

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

YEAR: 2019

- Burgert JM, Johnson AD, O'Sullivan JC, et al. Pharmacokinetic effects of endotracheal, intraosseous, and intravenous epinephrine in a swine model of traumatic cardiac arrest. *Am J Emerg Med* 2019;(in press). doi: 10.1016/j.ajem.2019.02.035** 1046
- 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.
- Farrokh S, Cho SM, Lefebvre AT, Zink EK, Schiavi A, Puttgen HA. Use of intraosseous hypertonic saline in critically ill patients. *J Vasc Access* 2019;20(4):427-32. doi: 10.1177/1129729818805958. Epub 2018 Oct 17** 1052
- 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.
- Itoh T, Lee-Jayaram J, Fang R, Hong T, Berg B. Just-in-time training for intraosseous needle placement and defibrillator use in a pediatric emergency department. *Pediatr Emerg Care* 2018;35(10):712-15. doi:10.1097/PEC.0000000000001516.** 984
- 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).
- Jousi M, Björkman J, Nurmi J. Point-of-care analyses of blood samples from intraosseous access in pre-hospital critical care. *Acta Anaesthesiol Scand* 2019;63(10):1419-25. doi: 10.1111/aas.13443** 1069
- 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 of 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.
- Jousi M, Skrifvars MB, Nelskylä A, et al. Point-of-care laboratory analyses of intraosseous, arterial and central venous samples during experimental cardiopulmonary resuscitation. *Resuscitation* 2019;137:124-32. doi: 10.1016/j.resuscitation.2019.02.014** 1055
- 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.
- Mansfeld A, Radafshar M, Thorgeirsson H, Hoijer CJ, Segerlantz M. Palliative sedation via intraosseous vascular access: A safe and feasible way to obtain a vascular access end of life. *J Palliat Med* 2019;22(1):109-111. doi: 10.1089/jpm.2018.0398** 1056
- 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.
- Sampson CS. Extravasation from a misplaced intraosseous catheter. *Clin Pract Cases Emerg Med* 2019;3(3):303-4** 1068
- 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.

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Sørgjerd R, Sunde GA, Heltne JK. Comparison of two different intraosseous access methods in a physician-staffed helicopter emergency medical service - A quality assurance study. *Scand J Trauma Resusc Emerg Med* 2019;27(1):15 doi: 10.1186/s13049-019-0594-6 1062

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.

Wiegele M, Hamp T, Gratz J, Pablik E, Schaden E. Comparison of ROTEM parameters from venous and intraosseous blood. *Sci Rep* 2019;9(1):3741. doi: 10.1038/s41598-019-40412-0 1064

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

Abramson TM, Alreshaid L, Kang T, Mailhot T, Omer T. FasciOotomy: Ultrasound evaluation of an intraosseous needle causing compartment syndrome. *Clin Pract Cases Emerg Med* 2018;2(4):323-25 1041

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).

Akman N, Braunschweig T, Honickel M, et al. Reversal of dabigatran by intraosseous or intravenous idarucizumab in a porcine polytrauma model. *Br J Anaesth* 2018;120(5):978-87. doi: 10.1016/j.bja.2018.01.027 956

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.

Auten J, Mclean JB, Kemp JD, et al. A pilot study of four intraosseous blood transfusion strategies. *J Spec Oper Med* 2018;18(3):50-6 1042

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.

Bjerkvig CK, Fosse TK, Apelseth TO, et al. Emergency sternal intraosseous access for warm fresh whole blood transfusion in damage control resuscitation. *J Trauma Acute Care Surg* 2018;84(6S):S120-4. doi:10.1097/TA.0000000000001850. (Norway) 962

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.

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Bowry R, Nour M, Kus T, et al. Intraosseous administration of tissue plasminogen activator on a mobile stroke unit. *Prehosp Emerg Care* 2018;25:1-6. doi:10.1080/10903127.2018.1526355 963

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.

Burgert J, Martinez A, O'Sullivan M, Blouin D, Long A, Johnson A. Sternal route more effective than tibial route for intraosseous amiodarone administration in a swine model of ventricular fibrillation. *Prehosp Emerg Care* 2018;22(2):266-75. doi:10.1080/10903127.2017.1358782 903

This study examined the measured mean plasma concentration, maximum plasma concentration (C_{max}), and time to maximum concentration (T_{max}) 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 T_{max} 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.

Chalopin T, Lemaigen A, Guillon A, et al. Acute tibial osteomyelitis caused by intraosseous access during initial resuscitation: a case report and literature review. *BMC Infectious Diseases* 2018;18(1):665. doi: 10.1186/s12879-018-3577-8 1047

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.

Chin SJ, Moore GA, Zhang M, et al. The AAHKS clinical research award: Intraosseous regional prophylaxis provides higher tissue concentrations in high BMI patients in total knee arthroplasty: A randomized trial. *J Arthroplasty* 2018;33(7S):S13-8. doi:10.1016/j.arth.2018.03.013. 966

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.

Cho Y, You Y, Park JS, et al. Comparison of right and left ventricular enhancement times using a microbubble contrast agent between proximal humeral intraosseous access and brachial intravenous access during cardiopulmonary resuscitation in adults. *Resuscitation* 2018;129:90-3. doi:10.1016/j.resuscitation.2018.06.014 967

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.

Collins T. Intraosseous access use in chemical, biological, radiation, and nuclear personal protective equipment. *Prehosp Emerg Care* 2018;22(1):10. http://dx.doi.org/10.1080/10903127.2017.1377791 910

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.

Crawford SB. Intraosseous vascular access device as a transarticular k-wire alternative in mallet finger laceration. *Clin Pract Cases Emerg Med* 2018;2(1):71-4. doi:10.5811/cpcem.2017.7.34811 969

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.

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- Czyz R, Wudarczyk, Leskiewicz M, Czyz I. Current advances in intraosseous access - A review of presently available devices. J Ed Health Sport 2018;8(8):939-50. doi: 10.5281/zenodo.1406964** 1049
- 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.
- Durnford S, Bulstrode H, Durnford A, Chakraborty A, Tarmey NT. Temporising an extradural haematoma by intraosseous needle craniostomy in the District General Hospital by non-neurosurgical doctors-A case report. J Intensive Care Soc 2018;19(1):76-9. doi:10.1177/1751143717734997** 971
- 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.
- El-Nawawy AA, Omar OM, Mona Khalil M. Intraosseous versus intravenous access pediatric septic shock patients admitted to Alexandria University Pediatric Intensive Care Unit. J Trop Pediatr 2018;64(2):132-40. doi:10.1093/tropej/fmx061** 932
- 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.
- Feldman O, Nasrallah N, Bitterman Y, et al. Pediatric intraosseous access performed by emergency department nurses using semiautomatic devices: A randomized crossover simulation study. Pediatr Emerg Care 2018;00:1-5. doi:10.1097/PEC.0000000000001621** 975
- 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** 976
- 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 (EVS), and fluid giving set connected to a simple 3-way extension set (TWS). The EVS 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.
- Fuchs Z, Scaal M, Haverkamp H, Koerber F, Persigehl T, Eifinger F. Anatomical investigations on intraosseous access in stillborns - Comparison of different devices and techniques. Resuscitation 2018;127:79-82** 978
- 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.
- Gendron B, Cronin A, Monti J, Brigg A. Military medic performance with employment of a commercial intraosseous infusion device: A randomized, crossover study. Mil Med 2018;183(5-6):e216-22. doi:10.1093/milmed/usx078** 933
- 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.

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- Markic J, Polic B, Mestrovic J, Kovacevic T, Zanchi I. Successful intraosseous therapy using EZ-IO system in a preterm neonate below 2 kg. *Minerva Pediatr* 2018;70(1):104-5. doi:10.23736/S0026-4946.16.04707-1. (Croatia)** 928
- 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.
- Morgan R. Novel method for splinting a flail chest. *Trauma* 2018;20(4):317-8** 997
- This abstract describes a new technique for splinting 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.
- Pifko E, Price A, Busch C, et al. Observational review of paediatric intraosseous needle placement in the paediatric emergency department. *J Paediatr Child Health* 2018;54(5):546-50. doi:10.1111/jpc.13773** 1011
- 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.
- Reic C, Fogg T, Healy G. Deformation of a humeral intraosseous catheter due to positioning for thoracostomy. *Clin Exp Emerg Med* 2018;5(3):208-9** 1013
- 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.
- Rideout M, Raszka W. Hypovolemic shock in a child: A pediatric simulation case. *MedEdPORTAL* 2018;14:10694. doi: 10.15766/mep_2374-8265.10694** 1060
- 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.
- Rodda LN, Volk JA, Moffat E, et al. Evaluation of intraosseous fluid as an alternative biological specimen in postmortem toxicology. *J Anal Toxicol* 2018;42(3):163-9. doi: 10.1093/jat/bkx096** 1014
- 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.
- Sawyer T, Nishisaki A. Intraosseous access during newborn resuscitation: It may be fast, but is it safe? *Pediatr Crit Care Med* 2018;19(5):499-501. doi:10.1097/PCC.0000000000001513** 1017
- 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 than 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.

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- Schwindt EM, Hoffmann F, Deindl P, Waldhoer TJ, Schwindt JC. Emergency vascular access and how to accelerate it: A simulation-based study performed in real-life neonatal resuscitation rooms. *Pediatr Crit Care Med* 2018;19(5):468-76. doi:10.1097/PCC.0000000000001508** 934
- 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.
- Simsek P, Bayram SB, Gursoy A. İlaç uygulamaları için farklı bir yol: İntraosseöz ulaşım ve infüzyon [A different route for drug administration: Intraosseous access and infusion]. *HEAD* 2018;15(1):40-44. doi: 10.5222/HEAD2018.040. Turkish** 1061
- 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.
- Szarpak L, Ladny JR, Dabrowski M, et al. Comparison of 4 pediatric intraosseous access devices: A randomized simulation study. *Pediatr Emerg Care* 2018;00:1-5. doi:10.1097/PEC.0000000000001587. [Epub ahead of print]** 1026
- 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.
- Wagner M, Olischar M, O'Reilly M, et al. Review of routes to administer medication during prolonged neonatal resuscitation. *Pediatr Crit Care Med* 2018;19(4):332-8. doi: 10.1097/PCC0000000000001493** 1029
- 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.
- Winkler M, Issa M, Lowry C, Chornenkyy Y, Sorrell V. Intraarticular extravasation, an unusual complication of computed tomographic angiography performed with intraosseous needle intravenous access. *Cardiovasc Diagn Ther* 2018;8(4):516-9. doi:10.21037/cdt.2018.06.04** 1033
- 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.
- Young SW, Zhang M, Moore GA, Pitto RP, Clarke HD, Spangehl MJ. The John N. Insall Award: Higher tissue concentrations of vancomycin achieved with intraosseous regional prophylaxis in revision TKA: A randomized controlled trial. *Clin Orthop Relat Res.* 2018;476:66-74** 1066
- 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**
- 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/s12909-017-0882-7. (Denmark)** 831
- 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.

Intraosseous Vascular Access Bibliography

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- Bewick VJ. Intraosseous cannulation in children. *Anaesth Intens Care Med* 2017;18(11):551-4. UK** 961
 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.
- Bielski K, Szarpak L, Smereka J, Ladny J, Leung S, Ruetzler K. Comparison of four different intraosseous access devices during simulated pediatric resuscitation. A randomized crossover manikin trial. *Eur J Pediatr* 2017;176(7):865-71. doi:10.1007/s00431-017-2922-z** 899
 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.
- Boysen SR, Pang JM, Mikler JR, Knight CG, Semple HA, Caulkett NA. Comparison of tranexamic acid plasma concentrations when administered via intraosseous and intravenous routes. *Am J Emerg Med* 2017;35(2):227-33. doi:http://dx.doi.org/10.1016/j.ajem.2016.10.054** 867
 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.
- Bromberg R, Dave K, Mankodi D, Danckers M. Soft tissue laceration caused by lower extremity intraosseous access insertion in an obese patient. *BMJ Case Rep* 2017;doi:10.1136/bcr-2017-220069. (United Kingdom)** 938
 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.
- Budach NM, Niehues SM. CT angiography of the chest and abdomen in an emergency patient via humeral intraosseous access. *Emerg Radiol* 2017;24(1):105-8. doi:10.1007/s10140-016-1438-6. (Germany)** 823
 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.
- Bulstrode H, Kabwamab S, Durnford A, Hempenstall J, Chakraborty A. Temporising extradural haematoma by craniostomy using an intraosseous needle. *Injury* 2017;45(5):1098-1100. doi:10.1016/j.injury.2017.02.011** 939
 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.
- Burgert JM, Johnson AD, Garcia-Blanco J, Fulton LV, Loughren MJ. The resuscitative and pharmacokinetic effects of humeral intraosseous vasopressin in a swine model of ventricular fibrillation. *Prehosp Disaster Med* 2017;32(3):305-10. doi:10.1017/S1049023X17000140** 940
 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.
- Collins T. Intraosseous access is effective whilst wearing CBRN protective equipment [abstract 31]. *BMJ Open* 2017;7(Suppl3);A1-A18. doi: 10.1136/bmjopen-2017-EMSAbstracts.31** 1048
 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.

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Iskrzycki L, Smereka J, Szarpak L. Knowledge, skills, and attitudes concerning intraosseous access among hospital physicians. Crit Care Med 2017;45(1):e117** 876
- 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.
- Jansen G, Leimkuhler K, Mertzlufft F. Intramedullary placement of intraosseous cannulas inserted in the preclinical treatment of polytrauma patients: A retrospective, computed tomography-assisted evaluation. Anaesthesist 2017;66(3):168-76. doi:10.1031007/s00101-016-0257-1** 985
- 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)
- Jousi M, Saikko S, Nurmi, J. Intraosseous blood samples for point-of-care analysis: Agreement between intraosseous and arterial analyses. Scand J Trauma Resusc Emerg Med 2017;25(1):92. doi.10.1186/s13049-017-0435-4** 945
- 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.
- Lee E. The first time. Ann Emerg Med 2017;70(1):99-100. DOI: <https://doi.org/10.1016/j.annemergmed.2017.01.021>** 883
- 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.
- Montez DF, Puga TA, Ruiz S, Philbeck TE. Accuracy of intraosseous lab values drawn after fluid infusion. Ann Emerg Med 2017;70(4 Suppl):S27. <https://doi.org/10.1016/j.annemergmed.2017.07.088>** 923
- 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.
- Salzman JG, Loken NM, Wewerka SS, et al. Intraosseous pressure monitoring in healthy volunteers. Prehosp Emerg Care 2017;21(5):567-74. doi:10.1080/10903127.2017.1302529** 927
- 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.
- Santos AP, Conkin R, Dowd K. Needle break: Complication and management of intraosseous vascular access. Am Surg 2017;83(1):e18-20** 1016
- 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.

Intraosseous Vascular Access Bibliography

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- Shina A, Baruch EN, Shlaifer A, et al. Comparison of two intraosseous devices: The NIO versus the EZ-IO by novice users- a randomized cross over trial. Prehosp Emerg Care 2017;21(3):315-21. doi:10.1080/10903127.2016.1247201** 817
- 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.
- Sotomayor T, Maraj C, Mott J, et al. Humeral head intraosseous access: Filling the military gap. J Def Model Simul 2017;14(4):361-9. doi: 10.1177/1548512916646888** 1022
- 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.
- Takei H, Nomura O, Yasuda M, Inoue N. Dermal abrasion due to semi-automatic intraosseous device. Pediatr Int 2017;59(5):641-2** 1027
- 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.
- Thadikonda KM, Egro FM, Ma I, Spiess AM. Deltoid compartment syndrome: A rare complication after humeral intraosseous access. Plast Reconstr Surg Glob Open 2017;5(1):e1208. doi: 10.1097/GOX.0000000000001208** 807
- 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.
- U.S. Army, CoTCCC, TCCC Working Group. Tactical combat casualty care: Lessons and best practices. Tactical combat casualty care (TCCC): Lessons and best practices. Handbook. No. 17-13: Version 5. May 2017** 1072
- 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).
- Winkler M, Talley C, Woodward C, et al. The use of intraosseous needles for injection of contrast media for computed tomographic angiography of the thoracic aorta. J Cardiovasc Comput Tomogr 2017;11(3):203-7. doi: 10.1016/j.jcct.2017.03.001** 825
- 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.
- Wolfson DL, Tandoh MA, Jindal M, Forgione PM, Harder VS. Adult intraosseous access by advanced EMTs: A statewide non-inferiority study. Prehosp Emerg Care 2017;21(7):7-13. doi:10.1080/10903127.2016.1209262** 816
- 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.
- Yee D, Deolankar R, Marcantoni J, et al. Tibial osteomyelitis following prehospital intraosseous access. Clin Pract Cases Emerg Med 2017;1(4):391-4** 936
- 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

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Young S, Zhang M, Moore GA, et al. Higher tissue concentrations of vancomycin with low-dose intraosseous regional versus intravenous systemic prophylaxis in revision total knee arthroplasty: A randomized trial. Paper presented at: American Academy of Orthopaedic Surgeons Annual Meeting; March 14-18, 2017; San Diego, CA. Abstract P118 1036

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>. 1038

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.

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 1037

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, Spangehl MJ. Higher tissue concentrations of vancomycin with intraosseous regional prophylaxis in revision TKA- A randomized controlled trial. Manuscript submitted for publication 930

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

Baadh AS, Singh A, Choi A, et al. Intraosseous vascular access in radiology: review of clinical status. AJR Am J Roentgenol 2016;207:W1-7. doi:10.2214/AJR.15.15784 756

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.

Burgert JM, Johnson AD, Garcia-Blanco J, et al. 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. Am J Emerg Med 2016;34:49-53. doi:10.1016/j.ajem.2015.09.007 778

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.

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- Davis J, Bates L. Rapid sequence induction via an intraosseous needle. J Intensive Care Society 2016;17(2):178-9** 788
 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.
- Davlatnes C, Miller LJ, Montez DF, Puga TA, Philbeck TE. Intraosseous catheter dwell-time appears safe for up to 48 hours: A preliminary report. The Journal of Vascular Access 2016;17(4):e26** 782
 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.
- Davlatnes C, Puga T, Montez D, Philbeck T, Miller L, DeNoia E. 48 hours dwell time for intraosseous access: A longer-term infusion using a temporary solution. Crit Care Med 2016;44(12)Suppl.:140** 820
 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.
- Drozd A, Madziala M. Which vascular access technique should be chosen during hypovolemic shock? Am J Emerg Med 2016;34(9):1886-7. doi:10.1016/j.ajem.2016.06.070** 824
 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
- Eriksson M, Larsson A, Lipcsey M, Strandberg G. Emergency intraosseous access: Novel diagnostic and therapeutic possibilities and limitations. ICU Manag Pract 2016;16(4):230-2** 1051
 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.
- Eriksson M, Strandberg G, Lipcsey M, Larsson A. Evaluation of intraosseous sampling for measurements of alanine aminotransferase, alkaline phosphatase, aspartate aminotransferase, creatinine kinase, gamma-glutamyl transferase and lactate dehydrogenase. Scand J Clin Lab Invest 2016;76(8):597-600. doi:10.1080/00365513.2016.1230774** 809
 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.
- Fulkerson J, Lowe R, Anderson T, Moore H, Craig W, Johnson D. Effects of intraosseous tibial vs. intravenous vasopressin in a hypovolemic cardiac arrest model. West J Emerg Med 2016;17(2):222-8. doi:10.5811/westjem.2015.12.28825** 777
 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.
- Garside J, Prescott S, Shaw S. Intraosseous vascular access in critically ill adults- a review of the literature. Nurs Crit Care 2016;21(3):16-7. doi:10.1111/nicc.12163** 749
 Literature review on contemporary practices of intraosseous (IO) vascular access in adult patients.
 Great Britain

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- Ginsberg-Peltz J. Time to bone healing after intraosseous placement in children is ill defined. *Pediatr Emerg Care* 2016;32(11):799-800. doi:10.1097/PEC.0000000000000652** 944
- 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.
- Greenstein YY, Koenig SJ, Mayo PH, Narasimhan M. A serious adult intraosseous catheter complication and review of the literature. *Crit Care Med* 2016;44(9):e904-9. doi: 10.1097/CCM.0000000000001714** 775
- 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.
- Hess T, Böhmer R, Arndt F, et al. Bilateraler intraossärer zugang am humerus bei reanimation eines 3-Jährigen [Case Report-Bilateral humeral intraosseous access for CPR in a 3-years-old child]. *Anästhesiol Intensivmed Notfallmed Schmerzther* 2016;51(07-08):468-74. doi:10.1055/s-0042-110237.** 819
- 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.
- Johnson M, Inaba K, Byerly S, et al. Intraosseous infusion as a bridge to definitive access. *Am Surg* 2016;82(10):876-80** 826
- 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".
- Kehrl T, Becker BA, Simmons DE, Broderick EK, Jones RA. Intraosseous access in the obese patient: Assessing the need for extended needle length. *Am J Emerg Medicine* 2016;34(9):1831-4. doi:10.1016/j.ajem.2016.06.055** 780
- 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 \leq 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.
- Krishnan M, Lester K, Johnson A, Bardelozza K, Edemekong P, Berim I. Case report: Bent metal in a bone: A rare complication of an emergent procedure or a deficiency in skill set? *Case Reports in Critical Care* 2016;doi:10.1155/2016/4382481** 806
- 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.
- Lind T. Alternative access routes for fluid resuscitation. *Top Companion Anim Med* 2016;31(2):61-7. doi:10.1053/j.tcam.2016.08.005** 886
- This veterinary care article describes vascular access methods and devices used for small animal emergencies, including intraosseous devices.
- Montez D, Puga T, Davlantes C, Philbeck T. IO infusion pain mitigation in the sternum and proximal humerus: Establishing a regimen. *Crit Care Med* 2016;44(12 Suppl):154** 822
- 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.

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- Montez DF, Puga TA, Davlantes C, Higgins R, Miller LJ, Philbeck TE. Blood transfusion via intraosseous access: A pre-clinical study. J Vasc Access 2016;17(4):e5-6** 783
- 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.
- Muir SL, Sheppard LB, Maika-Wilson A, et al. A comparison of the effects of intraosseous and intravenous 5% albumin on infusion time and hemodynamic measures in a swine model of hemorrhagic shock. Prehosp Disaster Med. 2016;31(4):436-42** 1058
- 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.
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- 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.
- Penketh J, McDonald M, Kelly FE. EZ-IO® intraosseous access teaching in the workplace using a mobile 'tea trolley' training method. Resuscitation 2016;99:e17-8. doi:10.1016/j.resuscitation.2015.11.016** 860
- 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.
- United Kingdom
- Petitpas F, Guenezan J, Vendeuvre T, Scepti M, Oriot D, Mimoz O. Use of intra-osseous access in adults: A systematic review. Crit Care 2016;20:102. doi:10.1186/s13054-016-1277-6.** 810
- 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
- Philbeck TE, Montez DF, Puga TA, Davlantes C, Miller LJ. Infusion flow rates and insertion success through the sternum using a multi-site intraosseous device. J Vasc Access 2016;17(4):e131** 784
- 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.
- Puga T, Montez D, Philbeck T, Davlantes C. Adequacy of intraosseous vascular access insertion sites for high-volume fluid infusion. Crit Care Med 2016;44(12 Suppl):143** 821
- 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 $9,587 \pm 2,706 \text{ mL/hr}$ ($n=27$); mean PH infusion rate was $6,292 \pm 3,277 \text{ mL/hr}$ ($n=52$). 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 $13,000 \text{ mL/hr}$, surpassing that of the sternum. This study was sponsored by Teleflex Incorporated.

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- 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** 785
 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.
- Savell S, Mora AG, Perez CA, Bebartá VS, Maddry JK. En route intraosseous access performed in the combat setting. Am J Disaster Med 2016;11(4):225-31. doi:10.5055/ajdm.2016.0243** 847
 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.
- Smith S, Borgkvist B, Kist T, Annelin J, Johnson D, Long R. The effects of sternal intraosseous and intravenous administration of amiodarone in a hypovolemic swine cardiac arrest model. Am J Disaster Med 2016;11(4):271-7. doi:10.5055/ajdm.2016.0249** 830
 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.
- Strandberg G, Lipcsey M, Eriksson M, Lubenow N, Larsson A. Analysis of thromboelastography, PT, APTT and fibrinogen in intraosseous and venous samples-an experimental study. Scand J Trauma Resusc Emerg Med 2016;24:131. doi:10.1186/s13049-016-0318-0** 814
 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.
- Szarpak L, Czyzewski L, Woloszczuk-Gebicka B, Krajewski P, Fudalej M, Truszewski Z. Comparison of NIO and EZ-IO intraosseous access devices in adult patients under resuscitation performed by paramedics: A randomized crossover manikin trial. Am J Emerg Med 2016;34(6):1166-7. doi:10.1016/j.ajem.2016.03.017.** 774
 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
- Szarpak L, Truszewski Z, Smereka J, Krajewski P, Fudalej M. Ability of paramedics to perform intraosseous access. A randomized cadaver study comparing EZ-IO and NIO devices. Resuscitation 2016;104:e5-e6. doi:10.1016/j.resuscitation.2016.04.011** 795
 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.
- Uwaydah NI, Hoskins SL, Bruttig SP, et al. Intramuscular versus intraosseous delivery of nerve agent antidote pralidoxime chloride in swine. Prehosp Emerg Care 2016;20(4):485-92. doi:10.3109/10903127.2014.942479** 842
 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.

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Vallier DJ, Torrence AD, Stevens, III R, Arcinue PN, Johnson D. The effects of sternal and intravenous vasopressin administration on pharmacokinetics. *Am J Disaster Med* 2016;11(3):203-9. doi:10.5055/ajdm.2016.0240 841

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.

Wilson J, Passmore A, Leger S, Lannan J, Bentley M, Johnson D. Effects of tibial intraosseous and intravenous administration of Hextend on tiem of administration and hemodynamics in a hypovolemic swine model. *Am J Disaster Med* 2016;11(3):193:201. doi:10.5055/ajdm.2016.0239 836

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 (\pm 2 minutes 47 seconds), and for the IO group it was 10 minutes 12 seconds (\pm 1 minutes 36 seconds). There was no significant difference in systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, and stroke volume.

Wimmer MH, Heffner K, Smithers M, et al. The comparison of humeral intraosseous and intravenous administration of vasopressin on return of spontaneous circulation and pharmacokinetics in a hypovolemic cardiac arrest swine model. *Am J Disaster Med* 2016;11(4):237-42. doi:10.5055/ajdm.2016.0245 827

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.

Wong MR, Reggio MJ, Morocho FR, et al. Effects of intraosseous epinephrine in a cardiac arrest swine model. *J Surg Res* 2016;201(2):327-33. doi:10.1016/j.jss.2015.11.015 776

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.

Woodhart B, Shaw J. A study to determine the EZ-IO intraosseous infusion system success rate, including impact on return of spontaneous circulation. *Emerg Med J* 2016;33:e5. doi: 10.1136/emered-2016-206139.19 1034

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

Anson JA, Sinz EH, Swick JT. The versatility of intraosseous vascular access in perioperative medicine: a case series. *J Clin Anesth* 2015;27(1):63-7. http://dx.doi.org/10.1016/j.jclinane.2014.10.002 729

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.

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 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, Lipcsey M, Larsson A. Intraosseös provtagning kan vara vardefull i akuta lagen [Intraosseous sampling can be valuable in emergency situations]. Lakartidningen 2015 Feb 24;112pii:DCR3. Swedish** 789
 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.
- Eriksson M, Strandberg G, Lipcsey M, Larsson A. Troponin I can be determined in intraosseous aspirates in a porcine shock model. Clin Lab 2015;doi:10.7754/Clin.Lab.2015.141212** 758
 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.
- Frascone RJ, Salzman JG, Adams AB, Bliss P, Wewerka SS, Dries DJ. Evaluation of intraosseous pressure in a hypovolemic animal model. J Surg Res 2015;193(1):383-90. http://dx.doi.org/10.1016/j.jss.2014.07.007** 736
 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.
- Goldschalt C, Doll S, Ihle B, Kirsch J, Mutzbauer TS. Peripheral venous or tibial intraosseous access for medical emergency treatment in the dental office? Br Dent J 2015;281(9):E16. doi: 10.1038/sj.bdj.2015.384** 869
 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.
- Grabel Z, DePasse JM, Lareau CR, Born CT, Daniels AH. Intra-articular placement of an intraosseous catheter. Prehosp Disaster Med 2015;30(1):1-4. doi:10.1017/S1049023X14001290** 741
 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).
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 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.
- Helm M, Haunstein B, Schlechtriemen T, Ruppert M, Lampi L, Gäßler M. EZ-IO® intraosseous device implementation in German Helicopter Emergency Medical Service. Resuscitation 2015;88:43-7. doi: 10.1016/j.resuscitation.2014.12.015.** 737
 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.
 Germany

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- Hill SL, Thomas SHL, Flecknell PA, et al. Rapid and equivalent systemic bioavailability of the antidotes HI-6 and dicobalt edetate via the intraosseous and intravenous routes. Emerg Med J 2015;32(8):626-31. doi: 10.1136/emmermed-2014-204171** 751
- 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.
- Ker K, Tansley G, Beecher D, et al. Cochrane Database Syst Rev 2015;2:CD011386. doi: 10.1002/14651858.CD011386.pub2. Comparison of routes for achieving parenteral access with a focus on the management of patients with Ebola virus disease. Cochrane Database Syst Rev 2015;2:CD011386. doi: 10.1002/14651858.CD011386.pub2** 878
- 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.
- Lee PMJ, Lee C, Rattner P, Wu X, Gershengorn H, Acquah S. Intraosseous versus central venous catheter utilization and performance during inpatient medical emergencies. Crit Care Med 2015;doi: 10.1097/CCM.0000000000000942** 762
- 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.
- Means L, Gimbar RP. Prothrombin complex concentrate administration through intraosseous access for reversal of rivaroxaban. Am J Emerg Med 2015;34(3):685.e1-2. doi:10.1016/j.ajem.2015.07.057. doi: 10.1016/j.ajem.2015.07.057** 765
- 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.
- Montez DF, Puga T, Miller L, et al. Intraosseous infusions from the proximal humerus reach the heart in less than 3 seconds in human volunteers. Ann Emerg Med 2015;66(4s):S47. http://dx.doi.org/10.1016/j.annemergmed.2015.07.165** 771
- 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.
- Ohchi F, Komazawa N, Mihara R, Minami T. Comparison of mechanical and manual bone marrow puncture needle for intraosseous access; a randomized simulation trial. Springer Plus 2015;doi:10.1186/s40064-015-0982-y** 766
- 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.
- Overbaugh R, Davlantes C, Miller L, Montez D, Puga T, Philbeck TE. Intraosseous vascular access catheter appears safe during extended dwell: a preliminary report. Ann Emerg Med 2015;66(4):S5** 772
- 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.
- Overbey JK, Kon AA. Dermal abrasion experienced as an adverse effect of the EZ-IO. J Emerg Med 2016;50(1):e7-10. doi: 10.1016/j.jemermed.2015.09.003.** 753
- 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.

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- Pasley J, Miller CHT, DuBose J, et al. Intraosseous infusion rates under high pressure: a cadaveric comparison of anatomic sites. *J Trauma Acute Care Surg* 2015;78(2):295-9. DOI: 10.1097/TA.0000000000000516** 750
- 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.
- Paxton J, Wilburn J, Ottolini J, Sherwin R. Does the choice of initial vascular access device delay cardiac arrest resuscitation? *Crit Care Med* 2015;43(12 Suppl):46. doi: 10.1097/01.ccm.0000474007.72329.42. abstract 179** 862
- 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.
- Paxton JH, Ottolini J, Wilburn JM, Sherwin RL, Courage C. Does the choice of vascular access device delay appropriate emergency department resuscitation of adult out-of-hospital cardiac arrest patients? *Ann Emerg Med* 2015;66(4s):s35** 863
- 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.
- Paxton JH, Ottolini J, Wilburn JM, Sherwin RL, Courage C. Does the choice of vascular access device delay appropriate emergency department resuscitation of adult out-of-hospital cardiac arrest patients? *Ann Emerg Med* 2015;66(4s):s35** 924
- 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.
- Philbeck TE, Puga T, Montez DF, Miller LJ, Saussy J, Davlantes C. Sternal flow rates and insertion success using a multisite intraosseous device. *Ann Emerg Med* 2015;66(4s):s48** 787
- 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.
- Pifko EL, Busch C, Price A, et al. An observational review of pediatric intraosseous needle placement in the pediatric emergency department. *Ann Emerg Med* 2015;66(4s):S87** 754
- 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.
- Puga T, Hanes MA, Miller LJ, et al. Intramedullary effects of power-infused contrast by intraosseous access. *Ann Emerg Med* 2015;66(4s):s95** 786
- 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

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Rubal BJ, Meyers BL, Kramer SA, Hanson MA, Andrews JM, DeLorenzo RA. Fat intravasation from intraosseous flush and infusion procedures. *Prehosp Emerg Care* 2015;19(3):376-90. doi: 10.3109/10903127.2014.980475 748

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.

Salzman J, Burnett A, Frascione R, et al. Intraosseous pressure monitoring in critically ill and injured patient. *Crit Care Med* 2015;43(12 Suppl):abstract 183:47. doi: 10.1097/01.ccm.0000474011.25695.a8 848

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.

Salzman JG, Frascione RJ, Zagar AE et al. Intraosseous pressure monitoring in critical care patients. *Ann Emerg Med* 2015;66(4s):S148 755

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 $34.5 \pm 13.4\%$, $40.5 \pm 22.3\%$, and $40.1 \pm 17.1\%$ 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.

Sampson CS, Bedy S-M. Lipid emulsion therapy given intraosseously in massive verapamil overdose. *Am J Emerg Med* 2015;33(12):1844.e1. doi: 10.1016/j.ajem.2015.04.061 767

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.

Stimac J, Paxton J. The "Golden Hour" of volume resuscitation: Pilot data from the shock access for emergent resuscitation (SAFER) study. *Ann Emerg Med* 2015;66(4s):S110 1010

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

Stimac J. Resuscitation and the humeral intraosseous line. *EM Resident* 2015; <http://www.emresident.org/resuscitation-and-the-humeral-intraosseous-line/>. Accessed June 13, 2015. 763

An overview of IO vascular access with a focus on the proximal humerus IO insertion site.

Strandberg G, Larsson A, Lipcsey M, Michalek J, Eriksson M. Intraosseous and intravenous administration of antibiotics yields comparable plasma concentrations during experimental septic shock. *Acta Anaesthesiol Scand* 2015;doi: 10.1111/aas.12454 738

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

Intraosseous Vascular Access Bibliography

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- Suominen P, Nurmi E, Lauerma K. Intraosseous access in neonates and infants: Increased risk of compartment syndrome and leg amputation. *Resuscitation* 2015;96(Suppl 1):S131-2. <http://dx.doi.org/10.1016/j.resuscitation.2015.09.313>** 1024
- 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.
- Suominen PK, Nurmi E, Lauerma K. Intraosseous access in neonates and infants: risk of severe complications- a case report. *Acta Anaesthesiologica Scandinavica* 2015;59(10):1389-93. doi: 10.1111/aas.12602** 769
- 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.
- Ventura AMC, Shieh HH, Bousso A, et al. Double-blind prospective randomized controlled trial of dopamine versus epinephrine as first-line vasoactive drugs in pediatric septic shock. *Crit Care Med* 2015;43(11):2292-302. doi:10.1097/CCM.0000000000001260** 840
- 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.
- Zu L, Zhou B, Wang Y, Gao W. The history, current The history, current situation and future of bone marrow intraosseous infusion. *Chin Med Frontier Mag* 2015;7(1):114-9.Chinese** 888
- This is a review article written in the Chinese language describing intraosseous vascular access.
- YEAR: 2014**
- Abbal B, Perbet S, Pereira B, et al. Utilisation de la voie intraosseuse chez l'adulte en France en 2012 [Use of the intraosseous access in adult patients in France in 2012]. *Annales Francaises d'Anesthesie et de Reanimation* 2014;33(4):221-6. <http://dx.doi.org/10.1016/j.annfar.2014.02.006>** 696
- 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
- Barlow B, Kuhn K. Orthopedic management of complications of using IO catheters. *Am J Orthop* 2014;43(4):186-90** 694
- 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).
- Barnard EBG, Moy RJ, Kehoe AD, Bebartta VS, Smith JE. Rapid sequence induction of anesthesia via the intraosseous route: a prospective observational study. *Emerg Med J* 2014;32(6):449-52. doi:10.1136/emmermed-2014-203740** 702
- 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) laryngoscopic 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

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- Bebarta VS, Pitotti RL, Bondreau S, Tanen DA. Intraosseus versus intravenous infusion of hydroxocobalamin for the treatment of acute severe cyanide toxicity in a swine model. *Aca Emerg Med* 2014;21(11):1203-11** 865
- 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.
- Bebarta VS, Vargas TE, Castaneda M, Boudreau S. Evaluation of extremity tissue and bone injury after intraosseous hypertonic saline infusion in proximal tibia and proximal humerus in adult swine. *Prehosp Emerg Care* 2014;doi:10.3109/10903127.2014.912704** 697
- 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.
- Burgert J, Mozer J, Williams T, et al. Effects of intraosseous transfusion of whole blood on hemolysis and transfusion time in a swine model of hemorrhagic shock: a pilot study. *AANA Journal* 2014;82(3):198-202** 733
- 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** 968
- 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*
- Cullen PM. Intraosseous cannulation in children. *Anaesth Intensive Care Med* 2014;15(12):567-9** 734
- 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*
- Danz M, Schulz G, Hinkelbein J, Braunecker S. Breaking the needle: A rare complication on EZ-IO removal. *Eur J Anaesthesiol* 2014;31:172-80** 742
- 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*
- Demir OF, Aydin K, Akay H, Erbil B, Karcioğlu O, Gulalp B. Comparison of two intraosseous devices in adult patients in the emergency setting: a pilot study. *Eur J Emerg Med* 2014;DOI:10.1097/MEJ.000000000000187** 735
- 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*

Intraosseous Vascular Access Bibliography

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- 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** 706
- 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
- Dev SP, Stefan RA, Saun T, Lee S. Insertion of an intraosseous needle in adults. N Engl J Med 2014;370(24):e35(1)-e35(5). Doi:10.1056/NEJMvcm1211371** 700
- 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.
- Goldschalt C, Doll S, Ihle B, Kirsch J, Mutzbauer TS. Intraosseous vascular access through the anterior mandible- a cadaver model pilot study. PLoS ONE 2014;9(11):e112686. doi:10.1371/journal.pone.0112686** 790
- A cadaveric study performed by dentistry and medical students evaluating the feasibility of gaining vascular access via the anterior mandible bone.
- Gurman P, Chi A, Hood T, et al. Prefilled devices for parenteral applications. Expert Rev Med Devices 2014;11(2):205-223** 981
- 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.
- Johnson D, Dial J, Ard J, et al. Effects of intraosseous and intravenous administration of Hextend on time of administration and hemodynamics in a swine model. J Spec Oper Med 2014;14(1):79-85** 713
- 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
- Kurowski A, Timler D, Evrin T, Szarpak T. Comparison of three different intraosseous access devices for adults during resuscitation: randomized cross-over manikin study. Am J Emerg Med 2014;32:1490-3. DOI: http://dx.doi.org/10.1016/j.ajem.2014.09.007** 739
- 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
- Kwon OY, Park SY, Yoon TY. Educational effect of intraosseous access for medical students. Korean J Med Educ. 2014;26(2):117-24. http://dx.doi.org/10.3946/kjme.2014.26.2.117** 757
- 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.
- Lee BK, Jeung KW, Lee HY, et al. Confirmation of intraosseous cannula placement based on pressure measured at the cannula during squeezing the extremity in a piglet model. Resuscitation 2014;85(1):143-7. doi: 10.1016/j.resuscitation.2013.09.001** 678
- 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.

Intraosseous Vascular Access Bibliography

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- Lewis P, Wright C. Saving the critically injured trauma patient: a retrospective analysis of 1000 uses of intraosseous access. Emerg Med J 2014;31(9):784. doi:10.1136/emered-2014-203588** 714
- 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.
- Lingner M, Niederer O, Majolk J, Kromholz K. Kasuistik: Die intraossare infusion als alternative in der sepsistherapie beim erwachsenen [Case report: Intraosseous infusion as an alternative solution in the therapy of septicemia in an adult]. Anesthesiol Intensivmed Notfallmed Schmerzther. 2014;49(2):100-3. doi:10.1055/s-0034-1368674** 698
- 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
- Lottenberg L, Lovato L, Bloch S, Puga T, Philbeck T. The proximal humerus may be a viable site for contrast injection using a power infuser for CT exam. Crit Care Med. 2014;42(12):abstract 1075.** 759
- 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.
- Loughren M, Banks S, Naluan C, Portenlanger P, Wendorf A, Johnson D. Onset and duration of intravenous and intraosseous Rocuronium in swine. West J Emerg Med 2014;XV(2):241-5** 721
- 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 from 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.
- Martin Reyes B, Abolafia del Balazo R, Estepa Sanchez A, Garcia Cazalilla M, camara Anguita S, Rojas Jimenez AM. Emergencies medical services: intraosseous drill in CPR. Resuscitation 2014;85(S):S24** 715
- 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
- Mochizuki T, Yamashita K, Matsushima H, Yoshino A. A practical seminar on intraosseous needle placement (IO) and point-of-care color Doppler ultrasound confirmation. The Journal of Japan Society for Clinical Anesthesia 2014;34(3):429** 752
- 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.
- Montez D, Puga T, Garcia M, et al. Lactate levels in venous and intraosseous blood correlate; prothrombin time/INR levels do not. Aca Emerg Med 2014;21(5)Supp1:S304.** 773
- 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.

Intraosseous Vascular Access Bibliography

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- Nadler R, Gendler S, Chen J, Lending G, Abramovitch A, Glassberg E. The Israeli Defense Force experience with intraosseous access. *Military Medicine* 2014;179(11):1254-7** 740
- 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
- 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.000000000000069** 723
- 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** 699
- 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
- Pasley J, Miller C, Dubose J, et al. Intraosseous infusion rates under high pressure: a cadaveric comparison of anatomic sites. 2014 Annual Scientific Assembly for the Eastern Assoc for the Surgery of Trauma meeting. <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA597324>. Published January 2014. Accessed May 12, 2014** 728
- 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.
- Polat O, Oguz AB, Comert A, Demirkan A, Gunalp M, Tuccar E. Intraosseous access learning curve; is it really practical? *Am J Emerg Med* 2014; 32(12):1543-4.doi: 10.1016/j.ajem.2014.09.018** 747
- 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
- 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** 760
- 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.

Intraosseous Vascular Access Bibliography

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- Rush S, D'Amore J, Boccio E. A review of the evolution of intraosseous access in tactical settings and a feasibility study of a human cadaver model for a humeral head approach. *Mil Med* 2014;179(8 Suppl):24-8. doi: 10.7205/MILMED-D-13-00484** 726
- 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.
- Schlump CJ, Solomon C, Keibl C, et al. Recovery of fibrinogen concentrate after intraosseous application is equivalent to the intravenous route in a porcine model of hemodilution. *J Trauma Acute Care Surg* 2014;76(5):1235-42** 717
- 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.
- Sontgerath JS, Rubal BJ, DeLorenzo RA, Morgan TL, Ward JA. Variability in intraosseous flush practices of emergency physicians. *Am J Emerg Med* 2014;http://dx.doi.org/10.1016/j.ajem.2014.03.001** 719
- 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.
- Vassallo J, Horne S, Smith JE. Intraosseous access in the military operational setting. *J R Nav Med Serv* 2014;100(1):36-9** 794
- 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).
- Vincent-Lambert C, Carpenter AP. Factors affecting the frequency of vascular access via intraosseous cannulation performed by paramedics in Johannesburg. *J Vasc Access* 2014;15(6):503-6. doi:10.5301/jva.5000263** 838
- 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.
- Winkler M, Talley C, Landwehr K, et al. Use of intraosseous needles for power injection of iodinated contrast media for emergency computed tomography angiography. *J Cardiovasc Comput Tomogr* 2014;9th annual scientific meeting abstracts:S76-7** 701
- 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.
- Young SW, Zhang M, Freeman JT, Mutu-Grigg J, Pavlou P, Morre GA. The Mark Coventry Award: Higher tissue concentrations of vancomycin with low-dose intraosseous regional versus systemic prophylaxis in TKA. *Clin Orthop Relat Res* 2014;472(1):57-65. doi:10.1007/s11999-013-3038-z** 620
- 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.

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YEAR: 2013

Ahrens KL, Reeder SB, Keevil JG, Tupesis JP. Successful computed tomography angiogram through tibial intraosseous access: a case report. J Emerg Med 2013;45(2):182-5. doi: 10.1016/j.jemermed.2012.11.091 632

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.

Barratt JW. Re: reasons for not using intraosseous access in critical illness. Emerg Med J 2013;30(6):516-7. doi:10.1136/emered-2012-202120 703

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

Bloch SA, Bloch AJ, Silva P. Adult intraosseous use in academic Eds and simulated comparison of emergent vascular access techniques. Am J R Emerg Med 2013. http://dx.doi.org/10.1016/ajem.2012.11.021 652

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).

Byars DV, Tsuchitani SN, Yates J, Knapp B. A multijurisdictional experience with the EZ-IO intraosseous device in the prehospital setting. Am J Emerg Med 2013;31(12):1712-3. doi: 10.1016/j.ajem.2013.08.056 656

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.

Dolister M, Miller S, Borrón S, et al. Intraosseous vascular access is safe, effective and costs less than central venous catheters for patients in the hospital setting. J Vasc Access 2013;14(3):216-24. doi:10.5301/jva.5000130 583

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.

Erdmann L, Doll S, Ihle B, Kirsch J, Mutzbauer TS. Evaluation of the sternal intraosseous route as alternative emergency vascular access for the dental office: a manikin and cadaver model pilot study. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116(6):686-91 657

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.

Fetissov H, Nadaud J, Landy C, Millot I, Paris R, Plancade D. Amines on intraosseous vascular access: A case of skin necrosis. Ann Fr Anesth Reanim 2013;32(5):e89-90.http://dx.doi.org/10.1016/j.annfar.2013.02.022 644

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.

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- Frascone RJ, Salzman JG, Bliss P, Adams A, Wewerka SS, Dries DJ. Decreasing intraosseous pressure and increasing respiratory variability track fluid volume reduction in a porcine hypovolemia model. *Ann Emerg Med* 2013;62(4S):S14** 666
- 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.
- Frascone RJ, Salzman JG, Bliss P, Adams A, Wewerka SS, Dries DJ. Intraosseous pressure tracings mimics arterial pressure tracings in timing and contour. *Ann Emerg Med* 2013;62(4S):S13 - 4** 665
- 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.
- Frascone RJ, Salzman JG, Ernest EV, Burnett AM. Use of an intraosseous device for invasive pressure monitoring in the ED. *Am J of Emerg Med* 2014;32(6):692.e3-692.e4.doi:10.1016/j.ajem.2013.12.029** 667
- 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.
- Grossman V. Hot Topics: CT contrast and intraosseous lines: friends or enemies? *J Radiol Nurs* 2013; 32(1):41-4. <http://dx.doi.org/10.1016/j.jradnu.2012.12.004>** 643
- 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.
- Hafner JW, Bryant A, Huang F, Swisher K. Effectiveness of a drill-assisted intraosseous catheter versus manual intraosseous catheter by resident physicians in a swine model. *Western J Emerg Med* 2013;XIV(6):629-32** 668
- 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.
- Hallas P, Brabrand M, Folkestad L. Complication with intraosseous access: Scandinavian users' experience. *West J Emerg Med* 2013;14(5):440-3. doi:10.5811/westjem.2013.1.1200** 669
- 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
- Denmar
- Helm M, Richter D, Schramm A, Lampl L, Hossfeld B.. Ist die intraossare punktion ein alternativer gefabzugang beim notfall in der zahnarztlichen praxis? *Notfall Rettungsmed* 2013;16:27-32. Doi:10.1007/s10049-012-1629-y. German** 612
- 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
- Hunsaker S, Hillis D. Intraosseous vascular access for alert patients. *Am J Nurs* 2013;113(11):34-9** 672
- 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.

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- Junkin R, Litchfield K. Intraosseous vascular access skill acquisition in labour ward staff: results of a training programme. *Int J Obstet Anesth* 2013;22(1):S31** 674
- 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
- Junkin R, Selfridge J, Litchfield. Intraosseous vascular access in obstetric emergencies: an OAA approved national survey. *Int J Obstet Anesth* 2013;22(1):S31** 673
- 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** 647
- 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.
- Lairet J, Bebartha V, Lairet K, et al. A comparison of proximal tibia, distal femur, and proximal humerus infusion rates using the EZ-IO intraosseous device on the adult swine (*Sus scrofa*) Model. *Prehosp Emerg Care* 2013;17:280-4. Doi:10.3109/10903127.2012.755582** 642
- 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.
- Lewis GC, Crapo SA, William JG. Critical skills and procedures in emergency medicine- vascular access skills and procedures. *Emerg Med Clin N Am* 2013;31(1):59-86. doi: 10.1016/j.emc.2012.09.006** 631
- 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>** 615
- 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.
- Mills A, Pappin D, Field V, Thorp-Jones D. Intraosseous access in the peripartum patient: is your needle long enough? *Int J Obstet Anesth* 2013;22(1):S30** 675
- 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
- Montez DF, Puga TA, Garcia MR, et al. Intraosseous blood correlates with venous blood in healthy subjects using point-of-care analyzers. *Ann Emerg Med* 2013;62(4S):S40** 676
- 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.

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- Myers LA, Arteaga GM, Kolb LJ, et al. Prehospital peripheral intravenous vascular access success rates in children. *Prehosp Emerg Care* 2013;17(4):425-8. doi: 10.3109/10903127.2013.818180** 1000
- 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** 685
- 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).
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- Plancade D, Ruttimann M, Wagnon G, et al.. La perfusion intraosseuse chez l'adulte. *Annales Francaises d'Anesthesie et de Reanimation* 2013;<http://dx.doi.org/10/1016/j.annfar.2013.02.024>. French** 617
- 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.
- Pozza M, Lunardi F, Pflipsen M. Emergency intraosseous access: a useful, lifesaving device use in Afghanistan. *J Spec Oper Med* 2013;13(1):25-8** 684
- 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.
- Reinhardt L, Brenner T, Bernhard M, et al. Four years of EZ-IO system in the pre- and in-hospital emergency setting. *Central European Journal of Medicine* 2013;8(2):166-71. Doi:10.2478/s11536-012-0125-6** 618
- 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.
- Reiter DA, Strother CG, Weingart SD. The quality of cardiopulmonary resuscitation using supraglottic airways and intraosseous devices: a simulation trial. *Resuscitation* 2013;84:93-7. doi:10.1016/j.resuscitation.2012.07.003** 586
- 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.
- Santos D, Carron PN, Yersin B, Pasquier M. EZ-IO intraosseous device implementation in a pre-hospital emergency service: a prospective study and review of the literature. *Resuscitation* 2013;84(4):440-5. <http://dx.doi.org/10.1016/j.resuscitation.2012.11.006>** 604
- 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 induced in 7 patients. Drugs infused are listed. There were no serious complications.
- Souchtchenko SS, Benner JP, Allen JL, Brady WJ. A review of chest compression interruptions during out-of-hospital cardiac arrest and strategies for the future. *J Emerg Med* 2013. <http://dx.doi.org/10.1016/j.jemermed.2013.01.023>** 624
- 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.

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- Torres A, Banister N, Fernandez M, Cox K, Fletcher J. Appropriateness and complications of intraosseous needle placements during pediatric transports. Crit Care Med 2013;41(12):abstract 215** 792
- 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.
- Torres F, Galán MD, Alonso MD, Suarez R, Camacho C, Almagro V. Intraosseous access EZ-IO in a prehospital emergency service. J Emerg Nurs 2013;39(5):511-4. doi: 10.1016/j.jen.2012.03.005** 572
- 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.
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- 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.
- Wiese CHR, Semmel T. Aktuelles zum intraossaren Zugang- Weib das team bescheid? Notfall + Rettungsmedizin. 2013; doi:10.1007/s10049-013-1698-6. German** 621
- Young SW, Zhang M, Freeman JT, Vince KG, Coleman B. Higher cefazolin concentrations with intraosseous regional prophylaxis in TKA. Clin Orthop Relat Res 2013;471(1):244-9. doi:10.1007/s11999-012-2469-2** 576
- 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.
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- 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
- Burgert J, Gegel 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** 660
- 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.
- Cairney K, Matthew I. Options for intravascular access during resuscitation of adults. Emerg Nurse 2012;20(1):24-8** 536
- 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.

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Carness JM, Russell JL, Lima RM, Navarro LHC, Kramer GC. Fluid resuscitation using the intraosseous route: Infusion with lactated ringers and hetastarch. Mil Med 2012;177(2):222-8.** 529
- 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.
- Carr BG, Proehl JA, Fox M, Miller LJ, Philbeck TE. Intraosseous vascular access: physicians and nurses identify knowledge gaps and barriers to implementation. J Vasc Access 2012;13:13A. doi:10.5301/JVA.2012.9362** 596
- 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.
- Duncan L, Cohen J, Triner W, Rea J, King C. Intraosseous administration of CT Contrast in a porcine model: a feasibility study. Ann Emerg Med 2012;60(4S):S92** 598
- 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** 764
- 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.
- Greene N, Bhananker S, Ramaiah R. Vascular access, fluid resuscitation, and blood transfusion in pediatric trauma. Int J Crit Illn Inj Sci 2012;2(3):135-42 doi: 10.4103/2229-5151.100890** 980
- 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.
- Hoskins SL, Nascimento P Jr., Lima RM, Espana-Tenorio, JM, Kramer GC. Pharmacokinetics of intraosseous and central venous drug delivery during cardiopulmonary resuscitation. Resuscitation 2012;83(1):40-5. doi:10.1016/j.resuscitation.2011.07.041** 442
- Pharmacokinetics of IO drug delivery was compared using the tibia or sternum, versus central venous delivery during CPR. Anesthetized swine with KCI 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** 599
- 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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- Kalechstein S, Permual A, Cameron BM, et al. Evaluation of a new pediatric intraosseous needle insertion device for low-resource setting. *J Pediatr Surg* 2012;47(5):974-9. doi: 10.1016/j.pedsurg.2012.01.055** 546
- 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.
- Landy C, Plancade D, Gagnon N, Schaeffer E, Nadaud J, Favier JC. Complication of intraosseous administration of systemic fibrinolysis for a massive pulmonary embolism with cardiac arrest. *Resuscitation* 2012;83(6):e149-50. doi: 10.1016/j.resuscitation.2012.01.044** 547
- 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.
- Leidel BA, Kirchoff C, Bogner V, Braunstein V, Biberthaler P, Kanz KG. Comparison of intraosseous versus central venous vascular access in adults under resuscitation in the emergency department with inaccessible peripheral veins. *Resuscitation* 2012;83(1):40-5. doi:10.1016/j.resuscitation.2011.08.017** 439
- 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** 513
- 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.
- Miller LJ, Montez DF, Puga TA, Philbeck TE. Intraosseous vascular access in the 21st century: improvements further reduce complication rates. *Ann Emerg Med* 2012;60(4S):S112** 597
- 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.
- Miller LJ, Puga TA, Montez DF, Morgan J. New in therapeutic hypothermia: preclinical evidence validates the IO Route; chilled tubing works best. *Ann Emerg Med* 2012;60(4S):S90** 601
- 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.
- Myers LA, Russi, CS, Kolb L. Prehospital semiautomatic intraosseous placement in adults. *Prehosp Emerg Care* 2012;16(1):173. doi:10.3109/10903127.2011.624676** 514
- 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%.



Intraosseous Vascular Access Bibliography

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- Olaussen A, Williams B. Intraosseous access in the prehospital setting: literature review. *Prehosp Disaster Med* 2012;27(5):468-72. doi:10.1017/S1049023X12001124. http://journals.cambridge.org/abstract_S1049023X12001124** 582
- 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.
- Page D. Intraosseous intrigue: Studies examine success rates on pediatric, adult & obese patients. *JEMS* January 2012;32-3** 515
- In this article, the author discussed five recent studies on intraosseous access providing his opinion about the quality of each study.
- Paxton JH. Intraosseous vascular access: A review. *Trauma* 2012;14(3):195-232. DOI:10.1177/1460408611430175** 690
- 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.
- Plancade D, Nadaud J, Lapierre M, et al. Feasibility of a thoraco-abdominal CT with injection of iodinated contrast agent on sternal intraosseous catheter in an emergency department. *Annales Francaises d'Anesthesie et de Reanimation* 2012;<http://dx.doi.org/10.1016/j.annfar.2012.10.009>** 580
- 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.
- Rogers J, Fox M. The safety of intraosseous vascular access. *Emergency Medicine Patient Safety Foundation Forum. Fall 2012:18-21*** 606
- 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.
- Rogers JJ, Fox M, Miller LJ, Philbeck TE. Safety of intraosseous vascular access in the 21st century. *J Vasc Access* 2012;13:19A** 579
- 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.
- Rose EC. The evidence-based use of intraosseous lines in pediatric patients. *Pediatr Emerg Med Pract* 2012;9(6):1-12. www.edmedicine.net** 585
- 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.
- Rubal BJ, McKay K, Armstrong KR, Rubal MP, Marbach MJ. Variability in intraosseous pressure induced by saline flush of an intraosseous cannula by multiple practitioners. *Lab Animal* 2012;41(8):224-9** 578
- 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.



Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Rush S, Bremer J, Foresto C, Rubin AM, Anderson PI. A magnetic resonance imaging study to define optimal needle length for humeral head IO devices. *J Spec Oper Med* 2012;12(2):77-82** 577
- 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.
- Severyn FA. Complication after intraosseous needle removal following successful systemic thrombolysis for a massive pulmonary embolism. *Resuscitation* 2012;83(11):e207. doi:10.1016/j.resuscitation.2012.07.014** 575
- 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.
- Tan BKK, Chong S, Koh ZX, Ong MEH. EZ-IO in the ED: an observational, prospective study comparing flow rates with proximal and distal tibia intraosseous access in adults. *Am J Emerg Med* 2012;30(8):1602-6.doi.10.1016/j.ajem.2011.10.025** 519
- 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.
- Truemper EJ, Beamer CL, Miller LJ, et al. Distal femur site is a viable option for IO vascular access in pediatric patients. *Ann Emerg Med* 2012;60(4S):S90** 761
- 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.
- Vassallo J, Horne ST, Smith JE. Intraosseous access on military operations: a 4 month review. Poster presentation at International Conference on Emergency Medicine, Dublin, Ireland. June 27-30, 2012** 593
- 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%.
- Voigt J, Waltzman M, Lottenberg L. Intraosseous vascular access for in-hospital emergency use: A systematic clinical review of the literature and analysis. *Pediatr Emerg Care* 2012;28(2):185-99** 562
- 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
- Wampler D, Schwartz D, Shumaker J, Bolleter S, Beckett R, Manifold C. Paramedics successfully perform humeral EZ-IO intraosseous access in adult out-of-hospital cardiac arrest patients. *Am J of Emerg Med* 2012;30:1095-9. doi:10.1016/j.ajem.2011.07.010** 520
- 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.

Intraosseous Vascular Access Bibliography

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Weiser G, Hoffmann Y, Galbraith R, Shavit I. Current advances in intraosseous infusion - a systematic review. Resuscitation 2012;83(1):20-6. doi:10.1016/j.resuscitation.2011.07.020 454

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

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 490

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.

Borron SW, Arias JC, Bauer CR, et al. Intraosseous line placement for antidote injection by first responders and receivers wearing personal protective equipment. Am J Emerg Med 2011;29(4):373-81.doi:10.1016/j.ajem.2009.10.009 424

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.

Brady M. Intraosseous infusion: A 'humerus' subject? J Paramed Pract. 2011;3(4):198. 1045

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%.

Chatterjee DJ, Bukunola B, Samuels TL, Induruwage L, Uncles DR. Resuscitation in massive obstetric haemorrhage using an intraosseous needle. Anaesthesia 2011;66(4):306-10.doi:10.1111/j.1365-2044.2011.06629.x 472

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.

Cotte J, Prunet B, d'Aranda E, Asencio Y, Kaiser E. [A compartment syndrome secondary to intraosseous infusion]. Ann Fr Anesth Reanim 2011;30(1):90-1. doi: 10.1016/j.annfar.2010.05.038. French 691

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

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 A895. 539

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.

Cullen PM. Intraosseous cannulation in children. Paediatric Critical Care 2011;13(1):28-30 523

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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- Day MW. Intraosseous devices for intravascular access in adult trauma patients. Crit Care Nurs 2011;31:76-90. doi: 10.4037/ccn2011615** 540
- An overview of available intraosseous vascular access devices, including the EZ-IO.
- de Vogel J, Heydanus R, Mulders AGM, Smalbrakk DJC, Papatsonis DNM, Gerritse BM. Lifesaving intraosseous access in a patient with a massive obstetric hemorrhage. Am J Perinatol Rep 2011;1(2):119-122. doi: <http://dx.doi.org/10.1055/s-0031-1293514>** 541
- 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** 453
- 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.
- Eich C, Weiss M, Neuhaus D, et al. Handlungsempfehlung zur intraossären Infusion in der Kinderanästhesie [Recommended action for intraosseous infusion in children's anesthesia]. Anästh Intensivmed 2011;52:S46-52. German** 770
- 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 "intravenous" anaesthesia (as in malignant hyperthermia). This article is in German.
- Gazin N, Auger H, Jabre P, et al. Efficacy and safety of the EZ-IO™ intraosseous device: Out-of-hospital implementation of a management algorithm for difficult vascular access. Resuscitation 2011;82(1):126-9** 494
- 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.
- Hafeez W, Ronca LT, Maldonado TE. Pediatric advanced life support update for the emergency physician: Review of 2010 guideline changes. Clin Pediatr Emerg Med 2011;12(4):255-65** 525
- General overview of PALS updates. Various IO devices were specifically mentioned in the vascular access section, including the EZ-IO.
- Harcke HT, Crawley G, Mabry R, Mazuchowski E. Placement of tibial intraosseous infusion devices. Mil Med 2011;176(7):824-7** 469
- 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.
- Harcke T, Crawley G, Ritter B, Mazuchowski E. Feedback to the field: an assessment of sternal intraosseous (IO) infusion. J Spec Oper Med 2011;11(1):23-6** 544
- 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.

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- Heyder-Musolf J, Giest J, Straub J. Kasuistik-Intraossärer Zugang bei einem 1300 g schweren septischen Neugeborenen[Case history-Intraosseous access on a 1300 g septical premature infant]. *Anesthesiol Intensivmed Notfallmed Schmerzther* 2011;46(10):654-7. doi: 10.1055/s-0031-1291943. [German]** 864
- Case description of a critically ill 15 day old premature infant weighing 1300 g. Tibial IO access was placed perioperatively for an urgent surgery.
- Howarth D. Adult intraosseous access: experiences in a remote emergency department. *Australian Family Physician* 2011;40(7):510-1** 483
- 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.
- Jackson EE, Ashley TC, Snowden KF, et al. Performance and longevity of a novel intraosseous device in a goat (*capra hircus*) model. *J Am Assoc Lab Anim Sci* 2011;50(3):365-73** 473
- 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** 485
- 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.
- Knuth TE, Paxton JH, Myers D. Intraosseous injection of iodinated computed tomography contrast agent in an adult blunt trauma patient. *Ann Emerg Med* 2011;57(4):382-6. doi:10.1016/j.annemergmed.2010.09.025** 463
- 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.
- Lairet J, Beberta V, Lairet K, et al. A comparison of proximal tibia, proximal humerus, and distal femur infusion rates under high pressure (>300mmHg) using the EZ-IO intraosseous device on an adult swine (*sus scrofa*) model. *Prehosp Emerg Care* 2011;15(1):117** 493
- 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.
- Larabee TM, Campbell JA, Severyn FA, Little CM. Intraosseous infusion of ice cold saline is less efficacious than intravenous infusion for induction of mild therapeutic hypothermia in a swine model of cardiac arrest. *Resuscitation* 2011;82(5):603-6.doi:10.1016/j.resuscitation.2011.01.007** 476
- 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** 887
- This is a review article describing intraosseous vascular access, including techniques and device used, and contraindications.

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- Mikrogianakis A, Kam A, Silver S, et al. Telesimulation: An innovative and effective tool for teaching novel intraosseous insertion techniques in developing countries. Acad Emerg Med 2011;18(4):420-7. doi:10.1111/j.1553-2712.2011.01038.x** 440
- 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, Montez DF, et al. Utility of an intraosseous vascular access system to deliver contrast dye using a power injector for computerized tomography studies. Ann Emerg Med 2011;58(4S):S240** 443
- 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.
- 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** 475
- 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.
- Myers L, Russi CS, Arteaga GM. Semiautomatic intraosseous devices in pediatric prehospital care. Prehosp Emerg Care 2011;15(4):473-6. doi:10.3109/10903127.2011.598611** 431
- 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** 508
- 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.
- Nagler J, Krauss B. Intraosseous catheter placement in children. NEJM 2011;364(8):e14-8** 491
- This article provides an overview of intraosseous vascular access for pediatrics and discusses general indications, contraindications, complications, and intraosseous devices.
- Neuhaus D. [Intraossärer Zugang]. Notfall Rettungsmed 2011;14(7):543. doi:10.1007/s10049-011-1445-9. German** 480
- This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.

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- Olaussen A. Best evidence topic reports: which intraosseous device is best in the prehospital setting? *Emerg Med J* 2011;28(8):717-8. doi: 10.1136/emj.2010.108381** 724
- 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
- Reades R, Studneck J, Garrett J, Vandeventer S, Blackwell T. Comparison of first-attempt success between tibial and humeral intraosseous insertions during out-of-hospital cardiac arrest. *Prehosp Emerg Care* 2011;15(2):278-81. doi:10.3109/10903127.2010.545479** 464
- 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.
- Reades R, Studnek JR, Vandeventer S, Garrett J. Intraosseous versus intravenous vascular access during out-of-hospital cardiac arrest: a randomized controlled trial. *Ann Emerg Med* 2011;58(6):509-16. doi:10.1016/j.annemergmed.2011.07.020** 470
- 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.
- Ruiz-Hornillos PJ, Marinez-Camara F, Elizondo M, et al. Systemic fibrinolysis through intraosseous vascular access in ST-segment elevation myocardial infarction. *Ann Emerg Med* 2011;57(6):572-4. doi:10.1016/j.annemergmed.2010.09.011** 496
- 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.
- Schalk R, Schweigkofler U, Lotz G, et al. Efficacy of the EZ-IO needle driver for out-of-hospital intraosseous access- a preliminary, observational, multicenter study. *Scand J Trauma Resusc Emerg Med* 2011;19(1):65. doi:10.1186/1757-7241-19-65** 516
- 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.
- Schexnayder SM, Storm EA, Stroud MD, et al. Chapter 15-Pediatric vascular access and centeses. *Pediatric Critical Care* 2011;4th ed:139-63. ISBN: 978-0-323-07307-3** 680
- 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.
- Sheehan C, Sodhi V, Esler M. Intraosseous needles on the delivery suite. *Int J Obstet Anesth* 2011;20(3):272-3. doi: 10.1016/j.ijoa.2011.01.003.** 553
- 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.
- Smart RJ, Marsh S, Rosenberg M. Intraosseous access in oral and maxillofacial surgical practice. *J Oral Maxillofac Surg* 2011;69(11):2708-13. doi:10.1016/j.joms.2011.02.101** 441
- 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.

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Sommer A, Weiss M, Deanovic D, Dave M, Neuhaus D. [Einsatz der intraossaren infusion im padiatrischen notarztdienst: Analyse von notarzteinsetzten 1990-2009]. Anaesthesist 2011;60:125-131. German 488

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 484

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.

Thim T, Grove EL, Krarup NJV, Løfgren B. [Intraossøs adgang]. Ugeskr Læger 2011;173(21):1496-8. Danish 474

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/intraosseous-access-its-operator-and-not-device> 563

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

Bloch SA, Bloch AJ, Silva P. Adult intraosseous use in academic emergency departments and simulated comparisons of emergency vascular access techniques. Ann Emerg Med 2010;56(3):S152 497

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.

Bukoski A, Winter M, Bandt C, Wilson M, Shih A. Comparison of three intraosseous access techniques in cats. J Vet Emerg Crit Care 2010;20(4):393-7.doi:10.1111/j.1476-4431.2010.00558.x 437

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.

Eich C, Weiss M, Neuhaus D, et al. Intraosseous infusion in paediatric emergency medical care and anaesthesia. Anasth Intensivmed 2010;51:75-81. German 972

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.

Fenwick R. Intraosseous approach to vascular access in adult resuscitation. Emerg Nurse 2010;18(4):22-5 456

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.

Gillum L. All access pass: mastering the use of IO devices. JEMS 2010;35(6):30, 32. doi: 10.1016/S0197-2510(10)70142-X 466

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.

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- Hulse EJ, Thomas GOR. Vascular access on the 21st century military battlefield. J R Army Med Corps 2010;156(4 Suppl 1):s385-90** 629
 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 praxlinischen notarztendienst: Diskrepanzzwischen leitlinien-empfehlungen und realitat!] Notfall Rettungsmedizin 2010; doi:10.1007/s10049-010-1381-0. German** 489
 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** 505
 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.
- Lairet JR, Bebarta V, Lairet K, et al. Intraosseous pressure infusion comparison using a rapid infusion device and a pressure bag in a swine model. Ann Emerg Med 2010;56(3):S26** 502
 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.
- Lamhaut L, Dagron C, Apriotesei R, et al. Comparison of intravenous and intraosseous access by pre-hospital medical emergency personnel with and without CBRN protective equipment. Resuscitation 2010;81(1):65-8. Epub 2009 Oct 24** 437
 Training study with nurses and physicians comparing EZ-IO to IV lines under Hazmat conditions. IO procedure significantly shorter.
- Leidel BA, Kirchoff C, Braunstein V, Bogner V, Biberthaler P, Kanz KG. Comparison of two intraosseous access devices in adult patients under resuscitation in the emergency department: A prospective, randomized study. Resuscitation 2010;81(8):994-9. doi:10.1016/j.resuscitation.2010.03.038** 430
 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.
- Lima R, Navarro L, Cesani F, et al. Repeated doses of adriamycin may be safely delivered through the intraosseous route in different bones in swine. Blood 2010;116(21):4344. Accessed May 25, 2017. Retrieved from <http://www.bloodjournal.org/content/116/21/4344>** 949
 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.
- Luck RP, Haines C, Mull CC. Intraosseous access. J Emerg Med 2010;39(4):468-75. doi:10.1016/j.jemermed.2009.04.054** 492
 This article provides an overview of intraosseous vascular access and discusses general indications, contraindications, complications, and intraosseous devices.
- Mader TJ, Walterscheid JK, Kellog AR, Lodding CC. The feasibility of inducing mild therapeutic hypothermia after cardiac resuscitation using iced saline infusion via an intraosseous needle. Resuscitation 2010;81(1):82-6** 440
 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.



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- Miller L, Philbeck T, Bolleter S, Garcia G. Tactile feedback comparison of three types of intraosseous access devices for needle insertion accuracy. *Ann Emerg Med* 2010;56(3):S133** 500
- 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.
- Miller L, Philbeck T, Montez D, Puga T. A two-phase study of fluid administration measurement during intraosseous infusion. *Ann Emerg Med* 2010;56(3):S151** 498
- 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.
- Miller L, Philbeck T, Montez D, Puga T. Volunteer studies of pain management during intraosseous infusion. *Ann Emerg Med* 2010;56(3):S141** 499
- 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.
- 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** 503
- 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.
- Mitchell C, Tauferner D, Huebner K. Placement of the EZ-IO sternal and EZ-IO manual needle sets with and without chemical protective equipment: a cadaveric study. *Prehosp Emerg Care* 2010;14:14-5** 448
- 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.
- Molin R, Hallas P, Brabrand M, Schmidt TA. Current use of intraosseous infusion in Danish emergency departments: a cross-sectional study. *Scand J Trauma Resusc Emerg Med* 2010;18(37). doi:10.1186/1757-7241-18-37** 433
- 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.
- Neuhaus D, Weiss M, Engelhardt T, et al. Semi-elective intraosseous infusion after failed intravenous access in pediatric anesthesia. *Pediatr Anesth* 2010;20(2):168-71. doi: 10.1111/j.1460-9592.2009.03244.x** 425
- 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.
- Ota S, Taguchi H, Otake Y, et al. Experience using bone marrow piercing drill EZ-IO system during adult cardiopulmonary resuscitation. *Japan Emerg Med J* 2010;21:143-5. Japan** 1007
- 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

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- Philbeck TE, Miller LJ, Montez D, Puga T. Hurts so good; easing IO pain and pressure. JEMS 2010;35(9):58-69** 504
 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.
- Rubal BJ, Gerhardt RT, Sartin CW, et al. Medullary shear and pressure changes associated with high intraosseous infusion rates in an isolated hind limb preparation. Ann Emerg Med 2010;56(3):S113** 501
 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.
- Sunde GA, Heradstveit BE, Vikenes BH, Heltne JK. Emergency intraosseous access in a helicopter emergency medical service: a retrospective study. Scand J Trauma Resusc Emerg Med 2010;18:52. doi. 10.1186/1757-7241-18-52.** 495
 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.
- Tobias JD, Ross AK. Intraosseous infusions: A review for the anesthesiologist with a focus on pediatric use. Anesth Analg 2010;110(2):391-401.** 428
 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.
- Turkan H. How does the training effect the use of intraosseous access with a battery driven device? Resuscitation 2010;81(2):S93. doi:http://dx.doi.org.10.1016/j.resuscitation.2010.09.380** 768
 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** 681
 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** 482
 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.
- Wampler DA, Shumaker J, Manifold C, Bolleter S, Frandsen J. Humeral intraosseous access success rate in adult out-of-hospital cardiac arrest. Ann Emerg Med 2010;56(3):S88** 479
 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.



Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

YEAR: 2009

Ahn KI, Shin SD, Jung JH, Kim DK. Evaluation of the effect of education on prehospital intraosseous access by level 1 emergency medical technicians. *Prehosp Emerg Care* 2009;13(1):102 415

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.

Borron SW, Arias JC, Bauer CR, Sanchez M, Fernandez M, Jung I. Hemodynamics after intraosseous administration of hydroxocobalamin or normal saline in a goat model. *Am J Emerg Med* 2009;27:1065-71 439

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".

Brenner T, Gries A, Helm M, Bernhard M. Letter to the editor: Intraosseous infusion systems in the prehospital setting. *Resuscitation* 2009; 80(5):607.doi:10.1016/j.resuscitation.2009.02.009 423

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: 359-63 435

Case report of IO infusion in 79-year old woman with hematemesis after intestinal surgery.

Day MW. Boning up on intraosseous. *Nurs Crit Care* 2009;4(3):22-6 608

This article provides a general overview of intraosseous access and its use in emergency situations. A description of available IO access devices is provided.

Frascone RJ, Jensen J, Wewerka SS, Salzman JG. Use of the pediatric EZ-IO needle by emergency medical services providers. *Pediatr Emerg Care* 2009;25:329-32 424

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

Leidel BA, Kirchoff C, Bogner V, Stegmaier J, Mutschler W, Kanz KG, Braunstein V. Is the intraosseous access route fast and efficacious compared to conventional central venous catheterization in adult patients under resuscitation in the emergency department? A prospective observational pilot study. *Patient Saf Surg* 2009;3:24 436

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.

Levitan RM, Bortle CD, Snyder TA, Nitsch DA, Pisaturo JT, Butler KH. Use of a battery-operated needle driver for intraosseous access by novice users: skill acquisition with cadavers. *Ann Emerg Med* 2009;54(5):692-4 438

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.

MacKinnon KA. Intraosseous vascular access use at a Signature Healthcare Brockton Hospital Department of Emergency Services. *J Emerg Nurs* 2009; 35: 425-8 431

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.

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Mader TJ, Walterschild JK, Kellogg AR, Lodding CC. Feasibility of intraosseous infusion of iced saline to induce therapeutic hypothermia after cardiac resuscitation. *Ann Emerg Med* 2009;54(3):S140** 477
- 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.
- Menegazzi JJ, LaCovary AC, Negron KI, et al. Potential reduction in time to drug administration if vascular access preceded intubation during out-of-hospital cardiac arrest. *Prehosp Emerg Care* 2009;13(1):133** 416
- 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.
- Miller J, Lairet J, DeLorenzo R, Pitotti R. Intraosseous infusion of crystalloid fluid immediately after intraosseous infusion of nitroglycerin in the proximal tibia of a swine (*sus scrofa*) model. *Ann Emerg Med* 2009;54(3):S140** 414
- 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.
- Miller L, Philbeck T, Montez D, Spadaccini C. A new study of intraosseous blood for CBC and chemistry profile. *Ann Emerg Med* 2009;54(3):S59** 412
- 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** 409
- 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.
- Ngo AS-Y, Oh JJ, Chen Y, et al. Intraosseous vascular access in adults using the EZ-IO in an emergency department. *Int J Emerg Med* 2009. Available at <http://www.springerlink.com/content/d16841757807k635/fulltext.pdf>. Accessed 09/09/2009** 411
- 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.
- Nutbeam T, Fergusson A. Intraosseous access in osteogenesis imperfecta (IO in OI). *Resuscitation* 2009;80(12):1442-3. doi:10.1016/j.resuscitation.2009.08.016** 408
- 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** 417
- 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

Arrow® EZ-IO®

- Ong ME, Ngo AS, Wijaya R. An observational prospective study to determine the ease of vascular access in adults using a novel intraosseous access device. *Ann Acad Med Singapore* 2009;38:121-4** 420
- 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.
- Ornato JP, Peberdy MA, Kurz MC. Abstract P134: A building block strategy for optimizing outcomes from out of hospital cardiac arrest. *Circulation* 2009;120:S1470-a** 404
- 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.
- Paxton JH, Knuth TE, Klausner HA. Proximal humerus intraosseous infusion: a preferred emergency venous access. *J Trauma* 2009;67:606-11** 430
- 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.
- Philbeck T, Miller L, Montez D. Pain management during intraosseous infusion through the proximal humerus. *Ann Emerg Med* 2009;54(3):S128** 413
- 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.
- Plancade D, Ruttimann M, Boulland P, et al. [Evaluation d'un nouveau catheter pour perfusion intra-osseuse en OPEX]. *La Revue du CARUM-Réanoxyo* 2009;25(2):49-50. French** 410
- 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.
- Sarkar D, Philbeck T. The use of multiple intraosseous catheters in combat casualty resuscitation. *Mil Med* 2009;174:106-8** 418
- 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.
- Schutt RC, Bowman B, Cevik C, et al. Intraosseous line placement does not improve outcome in adults with out-of-hospital cardiac arrest. *Prehosp Emerg Care* 2009;13(1):102** 417
- 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.
- Shavit I, Hoffmann Y, Galbraith R, Waisman Y. Comparison of two mechanical intraosseous infusion devices: a pilot, randomized crossover trial. *Resuscitation* 2009;80(9):1029-33. doi: 10.1016/j.resuscitation.2009.05.026** 429
- 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.
- Sunde GA, Thoresen A, Heltne J-K. [Intraossøs tilgang på kritisk syke pasienter - gammel teknikk får ny heder, eller kun for spesielt interessert]? *NAForum* 2009;22(1):33-7. German** 407
- 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.

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Toursarkissian M, Schmidbauer W, Breckwoldt J, Spies C. [Präklinischer Einsatz von intraossären Zugängen beim Erwachsenen: Überblick und Anwendungsbeispiele] Preclinical use of intraosseous access (IO) in adults: Literature review and case reports. *Anesthesiol Intensivmed Notfallmed Schmerzther* 2009;44(1):22-7. German** 416
 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.
- Truhlar A, Skulec R, Rozsival P, Cerny V. Efficient prehospital induction of therapeutic hypothermia via intraosseous infusion. *Resuscitation* 2010;81(2):262-3. doi: 10.1016/j.resuscitation.2009.10.029. Epub 2009 Dec 16** 442
 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 équivalente à la perfusion intraveineuse? *Urgence Pratique* 2009;36:36-40** 507
 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.
- Weiss M, Henze G, Eich C, Neuhaus D. [Intraossäre Infusion: Eine wichtige Technik auch für die Kinderanästhesie]. *Der Anaesthetist* 9 2009:863-75. Norwegian** 406
 This article, in Norwegian, describes IO access and modern IO devices, including the Bone Injection Gun, FAST1, and EZ-IO.
- Weiss M, Henze G, Eich C, Neuhaus D. Intraossäre Infusion: Eine wichtige Technik auch für die Kinderanästhesie [Intraosseous infusion: an important technique also for paediatric anaesthesia]. *Anaesthetist* 2009;58(9):863-75. doi: 10.1007/s00101-009-1605-1 German** 434
 Discusses use of IO for pediatric anesthesia. Specifies importance of equipment, education, guidelines.
- Wright JK, Christy RJ, Tharp RV, Kalns JE. Evaluation of intraosseous delivery of factor VIIa during hemorrhagic shock in the pig. *Mil Med* 2009;174:119-23** 419
 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**
- Atanda A Jr, Statter MB. Compartment syndrome of the leg after intraosseous infusion: guidelines for prevention, early detection, and treatment. *Am J Orthop* 2008;37:E198-200** 413
 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.
- Borron S, Arias J, Sanchez M, Bauer C. Hemodynamics following intraosseous administration of hydroxocobalamin in the goat. *Ann Emerg Med* 2008;52(4):S96** 421
 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.

Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Borron S, Arias J, Sanchez M, et al. Intraosseous line placement by hazardous materials responders and receivers for hydroxocobalamin administration. *Ann Emerg Med* 2008;52(4):S97** 420
- 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.
- Brenner T, Bernhard M, Helm M, et al. Comparison of two intraosseous infusion systems for adult emergency medical use. *Resuscitation* 2008;78(3):314-9** 380
- 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** 363
- 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.
- DeBoer S, Russell T, Seaver M, Vardi A. Infant intraosseous infusion. *Neonatal Network* 2008;27:25-32** 403
- 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.
- 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** 418
- 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** 381
- 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.
- Leidel BA, Kirchoff C. [Intraossäre infusion beim erwachsenen]. *Der Chirurg* 2008; 4:315-26. German** 402
- Article describing IO access.
- Paxton JH, Knuth TE, Klausner HA. Humeral head intraosseous insertion: The preferred emergency venous access. *Ann Emerg Med* 2008;52(4):S58** 419
- 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.



Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

Pointer JE, Vultaggio D, Schnepf R, Kleveno A. Fast or easy? Comparing two adult IO infusion devices. JEMS.com 2008 382

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).

Available at http://www.jems.com/news_and_articles/articles/Fast_or_Easy.html. Accessed 01/24/2008

Von Hoff DD, Kuhn JG, Burriss HA, Miller LJ. Does intraosseous equal intravenous? A pharmacokinetic study. Am J Emerg Med 2008; 26: 31-8 387

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.

Woosley CR, Mayes TC. The pediatric patient and thoracic trauma. Thor Cardiovasc Surg 2008;20:58-63 399

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

Beamer CL, Horton M. Powered needle insertion provides safe and effective vascular access for pediatric emergency patients. Ann Emerg Med 2007;50(3):S40 395

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.

Buck ML, Wiggins BS, Sesler JM. Intraosseous drug administration in children and adults during cardiopulmonary resuscitation. Ann Pharmacother 2007;41:1679-86 374

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.

Cooper BR, Mahoney PF, Hodgetts TJ, Mellor A. Intra-osseous access (EZ-IO®) for resuscitation: UK military combat experience. J R Army Med Corps 2007;153(4):314-6 379

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;23:422-4 372

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®.

DeBoer S, Andrews D. Infant venous access: 'Counting fingers' and 'playing baseball'. Australasian Emerg Nurs J 2007; 10: 46-51 356

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 R, Gallagher JV, Isaacs SM, Ossman E, Pepe P, Wayne W. The role of intraosseous vascular access in the out-of-hospital environment (resource document to NAEMSP position statement). Prehosp Emerg Care 2007;11:63-6 355

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.

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=17169880



Intraosseous Vascular Access Bibliography

Arrow® EZ-IO®

- Fowler RL. Prehospital intraosseous access: elemental to the field? JEMS 2007; doi:<http://jems.com/print/9198>** 543
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.
- Frascone RJ, Jensen JP, Kaye K, Salzman JG. Consecutive field trials using two different intraosseous devices. Prehosp Emerg Care 2007;11(2):164-71** 357
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** 376
Article in Italian describing IO access and EZ-IO
- Harrington LL, Rehbolz C, Mitchell PM, Dyer KS, King K, Moyer P. Out-of-hospital placement of adult intraosseous access using the EZ-IO device. Ann Emerg Med 2007;50(3):S81-2** 396
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** 386
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** 361
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®.
- Mathew N, McGinnis-Hainsworth D, Megargel R, Cleary A, O'Connor R. Trends in the usage of intraosseous access in the prehospital setting. Prehosp Emerg Care 2007;11(1):130** 362
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** 398
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** 400
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