

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

**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** 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.

*Denmark*

**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** 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.

*Germany*

**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® EZIO 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.

**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.

**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. http://dx.doi.org/10.1016/j.jcct.2017.03.001TS** 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.

**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-W7. 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.

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## Arrow® EZ-IO®

- 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.
- 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):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.
- 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*
- 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. Bilateral 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. German** 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.

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## Arrow® EZ-IO®

- 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;(2016):Article ID 4382481, 5 pages. 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.
- 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):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.
- 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.
- 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. http://dx.doi.org/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.  
UK
- 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):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  $9,587 \pm 2,706$  mL/hr (n=27); mean PH infusion rate was  $6,292 \pm 3,277$  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 mL/hr, surpassing that of the sternum.

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## Arrow® EZ-IO®

- 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, Bebartha 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.
- 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. http://dx.doi.org/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.
- 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.

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## Arrow® EZ-IO®

- Wilson J, Passmore A, Leger S, Lannan J, Bentley M, Johnson D. Effects of tibial intraosseous and intravenous administration of Hextend on time 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.
- 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.
- Chreiman KM, Kim PK, Garbovsky LA, Schweickert WD. Blueprint for implementing new processes in acute care. J Trauma Nurs 2015;22(5):266-73** 793
- 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. [Intraosseous provtagning kan vara vardefull i akuta lagen]. 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.

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## Arrow® EZ-IO®

- 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 LLC.
- 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).
- Hammer N, Möbius R, Gries A, Hossfeld B, Bechmann I, Bernhard M. Comparison of the fluid resuscitation rate with and without external pressure using two intraosseous infusion systems for adult emergencies, the CITRIN (comparison of intraosseous infusion systems in emergency medicine)- study. PLoS ONE 2015;10(12):e0143726. doi:10.1371/journal.pone.0143726** 791  
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, Lampl 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*
- 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/emered-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.
- 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.

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

- Means L, Gimbar RP. Prothrombin complex concentrate administration through intraosseous access for reversal of rivaroxaban. Am J of Emerg Med 2015;34(3):685.e1-2. doi:10.1016/j.ajem.2015.07.057** 765
- A case study report describing administration of prothrombin complex concentrate (PCC) via IO access to treat bleeding caused by Rivaroxaban oral anticoagulant in a 64 year old male. Proximal humerus IO access was established and 1490 units of PCC were administered at its maximum rate of 10 mL/min without adverse event. The same dose that would be administered IV was given IO. The patient experienced pain with IO infusion despite administration of 10 mg of lidocaine and 3 doses of fentanyl 25 mcg given via IO access. The patient was transferred to the medical intensive care unit and ultrasound guided IV access was established. The authors concluded that Profilnine is well tolerated when administered via IO access; however further studies are needed to evaluate if this is an effective practice.
- 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, Komasaawa 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.
- 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.

# Intraosseous Vascular Access Bibliography

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- 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.
- 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.
- 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  $\leq 300$  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  $39.5 \pm 12.7$  mm Hg,  $31.5 \pm 7.6$  mmHg, and  $35.0 \pm 8.8$  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.



# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

**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. 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*

**Suominen PK, Nurmi E, Lauerma K. Intraosseous access in neonates and infants: risk of severe complications- a case report. Acta Anaesthesiologica Scandinavica 2015;96:131-132. 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.

**Suominen PK, Nurmi E, Lauerma K. Intraosseous access in neonates and infants: risk of severe complications-a case report. Acta Anaesthesiol Scand 2015;59(10):1389-93. doi: 10.1111/aas.12602** 798

Case study of a neonate that suffered a cardiac arrest, had ROSC and was treated with multiple medications and hypothermia. 24 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, Bouso 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.

**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*

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

- 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, Bebarta 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.
- Bebarta VS, Pitotti RL, Bondreau S, Tanen DA. Intraosseous 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.
- 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, Karcioglu 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.
- 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.
- 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/emermed-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.

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- Lingner M, Niederer O, Majolk J, Krombholz 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.
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This report describes a study conducted by the Air Force Research Laboratory comparing intraosseous infusion rates between IO sites in a cadaveric model to determine if there is a site that is most effective for volume resuscitation. Using 16 cadavers procured within 72 hours of death, IO access was established in the proximal tibia and proximal humerus using the EZ-IO and in the sternum using the FAST1. Results showed the mean flow rate in the sternum was 1.6 times greater than the humerus and 3.1 times greater than the tibia. An abstract describing this report was presented by oral presentation at the 2014 annual scientific assembly for the Eastern Association for the Surgery of Trauma meeting.
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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.
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- 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.
- Weiser G, Poppa E, Katz Y, Bahouth H, Shavit I. Intraosseous blood transfusion in infants with traumatic hemorrhagic shock - a case report and review of the literature. Am J Emerg Med 2013;31(3):640.e3-4. doi: 10.1016/j.ajem.2012.10.036** 646  
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.

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

**YEAR:** 2012

- Abrams-Ogg AC, Defarges A, Foster RA, Bienzle D. Comparison of canine core bone marrow biopsies from multiple sites using different techniques and needles. Vet Clin Pathol 2012;41(2):235-42. doi: 10.1111/j.1939-165X.2012.00422.x** 664  
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.
- 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 route 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.

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

- 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.
- 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, Placade 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.

# Intraosseous Vascular Access Bibliography

## Arrow® EZ-IO®

- 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. *Preshosp 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%.
- 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](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](http://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.

# Intraosseous Vascular Access Bibliography

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- 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.
- 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

## Arrow® EZ-IO®

- 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 an animal trial that assessed the ability of protected, experienced first responders and limited-experience first receivers to place IO lines for antidote administration using the Vidacare 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.
- 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*
- 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.

# Intraosseous Vascular Access Bibliography

## Arrow® 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. [The intraosseous infusion in pediatric emergency medicine and pediatric anesthesia]. Anästhesiologie 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.
- Heyder-Musolf J, Giest J, Straub J. [Intraosseous access on a 1300 g septical premature infant]. Anesthesiologie 2011;46(10):654-7. doi: [10.1055/s-0031-1291943](http://dx.doi.org/10.1055/s-0031-1291943). [German]** 864  
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- Howarth D. Adult intraosseous access: experiences in a remote emergency department. Australian Family Physician 2011;40(7):510-1** 483  
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- 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  
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- 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, Bebartha 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.
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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.
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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.

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- 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.
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- 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.
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- This article in German discusses use of IO access and its multiple applications, focusing on the EZ-IO Infusion System.
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- 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.
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- 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 (the obvious) 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.
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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.
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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.
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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.

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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.
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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.
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- 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.
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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
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- 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.
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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.
- 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.
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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.
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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.
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- 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.
- 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 goat study, researchers assessed the hemodynamics of hydroxocobalamin (OHCo) and normal saline (NS) by the IO route and concluded that the effects of OHCo given by the IO route in non-CN-poisoned goats are mild and well tolerated.
- 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.

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- 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.
- 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.



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- 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.

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- 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: ILiterature 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 equivalente a 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.
- 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.
- 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.

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- 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,  $1.9 \pm 0.7$  vs. EZ-IO  $1.2 \pm 0.4$ ,  $p < 0.01$ ).
- 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;24:347-50** 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.
- 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](http://www.jems.com/news_and_articles/articles/Fast_or_Easy.html). Accessed 01/24/2008*
- Von Hoff DD, Kuhn JG, Burris 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.

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- Woodsley 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 (EZIO®) for resuscitation: UK military combat experience. JR Army Med Corps 2008;153:314-6** 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-** 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](http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=17169880)
- 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;11:164-71** 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

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- Harrington LL, Rebolz 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%.
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