The Evidence-Based Use Of Intraosseous Lines In Pediatric Patients

Abstract

For pediatric resuscitation, vascular access must be established quickly, often in difficult circumstances. Alternative methods of peripheral access, such as umbilical catheter, central venous lines, venous cut-down, and ultrasound-guided access, may be poor options because of the patient’s age or condition, the urgency of resuscitation, and/or the skill of available clinicians. When peripheral access fails after 3 attempts (or in 90 seconds), an intraosseous line offers emergency clinicians a fast and effective alternative for venous access in children of all ages. They can be inserted within 5 to 60 seconds, and they require little clinician experience or training and minimal equipment. The American Heart Association, the International Committee on Resuscitation, and the American College of Surgeons all recommend intraosseous line use. Although contraindications include existing bone fracture or bone disease, complication rates are similar to central venous catheters. This review looks at the guidelines, recommendations, and evidence on using intraosseous lines in pediatric patients and gives information about mechanical devices used, techniques for insertion, and possible complications.
Case Presentation

It is a quiet Sunday morning in your single-coverage ED when the base station alerts you that they are bringing a 3-year-old girl who is actively seizing. The child’s mother gave rectal diazepam at home and paramedics gave buccal midazolam, but the child is still seizing when she arrives. By this time, she has been actively seizing for 30 minutes. Paramedics were unable to secure a line, and 3 nurses are frantically trying to start an IV as the child thrashes around on the gurney. Your highly skilled charge nurse successfully secures a small line in the foot, but the vein blows during her flush. What should you do now?

Introduction

Vascular access is of paramount importance in emergency care, but before the wide use of intraosseous (IO) lines, establishing a line was often the most difficult aspect of a pediatric resuscitation. Choices for venous access include peripheral venous access, ultrasound-guided peripheral venous access, umbilical venous access, subcutaneous fluid administration with recombinant hyaluronidase enzyme, central venous access, and simplified mini-venous cut-down. However, these alternatives may be age-restrictive (such as with umbilical catheters), more complex (such as with ultrasound-guided venous access and central venous lines, which require specialized skills), and/or more time-consuming (such as with venous cut-down, which requires 6 to 10 minutes). Placing a central line in a pediatric patient presents specific challenges, including achieving proper positioning of the neck, working with patients with large heads (for the internal jugular neck access approach), navigating challenging landmarks and tricky access (for the subclavian approach), mitigating the risk of inadvertent arterial puncture/cannulation, and avoiding hematomas.

In contrast, IO lines are inserted quickly (within 5-60 seconds), are effective, are easy to learn, require little experience, can be used in any age group, and are essential tools in the management of critically ill children. IO lines should be used for first-line access in any coding child and should be placed after 90 seconds or 3 attempts of peripheral access in a critically ill child. IO lines are also useful in circumstances such as volume depletion, shock, burns, or in obese patients. IO lines have the added benefit that the medullary cavity functions as a large, noncompressible vascular space that can be located in the child when other vessels are collapsed and inaccessible. In addition, the most common locations of IO sites are accessible during cardiopulmonary resuscitation (CPR). Lastly, placing an IO line is a skill that can be maintained even if it is not frequently used.

Critical Appraisal Of The Literature

The authors performed an electronic search of PubMed, Ovid MEDLINE®, Google Scholar, and the Cochrane Database of Systematic Reviews. Individual journals were searched for articles on intraosseous access, including American Journal of Emergency Medicine, Annals of Emergency Medicine, Pediatrics, Journal of Emergency Medicine, Lancet, Journal of Trauma, New England Journal of Medicine, and Pediatric Emergency Care. Bibliographies of journal and review articles were searched for additional references. IO device manufacturer websites were also used to obtain information about specific devices.

History Of Intraosseous Lines

Therapeutic IO infusion in humans was first described by Josefsen in 1934 in patients with pernicious anemia. In 1941, Tocantins et al published a report of IO infusion applications in pediatric patients. IO infusions were also used in children during the 1940s, and they were commonly used in soldiers during World War II. Though still used in the military and the Third World, IO line use diminished with the advent of disposable plastic catheters for IV use during the 1950s. In 1977, Valdez published a review of IO infusion and described IO line use in 15 patients, but it was during the 1980s that IO lines were again used in pediatric resuscitation. In 1984, Berg published a report of catecholamine infusion in a 6-month-old, and Orlowski published an accompanying editorial emphasizing the importance of IO line access in critically ill children. IO lines were not originally included in the initial American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) or Pediatric Advanced Life Support (PALS) curricula, but the AHA has supported IO line use since 1986. Two instrumental studies promoting IO line use in resuscitation were published in 1988 by Glaeser and Brunette. In 1988, PALS curriculum recommended IO line use in cases of difficult vascular access in patients less than 6 years of age. IO line use was initially limited to younger children because of difficult penetration of the thicker bony cortex in older children and adults; however, several mechanical IO line devices are now available and have made IO line use in older patients easier. IO line use is now recommended by the AHA, the International Committee on Resuscitation, and the American College of Surgeons Advanced Trauma Life Support® curriculum.

Prehospital Care

The IO line is an important tool for prehospital providers. Several studies have demonstrated that IO
access can be obtained rapidly in the prehospital setting with a high success rate. Learning to obtain IO access is a skill that has a high retention rate even if it is not frequently used.

**Use Of Intraosseous Lines In The Emergency Department**

Bones are inherently vascular. The hard outer bony cortex encloses the inner vascular medullary cortex, and the vessels of this inner cortex drain into the central circulation via the longitudinal Haversian canals and the connecting Volkmann canals. These veins are supported by the firm, bony matrix and are noncollapsible. The marrow circulation is capable of rapidly transporting fluids to the central circulation. It is important to remember during infusion in awake patients that the periosteum of bone contains somatic pain sensors and the IO space contains visceral pain sensors.

**Indications For The Intraosseous Line**

The IO line is used as first-line access in a coding patient and second-line access (after 90 seconds of peripheral access attempt) in a critically ill child. IO lines are also a reasonable alternative in a nonemergency situation where multiple attempts at peripheral access have failed and central line insertion is not indicated or not feasible. The complication rate is similar to central venous catheters, and IO lines require less skill and specific equipment. IO access can be used for medication administration, for fluid therapy, and to obtain diagnostic studies. IO lines have been used in preterm and full-term neonates without major complications, and it may be faster to obtain IO access than to place an umbilical line in a neonate. The development of powered devices has increased success of IO line placement in older children and adults. As a result, ACLS guidelines now recommend IO lines as a second-line option in the resuscitation of an adult. IO lines are a useful adjunct in children who are overweight and thus more challenging to find peripheral veins.

**Contraindications For The Intraosseous Line**

In a stable patient, an IO line should not be used if peripheral access is easily gained. Absolute contraindications include a fractured bone or previous IO line attempt in the same bone. In general, IO access should not be used if there is significant damage to the limb proximal to the site of insertion. Relative contraindications include bone disease such as osteogenesis imperfecta or osteoporosis (bones may be easily fractured during placement) or osteoarthrosis (the bone may be difficult to penetrate). Sites with overlying cellulitis, abscess, or other infection should be avoided. An area with an overlying burn should, ideally, be avoided; however, IO access may be the best option in a severely burned patient or a patient with difficult venous visualization with limited other options. Patients who have a known intracardiac shunt may be at greater risk for cerebral fat or bone marrow emboli. (See Complications Of Intraosseous Lines, page 6.)

**Locations For The Intraosseous Line**

IO access may be obtained in virtually any bone. As children age, the cortex hardens and becomes more difficult to penetrate with manual needles. The proximal tibia is most commonly used, due to clear landmarks, superficial bone, and distance from surrounding structures that could cause significant morbidity, if injured. Common locations of IO lines are shown in Table 1. Use of sternal sites may pose a challenge for cardiac massage during CPR.

**Diagnostic Studies**

**Imaging**

Imaging confirmation of IO line placement is not required or recommended but has been described with the use of fluoroscopy, injection of contrast, and use of ultrasound.

**Laboratory Tests**

Several studies have compared venous blood with bone marrow samples obtained from IO lines. Bone marrow laboratory values that may be used clinically include: glucose, hemoglobin, pH, partial pressure of carbon dioxide (PCO₂), serum bicarbonate,

**Table 1. Common Locations For Intraosseous Lines**

<table>
<thead>
<tr>
<th>Site*</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>Proximal tibia</td>
<td>1 cm below the tibial tuberosity and medially located on the tibial plateau</td>
</tr>
<tr>
<td>Distal femur</td>
<td>Midline, 2-3 cm above the external femoral condyles</td>
</tr>
<tr>
<td>Malleoli sites</td>
<td>1 cm superior to the malleoli in the midline (medial is easier to penetrate than lateral)</td>
</tr>
<tr>
<td>Humerus</td>
<td>Greater tubercle (larger target that may be useful in obese patients). Have patient place his hand on his abdomen and palpate the most prominent aspect of the greater tubercle's outer margins. Use the 45-mm needle if using the EZ-IO®.</td>
</tr>
</tbody>
</table>

*Other sites that have been described include: Distal tibia, Proximal humerus, Sternum (if age > 5 years), Anterior iliac spine, Distal radius, Clavicle, Os calcis.
ate (except after IO bicarbonate infusion), sodium, chloride, blood urea nitrogen, creatinine, serum drug levels, and cultures. There are conflicting data regarding the accuracy of bone marrow potassium values. Blood type and Rh may be accurately obtained from the IO site. Studies that may not be accurate include blood oxygenation, white blood cell count, aspartate aminotransferase, alanine aminotransferase, or ionized calcium. A divergence of pH and PCO₂ between venous and bone marrow values may occur with prolonged resuscitation. Many laboratory tests taken from the marrow space may be inaccurate after prolonged CPR.

**Devices For Intraosseous Lines**

**Manual Devices**

There are several commercially available manual IO needles. An 18-gauge spinal needle or a butterfly needle may also be used, but these needles may bend, and needles lacking a stylet may easily become obstructed with marrow. All marketed IO needles are made of steel to prevent bending, and all have central stylets. Manual needles are more difficult to place in older children because their outer bony cortex is thicker. The most commonly used manual devices include the Dieckmann Modification needle (see Figure 1), the threaded Sur-Fast™ needle (both manufactured by Cook Medical Incorporated Bloomington, IN), and the Jamshidi™ needle (CareFusion Corporation, San Diego, CA). For more information on the use of these products, see Techniques For Inserting And Securing An Intraosseous Line.

**Automatic Devices**

There are 2 spring-loaded devices (the FAST1® and the Bone Injection Gun™) and 1 powered driver (the EZ-IO®) available.

**Fast Access For Shock And Trauma (FAST1®)**

The FAST1® Intraosseous Infusion System (Pyng Medical Corporation, Vancouver, BC, Canada) is a spring-loaded sternal IO infusion device that can be used in adolescents and adults. (The sternal site should not be used in children under the age of 3 years). This device was approved in 1997 by the United States Food and Drug Administration (FDA) for adults and is now approved for children as young as 12 years of age. The device is a hand-powered introducer with several spring-loaded needles. Continuous manual pressure is required to activate the central penetrating needle into the sternal medullary space. First-time success rates in military and prehospital care personnel vary from 55% to 94%.

**The Bone Injection Gun™ (B.I.G.)**

The Bone Injection Gun™ (B.I.G.) (PerSys Medical, Houston, TX) is a small, disposable, spring-loaded automatic IO injector device with a trigger. (See Figure 2.) This device has an adjustable insertion depth between 0.5 cm and 1.5 cm. Because it is trigger-driven, the device must be at the correct location and angle (90°) when triggered. The pediatric needle is 18-gauge and is used for children under 12 years of age. A 15-gauge needle is used for those over 12 years of age. The FDA has approved this device for use in the proximal tibia, but use has been described in other bones.

**EZ-IO®**

The EZ-IO® Power Driver (Vidacare Corporation, San Antonio, TX) is a reusable, lithium battery-powered IO driver with a needle set that was approved by the FDA in 2004 for the tibia and in 2005 for the humerus. (See Figure 3.) The newer, smaller driver averages 300 to 500 insertions, based on utilization. The needles are 15 gauge and color-coded by length. Pink-capped needles are 15 mm long and are for children who weigh 3 to 39 kg. Blue-capped needles are 25 mm long and are used for patients who weigh > 39 kg. Yellow-capped needles are 45 mm long and are available for patients with extra tissue over the insertion site, such as obese patients (ie, patients with a body mass index [BMI] > 30), and are recommended for proximal humerus insertion. For insertion, the EZ-IO® disposable needle is attached to the powered driver. The needle is then placed at the skin at 90°, and the trigger on the driver is depressed to activate the needle. The manufacturer recommends applying only gentle pressure to the site with the driver, as applying too much pressure can cause the device to stall. Some have described twisting of the skin or the operator’s glove becoming stuck in the driver unless only gentle pressure is applied.

**Figure 1. Dieckmann Modification Intraosseous Infusion Needle**

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Effectiveness Of Devices
Several studies have evaluated the effectiveness of powered IO insertion devices. The EZ-IO® has been shown to be fast, easy to learn, and effective. Calkins et al compared 4 devices in an unblinded crossover study. The FAST1®, Bone Injection Gun™, SurFast®, and Jamshidi® needles were all rated as easy to learn and easy to use. Leidel et al compared the Bone Injection Gun™ and the EZ-IO® devices and found no statistically significant difference between the 2 devices. The sternal location used in FAST1® may interfere with resuscitation efforts. A disadvantage of the Bone Injection Gun™ is that the device may only be used once per patient. As stated previously, automatic devices are easier to use in older children and adults as compared to manual devices. An additional disadvantage of manual needles is that they often protrude far above the skin, which increases the risk of dislodgment; however, proper insertion technique can mitigate that risk.

Techniques For Inserting And Securing An Intraosseous Line
Place a towel roll under the knee if the proximal tibial or distal femur site is being used. Cleanse the area with chlorhexidene, chlorhexidine, povidone-iodine, or an alcohol-based antibacterial solution. If the patient is conscious, consider injection of local anesthesia to the placement site. Be careful to only instill the minimal amount required for this, as the tissue swelling from the injection may be difficult to differentiate from potential extravasation that can occur from the IO infusion itself. If using a manual needle, introduce the needle perpendicular to the bone, twisting the needle back and forth while applying pressure. The importance of avoiding the growth plate in long-bone IO insertion cannot be overemphasized.

A “pop,” or decrease in resistance, is felt once the needle passes through the bony cortex and into the marrow. Penetration of the inner cortex typically occurs around 1 cm but may vary, depending on the age of the child and the amount of overlying soft tissue. After penetration, attempt bone marrow aspiration. Smaller needles cannot aspirate bone marrow well, and it may take a considerable amount of force to successfully aspirate. Even if aspiration does not occur, the needle may still be in the correct location. Correct placement is confirmed if aspiration is successful, if infusion occurs without evidence of extravasation, and if the needle stands alone and appears firmly in place. Once placement is confirmed, the needle and tubing should be secured to prevent dislodgement. The ideal method for securing the line allows for visualization of the surrounding tissue to monitor the site for signs of extravasation. One potential method is to secure the IO needle with a hemostat or needle driver. The hemostat or needle driver’s teeth are clicked on the IO needle at the insertion site, then the rings of the hemostat or needle driver are well-secured with tape and gauze, away from the IO line.

Infusion through an IO line often requires a pump, pressure bag, or manual infusion with a syringe due to resistance to flow through the medullary space and into the central circulation. Use of a pressure bag can increase risk of extravasation if the needle is not seated properly in the bone. Although awake patients have described minimal pain with actual IO line placement, it is commonly reported that fluid infusion through the bone marrow is painful. To avoid significant discomfort, lidocaine may be infused prior to IO infusion in an awake patient. The typical recommendation is 2% preservative-free lidocaine at a dose of 0.5 mg/kg for patients weighing 3 to 39 kg and 20 to 40 mg in patients who weigh more than 39 kg.

Drug Infusion With Intraosseous Lines
In general, anything that can be given through a central line can be safely administered by the IO route. Drugs given via IO access have a comparable onset of action and drug levels to venous sites; however, time to peak concentration is likely somewhat longer. This is likely of limited clinical significant except in situations where seconds matter, such as in rapid sequence intubation. Providers should be aware that succinylcholine given via IO line may take 20 to 30 seconds longer to achieve paralysis than if administered intravenously.
Multiple studies have been performed comparing serum and bone marrow levels as well as measuring serum drug levels and clinical effectiveness after IO administration. The preliminary studies were in animals, but multiple clinical reports in humans have been performed. A depot effect (lower peak serum levels and longer period of elevated drug levels) may occur with IO infusions. Lower serum concentrations of ceftriaxone, chloramphenicol, phenytoin, tobramycin, and vancomycin may be observed. This may be partially offset by the administration of 3- to 10-mL sodium chloride 0.9% flush after drug administration. Adenosine has been used successfully via IO injection in case reports; however, there are also reports of failure. IO access has been described for administration of radiologic contrast. There may be some retained contrast material within the marrow that may cause a radiographic band of increased metaphyseal density within hours after the infusion. A fictitious fracture has been reported after contrast administration. In this case, contrast material had extravasated from the bone marrow cavity and infiltrated the subperiosteal space along the tibia, creating the impression of a fracture of the shaft of the tibia. If the IO route is used for contrast, a low osmolality agent is recommended to decrease complications of surrounding tissue necrosis if extravasation occurs.

**Complications Of Intraosseous Lines**

The rate of major complications from IO infusions is relatively low. The more frequent, minor complications include difficulty securing the line, dislodgement, and infiltration of surrounding tissue. Localized cellulitis and subcutaneous abscess may rarely occur.

The most common minor complication described is fluid extravasation, which may occur approximately 12% of the time. The risk of extravasation increases if more than 1 attempt is made. Fluid extravasation is likely the mechanism behind rare, but more serious, complications such as compartment syndrome. In an animal study, the needle type (threaded vs nonthreaded) was not shown to affect extravasation rate.

There are several recommended steps to reduce extravasation and its potential sequelae:

- Limit attempts to 1 for each long bone.
- Ensure proper needle position (see confirmation).
- Secure device well, but monitor site frequently for extravasation (especially if using an infusion pump).
- Immobilize the extremity.

Significant complications are rare. Several major complications have been described in case reports, as listed in Table 2. There have not been any studies large enough to adequately describe major complication rates in the era of powered IO insertion.

**Osteomyelitis**

The overall risk of osteomyelitis is less than 1% with IO infusions. Rosetti et al reported a 0.6% incidence of osteomyelitis in 4270 IO infusions. Conditions that increase risk of osteomyelitis include aseptic techniques, prolonged IO line use, bacteremia, and

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**Clinical Pathway For Intraosseous Line Placement**

1. **Critically ill child**
2. **Pulse?**
   - **NO**
     - Immediate IO line placement
   - **YES**
     - 3 peripheral IV attempts OR for 90 seconds
     - Failure of IV access

For locations for IO line placement, see Table 1, page 3.

Abbreviations: IO, intraosseous; IV, intravenous.
the infusion of hypertonic fluids.52,62 Heinild’s study in 1947 showed a 13% incidence of osteomyelitis with hypertonic fluids (50% glucose or concentrated serum).87 IO lines should be considered temporary and, ideally, used for less than 8 to 12 hours. Maximum-use time for an IO line should be 24 hours.80

**Compartment Syndrome**

There are several case reports in the literature of compartment syndrome after IO line placement. In these cases, the patients had a complex medical history,79 prolonged resuscitation with multiple medications administered,78 or prolonged infusion time.80,81 Compartment syndrome is likely caused by extravasation of fluids into tissues surrounding the intended placement site and should be carefully monitored. From a patient safety standpoint, protocols and/or documentation that the site is checked frequently while other vascular access is being attempted is important.

**Fracture/Growth Plate Injury**

Fracture as a reported complication of IO line use presents in case reports, although it is rare.84 Growth plate insertion is a proposed theoretical risk, but there is no evidence to suggest long-term growth effects occur with the use of IO infusions. Several small studies have prospectively evaluated tibial growth after IO infusion in humans, and no appreciable growth disturbances were noted.88,89 Animal studies have not demonstrated growth disturbances when the needle was intentionally inserted into the growth plate and hypertonic sodium bicarbonate was injected directly into the epiphyseal plate.90,91 Growth plate insertion is best avoided by being cognizant of the growth plate location using landmarks and palpation as well as by not forcing the IO needle such as to cause a fracture in the vicinity.

**Table 2. Minor And Major Complications Of Intraosseous Line Insertion**

<table>
<thead>
<tr>
<th>Minor Complications</th>
<th>Major Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extravasation</td>
<td>Osteomyelitis74</td>
</tr>
<tr>
<td>without significant sequel</td>
<td>Fat embolism75,75</td>
</tr>
<tr>
<td>Cellulitis</td>
<td>Compartment syndrome77,81</td>
</tr>
<tr>
<td>Abscess</td>
<td>Growth plate abnormalities82</td>
</tr>
<tr>
<td>Failed placement</td>
<td>Myonecrosis with hypertonic saline infusion4,81</td>
</tr>
<tr>
<td>Needle obstruction</td>
<td>Fracture4</td>
</tr>
<tr>
<td>Needle dislodgment</td>
<td>Leg amputation85</td>
</tr>
<tr>
<td>Necrosis in surrounding muscle and subcutaneous tissues</td>
<td></td>
</tr>
</tbody>
</table>

**Bone Marrow Emboli Or Fat Emboli**

Fat embolism has been reported in animal models and has been reported once in humans.76,92 There is potential risk of air/fat embolism, but studies have not yet substantiated these potential sequelae. Though emboli have been found on autopsy after IO infusion, the clinical significance is unclear. Animal studies have not shown a change in partial pressure of oxygen (PO2) that correlated with degree of emboli. It is prudent to consider the increased risk in a patient that has a known intracardiac shunt,31 but this is oftentimes not known, such as in patients with small patent foramen ovale. One study documented a patient who died from an undetermined cause after an IO line placement and was found to have an arterial artery embolism as well as a patent foramen ovale.93 Animal studies suggest that the presence of fat emboli in the pulmonary parenchyma seems to be independent of the method of IO fluid administration. IO infusion during CPR does not increase the incidence of fat and bone marrow embolism.75

**Sternal/Thorax Injury**

There have been documented cases of mediastinitis, hydrothorax, or injury to heart or great vessels with sternal IO lines in adults. As previously mentioned, sternal sites should not be used in children under 3 years of age because the bone is thin and easy to penetrate completely.

**Necrosis**

Skin necrosis94 and myonecrosis83 have been reported, likely due to extravasation of caustic substances. The risk of local skin necrosis can be reduced by placement verification prior to fluid administration (see Techniques For Inserting And Securing An Intraosseous Line, page 5), careful monitoring for infiltration, and prompt removal after venous access is obtained.

**Leg Amputation**

Leg amputation has been reported in complicated cases. One case was related to popliteal artery thrombosis and compartment syndrome in a 7-month-old child,85 and another case occurred after cardiac arrest with multiple drug infusions in a child with hemolytic uremic syndrome and compartment syndrome.95

**Arterial Thrombosis**

Arterial thrombosis has been described.85 In the earliest report in 1944, it was theorized that the thrombosis may have been related to the adhesive stripping down of the leg for complete immobilization.96

**Disposition**

IO access is typically reserved for the child that is critically ill, and virtually all of these children...
require admission for their underlying illness. An IO line is a temporary measure and should be used only until more permanent access can be secured. Ideally, an IO line should be used for 8 to 12 hours and no more than 24 hours.\(^8\) Although IO lines have been used for as long as 4 days, prolonged infusion times are associated with an increased rate of both minor and major complications.

During both the emergency and intensive care course, the IO site should be frequently monitored for signs of extravasation such as soft-tissue swelling, edema, discoloration, and pain (if the child is alert) as well as perfusion of the utilized distal extremity.

### Risk Management Pitfalls For Intraosseous Lines

1. “My needle became dislodged, so I put it back in the same place.”
   Do not make more than 1 attempt in the same bone. Multiple attempts increase the risk of fluid extravasation, which may result in more serious complications such as compartment syndrome.

2. “I couldn’t aspirate marrow, so I assumed that I was in the wrong spot and took out my needle.”
   A smaller-gauge needle may not be able to aspirate marrow even it is if correctly placed. Attempt to flush the line with normal saline even if you are unable to aspirate marrow.

3. “The line aspirated and flushed well, but the fluids infused slowly, so we removed the line.”
   IO lines flow more slowly than peripheral lines at gravity. To counter this, a pressure bag, infusion pump, or manual injection with a syringe will improve the infusion rate.

4. “The fluid was infusing well with a pressure bag, and I didn’t notice the leg swelling.”
   Extravasation is a common minor complication. This minor complication can lead to more severe complications, such as compartment syndrome, if not carefully monitored. Secure the line so frequent assessment for complications can occur.

5. “The IO needle went in without difficulty, but the child began screaming once we started fluid infusion. We removed the needle because we assumed that the needle was not properly placed.”
   IO needle insertion has been described as only mildly painful; however, bone marrow infusion causes significant discomfort. Lidocaine should be infused prior to fluid administration in an awake child. Preservative-free 2% lidocaine at 0.5 mg/kg (up to 39 kg) or 20 to 40 mg (> 39 kg or in adults) is recommended.

6. “I didn’t place an IO line because the child had > 90% total body surface area burn, so I couldn’t find a place where there wasn’t overlying burn.”
   Although placing an IO line at a site with overlying burn is not ideal, it may be the best available option in a severely burned and critically ill child.

7. “I tried once, but I couldn’t get the IO line into a critically ill 7-year-old child with a manual needle, so I have given up on using them.”
   The bony cortex becomes harder to penetrate with manual needles after 3 to 5 years of age. Powered and spring-loaded devices have made it easier to place IO needles in older children and adults and have significantly improved the placement success rate.

8. “The child was severely dehydrated and peripheral access was difficult to obtain, but an IO line seemed quite extreme. I just wanted to give the nurses more time.”
   IO lines have a relatively low serious complication rate and should be second line to peripheral attempts in any critically ill child. Because of speed of access, it is the recommended first-line option in a coding child and a second-line option in a critically ill child after 90 seconds or 3 attempts for a peripheral line.

9. “The IO site was working well and we had no intensive care unit beds, so we kept using it during the 30 hours that the child was waiting for a bed.”
   IO lines should be considered a temporizing measure and, ideally, used for only 8 to 12 hours. Twenty-four hours should be considered the maximum amount of time the line should be used.

10. “The complete blood count taken from the bone marrow showed blasts, so I told the mother that her child had leukemia.”
    Most tests have good correlation between bone marrow and venous samples. The white blood cell number is unreliable, however, and blasts may be seen in normal children.
Summary

IO access is safe, fast, and effective. IO line placement is an essential skill for all emergency clinicians who are involved in the critical care of patients. IO lines should be used immediately in a child that is coding or within 90 seconds or 3 attempts of peripheral IV in a critically ill child. Manual needles are often preferred for infants, and automatic devices are preferred for older children and adults. A fractured bone is the only absolute contraindication for placement. Confirmation of placement involves aspiration of marrow, ability to flush the line without resistance or soft-tissue swelling, and the needle standing firmly in place and able to stand alone. Fluid infusion into the bone marrow is painful, so lidocaine should be infused first if the patient is awake. A pressure bag or infusion pump is recommended to improve speed of flow. Any fluid, medication, or blood product may be given via IO access. Serum and marrow levels of glucose, electrolytes, hemoglobin, drug levels, blood group typing, and renal function correlate well. The correlation decreases with prolonged CPR. IO lines are a temporizing measure and should be a bridge to more definitive access, as longer infusion time is associated with increased complications. Ideally, an IO line is used for 8 to 12 hours and not longer than 24 hours. Minor complications such as extravasation occur about 12% of the time. Serial monitoring of the site for extravasation should occur, since more serious complications can occur if it is not carefully monitored. The most common serious complication is osteomyelitis, which occurs approximately 0.6% of the time. Rarer complications, such as compartment syndrome, have been reported, but they usually occur in association with unrecognized extravasation.

Case Conclusion

Access was obtained in the proximal tibia with an IO needle, and the child’s seizure was stopped by IO administration of lorazepam, followed by fosphenytoin infusion. The IO line was secured within 30 seconds by an intern who had only previously placed IO lines on chicken legs in a simulation scenario. The line was secured by hooking a hemostat to the needle base and taping the rings of the hemostat to the leg distal to the IO site. Nurses monitored the site and documented the absence of swelling or discoloration every 10 minutes during the fosphenytoin infusion. Peripheral access was later secured by nurses after the patient was stabilized. The child made a good recovery and was discharged at her baseline condition 2 days later. She had no noted complications from her IO line.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

The most informative references cited in this paper, as determined by the author, will be noted by an asterisk (*) next to the number of the reference.


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1. What is an absolute contraindication to IO placement?
   a. An awake patient
   b. Fractured bone
   c. Overlying burn
   d. Viral exanthem

2. Which laboratory values are not accurate when aspirated from bone marrow through an IO line, as compared to peripheral samples?
   a. Blood type
   b. Glucose
   c. Hemoglobin
   d. White blood cell count

3. All of the following are signs that confirm the placement of an IO line EXCEPT:
   a. Aspiration of bone marrow
   b. Fluid infuses without extravasation
   c. Needle stands alone without support
   d. Painless infusion
4. Which medication may take 20 to 30 seconds longer to take effect when delivered via IO line?
   a. Ceftriaxone
   b. Succinylcholine
   c. Penicillin
   d. Adenosine

5. Which one of the following is NOT a possible effect of medications delivered via IO line?
   a. Depot effect
   b. Delayed reaction
   c. Lower serum concentration
   d. Shorter time to peak concentration

6. What is the most common minor complication of IO lines?
   a. Compartment syndrome
   b. Fluid extravasation
   c. Fracture
   d. Growth arrest

7. All of the following are ways to reduce the risk of extravasation EXCEPT:
   a. Using a threaded needle
   b. Making only 1 attempt for each long bone
   c. Securing the device
   d. Immobilizing the extremity

8. What is the most common major complication of IO lines?
   a. Amputation
   b. Arterial embolism
   c. Compartment syndrome
   d. Osteomyelitis

9. What is the maximum number of hours an IO line should be used?
   a. 4 hours
   b. 8 hours
   c. 24 hours
   d. 30 hours

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EB Medicine
1-800-249-5770
Outside the U.S.: 1-467-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150
Norcross, GA 30092
E-mail: ebm@ebmedicine.net
Website: EBMedicine.net
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