taken off the shelf until the first drug or solution was administered. First attempt success rate was 90% for EZ-IO and 60% for CVC. The mean procedure times were 2.3 minutes for EZ-IO and 9.9 minutes for CVC, a clinically and statistically significant difference. Investigators concluded, because CVC was slower and less efficacious, IO may improve the safety of patients requiring resuscitation in the ED.

This article describes a cadaver study to determine skill acquisition and performance by use of the EZ-IO system by novices. Overall success rate for the 99 operators was 97%, and mean insertion time was 6 seconds. All operators rated the device faster and easier than using a central line, and 99% expressed willingness to use the device for cardiac arrest patients.

This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study designed to determine the feasibility of inducing therapeutic hypothermia (TH) after resuscitation by giving an IO infusion of iced saline. Researchers concluded that rapid, large volume IO infusion of iced saline is as effective for lowering core body temperature after resuscitation as central access and peripheral IV. This research was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.

This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 28 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants.

This article describes a case in which IO access, using the EZ-IO, was attempted in a patient with osteogenesis imperfecta. In each of 3 attempts, the needle became loose immediately after IO insertion. The author acknowledged that during emergencies it is difficult to assess and consider every possible contraindication for every intervention; and that IO access using the EZ-IO is the author's choice for emergency vascular access when peripheral access is difficult or has failed.
Intraosseous Vascular Access Bibliography

Infusion Devices

Ong ME, Chan YH, Oh HH, Ngo AS. An observational prospective study comparing tibial and humeral intraosseous access using the EZ-IO. *Am J Emerg Med* 2009;27:8-15
Comparison of tibial and humeral IO use in 24 adults. Both sites suitable for IO infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article describes a prospective, observational study involving a convenience sample of 25 medical students, physicians and nursing staff recruited evaluate the EZIO powered drill device on a bone model. Twenty-three (92%) of the 25 study subjects required only one attempt at placing the EZ-IO. Investigators concluded that the device was easy to use with high success rates of insertion with inexperienced participants. (Note: This study was also described in an earlier article published in American Journal of Emergency Medicine) This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This abstract describes a small study designed to determine if IO line placement improves outcome in adult patients with out-of-hospital cardiac arrest. This 165 patient study did not demonstrate improved survival.

Authors of this article describe a pilot study designed to compare the success rate for insertion and ease-of-use of the Bone Injection Gun (BIG) spring-loaded device and the EZ-IO battery-powered device on a turkey bone model. Investigators concluded that the EZ-IO demonstrated higher success rates than the BIG (28/29 vs. 19/29, p=0.016), and the EZ-IO was the preferred device.

This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.

This review article in German describes intraosseous vascular access, and includes descriptions of the Waismed Bone Injection Gun, Vidacare EZ-IO, Jamshidi and Cook Medical IO devices.

This French version of an article previously published in American Journal of Emergency Medicine describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous using the Vidaptor (a predecessor of the Vidacare EZ-IO) vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine for nearly all pharmacokinetic parameters, including maximum plasma concentration, time to maximum plasma concentration, and area under plasma concentration-time curve. There was a significant difference in the volume of distribution in the central compartment, which investigators attributed to a minor deposition effect near the IO port or in the bone marrow. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.

This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.

YEAR: 2008

Review of IO infusion methods and devices. Devices described include Jamshidi, Cook, FAST 1, BIG, and EZ-IO.
Intraosseous Vascular Access Bibliography

**Infusion Devices**

**Borron S, Arias J, Sanchez M Bauer C. Hemodynamics following intraosseous administration of hydroxocobalamin in the goat.** *Ann Emerg Med 2008;52(4):S96*

Animal (goat) study to determine if IO administration of hydroxocobalamin for antidotal treatment for exposure to cyanide and other poison agents would be faster and require less fine motor coordination and sensitivity; and would result in similar hemodynamic changes compared to IV administration. Using the EZ-IO device, researchers concluded that hemodynamic effects of hydroxocobalamin given by the IO route in non-poisoned goats are mild and similar in magnitude to those of saline control animals.

**Bosworth NJ. The occasional intraosseous infusion.** *Can J of Rural Med 2008; 13: 80-3*

Overview of intraosseous vascular access in infants; includes indications, contraindications, complications, equipment (Sur-Fast and Jamshidi), and procedure. Also, small section on IO for adults; describes the FAST-1, Bone Injection Gun, and EZ-IO.


Study comparing manual intraosseous insertion with EZ-IO using adult human cadavers as a model. No significant difference in insertion time between 39 manual insertions and 45 EZ-IO insertions. Found a difference in the success rate (manual, 79.5% vs. EZ-IO 97.8%, p<0.01). The EZ-IO had fewer complications (manual, 15.4% vs. EZ-IO 0.0%, p<0.01) and scored higher on user friendliness (school grading system: manual, 1.9±0.7 vs. EZ-IO 1.2±0.4, p<0.01).

**de Caen AR, Reis A, Bhutta A. Vascular access and drug therapy in pediatric resuscitation.** *Pediatr Clin N Am 2008;55:909-27*

Describes common drugs used in pediatric resuscitation and evidence supporting their use. Also describes routes of administration including intravenous, intraosseous, and intratracheal. Describes IO systems including Bone Injection Gun, FAST-1, and EZ-IO.

**Fowler RL, Pierce A, Nazeer S, Philbeck TE, Miller LJ. 1,199 case series: Powered intraosseous insertion provides safe and effective vascular access for emergency patients.** *Ann Emerg Med 2008;52(4):S152*

Large retrospective study of patients for whom emergency vascular access was obtained using the Vidacare EZ-IO intraosseous system. Insertion success was 92% and within 10 seconds for 84% of the one-attempt successful cases. Complication rate was low (4.8%), none were serious, and extravasation was the most frequent (0.8%). The device was rated easy to use 72% of the time, and researchers concluded that the powered IO device is safe and effective for achieving vascular access in the resuscitation and stabilization of emergency patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

**Horton MA, Beamer C. Powered intraosseous insertion provides safe and effective vascular access for pediatric emergency patients.** *Pediatr Emerg Care 2008;24(6):347-50*

A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

**Moloff A. IO objectives.** *JEMS 2008; 33: 22*

This is a letter to the editor challenging a recent publication in JEMS describing clinical studies involving various IO devices.


Interim report for quasi-controlled prospective study of emergency department patients for whom emergency vascular access using the Vidacare EZ-IO intraosseous (IO) system (n=6) inserted in the proximal humerus was compared to access using central or peripheral intravenous (IV) lines (n=60). Researchers concluded that proximal humerus IO insertion is significantly faster than central or peripheral intravenous (IV) line insertion. Complications and pain profiles were similar for IO and IV techniques. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

**Pointer JE, Vultaggio D, Schnepf R, Kleveno A. Fast or easy? Comparing two adult IO infusion devices.** *JEMS.com 2008*

This article describes an observational study in which two intraosseous devices were compared: the Pyng Medical F.A.S.T.1 and the Vidacare EZ-IO. For the 117 patients on which the F.A.S.T.1 was used, there was an 84% success; compared to a 97% success rate for the EZ-IO (n=71).


Prospective observational study of the use of the Bone Injection Gun in Israel from 2000 to 2004. Of the 189 patients enrolled in the study, successful insertion on first attempt was accomplished in 91% of cases.

YEAR: 2007


Data from the largest combat trauma database was analyzed to identify how new or improved devices, dressings or drugs have impacted prehospital casualty care, how guidelines and resuscitation strategy have changed, and discusses lessons learned and how concepts have crossed back into the civilian practice. Intraosseous access, particularly the sternal site, is identified as one of the advances for vascular access in combat medicine.


This article reviews and assesses the literature on the use of IO drug administration during cardiopulmonary resuscitation. It addresses the risks and benefits of using IO in adults and children. The article describes the FDA-cleared devices available for use including the Pyng F.A.S.T.1, Waismod Bone Injection Gun and the Vidacare EZ-IO.


Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.

de Caen A. Venous access in the critically ill child. Pediat Emerg Care 2007;23:422-4

This review article states the availability of intraosseous (IO) needles for pediatric patients, outlines the limitations of traditional venous access, and discusses the various IO devices currently available, including the Vidacare EZ-IO®.


This article summarized the challenges and methods of providing vascular access for infants. It describes IO techniques and devices, including the Jamshidi, Cook, EZ-IO® and Bone Injection Gun (BIG) devices.

Fowler RL. Prehospital intraosseous access: elemental to the field? JEMS 2007; doi:http://jems.com/print/9198

Discussion of the role intraosseous vascular access can play in the prehospital setting where vascular access is often difficult or impossible to establish. The EZ-IO is named as a new IO device along with descriptions of Jamshidi, Pyng Fast 1, and BIG needles.


This article describes authors’ evaluation of provider performance using two IO devices; the Pyng Medical F.A.S.T.1™ and the Vidacare EZ-IO®. Of 89 insertions with each device, success rate for 72% for the F.A.S.T.1 and 87% for the EZ-IO, a significant difference (p=0.009). The time to fluid insertion for the EZ-IO was also faster (p=0.02). Authors noted that the EZ-IO is unique and much more useful than the F.A.S.T.1.

Gagliardi P, Purrone G. [Il potere di salvare vite l'infusione di liquidi e farmaci in emergenza con accesso veneso non reperibile]. N & A Mensile Italiano del Soccorso 2007; 177: 20-3. Italian

Article in Italian describing IO access and EZ-IO

Landes AH. Intra-osseous infusions: the current status. Care of the Critically Ill 2007; 23: 53-8

Overview of IO access. Includes historical aspects, current status, indications for use, advantages and disadvantages, IO kinetics, insertion sites, complications and contraindications and description of available IO devices, including EZ-IO®.
Intraosseous Vascular Access Bibliography
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Article in Dutch describing IO access and EZ-IO.

Wayne MA. Intraosseous vascular access: devices, sites and rationale for IO use. JEMS 2007;32:s23-5
This article reviews intraosseous vascular access in general, and summarizes the various devices available. These include the Waismed B.I.G., the VidaCare EZ-IO, and Pyng F.A.S.T.1.

This article in German (with abstract in English) describes IO infusion in detail. It includes techniques, indications, complications, and recommendations. Also describes the various devices available, including Cook, Bone Injection Gun (BIG), First Access for Shock and Trauma (F.A.S.T.1), and the EZ-IO®.

YEAR: 2006

An abstract describing a prehospital study comparing peripheral IV to tibial IO access for placement success, time to access and time to drug delivery. The authors concluded that using IO access on the first attempt results in faster drug administration than if IO access were used as a rescue line after failed IV.

Evaluation of the Pyng Medical F.A.S.T.1 intraosseous device in simulated prehospital scenarios. Mean procedure time for initiation of fluid flow was 92 ± 32 seconds. Concludes that the F.A.S.T.1 is fast, accurate and easy to use.

In this study, presented at the NAEMSP 2006 annual meeting, investigators reported the results of a study that evaluated the performance of the EZ-IO® compared to an earlier evaluation of the Pyng F.A.S.T.1 system. There was a statistically significant higher success rate using the EZ-IO® compared to Pyng system, and investigators concluded that the EZ-IO® appears to be a superior device with regard to insertion success.

Prospective observational study evaluating EMT-B ability to provide care in out-of-hospital cardiac arrests. Found that EMT-Bs were able to place the EZ-IO with a 94% success rate. Median time to placement was 72 seconds.

Hoskins SL, Kramer GC, Stephens CT, Zachariah BS. Abstract 79: Efficacy of epinephrine delivery via the intraosseous humeral head route during CPR. Circulation 2006;114:II_1204
Results from this study which sought to determine the efficacy of intraosseous drug delivery using the proximal humerus during CPR in swine showed that the humeral route generated higher mean arterial pressures than central venous or endotracheal delivery.

An overview of intraosseous cannulation in the pediatric population. Anatomy, technique, contraindications, complications and laboratory investigations are all discussed.

Article in French describes IO access and IO devices, including B.I.G., F.A.S.T.1 and EZ-IO®.

The author provides an overview of intraosseous vascular access discussing evolution of the practice, equipment, treatment options and contraindications.

11/9/2019
Intraosseous Vascular Access Bibliography

Infusion Devices

YEAR: 2005

A review of 129 cases comparing the BIG to standard IO needles. Concludes that the BIG is equivalent to manually driven IO needles in effectiveness and likely faster than manual needles in achieving IO access.

Article describes intraosseous access for adults and pediatrics. Describes and discusses IO devices available including Jamshidi, Bone Injection Gun, F.A.S.T.1, and EZ-IO®.

Heightman AJ. The rebirth of adult IO: a first-hand account of recent advances in intraosseous infusion for adults, drawn from a scientific workshop and practical lab experience. JEMS 2005;30(10):s4-7
Editorial article highlighting recent advances in intraosseous (IO) infusion and IO devices based on the author’s experience at a scientific seminar hosted by Vidacare. Makes recommendations on the efficiency and safety of the devices.

This animal study compared IO drug delivery in the tibia versus the sternum during CPR. Researchers concluded that during CPR IO infusions delivered via both sites were effective—although sternal delivery was faster; and that IO sternum access is comparable to IV access for drug delivery during CPR.

This study abstract discusses use of the EZ-IO to determine the pharmacokinetics (PK) and efficacy of tibial IO drug delivery during treatment of cardiac arrest in the swine model, as compared to IV access. Results showed that PK analysis of IO drug delivery via the tibial route showed a delay of 20-50 seconds compared to IV; however, physiologically significant levels of epinephrine were reached as MAP. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Preclinical study of one IO device (FAST-1) in cadavers. Design criteria were validated in that 75 out of 77 attempts were successful.

Nursing article discussing the utility of the sternum as a site for IO infusion.Includes clinical indications, insertions techniques, contraindications, potential complications, post-insertion care and considerations for discontinuing the sternal device.

Experimental study of the FAST-1 sternal IO device, with 29 EMT-B’s with minimal training placing the device on mannequins. Authors reported 16 of 29 EMT-B’s placed the device successfully on the first attempt and 27 of 29 on the fourth attempt.

Miller LJ, Kramer GC, Bolleter S. Rescue access made easy: Intraosseous infusion, once limited to use in children, is now becoming a reliable access site for adults. JEMS 2005;30(10):Suppl 8-18
Overview of IO therapy. Includes 10 Myths about Adult IO and description of available IO devices, including the EZ-IO®.

Describes a training course for medical students to learn advanced emergency procedures using unembalmed cadavers. The course includes clinical indications and contraindications for specific procedures, as well as techniques. Also discusses students’ confidence levels in performing procedures.

YEAR: 2004

A brief review comparing screw tipped IO needles with standard IO needles.
Intraosseous Vascular Access Bibliography

Infusion Devices


Web publication discussing the indications, contraindications, insertion sites and complications of IO access.


Review article describing how IO has replaced saphenous venous cutdowns in pediatric emergencies and decreased need for immediate central venous access.


Study compared the VidaPort (now EZ-IO®) and the Bone Injection Gun (B.I.G.). Of 32 cases for each device, insertion rates were 100% for the VidaPort and 88% for the B.I.G. Average insertion times were 16 seconds for the Vidaport and 21 seconds for the B.I.G.


Evaluation of the Bone Injection Gun (BIG) for the administration of contrast media for urography. Concludes that BIG-assisted intraosseous urography may be an effective and reliable alternative to intravenous urography in pediatric and adult human patients.

Walls RM.  *Adult intraosseous device aids terrorism response.*  Journal Watch Emergency Medicine July 28, 2004

Evaluation of the B.I.G. in a simulated mass casualty attack with 88.9% of IO attempts successful.

http://emergency-medicine.jwatch.org/content/vol2004/issue728/

**YEAR:**  2003


Study evaluating the ability of physicians to establish IO access in patients while wearing full protective gear. Concludes that IO insertion of the BIG needle is rapid, but the protective gear increased insertion time 50%.


This article in Spanish discusses general IO principles.

Day MW.  *Act FAST with intraosseous infusion.*  Nursing 2003;33:50-2

Nursing article describing techniques for use of the FAST-1 IO device and cautions about IO sternal infusion.


Experimental study of the FAST-1 by EMS personnel. In 32 patients with previous unsuccessful IV attempts, the FAST-1 was placed successfully in 22 patients (69% success rate). Mean time to IO insertion was 73 seconds (estimated). No major complications other than failure to place device.


Web article discusses IO cannulation procedure insertion sites, pathophysiology, risks, contraindications and complications.

Lake W, Emmerson AJB.  *Use of a butterfly as an intraosseous needle in an oedematous preterm infant.*  Arch Dis Child Fetal Neonatal Ed 2003;88(5):F409

An 18 gauge butterfly needle was inserted into the proximal tibia of a premature infant born at 25-weeks gestation, following inability to establish other modes of vascular access due to gross oedema. The intraosseous line was left in place for 6 days until it was lost; there were no adverse events reported however the author noted that no safety data on long term use of the device was collected.


A comprehensive and accessible review of the history, anatomy, technique, and clinical application of intraosseous infusion.
**Intraosseous Vascular Access Bibliography**

**Infusion Devices**

**Lindsey J. Ready, aim fire! New IO device simplifies vascular access in severe cases. JEMS 2003; 28: 97-8**
Description of the Bone Injection Gun (B.I.G.) and directions for use.

Study of the Power Infuser, a device that can infuse fluids up to 6 L/hr, on patients presenting to the Emergency Department with evidence of hypovolemia. Resolution of hypovolemia was significantly faster with the Power Infuser compared to gravity infusion.

**YEAR: 2002**

Evaluation found that the device was useful in delivering IV fluids consistently and accurately to a wide range of patients in a difficult care environment.

Veterinary study comparing the B.I.G. with the manually driven Jamshidi IO needle. Concludes the B.I.G. provides more rapid access to the IO space.

**YEAR: 2001**

Results of a literature search to determine if a standard bone marrow needle can be used to establish IO access in a pediatric patient. Results showed only one article addressing the issue that indicated standard bone marrow aspiration needles can be used for IO infusion.

Article for Air Medical EMS audience describing the FAST-1 and use in attaining IO access. Reports 74% successful for first time users.

**Hubble MW, Trigg DC. Training prehospital personnel in saphenous vein cutdown and adult intraosseous access techniques. Prehosp Emerg Care 2001;5(2):181-9**
Study in EMS personnel comparing saphenous vein cutdown to IO access (B.I.G.) in the adult patient. Times to fluid flow were 7.6 minutes for saphenous cutdown and 3.9 minutes for IO. Investigators conclude that use of the B.I.G. was more rapid and successful with fewer complications than saphenous cutdown.

**Kalappanavar NK, Kesaree N, Banapurmath CR. Simplified intraosseous needle. Indian Pediatr 2001; 38: 378-80**
Brief report on the development of 18G and 22G IO needles in India.

Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.

**YEAR: 2000**

Study comparing 4 IO devices (FAST-1, B.I.G., Sur-fast, and Jamshidi) used by 31 Navy Seals Special Operations personnel. Results: 29 of 30 FAST-1 insertions successful, mean placement time 114 ± 36 seconds; 30 of 31 B.I.G. insertions successful, mean placement time 70 ± 33 seconds; 31 of 31 Sur-fast placements were successful, mean placement time 88 ± 33 seconds; 30 of 31 Jamshidi insertions successful. Participants rated no one device significantly better than the others.

Nursing article discussing the role of IO infusion when peripheral veins are collapsed. Describes advantages of IO, including ready availability, ability to establish vascular access without interrupting CPR.

Literature review of safety and efficacy of IO infusion of drugs and fluids, with emphasis on utility for the injured soldier. Discusses insertion times and flow rates. Includes literature citations from non-military studies in pediatrics, animals, and human cadavers.


Brief review of the discovery and evolution of IO access in emergency care.


This article reports the first 50 uses of the Pyng F.A.S.T.1 sternal IO infusion system in adults. Six emergency departments and 5 EMS systems participated. Results showed the overall success rate for the system was 84%. Success rates were 74% for first-time users and 95% for experienced users. Mean time to vascular access was 77 seconds.


Overview of pediatric IO infusion targeted for an EMS/paramedic audience. Discusses anatomy of long bones, indications, advantages, contraindications, steps for insertion, fluid administration and ongoing assessment and documentation.


A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient.


Study comparing B.I.G. and Jamshidi IO needle in an EMS training program. 38 EMT trainees performed the insertion. Time to placement was 12 seconds for the B.I.G. and 17 seconds for the Jamshidi needle. There were no statistical differences in ease-of-use ratings between the devices.


Brief overview of IO infusion for an anesthesiology audience. Discusses technique, indications, contraindications, equipment, anatomical target sites and potential complications.

YEAR: 1999


A retrospective non-comparative study of IO infusion in 41 children. Concludes that IO insertion is an easy technique. Recommends IO for emergency cases when other vascular access techniques have failed in the first 5 minutes of treatment.

Abstract

Daga SR, Gosavi DV, Verma B. Intraosseous access using butterfly needle. Trop Doct 1999;29(3):142-4

Evaluation of the utility of 18-gauge butterfly needles for IO administration of fluids and drugs in 23 children presenting in shock. 22 of 23 children were successfully stabilized after IO infusion.

Abstract


Nursing article describing the FAST-1, directions for use and device removal.


Observational study in 27 newborns, describing 30 intraosseous lines placed after failed IV access. Reports that all patients survived the resuscitation procedures with no long-term side effects.

Patent application for a device and method for rapid access to the bone marrow for the infusion of drugs and other fluids into the bone marrow. US Patent issued on October 5th, 1999.

**YEAR: 1998**


Study comparing placement of Cook and Jamshidi IO needles in turkey bones.


Review article discussing techniques for venous access in the pediatric patient includes anatomical target sites, clinical indications, advantages and disadvantages.

Review

**YEAR: 1997**


Seminal study on the use of the B.I.G. in elective and emergency situations in 50 adult patients. Success rate for IO insertion was 100%. No complications were observed.

**YEAR: 1996**

Brandt MR. [Intraosseous administration]. Ugeskr Laeger 1996;158(40):5638. Danish

Article in Danish


Discusses indications, contraindications, method of supervision, and complications intraosseous infusion. Concludes that intraosseous infusion is an attractive alternative to the intravenous route in emergency situations.


Article describing IO infusion 18 pediatric resuscitative situations. Authors conclude that 11 patients would not have survived without IO access. Complications included a minor fracture, 1 case of compartment syndrome that did not require surgical intervention and a minor fat embolism that was of no clinical significance.

**YEAR: 1995**


Study comparing extravasation rates and insertion complications between threaded and non-threaded IO needles. Needle type did not affect extravasation rate under ideal conditions. Common complications during stressful emergency situations included insertion difficulty and accidental penetration of both cortices of the bone. Concludes that these complications may lead to extravasation.


Article in French.

No abstract available


Suggests that intraosseous infusion is reliable alternative to peripheral vein access for rapid infusion of fluids in neonates and infants when venous access is impossible.

Abstract only
Intraosseous Vascular Access Bibliography

Infusion Devices


Case report of IO access in a non-emergency situation. A blood transfusion was performed with no complications in a severely anemic 1-month old infant with an 18 G IO needle (Cook).

YEAR: 1994


Study of IO training for advanced life support providers. Providers were able to establish IO access in 13 of 15 (87%) of pediatric patients (age range 1-24 months) following completion of an 1-hour training course and supervised hands-on simulation. All procedures were performed in less than 10 minutes.


Describes causes and treatment of hypovolemic and septic shock. Discusses techniques for intraosseous puncture and infusion. *Article in German - abstract only*

Banerjee S, Singhi SC, Singh S, Singh M. The intraosseous route is a suitable alternative to intravenous route for fluid resuscitation in severely dehydrated children. *Indian Pediatr* 1994;31:1511-20

Study of IO vs. IV for administering fluids for resuscitation in 60 children (age range 3-24 months) with severe dehydration. The IO route was successful in all cases within the first 5 minutes of attempt. The IV line could not be secured in 33% of patients within 5 minutes. Time for successful IV access was 129 seconds, significantly longer than time t for IO cannulation. Fluid infusion through either route was equally effective in stabilizing vital signs and normalizing laboratory values. No significant complications of IO route were noted on short-term follow-up.


Review of IO infusion in children 6 years old and younger. Recommends IO for patients with life-threatening conditions requiring immediate vascular access. Reports less than 1% complication rate.


Describes design process and results for a high-pressured infusion system intended for automating external infusions in emergency situations.


Case report of compartment systems following improper intraosseous infusion technique.


Discussion of IO infusion, including ease of use, low complication rates, and variety of fluids and drugs that can be administered through the IO route in children and adults.


This abstract describes clinical use of the SurFast Cook Critical Care IO needle. Thirty-two IO insertion attempts were made, 87.5% were successful on first attempt. Average time to insertion was less than one minute; flow rate for infants and children was 1-2 mL/kg/min; flow rate for adults was 150-200 mL/min. There were two reports of minimal extravasation.


Describes frustration associated with difficult venous access. Recommends intraosseous infusion technique as a non-collapsible vein for parenteral infusions.


Review article suggesting that IO infusion should be the primary technique of intravascular access in infants for pediatric resuscitation and the first alternative technique for vascular access after failed intravenous access in young children. *Abstract only*
Intraosseous Vascular Access Bibliography

Infusion Devices

Seminal article describing alternatives to intravenous cannulation including intraosseous access, intratracheal drug administration, sublingual and intralingual injection, intra-penile administration, and intracardiac injection. Concludes that the intraosseous method is an effective alternative to intravenous access in emergency situations.
Review

Review
Review of the history, insertion techniques, available devices, and applications of the intraosseous infusion as well as the indications and contraindications for intraosseous infusion in all critically ill patients.

YEAR: 1993

Letter to the editor recommending intraosseous infusion only for truly urgent situations.

YEAR: 1992

Article promoting increased awareness of intraosseous infusion, familiarity with IO insertion techniques, and careful use of anatomical landmarks.
Abstract only

Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure.
Abstract only

A review of intraosseous infusion and the possible applications in pediatric emergency medicine.
Abstract only

YEAR: 1991

A review of the use of IO infusion in children and the potential complications.
Abstract only

YEAR: 1990

Case reports in 2 children finding IO infusion of vecuronium allowed for successful rapid sequence induction/intubation.

Case report of IO infusion for induction and maintenance of anesthesia in an infant with other IV access.
Intraosseous Vascular Access Bibliography

Infusion Devices

Preclinical study of an implantable intraosseous infusion device (the osteoport) in a goat model. The device allowed for ready access to the vascular system through intraosseous infusion fluids and medications. IO infusion may result in fewer complications than conventional methods of vascular access.

YEAR: 1991

Article for nurses on intraosseous infusion as an alternative to intravenous vascular access presented in a question and answer format.

Review article discussing aspects of intraosseous infusion, including indications, technique, and pharmacokinetic factors. Concludes that multiple drugs and fluids can be safely administered through the intraosseous route.

Describes the design of a larger and more user friendly sternal intraosseous needle for bone marrow aspiration.

Review of indications and benefits of intraosseous infusion. Concludes IO access may be especially valuable for medical personnel who rarely care for critically ill children because the IO technique is easily mastered even with limited practice.

Review of intraosseous vascular access targeted for an oncology audience. Describes an implantable IO device with potential to make intraosseous access more convenient for the patient.

YEAR: 1990

Review of the use of intraosseous infusion in children in the prehospital setting and in the emergency department. Outlines anatomy, indications and contraindications, technique, complications and role of intraosseous infusion in pediatrics.

Preclinical study comparing a sternal IO infusion device to IV fluids for resuscitation. Blood pressure and cardiac output were normalized at 10 minute post infusion in both groups. Advocates use of IO infusion as a way for pre-hospital rescuers to consistently incorporate fluid therapy in their scoop and run policies.

Concludes that infusion of fluids and drugs can be readily performed with the intraosseous technique.

Nursing article describing intraosseous infusion techniques and benefits.

Discusses method for teaching the IO technique using chicken legs. Format combining lecture with lab practical allows for IO technique to be taught quickly and inexpensively. Suggests turkey legs or beef ribs with thin bone cortex as alternatives to chicken legs.
Intraosseous Vascular Access Bibliography
Infusion Devices

YEAR: 1989

Study of 22 cardiac arrest patients arriving at the Emergency Department with no or insufficient intravenous access. Intraosseous needle placed and flow established in less than 1 minute in all patients. Observed flow rates of 5 to 12 mL/min with pressure bag attached. IO needle placed in the medial supramalleolar.

Preclinical study of IO infusion in a swine model. Concludes that IO infusion holds potential as a first line of action for fluid resuscitation in pediatric subjects.

Review article for a nursing audience presenting a brief historical overview of IO technique and insertion methods, with discussion of clinical applications and nursing management aspects.

YEAR: 1988

Description of IO infusion technique, site selection, procedure, anatomy, physiology, historical perspectives, contemporary research, indications, contraindications, complications, and future direction.

Retrospective chart review of 33 pediatric patients finding 83% success in establishing IO infusion. IO and percutaneous peripheral catheterization were the quickest methods for vascular access. Observed no major and minimal delayed complications.

This article describes the Kormed/Jamshidi disposable Illinois sternal/iliac needle as well suited to establish intraosseous vascular access in the pre-hospital and hospital setting.

Case report of anesthetic induction through IO administration of succinylcholine chloride, atracurium besylate, and thiopental sodium in a child with seizure activity.

Article for emergency nursing audience describing IO technique, anatomy, absorption rates, clinical indications and contraindications, technique, complications and training in critically ill or injured infants and children.

Preclinical study finding IO infusion of hypertonic glucose and dopamine to be as effective as IV administration.

Nursing article recommending IO early in the treatment of critically ill or injured children with difficult venous access. Highlights speed and ease of IO technique.

Article discussing IO infusion and associated rapid intravascular absorption of solutions.

Comparison study of success rate in establishing IO infusion in anesthetized piglets with 4 types of IO needles: standard hypodermic, spinal, bone marrow, Turkel. Practitioners were 24 medical residents with no prior experience in IO technique. Overall success rate was 67.7%. There were no statistical differences in success rate among the 4 different types of needles.
**Intraosseous Vascular Access Bibliography**

**Infusion Devices**

**YEAR: 1987**


Review article on IO infusion, includes historical background, physiology, method, clinical applications and complications of the IO procedure.

**YEAR: 1986**


Review of medical literature and research on the problem of difficult intravenous access.


This article describes case reports and also a study comparing 3 types of needles for IO insertion: spinal needles, standard IV needles, and bone marrow aspiration/biopsy needles on a pediatric cadaver leg. The bone marrow aspiration needle was easiest to insert. The clinical cases described 5 adult and 10 pediatric IO patients with insertion at the "medial malleolus." Authors conclude that IO infusion is a safe, rapid way to access the venous circulation, providing a stable, usable fluid line in dehydrated pediatric patients. *(Often referred to as distal tibia.)*


Evaluation of a sequential protocol comparing femoral vein catheterization, saphenous vein cutdown, and IO (in order) when conventional IV access was impossible in a pediatric patient population. Found that IV access was attained in 4.5 minutes when the protocol was followed, compared to 10 minutes when protocol was not followed. Suggests that IV access should always be attained in 5 minutes or less.


Discusses rediscovery of intraosseous infusion as a straightforward technique for an extremely difficult clinical problem. Suggests that many fluids and medications can be administered via the IO route.


Discusses IO route as a safe, proven, and technically easy method for administration of replacement fluids, blood products, and resuscitative drugs. Presents value, historical context, technique, and complications of the IO infusion.


Case report of child with status epilepticus. IO phenytoin resulted in seizure resolution and therapeutic serum levels of drug.

**YEAR: 1985**


Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.


Letter to the editor asserting that while the Turkel trephine technique may stabilize the IO needle better and minimize fluid leakage into the subcutaneous tissue, few physicians are familiar with the technique and it is more time-consuming than using a standard bone marrow needle or standard hypodermic needle.

**YEAR: 1984**


Case report of continuous IO infusion of dopamine hydrochloride and dobutamine hydrochloride in a 6 month old infant. Concludes that IO infusion is efficacious and complications rare.

Turkel H. *Emergency infusion through the bone. Military Medicine* 1984;149:349-50

Article for military medicine audience concluding that the intraosseous route is more safe and effective than the intravenous route for several clinical indications, including burns and shock, circulatory collapse, uncooperative patients, patients in transit, shortage of physicians, especially under emergency conditions. States that IO infusion is an established alternative to intravenous infusion.
**Intraosseous Vascular Access Bibliography**

**Infusion Devices**

**YEAR: 1954**

*Pillar S. Re-emphasis on bone marrow as a medium for administration of fluid. N Eng J Med 1954;251(21):846-51*

Recommends IO for administering fluids, with the iliac crest as the preferred anatomical site.

**YEAR: 1952**

*Tarrow AB, Turkel H, Thompson MS. Infusions via the bone marrow and biopsy of the bone and bone marrow. J Anesthesiol 1952;13(5):501-9*

Article for an anesthesiology audience discussing the extensive blood supply within the bone marrow and the utility of IO anesthesia administration.

**YEAR: 1947**


Describes a sternal trocar and cannula designed to prevent accidental penetration of the mediastinum.


Early article on IO puncture and infusion, emphasizing technique. Concludes their technique is safer and more effective than previously described techniques.

**YEAR: 1946**


Historical article discussing refinements in IO technique and analysis of IO complications. Includes case report of an infant who developed osteomyelitis subsequent to IO infusion.

**YEAR: 1944**


Recommends IO cavity of the manubrium as useful as IV for anesthetic infusion.


Describes a simple method of bone marrow transfusion using a specially designed needle that is more safe and effective than intravenous needles.


Early observational study on IO infusion at the Children’s Hospital of Akron, OH.

**YEAR: 1943**

*Macht D. Studies on intraosseous injections of epinephrine. Am J Physiol 1943;138(2):269-72*

Study of the clinical effects of intraosseous, intramuscular and intravenous injections of aqueous versus oil solutions of epinephrine.


Early study finding comparable circulation times between IV and IO infusions in 21 subjects.

**YEAR: 1942**

*Doud E, Tysell, J. Massive intramedullary infusions JAMA 1942;120(15):1212. doi:10.1001/jama.1942.82830500006010c*

This article discusses use of the medullary route for massive replacement therapy when the usual methods of administration and not available or practical. The article also reviews a case study of a man in receipt of a sternal puncture needle inserted into the medullary cavity where he received the infusions through this needle of whole blood and fluids.
Papper EM. The bone marrow route for injecting fluids and drugs into the general circulation. Anesthesiology 1942;3(3):307-13
Discusses IO infusion, pioneered by Tocantins, as a viable route for parenteral fluids, drug therapy, and anesthesia. Includes case reports.

YEAR: 1941

Early study of 4 patients with acute failure of the peripheral circulation. IO infusion of blood, fluids, or drugs via the bone marrow resulted in a prompt recovery from the state of collapse. Recommends IO route when peripheral veins are not available and a fluids are urgently needed.

Tocantins LM, O'Neill JF. Infusions of blood and other fluids into the general circulation via the bone marrow. Surg Gynecol Obstet 1941;73:281-7
Clinical study of 52 IO infusions of fluids in 40 patients (33 adults and 7 infants). Found no local, constitutional, immediate, or delayed reactions accompanying or following any infusion.

YEAR: 1940

Clinical study finding that IO infusion for parenteral therapy was successful in 16 of 17 trials in 14 patients. Found that citrated blood, plasma, glucose and salt solutions could be infused with no complications.

Seminal study demonstrating that substances injected into the IO cavity of the tibia of the rabbit and the sternum of man immediately appeared in the central circulation, similar to IV administration.

YEAR: 1922

Seminal article on blood circulation in the IO space. Demonstrates movement of red blood cells from the bone marrow into the circulating blood by perfusion of the tibia of the dog and by injections into the bone marrow in the rabbit and cat.
Intraosseous Vascular Access Bibliography

**YEAR: 2018**


This paper is a letter to the editor describing successful insertion of EZ-IO in a neonate weighing less than 2 kg with respiratory failure, signs of sepsis, and shock. After successful insertion the patient was resuscitated and later stabilized. The authors advise that IO access is safe, effective, and attainable in all age groups despite FDA approval only in patients greater than 3 kg.


This is an article published in a Turkish nursing journal and written in Turkish. From the abstract, the IO route is described as an alternative approach to vascular access when venous access via a peripheral catheter cannot be obtained quickly. Complications of IO access and how to prevent them using nursing interventions are discussed. EZ-IO is discussed in the article.

**YEAR: 2017**

Afzali M, Kvisselgaard AD, Lyngeraa TS, Viggers S. Intraosseous access can be taught to medical students using the four-step approach. BMC Medical Education 2017;17(30):doi:10.1186/s12909-017-0882-7. (Denmark)

This study evaluated the ability to teach the skill of IO access in a four hour timeframe to medical students using a modified Walker and Peyton’s four-step approach teaching method and a cadaveric model. The learner’s competencies were evaluated with an objective structured clinical examination checklist. This study found the teaching method was successful. Authors recommend repetitive training to be integrated to medical curriculum for maximal skill retention.


This case report describes a complication of a laceration that occurred in an 85 year old morbidly obese female that presented in septic shock and received a proximal tibial IO placement. A 45 mm needle set was used for the initial insertion, which was completed without any initial problems; no stabilizer was placed. The patient had fluid resuscitation via the IO site with rapidly improved hemodynamics. During transport she developed a 7 cm laceration across the IO insertion site. The catheter was removed and laceration sutured. Authors opined that the lack of use of the EZ-Stabilizer dressing, the amount of soft tissue and thin skin and traction forces on the IO site applied during transport contributed to this complication.


This case report describes a CT angiography of the chest and abdomen done via an EZ-IO catheter placed in a critically ill patient’s proximal humerus. The contrast media was infused at a rate of 4 mL/s and the infusion pressure never exceeded 300 mmHg. No immediate or short term complications were observed. The authors describe the overall image quality and vessel contrast observed as excellent.


This article describes a retrospective, CT-assisted evaluation of IO cannula placement. Over a 5 year period all multislice-CT trauma scans performed in a trauma center were monitored for intraosseous devices in situ. 982 patients were evaluated and 13 IO cannulas were found in 11 patients. In all cases, the EZ-IO device was used. Evaluation of placement found that all applications were placed correctly, but none were according to current guidelines. The site of puncture deviated in all cases with the most common error of overshooting during needle introduction. (Article in German)


This study evaluated the efficacy and safety of Shengxue mixture when combined with IO blood infusion for the treatment of aplastic anemia patients at Shaanxi Medical University in China. Patients were treated with oral Shengxue mixture, stanozolol tabs, mycophenolate and IO infusion of recombinant human EPO, G-CSF, IL-11, and dexamethasone. After 1 month of treatment the response rate was 90.57%. After 3-6 months the response rate was 96.23%. The authors concluded that Shengxue mixture combined with IO infusion was a fast, efficient, and safe method of treatment of aplastic anemia. Article in Chinese.


This paper describes skill sets and training for the Defence Medical Services in the UK, specifically the revised Military Higher Module and how it will be implemented in the future either during deployment or times of peace. IO devices as a means to control catastrophic haemorrhage is listed as a competency.
Intraosseous Vascular Access Bibliography
International


Using a porcine hind leg model authors compared the success rate and ease-of-use ratings of an IO device, the NIO® in comparison to the Arrow® EZ-IO by novice users. NIO success rates were comparable to those of EZ-IO; 54% of the participants preferred using the EZ-IO over the NIO.

YEAR: 2016


The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.

Singapore


This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.

Poland


In this letter to the editor authors discuss the difficulties of obtaining vascular access in patients in shock; and make a case for use of intraosseous access (IOA) in shock. Authors note IOA access as a safe, effective alternative to venous access with relatively rare complications.

Poland


This study was conducted to determine the level of experience as well as the beliefs and attitudes of trauma practitioners in Canada, Australia and New Zealand about using IO devices in adult trauma patients. The study used a web-based survey submitted to 1771 to all members of 4 national emergency and trauma organizations. Surveys were completed by 425 participants and most participants surveyed were comfortable using the IO device in resuscitation of adult trauma patients.

Great Britain


This preclinical study compared arterial and intraosseous derived biomarkers to determine if the results would correlate well enough over a period of 6 hours to consider use of IO derived blood when traditional samples are difficult to obtain. Authors noted there were no clinically relevant average differences between alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase, creatinine kinase and gamma-glutamyl transferase values which may be good enough for initial estimates of these markers analyzed in intraosseous and arterial samples. However the lactate dehydrogenase levels showed less correlation; and the precision of IO samples may be limited.

Great Britain


Literature review on contemporary practices of intraosseous (IO) vascular access in adult patients.

Great Britain


This article in German describes a case study of a 3 year old child with a serious heart defect (after total cavopulmonary anastomosis) in which bilateral humeral IO access sites were obtained to manage her condition and the patient was discharged after 30 days without neurological deficits. Key messages include that IO access in children should be a primary access route in emergent and urgent situations, unless a suitable venous access is already available; the humeral head insertion site is an accepted method in emergency situations in adults and children; and IO access is intended for regular emergency administration of drugs. The purely preventive use of an IO is not indicated. Article in German.

This reports a case of left lower extremity compartment syndrome in a multi-trauma patient that received bilateral proximal tibia IO catheters. The patient had 1L crystalloid and 2 units of packed red blood cells infused into his left IO tibial site. While in the operating room the team noticed the left leg was tense and swollen. He was diagnosed with compartment syndrome and fasciotomies were done. A left fibula fracture was also discovered but authors do not believe that or the soft tissue injuries present were enough to cause the compartment syndrome.


This article describes an experimental study to determine patient perception of discomfort during IO injection for dental procedures involving the mandibular molars. Subjects (N=70) received either IO injection (N=35) or inferior alveolar nerve block (N=35) with articaine/epinephrine. Both groups reported similar rates of supplemental injection (P=0.80) while the IO group reported less perceived discomfort (P=0.00), differing statistically.


This letter to the editor describes a novel training technique employed to provide training to clinicians on use of the EZ-IO system, in 15-minute sessions. Implementation of this program has resulted in 97% of participants reporting an increase in confidence using the EZ-IO system and 100% were able to correctly identify the locations of the devices for their clinical areas.


This article reports the results of a systematic review using PubMed for current evidence through 2015 for intraosseous (IO) vascular access use in adults requiring resuscitative procedures. General anatomy, indications and contraindications and available devices are discussed. Authors determined IO infusion is indicated in all critical situations with difficult vascular access; contraindications are few; and serious complications uncommon.


A cadaveric study evaluating the function and safety of a manual, screw IO device designed to gain access to the medullary space. Twelve insertions were performed by the same device operator, of which 10 were successful. The 2 failed insertions were due to overshooting of the needle. The authors concluded the new device could successfully penetrate the bone cortex in adult cadaver bones, and that further testing and comparison to commercially available devices is needed.


A survey study evaluating the perception and use of intraosseous vascular access among nurses in Poland. The study included 210 respondents. Fifteen (15) had previous experience with IO access and 10.9% had received intraosseous access training, suggesting a low level of knowledge. The authors concluded that providing intraosseous vascular access training to nurses will help improve their perception of IO access.


In this porcine study IO and venous samples were analyzed for thromboelastography (TEG), prothrombin time (PT), activated partial thromboplastin time (APTT) and fibrinogen concentration. The IO samples were clinically hypercoagulable, rendering some samples un evaluable; clinically relevant differences were observed for APTT but not for PT and fibrinogen and the TEG demonstrated a shortened reaction time. The ability to use IO drawn blood for coagulation studies may be limited.

This randomized crossover manikin trial compared the NIO and EZ-IO devices for time to placement and ease of use. For both parameters the NIO performed better.

Poland


A questionnaire study among sixty junior doctors, in Poland, regarding their knowledge of intraosseous vascular access. The authors concluded the level of knowledge was insufficient.


A manikin study in which 40 paramedics dressed with and without CBRN PPE attempted to establish tibial intraosseous (IO) access using the jamshidi and BIG devices, time to placement was measured. Results showed that in participants with and without CBRN PPE, BIG access was faster than Jamshidi.


A prospective study comparing use of the NIO device by 84 paramedics to establish proximal humerus and proximal tibia intraosseous (IO) access for first attempt success rate, time to access, and user feedback on ease of use and preference. IO access was established in fresh (within 72 hours of expiration) cadavers. The first attempt success rate with tibial IO access was 89.3% vs 73.8% humeral; procedure time was significantly faster for the tibial IO site; and participants found IO access in the proximal tibia as easier to obtain than the proximal humerus IO site.


This letter to the editor describes a prospective, randomized, cross-over cadaveric study that evaluated use of the EZ-IO and NIO devices by novice paramedic device users. Following a brief in-service on use of both devices and practice insertions using a leg-trainer manikin, each participant attempted to establish IO access using each device in a resuscitation simulation with in an adult cadaver with CPR in progress. Results showed first attempt success rates of 97.4% with the NIO and 100% with the EZ-IO; and mean time to insertion was 16.8 seconds with the NIO and 42 seconds with the EZ-IO.


This article describes a questionnaire study regarding knowledge and application of intraosseous vascular access among 420 clinical medical staff in 8 Beijing Hospitals. Based upon results of the questionnaire, the authors concluded that the awareness rate of intraosseous infusion in Chinese medical staffs and carry-out rate in the hospital is very low and strengthening of knowledge and training is necessary.


A simulation study comparing use of peripheral IV access and tibial intraosseous access via the NIO device, by internal medicine specialists. Forty-three participants attempted to establish access using the two methods in a manikin; first attempt success, time to access and ease of procedure were measured. The NIO device was superior to IV device with regard to all endpoints.

YEAR: 2015

Eriksson M, Strandberg G, Lipcey M, Larsson A. Intraosseös provtagnings kan vara vardefull i akuta lagen [Intraosseous sampling can be valuable in emergency situations]. Lakartidningen 2015 Feb 24;112pii:DCR3. Swedish

This article in Swedish describes a study evaluating use of aspirate obtained from the IO space for laboratory analysis. The authors note that point-of-care equipment should be used for analysis. Creatinine, morphine and troponin was successfully analyzed; leucocytes and platelets were noted to possibly cause falsely elevated values.
Intraosseous Vascular Access Bibliography


A preclinical study in which 8 anesthetised swine were put into an induced septic shock state to allow troponin I level measurements to be compared from serial venous plasma, arterial plasma and intraosseous aspirate specimens collected hourly. Two milliliters of IO aspirate were wasted before collecting each IO specimen for analysis. The levels of IO troponin I increased during the first 3 hours of shock but then plateaued at a high level while the venous and arterial levels continued to increase. Authors concluded that troponin I can be analyzed in bone marrow aspirates in a shock model and that this information may be useful in medical emergencies where cardiac damage is suspected to be involved.


A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.


Retrospective analysis of IO needle insertions performed in all HEMS missions during the first three years (2009-2011) using the EZ-IO®system. Overall success rate of EZ-IO procedures (N=348) was 98.6%, with a first attempt success rate of 85.9%; and high user satisfaction rate of 93%. IO as access was mostly second line overall but first line in children <7, trauma and cardiac arrest. There was one failure and four needle insertion problems noted; no serious complications.

Germany


A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.


A simulation study comparing use of manual (Cook Medical) and mechanical (Arrow EZ-IO) intraosseous (IO) devices to establish IO access in mannequin bones representing infant, pediatric and adult tibias. Twenty-two anesthesiologists with no prior experience with IO devices participated in the study. The outcome measures were success rate, insertion time and operator reported difficulty of use. Results were in favor of the mechanical device for insertion time in each category, and success rate in the adult tibia group; there was no statistical difference in the difficulty of use evaluation.


Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) antibiotic (cefotaxime and gentamicin) concentrations during septic shock. Both methods of administration yielded comparable concentrations. Authors concluded in an emergency, IO administration of these antibiotics may be considered in severe infections when venous access is impractical.

Sweden


This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.


This is a review article written in the Chinese language describing intraosseous vascular access.

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This article in French is a survey of residents and doctors in France that practice in ED, ICU and anesthesiologists units seeking their opinions and practice habits in regard to IO access. Only 29% had ever used an IO kit; with a correlation between years of experience in practice and use of IO access. 555 had received some IO access training; 90% of untrained doctors believed training was necessary. The powered system was the most utilized (EZ-IO).

France


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.

Zambia


This article describes a case study of a 31-month old infant that suffered hypovolemic shock due to severe epistaxis. After several failed peripheral and central line attempts an 18g needle was inserted intraosseously through the proximal tibia. The child received 300 mL of Ringer’s Lactate in one hour then 200 mL of blood via the IO route by syringe boluses resulting in improvement. Cloxacillin was also administered IO as prophylaxis for infection. Authors conclude an IO blood transfusion should be the immediate intervention in similar life-threatening situations.

Canada

Cheung WJ, Rosenberg H, Vaillancourt C. Barriers and facilitators to intraosseous access in adult resuscitations when peripheral intravenous access is not achievable. Acad Emerg Med 2014;21:250-6. doi:10.111/acem.12329

This survey study sought to identify the barriers and facilitators to use of intraosseous vascular access for adult resuscitations when peripheral IV (PIV) access is not available, among physicians from various clinical care settings in 3 teaching hospitals in Ottawa, Ontario. Completed survey responses were received from 205 physicians; results suggest that to increase IO use educational interventions need to address their attitudinal, normative, and control beliefs. Specific beliefs that act as barriers are described.

Craiu M, Stan V, Chochino AV. Intraosseous access—A classical method for vascular access that regains an important role as resuscitation tool. Ro J Pediatr 2014;68(3):233-7. Romanian

This article reviews the initial development of IO access and provides an overview of IO use in pediatric populations including insertion technique, side effects, and contraindications.

English and Romanian article


This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK


This letter to the editor describes a single case of a needle breaking off after a proximal tibial insertion of the EZ-IO into a volunteer (one of the letter’s authors) during a training session. “Divergent from manufacturer instructions the sterile steel stylet was put back into place to achieve better grip for a manual pull-out. Under steady pull in strict axial alignment and gentle clockwise turn, the needle broke away from the plastic connector”. The needle was extracted using combination pliers and there is no evidence of damage to the leg. Authors acknowledge this can be avoided by adherence to manufacturer’s directions for use.

Germany
Intraosseous Vascular Access Bibliography

International


This was a prospective, randomized controlled clinical pilot study comparing the BIG and EZ-IO intraosseous (IO) vascular access devices in 52 adult patients admitted to an emergency department with difficult peripheral venous access. Twenty-six patients were randomized to each device; results were first attempt insertion success BIG 92.3%, EZ-IO 84.6% (P=0.668); procedure time: BIG 2.8 ± 1.2 seconds, EZ-IO 5.2 ± 2.2 seconds (P<0.001), significant; difficulty of use (with visual analogue scale): BIG 8.6 ± 6.4 mm, EZ-IO 25.4 ± 12.6 mm (P<0.001), significant. Authors concluded both EZ-IO and BIG are shown to be reliable and safe methods for insertion of intravascular access in emergency conditions. There were no adverse events or complications reported.

Turkey

Derikx HJGM, Gerritse BM, Gans R, vander Meer NJM. A randomized trial comparing two intraosseous access devices in intrahospital healthcare providers with a focus on retention of knowledge, skill, and self-efficacy. Eur J Trauma and Emerg Surg 2014; doi:10.1007/s00068-014-0385-8

This article describes a randomized trial comparing the retention knowledge, skill and self-efficacy among anesthesiologists and registered nurses of anesthesia with use of the EZ-IO and Bone Injection Gun (B.I.G.). Participants were randomized to be trained on one device and were tested at 0, 3, and 12 months post training. The authors concluded that training anesthesiologists on use of the EZ-IO with the educational tools provided by the manufacturer will ensure optimal performance for a period of one year.

The Netherlands

Egypt


The objective of this study was to use a competency exam to compare different emergency skills and knowledge between out of hospital emergency physicians (OOHEP) and those who are not OOHEP at the time of their mandatory biannual refresher courses. Results from 836 respondents suggested that OOHEP are significantly more likely to initiate intraosseous access, initiate mild-therapeutic hypothermia, and had higher knowledge about the used defibrillator.

Austria


A cadaveric study performed by dentistry and medical students evaluating the feasibility of gaining vascular access via the anterior mandible bone.


This article discusses use of IO access in adults in children with regard to implementation, indications, problems and risks.

German

Ibrahim M, Cairney K. A comparison of intravenous and intraosseous vascular access during simulated cardiac arrest on an Advanced Life Support course. Resuscitation 2014;85S:S20

This abstract describes a simulation study that evaluated the time to access and rate of first attempt success for establishing IV and proximal humerus IO access in an ALS training course. Thirty-three participants had a first attempt IV success rate of 70% compared to a 100% success rate with IO access. The authors concluded that successful humeral IO access can be achieved following a short education intervention.

UK

Manikin study conducted in Poland with 107 paramedic operators designed to investigate the success rate, time of insertion and perceived difficulty of intraosseous access devices during simulated resuscitation using the EZ-IO, Bone Injection Gun and Jamshidi needles. Results were first attempt success: B.I.G.: 91.59%; EZ-IO: 82.66%; Jamshidi: 47.66%; mean procedure time: B.I.G.: 2.0 min ± 0.7; EZ-IO: 3.1 min ± 0.9; Jamshidi: 4.2 min ± 1.0; and ease of use (1-very easy to 5-very hard): B.I.G.: 1.83; EZ-IO: 2.92; Jamshidi: 4.68.


The objective of this study was to evaluate inclusion of IO access in Korean medical education with a selected group of 50 medical students. Students received 1 hour of didactic lecture and a 1 hour hands on session using the EZ-IO and artificial tibias and were tested. Results showed an insertion success rate of 88%. The authors concluded IO access was adequate for medical education in Korea.


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FASTI IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.


Case study of 36 year-old in septic shock with co-morbidities of IV drug abuse, endocarditis, tricuspid valve insufficiency and pulmonary embolism. Initially impossible to obtain PIV or CVC access; then unable to give desired fluids through 22 gauge PIV when finally placed. Proximal humerus IO access was established with the EZ-IO 45 mm needle set and the patient was resuscitated with 30 mL/kg fluids and multiple medications given in first hour. Conclusions included that CVCs are not always possible and volume treatment with an IO placed sooner rather than later, especially in children but also in adults, can be lifesaving. IO systems should be extensively available throughout the clinical setting. Article in German.


This abstract describes an observational study evaluating use of the intraosseous drill (EZ-IO) in 20 patients assisted by EMS and receiving CPR within a 3 year period. The study includes 4 pediatric and 16 adult patients. The authors concluded that IO access is a reliable alternative to peripheral venous access and can be implemented fast and with high success rate of CPR in which drugs and fluids are given.


This abstract describes a practice seminar held at the 32nd annual meeting of the Japanese Society of Reanimatology for establishing intraosseous vascular access in simulation using the EZ-IO and using Doppler ultrasound to confirm placement. The authors concluded the EZ-IO system enables immediate vascular access to the central circulation and the Doppler method enables objective recognition of needle misplacement.


Retrospective study of the Israeli Defense Force (IDF) registry from January 1999 through October 2012 to identify all cases in which IO access was attempted. The Bone Injection Gun (B.I.G.) was the device used for IO access. A total 37 attempts were made in 30 patients. First attempt success was 53% with an overall success rate 49% when factoring subsequent attempts. Most frequent cause for failure related to providers skill level, and due to the device design allowing little room for error. This study prompted the IDF to seek an alternative for the B.I.G.
International Neuhaus D. Intraosseous Infusion in elective and emergency pediatric anesthesia: when should we use it? Curr Opin Anaesthesiol 2014;27(3):282-7. DOI: 10.1097/ACO.0000000000000069

General review of IO access, with particular attention to perioperative setting and includes published guidelines of the German Scientific Working Group for Pediatric Anesthesia for use of intraosseous access. The author recommends that for children with known difficult venous access physicians discuss the possibility of IO access preoperatively with the family.

Switzerland Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4
Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, "fluids" and calcium. Demarcation of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.

This letter to the editor describes a cadaver study performed by 50 interns who had never performed IO insertion, to determine if there is a learning curve associated with use of the EZ-IO for establishing IO vascular access in the proximal tibia. Following training each intern performed 10 IO insertions and were timed. The results showed a difference between the first and the eighth attempts resulting in a decrease in time to insertion by half. The authors concluded that practice insertions are necessary to become comfortable with the device.

A preclinical study comparing the recovery of fibrinogen in a porcine model when fibrinogen concentrate is administered via IV and IO access. The study results suggested intraosseous administration of fibrinogen concentrate results in a recovery of fibrinogen similar to that of intravenous administration.

This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).

A questionnaire and interview study evaluating the reasons paramedics do not perform intraosseous (IO) vascular access more frequently. Twelve paramedics in Johannesburg, South Africa were interviewed for the study. Results suggested access to inappropriate equipment (pink hypodermic needles), inadequate training, lack of use in hospital Emergency Departments to which they serve, and the perceived invasiveness of the procedure and pain caused during infusion dissuaded paramedics from performing the procedure.

This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.
Intraosseous Vascular Access Bibliography
International


A survey study assessing the knowledge of members of emergency medical teams in Poznan about the BIG intraosseous device.

YEAR: 2013


This article describes a questionnaire study that was given to UK Role One military clinicians deployed to Afghanistan to assess the level of experience and confidence rating with use of IO access, using the FAST-1 and EZ-IO, and IV access. Thirty-three responses were received; clinicians felt more confident with IV access over IO access; clinicians felt more confident with FAST-1 IO access than EZ-IO IO access.

UK


A letter to the editor reporting a case study of skin necrosis after IO administration of norepinephrine following resuscitation of a 74 years old in septic shock. The EZ-IO was placed to the proximal tibia; approximately 45 minutes post- norepinephrine administration symptoms of necrosis were evident.

Authors cite 3 hypotheses for the cause of necrosis and consider that amines’ high level concentration could induce local toxicity in the bone matrix and artery spasm; suggesting it is necessary to define an upper limit of amines’ concentration that should be administered through IO vascular access.

UK


A questionnaire study in which Scandinavian emergency physicians, anesthesiologist and pediatricians reported complications they have experienced with IO vascular access based on recollection alone. Complications were reported related to establishing IO access and using established IO access. Out of 1,802 IO cases reported by 386 responders, the most frequently reported complications included difficulty with periosteum penetration and bone marrow aspiration when establishing IO access; and slow infusion and needle displacement with established IO access. Osteomyelitis and compartment syndrome were reported with an occurrence of 0.4% and 0.6%. Researchers concluded that potential complications following IO insertion should be addressed during training. Devices discussed included the EZ-IO, BIG, Cook-Surfast, and other unidentified IO devices

Denmark


This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handmade IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult.

Iraq


This article in German explores use of intraosseous access in a dental practice emergency. In a simulation study, dental students attempted to establish standard peripheral IV access and IO access using 3 different devices: EZ-IO, BIG, and manual IO. Results showed the manual was the fastest to insert, however, the EZ-IO had the highest first-attempt success rate as well as the lowest number of total attempts to IO access.

German


This abstract describes a study in which 66 obstetric anesthetists, obstetricians and midwives were training on the EZ-IO and evaluated for successful application of the skill in a mannequin study. The participants also completed a survey following their insertion attempt regarding their perceived ease of use and likeliness to consider IO use in the future. Results showed first attempt success was 95.5%, respondents indicated they found the EZ-IO to be easier than establishing PIV access and 100% indicated they would consider IO use in the future.

UK
Intraosseous Vascular Access Bibliography

International


This abstract describes the results of an online survey taken by members of the Obstetric Anaesthetists’ Association, evaluating use of IO access in obstetric emergencies, and availability of IO equipment on UK labor wards. Results showed many members are trained on IO access, consider it a viable option during emergencies however have limited access to equipment.


In this preclinical swine study, investigators sought to evaluate whether intraosseous blood samples can be used to measure opioids, and if so, to determine the level of accuracy of those measurements. Blood samples were drawn from bilateral tibial IO catheters and from a central venous catheter for six hours. Authors concluded that IO blood samples can be used for the analysis of opioids if an IV route is not available.


This article in Spanish provides an overview of intraosseous vascular access.


This abstract describes a study in which the investigators sought to determine the approximate patient population in which the 25mm EZ-IO needle set was sufficient length to establish IO access in peripartum patients. Ultrasound was used to determine the tissue depth at four insertion sites. Twenty-six women were recruited with a median gestation of 34 weeks. In 88% of patients with a BMI<40 kg/m² the 25mm needle is sufficient to reach the bone marrow at both tibial sites. For the humeral site, IO placement may be more difficult for patients with a BMI>25 kg/m².

**Oksan D, Ayfer K.** *Powered intraosseous device (EZ-IO) for critically ill patients.* Indian Pediatr 2013;50(7):689-91

A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 60 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case).

**Plancade D, Millot I, Fetissof H, et al..** *Sternal perforation with an intraosseous device and hemomediastinum infusion* Ann Fr Anesth Reanim 2013;http://dx.doi.org/10.1016/j.annfar.2013.01.009

A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for sternal use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.


An observational study evaluating use of the EZ-IO by two ground and one air based physician staffed EMS and at a German surgical university hospital between January 1, 2008 and December 31, 2011. The EZ-IO was used to establish IO access 88 times in 87 patients; 83 insertions were performed in the EMS and 5 were performed in the hospital. The proximal tibia was the primary site used (97.7%) and the first attempt success rate was 94%. IO access was the first approach for vascular access in children compared to adults (38.9% vs. 86.2%). There were 5 failures attributed to missed insertions or extravasation and 2 for wrong needle length. There were no serious complications.
Intraosseous Vascular Access Bibliography


Five point summary of things to know about intraosseous vascular access including, use of the IO access for fluid/drug/blood product infusion and obtaining blood samples, possible IO insertion sites, pain management, use during resuscitation efforts, contraindications, and possible complications.


An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal tibia was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse, difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.


This study conducted by the Norwegian Navy evaluated the ability of 25 soldiers to perform buddy transfusion by starting phlebotomy, establishing sternal IO access using the FAST1, and infusing 1 unit of whole blood. Physical performance was evaluated pre and post blood donation and lactate levels were recorded. The authors concluded that physical and combat performances are preserved within limits post whole blood donation and that soldiers are able to learn the phlebotomy and sternal reinfusion with only a short lecture on the procedure.


This observational pre-hospital study conducted in Madrid, Spain prospectively evaluated use of the EZ-IO Jan 2007- Dec 2009 as an alternative to peripheral IV access. During the study period, 107 patients underwent 114 EZ-IO insertions and all were successful on first attempt. IO access was established in the proximal tibia (49%), distal tibia (25.2%), radius (14.9%), and humerus (10.5%) and all lines were the first form of vascular access established in the patient. There were no adverse events or complications.


A study evaluating the use of X-tip intraosseous injection of 2% lidocaine with 1:80,000 epinephrine in dental patients with irreversible pulpitis in whom inferior alveolar nerve block has failed. Thirty patients were included and 93% of X-tip injections were successful. Ninety-six percent of patients had subjective/objective increase in heart rate. Results showed X-tip intraosseous injection of 2% lidocaine was effective in achieving pulpal anesthesia in patients with irreversible pulpitis.


This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 mL of red blood cells via the EZ-IO in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock; and RBC infusions via the IO route are feasible in this age group.


A clinical study comparing Cefazolin concentrations found at the operation site following total knee arthroscopy when prophylactic antibiotics are administered systemically, through IV administration, and regionally, through IO injection directly at the site using the EZ-IO. Subcutaneous fat and bone samples were collected for evaluation from 22 subjects. Authors concluded that regional IO administration of prophylactic antibiotics can achieve tissues levels higher than with systemic administration.
A pre-clinical study that compared the EZ-IO 15 gauge 25mm needle set and the 13 gauge Jamshidi aspiration/biopsy needle when used to obtain core biopsy specimens in canines.

Canada

A pre-clinical study evaluating the systemic bioavailability of antidotes when administered via the intraosseous (IO), intravenous (IV), and intramuscular (IM) routes is described. Results showed rapid and substantial antidote bioavailability after IO administration similar to that of the IV route. Authors concluded that the IO route of antidote administration should be considered when IV access is difficult or impossible.

This article describes a study in which the management of simulated pediatric multiple trauma cases was compared to the 8 tasks validated in a polytrauma training program from Cincinnati Children's Hospital. The authors concluded that primary care pediatricians have difficulty applying the sequence of trauma and cervical screening maneuvers in a simulated setting and that pediatric training programs should strengthen practical initial care for trauma.

A prospective, observational study which evaluated use of the EZ-IO within the prehospital setting over the course of a 3 year period, in Barcelona, Spain. Included patients were in cardiac arrest or with hemodynamic instability, without peripheral venous access after 90 seconds or 3 attempts to establish access. Results showed IO access was attempted in 49 pediatric and adult patients with an overall success rate of 93.9%; complications included extravasation and pain. IO access sites included the proximal tibia (71.4%), proximal humerus (22.4%) and distal tibia (6.1%). The author concluded that IO access is a viable access route for the management of critical patients or those in cardiac arrest in the pre-hospital setting due to the ability to obtain rapid access and the high first attempt success rate.

This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access.

This article discusses a retrospective review of Japanese prehospital system for intravenous infusion success rates in cardiopulmonary arrest (CPA) patients and a prospective simulation study. A nationwide database was reviewed for CPA records from 1 January 2005 to 31 December 2008 yielding 431,968 cases. Results showed the IV infusion success rate in adults increased annually, however the rate in pediatrics did not; and while the administration of adrenaline increased the 1-month survival rate did not. In the simulation study, 100 EMS technicians used the Bone Injection Gun (BIG) in simulator adult, pediatric and infant legs. There was no difference in the time to establish IO access between the simulation models. The authors concluded that IO access should be considered when IV access is difficult or impossible.

A preclinical study evaluating the effects of propofol on selected blood parameters and physiological variables during general anesthesia in rabbits when administered via intraosseous and intravenous routes. Results showed the IO route was as effective as the IV route for propofol administration at doses inducing general anesthesia. The authors concluded that use of IO propofol could be recommended as a safe method of anesthesia in small animals with limited vascular access.

A pre-clinical study that compared the EZ-IO 15 gauge 25mm needle set and the 13 gauge Jamshidi aspiration/biopsy needle when used to obtain core biopsy specimens in canines.

A pre-clinical study evaluating the time to loss of consciousness and effective maintenance of anesthesia following IO and IV administration of propofol in 24 rabbits. The authors concluded that in all evaluated aspects of anesthesia, IO administered propofol was as effective as IV administration in rabbits.

A pre-clinical study evaluating the systemic bioavailability of antidotes when administered via the intraosseous (IO), intravenous (IV), and intramuscular (IM) routes is described. Results showed rapid and substantial antidote bioavailability after IO administration similar to that of the IV route. Authors concluded that the IO route of antidote administration should be considered when IV access is difficult.

A literature review of articles describing intraosseous vascular access devices used in the pre-hospital setting. Twenty articles met the inclusion criteria and described the manual devices, BIG, Fast-1 and the EZ-IO. The authors concluded that the literature suggests that semiautomatic IO devices may be more effective than manual devices.


This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.


This article describes a post mortem study evaluating a newly developed technique to study the intraosseous vasculature of the humerus involving injection of ink directly into the anterior circumflex humeral artery. This technique allowed visualization of the main nutrient artery to the proximal humerus vasculature until they reached articular cartilage or crossed cortical bone again to enter the rotator cuff tendons.


This letter to the editor describes a case in which sternal IO access was established using a Jamshidi needle to administer iodinated contrast for a thoraco abdominal CT on a 61-year old male who presented to the ED with respiratory distress. Picture quality was deemed excellent by the radiologists. The authors conclude that the sternal IO route can be used with excellent picture quality but it should be used only in exceptional cases due to the potential risks of a high-power injection through the bone. EZ-IO is mentioned as an alternative IO device available.

Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14

The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access.

Brazil


This article argues the pros and cons to routinely establishing IV access in anesthetized children. IO access is discussed in the con debate as an alternative to routine peripheral IV access in this population.


This poster presented at the 2012 International Conference of Emergency Medicine described a 4 month review of intraosseous access in UK military operations in Afghanistan. During the timeframe the EZ-IO was used to establish IO access in the proximal humerus and tibia sites; the FAST1 was used to establish sternal IO access. Of the 87 EZ-IO applications there were 12 functional issues and the placement success rate for both sites combined was 86.3%. In 24 FAST1 applications there were 4 functional issues and the placement success rate was 83.4%.


This article is making a case for pediatric anesthesiologists to have IO access equipment readily available wherever children are anesthetized; and for anesthesiologists to consider IO access not only as a last resort but as the route of choice in children requiring urgent vascular access.
Intraosseous Vascular Access Bibliography

International

YEAR:  2011


A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthesia recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anaesthesia by IO access was satisfactory without necessity of other infusion access.

Brazil


This article in German presents a case of a 67-year-old female patient with an arterial bleed and venous access difficulties in whom IO access was attempted unsuccessfully two times using two different IO systems. The author concluded that IO success is dependent upon IO anatomy and physiology knowledge as well as knowledge of the device being used.


This abstract reports a literature review using both MEDLINE and Embase databases up to August 2010 to determine feasibility and safety of IO administration during adult cardiac arrest. Authors reported a lack of literature (only two studies met their level of evidence criteria) but concluded IO access in adults appears to be a fast, reliable method to deliver drugs and fluid during CPR allowing adequate drug concentrations and pharmacological response; and should be considered if other medication delivery methods have failed. (Presented at the March 2011 International Symposium on Intensive Care and Emergency Medicine)


This article in Spanish describes an IO complication case in which a newborn infant developed tissue necrosis as a result of extravasation during IO infusion.


A case study report in French describing compartment syndrome secondary to intraosseous infusion in a 57-year-old burn patient. IO access was established in the proximal tibia on second attempt; both attempts were made in the same limb though it was noted that the first attempt did not penetrate the cortex. Drug and fluid infusion was initiated; ten hours later the limb was found to appear ischemic. The IO catheter was removed and compartment release was performed. The author concluded that IO access remains an important mode of vascular access and that adherence to contraindications and careful clinical monitoring should decrease risk of complications.

France


This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK


German Society of Anaesthesiology and Intensivmedizin eV (DGAnI), includes a general discussion of intraosseous (IO) as vascular access, overview of devices and recommendations for pediatric anesthesia with indications for intraosseous infusion in pediatric anesthesia and perioperative care in children. Early or primary IO indications are respiratory and circulatory arrest; critical hemodynamic instability before or during anesthesia introduction; severe laryngospasm; anesthesia induction in respiratory bleeding. Urgent indications (decision based on each case is necessary) include urgent induction of anesthesia in non-fasted children (Ileus, RSI); induction of anesthesia in children with unstable circulation or severe cardiac insufficiency. Semi-elective indications (decision based on each case is necessary) after mask induction of anaesthesia (if vascular access required); mandatory induction of "intraavenous" anesthesia (as in malignant hyperthermia). This article is in German.


This article in German evaluates use of IO vascular access in rescue missions performed by rescue helicopters of the ADAC (German Automobile Club) Air Rescue as well as the German Air Rescue Service between January 2005 and December 2008. The author concluded that the expanded indication of IO access is relevant in the pre-hospital setting.

Case description of a critically ill 15 day old premature infant weighing 1300 g. Tibial IO access was placed perioperatively for an urgent surgery.


This abstract in German explores the role of IO infusion in emergency cases with venous access difficulties. The author noted that IO access may help minimize the therapy-free period in which vascular access has not been established, and the preclinical rescue time all together.


This article in Spanish describes the Spanish military medical staff's experience with the use of intraosseous lines for fluid therapy in a combat zone from March 2007 to June 2008. Twenty-five patients had an IO placed with the Bone Injection Gun (BIG). Placement success rates were 76% for the 19 pre-hospital placements and 100% for the 6 in-hospital placements. There were no complications during insertion. Conclusion was intraosseous access can provide an alternative to venous access for treating trauma patients in combat zones.


This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.


This article describes a literature review study with the objective of establishing which intraosseous device is best for prehospital use. This short review searched Medline 1950-2010, CINAHL 1982-2010 and EMBASE 1980-2010 and identified two studies meeting their evidence search criteria, one study compared the BIG vs. manual; the second compared EZ-IO vs. FAST-1. The clinical bottom line asserted by the author was traditional manual IO devices have faster, better success rates in the pre-hospital setting; but that more randomized trials are needed to determine the best device.


This study conducted in Germany and Switzerland evaluated use of the EZ-IO in the prehospital setting over a 24 month period. The decision to use IO access was left to the discretion of the onsite clinician, a paramedic or an emergency physician. Results showed IO access was attempted in 77 patients, and was successful on first attempt in 75 patients. Significant pain with infusion was reported in the majority of responsive patients.


This article in German concludes that the introduction of IO in pre-hospital pediatric emergency system has markedly reduced the number of critically ill or severely injured pediatric patients without vascular access or with less reliable alternative administration routes in the last 20 years.


In this pre-clinical study, IO and arterial blood samples were collected over a 6-hour timeframe from the tibia of anesthetized swine, analyzed using an iStat and compared. Results showed compliant values between IO and arterial blood for electrolytes, hemoglobin, pH, and pCO2. Lactate, BE, PO2 and SO2 were less compliant. There were high correlations between SO2 and PO2 although the levels in arterial blood were higher.


This article in Danish discusses use of the IO route for second line vascular access when peripheral IV access is difficult or impossible.

A 7-month-old male infant in septic shock from Neisseria meningitides experienced a complication of bilateral extravasation of noradrenalin at the proximal tibia intraosseous infusion site resulting in severe soft tissue necrosis. Necrosectomy was performed bilaterally and surgical interventions were successfully performed to salvage both limbs. At 19 months the patient was able to crawl without extension deficit.

YEAR: 2010


This abstract describes a retrospective case-series analysis of pediatric IO recipients from 1998-2009. Seventy-two (72) patients were included in the study; IO access was established in the proximal tibia (n=61), medial tibia (n=8), distal tibia (n=1), sternum (n=1), and iliac crest (n=1). IO access devices used in the proximal tibia included the Cook Critical Care needle (n=4), the Jamshidi needle (n=2), the BIG (n=1), and an 18 gauge spinal needle (n=54). The authors concluded that a spinal needle can be used to provide IO vascular access in children.


This article, written in German, gives an overview of intraosseous access in pediatric patients especially with regard to particularly difficult vascular access in the areas of pediatric anesthesia and perioperative care. The article also gives an overview of various devices available to gain IO access, including the Cook needle and the EZ-IO device.


An article evaluating various methods of obtaining vascular access in the management of 21st century battlefield trauma including, peripheral IV access, intraosseous access, venous cut-down, and central venous access. The authors conclude that IO access should be the first line vascular access in casualties with severe trauma to avoid delay initiating resuscitation in pre-hospital or hospital setting.


This article in German describes the results of a survey of rescue assistants and physicians, in which they found that IO use was still a rarity in the Berlin emergency medical service and, therefore, presumably nationwide.


2010 updated guidelines for resuscitation by the European Resuscitation Council. This update notes IO access as the preferred mode of vascular access for drug administration, over endotracheal administration, when IV access is unavailable. IO blood is also noted as useful for typing and evaluating laboratory values.

European Union


This paper describes experiences with the EZ-IO device in Japan in 24 adult patients during CPR. The device is not sold in Japan. Article in Japanese

Turkan H. How does the training effect the use of intraosseous access with a battery driven device? Resuscitation 2010;82(1):593. doi:http://dx.doi.org.10.1016/j.resuscitation.2010.09.380

This abstract describes a study in which 60 physicians, nurses, and paramedics naive to IO vascular access were trained on the Arrow EZ-IO system. After lecture and hands-on training, the clinicians attempted to perform the procedure using a bone model and evaluated the device for ease of insertion, number of attempts, time to insertion, and their opinion on the device. The authors concluded use of the EZ-IO system can result in high success rates of insertion with inexperienced device users.

Werner M, Daniel HP, Holitz J. [Intraossarer zugang beim innerklinischen notfall intensivmedizinischer fallbericht]. Der Anaesthesist 2010;59(7):628-32. German

This article in German reports a case of IO access performed in the ICU due to difficult peripheral access. The authors suggested that based on this case different strategies of critical care and possible improvements should be made.
Intraosseous Vascular Access Bibliography

International


This article in Chinese, describes a study that evaluated the effects to the bone marrow following IO infusion of hypertonic saline-hydroxyethyl (HSH) in the dog model; using a normal saline group (NS) and a non-infusion group. The test subjects were put into shock and resuscitated. Results showed that at 48 hours post infusion and 1 week post infusion changes were seen in the bone marrow and peripheral blood in the HSH and NS groups as compared to the non-infusion group. At 4 weeks post infusion, the NS group and HSH group recovered to normal level. Bone marrow morphology changed slightly but no bone necrosis occurred. The author concluded that HSH in small amounts via IO is safe and effective as a fluid resuscitation measure for shock, and little change in bone marrow has been found after infusion.

YEAR: 2009


Case study of a 9-month old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.


This is a letter to the editor, written in German, that states that intraosseous access supplies should be available in every pediatric care setting. It also stresses the need for proper training and experience in order to use the IO devices safely and effectively.


This article describes an observational study performed by the French military air surgical team in Chad. There were 11 patients with no insertion failures. For 7 patients, the insertion site was the proximal tibia and for the remainder the site was the proximal humerus. The authors concluded that the EZ-IO is a device that is simple, reliable and which gives satisfaction for the administration of drugs.


Article in French. English translation not available.


This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.


This review article in German describes intraosseous vascular access, and includes descriptions of the Waismed Bone Injection Gun, Vidacare EZ-IO, Jamshidi and Cook Medical IO devices.


This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.


Discusses use of IO for pediatric anesthesia. Specifies importance of equipment, education, guidelines.

YEAR: 2008


Article describing IO access.
Intraosseous Vascular Access Bibliography

International


Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter by S. Nicoll and S. Rochester states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation. The second by R. Salter notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.

UK

YEAR: 2007


Article describes the IO route to deliver epinephrine.

Gagliardi P, Purrone G. [Il potere di salvare vite: l'infusione di liquidi e farmaci in emergenza con accesso venoso non reperibile]. N & A Mensile Italiano del Soccorso 2007; 177: 20-3. Italian

Article in Italian describing IO access and EZ-IO


A pre-clinical study evaluating use of intraosseous infusion into the skull, in large adult swine, for the purpose of cerebrospinal fluid (CSF) reabsorption. The authors created intraosseous infusion devices designed specifically for use in this study. Results showed IO infusion demonstrated similarities to systemic absorption characteristics; and authors concluded IO skull infusion may eventually provide another alternative in the management of hydrocephalus.

Canada

YEAR: 2006


Article in Dutch describing IO access and EZ-IO.


This article in German (with abstract in English) describes IO infusion in detail. It includes techniques, indications, complications, and recommendations. Also describes the various devices available, including Cook, Bone Injection Gun (BIG), First Access for Shock and Trauma (F.A.S.T.1), and the EZ-IO®.

YEAR: 2006

Isbye DL, Nielsen SL. Intraosseous access in adults-an alternative if conventional vascular access is difficulty. Ugeskr Laeger 2006;168(34):2793-7. Abstract

This article in Danish covers an overview of intraosseous vascular access and its utility in the adult patient.


Article in French describes IO access and IO devices, including B.I.G., F.A.S.T.1 and EZ-IO®.


The author provides an overview of intraosseous vascular access discussing evolution of the practice, equipment, treatment options and contraindications.

11/9/2019
**Intraosseous Vascular Access Bibliography**

**International**

### YEAR: 2005


Review article on IO vascular access in the pediatric patient. Advises that it is not necessary to adjust doses from IV doses, except for hypertonic solutions. Recommends that IO needle be replaced by an IV within 2 hours to avoid complications. 

Abstract only. Article in German

### YEAR: 2004


Multicenter, prospective study of cardiopulmonary resuscitation data over 18 months. The study was design to evaluate the impact of survival of IV or IO high-dose epinephrine compared to standard doses in children with cardiorespiratory arrest. Limited conclusions showed that there is no significant difference between the two treatments.

### YEAR: 2003


This article in Spanish discusses general IO principles.

**Lake W, Emmerson AJB.** Use of a butterfly as an intraosseous needle in an oedematous preterm infant. *Arch Dis Child Fetal Neonatal Ed* 2003;88(5):F409

An 18 gauge butterfly needle was inserted into the proximal tibia of a premature infant born at 25-weeks gestation, following inability to establish other modes of vascular access due to gross oedema. The intraosseous line was left in place for 6 days until it was lost; there were no adverse events reported however the author noted that no safety data on long term use of the device was collected.


Study of the Power Infuser, a device that can infuse fluids up to 6 L/hr, on patients presenting to the Emergency Department with evidence of hypovolemia. Resolution of hypovolemia was significantly faster with the Power Infuser compared to gravity infusion.

### YEAR: 2001

**Orgiler Uranga PE, Navarro Arnedo JM, De Haro Marin S.** [The intraosseal route. When the veins have disappeared]. *Enferm Intensiva* 2001;12(1):31-40. Spanish

Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.

### YEAR: 2000

**Dalenius E.** [Reduced but better health care for armed forces]. *Lakartidningen* 2000; 97: 3624-8. Swedish. Abstract

Report on reorganization of the medical capacity of the Swedish Armed Forces focusing on new treatment modalities such as intraosseous infusion.


A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient. Canada
Intraosseous Vascular Access Bibliography

International


Intraosseous transplantation of bone marrow in combination with long-acting Adriamycin may inhibit acute and chronic graft versus host reactions.

YEAR: 1999


A retrospective non-comparative study of IO infusion in 41 children. Concludes that IO insertion is an easy technique. Recommends IO for emergency cases when other vascular access techniques have failed in the first 5 minutes of treatment.

Abstract


Retrospective study of 32 cases of IO infusion over a 3 year period. Concludes that IO is rapid, safe and effective and provides an essential alternative vascular route in pediatric resuscitation.

Abstract

Efimov IuV, Zaitsev VG, Sychugov AV. [The treatment of patients with complicated mandibular fractures using a method for the intraosseous administration of biologically active drug agents]. Stomatologlia (Mosk) 1999; 78; 26-7. Russian

Article in Russian; no English translation.

YEAR: 1998


Case report of a 34-week-old pre-term neonate with septic shock requiring emergency treatment. Umbilical vein was unusable. Resuscitation with IO access was successful. Concludes that IO access be used before attempting access with superior longitudinal sinus.

Abstract

YEAR: 1996

Brandt MR. [Intraosseous administration]. Ugeskr Laeger 1996;158(40):5638. Danish

Article in Danish


Discusses indications, contraindications, method of supervision, and complications intraosseous infusion. Concludes that intraosseous infusion is an attractive alternative to the intravenous route in emergency situations.

YEAR: 1995


Case report of successful IO administration colloid, human albumin, and 1.4% sodium bicarbonate via the left hip of a 5-month-old infant with profound hypovolemia. Patient was discharged 4 days after admission.

Abstract only


Article in French.

No abstract available
Intraosseous Vascular Access Bibliography

International

YEAR: 1994

Preclinical study in 86 injured dogs with hemostasis disorders. Plasma and platelet disorders normalized 3 hours after the onset of infusion therapy. The response was enhanced by IO infusion of isotonic saline.
Article in Russian-abstract only

Review article suggesting that IO infusion should be the primary technique of intravascular access in infants for pediatric resuscitation and the first alternative technique for vascular access after failed intravenous access in young children.
Abstract only

YEAR: 1993

Case reports of 2 9-month-old infants with severe dehydration treated with IO infusions after failed IV attempts. IO lines were replaced shortly after venous access was obtained.
Abstract only

YEAR: 1992

Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure.
Abstract only

A review of intraosseous infusion and the possible applications in pediatric emergency medicine.
Abstract only

YEAR: 1991

Discussion of case reports of IO infusion, as well as physiology of IO and technique for IO access. Concludes that IO infusion is simple and safe. The technique can be successfully performed under field conditions by paramedical personnel, even by untrained personnel.
Abstract only

YEAR: 1990

Case report of a critically ill preterm neonate who received needed emergency fluids via IO infusion.

YEAR: 1934

This article describes one clinician’s use of sternal IO access for infusion of campolon to treat anemia in 1930. The author performed over 50 injections without serious complications.
Sweden
**Intraosseous Vascular Access Bibliography**

**Intraosseous Overview**

**YEAR: 2018**


This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.


The objective of this study was to evaluate success and ease-of-use ratings when experienced paramedics attempted EZ-IO intraosseous (IO) access in a cadaveric model when wearing their standard uniform and wearing Chemical, Biological, Radiation and Nuclear (CBRN) personal protective equipment. There was no significant difference for the tasks of land marking, humeral site insertion, saline flush, holding and manipulating driver and catheter removal. Insertion times were statistically longer (by 9.4 seconds) wearing CBRN. Investigator concluded IO access can be effectively and promptly achieved while wearing CBRN.


This is an article published in a Turkish nursing journal and written in Turkish. From the abstract, the IO route is described as an alternative approach to vascular access when venous access via a peripheral catheter cannot be obtained quickly. Complications of IO access and how to prevent them using nursing interventions are discussed. EZ-IO is discussed in the article.

**YEAR: 2017**


This article presents a review of current evidence regarding different routes for the administration of medications during neonatal resuscitation, of which the intraosseous route is included. A table comparing four different intraosseous devices, including EZ-IO, is presented in the document.


This article describes the anatomy and physiology of IO cannula insertion as well as indications and contraindications of IO use. Devices and techniques as applied to the pediatric population are discussed, including EZ-IO.


This journal article discusses the importance of early in medical school and/or residency training of intraosseous access by use of cadaver courses can help increase the skills for IO use needed for use in real life situations thus improving patient safety.


This article describes the anatomy and physiology of IO cannula insertion as well as indications and contraindications of IO use. Devices and techniques as applied to the pediatric population are discussed, including EZ-IO.


This study compared success rate, procedure time and user satisfaction of pediatric NIO vs. Pediatric BIG, EZ-IO and Jamshidi intraosseous access devices in pediatric manikins. Study was randomized, crossover trial with 87 paramedics participating. The study evaluated each device on the ease of use in performing their procedures. Results of this study found that paramedics favored the NIO in ease of use in the pediatric manikins.


This study reviews current IO administration of antidotes for patients that have presented to the emergency department with serious poisoning and IV access is not available. The study concluded that the evidence supporting the use of IO route for administering antidotes for poisoning patients is rare. Most evidence of IO access administration of antidotes has occurred in animal studies and case reports. Per author, despite lack of evidence, IO access is a potential option for antidotal treatments for resuscitation for patients where IV access is not available.
Intraosseous Vascular Access Bibliography

Intraosseous Overview


This retrospective cohort study evaluated emergency medical services (EMS) that treated adult patients with atraumatic out of hospital cardiac arrest (OHCA) in order to compare drug administration via intraosseous (IO) versus intravenous (IV) and the effectiveness. Study endpoints were survival to hospital discharge, return of spontaneous circulation (ROSC), and survival to hospital admission. The study included 1,800 patients, 1,525 of whom received IV access and 275 who received IO access. The practice for OHCA management in the EMS system from which the data was obtained was to attempt tibial IO access after failed IV attempts. The authors concluded that use of IO access was associated with a lower likelihood of ROSC and hospitalization; and acknowledged that further study of how vascular access routes affect OHCA patient outcomes is warranted.


This article provides an overview of intraosseous infusion including indications, contraindications, types of devices, administration technique, and complications.

**YEAR:** 2016


This study compared maximum concentration time (Cmax) to maximum concentration mean (Tmax) of mean serum concentration of vasopressin, return of spontaneous circulation (ROSC), time to ROSC, with odds of survival to vasopressin administration by tibial intraosseous, proximal humerus intraosseous (PHIO), and intravenous (IV) routes in a cardiac arrest model. Authors concluded TIO and PHIO provide rapid and reliable access in administration of life-saving medications during cardiac arrest and may be faster due to IV difficulty.


This article provides a brief overview of intraosseous access for radiologists followed by a discussion of the use of IO access devices in the radiology suite, particularly for CT imaging. The protocol established at the authors’ institution for use of the EZ-IO system is described which emphasizes obtaining confirmation of proper IO catheter placement by use of imagery prior to full infusion of contrast medium.


This study examined the differences of pharmacokinetics and pharmacodynamics of epinephrine via of tibial intraosseous access and IV access. Interruptions in CPR in order to obtain vascular access reduces the flow of blood to vital organs. Study results showed that TIO access may be a faster alternative to IV access for delivery of vasoactive medications.


This study was to determine if there were any significant differences between humerus intraosseous (PHIO), sternal intraosseous (SIO) and intravenous (IV) administration of Hextend on the hemodynamics or administration time in a hypovolemic swine model. Time of administration of the Hextend on effects on systolic and diastolic blood pressure, mean arterial pressure, heart rate, cardiac output and stroke volume. After administration of Hextend, data was collected every 2 minutes for 8 minutes total. Results found no significant difference in these measures among the PHIO, SIO or IV groups.


This journal article literature review was written to provide information about the history, clinical considerations, and devices associated with intraosseous access to administer resuscitative drugs when IV access can’t quickly or easily obtained.


This literature review examined the increase in use of intraosseous access for administration of resuscitative fluids and drugs to patients where intravenous access could not quickly or easily obtained during disasters and mass casualty events. The review also included a comparison of IO route to other routes for establishing vascular access in patients that have been involved in mass casualty or disasters.
Intraosseous Vascular Access Bibliography

Intraosseous Overview


In this letter to the editor authors discuss intraosseous access (IO) via proximal anterior tibia and proximal humerus. Per authors, the tibial site was used more frequently due to ease of identifying the landmarks for insertion and accessibility to this area while proximal humerus intraosseous access (PHIO) site can be more difficult to identify landmarks for insertion. The authors discuss the use of ultrasound to identify structures for PHIO access has the potential to increase the success rate of proper site insertion.


In this letter to the editor authors discuss the importance of establishing access to circulatory system during CPR. The authors referenced the study "The effects of proximal and distal routes of intraosseous epinephrine administration on short-term resuscitative outcome measures in an adult swine model of ventricular fibrillation: a randomized controlled study" and the study "Intraosseous versus intravenous vascular access during out-of-hospital cardiac arrest: a randomized controlled trial". Authors concluded that intraosseous access seems reasonable for patients in cardiopulmonary arrest or severe shock that do not have available and quick IV access for administration of medications and fluids.


This prospective, experimental study was to characterize and compare the pharmacokinetics of atropine that is administered via sternal intraosseous (IO) route in hypovolemic and non-hypovolemic swine. Main outcomes PK parameters, maximum concentration (Cmax) and time to reach maximum concentration (Tmax). Authors concluded sternal IO route is effective for administration of atropine and data gained from this study was found to be similar to previous information reported on tibial IO and IV administration even in situations of significant hemorrhage.


This study examined the attitudes of nurses working with pediatric patients and intraosseous access in pediatric patients. The study was conducted with the use of a diagnostic survey distributed to 200 nurses, with 135 nurses returning the surveys. The study found that there is a need for more training with nurses to increase their level of knowledge of intraosseous access and improve nurses attitudes for use of intraosseous access in pediatric population in emergency situations.


In this letter to the editor authors discuss the difficulties of obtaining vascular access in patients in shock; and make a case for use of intraosseous access (IOA) in shock. Authors note IOA access as a safe, effective alternative to venous access with relatively rare complications.


This paper provides a brief overview of IO access and discusses advantages and disadvantages of IO use. Validation of IO blood gases by point-of-care technology, IO administration of antibiotics, IO monitoring of renal function, and IO access in acute cardiac care are also discussed.


Literature review on contemporary practices of intraosseous (IO) vascular access in adult patients.


This article reports the results of a systematic review using PubMed for current evidence through 2015 for intraosseous (IO) vascular access use in adults requiring resuscitative procedures. General anatomy, indications and contraindications and available devices are discussed. Authors determined IO infusion is indicated in all critical situations with difficult vascular access; contraindications are few; and serious complications uncommon.

Page 3 of 21
Intraosseous Vascular Access Bibliography
Intraosseous Overview

This article reviews the best practices for optimal cardiac arrest management, echoing the 2015 ACLS guidelines. Intraosseous vascular access is identified as an access route for delivery of pharmacological agents to aid in patient management.

In this letter to the editor, the author calls into question the continued recommended use of the umbilical venous catheter in neonatal resuscitation by the European Resuscitation Council and the lack of intraosseous vascular access recommendation. The author makes the argument that accessing the umbilical vein is difficult for even the most experienced NICU clinicians and that time cannot be spared in these resuscitations; and intraosseous access can provide a viable option for drug delivery.

YEAR: 2015

This article presents a 5-case series describing use of IO vascular access by anesthesiologists in the perioperative and critical care settings. All insertions were made in the proximal tibia and there were no adverse events reported. The devices cited as being used were the EZ-IO and the Cook Surfact manual needle. A proposed perioperative vascular access algorithm incorporating IO access is presented. The authors address key topics around IO access including use of same drug dosing as IV administered drugs, frequent palpation and monitoring of the insertion site for extravasation, low complication rate and actual risks associated with fat emboli and bone injury, pain and anxiety management in the awake patient and clinician-perceived pain. Administration of blood products, ACLS drugs, Lactated Ringer’s solution and anesthetics are noted without complication. Use of IO aspirate for laboratory testing is noted, however use of the initial aspirate is indicated. Several patients in the case series were reported to find the discomfort of IO insertion preferable to multiple intravenous attempts. The authors concluded: IO lines can be placed quickly and safely in emergency situations or in elective surgical patients with difficult intravenous access; IO access can be useful in a wide variety of clinical settings; and is an important skill for anesthesiologist to learn.

This document is a tutorial provided by the World Federation of Anaesthesiologists geared at understanding and establishing intraosseous access. It provides an overview of venous blood drainage from bones as well as indications, contraindications, common access sites, advice for establishing access, an overview of device types, insertion techniques, and complications.

This crossover study using mature mini-swine was performed to assess the efficacy of intraosseous administration of contrast agents for CT (computed tomography) imaging of the chest and abdomen. Authors concluded that in the model used, an injection intraosseous (IO) of contrast through the proximal humerus resulted in improved quality of trauma-protocol CT images.

This study examined whether the use of dual-intraosseous needles to deliver fluid and medication when vascular access is insufficient. The study used a single porcine humerus. The authors concluded that dual intraosseous needles are feasible and may help the rapid resuscitation of patients.

An overview of IO vascular access with a focus on the proximal humerus IO insertion site.

This is a review article written in the Chinese language describing intraosseous vascular access.

YEAR: 2014

Anson JA. Vascular access in resuscitation: Is there a role for the intraosseous route? Anesthesiology 2014;120(4):1015-31
Literature review through August 1, 2013 with primary aim to determine whether there is a role for intraosseous vascular access in the resuscitation of critically ill patients. Secondary aims were to investigate the evidence regarding clinical use, drug administration, and complications of IO access. The authors concluded that IO access can be achieved quickly and accurately in emergency situations and there is clearly a role for it in resuscitation of ill patients; anesthesiologists should become familiar with IO access.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

This literature review article sought to identify the diseases or syndromes most often associated with intraosseous injection within the published literature. The top 35 articles identified in the search are cited within the article; most are related to dental applications.

This literature review article sought to identify the functional concepts associated with intraosseous injection within the published literature. The top 40 articles identified in the search are cited within the article.

This literature review article sought to identify organic chemicals associated with intraosseous injection within the published literature. The top 31 articles identified in the search are cited within the article.

Craiu M, Stan V, Cochino AV. Intraosseous access-A classical method for vascular access that regains an important role as resuscitation tool. Ro J Pediatr 2014;68(3):233-7. Romanian
This article reviews the initial development of IO access and provides an overview of IO use in pediatric populations including insertion technique, side effects, and contraindications.
English and Romanian article

This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.
UK

Text article that accompanies video featured in The New England Journal of Medicine on intraosseous access which provides a general overview of IO access and demonstration of IO insertion using the EZ-IO and one manual IO needle set.

Faminu F. Intraosseous vascular access: boning up on the basics. Nursing 2014;44(8):60-4. doi:10.1097/01.nurse.0000451529.25093.4b
This article provides an overview of intraosseous vascular access including history, cost and time savings, anatomical sites, infusion pain management, and complications, with a focus on the perspective of the nurse.

This is a discussion of a case study involving a hospitalized woman who had an IO line placed during a code after becoming unresponsive. Several unsuccessful attempts at peripheral venous access were made prior to IO access. The patient was diagnosed 3 hours later with compartment syndrome due to extravasation that required complex ongoing care in the ICU for 2 months.

This review provides a comprehensive summary of pharmacologic therapies that utilize prefilled devices as a delivery mechanism for parenteral application. Six categories are described: endocrine, neurological, pain management, immune disorders, anaphylaxis, and emergency medicine. Within emergency medicine IO access is recommended as an alternative to IV access when IV access cannot be obtained. Various devices for IO access, including the EZ-IO device, are listed.

This article discusses use of IO access in adults in children with regard to implementation, indications, problems and risks.
German
Intraosseous Vascular Access Bibliography

Intraosseous Overview

Neuhaus D.  *Intraosseous Infusion in elective and emergency pediatric anesthesia: when should we use it?* Curr Opin Anaesthesiol 2014;27(3):282-7. DOI: 10.1097/ACO.0000000000000069

General review of IO access, with particular attention to perioperative setting and includes published guidelines of the German Scientific Working Group for Pediatric Anesthesia for use of intraosseous access. The author recommends that for children with known difficult venous access physicians discuss the possibility of IO access preoperatively with the family.

YEAR: 2013


In a letter to the editor this study reports data collected (during a survey of one third of academic emergency medicine programs in the U.S.) regarding IO use in adults and comparing IO access with other vascular access techniques through simulation. Data suggest that IOs were used less than 5% of the time patients needed emergent access and a peripheral line was unobtainable. The EZ-IO was most often used IO device. Authors conclude IO use should be considered more frequently in critical, unstable patients. (This research was presented at the ACEP Research Forum in 2010).


This article explores the use of IO access for blood product administration and whether or not it is clinically effective. Based upon lack of clinical evidence and physics principles, the author argues that maximum flow rates attainable for IO blood infusion are not adequate for resuscitation.


This article presents an overview of IO access focused on nurses’ use of the technique. A list of available devices, history and support for use and possible complications are included.


Pre-clinical study comparing flow rates acheived after insertion with the EZ-IO in the proximal tibia, distal femur, and proximal humerus in a swine model. IO catheters were placed in each site and normal saline was infused for 10 minutes using a pressure bag at the highest achievable pressures greater than 300mmHg. The flow rates through the proximal humerus were statistically greater than that of the femur or proximal tibia. The femur flow rates were higher than the proximal tibia but similar. Post-mortem histopathologic evaluations done to assess for damage due to the high infusion pressures were consistent with IO catheter placement.


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedure steps and special considerations are outlined for each access methods discussed.


This article in Spanish provides an overview of intraosseous vascular access.


This article in French gives an overview of intraosseous vascular access including the physiology of IO infusion, insertion sites, indications, and complications. Available IO devices on the market are described including, time to insertion, success rate and cost.


Five point summary of things to know about intraosseous vascular access including, use of the IO access for fluid/drug/blood product infusion and obtaining blood samples, possible IO insertion sites, pain management, use during resuscitation efforts, contraindications, and possible complications.
This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the intraosseous access. Simul Healthc 2012;7(3):171-5. doi:10.1097/SIH.0b013e31824a5c20


This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access. Ibrahimi M, Cairney K. Intraosseous (IO) infusion as a means of vascular access. Br J Resuscitation 2012;Autumn:23-6

This abstract presented at the 2nd World Congress on Vascular Access 2012 reports data collected on the knowledge gaps and barriers to IO vascular access use. Two focus group discussions were held at professional conferences (American College of Emergency Physicians and the Emergency Nurses Association) and facilitated by clinical researchers. Data was qualitatively evaluated and researchers identified several main areas of concern for clinicians in both implementation and knowledge gap areas. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article, part of a Review Snapshot series in Annals summarizes a literature review (Rouhani et al in Pediatrics 2011) for evidence of alternatives to traditional IV hydration in a dehydrated child. Thirty-eight articles were included for the analysis with five of them randomized controlled trials; and one of those comparing IO to IV rehydration. (Banerjee et al, which found IO placement faster with no therapeutic outcome differences). The focus of this review was on nasogastric tube rehydration as effective when IV fails and as less invasive than IO or CVC placement.

This editorial discussed the numerous changes in practice with regard to cardiopulmonary resuscitation, and explored the scientific basis upon which the changes were made. Changes in drug administration and vascular access methods, including IO, are discussed. The author's overall view was that perhaps clinical practice in cardiopulmonary resuscitation is too quickly changed with the presentation of minimal scientific data.

This article describes a questionnaire study in which members of selected Scandinavian medical societies were surveyed to identify reasons for not using IO access during resuscitation when IV access is difficult. There were 759 evaluable responses from doctors, nurses, and ambulance staff. Of the respondents, 178 (23.5%) had experienced at least one situation where there was an indication for IO but it was not attempted. The most common reason for not using IO was unavailability of equipment (n=86) and lack of training. The author concluded that increased training in IO use and greater availability of IO equipment for front-line staff should be implemented.

This abstract presented at the 2012 ACEP Research Forum discusses a literature review of intraosseous access publications since 1985 and 6 cases of compartment syndrome secondary to extravasation reported. Of the 192 articles identified, 140 described the EZ-IO. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.
Intraosseous Vascular Access Bibliography
Intraosseous Overview

**Page D. Intraosseous intrigue: Studies examine success rates on pediatric, adult & obese patients. JEMS January 2012;32-3**

In this article, the author discussed five recent studies on intraosseous access providing his opinion about the quality of each study.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.

**Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14**

The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access.


An article discussing the technique and safety profile of intraosseous access using the EZ-IO device. Needle selection, contraindications, insertion sites and techniques, catheter stabilization and removal are all discussed along with the safety profile of the EZ-IO against other IO devices and central venous catheters. The authors concluded that IO access should be considered whenever immediate vascular access is required. This article was co-written by an employee of Vidacare Corporation, acquired by Teleflex Incorporated.


This abstract presented at the 2nd World Congress on Vascular Access 2012 describes the results of an analysis of published IO complications since 1985. The safety profile of the EZ-IO is also discussed in this abstract. The authors conclude that new devices and techniques have resulted in an approved IO safety profile. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.


This abstract presented at the 2012 ACEP Research Forum explored the viability of the distal femur as an IO insertion site with a literature review of IO vascular access and brief overview of a post-mortem study of pediatric distal femur insertion success. Authors concluded that clinical literature, clinical studies, and a post-mortem study confirm that the distal femur is a viable option for IO infusion in pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO


This article is making a case for pediatric anesthesiologists to have IO access equipment readily available wherever children are anesthetized; and for anesthesiologists to consider IO access not only as a last resort but as the route of choice in children requiring urgent vascular access.

**YEAR: 2011**


This article reports a literature review using both MEDLINE and Embase databases up to August 2010 to determine feasibility and safety of IO administration during adult cardiac arrest. Authors reported a lack of literature (only two studies met their level of evidence criteria) but concluded IO access in adults appears to be a fast, reliable method to deliver drugs and fluid during CPR allowing adequate drug concentrations and pharmacological response; and should be considered if other medication delivery methods have failed. (Presented at the March 2011 International Symposium on Intensive Care and Emergency Medicine)
This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK

This abstract explored the clinical utility of intraosseous vascular access and its development from exclusive use in children to widespread utility in the adult patient.

This article describes a military study in which post-mortem autopsy multidetector CT was used to assess placement of tibial IO needles in battlefield trauma deaths where IO was used as part of the medical intervention. Results showed 58 of 61 (95%) tibial IO needles were correctly placed. In this study, the device used for IO placement was not recorded, but may have been the manual device or EZ-IO as the Army has access to both.

Lowther A.  Intraosseous access and adults in the emergency department. Nurs Stand 2011;25(48):35-8
This is a review article describing intraosseous vascular access, including techniques and device used, and contraindications.

This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.

This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.

This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.

This article describes IO access in terms of efficacy, indications/contraindications for use, and the IO procedure and comparison of devices to make a case for IO use in oral and maxillofacial surgical practice. In discussing IO devices citing published data, the author identified the EZ-IO device as the most accurate, efficacious, and precise system when trying to achieve IO access.

This article in German concludes that the introduction of IO in pre-hospital pediatric emergency system has markedly reduced the number of critically ill or severely injured pediatric patients without vascular access or with less reliable alternative administration routes in the last 20 years.

This article in Danish discusses use of the IO route for second line vascular access when peripheral IV access is difficult or impossible.

YEAR:  2010

This article, written in German, gives an overview of intraosseous access in pediatric patients especially with regard to particularly difficult vascular access in the areas of pediatric anesthesia and perioperative care. The article also gives an overview of various devices available to gain IO access, including the Cook needle and the EZ-IO device.
**Intraosseous Vascular Access Bibliography**

**Intraosseous Overview**

*Fenwick R.*  *Intraosseous approach to vascular access in adult resuscitation.*  *Emerg Nurse* 2010;18(4):22-5

This article reviews intraosseous vascular access and its increased use in adult resuscitation. The IO route is described, including indications, contraindications, insertion sites and devices.

*Gerardi MJ, Youngberg B.*  *Establishing emergency vascular access: the benefits of an alternative approach.*  *Journal of Emergency Nursing* 2010; February:16-8

This article gives an overview of IO vascular access reviewing the history, devices and complications associated with IO access.

*Kovar J, Gillum L.*  *Alternate route: the humerus bone - a viable option for IO access.*  *JEMS* 2010;35(8):52-59

Authors describe an early observational study (N=120) comparing intraosseous access in the humerus and the tibia, using the EZ-IO. Investigators concluded that the humerus is an acceptable IO site, which may be preferable under certain clinical conditions. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


In an abstract presented at the 2010 ACEP Research Forum, investigators describe a swine study designed to compare IO infusion rates using the Belmont FMS 2000 rapid infusion device and a pressure bag through the proximal tibia and proximal humerus. Investigators concluded that infusion rates were highest using the pressure bag via the proximal humerus.


This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.

*Miller LJ, Philbeck TE, Montez D, Spadaccini CJ.*  *A new study of intraosseous blood for laboratory analysis.*  *Arch Pathol Lab Med* 2010;134:1253-60

Authors describe a 10 subject volunteer study that compared intraosseous (IO) blood samples to venous blood samples for complete blood count (CBC) and chemistry profile testing. They concluded that IO blood may serve as a reliable alternate for hemoglobin and hematocrit levels, as well as for most analytes in a basic blood chemistry profile. Exceptions are CO₂ levels, platelets, and WBC. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article describes an online questionnaire study in which the Heads of Department of 20 EDs in Denmark were asked about IO infusion within their institution. Nineteen responses were received; 14 hospitals (74%) reported having IO devices available with the median number of IO procedures performed as 5. In 9 departments training had not been provided and 8 departments didn’t have IO guidelines. The favored device was the EZ-IO found in 18 of the EDs, 2 had EZ-IO and Cook Surfact and 1 had the BIG.

*Navarro K.*  *Intraosseous infusion.*  *Texas EMS Magazine* 2010;Nov/Dec:34-9

This article provides a brief history of IO infusion and further discusses this vascular access technique in terms of anatomy and physiology, indications and contraindications, performing the manual procedure, and possible complications. A case study is discussed in which a 7-month-old male was treated under emergency circumstances with IO infusion in the lower limb and developed compartment syndrome, resulting in a below the knee amputation.

*Philbeck TE, Miller LJ, Montez D, Puga T.*  *Hurts so good; easing IO pain and pressure.*  *JEMS* 2010;35(9):58-69

This article describes two studies designed to compare Lidocaine’s effect on pain during fluid infusion through the tibial and humeral IO routes and to determine infusion flow rates. Authors concluded that, for adequate IO infusion rates with minimal and tolerable pain, 40mg of preservative-free Lidocaine may be needed; followed by a rapid normal saline syringe flush of at least 10mL and another 20mg of Lidocaine. Additional dosing and flushing may be required. For less overall pain due to IO infusion, and greater infusion flow rates, the proximal humerus should be strongly considered, using a longer IO needleset. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


This article discusses use of IO access within the hospital setting in the emergent and non-emergent patient populations. The history of IO access, clinical situations in which IO access may be considered, devices, contraindications, and complications are discussed. Additionally, pain management, economics, education and training and risk management are explored. This article is co-published in Journal of Infusion Nursing, the Journal of Pediatric Nursing, and Critical Care Nurse and was produced by the Consortium on Intraosseous Vascular Access in Healthcare Practice.
Intraosseous Vascular Access Bibliography
Intraosseous Overview


This abstract describes an animal study, presented at the 2010 ACEP Research Forum, that examined shear and pressure changes within the medullary space during intraosseous infusion. Results suggest that resistance to flow depends on cannula placement site, IO pressure rises rapidly with infusion rates, and medullary compression and axial shear are present at high infusion rates.


The authors describe literature that support the use of IO access for administering anesthesia in the ICU, perioperative and operating room, including a study in which IO access was used successfully for providing intraoperative anesthesia for 106 of 109 patients. Among their conclusions, the authors reported that, even though rarely reported in anesthesia literature, IO access is a technique anyone providing care to children should consider when the patient has difficult IV access. They also concluded that IO access should be a part of an algorithm that includes numbers of attempts at peripheral access, feasibility of central access and the need for continued postoperative access; and that considering that IO access may be occasionally used in the perioperative setting in both emergent and nonemergent scenarios, it may be beneficial to have appropriate IO needles in the OR.

Vegunta RK. Chapter 8-Vascular access. Ashcraft's Pediatric Surgery 2010;5th ed:110-6

This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.


This article provides an overview of IO anatomy and physiology, IO access indications, care, and management; describes therapies administered via IO access; and discusses the expanding use of IO access into areas within hospitals during nonemergency clinical situations. It also includes a table addressing indications for IO access in the hospital, as well as a table addressing the general insertion procedure for IO access.

YEAR: 2009


Article for nursing audience.

Barrett J. Adult Intraosseous infusion: "Good to the bone!" Response 2009;36(3):19-21

This article addresses adult IO infusion, primarily in the pre-hospital setting, with regard to the history of IO, anatomy and physiology, training considerations, clinical guidelines and contraindications, and financial considerations.


Instructional program on IO.


This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.


This review article in German describes intraosseous vascular access, and includes descriptions of the Waismed Bone Injection Gun, Vidacare EZ-IO, Jamshidi and Cook Medical IO devices.


This French version of an article previously published in American Journal of Emergency Medicine describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous using the Vidaport (a predecessor of the Vidacare EZ-IO) vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine for nearly all pharmacokinetic parameters, including maximum plasma concentration, time to maximum plasma concentration, and area under plasma concentration-time curve. There was a significant difference in the volume of distribution in the central compartment, which investigators attributed to a minor deposition effect near the IO port or in the bone marrow. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.
Intraosseous Vascular Access Bibliography

Intraosseous Overview


This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.


Discusses use of IO for pediatric anesthesia. Specifies importance of equipment, education, guidelines.

YEAR: 2008


No abstract available.


Review of IO infusion methods and devices. Devices described include Jamshidi, Cook, FAST 1, BIG, and EZ-IO.


Overview of intraosseous vascular access in infants; includes indications, contraindications, complications, equipment (Sur-Fast and Jamshidi), and procedure. Also, small section on IO for adults; describes the FAST-1, Bone Injection Gun, and EZ-IO.


Describes common drugs used in pediatric resuscitation and evidence supporting their use. Also describes routes of administration including intravenous, intraosseous, and intratracheal. Describes IO systems including Bone Injection Gun, FAST-1, and EZ-IO.


This article presents a case study of an IO infusion during the anesthetic care of an infant with cyanotic congenital heart disease (CHD). The article also discusses the role of the IO route in perioperative care and reviews the adverse effect profile.


Case reports in which intraosseous (IO) vascular access was successfully used on adults. Summarizes indications for use, complications, and precautions/considerations.


Article describing IO access.

YEAR: 2007


Data from the largest combat trauma database was analyzed to identify how new or improved devices, dressings or drugs have impacted prehospital casualty care, how guidelines and resuscitation strategy have changed, and discusses lessons learned and how concepts have crossed back into the civilian practice. Intraosseous access, particularly the sternal site, is identified as one of the advances for vascular access in combat medicine.


This article reviews and assesses the literature on the use of IO drug administration during cardiopulmonary resuscitation. It addresses the risks and benefits of using IO in adults and children. The article describes the FDA-cleared devices available for use including the Pyng F.A.S.T.1, Waismed Bone Injection Gun and the Vidacare EZ-IO.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

de Caen A. Venous access in the critically ill child. Pediatr Emerg Care 2007;23:422-4
This review article states the availability of intraosseous (IO) needles for pediatric patients, outlines the limitations of traditional venous access, and discusses the various IO devices currently available, including the Vidacare EZ-IO®.

This article summarized the challenges and methods of providing vascular access for infants. It describes IO techniques and devices, including the Jamshidi, Cook, EZ-IO® and Bone Injection Gun (BIG) devices.

Fowler RL. Prehospital intraosseous access: elemental to the field? JEMS 2007; doi:http://jems.com/print/9198
Discussion of the role intraosseous vascular access can play in the prehospital setting where vascular access is often difficult or impossible to establish. The EZ-IO is named as a new IO device along with descriptions of Jamshidi, Pyng Fast 1, and BIG needles.

Gagliardi P, Purrone G. [Il potere di salvare vite: l'infusione di liquidi e farmaci in emergenza con accesso venoso non reperibile]. N & A Mensile Italiano del Soccorso 2007; 177: 20-3. Italian
Article in Italian describing IO access and EZ-IO

Landes AH. Intra-osseous infusions: the current status. Care of the Critically Ill 2007; 23: 53-8
Overview of IO access. Includes historical aspects, current status, indications for use, advantages and disadvantages, IO kinetics, insertion sites, complications and contraindications and description of available IO devices, including EZ-IO®.

Minkler MA. Nailing down IO insertion: the whys, whens, wheres, and hows of delivering fluids and medications the intraosseous way. EMS Mag 2007; 36: 38-42
Practical article for EMS audience.

Article in Dutch describing IO access and EZ-IO.

Wayne MA. Intraosseous vascular access: devices, sites and rationale for IO use. JEMS 2007;32:s23-5
This article reviews intraosseous vascular access in general, and summarizes the various devices available. These include the Waismed B.I.G., the Vidacare EZ-IO, and Pyng F.A.S.T.1.

This article in German (with abstract in English) describes IO infusion in detail. It includes techniques, indications, complications, and recommendations. Also describes the various devices available, including Cook, Bone Injection Gun (BIG), First Access for Shock and Trauma (F.A.S.T.1), and the EZ-IO®.

YEAR: 2006

An overview of IO vascular access use in neonates, including focus on available evidence, history, technique, physiology, clinical indications, complications, and contraindications. The author closes acknowledging IO administration of resuscitation medications and fluids in neonates is an alternative when IV access is not possible.

Isbye DL, Nielsen SL. Intraosseous access in adults—an alternative if conventional vascular access is difficulty. Ugeskr Laeger 2006;168(34):2793-7. Abstract
This article in Danish covers an overview of intraosseous vascular access and its utility in the adult patient.

Article in French describes IO access and IO devices, including B.I.G., F.A.S.T.1 and EZ-IO®.

The author provides an overview of intraosseous vascular access discussing evolution of the practice, equipment, treatment options and contraindications.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

YEAR: 2005

Article describes intraosseous access for adults and pediatrics. Describes and discusses IO devices available including Jamshidi, Bone Injection Gun, F.A.S.T.1, and EZ-IO®.

YEAR: 2004

Web publication discussing the indications, contraindications, insertion sites and complications of IO access.

YEAR: 2003

This article in Spanish discusses general IO principles.

Web article discusses IO cannulation procedure insertion sites, pathophysiology, risks, contraindications and complications.

YEAR: 2002

This article provides an indepth overview of intraosseous circulation including blood vessel anatomy, vascularization, intraosseous blood flow, angiogenesis, bone remodeling, osteonecrosis, bone infarction, and osteoporosis.

YEAR: 2001

Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.
**Intraosseous Vascular Access Bibliography**  
**Intraosseous Overview**

**YEAR: 2000**

**Day MW.** *Using intraosseous access in children. Nursing* 2000;30(1):68  
Nursing article discussing the role of IO infusion when peripheral veins are collapsed. Describes advantages of IO, including ready availability, ability to establish vascular access without interrupting CPR.

Literature review of safety and efficacy of IO infusion of drugs and fluids, with emphasis on utility for the injured soldier. Discusses insertion times and flow rates. Includes literature citations from non-military studies in pediatrics, animals, and human cadavers.

Brief review of the discovery and evolution of IO access in emergency care.

This article describes a study that compared the speed and ease of use when using a standard bone marrow needle and a Sur-Fast intraosseous access needle. Medical students inserted the needles in turkey femurs or pork ribs. Results showed, regarding success rate, procedure time, difficulty scores, the Sur-Fast needle did not show superiority over the standard bone marrow needle.

**Mattera CJ.** *Take aim--hit your IO target. A comprehensive approach to pediatric intraosseous infusion, including site selection, needle insertion & ongoing assessment. Part 2. JEMS* 2000;25(4):38-48  
Overview of pediatric IO infusion targeted for an EMS/paramedic audience. Discusses anatomy of long bones, indications, advantages, contraindications, steps for insertion, fluid administration and ongoing assessment and documentation.

Brief overview of IO infusion for an anesthesiology audience. Discusses technique, indications, contraindications, equipment, anatomical target sites and potential complications.

**YEAR: 1999**

**Bohn D.** *Intraosseous vascular access: from the archives to the ABC. Crit Care Med* 1999; 27: 1053-4  
Brief review of IO history, flow rates, fluids and medications.

**Feillet F, Borsa A, Monin P.** *[Intraosseous approach, yes but...]. Arch Pediatr. 1999; 6: 1349-50. French*  
No abstract available.

**YEAR: 1998**

Review article discussing techniques for venous access in the pediatric patient includes anatomical target sites, clinical indications, advantages and disadvantages.  
*Review*

**YEAR: 1996**

This study’s objective was to determine the anesthetic efficacy of the intraosseous injection as a primary technique in human maxillary and mandibular teeth. Forty subjects were enrolled and received 2 sets of intraosseous injections with 1.8ml of 2% lidocaine with 1:100,000 epinephrine on two different occasions. Authors concluded that in 75%-93% of non-inflamed teeth subjects, an intraosseous injection may provide pulpal anesthesia. Authors cautioned that the duration of the anesthesia declines over an hour.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

Moller JC, Tegtmeyer FK, Schaible TF, Sussmane JB. [Intraosseous puncture as vascular access in pediatric emergency and intensive care medicine]. Anaesthesiol Reanim 1996;21(4);103-7. German. Abstract

Article describing IO infusion 18 pediatric resuscitative situations. Authors conclude that 11 patients would not have survived without IO access. Complications included a minor fracture, 1 case of compartment syndrome that did not require surgical intervention and a minor fat embolism that was of no clinical significance.

YEAR: 1995


Suggests that intraosseous infusion is reliable alternative to peripheral vein access for rapid infusion of fluids in neonates and infants when venous access is impossible.

Abstract only

YEAR: 1994


Review of IO infusion in children 6 years old and younger. Recommends IO for patients with life-threatening conditions requiring immediate vascular access. Reports less than 1% complication rate.


Discussion of IO infusion, including ease of use, low complication rates, and variety of fluids and drugs that can be administered through the IO route in children and adults.


Seminal article describing alternatives to intravenous cannulation including intraosseous access, intratracheal drug administration, sublingual and intralingual injection, intra-penile administration, and intracardiac injection. Concludes that the intraosseous method is an effective alternative to intravenous access in emergency situations.

Review


Review

Review of the history, insertion techniques, available devices, and applications of the intraosseous infusion as well as the indications and contraindications for intraosseous infusion in all critically ill patients.

YEAR: 1992


This prospective, nonrandomized, crossover study evaluated bone marrow aspiration from the posterior iliac crest and peripheral venous blood for ABO and Rh typing as well as the presence of human leukocyte activity. No differences were seen in the ABO and Rh typing, and human leukocyte activity was detected in both the marrow and venous samples.


Article promoting increased awareness of intraosseous infusion, familiarity with IO insertion techniques, and careful use of anatomical landmarks.

Abstract only


A review of intraosseous infusion and the possible applications in pediatric emergency medicine.

Abstract only


Letter to the editor written in response to previous article on IO access that includes sternal access as a site for children. This author states IO route for fluids and drugs is underutilized but believes sternal site to be hazardous and upper tibia, lower femur and humerus are favored.

11/9/2019
Preclinical study of an implantable intraosseous infusion device (the osteoprot) in a goat model. The device allowed for ready access to the vascular system through intraosseous infusion fluids and medications. IO infusion may result in fewer complications than conventional methods of vascular access.

**YEAR: 1991**

**Clarke P.** *Making sense of intraosseous infusion.* Nurs Times 1991;87(1):40-1

Article for nurses on intraosseous infusion as an alternative to intravenous vascular access presented in a question and answer format.


Review article discussing aspects of intraosseous infusion, including indications, technique, and pharmacokinetic factors. Concludes that multiple drugs and fluids can be safely administered through the intraosseous route.

**Von Hoff DD.** *Intraosseous infusions: an important but forgotten method of vascular access.* Cancer Invest 1991;9(5):521-8

Review of intraosseous vascular access targeted for an oncology audience. Describes an implantable IO device with potential to make intraosseous access more convenient for the patient.

**YEAR: 1990**


Textbook chapter on IO.


Concludes that infusion of fluids and drugs can be readily performed with the intraosseous technique.


Nursing article describing intraosseous infusion techniques and benefits.

**Miccolo MA.** *Intraosseous infusion.* Crit Care Nurse 1990;10(10):35-47

Nursing article that describes benefits of intraosseous infusion. Recommends IO for cardiopulmonary arrest and other medical emergencies.


This abstract describes a review of the literature on intraosseous pathways and reaches the conclusion that the rate of fluid administered is limited by the size of the marrow cavity and the complication is extravasation of fluids and/or drugs into the soft tissue.

**YEAR: 1989**


Study of 22 cardiac arrest patients arriving at the Emergency Department with no or insufficient intravenous access. Intraosseous needle placed and flow established in less than 1 minute in all patients. Observed flow rates of 5 to 12 mL/min with pressure bag attached. IO needle placed in the medial supramalleolarus.


Study of IO infusion by paramedics on pediatric patients (>5 years of age) in cardiac arrest. Paramedics completed a training program in IO technique. Observed 85% success rate (10 of 12 IO attempts). Discusses training methods, limitations and implications for future use.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

Preclinical study of IO infusion in a swine model. Concludes that IO infusion holds potential as a first line of action for fluid resuscitation in pediatric subjects.

Review article for a nursing audience presenting a brief historical overview of IO technique and insertion methods, with discussion of clinical applications and nursing management aspects.

YEAR: 1988

Article for emergency nursing audience describing IO technique, anatomy, absorption rates, clinical indications and contraindications, technique, complications and training in critically ill or injured infants and children.

Nursing article recommending IO early in the treatment of critically ill or injured children with difficult venous access. Highlights speed and ease of IO technique.

YEAR: 1987

Brillman JC. Intraosseous infusion for emergency vascular access. West J Med 1987;146(5):603
A brief overview of intraosseous vascular access. The author concluded that IO vascular access is a firmly established practice based on scientific fact and clinical significance.

Review article on IO infusion, includes historical background, physiology, method, clinical applications and complications of the IO procedure.

YEAR: 1986

Review of medical literature and research on the problem of difficult intravenous access.

This article describes case reports and also a study comparing 3 types of needles for IO insertion: spinal needles, standard IV needles, and bone marrow aspiration/biopsy needles on a pediatric cadaver leg. The bone marrow aspiration needle was easiest to insert. The clinical cases described 5 adult and 10 pediatric IO patients with insertion at the "medial malleolus". " Authors conclude that IO infusion is a safe, rapid way to access the venous circulation, providing a stable, usable fluid line in dehydrated pediatric patients. "(Often referred to as distal tibia.)

YEAR: 1985

Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.

Discusses the historic technique of tibial intraosseous infusion as an alternative IV route in young children. Concludes from review of the medical literature that IO access is a rapid, reliable method with acceptably low complication rate. Discusses substances absorbed through the marrow, flow rates, technical difficulties, and complications.
Intraosseous Vascular Access Bibliography

Intraosseous Overview

YEAR: 1984

Seminal article on IO infusion by the “Father of IO.” Drugs and fluids infused through the IO space enter the central circulation as rapidly as through IV routes. Unlike peripheral veins, the intramedullary blood vessels will not collapse in shock.

Outlines problems with conventional vascular access in emergency medicine. Discusses possible resurgence of the “old” technique of intraosseous infusion.

Turkel H. Emergency infusion through the bone. Military Medicine 1984;149:349-50
Article for military medicine audience concluding that the intraosseous route is more safe and effective than the intravenous route for several clinical indications, including burns and shock, circulatory collapse, uncooperative patients, patients in transit, shortage of physicians, especially under emergency conditions. States that IO infusion is an established alternative to intravenous infusion.

YEAR: 1954

Describes a new method of ascending venography of the lower limb and pelvis in which contrast medium is injected into the IO space of the bone. Concludes that IO venography is be safe, simple, flexible, and reliable for visualization of the deep, superficial, and communicating veins of the legs and pelvis.

Recommends IO for administering fluids, with the iliac crest as the preferred anatomical site.

YEAR: 1952

Tarrow AB, Turkel H, Thompson MS. Infusions via the bone marrow and biopsy of the bone and bone marrow. J Anesthesiol 1952;13(5):501-9
Article for an anesthesiology audience discussing the extensive blood supply within the bone marrow and the utility of IO anesthesia administration.

YEAR: 1947

Early study on IO. Makes strong distinction between ordinary blood transfusion or infusion of isotonic solutions (generally safe) and continuous infusion or the infusion of hypertonic solutions. The latter carries considerable risk of osteomyelitis and subsequent disturbance in growth of the bone.

YEAR: 1946

Historical article discussing refinements in IO technique and analysis of IO complications. Includes case report of an infant who developed osteomyelitis subsequent to IO infusion.

YEAR: 1944

Early article describes technique for tibial bone marrow infusion. Reports 6 failures and 2 partial failures in 43 attempts on 34 young children. X-ray studies post IO infusion showed small bone defects and periosteal elevation with new bone formation.

Recommends IO cavity of the manubrium as useful as IV for anesthetic infusion.
Bailey H.  Bone marrow as a site for the reception of infusions, transfusions and anaesthetic agents: a review of the present position.  Anesthesiology 1944;5(5):545-6
This abstract describes one physician's summary of experience using the sternum as an intraosseous vascular access site for 60 cases. Discusses potential benefits and complications compared to intravenous access.

Early observational study on IO infusion at the Children's Hospital of Akron, OH.

YEAR:  1943

Macht D.  Studies on intraosseous injections of epinephrine.  Am J Physiol 1943;138(2):269-72
Study of the clinical effects of intraosseous, intramuscular and intravenous injections of aqueous versus oil solutions of epinephrine.

Early study finding comparable circulation times between IV and IO infusions in 21 subjects.

YEAR:  1942

This article discusses use of the medullary route for massive replacement therapy when the usual methods of administration and not available or practical. The article also reviews a case study of a man in receipt of a sternal puncture needle inserted into the medullary cavity where he received the infusions through this needle of whole blood and fluids.

Papper EM.  The bone marrow route for injecting fluids and drugs into the general circulation.  Anesthesiology 1942;3(3):307-13
Discusses IO infusion, pioneered by Tocantins, as a viable route for parenteral fluids, drug therapy, and anesthesia. Includes case reports.

YEAR:  1941

Tocantins LM, O'Neill JF, Jones H.  Infusion of blood and other fluids via the bone marrow: Application in pediatrics.  JAMA 1941a; 117(5):1229-34
Describes emergency IO infusion of citrated blood and saline into the tibia or femur of 9 infants. IV access was impossible. Found no complications upon clinical or x-ray examination post-infusion.

Early study of 4 patients with acute failure of the peripheral circulation. IO infusion of blood, fluids, or drugs via the bone marrow resulted in a prompt recovery from the state of collapse. Recommends IO route when peripheral veins are not available and fluids are urgently needed.

Tocantins LM, O'Neill JF.  Infusions of blood and other fluids into the general circulation via the bone marrow.  Surg Gynecol Obstet 1941;73:281-7
Clinical study of 52 IO infusions of fluids in 40 patients (33 adults and 7 infants). Found no local, constitutional, immediate, or delayed reactions accompanying or following any infusion.

YEAR:  1940

Clinical study finding that IO infusion for parenteral therapy was successful in 16 of 17 trials in 14 patients. Found that citrated blood, plasma, glucose and salt solutions could be infused with no complications.

Seminal study demonstrating that substances injected into the IO cavity of the tibia of the rabbit and the sternum of man immediately appeared in the central circulation, similar to IV administration.

Seminal article on blood circulation in the IO space. Demonstrates movement of red blood cells from the bone marrow into the circulating blood by perfusion of the tibia of the dog and by injections into the bone marrow in the rabbit and cat.
This pre-clinical study compared various PK parameters, return of spontaneous circulation (ROSC), time to ROSC, and odds of ROSC after epinephrine was administered via endotracheal (ETT), IO, and IV routes in a swine traumatic cardiac arrest model (TCA). IO groups included sternal IO (SIO), humeral IO (HIO), and tibial IO (TIO). CPR only and CPR plus defibrillation (CPRD) groups were included for analyzing ROSC. The Cmax of the IV epinephrine group was significantly higher than that of the IO group (p=0.049). The Tmax of the TIO group was significantly longer than that of all other groups (p=0.008). There were significant differences in mean plasma concentrations over time between the IV and TIO groups at 90, 120, 150, and 180 seconds (p<0.05) with the TIO group having an unexpectedly prolonged absorption phase. There was no difference in the rate of ROSC between ETT, TIO, HIO, SIO, IV, and CPRD groups. The PK findings relative to ROSC support the concept that neither epinephrine nor the route of administration influenced the outcome. All IO insertions were performed using the EZ-IO device.


Retrospective case report of six patients describing the use of intraosseous (IO) administration for 23.4% saline administration to treat intracranial hypertension. In all six cases sodium levels were increased and there were no IO complications.


This is a case report of IO access for palliative sedation with propofol in a 56-year-old man with no venous access. IO access was gained using an EZ-IO driver and the patient was successfully treated with propofol for 4 days to manage intractable pain and agitation.


A 75-year old female presented by EMS to the Emergency Department (ED) after a ventricular fibrillation cardiac arrest. EMS defibrillated the patient and placed a right proximal tibial EZIO intraosseous (IO) catheter which multiple medications (epinephrine, magnesium, amiodarone, and calcium chloride) were administered; and she had return of spontaneous circulation prior to ED arrival. The IO catheter wasn't patent upon arrival in the ED and was removed. The patient was discharged on day four with ecchymosis near the insertion site. Three weeks post discharge the patient presented with tissue necrosis in an area surrounding the initial proximal tibial IO insertion site. The patient’s leg was debrided and grafting was performed; the author reported "good healing" three months post-event.


Retrospective case-control feasibility study comparing proximal tibial intraosseous (PTIO) and peripheral intravenous (PIV) delivery of contrast media in 24 patients receiving emergent CT scans as part of trauma diagnostics (n=4 PTIO, n=20 PIV). Delivery of contrast media was by power injection with rates of 5cc/sec for CT images of the head and neck, chest, abdomen and leg vessels. There were no significant differences in ability to complete imaging protocols or image quality. There were no complications. The study was limited by low patient numbers.


Retrospective analysis of 76 patients exhibiting clinical symptoms of intracranial hypertension (ICH) that received 23.4% NaCl via the central venous catheter (CVC, n=38) or intraosseous (IO, n=38) access. IO insertion success was 97%; 33 were placed in the proximal humerus and 5 in proximal tibia. Transient hypotension was noted in 10 patients with IO devices and 3 with CVCs, an insignificant difference. No IO specific complications were noted. Time to delivery of 23.4% NaCl was faster with IO access; outcomes for CVC and IO were similar. Limitations include retrospective data, no ICP monitors, small numbers of patients.

**YEAR: 2018**


This study compared the efficacy and safety of IO versus IV idarucizumab for dabigatran reversal in a porcine polytrauma model. Twenty-one male pigs received oral dabigatran for 3 days and on the 4th day received dabigatran infusion while another 7 received a sham treatment. The treated pigs were then randomized to one of three groups; IO saline, IV idarucizumab, IO idarucizumab while the other 7 comprised the sham group. The pigs were subjected to polytrauma (femur fracture and blunt liver injury). Blood loss, hemodynamic values, and blood samples were measured and recorded. Blood loss was highest in the control group, followed by the two idarucizumab groups, and lowest in the sham group. Survival to 240 minutes was 100% in the sham group and both idarucizumab groups, and 14% in the control group. IO and IV idarucizumab promptly normalized global coagulation assays and thrombin generation and were comparable for reversing dabigatran.
Intraosseous Vascular Access Bibliography

Medications


This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.


This study compared tissue concentrations of low-dose vancomycin via intraosseous regional administration (IORA) vs actual body weight-adjusted IV dosing in total knee arthroplasty (TKA) in obese patients (BMI>35). The obese patient population has an increased risk of periprosthetic joint infection after TKA. 22 patients were randomized to receive either 15mg/kg (max 2 g) of systemic vancomycin or 500 mg vancomycin via IORA. Fat and bone samples were taken and antibiotic concentrations measured. The overall mean tissue concentration in the subcutaneous fat was 39.3 µg/g in the IORA group vs 4.4 µg/g in the IV group (P<0.01). Mean tissue concentrations in bones were 34.4 µg/g in the IORA group vs 6.1 µg/g in the IV group (P<0.01). Low-dose IORA vancomycin was effective in providing tissue concentrations 5-9 times higher than IV administration in this high risk patient population.


This paper discusses prosthetic joint infection (PJI) after total knee arthroplasty (TKA) and the use of prophylactic antibiotics to prevent PJI. Current literature recommends IV administration of cephalosporins, however, rising resistance rates limit the effectiveness of IV cephalosporins. Alternatives include clindamycin, teicoplanin, and vancomycin. The author reviews alternative routes of administration to increase time dependent or concentration dependent antibiotic killing including intravenous regional administration (IVRA) and intraosseous regional administration (IORA). Supporting literature is reviewed. The author concludes that IVRA and IORA of prophylactic antibiotics in TKA is a novel way to increase tissue concentrations of prophylactic antibiotics and the current literature supports changing guidelines (after further research) to allow IVRA and IORA in TKA. The EZ-IO device was utilized for IORA of prophylactic antibiotics in the reviewed studies.


This is a prospective, randomized, controlled trial of patients undergoing revision total knee arthroplasty (TKA). Twenty patients were randomized to receive systemic IV or IO regional administration (IORA) of vancomycin as prophylaxis. Higher tissue and bone concentrations were consistently achieved in the IORA group with tissue concentrations during the procedure 5 to 20 times higher in the IORA group versus the IV group. The EZ-IO device was used to gain IO access in this study.

YEAR: 2017


Swine study comparing pharmacokinetic (pk) parameters of TXA given by the IO vs IV route. For the 4 min and 5 min results Cmax plasma concentrations were higher in the IV group but similar from injection completion onwards. Other pk parameters were not significantly different. Limitations included swine model, normotensive animals and proximity of sampling site (jugular vein) to the IV infusion site (auricular). Investigators concluded this study supports the pharmacokinetic bioequivalence of IO and IV administration of TXA in this animal model.


This case report describes a CT angiography of the chest and abdomen done via an EZ-IO catheter placed in a critically ill patient’s proximal humerus. The contrast media was infused at a rate of 4 mL/s and the infusion pressure never exceeded 300 mmHg. No immediate or short term complications were observed. The authors describe the overall image quality and vessel contrast observed as excellent.


This preclinical study reported data evaluating the pharmacokinetics of HIO and IV vasopressin and the ROSC in a swine model of ventricular fibrillation cardiac arrest. For the parameters of occurrence of ROSC, odds of ROSC, time to ROSC, Cmax, Tmax, and plasma concentrations over time, the IO and IV routes results were comparable.
Intraosseous Vascular Access Bibliography

Medications


A retrospective chart review was done to analyze data of three EMS agencies over an 18 month timespan. Analysis was done on charts from adults who suffered OHCA and received epinephrine through EMS established IV or IO access. An IO first approach was found non-inferior to an IV first approach based on the end point ROSC at time of emergency department arrival.


This study reviews current IO administration of antidotes for patients that have presented to the emergency department with serious poisoning and IV access is not available. The study concluded that the evidence supporting the use of IO route for administering antidotes for poisoning patients is rare. Most evidence of IO access administration of antidotes has occurred in animal studies and case reports. Per author, despite lack of evidence, IO access is a potential option for antidotal treatments for resuscitation for patients where IV access is not available.


This retrospective cohort study evaluated emergency medical services (EMS) that treated adult patients with atraumatic out of hospital cardiac arrest (OHCA) in order to compare drug administration via intraosseous (IO) versus intravenous (IV) and the effectiveness. Study endpoints were survival to hospital discharge, return of spontaneous circulation (ROSC), and survival to hospital admission. The study included 1,800 patients, 1,525 of whom received IV access and 275 who received IO access. The practice for OHCA management in the EMS system from which the data was obtained was to attempt tibial IO access after failed IV attempts. The authors concluded that use of IO access was associated with a lower likelihood of ROSC and hospitalization; and acknowledged that further study of how vascular access routes affect OHCA patient outcomes is warranted.


This article describes a case in which adenosine was administered to a 2-week old patient with supraventricular tachycardia, which was successfully terminated following intraosseous administration of the drug.


This case study describes a resident’s experience treating an infant in respiratory arrest. Among the interventions were tibial intraosseous vascular access using the Arrow® EZ-IO and administration of epinephrine. The baby did not survive.


These are guidelines for prolonged field care (PFC) intended to be used after Tactical Combat Casualty Care (TCCC) when evacuation to higher level of care is not immediately possible. The intent of these guidelines is to identify potential issues to consider when providing analgesia with or without sedation for an extended time period (4-72 hours). IO is listed as an optional route of administration.


This retrospective study of a quality and safety database compared procedures performed by use of intraosseous vascular access for contrast media infusion to a control group of the studies in the database performed with antecubital intravenous access. The quality metrics of the two groups were similar, with the intraosseous needle group being slightly better. There were no complications related to IO use in general or specifically associated with the procedures. Limitations included this was a single-center study with small sample size and possible selection bias due to unfamiliarity with IO access.


This retrospective non-inferiority study examined EMS data extracted from a statewide EMS data system over a two year period. IO insertions performed by advanced EMTs (AEMT) and Paramedics were compared for insertion success rates. The majority of IO placements were with the EZ-IO®. The investigators concluded successful IO access was not different among AEMTs and Paramedics lending evidence in support of expanding the scope of practice of AEMTs to include establishing IO access in adults.

Young SW, Zhang M, Moore GA, Pitto RP, Clarke HD, Spangehl MJ. Higher tissue concentrations of vancomycin with intraosseous regional prophylaxis in revision TKA- A randomized controlled trial. Manuscript submitted for publication

A randomized controlled study comparing antibiotic tissue concentrations when vancomycin is administered for total knee arthroscopy via IO and IV access. Ten subjects were randomized to each group. The IO group received 500 mg vancomycin injected directly into the proximal tibia IO insertion site below an inflated thigh tunicate, and the IV group received 1 gram vancomycin, both were given before skin incision. Results showed IO tissue concentrations of vancomycin were 5-20 times higher than systemic IV despite the lower dose. This study was sponsored by Teleflex Incorporated.
YEAR: 2016


This study compared maximum concentration time (Cmax) to maximum concentration mean (Tmax) of mean serum concentration of vasopressin, return of spontaneous circulation (ROSC), time to ROSC, with odds of survival to vasopressin administration by tibial intraosseous, proximal humerus intraosseous (PHIO), and intravenous (IV) routes in a cardiac arrest model. Authors concluded TIO and PHIO provide rapid and reliable access in administration of life-saving medications during cardiac arrest and may be faster due to IV difficulty.


This study examined the differences of pharmacokinetics and pharmacodynamics of epinephrine via tibial intraosseous access and IV access. Interruptions in CPR in order to obtain vascular access reduces the flow of blood to vital organs. Study results showed that TIO access may be a faster alternative to IV access for delivery of vasoactive medications.


This study was to determine if there were any significant differences between humerus intraosseous (PHIO), sternal intraosseous(SIO) and intravenous (IV) administration of Hextend on the hemodynamics or administration time in a hypovolemic swine model. Time of administration of the Hextend on effects on systolic and diastolic blood pressure, mean arterial pressure, heart rate, cardiac output and stroke volume. After administration of Hextend, data was collected every 2 minutes for 8 minutes total. Results found no significant difference in these measures among the PHIO, SIO or IV groups.


Investigators conducted a retrospective prehospital study over a 3 month time period comparing IV vs. IO access for return of spontaneous circulation (ROSC). With approximately 800 cases of out-of-hospital cardiac arrest (OOHCA) they found a significantly greater success rate for IO access but no difference between IO and IV for ROSC or time to first epinephrine.


This journal article literature review was written to provide information about the history, clinical considerations, and devices associated with intraosseous access to administer resuscitative drugs when IV access can’t quickly or easily obtained.


This literature review examined the increase in use of intraosseous access for administration of resuscitative fluids and drugs to patients where intravenous access could not quickly or easily obtained during disasters and mass casualty events. The review also included a comparison of IO route to other routes for establishing vascular access in patients that have been involved in mass casualty or disasters.


In this letter to the editor authors discuss the importance of establishing access to circulatory system during CPR. The authors referenced the study "The effects of proximal and distal routes of intraosseous epinephrine administration on short-term resuscitative outcome measures in an adult swine model of ventricular fibrillation: a randomized controlled study" and the study "Intraosseous versus intravenous vascular access during out-of-hospital cardiac arrest: a randomized controlled trial". Authors concluded that intraosseous access seems reasonable for patients in cardiopulmonary arrest or severe shock that do not have available and quick IV access for administration of medications and fluids.


The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.


This prospective, experimental study was to characterize and compare the pharmacokinetics of atropine that is administered via sternal intraosseous (IO) route in hypovolemic and non-hypovolemic swine. Main outcomes PK parameters, maximum concentration (Cmax) and time to reach maximum concentration (Tmax). Authors concluded sternal IO route is effective for administration of atropine and data gained from this study was found to be similar to previous information reported on tibial IO and IV administration even in situations of significant hemorrhage.
Intraosseous Vascular Access Bibliography

Medications

This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.

Online article that briefly discusses use of intraosseous access to obtain a CTA study for pulmonary vasculature imaging when intravenous access is difficult.

Randomized, prospective preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered vasopressin during cardiac arrest and CPR until ROSC was achieved. No difference was noted for ROSC between TIO and IV delivered vasopressin. Authors concluded the use of IO access could avoid the time delay associated with IV access, and that it is effective for treatment of hypovolemic cardiac arrest and should be first line for rapid vascular access.

This article includes a case study of an adult patient who received an intraosseous (IO) catheter, that may have extravasated, resulting in vascular compromise. The patient was treated with pharmacologic intervention and the status was reversed. A review of the literature on adult IO complications is also described.

This study compared IV to tibial IO administration of amiodarone. Investigators found no significant differences for the endpoints of Cmax, Tmax and time to rate of ROSC between IO and IV.

In a swine study comparison of the humeral IO and IV amiodarone administration routes investigators found no difference in time to ROSC or rate, time to maximum concentration (Tmax) p = 0.501) or in maximum plasma drug concentration (Cmax) (p = 0.232).

This abstract describes indications, techniques and mechanism of percutaneous intraosseous doxycycline injections for the treatment of aneurysmal bone cysts.

This letter to the editor expresses support for the practice of injecting lidocaine into the intraosseous (IO) space prior to IO infusion in order to mitigate the pain associated with IO infusion.

This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access "should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation".

Authors described a randomized, double-blind trial, comparing parenteral amiodarone, lidocaine, and saline placebo, along with standard care, in adults who had non-traumatic out-of-hospital cardiac arrest, shock-refractory ventricular fibrillation or pulseless ventricular tachycardia after at least one shock, and vascular access (N=3026). The focus of the study was not intraosseous access, but eligible patients had intravenous or intraosseous access (n=661).
Intraosseous Vascular Access Bibliography

Medications


A prospective study with 30 evaluable healthy volunteers receiving PH and sternal IO access (Arrow® EZ-IO® Vascular Access System and T.A.L.O.N.™, Teleflex, Wayne, PA) was conducted to determine if there is a significant difference between pain after a total of 60mg or 40mg of 2% preservative-free and epinephrine-free lidocaine. Endpoints were subject reported pain scores during 5 minutes of rapid infusion at 300 mmHg and 15 and 30 minutes at a rate of 125 mL/hour per pump. Authors concluded infusion pain through a PH IO may be managed with a single 40mg lidocaine prior to infusion, but a total of 60mg may be considered for sternal IO infusion. This study was sponsored by Teleflex Incorporated.


A preclinical study evaluating blood transfusion via IO vascular access in anesthetized swine. Results showed pressurized blood transfusion through IO vascular access resulted in acceptable flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating vascular access routes used for US Military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) use including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. PIV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.


A preclinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.


This case study describes the medical management of a 20 year old male post high-speed motor vehicle crash with multisystemic failure who arrived in shock upon air medical team arrival. Care entailed aggressive airway support, bilateral chest decompressions, management of potential pelvic bleeding with a pelvic binder, one peripheral IV through which packed red blood cells and plasma were given and one proximal humerus IO through which 1 g tranexamic acid (TXA) was given.


A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, after 2 minutes CPR was initiated for 2 minutes, then 40 units of vasopressin was administered via IV or SIO route. Results showed no significant difference in SIO and IV groups for Cmax or Tmax.
Intraosseous Vascular Access Bibliography

Medications


A preclinical study comparing administration of Hextend via IV and tibial intraosseous (IO) access routes for time for administration and hemodynamic measures in a hypovolemic swine model. Following exsanguination, 500 mL of Hextend was administered via both routes; a control group received no Hextend. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for administration in the IV group was 10 minutes 16 seconds (± 2 minutes 47 seconds), and for the IO group it was 10 minutes 12 seconds (± 1 minute 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing IV and humeral intraosseous (IO) access administration of vasopressin in a hypovolemic swine model in cardiac arrest. Following exsanguination, the swine were placed in cardiac arrest for 2 minutes, then resuscitated for 2 minutes in accordance with ACLS guidelines. Vasopressin was administered. Blood samples were collected at various time points following vasopressin injection and analyzed for maximum concentration (Cmax) and time to maximum concentration (Tmax) between groups; return of spontaneous circulation was also captured. ROSC was achieved for all HIO subjects (n=7) and in seven out of eight IV subjects; mean time to ROSC was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV administration of vasopressin for achievement of ROSC, time to ROSC, Cmax, Tmax, concentration over time, survivability, or odds ratio.

YEAR: 2015


This study examined whether the use of dual-intraosseous needles to deliver fluid and medication when vascular access is insufficient. The study used a single porcine humerus. The authors concluded that dual intraosseous needles are feasible and may help the rapid resuscitation of patients.


This article discusses a retrospective analysis of data collected to investigate the possible time-dependent outcomes associated with adrenaline administration by personnel with Emergency Medical Services (EMS). Primary endpoint was survival to hospital discharge and positive neurological outcome. The study included 3,469 patients with out of hospital cardiac arrest (OHCA). Study concluded patients with OHCA that had been treated early with adrenaline and had a shockable rhythm had a survival rate to hospital discharge.


A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, established via the EZ-IO, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.


In a healthy adult volunteer study contrast media was injected through the proximal humerus site and captured under fluoroscopy as it entered the heart. The mean time it took from injection at the insertion site to visualize contrast entry into the superior vena cava and the right atrium was 2.42 seconds. Abstract presented at ACEP 2015. This study was sponsored by Teleflex Incorporated.


A case study report of a 25-year old female who presented to the emergency department after consuming an over dose amount of verapamil. Central and peripheral venous access were obtained for delivery of vasopressors and intravenous fat emulsion 20% (IFE). IFE was initiated via peripheral IV (PIV) access but access was lost; administration through central access was not possible due to the potential drug interaction. Intraosseous (IO) access was established using the Arrow EZ-ID system in the proximal tibia without complication and IFE administration was resumed. The patient reported some pain with infusion. After half the bolus administration was delivered, the infusion pump alarmed due to inadequate flow. PIV access was obtained and IFE administration was resumed using the newly obtained access route. The authors suggested that the viscosity of the medication may have caused the delivery failure by infusion pump through the IIO route and recommend slowing down the bolus rate of infusion for clinicians attempting this route for IFE administration in the future.


This review article describes various protocols for haemorrhage control, specifying routes of access, including intraosseous vascular access infusion rates and volumes of various transfusion fluids.
Intraosseous Vascular Access Bibliography

Medications


Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) antibiotic (cefotaxime and gentamicin) concentrations during septic shock. Both methods of administration yielded comparable concentrations. Authors concluded in an emergency, IO administration of these antibiotics may be considered in severe infections when venous access is difficult.

Sweden


This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive drug in pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.

YEARS: 2014


This preclinical study investigated whether erythropoietin (EPO) given during hemorrhagic shock improved resuscitation and increased survival in a swine model. Swine were randomized to one of three groups: loss of 50% blood volume, loss of 65% blood volume, or loss of 65% blood volume plus vasopressin. Within each group half of the swine also received intraosseous EPO. EPO failed to improve initial resuscitability and 72 hour survival, however, EPO did attenuate acute organ injury. Additionally, vasopressin proved effective in improving survival.


Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) blood transfusion relative to hemolysis and transfusion time. IO transfusion does not significantly increase hemolysis (using free hemoglobin as outcome measure) or transfusion time compared with IV transfusion. Authors concluded transfusion of whole blood through an IO device is an effective transfusion method that may be used until other vascular access is obtained.


This literature review article sought to identify organic chemicals associated with intraosseous injection within the published literature. The top 31 articles identified in the search are cited within the article.

YEARS: 2013


A study evaluating the use of X-tip intraosseous injection of 2% lidocaine with 1:80,000 epinephrine in dental patients with irreversible pulpitis in whom inferior alveolar nerve block has failed. Thirty patients were included and 93% of X-tip injections were successful. Ninety-six percent of patients had subjective/objective increase in heart rate. Results showed X-tip intraosseous injection of 2% lidocaine was effective in achieving pulpal anesthesia in patients with irreversible pulpitis.

YEARS: 2011


German Society of Anaesthesiology and Intensivmedizin eV” (DGAI), includes a general discussion of intraosseous (IO) as vascular access, overview of devices and recommendations for pediatric anesthesia with indications for intraosseous infusion in pediatric anesthesia and perioperative care in children. Early or primary IO indications are respiratory and circulatory arrest; critical hemodynamic instability before or during anesthesia introduction; severe laryngospasm; anesthesia induction in respiratory bleeding. Urgent indications (decision based on each case is necessary) include urgent induction of anesthesia in non-fasted children (ileus, RS1); induction of anesthesia in children with unstable circulation or severe cardiac insufficiency. Semi-elective indications (decision based on each case is necessary) after mask induction of anaesthesia (if vascular access required); mandatory induction of “intraavenous” anaesthesia (as in malignant hyperthermia). This article is in German.
A case study describing administration of scorpion antivenom via intraosseous (IO) vascular access in a 16-month old female. Following failure to obtain IV access in pre-hospital and upon arrival at the ED, IO vascular access was established in the proximal tibia and 3 vials of antivenom in 50 mL saline were administered over 10 minutes. Within 5 minutes, the patients respiratory status improved, intubation was averted, and vital signs stabilized immediately; nystagmus and writhing resolved. The patient was discharged home after a short observation period. The authors concluded that when IV access is difficult, IO access may be a rapid and reasonable rescue maneuver for patients requiring scorpion antivenom.

Case study of a 9- month old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.

A dental study evaluating use of supplemental intraosseous injection of 3% mepivacaine in mandibular posterior teeth following application of an alveolar nerve block. Results showed supplemental injections increased anesthetic effect and a second injection was sometimes necessary.

A dental study comparing the anesthetic effect of 2% lidocaine (1:100,000 epinephrine) and 3% mepivacaine when injected in the mandibular first molars. The results showed the lidocaine to be more successful with a longer duration of pulpal anesthesia than mepivacaine.

Leonard MS. The efficacy of an intraosseous injection system of delivering local anesthetic. JADA 1995;126(1):81-6
This article describes a device used for the intraosseous delivery of local anesthesia during dental procedures.
Intraosseous Vascular Access Bibliography

Military Application

YEAR: 2018

This pilot study compares four different IO blood transfusion strategies with varying degrees of transfusion pressure in a swine model with similar bone density to that of an adult military servicemember. Animals were randomly assigned to one of four transfusion strategies: 1) gravity, 2) pressure-bag, 3) rapid-transfusion device, or 4) manual push-pull. Hemorrhage was simulated then IO access was obtained with the EZ-IO device. Gravity transfusion was the slowest with a flow rate 5 mL/min, followed by rapid-transfusion device (31 mL/min), single site pressure bag (78 mL/min), double site pressure bag (103 mL/min), and push-pull technique (109 mL/min). Single site or double site pressure bag was determined to be the best option for IO infusion because of the high flow rate and no associated incidences of overpressure or death.

Randomized crossover prospective study in which 77 of U.S. Army Combat Medics naive to the EZ-IO system were trained and then attempted IO access using the EZ-IO in bone models of the proximal tibial (PT) and proximal humerus (PH) sites. Success rate was the primary outcome with no significant differences in results between sites; and no significant learning or design confounding effects. Secondary outcomes of mean procedural time demonstrated a significant mean time advantage of 17.1 s (p < 0.05) in PT placement. There was no significant difference between sites for mean participant comfort level utilizing the EZ-IO® System. Authors concluded the overall first-attempt success rates with the EZ-IO® System are similar to the success rates of the FAST1® device.

This abstract describes interim results of a study in a swine model that discusses the utility of intraosseous blood transfusions for treating hypovolemic battlefield injuries, compares advantages and complications of humeral versus sternal IO access for resuscitation, and identifies flow rates, degree of intravascular hemolysis, and occurrence of coagulopathy in single versus double site intraosseous blood transfusion. The study found that in an animal model of hemorrhagic shock, double site IO transfusion appears to confer a significant advantage in flow rates without significant complications.

YEAR: 2017

The author discusses tactical combat casualty (TCCC), which has evolved over the past the past 20 years into a set of evidence-based, best practice prehospital trauma care guidelines for use in combat. TCCC has become a standard of trauma care in the US military and many other militaries of our allied nations. The Committee on TCCC and the Joint Trauma System are working with civilian trauma colleagues to advance prehospital trauma care into civilian trauma care in situations such as shooter events, terrorist bombings, motor vehicle accidents, household accidents and criminal violence.

This article describes two cases in which FAST1 intraosseous needle tips were retained in the sternal manubrium of patients following device removal. In each case, there were no long-term complications.

This paper describes skill sets and training for the Defence Medical Services in the UK, specifically the revised Military Higher Module and how it will be implemented in the future either during deployment or times of peace. IO devices as a means to control catastrophic haemorrhage is listed as a competancy.

Using a porcine hind leg model authors compared the success rate and ease-of-use ratings of an IO device, the NIO® in comparison to the Arrow® EZ-IO by novice users. NIO success rates were comparable to those of EZ-IO; 54% of the participants preferred using the EZ-IO over the NIO.

This paper assesses the usability of the Partial Task Trainer (PTT) to train certain military medical providers on the technique of humeral head intraosseous infusion (HHIO). The PTT consists of an arm with functional structures and characteristics that allow trainees hands on practice locating anatomical landmarks, inserting the IO needle, and introducing the catheter into the humerus. Currently the US Army utilizes the EZ-IO Intraosseous Infusion System for HHIO infusions.
Intraosseous Vascular Access Bibliography

Military Application


The CoTCCC handbook was created as a guide to best practices created by the Committee on Tactical Combat Casualty Care (CoTCCC) which includes representatives from all the U.S. Armed Services that are part of the Tactical Combat Casualty Care (TCCC) Working Group. The recommendations are based on input from the battlefield as well as evidence in the civilian literature, examined and put together to provide guidelines for care. The recommendations and required skill sets include IO access as an alternative to IV access in multiple sections. The TCCC Medical provider skill set specifically includes the ability to demonstrate the use of IV/IO blood product administration (medical officers and operating room special operations medics) and the use of IV/IO tranexamic acid (TXA).

YEAR: 2016


This journal article discusses lessons learned from treatment of severe traumatic injury in combat situations and how they can be applied in the civilian environments when treating the same type injuries.


This abstract describes a study designed to describe and compare the use of intraosseous (IO) catheters by military MEDEVAC providers during recent conflicts. There were 12 patients that receive IO catheters following failed intravenous cannulation with an 83% success rate, and 74 patients for whom IO access was the first access attempted with an 85% success rate. Researcher concluded that IO access can be used successfully in the combat setting and accounted for approximately 12% of vascular access in the MEDEVAC population they studied.


This abstract describes the results of a healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used safely and successfully in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating vascular access routes used for US Military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) use including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. PIV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.


A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.
Intraosseous Vascular Access Bibliography

Military Application

YEAR: 2015


This analysis examines the current state of military trauma in high-income countries and how these developments could be applied to low/middle-income countries to help deliver affordable trauma care there. Intraosseous needles are identified as a key technology especially when working in a moving environment or on a bumpy road which would likely be encountered in a low/middle-income country. Under such circumstances normal cannulation would likely fail out, whereas an IO needle would remain in place.


This article discusses the trends in management of critical trauma disease (CTD) in the military combat and civilian setting. Authors of the article discuss the need in ongoing innovations in the management of trauma patients in ICUs. In order to achieve more innovations there is a need for improvement in the following areas: methodology in emergency care medicine, increased knowledge in resuscitation strategies, study of epidemiology of trauma disease and its effect on patient outcomes, application of methodologies for ensuring correct trauma care team performance.


This paper describes a survey of trauma military directors that suggested that military data supporting damage control resuscitation has altered civilian practice. Among those practices are the use of intraosseous vascular acces.


A healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. Military trained medics performed all device insertions. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used by military and tactical medicine personnel to safely and successfully establish IO access in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


Case report of a 13 year old girl suffering from severe hemorrhagic shock due to blast injuries and gun shot wounds that received freeze-dried plasma via IO access as part of prehospital resuscitative efforts. Her vital signs improved upon arrival to the hospital; and she was released after 3 weeks of hospitalization.

YEAR: 2014


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.


Authors briefly review clinical literature and discuss the historical development and research of pharmacological and procedural adjuncts such as Hextend, hypertonic saline, permissive hypotension and adenosine-lidocaine-magnesium cardioplegia to support restoration of hemostasis in the pre-hospital environment, especially in far-forward military scenarios. Properties of a proposed "ideal" fluid solution for hemorrhagic shock are listed and include easy delivery (IV or IO), protection from secondary brain damage, effective in small volumes amongst other attributes.


A preclinical study comparing intraosseous (IO) and intravenous (IV) administration of Hextend in 27 swine for time of administration and hemodynamics. IO access was established in the proximal humerus using the EZ-IO. Results showed time for administration was not significant; there were no significant differences between IV and IO relative to hemodynamics. The author concluded that the IO route is an effective method of administering Hextend.
This article describes a questionnaire study that was given to UK Role One military clinicians deployed to Afghanistan to assess the level of experience and confidence rating with use of IO access, using the FAST-1 and EZ-IO, and IV access. Thirty-three responses were received; clinicians felt more confident with IV access over IO access; clinicians felt more confident with FAST-1 IO access than EZ-IO IO access

YEAR: 2013


This article describes a questionnaire study that was given to UK Role One military clinicians deployed to Afghanistan to assess the level of experience and confidence rating with use of IO access, using the FAST-1 and EZ-IO, and IV access. Thirty-three responses were received; clinicians felt more confident with IV access over IO access; clinicians felt more confident with FAST-1 IO access than EZ-IO IO access.

UK
Intraosseous Vascular Access Bibliography

Military Application

This article describes the role of the casualty evacuation nurse role within the military. One case study briefly notes the use of proximal tibia IO access and the administration of packed red blood cells in a 22-year-old woman. No further follow up is provided other than noting the patients were expected to survive.

A 45-year-old woman in hemorrhagic shock with multiple injuries to the limbs, secondary to a war wound, received sternal IO access using the Jamshidi trocar (not specifically intended for sternal use). After initiating a blood transfusion through the IO line a contrast CT scan revealed sternal perforation and hemomediastinum, secondary to the transfusion, as well as drainage into the left pleural cavity. The catheter was removed, right thoracic drainage was performed, and the patient was released from ICU 48 hours later. The authors conclude this case report demonstrates the difficulty in selecting emergency insertion sites and the necessity of choosing an appropriate IO catheter.

A case study describing use of the EZ-IO in Afghanistan by US military on 5 patients with traumatic injury including one pediatric patient. Access was obtained in the proximal tibia on first attempt and was used to administer crystalloids in all patients along with opioids, analgesics and antibiotics. All ultimately received central venous access and peripheral access was established in one patient. There were no IO complications.

This study conducted by the Norwegian Navy evaluated the ability of 25 soldiers to perform buddy transfusion by starting phlebotomy, establishing sternal IO access using the FAST1, and infusing 1 unit of whole blood. Physical performance was evaluated pre and post blood donation and lactate levels were recorded. The authors concluded that physical and combat performances are preserved within limits post whole blood donation and that soldiers are able to learn the phlebotomy and sternal reinfusion with only a short lecture on the procedure.

YEAR: 2012

This article takes a look at the emergency medicine advances that result from war, including intraosseous resuscitation.

This pre-clinical study evaluated IO flow rates obtainable with infusion of lactated Ringer’s and hetastarch 6% through the proximal tibia and sternum IO insertion sites, using a swine model. The EZ-IO 25mm was used to facilitate tibial IO access; sternal access was established using a Jamshidi needle. Results showed that hemostasis flow rates were lower than lactated Ringer’s flow rates at both insertion sites; sternal infusion of hetastarch is likely to provide greater estimated intravascular volume expansion than lactated Ringer’s, despite the lower infusion rates; resuscitation using the IO rate is likely to benefit from pressure bag or high-pressure pump delivery. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

This is a case report of needle sheering associated with the use of the FAST-1 intraosseous infusion system. A soldier successfully placed a FAST-1 needle in the sternum of a healthy volunteer soldier during a training session. Upon completion of the training session, the soldier was unable to remove the needle. The retained needle was later removed surgically at a field hospital.

This abstract described a prospective observational study evaluating lifesaving interventions performed in a combat zone, including those that were incorrectly used. The use of intraosseous access in the study cohort of 449 patients was very low with only 26 IO lines established.
Intraosseous Vascular Access Bibliography
Military Application


This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.


This poster presented at the 2012 International Conference of Emergency Medicine described a 4 month review of intraosseous access in UK military operations in Afghanistan. During the timeframe the EZ-IO was used to establish IO access in the proximal humerus and tibia sites; the FAST1 was used to establish sternal IO access. Of the 87 EZ-IO applications there were 12 functional issues and the placement success rate for both sites combined was 86.3%. In 24 FAST1 applications there were 4 functional issues and the placement success rate was 93.4%.

YEAR: 2011


This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first receivers to place IO lines for antidote administration using the EZ-IO device. First responders placed IO lines successfully in 100% of cases, and first receivers placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.

Brisson M. Trauma and the military medic. EMS1.com 12/01/2011

This article describes use of IO access along with other prehospital interventions in a traumatically wounded soldier in a combat zone. The IO site used was the proximal humerus as the patient had 3 of 4 limbs traumatically amputated.


This article summarizes the case-based observations made by the Armed Forces Medical Examiner System on soldiers killed in action/died of wounds who had evidence of sternal intraosseous access. The Pyng Fast-1 is noted in the article as the sternal IO device most widely distributed by the department of defense (DOD); the EZ-IO is listed as another device that may be seen in emergency care facilities within the DOD. Of 98 cases, 78 (80%) showed proper placement; 20% were unsuccessful. It should be noted that the article incorrectly states that the EZ-IO using the powered driver is indicated for sternal placement.

YEAR: 2010


This article in Spanish describes the Spanish military medical staff’s experience with the use of intraosseous lines for fluid therapy in a combat zone from March 2007 to June 2008. Twenty-five patients had an IO placed with the Bone Injection Gun (BIG). Placement success rates were 76% for the 19 pre-hospital placements and 100% for the 6 in-hospital placements. There were no complications during insertion. Conclusion was intraosseous access can provide an alternative to venous access for treating trauma patients in combat zones.

YEAR: 2009


This case report describes a complication of use of a sternal IO device (FAST-1, Pyng Medical Corporation, Richmond, Canada) in a 21-year-old soldier who suffered multiple soft tissue fragmentation injuries, in which the needle tip broke in situ. The author concluded the complication resulted from the IO needle being placed when the patient was lying in a lateral position with the skin over the manubrium displaced from the midline.
Intraosseous Vascular Access Bibliography

Military Application


This article describes an observational study performed by the French military air surgical team in Chad. There were 11 patients with no insertion failures. For 7 patients, the insertion site was the proximal tibia and for the remainder the site was the proximal humerus. The authors concluded that the EZ-Io is a device that is simple, reliable and which gives satisfaction for the administration of drugs.


This case study describes injuries sustained in Iraq by an American soldier, and the concurrent use of 4 IO devices to resuscitate and stabilize him.

YEAR: 2008


Animal (goat) study to determine if IO administration of hydroxocobalamin for antidotal treatment for exposure to cyanide and other poison agents would be faster and require less fine motor coordination and sensitivity; and would result in similar hemodynamic changes compared to IV administration. Using the EZ-IO device, researchers concluded that hemodynamic effects of hydroxocobalamin given by the IO route in non-poisoned goats are mild and similar in magnitude to those of saline control animals.


Animal (goat) study to determine the capacity and time required for protected hazardous materials responders and receivers to accomplish vascular access and hydroxocobalamin administration for antidotal treatment for exposure to cyanide and other poison agents. Using the EZ-IO device, researchers concluded that the time required for IO administration of the drug was shorter than intravenous administration; and that IO placement is readily accomplished wearing all levels of chemical protective garments and equipment.

YEAR: 2007


Data from the largest combat trauma database was analyzed to identify how new or improved devices, dressings or drugs have impacted prehospital casualty care, how guidelines and resuscitation strategy have changed, and discusses lessons learned and how concepts have crossed back into the civilian practice. Intraosseous access, particularly the sternal site, is identified as one of the advances for vascular access in combat medicine.


Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.


Study investigating time difference in obtaining IO vs. IV access while wearing personal protective equipment (PPE) in simulated HazMat scenarios. With provider in PPE and mannequin not in PPE, vascular access was faster with IO (14 seconds vs. 46 seconds; p<0.001); also, fluid infusion time (28 seconds vs. 46 seconds; p<0.001). With provider and mannequin in PPE, all the following favored IO: needle to skin time (13 seconds vs. 25 seconds, p<0.001), vascular access time (17 seconds vs. 63 seconds; p<0.001), and fluid infusion time (30 seconds vs. 66 seconds; p<0.001). Investigators conclude that EZ-IO under HazMat conditions provides vascular access and fluid more quickly than IV access.


Article describes a controlled study in which the time difference between IV and IO access was compared while providers and simulated patients (mannequins) were wearing personal protective equipment (PPE). Twenty-two EMT-P providers measured the times to skin access, vascular access and fluid infusion in three scenarios: no PPE for providers or mannequins; providers only in PPE; and both providers and mannequins in PPE. In all scenarios, there was a statistically significant difference in vascular access and fluid infusion time, in favor of the EZ-IO. Investigators concluded that, overall, the EZ-IO provides vascular access and fluid more quickly than standard IV access, and that donning PPE does not hinder providers' use of the EZ-IO.
Intraosseous Vascular Access Bibliography

Military Application

YEAR: 2005

Butler FK, Holcomb JB. The tactical combat casualty care transition initiative. Army Medical Department Journal 8-0504/5/6 Apr/May/Jun 2005 -33-37
Article for a military audience describing strategies employed as part of the Tactical Combat Casualty Care Transition Initiative, including phased levels of battlefield care, more aggressive use of tourniquets, battlefield antibiotics, IV vs IM battlefield analgesia, hypotension resuscitation strategies, small volume colloid as a resuscitation fluid, cricothyrotomy vs intubation for a definite airway in maxillofacial trauma, and more aggressive use of needle decompression for suspected tension pneumothoraces. Advocates IO infusion devices over cutdowns for fluid replacement.

Describes a training course for medical students to learn advanced emergency procedures using unembalmed cadavers. The course includes clinical indications and contraindications for specific procedures, as well as techniques. Also discusses students' confidence levels in performing procedures.

Timboe HL, Bruttig SP, Ruemmler MW. Adult IO in the combat zone: the past, present and future use of intraosseous infusion by the U.S. military. JEMS 2005; 30: 27-8
Article discussing the use of IO in the combat zone. Highlights newer medical devices that make IO access and infusion safer.

YEAR: 2004

Gawande A. Casualties of war-military care for the wounded from Iraq and Afghanistan. NEJM 2004; 351: 2471-5
Article describing the military medical system's strategies and systems of battle care.

Evaluation of the BIG in a chemical warfare mass casualty scenario. Found 73.4% simulated survival in the IO group and 3.3% in the control group (no IO). Average treatment goals obtained in 3.5 minutes for IO group and 10 minutes for control group. Concludes that IO has great potential for early treatment of chemical.

Evaluation of the B.I.G. in a simulated mass casualty attack with 88.9% of IO attempts successful.
http://emergency-medicine.jwatch.org/content/vol2004/issue728/

YEAR: 2003

Study evaluating the ability of physicians to establish IO access in patients while wearing full protective gear. Concludes that IO insertion of the BIG needle is rapid, but the protective gear increased insertion time 50%.

This article describes the development of a simulation-based training program for anesthesiologists to treat nerve gas intoxication in mass casualty scenarios. As part of the program, the Bone Injection Gun was used for vascular access for delivery of fluids and medications. Most participants (22 of 25) concluded that the training program was an effective means to prepare for nerve gas intoxication in mass casualty situations.

Review article asserting that IO administration of hypertonic saline dextran is consistent with the concept of permissive hypotension. Calls for innovative techniques in resuscitating patients from severe hemorrhage.

Historical perspective on combat casualty care perspectives, differences in combat and civilian trauma cases, hypotensive resuscitation and hemorrhage control. Recommends instituting an algorithm for fluid resuscitation in combat casualties.
YEAR: 2000

Report on reorganization of the medical capacity of the Swedish Armed Forces focusing on new treatment modalities such as intraosseous infusion.

Literature review of safety and efficacy of IO infusion of drugs and fluids, with emphasis on utility for the injured soldier. Discusses insertion times and flow rates. Includes literature citations from non-military studies in pediatrics, animals, and human cadavers.

YEAR: 1997

Review article highlighting preclinical data and 1 clinical study. Demonstrates that IO administration can be used for safe and rapid infusion of hypertonic saline dextran with the hemodynamic effect as IV administration.

YEAR: 1996

Discusses research directions for resuscitation from trauma-induced acute hemorrhagic shock, particularly uncontrolled hemorrhagic shock, with emphasis on fluid resuscitation.

YEAR: 1984

Turkel H. Emergency infusion through the bone. Military Medicine 1984;149:349-50
Article for military medicine audience concluding that the intraosseous route is more safe and effective than the intravenous route for several clinical indications, including burns and shock, circulatory collapse, uncooperative patients, patients in transit, shortage of physicians, especially under emergency conditions. States that IO infusion is an established alternative to intravenous infusion.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

YEAR: 2019

This is a case report of IO access for palliative sedation with propofol in a 56-year-old man with no venous access. IO access was gained using an EZ-IO device and the patient was successfully treated with propofol for 4 days to manage intractable pain and agitation.

YEAR: 2018

This case study discusses the use of an IO vascular access device (EZ-IO) as a substitute for k-wire stabilization of mallet finger in a patient with distal fracture and tendon exposure of the third and fourth phalanx. The needle driver of the EZ-IO was placed in a sterile glove and was then used to place the inner stylet of the device through the tip of the finger to achieve splint fixation in extension. The patient had a favorable outcome.

This paper presents two case reports of IO anesthesia using a computer-controlled intraosseous system (CIAS) for non-surgical periodontal therapy (root planing). CIAS-based induction of local anesthesia during non-surgical periodontal therapy was more comfortable for both patients relative to previous conventional local infiltration anesthesia (CLIA) treatment.

This article investigates intraosseous fluid (IOF) as an alternative matrix for drug testing in deceased patients, especially in cases where the cadaver is severely compromised following death. IO access was obtained at 4 sites, bilateral proximal tibia and bilateral proximal humerus, using the EZ-IO device. Samples in 29 subjects were collected and screened for a host of illicit substances. Study results support the possible use of IOF as an alternative postmortem specimen for toxicological investigations when necessary.

This paper discusses prosthetic joint infection (PJI) after total knee arthroplasty (TKA) and the use of prophylactic antibiotics to prevent PJI. Current literature recommends IV administration of cephalosporins, however, rising resistance rates limit the effectiveness of IV cephalosporins. Alternatives include clindamycin, teicoplanin, and vancomycin. The author reviews alternative routes of administration to increase time dependent or concentration dependent antibiotic killing including intravenous regional administration (IVRA) and intraosseous regional administration (IORA). Supporting literature is reviewed. The author concludes that IVRA and IORA of prophylactic antibiotics in TKA is a novel way to increase tissue concentrations of prophylactic antibiotics and the current literature supports changing guidelines (after further research) to allow IVRA and IORA in TKA. The EZ-IO device was utilized for IORA of prophylactic antibiotics in the reviewed studies.

This is a prospective, randomized, controlled trial of patients undergoing revision total knee arthroplasty (TKA). Twenty patients were randomized to receive systemic IV or IO regional administration (IORA) of vancomycin as prophylaxis. Higher tissue and bone concentrations were consistently achieved in the IORA group with tissue concentrations during the procedure 5 to 20 times higher in the IORA group versus the IV group. The EZ-IO device was used to gain IO access in this study.

YEAR: 2017

This is an abstract of a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Overall geometric mean tissue concentrations in fat samples were 3.7 µg/g in the IV group vs 49.3 µg/g in the IORA group (P<0.001) while mean tissue concentrations in the femoral bone were 6.4 µg/g in the IV group vs 77.1 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.
This abstract describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional administration (IORA) in revision TKA. Twenty patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin. Mean tissue concentrations in fat samples were 4.1 µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

This e-poster describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional prophylaxis (IORA) in revision TKA. Twenty-two patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin with 20 patients analyzed. Mean tissue concentrations in fat samples were 4.1 µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

A randomized controlled study comparing antibiotic tissue concentrations when vancomycin is administered for total knee arthroscopy via IO and IV access. Ten subjects were randomized to each group. The IO group received 500 mg vancomycin injected directly into the proximal tibia IO insertion site below an inflated thigh tunicate, and the IV group received 1 gram vancomycin, both were given before skin incision. Results showed IO tissue concentrations of vancomycin were 5-20 times higher than systemic IV despite the lower dose. This study was sponsored by Teleflex Incorporated.

This abstract describes a study that compared tissue concentrations of vancomycin administered intravenously (IV) versus intraosseous regional prophylaxis (IORA) in revision TKA. Twenty-two patients were randomized to 2 groups: 1 g IV vancomycin or 500 mg IORA vancomycin with 20 patients analyzed. Mean tissue concentrations in fat samples were 4.1 µg/g in the IV group vs 115 µg/g in the IORA group (P<0.001) while tissue concentrations in the femoral bone were 7.2 µg/g in the IV group vs 101 µg/g in the IORA group (P<0.001). IORA of low-dose vancomycin provided tissue concentrations 5-20 times higher than IV administration. IO access was obtained using the EZ-IO device. This study was sponsored by Teleflex Incorporated.

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This article presents a 5-case series describing use of IO vascular access by anesthesiologists in the perioperative and critical care settings. All insertions were made in the proximal tibia and there were no adverse events reported. The devices cited as being used were the EZ-I0 and the Cook Surfast manual needle. A proposed perioperative vascular access algorithm incorporating IO access is presented. The authors address key topics around IO access including use of same drug dosing as IV administered drugs, frequent palpation and monitoring of the insertion site for extravasation, low complication rates and frequency of fat emboli and bone injury, and pain and anxiety management in the awake patient and clinician-perceived pain. Administration of blood products, ACLS drugs, Lactated Ringer’s solution and anesthetics are noted without complication. Use of IO aspiration for laboratory testing is noted, however use of the initial aspirate is indicated. Several patients in the case series were reported to find the discomfort of IO insertion preferable to multiple intravenous attempts. The authors concluded: IO lines can be placed quickly and safely in emergency situations or in elective surgical patients with difficult intravenous access; IO access can be useful in a wide variety of clinical settings; and is an important skill for anesthesiologist to learn.


A pilot study evaluating the relationship between intraosseous (IO) pressure measurements and blood pressure obtained via external blood pressure cuff in ICU patients. Patients with IO access established by EMS or in the emergency department with planned admission to the ICU or surgical ICU were included in the study. External pressures were recorded every 15 minutes and IO pressure was monitored via a transducer for 12 continuous hours. Results showed IO pressures were approximately 30% of external blood pressure cuff readings.


The authors described a proof of concept pilot study conducted to determine intraosseous (IO) pressure measures and their relationship to blood pressure obtained using an external blood pressure cuff in ICU patients. The average IO systolic blood pressure, IO diastolic blood pressure, and IO mean were 39.5±12.7 mmHg, 31.5±7.6 mmHg, and 35.0±8.6 mmHg respectively. The ratio of IO systolic blood pressure to cuff systolic blood pressure, IO diastolic blood pressure to cuff diastolic blood pressure, and IO mean to cuff mean were 34.5±13.4%, 40.5±22.3%, and 40.1±17.1% respectively. There were no adverse events reported. Investigators concluded that in their convenience sample of severely ill and injured patients, IO pressure was reliably obtained and appeared to be 35% to 40% of blood pressure readings obtained via external blood pressure cuff; and that this method of pressure monitoring may be an appropriate alternative to invasive monitoring option in the future. This study was sponsored by Teleflex Incorporated.

Hagglund H, Remberger M, Ringden O. Twenty-year follow-up of a randomized trial comparing intraosseous and i.v. BM transplantation [letter to the editor]. Bone Marrow Transplant 2014;49(12):1541-2. doi: 10.1038/bmt.2014.184

This letter to the editor reports the 20 year follow-up of a randomized study comparing IO and IV transplantation of allogeneic hematopoietic stem cells from sibling donors conducted in 1998. At the 20 year follow-up the probability of graft versus host disease, treatment related mortality, and relapse probability were similar between the two groups. None of the patients in the trial developed a secondary malignancy.


In a series of studies using healthy adult volunteers the objective was to add to available data comparing IO marrow/blood (initial 1 mL aspirate), IO blood (subsequent aspirate), and venous and capillary blood to determine if there is a correlation between samples for serum lactate and PT/INR levels. Two point-of-care analysers were used. Conclusions were lactate levels obtained from IO blood appear comparable to lactate levels from venous blood; the PT/INR levels did not correlate. This study was sponsored by Teleflex Incorporated.


This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

YEAR: 2013

A pre-clinical study that compared intraosseous (IO), central venous and arterial pressure tracings in a porcine model. Results showed that IO pressure was approximately 25% of arterial pressure. A sampling of IO blood gases revealed oxygenation levels of venous blood. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measurable blood pressure and it correlates with pressure obtained through conventional techniques.

In this preclinical swine study, investigators sought to evaluate whether intraosseous blood samples can be used to measure opioids, and if so, to determine the level of accuracy of those measurements. Blood samples were drawn from bilateral tibial IO catheters and from a central venous catheter for six hours. Authors concluded that IO blood samples can be used for the analysis of opioids if an IV route is not available.

Authors described a study in which adult living donor kidney transplantation recipients (N=7) were given mesenchymal stem cells (MSC) derived from the donor bone marrow to evaluate the safety and the feasibility of immunological changes related to the intraosseous injection of MSC into the bone marrow. They concluded that donor MSC injection into the iliac bone at the time of transplant was feasible and safe.

A clinical study evaluating the relationship between IO blood and peripheral venous blood lactate levels analyzed using the i-STAT point-of-care analyzer in healthy volunteers. Results showed IO blood lactate levels were comparable to venous blood lactate levels with a positive statistical correlation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

A study evaluating the use of X-tip intraosseous injection of 2% lidocaine with 1:80,000 epinephrine in dental patients with irreversible pulpsitis in whom inferior alveolar nerve block has failed. Thirty patients were included and 93% of X-tip injections were successful. Ninety-six percent of patients had subjective/objective increase in heart rate. Results showed X-tip intraosseous injection of 2% lidocaine was effective in achieving pulpal anesthesia in patients with irreversible pulpsitis.

A clinical study comparing Cefazolin concentrations found at the operation site following total knee arthroscopy when prophylactic antibiotics are administered systemically, through IV administration, and regionally, through IO injection directly at the site using the EZ-IO. Subcutaneous fat and bone samples were collected for evaluation from 22 subjects. Authors concluded that regional IO administration of prophylactic antibiotics can achieve tissues levels higher than with systemic administration.

YEAR: 2012

A pre-clinical study that compared the EZ-IO 15 gauge 25mm needle set and the 13 gauge Jamshidi aspiration/biopsy needle when used to obtain core biopsy specimens in canines.

Canada
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

Barker LT. In the child with gastroenteritis who is unable to tolerate oral fluids, are there effective alternatives to intravenous hydration? Ann Emerg Med 2012;60(5):607-8. doi: 10.1016/j.annemergmed.2012.04.003

This article, part of a Review Snapshot series in Annals summarizes a literature review (Rouhani et al in Pediatrics 2011) for evidence of alternatives to traditional IV hydration in a dehydrated child. Thirty-eight articles were included for the analysis with five of them randomized controlled trials; and one of those comparing IO to IV rehydration. (Banerjee et al, which found IO placement faster with no therapeutic outcome differences). The focus of this review was on nasogastric tube rehydration as effective when IV fails and as less invasive than IO or CVC placement.


Manuscript of a literature review and critical analysis done to develop the Emergency Nurse’s Association (ENA) December 2011 Emergency Nursing Resource (ENR) which focused on the clinical issue of difficult IV access. Graded recommendations and decision options are provided for alternatives to IV access, including IO.


This article provides an overview of intraosseous vascular access, including applicable patient population, IO access sites, pain management, IO education and compares IO access to central venous access.


A preclinical study evaluating the effects of propofol on selected blood parameters and physiological variables during general anesthesia in rabbits when administered via intraosseous and intravenous routes. Results showed the IO route was as effective as the IV route for propofol administration at doses inducing general anesthesia. The authors concluded that use of IO propofol could be recommended as a safe method of anesthesia in small animals with limited vascular access.


This abstract presented at the 2012 NAEMSP scientific assembly described a randomized, cross-over study in which 8 swine were administered chilled saline via IV and IO routes to determine if the two routes were equivalent. The results suggested no clinical or statistical difference between IV and IO routes for infusion of chilled saline for therapeutic hypothermia. This study was sponsored by VidaCare Corporation, acquired by Teleflex Incorporated.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider’s armamentarium.


This article describes a retrospective study in which 50 consecutive MRI images were evaluated of the humerus for the purpose of determining the optimal needle length necessary for successful proximal humerus IO insertion. Results showed the cortical thickness was 4mm in all cases and that an IO needle length ranging between 40-50mm should be used via the anterior approach. The EZ-IO is specifically discussed in relation to the proximal humerus IO insertion site; and a 24 patient post mortem review of the EZ-IO placed in the proximal humerus is discussed.


This letter to the editor is written in response to the case report by Landy titled, Complication of intraosseous administration of systemic thrombolysis for a massive pulmonary embolism with cardiac arrest. The author suggests that the tissue necrosis described by Landy may have been due to the removal of the IO needle while there was still significant fibrinolytic activity at the needle insertion site. The author suggests a change in medical care after return of spontaneous circulation (ROSC) in patients following thrombolytic administration through IO access to convert the functioning IO line to a non-flowing saline lock. The EZ-IO was used to provide IO access in the case report by Landy.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications


The objective of this study was to retrospectively evaluate the relationship between out-of-hospital IV access and mortality among non-injured, non-cardiac arrest patients transported by 4 advanced life support agencies between January 1, 2002 and December 31, 2006. A total of 56,332 patients were included in the study. The author concludes that efforts to establish IV access in the out-of-hospital setting is associated with reduction in hospital mortality among non-injured, non-cardiac arrest patients.


This abstract presented at the 2012 NAEMSP scientific assembly evaluated end-tidal carbon dioxide (ETCO2) levels under initial induction of hypothermia, rewarming, and a second induction of hypothermia, via IO and IV infusion in the swine model. The authors concluded that there was no demonstrated association of ETCO2 with brain temperature during the initial induction. However, during rewarming and second induction of hypothermia the association of ETCO2 and brain temperature had a direct and proportional association. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

YEAR: 2011


A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthesia recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anesthesia by IO access was satisfactory without necessity of other infusion access.

Brazil


Case study of a 42 year-old woman with massive obstetric hemorrhage ultimately resulting in postpartum hysterectomy. Massive blood loss and inability to stop bleed prevented sufficient resuscitation via established PIV lines. IO access was established with the EZ-IO and used for fluid replacement and administration of cardiac resuscitation drugs. Fluid administered through IO access was 75% of the total infusion volume.


German Society of Anaesthesiology and Intensivmedizin eV (DGAI), includes a general discussion of intraosseous (IO) as vascular access, overview of devices and recommendations for pediatric anesthesia with indications for intraosseous infusion in pediatric anesthesia and perioperative care in children. Early or primary IO indications are respiratory and circulatory arrest; critical hemodynamic instability before or during anesthesia introduction; severe laryngospasm; anesthesia induction in respiratory bleeding. Urgent indications (decision based on each case is necessary) include urgent induction of anesthesia in non-fasted children (ileus, RSI); induction of anesthesia in children with unstable circulation or severe cardiac insufficiency. Semi-elective indications (decision based on each case is necessary) after mask induction of anaesthesia (if vascular access required); mandatory induction of “inavenous” anaesthesia (as in malignant hyperthermia). This article is in German.


The Emergency Nurse’s Association (ENA) published a series of Emergency Nursing Resources with emphasis on clinical or practice based issues. This issue focused on difficult IV access and provides a summary of the literature review, with graded recommendations and decision options for practice for IO access, ultrasound guidance, subcutaneous rehydration therapy and several other alternatives. IO access is graded as having a high level of evidence supporting use of IO access when difficult IV access is known or suspected for high success rates and rapid time to insertion.


This article describes a military study in which post-mortem preautopsy multidetector CT was used to assess placement of tibial IO needles in battlefield trauma deaths where IO was used as part of the medical intervention. Results showed 58 of 61 (95%) tibial IO needles were correctly placed. In this study, the device used for IO placement was not recorded, but may have been the manual device or EZ-IO as the Army has access to both.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

Howarth D. Adult intraosseous access: experiences in a remote emergency department. Australian Family Physician 2011;40(7):510-1
In this article, the author makes a supporting case for remote emergency departments to stock adult intraosseous kits by referencing two adult septic shock cases in which IO access was used for rapid IV fluid replacement as well as IV antibiotics and inotrope support.

In this abstract the authors attempted to establish a relationship in obese patients (BMI >30) between BMI, ability to palpate the tibial tubercle, and tissue depth at the IO insertion sites. Results showed that in obese patients, IO placement with a 25mm catheter is feasible at the proximal and distal tibial sites if the tibial tubercle is palpable and that insertion into the proximal humerus in this population is not recommended.
Abstract only

This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.

This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.

This article discusses how a group of obstetricians and anesthesiologists prepared for what they expected to be a difficult delivery with limited venous access. The EZ-IO was brought into the delivery suite as a back-up option if they were unable to achieve venous access in an emergency situation. The authors did note their concern with the pain associated with IO infusion. Ultimately, the IO device was not needed for the delivery in question, but it has been added to their resuscitation kit within the delivery suites.

This article describes IO access in terms of efficacy, indications/contraindications for use, and the IO procedure and comparison of devices to make a case for IO use in oral and maxillofacial surgical practice. In discussing IO devices citing published data, the author identified the EZ-IO device as the most accurate, efficacious, and precise system when trying to achieve IO access.

YEAR: 2010

Authors report an observational study of 14 children in whom semi-elective IO infusion was performed under anesthesia after peripheral IV had failed. IO infusion was successful for all 14 patients, using the EZ-IO system for 8 patients and the Cook system for 6 patients.

This article discusses use of IO access within the hospital setting in the emergent and non-emergent patient populations. The history of IO access, clinical situations in which IO access may be considered, devices, contraindications, and complications are discussed. Additionally, pain management, economics, education and training and risk management are explored. This article is co-published in Journal of Infusion Nursing, the Journal of Pediatric Nursing, and Critical Care Nurse and was produced by the Consortium on Intraosseous Vascular Access in Healthcare Practice.

This article discusses vascular access procedures in critically ill obese patients. Anatomic considerations, general procedural considerations such as location of the procedure and patient positioning, catheter insertion technique, ultrasound guided insertion, intraosseous insertion, and other various considerations are evaluated.

The authors describe literature that support the use of IO access for administering anesthesia in the ICU, perioperative and operating room, including a study in which IO access was used successfully for providing intraoperative anesthesia for 106 of 109 patients. Among their conclusions, the authors reported that, even though rarely reported in anesthesia literature, IO access is a technique anyone providing care to children should consider when the patient has difficult IV access. They also concluded that IO access should be a part of an algorithm that includes numbers of attempts at peripheral access, feasibility of central access and the need for continued postoperative access; and that considering that IO access may be occasionally used in the perioperative setting in both emergent and nonemergent scenarios, it may be beneficial to have appropriate IO needles in the OR.

Vegunta RK. *Chapter 8-Vascular access.* Ashcraft's Pediatric Surgery 2010;5th ed:110-6

This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.

Vizcarra C, Clum S. *Intraosseous route as alternative access for infusion therapy.* J Infus Nurs 2010;33(3):162-74

This article provides an overview of IO anatomy and physiology, IO access indications, care, and management; describes therapies administered via IO access; and discusses the expanding use of IO access into areas within hospitals during nonemergency clinical situations. It also includes a table addressing indications for IO access in the hospital, as well as a table addressing the general insertion procedure for IO access.

**YEAR: 2009**


Survey of 833 endodontists. 95% report using IO anesthesia.

**YEAR: 2008**


Case report of anesthetic use of IO infusion in a 8-month old infant during surgery.

**YEAR: 2006**


This letter to the editor discusses umbilical cord blood (UCB) transplantation in adults and proposes that IO transplantation of UCB is a way of overcoming the problem of delayed engraftment. Further study would be needed.

**YEAR: 2005**


Describes a training course for medical students to learn advanced emergency procedures using unembalmed cadavers. The course includes clinical indications and contraindications for specific procedures, as well as techniques. Also discusses students' confidence levels in performing procedures.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

YEAR: 2003

Dental study finding successful injections of 2% lidocaine with epinephrine in 27 of 33 (82%) X-tip IO injections (82%) for anesthesia in mandibular teeth.

YEAR: 2002

Preclinical study in mice demonstrating that transplantation of bone marrow from normal allogenic mice injected directly into the bone marrow cavity of irradiated recipient mice can prevent and treat osteoporosis.

Study describing IO infusion in patients with neurological symptoms of osteochondritis of lumbosacral intervertebral disks. Found relief and prompt regression of neurological symptoms after IO infusion.

Basic research study in sheep demonstrating that intraosseous injection of ethanol directly into the center of the femoral head produced necrotic changes similar to the early stages of osteonecrosis. The model holds potential for evaluating new therapeutics for the disease.

YEAR: 2001

Hancock SW, Knight G. Intraosseous needles: an essential emergency adjunct in paediatric anaesthesia. Paediatr Anaesth 2001;11(4):505-6
Review of the use of IO in anesthesiology. Advocates that IO needles be available in all clinical areas where IV access is required.

YEAR: 2000

Hurren JS. Can blood taken from intraosseous cannulations be used for blood analysis? Burns 2000; 26: 727-30
Study comparing IO blood samples to IV samples for blood chemistry values. For many parameters, IO and IV levels were similar. Authors caution that potassium and glucose levels should be interpreted with care. Also found that white cell and platelet counts in the IO samples were very different from those measured in IV blood samples.

Intraosseous transplantation of bone marrow in combination with long-acting Adriamycin may inhibit acute and chronic graft versus host reactions.

Dental study in 48 volunteers finding IO injection of etidocaine resulted in a significant increase in anesthetic effect. The majority of subjects receiving IO etidocaine solution experienced a transient increase in heart rate.

Osteoreflectory therapy (intraosseous injection of 0.5 to 1.0 ml of 0.9% saline solution) reduced alcohol craving in patients treated for alcoholism.
Abstract only
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

YEAR: 1998

Veterinary study in 14 iguanas were finding that IO propofol resulted in a significant decrease in heart rate that appeared 35 minutes after induction of anesthesia and persisted for 120 minutes. Serum pO2 values decreased after induction of anesthesia.
Abstract only

YEAR: 1997

Pediatric article detailing use of an IO line for bolus infusion of nonionic contrast material for CT contrast enhancement; a radiographic band may occur as a result of retained contrast material within the marrow.

YEAR: 1995

Leonard MS. The efficacy of an intraosseous injection system of delivering local anesthetic. JADA 1995;126(1):81-6
This article describes a device used for the intraosseous delivery of local anesthesia during dental procedures.

Clinical study of IO anesthesia during orthopedic surgery. Satisfactory anesthesia was obtained in 106 of 109 patients. Concludes that IO regional anesthesia is a valuable technique when IV anesthesia fails or is not feasible.

YEAR: 1994

Takada M, Yamamoto I, Morita R. Chronic intramedullary infusion of interleukin-1 alpha increases bone mineral content in rats. Calcif Tissue Int 1994; 55: 103-8
Preclinical study in rats examining bone mineral content following IO infusion of IL-1.

YEAR: 1991

Describes the design of a larger and more user friendly sternal intraosseous needle for bone marrow aspiration.

YEAR: 1989

This article describes a pre-clinical study comparing bone marrow, venous blood, and arterial blood specimen results when used for blood electrolytes, blood chemistries, blood gases and hemoglobin; and a clinical evaluation of bone marrow and venous blood used for cultures.

YEAR: 1983

Case report of 3-year-old child permanently blinded and brain damaged because of inability to administer anesthetic intravenously. Patient was on oxygen following an inhalation anesthetic. Concludes that IO administration of anesthesia would have prevented this poor outcome.

YEAR: 1982

Study finding that 23-gauge needle is less painful and yields purer bone marrow sample from the sternum.
Intraosseous Vascular Access Bibliography
Non-Emergency Applications

YEAR: 1980

Discusses clinical indications, needle types, and anatomical sites for bone marrow aspiration and Trephine biopsy.

Describes aspiration technique, preparation of bone marrow slides, Jamshidi-Swain trephine, as well as risks and aftercare involved in bone marrow aspiration and trephine biopsy.

YEAR: 1978

Intraosseous angiography and intraosseous pressure measurement can be useful for diagnosing bone pain and treatment site.

YEAR: 1977

Observational study of 15 patients needing emergency fluids and in whom IV’s were difficult to establish. Patients received drugs and fluids via IO. Concludes that IO therapy is effective with no serious complications.

YEAR: 1956

Study finding sternal puncture superior to iliac crest and spinous process punctures for bone marrow sampling. Cautions that inexperienced practitioners should use iliac crest or spinal process in the absence of training in sternal puncture.

YEAR: 1954

Describes a new method of ascending venography of the lower limb and pelvis in which contrast medium is injected into the IO space of the bone. Concludes that IO venography is be safe, simple, flexible, and reliable for visualization of the deep, superficial, and communicating veins of the legs and pelvis.

YEAR: 1944

Bailey H. Bone marrow as a site for the reception of infusions, transfusions and anaesthetic agents: a review of the present position. Anesthesiology 1944;5(5):545-6
This abstract describes one physician’s summary of experience using the sternum as an intraosseous vascular access site for 60 cases. Discusses potential benefits and complications compared to intravenous access.

YEAR: 1942

This article discusses use of the medullary route for massive replacement therapy when the usual methods of administration and not available or practical. The article also reviews a case study of a man in receipt of a sternal puncture needle inserted into the medullary cavity where he received the infusions through this needle of whole blood and fluids.

YEAR: 1934

This article describes one clinician’s use of sternal IO access for infusion of campolon to treat anemia in 1930. The author performed over 50 injections without serious complications.

Sweden
Intraosseous Vascular Access Bibliography

**Year: 2019**


This article describes a study comparing medical students' comfort level in performing IO needle placement and defibrillator use in a pediatric ED before and after just-in-time training (JITT). JITT sessions were facilitated by ED attending physicians. Sessions for IO placement included group discussion of the location of IO needle set, indications, contraindications, locations on the body for placement, confirmation of placement, and rejection of inappropriate needle size. Participants then had hands-on practice using the EZ-IO task trainer for the humerus and tibia. The comfort level increased from pre survey 0% to post survey 48% (P<0.0001).


This study compared IO insertions with the EZ-IO device (tibial/humeral insertions) to the FAST-R device (sternal insertions only) in a physician-staffed helicopter emergency medical service. Insertion time, insertion site, flow, indication for IO access, and complications were compared. Median insertion time was 15 seconds for EZ-IO and 20 seconds for FAST-R. Overall, 35.1% of EZ-IO insertions resulted in poor flow and required a pressure bag while 85.7% of FAST-R insertions had good or very good flow. EZ-IO complications included extravasation (2.4%), aspiration failure (11.9%), and insertion time >30 seconds (4.8%). Complications associated with FAST-R included user failure (12.5%) and insertion time >30 seconds (12.5%). The authors suggest that although EZ-IO is faster the FAST-R device may be more useful when high-flow infusion rates are required. The authors indicate that a low number of insertions were made with the FAST-R device and many outliers were observed in the data. However, the article does not present the total number of insertions per device.

**Year: 2018**


Prospective randomized clinical trial in which IO access was compared to peripheral intravenous access (PIV) in pediatric patients with septic shock. Children's ages ranged from 1 month to 36 months old and weights ranged from 4 to 14 kg with similar characteristics in both groups; 30 patients in each subset. The IO group had significantly shorter vascular access insertion times, shorter length of stay and reduced mortality. IO access was achieved in the proximal tibia on first attempt for all insertions; 50% of PIV attempts failed on first attempt. There were no complications for the IO subset compared to 26.7 % for PIV. There was a reduced ability to aspirate for labwork via the IO access. This study supports existing literature that early use of IO insertion is safe and effective with minimal complications.


This article investigates the success rate of IO access in preterm and term stillborns using two different needles (21G butterfly and 15G EZ-IO) inserted manually and one battery-powered semi-automatic drill (EZ-IO). All insertions were performed on the tibia. Estimated success rates were 61.1% for the butterfly needle, 43.0% for the hand twisted EZ-IO, and 39.7% for the EZ-IO drill. The authors conclude that IO access in premature and term neonates is best achieved by manual access with a twisted butterfly needle.


This paper is a letter to the editor describing successful insertion of EZ-IO in a neonate weighing less than 2 kg with respiratory failure, signs of sepsis, and shock. After successful insertion the patient was resuscitated and later stabilized. The authors advise that IO access is safe, effective, and attainable in all age groups despite FDA approval only in patients greater than 3 kg.


This case reports a serious compartment syndrome in a 2.5 year old infant which resulted in a left leg partial amputation. The IO device was placed to administer treatment following a respiratory arrest and extravasated.


These guidelines are a Japanese-specific set of guidelines for sepsis and septic shock created by the Japanese Society of Intensive Care Medicine and the Japanese Association for Acute Medicine. The IO route for administration of fluid resuscitation and circulatory inotropes when treating septic shock in pediatric patients is discussed. The authors conclude there is insufficient evidence to make a recommendation for this use.
Intraosseous Vascular Access Bibliography

Pediatric


This study compared the success rates and time to placement for Manual IO versus EZ-IO needles in pediatric emergency department (PED) patients ≤8 kg and >8 kg at a single institution. It was a retrospective, cross-sectional, descriptive study. All identified patients with an IO attempted in the PED were included. Fifty patients were identified. In patients ≤8 kg, overall success rates were 55% (17/31) for Manual IO and 47% (8/17) for EZ-IO. In patients >8 kg, Manual IO success rates were 100% (2/2) and EZ-IO success rates were 93% (14/15) for overall attempts. Time (minutes) to successful placement in patients ≤8 kg was 4.5 for Manual IO vs 12.8 for EZ-IO (P=0.02). In patients >8 kg, time to successful placement was 8.5 for Manual IO vs 10.2 for EZ-IO (P=0.70). Overall success rates in this study were poor in both groups, most likely due to lack of experience at IO insertion or inadequate device training. Access in smaller patients was more difficult and required greater time to insertion.


This is a learning module for fourth year medical students to learn about fluid management and IO needle placement. The module simulates hypovolemic shock in a 3 year old patient using a child mannequin. An IO kit, including an EZ-IO driver, is supplied for obtaining IO access. A pilot study was conducted in 2017 with 16 subinterns on a pediatric service. Perceived competence in management of volume depletion and procedural skills were high following the training session and students felt the case was a beneficial learning experience.


This article examines emergency vascular access during newborn resuscitation. It discusses the time needed to place an emergency umbilical vein catheter (eUVC) and intraosseous kits (EZ-IO) in a series of simulated newborn resuscitations across 4 studies. In all 4 studies IO placement was significantly faster than eUVC placement. An additional study found eUVC placement to be significantly faster with real human umbilical cords than with simulated umbilical cords as used in the aforementioned studies. While IO access in newborns appears faster then eUVC in simulated models, to date, no randomized trials or large case-cohort studies have systematically evaluated the short and long-term safety of IO placement during newborn resuscitation. Current guidelines still support eUVC as the preferred method of obtaining vascular access during newborn resuscitation. The authors suggest further studies are needed to determine short and long-term safety of IO access in newborns before widespread adoption of the process can be recommended.


In neonatal training events in 16 hospitals over two years, clinicians with neonatal experience simulated resuscitation of an asphyxiated newborn and were recorded for retrospective analysis. Clinicians could choose either umbilical venous catheter (UVC) or intraosseous access (IO), using the EZ-IO device for vascular access. Delays for both procedures were related to equipment availability and lack of familiarity; training and prepackaged kits may decrease this variable. IO access was more than twice as fast to obtain than eUVC access.


This study aimed to compare the success rates of 4 commonly used IO devices (NIO Pediatric, BIG Pediatric, EZ-IO, and a manual Jamshidi IO needle) in a pediatric model. Speed of insertion, ease of use, and complications were secondary outcomes. Seventy-five novice physicians from Warsaw, Poland participated in this study; none of whom had prior experience with IO devices. First attempt success rates were 43% (Jamshidi), 90% (BIG), 97% (EZ-IO), and 100% (NIO-P). Median time to achieve IO access was 18 seconds (NIO), 23 seconds (EZ-IO and BIG), and 34 seconds (Jamshidi). 39/68 participants preferred the NIO device, 18/68 preferred the EZ-IO device, 11/68 preferred the BIG device, and none of the participants preferred the Jamshidi needle.


This article presents a review of current evidence regarding different routes for the administration of medications during neonatal resuscitation, of which the intraosseous route is included. A table comparing four different intraosseous devices, including EZ-IO, is presented in the document.

YEAR: 2017


This article describes the anatomy and physiology of IO cannula insertion as well as indications and contraindications of IO use. Devices and techniques as applied to the pediatric population are discussed, including EZ-IO.
Intraosseous Vascular Access Bibliography

Pediatric


This study compared success rate, procedure time and user satisfaction of pediatric NIO vs. Pediatric BIG, EZ-IO and Jamshidi intraosseous access devices in pediatric manikins. Study was randomized, crossover trial with 87 paramedics participating. The study evaluated each device on the ease of use in performing their procedures. Results of this study found that paramedics favored the NIO in ease of use in the pediatric manikins.


This study addresses the need for the development of a reliable and validated tool to evaluate technical resuscitation skills in a pediatric simulation setting. The authors created four resuscitation and emergency simulation checklist and evaluation tools were created, (RESCAPE). Study found that use of the RESCAPE tools are reliable and validated tools for evaluation of resuscitation skills in pediatric simulation-based educational programs.


This article describes a case in which adenosine was administered to a 2-week old patient with supraventricular tachycardia, which was successfully terminated following intraosseous administration of the drug.


This case study describes a resident’s experience treating an infant in respiratory arrest. Among the interventions were tibial intraosseous vascular access using the Arrow® EZ-IO and administration of epinephrine. The baby did not survive.


This article describes a prospective, multicenter, in situ, simulation-based cohort study to describe the frequency of different types of errors between general emergency departments (GEDs) and pediatric emergency department (PEDs) in a simulated pediatric patient case of hypoglycemic seizure. During the debriefing portion of the simulation providers and teams were asked about obtaining vascular access (IV/IO). Questions involved how to obtain vascular access, barriers to obtaining access, assessment of confidence in ability to obtain access, location of access, needle size, time to gain access, who to contact after failed attempts at access, and how to decide which medications or fluids to administer.

YEAR: 2016


The objective of this study was to determine if there would be a difference in rates of vascular access and ROSC if paramedics were able to use IO access after two initial IV attempts failed. Investigators found higher vascular access success and prehospital epinephrine administration rates with the addition of IO access but no significant difference for ROSC.

Singapore


This study examined the attitudes of nurses working with pediatric patients and intraosseous access in pediatric patients. The study was conducted with the use of a diagnostic survey distributed to 200 nurses, with 135 nurses returning the surveys. The study found that there is a need for more training with nurses to increase their level of knowledge of intraosseous access and improve nurses attitudes for use of intraosseous access in pediatric population in emergency situations.


This article in German describes a case study of a 3 year old child with a serious heart defect (after total cavopulmonary anastomosis) in which bilateral humeral IO access sites were obtained to manage her condition and the patient was discharged after 30 days without neurological deficits. Key messages include that IO access in children should be a primary access route in emergent and urgent situations, unless a suitable venous access is already available; the humeral head insertion site is an accepted method in emergency situations in adults and children; and IO access is intended for regular emergency administration of drugs. The purely preventive use of an IO is not indicated. Article in German.
Intraosseous Vascular Access Bibliography
Pediatric

This retrospective study examined indications and outcomes associated with IO use at a Level 1 trauma center from 2008-2015. All 68 IO placements were with the EZ-IO device; most patients had trauma diagnoses. Most IO placements were successful on first attempt within 3 minutes of arrival. Non-serious extravasation was the most common complication. Authors concluded IO access "should be considered as a rapid, low risk, high yield aid to long-term IV access in both adults and children, and is an important bridge to definitive access in resuscitation".

This case study describes a "lifeless child" who had been trapped by an electrically operated garage door. An IO needle was placed in each tibia and adrenaline was administered. Despite being asystolic for up to 19 minutes, the child eventually recovered with neurologic reflexes and motor abilities intact.

Mittiga MR, FitzGerald MR, Kerrey BT. A survey assessment of perceived importance and methods of maintenance of critical procedural skills in pediatric emergency medicine. Pediatr Emerg Care 2016;0(0):1-6.[Epub ahead of print]
This paper describes a survey of pediatric emergency medicine physicians assessing the perceived importance of six critical procedural skills, including intraosseous line placement, in pediatric emergency medicine. IO line placement was perceived as extremely important by 80% of physicians surveyed.

In this letter to the editor, the author calls into question the continued recommended use of the umbilical venous catheter in neonatal resuscitation by the European Resuscitation Council and the lack of intraosseous vascular access recommendation. The author makes the argument that accessing the umbilical vein is difficult for even the most experienced NICU clinicians and that time cannot be spared in these resuscitations; and intraosseous access can provide a viable option for drug delivery.

A letter to the editor regarding use of intraosseous (IO) access in newborn babies compared to the use of umbilical catheterization. The author argues that the standard use of umbilical catheterization remains the preferred method of establishing vascular access urgently in newborns; and that though IO access has a role it should not be considered more reliable.

YEAR: 2015

This article describes various pediatric vascular anomalies, including intraosseous vascular malformations which can lead to weakness in the bone diaphysis, predisposing to pathological fracture.

This article describes a study evaluating the proximal humerus intraosseous insertion site in neonatal cadavers, to determine the viability of the site as an alternative to tibial insertion. The cadavers were placed in the supine position with the arm adducted and the hand secured near the umbilicus. A 22 gauge IV spinal needle was used to establish IO access in 60 neonatal humeri at the greater tubercle of the humerus. The tissue around each insertion site was then dissected and measured to evaluate the needle position in relation to the soft tissue, as well as bony landmarks. The results showed that the point of needle insertion is on average 11 mm from the axillary nerve and posterior circumflex humeral vessels and 8 mm from the long head of the biceps brachii tendon running through the intertubercular groove. The authors concluded that the proximal humerus IO insertion site is likely to be a safe alternative to the tibial IO site in neonates.

This article presents a case report of a 7 month old female who received intraosseous vascular access via the EZ-IO in the distal femur that resulted in a dermal abrasion where the needle hub contacted the skin. The wound healed without significant complication however the scar at the IO site persisted at 11 months post the event. The authors recommend that providers use the minimal force necessary when operating the EZ-IO to avoid similar adverse events.
Intraosseous Vascular Access Bibliography

Pediatric


Case study of 9-month-old patient (approximate weight 7 kg) presented with Ebola Virus Disease (EVD) and severe dehydration. IO access was obtained using a 15 g Jamshidi device to the right proximal tibia. A total bolus of 280 mL of lactated ringser solution was infused; then the IO infusion continued for 12 hours until an IV could be established. Authors stated it is important for emergency disaster responders, as well as their responding organizations, to know and understand that IO access is an important and safe modality to use in patients with EVD, and in the austere settings often found in disaster settings.


A retrospective study evaluating attempts to establish intraosseous vascular access in pediatric patients using a manual device and the EZ-IO, in a tertiary care pediatric emergency department. Results showed 35 patients had IO access attempted using manual and EZ-IO devices. In patients greater than and less than 8kg the EZ-IO had a higher success rate but time to placement was longer. Overall success rate including both devices was 64%. There were 2 complications of transient leg swelling after EZ-IO placement in 2 patients.


A retrospective study evaluating the use of pre-hospital and emergency department placed IO access in children before transport to a children's hospital. Data were extracted from a Level 1 trauma, tertiary care children's hospital transport database from 1993-2009. There were 143 eligible patients with an average transport distance of 33 miles; all but 8 catheters were placed by the ED. The most common reasons for IO placement were no IV access (53%) and no perfusion (33.6%); the most commonly reported complication was infiltration (27.3%); 46.9% of patients experienced no complication. The authors concluded IO access plays a significant role in promoting life-saving efforts when IV access is unachievable or no perfusion is determined.


Case report of a 13 year old girl suffering from severe hemorrhagic shock due to blast injuries and gun shot wounds that received freeze-dried plasma via IO access as part of prehospital resuscitative efforts. Her vital signs improved upon arrival to the hospital; and she was released after 3 weeks of hospitalization.


This is an abstract of a study that analyzed possible technical and anatomical factors leading to the complication of amputation as a result of IO placement. The study was prompted by a case report of amputation in a neonate after IO access using the EZ-IO device. The study measured medullary diameter of the proximal tibia at the recommended IO access site in three groups: 1-28 day old full term neonates, 1-12 month old infants, and 3-4 year old children. The mean diameter in each group was 7.7 mm, 9.9 mm, and 12.4 mm, respectively. The small size of the IO space, especially in neonates and infants, makes correct placement difficult. As such, complications should be taken into consideration in this patient population.


This case study describes a neonate who suffered a cardiac arrest, had return of spontaneous circulation (ROSC) and was treated with multiple medications and therapeutic hypothermia. The patient had received three IO needle insertions, one in the left tibia that was removed following swelling with bolus injection; one in the left distal femur that dislodged with movement of the patient's legs; and one in the right proximal tibia. Twenty-four hours after initial IO needle placement the child developed pallor and discoloration and was diagnosed with compartment syndrome to the right lower extremity. Five days post-IO insertion a below the knee amputation was performed. Medications infused via the IO access included epinephrine and norepinephrine infusions.


This article describes a prospective double-blind randomized controlled study evaluating the difference between use of dopamine and epinephrine as first-line vasoactive drug in pediatric septic shock patients. This study conducted in the pediatric intensive care unit (PICU) of Hospital Universitario da Universidade de Sao Paulo, Brazil. One hundred twenty-one patients aged 1 month to 15 years who met criteria were randomized to receive either epinephrine (n=57) or dopamine (n=63) via IV or intraosseous (IO) vascular access (via EZ-IO). The authors concluded dopamine was associated with an increased risk of death and healthcare-associated infection; whereas administration of epinephrine via IV or IO routes was associated with increased survival.
Intraosseous Vascular Access Bibliography

Pediatric

YEAR: 2014


This article describes a case study of a 31-month old infant that suffered hypovolemic shock due to severe epistaxis. After several failed peripheral and central line attempts an 18g needle was inserted intraosseously through the proximal tibia. The child received 300 mL of Ringer’s Lactate in one hour then 200 mL of blood via the IO route by syringe boluses resulting in improvement. Cloxacillin was also administered IO as prophylaxis for infection. Authors conclude an IO blood transfusion should be the immediate intervention in similar life-threatening situations.

Zambia

Craiu M, Stan V, Cochino AV. |trososseous access-A classical method for vascular access that regains an important role as resuscitation tool. Ro J Pediatr 2014;68(3):233-7. Romanian

This article reviews the initial development of IO access and provides an overview of IO use in pediatric populations including insertion technique, side effects, and contraindications.

English and Romanian article


This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed.

UK


The focus for the article is the need for early recognition and stabilization of a critically ill child presenting to local hospital and how hospitals admitting critically ill children must be able to resuscitate and stabilize the child prior to transferring to another hospital. The article discusses the initial assessment and resuscitation when a critically ill child presents to a local hospital and the pediatric transport process and the importance of communication between all teams. The article also discusses the need for clinicians working with critically ill children need to be properly trained and be able to maintain those skills.

Egypt


This article identifies new concepts and changes in neonatal resuscitation discussed at the Egyptian Pediatric Association national conference. Intraosseous vascular access is included stating, "temporary intraosseous access to provide fluids and medication to resuscitate critically ill neonates may be indicated following unsuccessful attempts to establish intravenous vascular access or when caregivers are more skilled at securing intraossoes access."


This discussion of pediatric sepsis focuses on the “global setting” making note of inherent differences in policies, diagnostics, causes and management approach between regions. A review of basic assessment, treatment, follow-up and prevention strategies applicable regardless of resources is offered. Goal directed therapy within the first 5 minutes includes establishment of IV/IO access.


This abstract describes an observational study evaluating use of the intraosseous drill (EZ-IO) in 20 patients assisted by EMS and receiving CPR within a 3 year period. The study includes 4 pediatric and 16 adult patients. The authors concluded that IO access is a reliable alternative to peripheral venous access and can be implemented fast and with high success rate of CPR in which drugs and fluids are given.

Spain

Neuhaus D. Intraosseous Infusion in elective and emergency pediatric anesthesia: when should we use it? Curr Opin Anaesthesiol 2014;27(3):282-7. DOI: 10.1097/ACO.0000000000000069

General review of IO access, with particular attention to perioperative setting and includes published guidelines of the German Scientific Working Group for Pediatric Anesthesia for use of intraosseous access. The author recommends that for children with known difficult venous access physicians discuss the possibility of IO access preoperatively with the family.

Switzerland
Oesterlie GE, Petersen KK, Knudsen L, Henriksen TB. Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. Ped Emerg Care 2014;30(6):413-4

Case study of newborn girl resuscitated with 15 mm EZ-IO catheter placed to her right proximal tibia. Medications given included antibiotics, “fluids” and calcium. Demarcation of the infants skin was noted immediately post-calcium administration; with progression to necrosis. Trans-tibial amputation was performed 1.5 months after initial IO access. Authors concluded calcium extravasation most likely caused the injury but were unable to identify extravasation cause; citing possible needle displacement. Cautionary steps to reduce risk emphasized by authors.

Denmark


A case study report describing a 12-year-old male who expired following a fatal myocardial ischemia. The patient complained of severe chest pains within the week prior to the event and was misdiagnosed as having GERD. ECG by first responders showed STEMI; IO access was established in the PT for vascular access.

YEAR: 2013


Reprint article of policy statement originally published 2009, endorsed by multiple professional societies providing guidelines for care of children in the emergency department. A recommendation for IO equipment in adult and pediatric sizes is included.


This letter to the editor describes a prospective, observational, trial that evaluated use of the EZ-IO in critically ill and injured patients (adult and pediatric) in a multijurisdictional prehospital setting; 9 EMS agencies were included. The 25mm needle set was the only needle size allowed for the study. One-hundred-eleven EZ-IO placements were performed by EMT-Intermediates and EMT-Paramedics with 96 successful placements (86.5%); the most common cause for failure reported by the author was thought to be patient obesity and inadequate needle length. Cardiac arrest patients made up 74.7% of the study population and the most common site accessed was the proximal tibia. Device operators rated the ease of use 7.87 using a 0 to 10 scale where 10=extremely easy.

Cleugh FM, Maconochie IK. Management of the multiply injured child. Paediatrics and Child Health 2013;23(5):194-9

General overview of care of a child with multiple trauma. IO vascular access is mentioned as a treatment option after 90 seconds or 3 failed PIV attempts. The B.I.G. is cited as an option along with the manual needles.


This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handmade IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult.

Iraq


This article presents an overview of IO access focused on nurses’ use of the technique. A list of available devices, history and support for use and possible complications are included.


This article provides an overview of various vascular access modalities in emergency medicine including peripheral IV, venous cut-down, central venous catheter, intraosseous access, umbilical vessel access, and arterial access. The anatomy and physiology, indications and contraindications, procedural steps and special considerations are outlined for each access methods discussed.
Intraosseous Vascular Access Bibliography

**Pediatric**


This retrospective study evaluated the number and type of critical procedures, including IO line placement, performed in the ED of a tertiary care pediatric institution over a 12 month period. The authors concluded that critical procedures were rarely performed in a large academic pediatric ED; pediatric emergency medicine faculty are at significant risk for skill deterioration; and fellows are unlikely to achieve competence in performing critical procedures.


This retrospective review of medical records submitted by paramedics identified patients 18 years or younger who had prehospital peripheral IV (PIV) attempts. Over 101 months at least 1 PIV attempt was made on 4188 patients ≤18 years old. The study demonstrated that success rates are significantly associated with patient age and each 1 year increase in age increased the odds of successful PIV placement by 11%. The authors suggest that IO access with the use of a semiautomatic IO device (EZ-IO) may be a more efficient first-line method for immediate treatment after 1 PIV access failure, especially in younger patients given their higher rate of PIV insertion failure.

**Oksan D, Ayfer K.** Powered intraosseous device (EZ-IO) for critically ill patients. *Indian Pediatr* 2013;50(7):689-91

A retrospective chart review evaluating use of the EZ-IO in 25 pediatric patients between July 2008 and August 2010 at a Turkish university affiliated hospital. All attempts were made in the proximal tibia and IO access was attempted following failed PIV access within 60 seconds. First attempt success was 80%; the most reported complication was simple extravasation (3 cases) and needle dislodgement (1 case).


An observational study evaluating use of the EZ-IO by two ground and one air based physician staffed EMS and at a German surgical university hospital between January 1, 2008 and December 31, 2011. The EZ-IO was used to establish IO access 88 times in 87 patients; 83 insertions were performed in the EMS and 5 were performed in the hospital. The proximal tibia was the primary site used (97.7%) and the first attempt success rate was 94%. IO access was the first approach for vascular access in children compared to adults (38.9% vs. 86.2%). There were 5 failures attributed to missed insertions or extravasation and 2 for wrong needle length. There were no serious complications.


An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal tibia was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse due to difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.


An overview of pediatric emergency medicine and critical procedures. One of the key points noted: intraosseous vascular access can be used in all ages.


A quality initiative study conducted evaluating use of the EZ-IO needles in pediatric patients and their associated complications rates when placed by EMS/ED staff compared Air Evac Lifeteam placement in 2012. The authors concluded that the powered IO device was appropriately utilized by ED/EMS staff as well as Air Evac staff and that there was no difference in the complication rate when the device was used by the two groups.


A prospective study comparing IO and venous laboratory values obtained from a point-of-care analyzer (i-STAT) in 20 children. IO blood specimens were collected from the iliac crest; 2 ml were discarded before the sample was collected analysis. Results showed differences between venous and IO sample were clinically acceptable for pH, base excess, sodium, ionized calcium and glucose in hemodynamically stable patients. Authors concluded that analysis of IO samples with a bedside point-of-care analyzer is feasible and in emergency situations may be useful to guide treatment.
This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 mL of red blood cells via the EZ-Io in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock; and RBC infusions via the IO route are feasible in this age group.

**YEAR: 2012**

**Barker LT. In the child with gastroenteritis who is unable to tolerate oral fluids, are there effective alternatives to intravenous hydration? Ann Emerg Med 2012;60(5):607-8. doi: 10.1016/j.annemergmed.2012.04.003**

This article, part of a Review Snapshot series in Annals summarizes a literature review (Rouhani et al in Pediatrics 2011) for evidence of alternatives to traditional IV hydration in a dehydrated child. Thirty-eight articles were included for the analysis with five of them randomized controlled trials; and one of those comparing IO to IV rehydration. (Banerjee et al, which found IO placement faster with no therapeutic outcome differences). The focus of this review was on nasogastric tube rehydration as effective when IV fails and as less invasive than IO or CVC placement.

**Cote C, Dumont M, Gagnon JA. Abnormal bone scanning following intraosseous access. Medecine Nucleaire 2012; doi:101016/j.mednuc.2012.02.175**

This case study describes a 12 month boy who received IO access for administration of anticonvulsant therapy. Three days post IO infusion sensitivity to the leg was noted and the child returned to the ED. Blood work showed elevated white blood counts and C-reactive protein. A bone scan showed a small round lucency at the site of IO access. Two weeks later, x-rays were normal. The authors suggest that IO access may cause an increased uptake on bone scan in absence of osteomyelitis.


PALS 2012 guidelines on pharmacotherapy and toxicological emergencies.


Physicians from two different emergency department settings reported 2 cases of supraventricular tachycardia (SVT) in infants (2 and 4 month old) in which IO administration of adenosine failed to convert SVT to a normal rhythm.


This article is a review of techniques and available evidence for establishing intravenous access, rational approaches to fluid resuscitation, and blood product transfusion in the pediatric trauma patient. IO needle systems are available for integration into pre-existing trauma care systems for pediatric patients.


This article describes a study evaluating a new manual needle insertion device, the Near Needle Holder, which uses hollow-bore needles to establish IO access. In a comparative study, healthcare professionals attempted IO insertion in the proximal tibia insertion site of a mannequin using the NNH and a standard Cook manual IO needle. Participants then completed a questionnaire regarding their experience. The most reported complication was the plunging of the needle into the medullary space from the decrease in resistance once the cortex was penetrated. Other IO devices on the market are mentioned, including the EZ-Io.


This simulation study evaluated the ability of 2 person EMS crews to manage a pediatric emergency and sought to determine root causes of errors made. Participating EMS crews used the BIG for IO access. The authors concluded that cognitive, procedural, affective, teamwork errors and error-producing conditions were identified as root causes for the errors made in the simulation. Authors also concluded that simulation followed by facilitated debriefing is an effective tool for identifying underlying causes of active and latent errors.


This article describes the validation testing of a newly developed performance assessment scale for evaluating the intraosseous manual insertion process in the proximal tibia during simulated procedures. The authors concluded that the scale was a reliable tool to assess the overall IO insertion procedure and that with modifications this scale may be used with other IO devices and in the clinical setting.
Ribiero de Sa RA, Melo CL, Dantas RB, Delfim LVV. Vascular access through the intraosseous route in pediatric emergencies. Rev Bras Ter Intensiva 2012;24(4):407-14
The authors evaluated use of IO access in pediatric emergencies through a literature review. The objective was to describe the techniques, professional responsibilities, and care related to obtaining IO access. Brazil

This article presents a general overview of intraosseous (IO) vascular access in the pediatric population through an IO literature review. Available IO devices were discussed.

This article argues the pros and cons to routinely establishing IV access in anesthetized children. IO access is discussed in the con debate an alternative to routine peripheral IV access in this population.

This abstract presented at the 2012 ACEP Research Forum explored the viability of the distal femur as an IO insertion site with a literature review of IO vascular access and brief overview of a post-mortem study of pediatric distal femur insertion success. Authors concluded that clinical literature, clinical studies, and a post-mortem study confirm that the distal femur is a viable option for IO infusion in pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

In this article the authors review the evidence supporting the use of IO access; determine the utilization IO access as described in the literature; and assess the level of specialty society support. Various IO devices are mentioned including the EZ-IO

This article is making a case for pediatric anesthesiologists to have IO access equipment readily available wherever children are anesthetized; and for anesthesiologists to consider IO access not only as a last resort but as the route of choice in children requiring urgent vascular access.

YEAR: 2011

A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthesia recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anesthesia by IO access was satisfactory without necessity of other infusion access. Brazil

This article in Spanish describes an IO complication case in which a newborn infant developed tissue necrosis as a result of extravasation during IO infusion.

This article presented a general overview of IO use in pediatrics. The history, techniques, anatomy and physiology, complications and a short discussion of most devices on the market, including the EZ-IO, were discussed. UK

This case report describes the difficulties encountered in the perioperative care of an 11-year-old boy who suffered compartment syndrome of the lower leg following the use of the EZ-IO for IO access. The authors highlight the importance of developing recommendations for maximum duration, dose, volume and rates for intraosseous infusion.

Friedman JN. Emergency management of the paediatric patient with generalized convulsive status epilepticus. Paediatr Child Health 2011;16(2):91-97

This article provides guidelines for the emergency management of generalized convulsive status epilepticus (CSE) in children and infants older than one month of age. Use of IO access is included for medication administration when IV access is not possible.


This retrospective cohort study evaluated data from 450 California hospitals and emergency departments to determine the rate of IO access use and related complications in the pediatric population from 2005-2007. Results showed 291 children had IO access placed in 90 hospitals out of 6.6 million pediatric ED visits and 2.2 million pediatric admissions; no complications were identified. The most frequent diagnosis related to IO use was cardiac arrest (34%).


German Society of Anaesthesiology and Intensivmedizin eV (DGAI), includes a general discussion of intraosseous (IO) access, overview of devices and recommendations for pediatric anesthesia with indications for intraosseous infusion in pediatric anesthesia and perioperative care in children. Early or primary IO indications are respiratory and circulatory arrest; critical hemodynamic instability before or during anesthesia introduction; severe laryngospasm; anesthesia induction in respiratory bleeding. Urgent indications (decision based on each case is necessary) include urgent induction of anesthesia in non-fasted children (Ileus, RSI); induction of anesthesia in children with unstable circulation or severe cardiac insufficiency. Semi-elective indications (decision based on each case is necessary) after mask induction of anaesthesia (if vascular access required); mandatory induction of "intravenous" anaesthesia (as in malignant hyperthermia). This article is in German.

Khan LAK, Anakwe RE, Murray A, Godwin Y. A severe complication following intraosseous infusion used during resuscitation of a child. Inj Extra 2011; doi:10.1016/j.injury.2011.05.015

This article describes the case of an 11-year-old boy who suffered compartment syndrome of the lower leg following use of the EZ-IO for resuscitation and 24 hours of intraosseous infusion of adrenaline, calcium and potassium. The author concluded that further work is needed to develop recommendations for maximum duration, dose, volume and rates for intraosseous infusion.


Retrospective study describing 3% saline administration during pediatric critical care transports. Primary indications for use included cerebral edema, intracranial bleed with edema and symptomatic hyponatremia. The primary infusion route was peripheral venous with 4 infusions via central line and 2 via the IO route. Most patients received one bolus enroute. No adverse reactions were noted for any route.


This article describes the changes in practice experienced when a 12-site statewide ambulance service changed from the manual to the semi-automatic IO device (EZ-IO). There was no statistically significant change in first-attempt success or the number of successes per attempt. However, the use of IO access more than tripled when changing from the manual to the semi-automatic device and PIV access attempts before IO access went from occurring in 35.5% of patients to 1.7% of patients.
**Intraosseous Vascular Access Bibliography**

**Pediatric**

*Myers LA, Russi CS, Arteaga GM. The introduction of a semiautomated (EZ-IO) device in pediatric prehospital care replacing a manual intraosseous (IO) device improves the success rate for attempts at vascular access. Prehosp Emerg Care 2011;15(1):110*

This abstract describes a 93 patient study presented at the 2011 National Association of EMS Physicians Annual Conference that examined the characteristics of pediatric patients receiving IO infusions and the primary EMS clinical impressions, success rates, and subsequent treatments delivered via manual IO vs. the powered EZ-IO device. Investigators concluded that for the pediatric cohort use of the powered device offered a marginally higher first-attempt success rate compared to the manual device; and that the rate of IO access utilization by EMS more than tripled after adoption of the powered device.


This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.


This study compared time to placement, errors in placement and perceived ease of use for healthcare providers placing umbilical venous catheters (UVC) and intraosseous needles in a simulated delivery room, responding to persistent bradycardia. Results showed mean IO placement time was 46 seconds faster than UVC placement; there was no significant difference in the number of errors and the perceived ease of use between UVC and IO.

*Reece A, Cohn A. Safety of power driven devices for intraosseous access in infants. BMJ 2011;343:d4362.doi:10.1136/bmj.d4362*

This letter to the editor is regarding the relative safety of using power driven IO devices in infants. Three cases of amputation secondary to compartment syndrome in children under 2 years of age are referenced. The author expressed concern with the weight designations for IO needles stating some of the needles intended for pediatric patients may actually be too long for smaller children and that manually inserted devices may be safer in younger children.


This article discusses alternative rehydration methods for pediatric patients, including the intraosseous route.


This document addresses pediatric vascular access and includes an overview of intraosseous vascular access. Indications, contraindications, supplies and equipment, technique, complications and maintenance are discussed.


This article discusses the use of IO access for neonatal and newborn resuscitation by the national park service and provides information as to how the decision was made to make IO access a standard of care for those patients.

*Taylor CC. Amputation and intraosseous access in infants. BMJ 2011;342:d2778. doi:10.1136/bmj.d2778*

This article describes two cases of leg amputation after intraosseous infusion in a 5-month-old girl and a 17-month-old boy. The author concluded that fluid extravasation, exacerbated by tibial fracture and needle dislodgement during transportation, caused limb ischemia in these two patients, and that adherence to the principles of careful needle placement, splinting/securing the catheter and limb, limited length of infusion and repeated monitoring of the limb will help avoid this devastating complication.


A 7-month-old male infant in septic shock from Neisseria meningitides experienced a complication of bilateral extravasation of noradrenaline at the proximal tibia intraosseous infusion site resulting in severe soft tissue necrosis. Necrosectomy was performed bilaterally and surgical interventions were successfully performed to salvage both limbs. At 19 months the patient was able to crawl without extension deficit.

**YEAR: 2010**


This abstract describes a retrospective case-series analysis of pediatric IO recipients from 1998-2009. Seventy-two (72) patients were included in the study; IO access was established in the proximal tibia (n=61), medial tibia (n=8), distal tibia (n=1), sternum (n=1), and iliac crest (n=1). IO access devices used in the proximal tibia included the Cook Critical Care needle (n=4), the Jamshidi needle (n=2), the BIG (n=1), and an 18 gauge spinal needle (n=54). The authors concluded that a spinal needle can be used to provide IO vascular access in children.

Authors reviewed two complications (extravasation and compartment syndrome) associated with IO access in children with meningococcal disease. Authors concluded that IO systems need formal evaluation to assess safety and complication profiles.


This article discusses the challenges of gaining vascular access in small infants and neonates and how new equipment such as ultrasound machines with pediatric probes can provide better guidance and improve safety and efficacy. The article also addresses the importance of education and training in ultrasound use. This article was based on literary research as well as authors’ experience.


This letter to the editor describes 2 cases in which IV administration of antivenom was not possible and was thereby administered via IO route, and in one case via the intramuscular route as well. In both cases the patients recovered.


Part 14 of the 2010 PALS update supports IO vascular access as easy and quick to establish, useful for first line access in cardiac arrest and equivalent for many medications.


This article describes the vascular access options available to physicians caring for children, including details about each method, placement technique, indication, and complications.


A case study describing administration of scorpion antivenom via intraosseous (IO) vascular access in a 16-month old female. Following failure to obtain IV access in pre-hospital and upon arrival at the ED, IO vascular access was established in the proximal tibia and 3 vials of antivenom in 50 mL saline were administered over 10 minutes. Within 5 minutes, the patient's respiratory status improved, intubation was averted, and vital signs stabilized immediately; nystagmus and writhing resolved. The patient was discharged home after a short observation period. The authors concluded that when IV access is difficult, IO access may be a rapid and reasonable rescue maneuver for patients requiring scorpion antivenom.


This article provides a brief history of IO infusion and further discusses this vascular access technique in terms of anatomy and physiology, indications and contraindications, performing the manual procedure, and possible complications. A case study is discussed in which a 7-month-old male was treated under emergency circumstances with IO infusion in the lower limb and developed compartment syndrome, resulting in a below the knee amputation.


Authors report an observational study of 14 children in whom semi-elective IO infusion was performed under anesthesia after peripheral IV had failed. IO infusion was successful for all 14 patients, using the EZ-I0 system for 8 patients and the Cook system for 6 patients.


This article provides an overview of pediatric trauma care in the pre-hospital setting by using a literature review to evaluate the risks and benefits of various aspects of care. Topics discussed include: pre-hospital care time, pre-hospital triage and transport, airway management, intravenous (IV) and intraosseous (IO) vascular access and infusions, cervical spine immobilization, traumatic brain injury, and pain assessment and management.

Vegunta RK. Chapter 8-Vascular access. *Ashcraft’s Pediatric Surgery* 2010;5th ed:110-6

This document discusses various vascular access methods available for pediatric and neonate patients, including intraosseous access.
Intraosseous Vascular Access Bibliography

PEDIATRIC

YEAR: 2009

Article for nursing audience.

Assessment of PALS training on EMS personnel. PALS-trained personnel had 100% success rate in IO placement (55% non-trained).

Case study of a 9-month-old treated with IO hydroxocobalamin for suspected smoke inhalation cyanide poisoning. The patient was discharged from the ICU without neurological sequelae. Authors stated the IO route for hydroxocobalamin warrants further exploration to improve ease and speed of treatment.

Prospective study of 246 EMS providers at 14 EMS agencies. Reports successful IO placement in 95% of cases (18 of 19).

This is a letter to the editor, written in German, that states that intraosseous access supplies should be available in every pediatric care setting. It also stresses the need for proper training and experience in order to use the IO devices safely and effectively.

This article, in German, describes the technique of IO access, the introduction of two different IO devices (Cook and EZ-IO) and describes IO use in pediatric emergency care.

Color Doppler ultrasound revealed extraosseous flow in incorrectly placed IO insertions. Recommends point-of-care Doppler machine to verify placement.

YEAR: 2008

Case report of resuscitation and insulin infusion in a 5-year old child with severe diabetic ketoacidosis.

Overview of intraosseous vascular access in infants; includes indications, contraindications, complications, equipment (Sur-Fast and Jamshidi), and procedure. Also, small section on IO for adults; describes the FAST-1, Bone Injection Gun, and EZ-IO.

Describes common drugs used in pediatric resuscitation and evidence supporting their use. Also describes routes of administration including intravenous, intraosseous, and intratracheal. Describes IO systems including Bone Injection Gun, FAST-1, and EZ-IO.

This article presents a case study of an IO infusion during the anesthetic care of an infant with cyanotic congenital heart disease (CHD). The article also discusses the role of the IO route in perioperative care and reviews the adverse effect profile.
Intraosseous Vascular Access Bibliography

Pediatric


A retrospective clinical study was conducted to demonstrate the safety and effectiveness of the EZ-IO intraosseous access device for pediatric patients. For the 95 eligible patients in the study, successful insertion and infusion was achieved in 94% of the patients. Insertion time was 10 seconds or less in 77% of the one-attempt successful cases reporting time to insertion. There were 4 minor complications (4%), but none significant. The results of this study support the use of the EZ-IO for children in emergency situations. The complication rate suggests that the powered IO device is safe and effective for the resuscitation and stabilization of pediatric patients. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Moen TC, Sarwark JF. Compartment syndrome following intraosseous infusion. Orthopedics 2008; 31: 815
Case report of compartment syndrome in a 6-year old girl after IO infusion during cardiac arrest.

Three-year study of IO training and use in 28 hospital and ambulance services in Switzerland. Standardized training improved IO success rate to 100%.
Abstract only

Case series of IO anesthesia in 181 children and adolescents. Success rates ranged from 88% to 95%, depending on tooth type.

In this case study a 7-month-old female with comorbidities was taken to the ED in cardiopulmonary arrest. IO access was the only vascular access method available for resuscitation. Post mortem CT of the head showed a considerable amount of air within the arterial circulation; the cause of death was listed as undetermined. The authors conclude that considering the details of the patient, the only logical explanation for the cerebral arterial air embolism is that air was introduced into the bloodstream via the IO route.

This article describes thoracic trauma in the pediatric population. Includes a review of the assessment of pediatric patients. Circulation section of the article strongly recommends rapid intravascular volume expansion by the intraosseous route, and recommends the EZ-IO for "...quick and reliable vascular access during resuscitation ...".

YEAR: 2007

This abstract for a presentation at the 2007 American College of Emergency Physicians Research Forum describes an observational study in which the EZ-IO was used to provide emergency vascular access for 95 pediatric patients. Successful insertion and infusion was achieved in 94% of the patients, and insertion time was within 10 seconds for 81% of the placements. There were four minor and no serious complications.

This article reviews and assesses the literature on the use of IO drug administration during cardiopulmonary resuscitation. It addresses the risks and benefits of using IO in adults and children. The article describes the FDA-cleared devices available for use including the Pyng F.A.S.T.1, Waismed Bone Injection Gun and the Vidacare EZ-IO.

Describes the experience of the UK Defence Medical Service using the EZ-IO for emergency vascular access in Afghanistan. They used the device for 26 patients, including 10 children. Of the 26 EZ-IO placements, 23 were made in the emergency department. There was a 97% insertion success rate with no infection. Significant infusion pain was felt by three patients.

11/9/2019
Intraosseous Vascular Access Bibliography

Pediatric

de Caen A.  Venous access in the critically ill child.  *Pediatr Emerg Care* 2007;23:422-4
This review article states the availability of intraosseous (IO) needles for pediatric patients, outlines the limitations of traditional venous access, and discusses the various IO devices currently available, including the Vidacare EZ-IO®.

This article summarized the challenges and methods of providing vascular access for infants. It describes IO techniques and devices, including the Jamshidi, Cook, EZ-IO® and Bone Injection Gun (BIG) devices.

This case study describes a 4-month-old boy that was found unresponsive. Resuscitation was started and continued through arrival to the ED; IO access at the proximal tibia was established using a 15 gauge aspiration needle as the only vascular access. Post mortem multislice CT examination showed gas in the hepatic veins, the right atrium, right ventricle, the upper pole of the right kidney and the cerebral vessels. Though air embolism was ruled out as the cause this death, it could have caused death in another case. The authors conclude that gas may have entered the body during resuscitation due to IO needle disconnections and that resuscitation with an inserted, disconnected IO needle should be avoided.

This article describes the experience of the Wake County (NC) EMS System in inducing hypothermia for patients with return of spontaneous circulation after cardiac arrest. Authors describe their use of the Vidacare EZ-IO (now Arrow® EZ-IO Intraosseous Vascular Access System) for the administration of chilled saline. In this report 56% of vascular access cooling was done utilizing the IO device and an additional 18% utilized a combination of IO and IV induced cooling. The overall EZ-IO use in this program for all insertions were 414 with an insertion success rate of 94%.

YEAR: 2006

**Buck ML.** Intraosseous administration of drugs in infants and children.  *Pediatr Pharm* 2006;12(12)
Overview article of IO vascular access describes technique, efficacy in medication delivery, utility in pediatric emergencies, use in neonates, complications, and commonly-infused medications.

An abstract describing a prehospital study comparing peripheral IV to tibial IO access for placement success, time to access and time to drug delivery. The authors concluded that using IO access on the first attempt results in faster drug administration than if IO access were used as a rescue line after failed IV.

**Engle WA.** Intraosseous access for administration of medications in neonates.  *Clin Perinatol* 2006;33(1):161-8
An overview of IO vascular access use in neonates, including focus on available evidence, history, technique, physiology, clinical indications, complications, and contraindications. The author closes acknowledging IO administration of resuscitation medications and fluids in neonates is an alternative when IV access is not possible.

**La May G, Friese G.** Pediatric fluid resuscitation and airway management - a primer on volume replacement in pediatric patients.  *EMS* 2006;May:65-72
An overview of managing pediatric fluid resuscitation and airway management in the pre-hospital setting.

Two case studies of neonates that successfully received IO infusion.

YEAR: 2005

This abstract describes a retrospective study evaluating use of IO access during pediatric critical care transport. From January 1, 2000 to March 31, 2002, 1,792 transports were performed and 47 patients received 58 IO catheter insertions. Insertion took a mean 1.2 attempts for placement and first attempt success was 78%. Most frequently accessed site as the proximal humerus (95%) and access was maintained for a mean 5.2 hours. The authors concluded EMT/paramedics, emergency physicians, and pediatric critical care transport teams should be familiar with IO placement.
Intraosseous Vascular Access Bibliography

Pediatric

Retrospective chart review demonstrating safe and effective IO placement on pediatric patients by EMT-Ps, ED physicians, and members of the transport team in the pediatric critical care transport environment.

Review article on IO vascular access in the pediatric patient. Advises that it is not necessary to adjust doses from IV doses, except for hypertonic solutions. Recommends that IO needle be replaced by an IV within 2 hours to avoid complications.
Abstract only. Article in German

Case studies in 2 children reviewed by 89 members of the Swiss Pediatric Anesthesia and heads of Anesthesia Departments of Swiss Teaching hospitals, IO was determined to be the safest method of vascular access on 1 of the cases.
Abstract only

Multicenter, prospective study of cardiopulmonary resuscitation data over 18 months. The study was design to evaluate the impact of survival of IV or IO high-dose epinephrine compared to standard doses in children with cardiorespiratory arrest. Limited conclusions showed that there is no significant difference between the two treatments.

Retrospective study over a 14-year period examining 129 IO insertions among 23,489 pediatric trauma patients. Patients receiving IO fluids and medications tended to be younger and sicker. Concludes that IO is an essential skill for anyone involved in pediatric trauma resuscitation.

YEAR: 2004

Case report of acute osteomyelitis developing 10 days alter IO infusion in a 5-month-old infant admitted for sepsis.

Web publication discussing the indications, contraindications, insertion sites and complications of IO access.

Review article describing how IO has replaced saphenous venous cutdowns in pediatric emergencies and decreased need for immediate central venous access.

This abstract evaluated the use of ultrasonography to confirm proper IO placement versus improper placement using chicken bone. Results showed 6 participants were able to confirm placement with 100% sensitivity and 94% specificity, suggesting use of ultrasonography in pediatric patients may be beneficial to confirm IO placement.

Evaluation of the Bone Injection Gun (BIG) for the administration of contrast media for urography. Concludes that BIG-assisted intraosseous urography may be an effective and reliable alternative to intravenous urography in pediatric and adult human patients.
Intraosseous Vascular Access Bibliography
Pediatric

YEAR: 2003

Investigation of the relationship between insertion site for the IO needle, epiphyseal growth plate and ease of needle insertion into the various locations of the tibia in newborn infants. Recommends that needle be placed 10 mm distal to the tibial tuberosity to avoid the epiphyseal growth plate and ensure ease of insertion.

Case report of IO infusion complicated by iatrogenic fracture at the IO insertion site. Concludes that multiple attempts to achieve IO access weakened the bone cortex and that "considerable force" applied by an anxious 100-kg emergency room doctor led to the fracture.

Prospective radiographic study of 23 children who had received intraosseous infusion via trocar. Found no long-term effect on tibial growth with properly placed trocar.

Web article discusses IO cannulation procedure insertion sites, pathophysiology, risks, contraindications and complications.

An 18 gauge butterfly needle was inserted into the proximal tibia of a premature infant born at 25-weeks gestation, following inability to establish other modes of vascular access due to gross oedema. The intraosseous line was left in place for 6 days until it was lost; there were no adverse events reported however the author noted that no safety data on long term use of the device was collected.

A comprehensive and accessible review of the history, anatomy, technique, and clinical application of intraosseous infusion.

Case report of a 7-month-old infant who developed severe compartment syndrome associated with popliteal arterial thrombosis following IO fluid infusion resulting in limb amputation.

Evaluation of IO models by 40 emergency and critical care physicians. Chicken, turkey bones and plastic IO models received similar scores, pork rib was rated poorly. Emphasizes that bone models should be age appropriate to the expected patient population when using for IO research and training purposes.

YEAR: 2002

Case report emphasizing that a cortical lesion in the proximal tibia corresponding to the site of IO insertion should not be mistaken for a radiographic sign of child abuse.

Case report of a 3-month-old infant developing osteomyelitis after IO administration of high-dose epinephrine. Speculates that administration of adrenalin in high concentrations may promote the development of osteomyelitis.

YEAR: 2001

Review advocating that pathological evidence of a few pulmonary fat emboli should not deter clinicians from using IO because of the many advantages of the technique.
This article gives an overview for nurses of the treatment of shock in children. Intraosseous administration of fluids is a means of resuscitation.

Results of a literature search to determine if a standard bone marrow needle can be used to establish IO access in a pediatric patient. Results showed only one article addressing the issue that indicated standard bone marrow aspiration needles can be used for IO infusion.

Hancock SW, Knight G. Intraosseous needles: an essential emergency adjunct in paediatric anaesthesia. Paediatr Anaesth 2001;11(4):505-6
Review of the use of IO in anesthesiology. Advocates that IO needles be available in all clinical areas where IV access is required.

Article implying that the risk of fat emboli is common with IO, but its clinical relevance is unclear.

Literature review on intraosseous administration of drugs during pediatric emergencies. Concludes that IO is a valid alternative route for infusion of drugs and other substances into the blood stream with a low complication rate.

YEAR: 2000

Study comparing practitioner experience with IO and umbilical vein catheterization with 42 medical students inexperienced in both techniques. IO was twice as fast as umbilical vein catheterization. Concludes that IO provides easy and rapid vascular access for clinicians who do not regularly perform newborn resuscitation.

Nursing article discussing the role of IO infusion when peripheral veins are collapsed. Describes advantages of IO, including ready availability, ability to establish vascular access without interrupting CPR.

Laboratory study comparing flow rates through different IV cannulas with an 18 G IO cannula. Found that fluids could be infused more quickly with the IO cannula. Speculates that the bone marrow cavity of an infant has more capacitance than a peripheral vein.

Pharmacokinetic study in piglets comparing IO and IV administration of fosphenytoin and phenytoin. Therapeutic plasma levels were achieved with both administration routes for both drugs. Concludes no need to adjust the standard drug doses of phenytoin for IO administration. Cautions slow infusion rates for fosphenytoin due to concerns over neurotoxicity.

Overview of pediatric IO infusion targeted for an EMS/paramedic audience. Discusses anatomy of long bones, indications, advantages, contraindications, steps for insertion, fluid administration and ongoing assessment and documentation.

Case report of a 3-year-old collapsed child successfully resuscitated with the use of an intraosseous needle placed in the calcaneum. Includes detailed description of needle insertion technique.
Intraosseous Vascular Access Bibliography

Pediatric

A retrospective chart review that evaluated use of IO access in pediatric patient resuscitation in a tertiary emergency department between 1989 and 1995. Results showed IO access was successfully established in 86% of patients. Median time to placement was 8 minutes; two complications of bone fracture were reported in one 10-day-old neonate patient.

Brief overview of IO infusion for an anesthesiology audience. Discusses technique, indications, contraindications, equipment, anatomical target sites and potential complications.

YEAR:  1999

Bohn D.  Intraosseous vascular access: from the archives to the ABC.  Crit Care Med 1999; 27: 1053-4
Brief review of IO history, flow rates, fluids and medications.

A retrospective non-comparative study of IO infusion in 41 children. Concludes that IO insertion is an easy technique. Recommends IO for emergency cases when other vascular access techniques have failed in the first 5 minutes of treatment.

Retrospective study of 32 cases of IO infusion over a 3 year period. Concludes that IO is rapid, safe and effective and provides an essential alternative vascular route in pediatric resuscitation.

Daga SR, Gosavi DV, Verma B.  Intraosseous access using butterfly needle.  Trop Doct 1999;29(3):142-4
Evaluation of the utility of 18-gauge butterfly needles for IO administration of fluids and drugs in 23 children presenting in shock. 22 of 23 children were successfully stabilized after IO infusion.

This article discusses the basic steps of performing rapid sequence intubation in children with a referenced case study and literature review. The authors stated that based upon the evidence, when emergency intubation is needed, IO access can be an acceptable route for RSI in the absence of peripheral venous access.

Observational study in 27 newborns, describing 30 intraosseous lines placed after failed IV access. Reports that all patients survived the resuscitation procedures with no long-term side effects.

No abstract available.

This case study described administration of iodinated contrast via IO infusion in the tibia, for an abdominal CT scan in a 7 week old infant. CT imagining demonstrated adequate enhancement of the solid organs and vasculature.

Case report of a 6-week-old female infant with methemoglobinemia successfully treated with IO Methylene blue when other venous access was not feasible.
Intraosseous Vascular Access Bibliography

**YEAR: 1998**


Study comparing placement of Cook and Jamshidi IO needles in turkey bones.


A 3-year old male presented at the emergency department with rapidly progressing circulatory collapse clinically aligned with meningococcal septicemia. Attempts at peripheral and central venous access were unsuccessful. Attempts at tibial IO insertion were unsuccessful with a number of needles bending when cortical penetration was attempted. IO insertion was successfully achieved at the medial aspect of the calcaneum. IO infusion was continued for 6 hours and removed when no longer needed. The patient fully recovered and the calcaneal site healed without complication.


Case report of a 34-week-old pre-term neonate with septic shock requiring emergency treatment. Umbilical vein was unusable. Resuscitation with IO access was successful. Concludes that IO access be used before attempting access with superior longitudinal sinus.


Case report of successful use of an IO access line in an 800 gm pre-term infant.


Review article discussing techniques for venous access in the pediatric patient includes anatomical target sites, clinical indications, advantages and disadvantages.

**YEAR: 1997**


Pediatric article detailing use of an IO line for bolus infusion of nonionic contrast material for CT contrast enhancement; a radiographic band may occur as a result of retained contrast material within the marrow.

**Manley L.** Pediatric hypovolemia: back to the basics. *Int J Trauma Nurs* 1997; 3:93-8

Review article for trauma nursing audience describing advances in trauma care.


Case report of an 18-month-old boy with cardiopulmonary arrest secondary to penicillin anaphylaxis successfully resuscitated by IO administration of emergency medications.

**Seigler RS.** Intraosseous infusion performed in the prehospital setting: South Carolina’s six-year experience. *J S C Med Assoc* 1997;93:209-15

Clinical study finding that prehospital IO did not improve outcome in pediatric patients with cardiac arrest. Cautions that the sample size was too small to reach a statistically significant conclusion.

**YEAR: 1996**


Case report of successful resolution of supraventricular tachycardia in an infant following IO administration of adenosine.


Describes a miniature C-arm imaging device to accurately confirm proper needle placement in intraosseous infusions.
Intraosseous Vascular Access Bibliography

Pediatric

Preclinical study finding no compartment syndrome with up to 350 ml of IO fluid infusion; however, radio-opaque dye was detected in the soft tissues with compartment pressures increasing to more than 35 mmHg. Calls for a dose and time independent scale for safe intraosseous infusion.

Article describing IO infusion 18 pediatric resuscitative situations. Authors conclude that 11 patients would not have survived without IO access. Complications included a minor fracture, 1 case of compartment syndrome that did not require surgical intervention and a minor fat embolism that was of no clinical significance.

YEAR: 1995

Case report of successful IO administration colloid, human albumin, and 1.4% sodium bicarbonate via the left hip of a 5-month-old infant with profound hypovolemia. Patient was discharged 4 days after admission.
Abstract only

Case report describing extravasation of fluids through a previous IO puncture site in the same tibia.

Case report finding IO a viable method of venous access in a child with burns.

Describes 2 cases of resuscitation of a scalded child by IO infusion following failed IV attempts. Reviews IO techniques.

Suggests that intraosseous infusion is reliable alternative to peripheral vein access for rapid infusion of fluids in neonates and infants when venous access is impossible.
Abstract only

Preclinical study examining hematologic parameters (hemoglobin, schistocytes, free hemoglobin in plasma, bilirubin, lactate dehydrogenase, platelets, fibrinogen, and alveolar-arteriolar O2 gradient) with IO and IV autologous blood transfusions. Found that all hematologic parameters remained within normal limits in both IO and IV groups. Concludes IO blood transfusions to be hematologically safe, i.e. without risk of appreciable hemolysis, DIC or fat embolism syndrome.

Case report of IO access in a non-emergency situation. A blood transfusion was performed with no complications in a severely anemic 1-month old infant with an 18 G IO needle (Cook).

Preclinical study in dog tibias demonstrating that circumferential pressure about an IO infusion site is a rapid method to detect incorrect placement of the IO needle.
Intraosseous Vascular Access Bibliography

Pediatric

YEAR: 1994

Case report of resuscitation of a 10-day-old female infant with 2 IO infusion sites. Patient received 240 ml fluids, epinephrine, dopamine, sodium bicarbonate, human albumin, packed red cells, fresh frozen plasma, glucose, ampicillin, gentamicin, vitamin K, and pancuronium.

Study of IO training for advanced life support providers. Providers were able to establish IO access in 13 of 15 (87%) of pediatric patients (age range 1-24 months) following completion of an 1-hour training course and supervised hands-on simulation. All procedures were performed in less than 10 minutes.

German
Describes causes and treatment of hypovolemic and septic shock. Discusses techniques for intraosseous puncture and infusion. Article in German - abstract only

Banerjee S, Singhi SC, Singh S, Singh M. The intraosseous route is a suitable alternative to intravenous route for fluid resuscitation in severely dehydrated children. Indian Pediatr 1994;31:1511-20
Study of IO vs. IV for administering fluids for resuscitation in 60 children (age range 3-24 months) with severe dehydration. The IO route was successful in all cases within the first 5 minutes of attempt. The IV line could not be secured in 33% of patients within 5 minutes. Time for successful IV access was 129 seconds, significantly longer than time t for IO cannulation. Fluid infusion through either route was equally effective in stabilizing vital signs and normalizing laboratory values. No significant complications of IO route were noted on short-term follow-up.

Case report of unilateral tibial osteomyelitis in a 20-month-old child following bilateral IO infusion. Reviews clinical indications, potential complications, and scan findings.

Review of IO infusion in children 6 years old and younger. Recommends IO for patients with life-threatening conditions requiring immediate vascular access. Reports less than 1% complication rate.

Case report of compartment systems following improper intraosseous infusion technique.

Preclinical study comparing IO administration of adenosine with peripheral and central venous routes to induce atrioventricular block during pacing. Found that IO administration was effective. Required dose of adenosine was highest for the peripheral venous route, lowest for central venous route.

Long bone fractures should be considered a potential, although rare, complication of intraosseous infusion in children.

Study demonstrating improved performance of pre-hospital endotracheal intubation and vascular access of younger children after introduction of an EMT-P PALS clinical course.

Describes frustration associated with difficult venous access. Recommends intraosseous infusion technique as a non-collapsible vein for parenteral infusions.
Intraosseous Vascular Access Bibliography

Pediatric


Review article suggesting that IO infusion should be the primary technique of intravascular access in infants for pediatric resuscitation and the first alternative technique for vascular access after failed intravenous access in young children.

Abstract only


Seminal article describing alternatives to intravenous cannulation including intraosseous access, intratracheal drug administration, sublingual and intralingual injection, intra-penile administration, and intracardiac injection. Concludes that the intraosseous method is an effective alternative to intravenous access in emergency situations.

Review


Case report of bilateral osteomyelitis secondary to intraosseous infusion.

Review


Case reports of 2 children with severe complications of IO infusions. One child developed severe tissue necrosis after IO placement. A second child developed compartment syndrome requiring fasciotomy.


In this study bone marrow aspirate from the iliac crest and peripheral venous blood samples from 30 pediatric patients were compared to investigate the predictive value of bone marrow aspirate in performing laboratory studies. Laboratory tests with high predictability, moderate but clinically useful predictability are summarized. Tests that were systematically different from venous blood are also summarized.


A brief overview on establishing intraosseous vascular access in the neonatal patient population. Discusses insertion techniques, anatomy and physiology, absorption rates, indications and contraindications.


Case report of compartment syndrome after prolonged intraosseous infusion (53 hours). Recommends that IO lines be used only temporarily until more permanent vascular access is established.

Review

YEAR: 1993


Preclinical study in 20 immature rabbits receiving IO infusion of saline, bicarbonate, or dopamine solutions into the tibia. Found no changes in bone growth or ephyseal injury related to IO infusion.


Case report of a 4-month-old infant developing compartment syndrome after IO infusion. The patient underwent a fasciotomy and had full and normal use of the leg at the 6 month follow up visit.


Retrospective analysis of prehospital IO infusion covering 165 attempts over a 5-year period, found a success rate of 73%, with success rates significantly higher in younger children (<2 years old). EMT-Ps maintained proficiency in the technique over time despite infrequent use.
Observational study finding 7 of 27 critically injured patients (ages 3mo-10y) successfully resuscitated using IO. Concluded that IO is a rapid, safe and simple method of obtaining short term vascular access in critically ill and injured children.

Case reports of 2 infants in the neonatal unit in which IO access was used for successful resuscitation from collapse.

Case report of fungal osteomyelitis following IO infusion in a child. Cautions that physicians consider both bacterial and fungal sources for infection.

This article presented two case studies in which pediatric patients received emergency IO infusions that ultimately resulted in compartment syndrome. In both cases the patients underwent a four-compartment fasciotomy and recovered without deficit. The authors conclude that though compartment syndrome is a risk of IO infusion, insertion of an IO line in emergency situations is a valuable technique.

Case reports of 2 9-month-old infants with severe dehydration treated with IO infusions after failed IV attempts. IO lines were replaced shortly after venous access was obtained.
Abstract only

Letter to the editor recommending intraosseous infusion only for truly urgent situations.

Selby IR, James MR. The intraosseous route for induction of anaesthesia. Anaesthesia 1993;48:982-4
Case report of a 6-week-old infant with a head injury resulting in a fractured skull and scalp haematoma who was successfully resuscitated and anesthetized with IO infusions of colloid, blood, midazolam, suxamethonium and atracurium.

Study comparing 3 vascular access routes for fluid administration: intravenous (6 patients), intraosseous (6 patients) and/or intraperitoneal routes (4 patients). Concluded that IO and intraperitoneal routes allowed for severely dehydrated children to be resuscitated without significant complications when IV access is difficult to establish.
abstract only

Case report outlining precautions to prevent compartment syndrome following IO infusion. Advocates early recognition and aggressive treatment to preserve function in the affected limb.

YEAR: 1992

Evaluation of the chain of survival from cardiac arrest using standard measurements of performance.

Article promoting increased awareness of intraosseous infusion, familiarity with IO insertion techniques, and careful use of anatomical landmarks.
Abstract only
Case reports of resuscitation of 2 pre-term infants with medications administered via the intraosseous route. Also includes a short review of the history, physiology, technique, complications and contraindications of IO procedure. Abstract only

A review of intraosseous infusion and the possible applications in pediatric emergency medicine. Abstract only

Descriptive comparison of the 4 available routes to provide drugs to adult patients during cardiopulmonary resuscitation.

Recommendation of the tibial site for intraosseous infusion in children and discussion of risk for complications.

Case reports in 2 children finding IO infusion of vecuronium allowed for successful rapid sequence induction/intubation.

Letter to the editor written in response to previous article on IO access that includes sternal access as a site for children. This author states IO route for fluids and drugs is underutilized but believes sternal site to be hazardous and upper tibia, lower femur and humerus are favored.

Case report of IO infusion for induction and maintenance of anesthesia in an infant with other IV access.

Tibballs J. Endotracheal and intraosseous drug administration for paediatric CPR. Aust Fam Physician 1992;21(10):1477-80
Article advocating IO administration of drugs and resuscitative fluids for CPR in children. Also asserts that adrenalin, lidocaine, and atropine can be readily absorbed through the respiratory tract via endotracheal administration. Abstract only

Preclinical study in pigs demonstrating that IO infusion of fluids and resuscitative drugs does not adversely affect subsequent bone growth and development.

Review article on IO access for a pediatric medicine audience. Concludes that IO administration can be used for all forms of medications. Osteomyelitis appeared in 0.6% of the cases. Abstract only

YEAR: 1991

Preclinical study comparing IV and IO administration of dobutamine and isoproterenol demonstrating significant physiologic responses to IO administered drugs comparable to response with IV administration.

Case reports of 2 patients with local skin necrosis complicating IO infusion.

Article for nurses on intraosseous infusion as an alternative to intravenous vascular access presented in a question and answer format.


Review article discussing aspects of intraosseous infusion, including indications, technique, and pharmacokinetic factors. Concludes that multiple drugs and fluids can be safely administered through the intraosseous route.


Case report of a child with severe compartment syndrome of both lower extremities following IO fluid resuscitation.


Clinical study demonstrating blood from the IO space to be a viable alternative source of blood for laboratory studies.


Review of indications and benefits of intraosseous infusion. Concludes IO access may be especially valuable for medical personnel who rarely care for critically ill children because the IO technique is easily mastered even with limited practice.


Case report of an 11-week old infant in cardiac arrest due to haemorrhage successfully treated using IO infusion. The child was discharged with no apparent neurological deficit.


Preclinical study in 39 puppies comparing IO treatment with Ringer’s lactate with antishock trousers and control group receiving no treatment. Concludes that emergency administration of IO fluids is safe and effective for the initial resuscitation of hypovolemic shock.

YEAR: 1990


Textbook chapter on IO.


Letter to the editor regarding a previous article, “Iatrogenic Bilateral Tibial Fracture After Intraosseous Infusion Attempts in a 3-Month-Old Infant.” Inquires if fractures were caused by questionable technique or an unexplainable complication of a proximally placed needle.


Case report of a critically ill preterm neonate who received needed emergency fluids via IO infusion.


Review of the use of intraosseous infusion in children in the prehospital setting and in the emergency department. Outlines anatomy, indications and contraindications, technique, complications and role of intraosseous infusion in pediatrics.


Case report of a 6-month-old infant in cardiac arrest successfully resuscitated with IO epinephrine.

Abstract


Case report of 2 severely burned children saved after IO was used to establish IV access.
**Intraosseous Vascular Access Bibliography**

**Pediatric**


Concludes that infusion of fluids and drugs can be readily performed with the intraosseous technique.

**Joffe M.** *Blasts in peripheral blood with intraosseous infusions.* Pediatr Emerg Care 1990;6:106-7

Case reports of 2 children who died from Sudden Infant Death Syndrome (SIDS) with immature white cells in the peripheral blood. Blood was sampled near IO infusion site. Urges physician awareness of that patients receiving IO infusion may be at risk for immature white blood cells in the peripheral circulation in the absence of malignant, infectious, or infiltrative disease of the marrow.


Nursing article describing intraosseous infusion techniques and benefits.

**Miccolo MA.** *Intraosseous infusion.* Crit Care Nurse 1990;10(10):35-47

Nursing article that describes benefits of intraosseous infusion. Recommends IO for cardiopulmonary arrest and other medical emergencies.

**Moscati R, Moore GP.** *Compartment syndrome with resultant amputation following intraosseous infusion.* Am J Emerg Med 1990; 8: 470-1

Case report of compartment syndrome following IO infusion. Emphasizes IO to be useful for temporary vascular access. Advises that that IV lines be placed as soon as possible after IO infusion. Recommends that radiograph be performed after the procedure in very young children to check for bone abnormalities.


Discusses current limited pre-hospital use of intraosseous infusion. Stresses need for a concerted effort to promote broad adoption.


This article describes two cases of IO administration of succinylcholine for emergency airway management in children that resulted in adequate intubating conditions within 45 seconds for both cases.

**Zenk KE.** *Use of intraosseous infusions in infants and children.* Clin Pharm 1990;9:90-1

Article advocating IO infusion over endotracheal administration of medications. Asserts that IO infusion is equivalent to IV infusion.

**YEAR:** 1989


Study of 22 cardiac arrest patients arriving at the Emergency Department with no or insufficient intravenous access. Intraosseous needle placed and flow established in less than 1 minute in all patients. Observed flow rates of 5 to 12 mL/min with pressure bag attached. IO needle placed in the medial supramalleolus.


Case report of bone fracture following IO access in an infant.

**Lathers CM, Jim KF, Spivey WH.** *A comparison of intraosseous and intravenous routes of administration for antiseizure agents.* Epilepsia 1989;30(4):472-9

Preclinical study in pigs finding equivalence in physiologic response between IO an IV administration of antiepileptic drugs.


Study of IO infusion by paramedics on pediatric patients (>5 years of age) in cardiac arrest. Paramedics completed a training program in IO technique. Observed 85% success rate (10 of 12 IO attempts). Discusses training methods, limitations and implications for future use.
Intraosseous Vascular Access Bibliography

Pediatric

Preclinical study in dogs examining lung samples for fat and bone marrow emboli following IO infusion. Found no significance difference in embolism formation or density between dogs receiving IO infusion of emergency drugs and control group.

Preclinical study of IO infusion in a swine model. Concludes that IO infusion holds potential as a first line of action for fluid resuscitation in pediatric subjects.

Prospective study finding EMS personnel able to successfully establish IO access in 16 of 17 pediatric patients with cardiopulmonary arrest. Observed 13 successful infusions within 1 minute on first attempts at IO access. No significant complications.

Review article for a nursing audience presenting a brief historical overview of IO technique and insertion methods, with discussion of clinical applications and nursing management aspects.

YEAR: 1988

Preclinical study in pigs examining the epiphyseal plate after intentional penetration with IO needle and subsequent fluid infusion. Found no significant growth defects despite injury to the developing growth plate.

Description of IO infusion technique, site selection, procedure, anatomy, physiology, historical perspectives, contemporary research, indications, contraindications, complications, and future direction.

Retrospective chart review of 33 pediatric patients finding 83% success in establishing IO infusion. IO and percutaneous peripheral catheterization were the quickest methods for vascular access. Observed no major and minimal delayed complications.

Retrospective chart review over a 1-year period finding IO reduced vascular access time in patients with cardiac arrest when standard techniques failed.

This article describes the Kormed/Jamshidi disposable Illinois sternal/iliac needle as well suited to establish intraosseous vascular access in the pre-hospital and hospital setting.

Case report of anesthetic induction through IO administration of succinylcholine chloride, atracurium besylate, and thiopental sodium in a child with seizure activity.

Article for emergency nursing audience describing IO technique, anatomy, absorption rates, clinical indications and contraindications, technique, complications and training in critically ill or injured infants and children.

Guidelines for IO in pediatric patients.
Intraosseous Vascular Access Bibliography

Pediatric

Preclinical study finding IO infusion of hypertonic glucose and dopamine to be as effective as IV administration.

Nursing article recommending IO early in the treatment of critically ill or injured children with difficult venous access. Highlights speed and ease of IO technique.

Article discussing IO infusion and associated rapid intravascular absorption of solutions.

Concludes intraosseous infusion to be a safe and viable technique in the pre-hospital setting, especially in the aeromedical area.

Comparison study of success rate in establishing IO infusion in anesthetized piglets with 4 types of IO needles: standard hypodermic, spinal, bone marrow, Turkel. Practitioners were 24 medical residents with no prior experience in IO technique. Overall success rate was 67.7%. There were no statistical differences in success rate among the 4 different types of needles.

**YEAR: 1987**

Preclinical study of IO flow rates during hypovolemia. Concludes that IO flow rates may be insufficient for definitive treatment of severe hypovolemic or hemorrhagic shock.

Review article on IO infusion, includes historical background, physiology, method, clinical applications and complications of the IO procedure.

**YEAR: 1986**

Case report illustrating value of familiarity with insertion technique for IO. Recommends that IO fluids and medications be considered early in patients requiring resuscitation.

This article describes case reports and also a study comparing 3 types of needles for IO insertion: spinal needles, standard IV needles, and bone marrow aspiration/biopsy needles on a pediatric cadaver leg. The bone marrow aspiration needle was easiest to insert. The clinical cases described 5 adult and 10 pediatric IO patients with insertion at the "medial malleolus".* Authors conclude that IO infusion is a safe, rapid way to access the venous circulation, providing a stable, usable fluid line in dehydrated pediatric patients. *(Often referred to as distal tibia.)

Evaluation of a sequential protocol comparing femoral vein catheterization, saphenous vein cutdown, and IO (in order) when conventional IV access was impossible in a pediatric patient population. Found that IV access was attained in 4.5 minutes when the protocol was followed, compared to 10 minutes when protocol was not followed. Suggests that IV access should always be attained in 5 minutes or less.

Discusses rediscovery of intraosseous infusion as a straightforward technique for an extremely difficult clinical problem. Suggests that many fluids and medications can be administered via the IO route.

Case report of an unresponsive 3-month-old infant with no cardiac activity. Patient was resuscitated and achieved stable cardiac rhythm and blood pressure through IO administered medications.
Intraosseous Vascular Access Bibliography

Pediatric

Letter to the editor discussing guidelines for IO in Standards and Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiac Care, and in the chapter on Intravenous and Intra-arterial Techniques for the Pediatric Advanced Life Support (Pals) textbook being completed by the Working Group on Pediatric Resuscitation of the American Heart Association.

Discusses IO route as a safe, proven, and technically easy method for administration of replacement fluids, blood products, and resuscitative drugs. Presents value, historical context, technique, and complications of the IO infusion.

Case report of child with status epilepticus. IO phenytoin resulted in seizure resolution and therapeutic serum levels of drug.

YEAR: 1985

Review of IO insertion techniques of insertion, clinical indications, contraindications, and complications.

Discusses the historic technique of tibial intraosseous infusion as an alternative IV route in young children. Concludes from review of the medical literature that IO access is a rapid, reliable method with acceptably low complication rate. Discusses substances absorbed through the marrow, flow rates, technical difficulties, and complications.

Preclinical study in pigs examining blood pH during CPR with sodium bicarbonate administered via different vascular access routes. Found that pH of blood obtained via central venous access and intraosseous access were significantly different from the peripheral group, and that all three groups were significantly different from the control. Pathology studies showed only minor damage to bone with IO sodium bicarbonate administration.

Letter to the editor asserting that while the Turkel trephine technique may stabilize the IO needle better and minimize fluid leakage into the subcutaneous tissue, few physicians are familiar with the technique and it is more time-consuming than using a standard bone marrow needle or standard hypodermic needle.

YEAR: 1984

Case report of continuous IO infusion of dopamine hydrochloride and dobutamine hydrochloride in a 6 month old infant. Concludes that IO infusion is efficacious and complications rare.

Seminal article on IO infusion by the “Father of IO.” Drugs and fluids infused through the IO space enter the central circulation as rapidly as through IV routes. Unlike peripheral veins, the intramedullary blood vessels will not collapse in shock.

Outlines problems with conventional vascular access in emergency medicine. Discusses possible resurgence of the "old" technique of intraosseous infusion.

YEAR: 1983

Case report of 3-year-old child permanently blinded and brain damaged because of inability to administer anesthetic intravenously. Patient was on oxygen following an inhalation anesthetic. Concludes that IO administration of anesthesia would have prevented this poor outcome.
Early article on IO puncture and infusion, emphasizing technique. Concludes their technique is safer and more effective than previously described techniques.

Early study on IO. Makes strong distinction between ordinary blood transfusion or infusion of isotonic solutions (generally safe) and continuous infusion or the infusion of hypertonic solutions. The latter carries considerable risk of osteomyelitis and subsequent disturbance in growth of the bone.

Historical article discussing refinements in IO technique and analysis of IO complications. Includes case report of an infant who developed osteomyelitis subsequent to IO infusion.

Abstract describes experience in one institution using tibial IO access to replace fluids, mostly due to dehydration.

Early article describes technique for tibial bone marrow infusion. Reports 6 failures and 2 partial failures in 43 attempts on 34 young children. X-ray studies post IO infusion showed small bone defects and periosteal elevation with new bone formation.

Behr G. Bone-marrow infusions for infants. Lancet 1944; (Oct 7):472-3
Describes the tibia as a useful route for infusions in infants. Main advantages over IV infusions are ease, speed, and firm placement.

Describes a simple method of bone marrow transfusion using a specially designed needle that is more safe and effective than intravenous needles.

Early observational study on IO infusion at the Children’s Hospital of Akron, OH.

This article provides a brief history of intraosseous infusion beginning in 1903 with supportive literature through the writing of this article in 1943. An overview of mediastinitis, a complication of intrasternal blood transfusion, is also provided followed by a case report of anterior mediastinitis in an infant.

Papper EM. The bone marrow route for injecting fluids and drugs into the general circulation. Anesthesiology 1942;3(3):307-13
Discusses IO infusion, pioneered by Tocantins, as a viable route for parenteral fluids, drug therapy, and anesthesia. Includes case reports.
YEAR: 1941

Tocantins LM, O'Neill JF, Jones H. Infusion of blood and other fluids via the bone marrow: Application in pediatrics. JAMA 1941a; 117(5):1229-34

Describes emergency IO infusion of citrated blood and saline into the tibia or femur of 9 infants. IV access was impossible. Found no complications upon clinical or x-ray examination post-infusion.

YEAR: 1922


Seminal article on blood circulation in the IO space. Demonstrates movement of red blood cells from the bone marrow into the circulating blood by perfusion of the tibia of the dog and by injections into the bone marrow in the rabbit and cat.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

YEAR: 2019

This pre-clinical study compared various PK parameters, return of spontaneous circulation (ROSC), time to ROSC, and odds of ROSC after epinephrine was administered via endotracheal (ETT), IO, and IV routes in a swine traumatic cardiac arrest model (TCA). IO groups included sternal IO (SIO), humeral IO (HIO), and tibial IO (TIO). CPR only and CPR plus defibrillation (CPRD) groups were included for analyzing ROSC. The Cmax of the IV epinephrine group was significantly higher than that of the IO group (p=0.049). The tmax of the TIO group was significantly longer than that of all other groups (p=0.008). There were significant differences in mean plasma concentrations over time between the IV and TIO groups at 90, 120, 150, and 180 seconds (p<0.05) with the TIO group having an unexpectedly prolonged absorption phase. There was no difference in the rate of ROSC between ETT, TIO, HIO, SIO, IV and CPRD groups. The PK findings relative to ROSC support the concept that neither epinephrine nor the route of administration influenced the outcome. All IO insertions were performed using the EZ-IO device.

YEAR: 2018

This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.

This paper discusses prosthetic joint infection (PJI) after total knee arthroplasty (TKA) and the use of prophylactic antibiotics to prevent PJI. Current literature recommends IV administration of cephalosporins, however, rising resistance rates limit the effectiveness of IV cephalosporins. Alternatives include clindamycin, teicoplanin, and vancomycin. The author reviews alternative routes of administration to increase time dependent or concentration dependent antibiotic killing including intravenous regional administration (IVRA) and intraosseous regional administration (IORA). Supporting literature is reviewed. The author concludes that IVRA and IORA of prophylactic antibiotics in TKA is a novel way to increase tissue concentrations of prophylactic antibiotics and the current literature supports changing guidelines (after further research) to allow IVRA and IORA in TKA. The EZ-IO device was utilized for IORA of prophylactic antibiotics in the reviewed studies.

YEAR: 2017

Swine study comparing pharmacokinetic (pK) parameters of TXA given by the IO vs IV route. For the 4 min and 5 min results Cmax plasma concentrations were higher in the IV group but similar from injection completion onwards. Other pK parameters were not significantly different. Limitations included swine model, normotensive animals and proximity of sampling site (jugular vein) to the IV infusion site (auricular). Investigators concluded this study supports the pharmacokinetic bioequivalence of IO and IV administration of TXA in this animal model.

This preclinical study reported data evaluating the pharmacokinetics of HIO and IV vasopressin and the ROSC in a swine model of ventricular fibrillation cardiac arrest. For the parameters of occurrence of ROSC, odds of ROSC, time to ROSC, Cmax, Tmax, and plasma concentrations over time, the IO and IV routes results were comparable.
Intraosseous Vascular Access Bibliography

Pharmacokinetics/Dynamics


A prospective study comparing results of intravenous (IV) and intraosseous (IO) blood specimens when analyzed using an EPOC point of care analyzer during resuscitation of non-traumatic cardiac arrest and critically ill patients. Seventeen patients who had IO and IV specimens collected within 5 minutes of each other were included in the study; IO samples were collected before administration through the IO catheter in the proximal tibia or proximal humerus. Results showed that based upon Bland Altman plots, there was reasonable agreement between IO and IV values for pH, bicarbonate, sodium and base excess, and moderate agreement for lactic acid. The intraclass correlation co-efficient was excellent for sodium and reasonable for pH, pO2, bicarbonate and glucose. The primary limitation noted was the small sample size (n=17) and the substantial impact of single outliers in the data.

YEAR: 2016


This study examined the differences of pharmacokinetics and pharmacodynamics of epinephrine via of tibial intraosseous access and IV access. Interruptions in CPR in order to obtain vascular access reduces the flow of blood to vital organs. Study results showed that TIO access may be a faster alternative to IV access for delivery of vasoactive medications.


Preclinical RCT evaluating the relationships between the anatomical distance of IO epinephrine and measures of resuscitative outcome in an adult swine model of ventricular fibrillation (VF). There were no significant differences between the HIO, TIO, and IV groups relative to the occurrence of ROSC, 30-minute post-ROSC survival, and time to ROSC. The anatomical distance of IO epinephrine injection from the heart did not affect short-term measures of resuscitative outcome in an adult swine model of VF including the occurrence of ROSC, 30 minute post-ROSC survival, and time to ROSC. Rapidly administered epinephrine, irrespective of route of administration, increased the chance of ROSC and survival to 30 minutes post-ROSC in this study.


This prospective, experimental study was to characterize and compare the pharmacokinetics of atropine that is administered via sternal intraosseous (IO) route in hypovolemic and non-hypovolemic swine. Main outcomes PK parameters, maximum concentration (Cmax) and time to reach maximum concentration (Tmax). Authors concluded sternal IO route is effective for administration of atropine and data gained from this study was found to be similar to previous information reported on tibial IO and IV administration even in situations of significant hemorrhage.


This article presents a case study of rapid sequence intubation via intraosseous (IO) access with a review of relevant literature. The authors describe a case of an adult male patient, peri-arrest with cardiogenic shock, cyanosed with un-recordable oxygen saturations and blood pressure. IO access was established in the proximal tibia and rapid sequence induction was performed using fentanyl, ketamine and suxamethonium. After 30 seconds direct laryngoscopy was attempted and intubation was secured on first attempt. The authors concluded that use of IO access for RSI can be useful in cases of difficult vascular access and rapid intubating conditions can be achieved which are comparable to using IV drug delivery.


This preclinical study compared arterial and intraosseous derived biomarkers to determine if the results would correlate well enough over a period of 6 hours to consider use of IO derived blood when traditional samples are difficult to obtain. Authors noted there were no clinically relevant average differences between alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase, creatinine kinase and gamma-glutamyl transferase values which may be good enough for initial estimates of these markers analyzed in intraosseous and arterial samples. However the lactate dehydrogenase levels showed less correlation; and the precision of IO samples may be limited.


Randomized, prospective preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered vasopressin during cardiac arrest and CPR until ROSC was acheived. No difference was noted for ROSC between TIO and IV delivered vasopressin. Authors concluded the use of IO access could avoid the time delay associated with IV access, and that it is effective for treatment of hypovolemic cardiac arrest and should be first line for rapid vascular access.

This study compared IV to tibial IO administration of amiodarone. Investigators found no significant differences for the endpoints of Cmax, Tmax and time to rate of ROSC between IO and IV.


In a swine study comparison of the humeral IO and IV amiodarone administration routes investigators found no difference in time to ROSC or rate, time to maximum concentration (Tmax) p = 0.501) or in maximum plasma drug concentration (Cmax) (p = 0.232).


A preclinical study evaluating blood transfusion via IO vascular access in anesthetized swine. Results showed pressurized blood transfusion through IO vascular access resulted in acceptable flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.


This study characterizes and compares the onset and duration of neuromuscular blockade after IV and IO administration of rocuronium in a hypovolemic swine model. Eight pigs were randomized to receive rocuronium IV or IO in a hypovolemic state. Onset and peak times were not statistically different between groups. The IO group took statistically longer than the IV group to return to 25, 50, 75, and 95 percent baseline.


This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9.58±2.706 mL/h (n=27); mean PH infusion rate was 6.29±3.277 mL/h (n=52). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000 mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.


A pre-clinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.


In this porcine study IO and venous samples were analyzed for thromboelastography (TEG), prothrombin time (PT), activated partial thromboplastin time (APTT) and fibrinogen concentration. The IO samples were clinically hypercoagulable, rendering some samples unevaluable; clinically relevant differences were observed for APTT but not for PT and fibrinogen and the TEG demonstrated a shortened reaction time. The ability to use IO drawn blood for coagulation studies may be limited.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.

A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, after 2 minutes CPR was initiated for 2 minutes, then 40 units of vasopressin was administered via IV or SIO route. Results showed no significant difference in SIO and IV groups for Cmax or Tmax.

A preclinical study comparing IV and humeral intraosseous (IO) access administration of vasopressin in a hypovolemic swine model in cardiac arrest. Following exsanguination, the swine were placed in cardiac arrest for 2 minutes, then resuscitated for 2 minutes in accordance with ACLS guidelines. Vasopressin was administered. Blood samples were collected at various time points following vasopressin injection and analyzed for maximum concentration (Cmax) and time to maximum concentration (Tmax) between groups; return of spontaneous circulation was also captured. ROSC was achieved for all HIO subjects (n=7) and in seven out of eight IV subjects; mean time to ROSC was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV administration of vasopressin for achievement of ROSC, time to ROSC, Cmax, Tmax, concentration over time, survivability, or odds ratio.

Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.

YEAR: 2015

This article in Swedish describes a study evaluating use of aspirate obtained from the IO space for laboratory analysis. The authors note that point-of-care equipment should be used for analysis. Creatinine, morphine and troponin was successfully analyzed; leucocytes and platelets were noted to possibly cause falsely elevated values.

A preclinical study in which 8 anesthetized swine were put into an induced septic shock state to allow troponin I level measurements to be compared from serial venous plasma, arterial plasma and intraosseous aspirate specimens collected hourly. Two milliliters of IO aspirate were wasted before collecting each IO specimen for analysis. The levels of IO troponin I increased during the first 3 hours of shock but then plateaued at a high level while the venous and arterial levels continued to increase. Authors concluded that troponin I can be analyzed in bone marrow aspirates in a shock model and that this information may be useful in medical emergencies where cardiac damage is suspected to be involved.

A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, established via the EZ-IO, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.
Sweden

difficult

Authors concluded in an emergency, IO administration of these antibiotics may be considered in severe infections when venous access is unobtainable. Both methods of administration yielded comparable concentrations.


Sweden
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

YEAR: 2014

A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.

Randomized swine study with the objective to compare the efficacy of IO delivery of hydroxocobalamin to intravenous (IV) injection for the management of acute cyanide toxicity. The survival rate, physiologic parameters such as reversal of hypotension, and pharmacokinetic results were similar between the IV and IO group. The primary limitation was use of a swine model. Investigators concluded intraosseous hydroxocobalamin may be as effective as the intravenous route in treatment of cyanide toxicity.

Randomized comparative study of adult pigs infused intraosseously with either: 7.5% hypertonic solution (HTS), 3% HTS or normal 0.9% isotonic saline. The animals were observed daily for infection, necrosis and gait up to 5 days, then necropsy and histological analysis was performed for tissue necrosis. Observations included regular tissue morphology and normal gait scores over the 5 day observation period; and absence of gross tissue necrosis and microscopic ischemia post IO HTS infusion in this swine model. Authors concluded this study confirms the clinical safety of IO HTS infusion and its use as an alternative lifesaving treatment.

Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) whole blood transfusion relative to hemolysis and transfusion time. IO transfusion does not significantly increase hemolysis (using free hemoglobin as outcome measure) or transfusion time compared with IV transfusion. Authors concluded transfusion of whole blood through an IO device is an effective transfusion method that may be used until other vascular access is obtained.

A letter to the editor questioning the practice of using IO blood for laboratory analysis. The author identifies there is a lack of clinical evidence supporting IO blood laboratory analysis and concludes that IO access should be limited to infusion of fluid and medications until the relationship of IO blood to peripheral blood is defined.

A preclinical study comparing intraosseous (IO) and intravenous (IV) administration of Hextend in 27 swine for time of administration and hemodynamics. IO access was established in the proximal humerus using the EZ-IO. Results showed time for administration was not significant; there were no significant differences between IV and IO relative to hemodynamics. The author concluded that the IO route is an effective method of administering Hextend.

This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.

A preclinical study comparing the time to onset, time to onset peak, and time to recovery of peripheral intravenous and tibial intraosseous administration of Rocuronium. Study results demonstrated there was no statistical difference front the time of administration to complete neuromuscular blockade between the IO and IV administration of Rocuronium; and the recovery of neuromuscular function was significantly longer after IO administration, however was not deemed clinically significant. The authors concluded that Rocuronium can effectively be used via the IO route without the need for dose adjustments.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

In this pre-clinical study, 18 units of blood were transfused into 10 anesthetized swine via intraosseous (IO) access. Venous specimens were collected to evaluate free hemoglobin levels as an indicator of hemolysis. Seventeen transfusions were given via the proximal humerus site and 1 via the proximal tibia, using a pressure bag set to 300 mmHg. Mean transfusion flow rate was 61.6 ± 37.3 mL/min and the mean blood volume transfused was 266 ± 74 mL (n=18). The authors concluded that blood transfusion via IO access resulted in high flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.

A preclinical study comparing the recovery of fibrinogen in a porcine model when fibrinogen concentrate is administered via IV and IO access. The study results suggested intraosseous administration of fibrinogen concentrate resulted in a recovery of fibrinogen similar to that of intravenous administration.

This prospective study sought to evaluate intraosseous flush practices of emergency physicians. Using cadavers, 15 emergency physicians were asked to flush an IO catheter placed in the proximal tibia and proximal humerus IO insertion sites with 10 mL normal saline as they would in clinical practice; IO pressure measurements were recorded using an IO catheter inserted in the diaphysis of the target bones. Results showed the median IO pressure generated was 903 mmHg and the median flush duration was 5.2 seconds. Results showed significant interoperator variability with greater than 35-fold difference in flush forces. The authors concluded that it may be prudent practice for providers to extend the flush over several seconds to limit the maximal pressures.

Abstract presented at the Society of Cardiovascular Computed Tomography on preliminary findings of an observational study done after training ER physicians and techs on intraosseous (IO) catheter use and implementation of a policy for IO access use. Authors report high injection rates and excellent computed tomography angiography (CTA) scans safety with use of an IO for power injection of iodinated contrast media (ICM). Authors concluded cardiovascular imaging physicians, surgeons, ER physicians, and CT technologists should be familiar with the techniques of IO needle placement and use for power injection of ICM for CTA. The diagnosis and treatment of critically ill and unstable patients may be hastened by this technique.

This randomized, controlled study compared tissue concentrations at the surgical site of regionally and systemically administered prophylactic vancomycin, in 30 patients undergoing total knee arthroscopy. The antibiotic was administered using three methods: 250mg through IO regional administration in the proximal tibia (IORA); 500mg through IORA; and 1g administered systemically through IV. Results showed the tissue concentration of vancomycin was greater in the 250mg IORA group than the systemic IV group, and the 500mg IORA group had higher concentrations than both groups.

YEAR: 2013

Case report of 54-year-old male obtunded patient requiring a CT angiogram to diagnosis a suspected massive pulmonary embolism. After several failed attempts to reestablish PIV access, 150mL of contrast were injected through the proximal tibia IO catheter placed by EMS. Excellent opacification of the pulmonary arteries was achieved and there were no immediate complications from the injection noted.

A case study describing intraosseous pressure monitoring, through tibial IO access, using a standard arterial pressure monitoring transducer during resuscitation of a 31-year-old male in cardiac arrest. Pressure readings were recorded for approximately 53 minutes and were compared to non-invasive blood pressure cuff monitoring at the same time points. IO systolic, diastolic and mean IO pressures were approximately 40% of arterial pressures. This is the first case report demonstrating IO space has a measureable blood pressure and it correlates with pressure obtained through conventional techniques.

General discussion on use of the intraosseous vascular access route for infusion of CT contrast, with attention to clinical considerations pertinent to nurses working in the imaging suite. Author also reviews general IO principles and IO devices.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


This 30 pediatric patient case series describes use of IO access in the perioperative setting when peripheral and central venous access failed during anesthesia administration for emergency surgery. Due to unavailability of modern IO devices, a standard 18-gauge IV needle with a handmade IV extension set were used to establish IO access. The authors reported administering ketamine, succinylcholine, pancuronium, atracurium, halothane, neostigmine, atropine, blood products, fluids and hydrocortisone through the IO line without complication. The authors concluded that although it is not the first-line method for anesthesia, IO access should be considered by pediatric anesthesiologist when peripheral and central venous access has failed or is difficult.


This article explores the use of IO access for blood product administration and whether or not it is clinically effective. Based upon lack of clinical evidence and physics principles, the author argues that maximum flow rates attainable for IO blood infusion are not adequate for resuscitation.


In this preclinical swine study, investigators sought to evaluate whether intraosseous blood samples can be used to measure opioids, and if so, to determine the level of accuracy of those measurements. Blood samples were drawn from bilateral tibial IO catheters and from a central venous catheter for six hours. Authors concluded that IO blood samples can be used for the analysis of opioids if an IV route is not available.


An observational study evaluating use of the EZ-IO in a Swiss pre-hospital EMS system between January 1, 2009 and December 31, 2011 and comparing those results to the literature. Sixty IO insertions were performed on 58 patients; the proximal tibia was used in all attempts except 1 attempt made in the proximal humerus. Overall success rate was 90%; the 6 failures were attributed to impossibility to infuse, difficult needle insertion, and incorrect insertion site (tibial plateau). Some of the indications for IO access included cardiorespiratory arrest, major trauma, and shock; general anesthesia was successfully inducted in 7 patients. Drugs infused are listed. There were no serious complications.


A case report describing administration of thrombolytics via tibial IO vascular access for pulmonary embolism in a 36-year-old woman. Due to the emergent nature of the situation, IO access was determined to be the best option for immediate vascular access. Alteplase was administered through the IO line at 100 mg over 2 hours without complication. The patient successfully recovered and was discharged from the hospital on day 7 without long-term disability. The author concluded that this case study raised the potential use of IO lines to deliver thrombolytics in patients with massive pulmonary embolism and that further evaluation is needed to compare the risk and benefits of the alternative method of administration.


A prospective study comparing IO and venous laboratory values obtained from a point-of-care analyzer (i-STAT) in 20 children. IO blood specimens were collected from the iliac crest; 2 ml were discarded before the sample was collected analysis. Results showed differences between venous and IO sample were clinically acceptable for pH, base excess, sodium, ionized calcium and glucose in hemodynamically stable patients. Authors concluded that analysis of IO samples with a bedside point-of-care analyzer is feasible and in emergency situations may be useful to guide treatment.


This article describes a case study of a 5-month old infant that suffered a head injury resulting in shock. She received 100 ml of red blood cells via the EZ-IO in the proximal tibia, resulting in rapid hemodynamic improvement. A literature search was completed for cases of IO blood transfusion in pediatric trauma. Authors note IO availability and knowledge play an important role in hemorrhagic shock, and RBC infusions via the IO route are feasible in this age group.
A study comparing Cefazolin concentrations found at the operation site following total knee arthroscopy when prophylactic antibiotics are administered systemically, through IV administration, and regionally, through IO injection directly at the site using the EZ-IO. Subcutaneous fat and bone samples were collected for evaluation from 22 subjects. Authors concluded that regional IO administration of prophylactic antibiotics can achieve tissues levels higher than with systemic administration.

**YEAR: 2012**

**Burghert J, Gege B, Loughren M.** Comparison of tibial intraosseous, sternal intraosseous, and intravenous routes of administration on pharmacokinetics of epinephrine during cardiac arrest: A pilot study. *AANA Journal* 2012;80(4):S6-S10

This pre-clinical study evaluated IO flow rates obtainable with infusion of lactated Ringer’s and hetastarch 6% through the proximal tibia and sternum IO insertion sites. Results showed that lactestarch flow rates were lower than lactated Ringer’s flow rates at both insertion sites; IO administration of contrast may be a viable alternative if other vascular access is unavailable or if establishing other access will lead to a delay in diagnostic evaluation. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Physicians from two different emergency department settings reported 2 cases of supraventricular tachycardia (SVT) in infants (2 and 4 month old) in which IO administration of adenosine failed to convert SVT to a normal rhythm. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


PALS 2012 guidelines on pharmacotherapy and toxicological emergencies.


Physicians from two different emergency department settings reported 2 cases of supraventricular tachycardia (SVT) in infants (2 and 4 month old) in which IO administration of adenosine failed to convert SVT to a normal rhythm.


Pharmacokinetics of IO drug delivery was compared using the tibia or sternum, versus central venous delivery during CPR. Anesthetized swine with KCl arrest were used for this study. CPR was initiated 8 minutes post arrest. Using 2 study groups, dye was injected as a bolus with adrenaline through either the IO sternum and tibial needles or through the IO sternum and IV central venous needles. Results showed peak arterial blood concentrations were faster for sternal IO vs tibial IO administration. Tibial IO delivered 65% of the total dose delivered with sternal administration. Peak blood concentrations were similar for sternal IO and central venous administration. Sternal IO delivered 86% of the total dose delivered by central venous administration. The EZ-IO and Jamshidi were used to facilitate IO access. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A preclinical study evaluating the effects of propofol on selected blood parameters and physiological variables during general anesthesia in rabbits when administered via intraosseous and intravenous routes. Results showed the IO route was as effective as the IV route for propofol administration at doses inducing general anesthesia. The authors concluded that use of IO propofol could be recommended as a safe method of anesthesia in small animals with limited vascular access.
A pre-clinical study evaluating the time to loss of consciousness and effective maintenance of anesthesia following IO and IV administration of propofol in 24 rabbits. The authors concluded that in all evaluated aspects of anesthesia, IO administered propofol was as effective as IV administration in rabbits.


This abstract presented at the 2012 ACEP Research Forum describes a preclinical swine study evaluating the ability to induce therapeutic hypothermia by infusing chilled saline via IV and IO access. The EZ-IO was used to facilitate IO access. Results showed statistical equivalence between IV and IO routes when used to deliver chilled saline to induce therapeutic hypothermia. Results also showed that use of chilled saline and infusion tubing submerged in an ice water bath provides the most effective means of cooling. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A pre-clinical study evaluating the systemic bioavailability of antidotes when administered via the intraosseous (IO), intravenous (IV), and intramuscular (IM) routes is described. Results showed rapid and substantial antidote bioavailability after IO administration similar to that of the IV route. Authors concluded that the IO route of antidote administration should be considered when IV access is difficult.


An overview of IO vascular access including a review of currently available literature. The author discusses various IO devices available and their performance metrics, IO access sites, flow rates, advantages and disadvantages of IO access compared to conventional access methods, complications and recommendations on use of the approach. The author concludes that while IO access may not be appropriate for all patients, it deserves a place in the modern provider's armamentarium.


This preclinical study sought to determine the accuracy of IO blood lab values by comparing lab results obtained using an I-Stat for IO blood and arterial blood. The authors concluded that the agreement between intraosseous and arterial analysis seemed to be good enough to be clinically useful, and that there were no clinically significant differences between samples collected from the right and left tibia.


This prospective observational study compared flow rates between distal and proximal tibia IO access in adults, with each adult serving as their own control. The EZ-IO was used to facilitate IO access. IO infusion was performed with and without pressure. The authors concluded that infusion flow rates were significantly higher in the proximal tibia as compared to the distal tibia, and that flow rates are significantly higher with pressured infusion vs. non-pressured infusion. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.

Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


A comparative study evaluating the effectiveness of IO access in relation to IV access for infusion of anesthetics (ketamine, midazolam, and fentanyl) and fluids during hemodynamic studies in 21 infants with congenital heart disease. IO access was established in the proximal tibia (n=11). Results showed, time to access was significantly shorter with IO access (3.6 vs 9.6 minutes); anesthetic onset was shorter with IV access (56.3 vs 71.3 seconds); and no significant difference between groups for hydration volume and anesthesia recovery time. The authors concluded that due to its easy manipulation and efficiency, hydration and anesthesia by IO access was satisfactory without necessity of other infusion access.

Brazil


This abstract reports a literature review using both MEDLINE and Embase databases up to August 2010 to determine feasibility and safety of IO administration during adult cardiac arrest. Authors reported a lack of literature (only two studies met their level of evidence criteria) but concluded IO access in adults appears to be a fast, reliable method to deliver drugs and fluid during CPR allowing adequate drug concentrations and pharmacological response; and should be considered if other medication delivery methods have failed. (Presented at the March 2011 International Symposium on Intensive Care and Emergency Medicine)
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


This abstract describes a study comparing the return to baseline of mean arterial blood pressure between two groups of swine (total n=24) in acute cyanide toxicity and treated with hydroxocobalamin via IV or IO. They also compared blood cyanide lactate, pH, nitrotyrosine levels, cerebral near infrared spectrometry oxygenation, and inflammatory markers. Results showed that all test values in both groups were similar. The author concluded that IO infusion of hydroxocobalamin was found to be equally efficacious to IV administration in the animal model.


This article describes a preclinical trial with a caprine model that assessed the ability of protected, experienced first responders and limited-experience first responders to place IO lines for antidote administration using the EZ-IO device. First responders placed IO lines successfully in 100% of cases, and first receivers placed IO lines successfully in 91% of the cases. Investigators concluded that IO lines may facilitate earlier administration of antidotes to hazardous material victims.


This abstract describes a study evaluating use of hydroxocobalamin as a treatment for hemorrhagic shock. Once the animal had a decrease of mean arterial pressure of 50% from baseline, the drug was infused over 7 minutes in 3 different dose groups; animals were observed for 90 minutes. Results showed the mean arterial pressure in the three groups rebounded to baseline at 105%, 90% and 78%, respectively. The authors concluded that IO administration of the drug significantly increased mean arterial blood pressure and systemic vascular resistance and that hydroxocobalamin may prove to be a pharmacologic adjunct for hemorrhagic shock.


This article discusses alternative rehydration methods for pediatric patients, including the intraosseous route.


In this pre-clinical study, IO and arterial blood samples were collected over a 6-hour timeframe from the tibia of anesthetized swine, analyzed using an iStat and compared. Results showed compliant values between IO and arterial blood for electrolytes, hemoglobin, pH, and pCO2. Lactate, BE, PO2 and SO2 were less compliant. There were high correlations between SO2 and PO2 although the levels in arterial blood were higher.


In this preclinical study, 30 swine in ventricular fibrillation received IO epinephrine, IV epinephrine, or placebo. Return of spontaneous circulation, 24-hour survival, and 24-hour survival with good neurological outcome was evaluated. Results showed ROSC to be nearly universal for the IV and IO groups with no differences between rates; 24-hour survival was substantially more likely in the IO group than the IV group; survival with good neurological outcome was more likely in the IO group than the IV group.

YEAR: 2010


This article explores the use of epinephrine during cardiac arrest to evaluate the lack of demonstrated efficacy in human trials of out-of-hospital cardiac arrest as compared to the laboratory animal model. The author concluded that the value of epinephrine as an adjust to resuscitation of cardiac arrest depends on the dosage, timing of administration and the initiating factor the cardiac arrest, and suggests that IO administration of epinephrine may help address the issue of timing of administration.


A case study describing administration of scorpion antivenom via intraosseous (IO) vascular access in a 16-month old female. Following failure to obtain IV access in pre-hospital and upon arrival at the ED, IO vascular access was established in the proximal tibia and 3 vials of antivenom in 50 mL saline were administered over 10 minutes. Within 5 minutes, the patients respiratory status improved, intubation was averted, and vital signs stabilized immediately; nystagmus and writhing resolved. The patient was discharged home after a short observation period. The authors concluded that when IV access is difficult, IO access may be a rapid and reasonable rescue maneuver for patients requiring scorpion antivenom.

This case study describes a 25 year-old woman who had a massive pulmonary thromboembolism and was administered thrombolysis via IO route (internal tibial malleolus) in the air-transfer pre-hospital setting. The patient recovered.


This article in Chinese, describes a study that evaluated the effects to the bone marrow following IO infusion of hypertonic saline-hydroxyethyl (HSH) in the dog model; using a normal saline group (NS) and a no-infusion group. The test subjects were put into shock and resuscitated. Results showed that at 48 hours post infusion and 1 week post infusion changes were seen in the bone marrow and peripheral blood in the HSH and NS groups as compared to the non-infusion group. At 4 weeks post infusion, the NS group and HSH group recovered to normal level. Bone marrow morphology changed slightly but no bone necrosis occurred. The author concluded that HSH in small amounts via IO is safe and effective as a fluid resuscitation measure for shock, and little change in bone marrow has been found after infusion.

YEAR: 2009


In a preclinical study using a caprine model, researchers assessed the hemodynamics of hydroxocobalamin (OHCo) compared to normal saline (NS) by the intraosseous (IO) route and concluded that the effects of OHCo given by the IO route in non-CN-poisoned goats are mild and well tolerated. Investigators concluded that IO administration of OHCo may "find a role in the settings of individual patients with cyanide-induced cardiovascular collapse or mass cyanide casualties".


This abstract describes a retrospective study to determine the time from EMS dispatch to IV or IO drug delivery, time savings to drug delivery if vascular access preceded intubation, the internal validity of that point estimate using matched cases in which IV/IO was performed first, and the theoretical increase in rate of return to spontaneous circulation. Investigators concluded that time from dispatch to IV/IO delivery could be reduced by 4 minutes if vascular access preceded intubation and could, potentially double ROSC.


This abstract for a presentation at the 2009 ACEP Research Forum describes a swine study that evaluated crystalloid fluid flow through an IO needle following nitroglycerin infusion in a swine model. Investigators concluded there was not a significant increase in flow rate after administration of IO nitroglycerin.


This French version of an article previously published in American Journal of Emergency Medicine describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous using the Vidaport (a predecessor of the Vidacare EZ-IO) vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine for nearly all pharmacokinetic parameters, including maximum plasma concentration, time to maximum plasma concentration, and area under plasma concentration-time curve. There was a significant difference in the volume of distribution in the central compartment, which investigators attributed to a minor deposition effect near the IO port or in the bone marrow. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.


This swine study was designed to determine if intraosseous infusion is suitable to delivery recombinant human factor VIIa (rFVIIa) during hemorrhagic shock. Investigators concluded that administration of rFVIIa via IO infusion is a safe route for delivery and is likely to produce blood levels required to improve hemostasis during shock.

YEAR: 2008


Animal (goat) study to determine the capacity and time required for protected hazardous materials responders and receivers to accomplish vascular access and hydroxocobalamin administration for antidotal treatment for exposure to cyanide and other poison agents. Using the EZ-IO device, researchers concluded that the time required for IO administration of the drug was shorter than intravenous administration; and that IO placement is readily accomplished wearing all levels of chemical protective garments and equipment.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


The objective of this study was to determine the anesthetic efficacy of repeated intraosseous injections of 2% lidocaine with epinephrine given 30 minutes following a primary injection for pain management for dental procedures. Results found that a repeated injection provided 15 minutes of additional pulpal anesthesia.


Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation; the second notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.


Two letters to the editor regarding use of IO blood for sampling in the emergency setting. One letter by S. Nicoll and S. Rochester states it should no longer be done and only arterial or femoral venous samples should be used during resuscitation. The second by R. Salter notes the importance of IO blood sampling in emergency situations when time cannot be delayed for central line access, stating it is key that the sample be properly labeled as IO blood.

UK


This article describes a 25-patient clinical study that compared the pharmacokinetics of intraosseous vs. intravenous administration of morphine sulfate in adults. Results showed no differences between IO and IV administration of morphine sulfate for nearly all pharmacokinetic parameters. Investigators concluded that the results support the bioequivalence of IO and IV administration of morphine in adults.

Canada


Overview article of IO vascular access describes technique, efficacy in medication delivery, utility in pediatric emergencies, use in neonates, complications, and commonly-infused medications.

Hoskins SL, Kramer GC, Stephens CT, Zachariah BS. Abstract 79: Efficacy of epinephrine delivery via the intraosseous humeral head route during CPR. Circulation 2006;114:II_1204

Results from this study which sought to determine the efficacy of intraosseous drug delivery using the proximal humerus during CPR in swine showed that the humeral route generated higher mean arterial pressures than central venous or endotracheal delivery.

YEAR: 2005


This animal study compared IO drug delivery in the tibia versus the sternum during CPR. Researchers concluded that during CPR IO infusions delivered via both sites were effective—although sternal delivery was faster; and that IO sternum access is comparable to IV access for drug delivery during CPR.

This study abstract discusses use of the EZ-IO to determine the pharmacokinetics (PK) and efficacy of tibial IO drug delivery during treatment of cardiac arrest in the swine model, as compared to IV access. Results showed that PK analysis of IO drug delivery via the tibial route showed a delay of 20-50 seconds compared to IV; however, physiologically significant levels of epinephrine were reached as MAP. This research was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


Animal study comparing distribution of technetium Tc 99m pertechnate following IO or IV injection. Both routes resulted in effective perfusion of the distal portion of the forelimb and similar distribution in the phalanges of horses.


Multicenter, prospective study of cardiopulmonary resuscitation data over 18 months. The study was design to evaluate the impact of survival of IV or IO high-dose epinephrine compared to standard doses in children with cardiorespiratory arrest. Limited conclusions showed that there is no significant difference between the two treatments.


Veterinary study of IO and IV pharmacokinetics of vancomycin in horses. Found no significant differences in pharmacokinetic variables and plasma drug concentrations between IO and IV administration.


Retrospective study over a 14-year period examining 129 IO insertions among 23,489 pediatric trauma patients. Patients receiving IO fluids and medications tended to be younger and sicker. Concludes that IO is an essential skill for anyone involved in pediatric trauma resuscitation.


Prospective randomized dental study of the pharmacokinetics and pharmacodynamic effect of lidocaine and epinephrine administered via IO and infiltration injections. Found no difference in plasma levels of lidocaine for maxillary anterior IO and infiltration injections. Found a significant increase in heart rate with IO administration compared to infiltration injection.

YEAR: 2004


Preclinical study in young pigs comparing IO and IV administration of hypertonic saline solution in an uncontrolled hemorrhagic shock swine model. Found no significant difference between IO and IV administration.

Abstract only


Cadaver study demonstrating immediate entry of methyl green dye into the venous system after IO infusion via the calcaneus in 14 of 20 cadaver legs (70%).

YEAR: 2003


Dental study finding successful injections of 2% lidocaine with epinephrine in 27 of 33 (82%) X-tip IO injections (82%) for anesthesia in mandibular teeth.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

YEAR: 2002


IO infusion of 7.5% hypertonic saline in this model was associated with a high rate of local complications (soft tissue or bone marrow necrosis).


Veterinary study comparing the B.I.G. with the manually driven Jamshidi IO needle. Concludes the B.I.G. provides more rapid access to the IO space.

YEAR: 2001


Veterinary study comparing IO and IV pharmacokinetics of Amikacin in horses. Found that maximal concentration of Amikacin concentration was significantly higher with IV perfusion.


Preclinical study in micropigs investigating the short and long term efficacy and safety of an implantable IO device. The study compared serum concentrations of Amikacin and Vancomycin administered through the implantable IO device, an intra-tibial needle, and a central IV line. Found similar concentration curves among all 3 routes for both antibiotics, though vancomycin levels did not reach therapeutic levels for both IO routes. Concludes that long term administration of antibiotics through an implantable IO device is feasible and safe in micro-pigs.

Donati F, Guay J. The substitute for the intravenous route. Anesthesiology 2001;95(4):1041

This letter is in response to an editorial on management of laryngospasms without previous intravenous access. The authors debate the use of intramuscular succinylcholine vs. intraosseous administration.


Preclinical study in pigs. Found that blood flow in the IO space is responsive to both physiologic stress response caused by electroshock and to vasopressors given during resuscitation after hypovolemic cardiac arrest. Blood flow in the IO space was nearly absent following successful resuscitation with high-dose epinephrine, but was maintained after high-dose vasopressin. Concludes there may be a need for a pressurized intraosseous infusion during hemorrhagic shock.

YEAR: 2000

Chamberlain TM, Davis RD, Murchison DF, Hansen SR, Richardson BW. Systemic effects of an intraosseous injection of 2% lidocaine with 1:100,000 epinephrine. Gen Dent 2000; 48: 299-302

Dental study of IO injection of lidocaine in 20 human volunteers. Found a statistically significant increase in heart rate immediately after IO injection (12 beats per minute) but no effect on blood pressure.


Dental study demonstrating that intraosseous injection of 1.8 ml of 3% mepivacaine to augment nerve block in the first molar significantly increased the anesthetic success over 30 minutes and had a minimal effect on heart rate.


Pharmacokinetic study in piglets comparing IO and IV administration of fosphenytoin and phenytoin. Therapeutic plasma levels were achieved with both administration routes for both drugs. Concludes no need to adjust the standard drug doses of phenytoin for IO administration. Cautions slow infusion rates for fosphenytoin due to concerns over neurotoxicity.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


Intraosseous transplantation of bone marrow in combination with long-acting Adriamycin may inhibit acute and chronic graft versus host reactions.


Dental study in 48 volunteers finding IO injection of etidocaine resulted in a significant increase in anesthetic effect. The majority of subjects receiving IO etidocaine solution experienced a transient increase in heart rate.

**YEAR: 1999**


This article describes use of intraosseous injection of anesthetic for dental applications.

**Efimov IuV, Zaitsev VG, Sychugov AV.** [The treatment of patients with complicated mandibular fractures using a method for the intraosseous administration of biologically active drug agents]. Stomatologiia (Mosk) 1999; 78; 26-7. Russian

Article in Russian; no English translation.


This case study described administration of iodinated contrast via IO infusion in the tibia, for an abdominal CT scan in a 7 week old infant. CT imagining demonstrated adequate enhancement of the solid organs and vasculature.


Preclinical study in hypovolemic pigs finding no significant difference in pharmacokinetic and pharmacodynamic parameters between IO and IV infusion of hydroxyethyl starch.

**Replogle K, Reader A, Nist R, Beck M, Weaver J, Meyers WJ.** Cardiovascular effects of intraosseous injections of 2 percent lidocaine with 1; 100,000 epinephrine and 3 percent mepivacaine. J Am Dent Assoc 1999;130(9):649-57

Dental study in 42 volunteers finding most subjects receiving IO Lidocaine-epinephrine solution experienced a transient increase in heart rate. No significant increase in heart rate was observed with the intraosseous injection of 3% Mepivacaine.


Preclinical study in pigs finding that plasma levels of vasopressin, hemodynamic variables, and return of spontaneous circulation were comparable for IO and IV administration. Concludes IO vasopressin may be a viable alternative during CPR when IV access is delayed or not available.

**YEAR: 1998**


Veterinary study in 14 iguanas were finding that IO propofol resulted in a significant decrease in heart rate that appeared 35 minutes after induction of anesthesia and persisted for 120 minutes. Serum pO2 values decreased after induction of anesthesia.

**YEAR: 1997**

**Dubick MA, Kramer GC.** Hypertonic saline dextran (HSD) and intraosseous vascular access for the treatment of haemorrhagic hypotension in the far-forward combat arena. Ann Acad Med Singapore 1997;26(1):64-9

Review article highlighting preclinical data and 1 clinical study. Demonstrates that IO administration can be used for safe and rapid infusion of hypertonic saline dextran with the hemodynamic effect as IV administration.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

YEAR: 1996

Case report of successful resolution of supraventricular tachycardia in an infant following IO administration of adenosine.

Preclinical study in piglets demonstrating successful resuscitation from hemorrhagic shock with IO administration of hypotonic saline.

YEAR: 1995

Nursing article on pharmacologic management of cardiac arrest discussing administration routes for cardiac medications.

Review article discussing medication administration routes during CPR when patient is in shock. Recommends IO access for medications, crystalloids and colloids as a viable alternative. Cautions against IO for hypovolemic shock due to lower infusion rates.

Preclinical study of IO versus resuscitation in hemorrhagic shock with an infusion of small volume hyperosmotic saline. Found that plasma catecholamine levels returned to normal 90 minutes after IO infusion. Found no significant differences in catecholamine levels between IV and IO infusion.

Preclinical study in pigs demonstrating that IO hyperosmotic resuscitation increases circulatory performance and reduces the plasma and catecholamines concentrations during hemorrhagic shock.

Clinical study of IO anesthesia during orthopedic surgery. Satisfactory anesthesia was obtained in 106 of 109 patients. Concludes that IO regional anesthesia is a valuable technique when IV anesthesia fails or is not feasible.

YEAR: 1994

Preclinical study comparing IO administration of adenosine with peripheral and central venous routes to induce atrioventricular block during pacing. Found that IO administration was effective. Required dose of adenosine was highest for the peripheral venous route, lowest for the central venous route.

Veterinary study comparing IO and IV administration of amikacin. Found no significant differences in pharmacokinetic parameters between the 2 administration routes.

Preclinical study in 86 injured dogs with hemostasis disorders. Plasma and platelet disorders normalized 3 hours after the onset of infusion therapy. The response was enhanced by IO infusion of isotonic saline. 
*Article in Russian-abstract only*
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics

Preclinical study demonstrating IO infusion of a saturated salt-dextran solution restored cardiac output in a pig model of hemorrhage. Suggests that IO-administered concentrated salt-dextran solution is a viable alternative during harsh field conditions where conventional resuscitation techniques may be impractical.
Abstract only

In this study bone marrow aspirate from the iliac crest and peripheral venous blood samples from 30 pediatric patients were compared to investigate the predictive value of bone marrow aspirate in performing laboratory studies. Laboratory tests with high predictability, moderate but clinically useful predictability are summarized. Tests that were systematically different from venous blood are also summarized.

Pharmacokinetic study comparing IO and IV administration of both sodium bicarbonate and a radioactive tracer. Found no significant differences in end tidal CO2 concentrations between the 2 routes of administration. Also found no differences in time for radiotracer to reach the central circulation. Suggests that dosage adjustments are not required for IO administration and that IO is an acceptable alternative to IV drug administration.

Review article on endotracheal administration of epinephrine highlighting poor pulmonary drug absorption with this technique.

YEAR: 1991

Review of indications and benefits of intraosseous infusion. Concludes IO access may be especially valuable for medical personnel who rarely care for critically ill children because the IO technique is easily mastered even with limited practice.

A pre-clinical study comparing IV and IO blood serum levels of antibiotics: ceftriaxone, cefotaxime, ampicillin and gentamicin in weanling pigs. Blood levels were compared at 15, 30, 45, 60 and 90 minutes and each animal served as their own control. Results showed that IO levels were initially lower than IV levels though the difference became indistinguishable after 30 minutes. Ceftriaxone levels however remained lower throughout the 90 minute sample period. The authors concluded that standard IV doses may be administered intraosseously though further study may suggest higher doses of ceftriaxone may be more beneficial.

YEAR: 1990

Preclinical study comparing a sternal IO infusion device to IV fluids for resuscitation. Blood pressure and cardiac output were normalized at 10 minute post infusion in both groups. Advocates use of IO infusion as a way for pre-hospital rescuers to consistently incorporate fluid therapy in their scoop and run policies.

Preclinical study of the pharmacokinetics of emergency medications in a canine model of shock. Found that endotracheal administration was unreliable, while IO administration was comparable to central and peripheral venous administration.

Preclinical study comparing the pharmacokinetics of 6 emergency medications in dogs. Found that IO administration resulted in similar physiologic effect and/or serum drug levels as central and peripheral venous administration.

This article describes two cases of IO administration of succinylcholine for emergency airway management in children that resulted in adequate intubating conditions within 45 seconds for both cases.

A 15mg/kg dose of phenytoin was administered over 15 minutes to 6 pigs using the IV route and 6 pigs using the tibial IO route. Blood samples were taken every 5 minutes for 35 minutes to determine phenytoin levels. There was no statistical difference between the two groups. Bone cortex and marrow were microscopically examined and were normal after 5 weeks. Authors concluded the IO route is an effective alternative to the IV route for administering phenytoin without permanent damage to the marrow.


Article advocating IO infusion over endotracheal administration of medications. Asserts that IO infusion is equivalent to IV infusion.

YEAR: 1989


Preclinical study in pigs and mathematical model using mean frequency of the ECG during ventricular fibrillation to predict downtime.


A pre-clinical study evaluating resultant serum levels when administering phenobarbital and phenytoin via intraosseous infusion as compared to IV administration in domestic swine. Results showed that current IV dosing of phenobarbital 20 mg/kg obtains and maintains therapeutic serum levels when given IO; Phenytoin 15 mg/kg does not maintain therapeutic levels and cannot be recommended for IO administration.


Preclinical study in pigs finding equivalence in physiologic response between IO an IV administration of antiepileptic drugs.


Preclinical study in dogs examining lung samples for fat and bone marrow emboli following IO infusion. Found no significance difference in embolism formation or density between dogs receiving IO infusion of emergency drugs and control group.

YEAR: 1987


Letter to the editor written by Dr. Edgren and Dr. Tilelli regarding a prior article by Dr. Spivey in which he suggested use of IO route for administration of diazepam for treatment of status epilepticus. They note a few complications of IO use such as osteomyelitis, epiphyseal damage and pulmonary embolism as reasons to use rectal administration over IO. Dr. Spivey responded noting IO administration should be considered as an option and that the complications they noted are very rare or never reported.


A preclinical study comparing IV and IO administration of diazepam in a pentylenetetrazol seizure model in pigs. Results showed that epileptogenic activity was suppressed within 1 minute in the IV group and within 2 minutes in the IO group; the difference was not statistically significant. The authors conclude the IO rate is a rapid and effective alternative for diazepam administration.


A preclinical study evaluating the effects of sodium bicarbonate on the medullary cavity following tibial infusion in swine 30 days prior. Results showed all roentgenographs, bone scans and microscopic specimens to be normal with the exception of one small cortical calcification at the site of needle puncture visible in one animal. The authors conclude that the study demonstrates that sodium bicarbonate does not have permanent adverse effects when injected into the marrow cavity of swine.

YEAR: 1986


Review of medical literature and research on the problem of difficult intravenous access.
Intraosseous Vascular Access Bibliography
Pharmacokinetics/Dynamics


This preclinical study compared CBCs and routine blood chemistries drawn from IO and IV blood. The authors concluded that IO blood chemistries reflected venous blood chemistries and may be used if venous blood cannot be obtained; CBC cannot be reliably obtained from IO blood.

YEAR: 1985


Preclinical study in pigs examining blood pH during CPR with sodium bicarbonate administered via different vascular access routes. Found that pH pf blood obtained via central venous access and intraosseous access were significantly different from the peripheral group, and that all three groups were significantly different form the control. Pathology studies showed only minor damage to bone with IO sodium bicarbonate administration.

YEAR: 1984


This preclinical study compared pH changes induced by administration of IV and IO sodium bicarbonate. The results showed that the rapidity and effectiveness of sodium bicarbonate administered via IO was clinically equivalent to that given by the IV route.

YEAR: 1979


Preclinical study of IO flow and pharmacokinetics in the bovine tibia. Mean time to initial effect of IO administration of epinephrine was 17 seconds with 90% maximal effect in 45 seconds. Concludes that experiment provides quantitative evidence of utility of IO infusion for resuscitation.
This pre-clinical study compared various PK parameters, return of spontaneous circulation (ROSC), time to ROSC, and odds of ROSC after epinephrine was administered via endotracheal (ETT), IO, and IV routes in a swine traumatic cardiac arrest model (TCA). IO groups included sternal IO (SIO), humeral IO (HIO), and ilial IO (TIO). CPR only and CPR plus defibrillation (CPRD) groups were included for analyzing ROSC. The Cmax of the IV epinephrine group was significantly higher than that of the IO group (p=0.049). The tmax of the TIO group was significantly longer than that of all other groups (p=0.008). There were significant differences in mean plasma concentrations over time between the IV and TIO groups at 90, 120, 150, and 180 seconds (p<0.05) with the TIO group having an unexpectedly prolonged absorption phase. There was no difference in the rate of ROSC between ETT, TIO, HIO, SIO, IV and CPRD groups. The PK findings relative to ROSC support the concept that neither epinephrine nor the route of administration influenced the outcome. All IO insertions were performed using the EZ-IO device.


This pre-clinical study compared IO, arterial, and venous point-of-care blood samples taken during cardiac arrest and CPR to pre-arrest arterial values to determine which method best reflected the pre-arrest state in a swine model. IO access was achieved using the EZ-IO device. The following parameters were assessed: partial pressure of oxygen, partial pressure of carbon dioxide, base excess, standard bicarbonate, pH, lactate, sodium, potassium, ionized calcium, glucose, and hemoglobin. The study found that these values change differently during cardiac arrest and CPR depending on the source of the sample. The authors suggest that if arterial or venous samples are not available then IO samples can be considered.

YEAR: 2018


This study compared the efficacy and safety of IO versus IV idarucizumab for dabigatran reversal in a porcine polytrauma model. Twenty-one male pigs received oral dabigatran for 3 days and on the 4th day received dabigatran infusion while another 7 received a sham treatment. The treated pigs were then randomized to one of three groups; IO saline, IV idarucizumab, IO idarucizumab while the other 7 comprised the sham group. The pigs were subjected to polytrauma (femur fracture and blunt liver injury). Blood loss, hemodynamic values, and blood samples were measured and recorded. Blood loss was highest in the control group, followed by the two idarucizumab groups, and lowest in the sham group. Survival to 240 minutes was 100% in the sham group and both idarucizumab groups, and 14% in the control group. IO and IV idarucizumab promptly normalized global coagulation assays and thrombin generation and were comparable for reversing dabigatran.


This pilot study compares four different IO blood transfusion strategies with varying degrees of transfusion pressure in a swine model with similar bone density to that of an adult military servicemember. Animals were randomly assigned to one of four transfusion strategies: 1) gravity, 2) pressure-bag, 3) rapid-transfusion device, or 4) manual push-pull. Hemorrhage was simulated then IO access was obtained with the EZ-IO device. Gravity transfusion was the slowest with a flow rate 5 mL/min, followed by rapid transfusion device (31 mL/min), single site pressure bag (78 mL/min), double site pressure bag (103 mL/min), and push-pull technique (109 mL/min). Single site or double site pressure bag was determined to be the best option for IO infusion because of the high flow rate and no associated incidences of overpressure or death.


This article studied subchondral intraosseous pressure (IOP) in an animal model during loading and with vascular occlusion. IOP recordings from 5 femoral condyles and 7 proximal tibias in 5 rabbit subjects were obtained. The effect on IOP of loading by 1 body weight, arterial occlusion then loading, and venous occlusion then loading were assessed. A load of 1 body weight caused the basal IOP to rise as well as IOP at various sites. A clip applied to the proximal femoral artery caused the IOP to fall while a clamp on the femoral vein caused the IOP to rise. Saline injected into the femoral head caused pressure at the femoral condyle to increase and vice versa when saline was injected at the femoral condyle. IO injection of saline in the femur had no effect on IOP at the tibia. The authors conclude that IOP is not constant.


This study explored the physiology of normal subchondral perfusion and IOP. Using 21 anesthetized rabbits intraosseous pressure (IOP) was measured using IO needles in the subchondral cancellous bone of the femoral head, femoral condyle, and proximal tibia. A series of experiments investigated the following: normal baseline IOP; method of measuring; IOP wave forms; drug administration; relationship between systemic blood pressure, IOP and pulse pressure; relationship between IOP and pulse pressure; and vascular occlusion. The authors concluded that subchondral cancellous bone behaves as a perfused tissue and that IOP is mainly a reflection of arterial supply. A single measure of IOP can vary and reflects only perfusion at the needle tip.
This study examined the measured mean plasma concentration, maximum plasma concentration (Cmax), and time to maximum concentration (Tmax) of amiodarone administered by 3 different routes, sternal IO (SIO), tibial IO (TIO), and IV over a time period of 5 minutes in 21 swine who were randomly assigned to one of the 3 routes. The swine were under general anesthesia and ventricular fibrillation was induced and CPR initiated. After 4 minutes in ventricular fibrillation the swine were administered 300 mg of amiodarone and blood samples were taken at 30 second intervals over 300 seconds. Authors concluded that the SIO and IV routes of amiodarone were comparable. The TIO group took almost 3 times longer to reach Tmax than the SIO and IV groups. In the swine model used in this study, the authors concluded that SIO route was more effective than the TIO route for the amiodarone delivery in a swine with VF and ongoing CPR.

This article describes a study that compared serum concentrations of tranexamic acid (TXA) when given IV and IO and compared the efficacy of IO administered TXA to IV at reversing hyperfibrinolysis in a porcine hemorrhage and ischemia-reperfusion model. There were no statistically significant differences in serum drug concentrations between IV and IO infusions at any of the measured time points. TXA infusion corrected the lysis index at 30 minutes in both the IO and IV groups.

This abstract describes interim results of a study in a swine model that discusses the utility of intraosseous blood transfusions for treating hypovolemic battlefield injuries, compares advantages and complications of humeral versus sternal IO access for resuscitation, and identifies flow rates, degree of intravascular hemolysis, and occurrence of coagulopathy in single versus double site intraosseous blood transfusion. The study found that in an animal model of hemorrhagic shock, double site IO transfusion appears to confer a significant advantage in flow rates without significant complications.

Swine study comparing pharmacokinetic (pk) parameters of TXA given by the IO vs IV route. For the 4 min and 5 min results Cmax plasma concentrations were higher in the IV group but similar from injection completion onwards. Other PK parameters were not significantly different. Limitations included swine model, nonmotivational animals and proximity of sampling site (jugular vein) to the IV infusion site (auricular). Investigators concluded this study supports the pharmacokinetic bioequivalence of IO and IV administration of TXA in this animal model.

This preclinical study reported data evaluating the pharmacokinetics of HIO and IV vasopressin and the ROSC in a swine model of ventricular fibrillation cardiac arrest. For the parameters of occurrence of ROSC, odds of ROSC, time to ROSC, Cmax, Tmax, and plasma concentrations over time, the IO and IV routes results were comparable.

This abstract describes a preclinical study conducted to determine how long an infusion must be stopped before drawing an IO specimen for analysis; to determine if there is a difference between IO specimen results when the first 2 mL of IO blood were discarded and not discarded; and add to existing data comparing lab results from IO vs. CVC access. Lab specimens were drawn following infusion of 0.9% NS and analyzed using a point-of-care analyzer and cartridge system. Results indicated the initial specimen drawn from the IO catheter for analysis may be adequate for analysis; and IO specimen results are comparable to those of CVC values. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography

Pre-Clinical Studies

YEAR: 2016


This study compared maximum concentration time (Cmax) to maximum concentration mean (Tmax) of mean serum concentration of vasopressin, return of spontaneous circulation (ROSC), time to ROSC, with odds of survival to vasopressin administration by tibal intraosseous, proximal humerus intraosseous (PHIO), and intravenous (IV) routes in a cardiac arrest model. Authors concluded TIO and PHIO provide rapid and reliable access in administration of life-saving medications during cardiac arrest and may be faster due to IV difficulty.


This study was to determine if there were any significant differences between humerus intraosseous (PHIO), sternal intraosseous(SIO) and intravenous (IV) administration of Hextend on the hemodynamics or administration time in a hypovolemic swine model. Time of administration of the Hextend on effects on systolic and diastolic blood pressure, mean arterial pressure, heart rate, cardiac output and stroke volume. After administration of Hextend, data was collected every 2 minutes for 8 minutes total. Results found no significant difference in these measures among the PHIO, SIO or IV groups.


Preclinical RCT evaluating the relationships between the anatomical distance of IO epinephrine and measures of resuscitative outcome in an adult swine model of ventricular fibrillation (VF). There were no significant differences between the HIO, TIO, and IV groups relative to the occurrence of ROSC, 30-minute post-ROSC survival, and time to ROSC. The anatomical distance of IO epinephrine injection from the heart did not affect short-term measures of resuscitative outcome in an adult swine model of VF including the occurrence of ROSC, 30 minute post-ROSC survival, and time to ROSC. Rapidly administered epinephrine, irrespective of route of administration, increased the chance of ROSC and survival to 30 minutes post-ROSC in this study.


This preclinical study compared arterial and intraosseous derived biomarkers to determine if the results would correlate well enough over a period of 6 hours to consider use of IO derived blood when traditional samples are difficult to obtain. Authors noted there were no clinically relevant average differences between alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase, creatinine kinase and gamma-glutamyl transferase values which may be good enough for initial estimates of these markers analyzed in intraosseous and arterial samples. However the lactate dehydrogenase levels showed less correlation; and the precision of IO samples may be limited.


Randomized, prospective preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibal IO (TIO) and IV-delivered vasopressin during cardiac arrest and CPR until ROSC was acheived. No difference was noted for ROSC between TIO and IV delivered vasopressin. Authors concluded the use of IO access could avoid the time delay associated with IV access, and that it is effective for treatment of hypovolemic cardiac arrest and should be first line for rapid vascular access.


This study compared IV to tibal IO administration of amiodarone. Investigators found no significant differences for the endpoints of Cmax, Tmax and time to/rate of ROSC between IO and IV.


In a swine study comparison of the humeral IO and IV amiodarone administration routes investigators found no difference in time to ROSC or rate, time to maximum concentration (Tmax) p = 0.501) or in maximum plasma drug concentration (Cmax) p = 0.232.


This paper discusses a recently developed novel approach of IO delivery of lenti-viral vectors to correct hemophilia A. Ex vivo hematopoietic stem cell (HSC) transduction/transplantation has been shown to successfully deliver Factor 8 (FVIII) into HemA mice but the procedure requires pre-conditioning using potentially toxic, myelosuppressive agents. IO delivery to transduce HSCs bypasses this step and potential thrombocytopenia associated with pre-conditioning. When compared to IV infusion of LVs, IO delivery directly introduced LVs into the bone marrow significantly enhancing transduction efficiency of HSCs. In mice, a single infusion of G-F8-LVs produced long-term stable expression of hFVIII in platelets and corrected hemophilia phenotype for the long term.
## Intraosseous Vascular Access Bibliography

### Pre-Clinical Studies


A preclinical study evaluating blood transfusion via IO vascular access in anesthetized swine. Results showed pressurized blood transfusion through IO vascular access resulted in acceptable flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.


This pre-clinical study compared the performance of IO and IV administered albumin. IO access was obtained via the tibia using an EZ-IO device. Mean infusion time for TIO was 7 minutes, 35 seconds. Mean infusion time for IV was 4 minutes, 32 seconds. There were no significant differences between groups relative to mean arterial pressure, cardiac output, heart rate, or stroke volume. Hemodynamic parameters were measured for only 3 minutes.


This study compared the effects of IO and IV administered resuscitative drugs (vasopressin, amiodarone, and epinephrine) on return of spontaneous circulation (ROSC) in a swine model of sudden cardiac arrest (SCA) with ongoing resuscitation. Swine were randomized to 1 of 5 groups; tibial IO, sternal IO, IV, CPR-defibrillation, and CPR-only. There was no significant difference in ROSC between SIO, TIO, and IV groups. However time to ROSC was significantly less for the SIO group compared to the TIO group (p=0.003). This is possibly related to higher fat content in tibial bone marrow relative to the sternum and the lipophilicity of amiodarone.

**Puga TA, Montez DF, Davlantes C, Miller LJ, Philbeck TE.** *Swine study shows no intramedullary effects of power-injected contrast media using intraosseous access.* J Vasc Access 2016;17(4):e16

A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.


A pre-clinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.


In this porcine study IO and venous samples were analyzed for thromboelastography (TEG), prothrombin time (PT), activated partial thromboplastin time (APTT) and fibrinogen concentration. The IO samples were clinically hypercoagulable, rendering some samples unevaluable; clinically relevant differences were observed for APTT but not for PT and fibrinogen and the TEG demonstrated a shortened reaction time. The ability to use IO drawn blood for coagulation studies may be limited.


A preclinical study comparing delivery of nerve agent antidote when administered via intramuscular (IM) and proximal tibia intraosseous (IO) routes, in normovolemic and hypovolemic swine. IO and IV administration of the antidote achieved and surpassed therapeutic levels in normovolemic groups; time to therapeutic level with IM was 2 minutes versus 15 seconds with IO access. Combined administration via IO route initially, followed by IM injection 60 minutes post IO injection resulted in therapeutic levels for a prolonged time, most closely mimicking standard hospital care of poisoned patients. The authors concluded the rapid increase in plasma concentrations, coupled with the sustainability of the drug in plasma supported advantages of IO over IM delivery.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, after 2 minutes CPR was initiated for 2 minutes, then 40 units of vasopressin was administered via IV or SIO route. Results showed no significant difference in SIO and IV groups for Cmax or Tmax.

A preclinical study comparing administration of Hextend via IV and tibial intraosseous (IO) access routes for time for administration and hemodynamic measures in a hypovolemic swine model. Following exsanguination, 500 mL of Hextend was administered via both routes; a control group received no Hextend. Hemodynamic measures data were collected every 2 minutes for 8 minutes. The mean time for administration in the IV group was 10 minutes 16 seconds (±2 minutes 47 seconds), and for the IO group it was 10 minutes 12 seconds (±1 minutes 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.


A preclinical study comparing IV and humeral intraosseous (IO) access administration of vasopressin in a hypovolemic swine model in cardiac arrest. Following exsanguination, the swine were placed in cardiac arrest for 2 minutes, then resuscitated for 2 minutes in accordance with ACLS guidelines. Vasopressin was administered. Blood samples were collected at various time points following vasopressin injection and analyzed for maximum concentration (Cmax) and time to maximum concentration (Tmax) between groups; return of spontaneous circulation was also captured. ROSC was achieved for all HIO subjects (n=7) and in seven out of eight IV subjects; mean time to ROSC was 9.8 minutes for HIO and 10.7 for the IV group. However, statistically there was no significant difference between HIO and IV administration of vasopressin for achievement of ROSC, time to ROSC, Cmax, Tmax, concentration over time, survivability, or odds ratio.


Preclinical study that examined the differences in pharmacokinetics and pharmacodynamics of tibial IO (TIO) and IV-delivered epinephrine during cardiac arrest and CPR. There were no significant differences between IV versus TIO epinephrine in achieving ROSC, time to ROSC, and Cmax. In the context of ROSC, epinephrine delivered via TIO route was a clinically relevant alternative to IV administration. The authors concluded that when IV access cannot be immediately obtained in cardiac arrest patients, TIO access should be considered.

YEAR: 2015


Preclinical study to determine whether intraosseous pressure (IOP) could be consistently recorded and similarity of IOP to central venous and arterial pressure in a porcine hemorrhagic shock model. IOP tracings were tracked reliably from the proximal humerus, distal femur, and proximal tibia. Baseline IOP ranged from 16-18 mm Hg among the three sites, which was approximately 23% of arterial pressure. This study was sponsored by Vidacare Corporation, acquired by Teleflex Incorporated.


A preclinical study evaluating the bioavailability of antidotes HI-6 oxime and dicobalt edetate when given via proximal tibia intraosseous (IO) access, established via the EZ-IO, compared to intravenous administration via central access in minipigs. Results showed rapid and similar systemic bioavailability of the antidotes when given by both routes and that IO access is an appropriate access route when IV access is impractical.


Prospective preclinical study by to determine the effects of humeral IO (HIO) and IV epinephrine administration during cardiac arrest on pharmacokinetics, ROSC, and odds of survival. There were no significant differences in ROSC, maximum concentration; except at 30 s, and time-to-concentration-maximum between the HIO and IV groups. Significant differences existed between the experimental groups and the control. The HIO delivered a higher concentration of epinephrine than the IV route at 30 s, which they noted may be a survival advantage. Authors suggested clinicians consider using the IO route to administer epinephrine when IV access is unobtainable.


A preclinical study evaluating the immediate effects of power injected contrast media on the medullary space of anesthetized swine. Contrast media (150 mL) was administered at a rate of 5 mL/second. For each limb receiving power injection a control limb was submitted for evaluation. The pathologist was blinded to which limb received power injection. Results showed no histological difference in limbs receiving and not receiving power injection. This study was sponsored by Teleflex Incorporated.
Intraosseous Vascular Access Bibliography
Pre-Clinical Studies


A preclinical study comparing three methods used to confirm intraosseous (IO) catheter tip placement within the IO space. Using an immature anesthetized swine, 8 IO needles were inserted, 4 properly placed within the IO space and 4 placed in the subcutaneous tissue. Physician sonographers (n=32) participated in the study and determine IO proper and improper IO line placement using physical examination, syringe aspiration, and ultrasonography after administering 5 cm3 of normal saline through each IO line. Confirmation via physical examination resulted in 32/32 successful evaluations; syringe aspiration resulted in 22/32 successful evaluations; and ultrasonography resulted in 30/32 successful evaluations.


Preclinical study using a porcine model to determine whether there were differences in intraosseous (IO) and intravenous (IV) antibiotic (cefotaxime and gentamicin) concentrations during septic shock. Both methods of administration yielded comparable concentrations. Authors concluded in an emergency, IO administration of these antibiotics may be considered in severe infections when venous access is difficult.

**Sweden**


This study compared the effectiveness of prophylactic intraosseous regional administration (IORA) of antibiotics with systemic administration using an in vivo murine model of total knee arthroplasty (TKA). Mice were randomized into 1 of 6 groups: control, IV vancomycin 110 mg/kg, IV cefazolin 25 mg/kg, IORA vancomycin 25 mg/kg, IORA cefazolin 100 mg/kg, or IV cefazolin 100 mg/kg. TKA was performed and an aliquot containing S aureus was pipetted into the joint. At 4 days post-surgery the bioluminescent signals as well as CFUs from the extracted joints obtained from mice administered IV vancomycin 110 mg/kg, IORA vancomycin 25 mg/kg, and IORA cefazolin 100 mg/kg were lower than those of the control group. Overall, in mice, IO antibiotic administration was more effective at reducing bacterial burden than the same dose of IV antibiotic.

**YEAR: 2014**


Randomized swine study with the objective to compare the efficacy of IO delivery of hydroxocobalamin to intravenous (IV) injection for the management of acute cyanide toxicity. The survival rate, physiologic parameters such as reversal of hypotension, and pharmacokinetic results were similar between the IV and IO group. The primary limitation was use of a swine model. Investigators concluded intraosseous hydroxocobalamin may be as effective as the intravenous route in treatment of cyanide toxicity.


This preclinical study investigated whether erythropoietin (EPO) given during hemorrhagic shock improved resuscitation and increased survival in a swine model. Swine were randomized to one of three groups: loss of 50% blood volume, loss of 65% blood volume, or loss of 65% blood volume plus vasopressin. Within each group half of the swine also received intraosseous EPO. EPO failed to improve initial resuscitability and 72 hour survival, however, EPO did attenuate acute organ injury. Additionally, vasopressin proved effective in improving survival.

**Puga T, Montez D, Davlantes C, et al. Whole blood transfusion via IO access does not result in gross hemolysis in a pre-clinical study. Crit Care Med 2014;42(12):A1421. abstract 251**

In this pre-clinical study, 18 units of blood were transfused into 10 anesthetized swine via intraosseous (IO) access. Venous specimens were collected to evaluate free hemoglobin levels as an indicator of hemolysis. Seventeen transfusions were given via the proximal humerus site and 1 via the proximal tibia, using a pressure bag set to 300 mmHg. Mean transfusion flow rate was 61.6 ± 37.3 mL/min and the mean blood volume transfused was 266 ± 74 mL (n=18). The authors concluded that blood transfusion via IO access resulted in high flow rates and did not result in appreciable hemolysis as indicated by free hemoglobin values. This study was sponsored by Teleflex Incorporated.

**YEAR: 2013**


Pre-clinical study comparing flow rates achieved after insertion with the EZ-IO in the proximal tibia, distal femur, and proximal humerus in a swine model. IO catheters were placed in each site and normal saline was infused for 10 minutes using a pressure bag at the highest achievable pressures greater than 300mmHg. The flow rates through the proximal humerus were statistically greater than that of the femur or proximal tibia. The femur flow rates were higher than the proximal tibia but similar. Post-mortem histopathologic evaluations done to assess damage for the high pressure infusions were consistent with IO catheter placement.
YEAR: 2010


This abstract describes a follow-up swine study to an earlier study done using concentrated doses of Adriamycin over 72 days in which bone complications occurred. Investigators studied different drug administration regimens that might be used to prevent complications. After the study was completed authors concluded that IO delivery of lower dose and diluted concentrations of Adriamycin was determined to be safer and resulted in less tissue abnormality when compared with higher dose/higher concentration; and use of the IO route with rotation of sites may be a feasible option for Adriamycin or other vesicant delivery.


In this study, using a swine model, investigators concluded that mild therapeutic hypothermia can be effectively induced after successful resuscitation of prolonged ventricular fibrillation through infusion of chilled saline via the IO catheter.

YEAR: 2007


A pre-clinical study evaluating use of intraosseous infusion into the skull, in large adult swine, for the purpose of cerebrospinal fluid (CSF) reabsorption. The authors created intraosseous infusion devices designed specifically for use in this study. Results showed IO infusion demonstrated similarities to systemic absorption characteristics; and authors concluded IO skull infusion may eventually provide another alternative in the management of hydrocephalus.

Canada

YEAR: 1995


This is an abstract of a study to determine whether the current pressure limit (300 mm Hg) of IV infusions can be significantly increased for IO infusion. Pressure flow in anesthetized and freshly killed swine, anesthetized sheep, and human cadavers were measured. The study concluded that pressures as high as 2500 mm Hg could be used to deliver lactated Ringer's via the IO route to resuscitate hypovolemic shock.

YEAR: 1993


Preclinical study in 18 piglets finding significant improvement in hemodynamic variables after IO infusion of hyperosmotic saline and IO transfusion of whole blood in an animal model of hemorrhagic shock. Concludes that IO infusion is easy to establish and holds utility for treatment of shock victims.
Intraosseous Vascular Access Bibliography
Proximal Humerus

YEAR: 2019

This pre-clinical study compared various PK parameters, return of spontaneous circulation (ROSC), time to ROSC, and odds of ROSC after epinephrine was administered via endotracheal (ETT), IO, and IV routes in a swine traumatic cardiac arrest model (TCA). IO groups included sternal IO (SIO), humeral IO (HIO), and tibial IO (TIO). CPR only and CPR plus defibrillation (CPRD) groups were included for analyzing ROSC. The Cmax of the IV epinephrine group was significantly higher than that of the IO group (p=0.049). The Tmax of the TIO group was significantly longer than that of all other groups (p=0.008). There were significant differences in mean plasma concentrations over time between the IV and TIO groups at 90, 120, 150, and 180 seconds (p<0.05) with the TIO group having an unexpectedly prolonged absorption phase. There was no difference in the rate of ROSC between ETT, TIO, HIO, SIO, IV, and CPRD groups. The PK findings relative to ROSC support the concept that neither epinephrine nor the route of administration influenced the outcome. All IO insertions were performed using the EZ-IO device.

YEAR: 2018

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This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.
Intraosseous Vascular Access Bibliography
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This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.

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Sternum


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**Tibia**


The CoTCCC handbook was created as a guide to best practices created by the Committee on Tactical Combat Casualty Care (CoTCCC) which includes representatives from all the U.S. Armed Services that are part of the Tactical Combat Casualty Care (TCCC) Working Group. The recommendations are based on input from the battlefield as well as evidence in the civilian literature, examined and put together to provide guidelines for care. The recommendations and required skill sets include IO access as an alternative to IV access in multiple sections. The TCCC- Medical provider skill set specifically includes the ability to demonstrate the use of IV/IO blood product administration (medical officers and operating room special operations medics) and the use of IV/IO tranexamic acid (TXA).

**YEAR: 2016**


A prospective study with 30 evaluable healthy volunteers receiving PH and sternal IO access (Arrow® EZ-IO® Vascular Access System and T.A.L.O.N.™, Teleflex, Wayne, PA) was conducted to determine if there is a significant difference between pain after a total of 60mg or 40mg of 2% preservative-free and epinephrine-free lidocaine. Endpoints were subject reported pain scores during 5 minutes of rapid infusion at 300 mmHg and 15 and 30 minutes at a rate of 125 mL/hour per pump. Authors concluded infusion pain through a PH IO may be managed with a single 40mg lidocaine prior to infusion, but a total of 60mg may be considered for sternal IO infusion. This study was sponsored by Teleflex Incorporated.


This study compared the effects of IO and IV administered resuscitative drugs (vasopressin, amiodarone, and epinephrine) on return of spontaneous circulation (ROSC) in a swine model of sudden cardiac arrest (SCA) with ongoing resuscitation. Swine were randomized to 1 of 5 groups; tibial IO, sternal IO, IV, CPR-defibrillation, and CPR-only. There was no significant difference in ROSC between SIO, TIO, and IV groups. However time to ROSC was significantly less for the SIO group compared to the TIO group (p=0.003). This is possibly related to higher fat content in tibial bone marrow relative to the sternum and the lipophilicity of amiodarone.


This abstract describes the results of a healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used safely and successfully in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.


This study was completed on 30 healthy subjects to evaluate infusion rates via the sternum (SIO) and proximal humerus (PH) sites under 300 mmHg via pressure bag. The mean SIO infusion rate was 9.58±2.706mL/hr (n=27); mean PH infusion rate was 6.292±3.277mL/hr (n=52). There were no serious complications; minor complications were 5 cases of excess pain, 2 cases vagal response, and mammary tissue engorgement. The mean PH flow rate was significantly lower than that of SIO, but placing IO catheters in each humeri with simultaneous infusion could result in fluid delivery of 13,000mL/hr, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.


A retrospective study evaluating vascular access routes used for US Military personnel injured in combat and transported by MEDEVAC. Medical records were reviewed for intravenous (IV) and intraosseous (IO) use including, number of attempts and rates of success; along with events occurring in transit, hospital and ICU stays and 30 day outcomes. Results showed IV and/or IO access was attempted in 832 patients. PIV was first line of attempt in 758 cases with 93% success; IO access was first line of attempt in 74 cases with 85% success. There were 25 attempts to establish IO as the second line of access with 100% successful placement. Success rates were 100% with tibia (29); 94% with humerus (21/22); and 89% with the sternum (41/46). The overall IO success rate was 88% for all attempts made.


This letter to the editor describes a simulation study evaluating use of the NIO device by 47 firefighters in a simulated anaphylactic shock model. The firefighters were trained on use of the device and standard anaphylactic shock management. An improvement in knowledge of intraosseous vascular access and anaphylactic shock protocol was demonstrated by the group.
Intraosseous Vascular Access Bibliography

**Tibia**


A pre-clinical study comparing the effects of IV and sternal IO administered amiodarone in a swine cardiac arrest model. Following 2 minutes of cardiac arrest, CPR was initiated and after an additional 2 minutes, amiodarone was administered via sternal IO or IV access. Blood samples were collected over 5 minutes. Results showed no statistical difference between routes for return of spontaneous circulation (ROSC), time to ROSC, T-max, or C-max. The authors concluded sternal IO route provides rapid and reliable access to administer life-saving medications during cardiac arrest.


A preclinical study comparing the maximum concentration (Cmax), time to maximum concentration (Tmax) when administering vasopressin via intravenous (IV) and sternal intraosseous (SIO) access in a cardiac arrest swine model. Anesthetized swine were put into cardiac arrest, after 2 minutes CPR was initiated for 2 minutes, then 40 units of vasopressin was administered via IV or SIO route. Results showed no significant difference in SIO and IV groups for Cmax or Tmax.

**YEAR: 2015**


A cadaveric study performed by twenty-seven medical students, inexperienced with IO vascular access, that compared use of the EZ-IO for access in the proximal humerus and proximal tibia insertion sites and the FASTR for access in the sternum. First pass insertion success, insertion times, and one minute flow rates using external pressures from 0 to 300 mmHg were evaluated. The authors concluded that both the EZ-IO and FASTR devices may be effective IO devices and are likely suitable for fluid resuscitation using a pressure bag.


A cadaveric study evaluating intraosseous (IO) vascular access insertion sites for attainable flow rates under 300 mmHg. The EZ-IO was used to establish IO access at the proximal humerus and proximal tibia sites; the FAST1 was used to establish sternal IO access. The total volume of fluid infused at the three IO access sites was 469 ± 190 mL for the sternum; 286 ± 218 mL for the humerus; and 154± 94 mL for the tibia. The mean flow rate infused at each site was as follows: 93.7 ± 37.9 mL/min for the sternum; 57.1 ± 43.5 mL/min for the humerus; and 30.7± 18.7 mL/min for the tibia. First attempt placement success was 100% for the sternum and proximal humerus and 81% for the tibia.


A healthy volunteer study evaluating use of the EZ-IO TALON in the sternal IO insertion site. Military trained medics performed all device insertions. IO infusion flowrate was measured and reported for gravity infusion, as well as pressured infusions at 100, 200, and 300 mmHg. The authors concluded the TALON device may be used by military and tactical medicine personnel to safely and successfully establish IO access in the sternum with excellent infusion flow rates. This study was sponsored by Teleflex Incorporated.

**YEAR: 2014**


A prospective observational study that evaluated use of intraosseous vascular access for delivery of rapid sequence intubation (RSI) drugs. Data was collected between January and May 2012 at a combat hospital in Afghanistan. Thirty-four (34) patients underwent RSI with drug delivery via the IO route. Access was established in the proximal humerus and tibia using the EZ-IO and in the sternum using the FAST-1. All placements were successful on first attempt; first pass intubation success rate was 97%; a Cormack-Lehane (C-L) laryngoscopical grade view of 1 was reported 91%. Authors concluded that IO access is a safe and feasible route for delivery of anesthetic drugs for RSI.


This retrospective study reported IO use over a 7-year period during combat operations in Afghanistan by the UK Defence Medical Services. The EZ-IO and FAST1 IO devices were available for use; IO use data was collected from the front line, during helicopter evacuation and at the combat hospital. A total of 1014 IO devices were inserted into 830 adult patients; various medications infused via IO access are listed. Across all cases there were no serious IO complications and 14 minor complications. The author concluded that in the pre-hospital setting in particular and in severely injured trauma patients, IO access should be considered a primary method of obtaining vascular access.
Intraosseous Vascular Access Bibliography

Tibia


This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.


This article describes a prospective, observational study conducted March – July 2011 at the emergency department, Camp Bastion, Afghanistan evaluating use of IO access in 117 patients established using the EZ-IO and the FAST1 devices (76% EZ-IO).

YEAR: 2012


This is a case report of needle sheering associated with the use of the FAST-1 intraosseous infusion system. A soldier successfully placed a FAST-1 needle in the sternum of a healthy volunteer soldier during a training session. Upon completion of the training session, the soldier was unable to remove the needle. The retained needle was later removed surgically at a field hospital.

YEAR: 1942


This article discusses use of the medullary route for massive replacement therapy when the usual methods of administration and not available or practical. The article also reviews a case study of a man in receipt of a sternal puncture needle inserted into the medullary cavity where he received the infusions through this needle of whole blood and fluids.