Infant Intraosseous Infusion

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Abstract

Neonatal health care providers are fortunate that the umbilical cord generally provides easy intravenous (IV) access for newborn patients. Outside of the immediate newborn period, however, it may be impossible to obtain peripheral or umbilical IV access in critically ill newborns. Intraosseous (IO) infusion is not widely used in the neonatal population, but is a viable option when IV access cannot be established quickly. This article examines IO infusion devices and placement sites and addresses assessment and care of the infant receiving IO fluids and medications.

In the NICU setting, it is very rare that intravenous (IV) access cannot be obtained, whether via the umbilical venous route or the peripheral.[1] However, what about these situations: the three-week-old infant who becomes septic and the umbilical vein is no longer an option or the four-day-old infant who presents to the emergency department in cardiac arrest with yet undiagnosed congenital heart disease? In infants such as these, where immediate IV access is needed but unobtainable, intraosseous (IO) line placement should be considered as a first-line option.[1,2]

UMBILICAL VEIN VERSUS IO ACCESS

IO infusion is not a new concept. The technique was first described in the early 1920s, but then "went away" with the absence of military conflict; the nonexistence of formalized emergency medicine; and to some extent, the introduction of plastic IV catheters.[1,3] Use of IO access is reemerging with the advent of more advanced user- and patient-friendly devices. Renewed interest has been seen in the adult, and especially the pediatric populations. In neonatal patients, however, the procedure has yet to be widely accepted, although it has been performed for many years with neonates and infants.[1,4–13]

In a sick newborn, the umbilical vein (UV) can be easily accessed to administer fluids and/or medications. Techniques for UV placement range from the "emergency just past the skin" technique to placement of a formal UV line that terminates above the diaphragm. Although this technique, in experienced hands, can be accomplished relatively quickly, it is not without potential serious complications, including thrombus formation, hepatic necrosis, intestinal ischemia, and hemorrhage.[14] In the emergency department or prehospital setting, where most practitioners have considerably less neonatal peripheral IV and UV placement experience, the IO route has been shown to be a faster and easier option.[2,15]

PHYSIOLOGY AND MEDICATIONS

Bone marrow is tissue located in the center of larger bones. The marrow cavity, also called the intramedullary space, is a highly vascular component of the bone and has a direct connection to the venous system. Unlike peripheral veins, even in shock states the intramedullary space functions as a "noncollapsible vein." Fluids and medications injected into the intramedullary space, as occurs with an IO infusion, quickly enter the bloodstream (Figure 1).[1]

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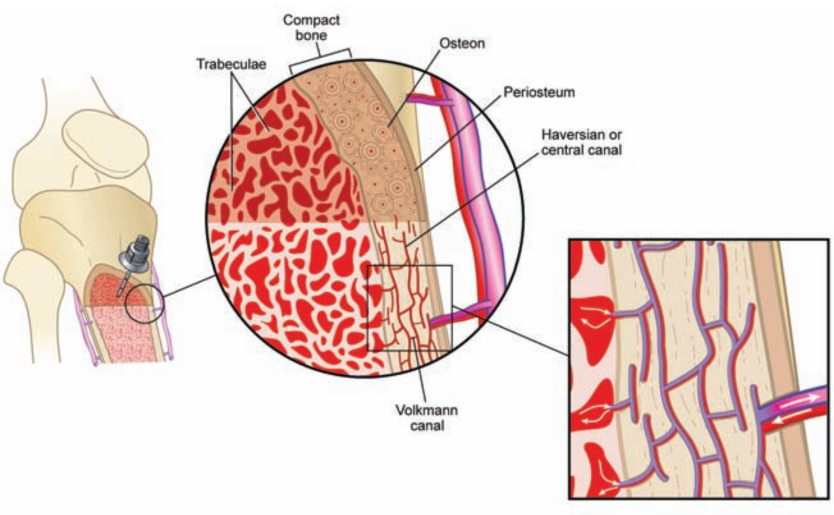
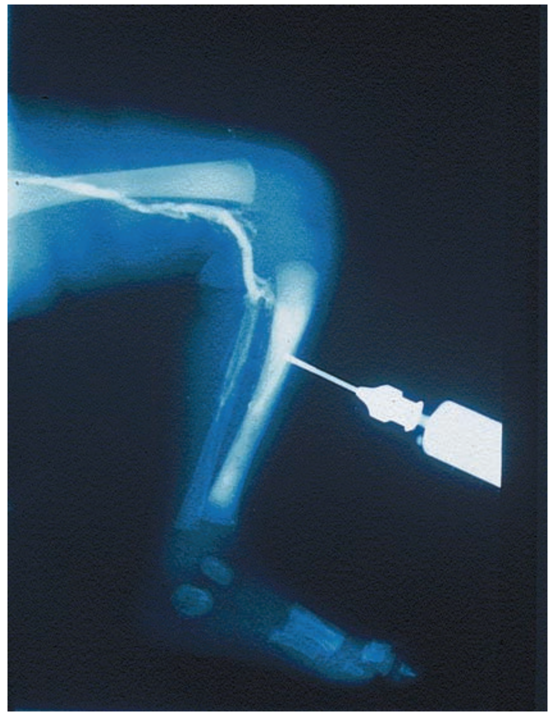
FIGURE 1 ■ Intraosseous blood flow.



Courtesy of Vidacare, www.vidacare.com

FIGURE 2 ■ Radiograph demonstrating IO flow.



Courtesy of WaisMed, www.waismed.com

Nearly all types of intravenous fluids and medications can safely be administered via the IO route in emergency situations. When an IO line is placed, medical and veterinary research and case studies show that common resuscitation medications, antibiotics, fluids, and even blood products can be administered via the IO route (Table 1).[1,16–18] Interestingly, in animal studies simulating pediatric and adult resuscitation situations, medications administered via the IO route reached the central circulation almost as fast as those administered via central line.[19,20] As for all patients in the NICU, fluids and infusions should be regulated via an infusion pump. This is

TABLE 1 ■ Common Fluids and Medications That Can Be Administered via the IO Route

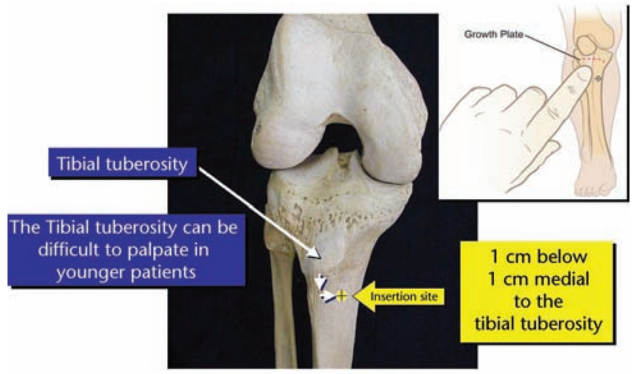
Analgesics, Anesthetics, Anticonvulsants, and Sedatives	Antibiotics	Fluids	Neuromuscular Blockers	Resuscitation Medications	Miscellaneous
Diazepam	Amikacin	Blood products	Atracurium	Adenosine	Antitoxins
Fentanyl	Ampicillin	Dextrose	Pancuronium	Atropine	Contrast media
Ketamine	Ceftoxamine	Hypertonic saline	Rocuronium	Calcium chloride	Dexamethasone
Lorazepam	Ceftriaxone	Lactated Ringer’s	Succinylcholine	Dextrose *(dilute if using D_{50})*	Diazoxide
Midazolam	Clindamycin	Normal saline	Vecuronium	Digoxin	Heparin
Morphine	Gentamycin			Dobutamine	Insulin
Pentothal	Sulfadiazine			Dopamine	Methylene blue
Phenobarbital	Vancomycin			Ephedrine	Methylprenisolone
Phenytoin				Epinephrine	Prostaglandins
Propofol				Isoproterenol	Vitamins
				Lidocaine	
				Sodium bicarbonate *(dilute if possible)*	
				Vasopressin	

Adapted from: Dubick, M., & Holcomb, J. (2000). A review of intraosseous vascular access: Current status and military applications. *Military Medicine, 165,* 552–559, and Revenis, M. (2002). Intraosseous infusions. In M. MacDonald & J. Ramasethu (Eds.), *Atlas of procedures in neonatology* (pp. 381–384). Philadelphia: Lippincott.

TABLE 2 ■ Selected Neonatal/Infant Intraosseous Infusion Cases

Reference	Number of Neonatal Patients	Age or Weight and Indications for IO
Heinild et al.[21]	3	Preterm infants weighing 1,150 gm, 1,200 gm, and 1,750 gm for resuscitation
Nasimi et al.[48]	1	34 weeks preterm for sepsis
Ramet et al.[12]	1	800 gm preterm for resuscitation
Ellemunter et al.[4]	27	20 preterm and 7 term infants for respiratory distress, perinatal asphyxia, or congenital heart disease (NOTE: Smallest neonate with IO was 515 gm)
Tomar and Gupta[13]	2	34 weeks preterm for sepsis at 9 days of age Term infant with hemorrhagic shock (out-of-hospital delivery)

FIGURE 3 ■ Anterior tibial IO insertion site.



From: Boon, J., Gorry, D., & Meiring, J. (2003). Finding an ideal site for intraosseous infusion of the tibia: An anatomical study. *Clinical Anatomy, 16,* 16.

especially important with IO infusions because although fluid boluses can be given with a syringe, gravity flow rates are unpredictable with IO infusions (Figure 2).[1]

CONTRAINDICATIONS

There are only two true contraindications to IO placement: (1) fracture of the bone and (2) a recent IO attempt in the same bone. Fluids administered into a bone with a fracture or previous puncture can extravasate into the surrounding tissues.

Relative and very rare relative contraindications include osteogenesis imperfecta, severe osteoporosis, and cellulitis over the insertion site.[1,14]

Prematurity is not a contraindication. The procedure has been performed in neonates weighing as little as 515 gm (Table 2).[4,12,13,21]

FIGURE 4 ■ Jamshidi IO needle.

Courtesy of Cardinal Health, www.cardinalhealth.com

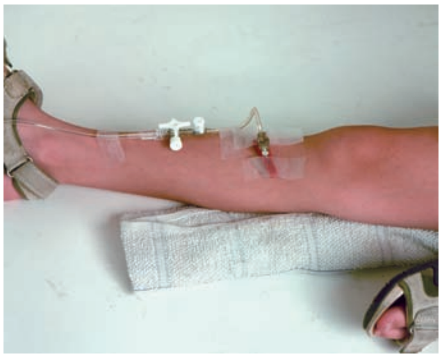
INSERTION SITES

In the pediatric and neonatal literature, the tibia and, less commonly, the femur are described as potential IO sites.[8,22] In the adult literature, although the tibia is the most common site, case reports also detail placement in the manubrium, radius, ulna, proximal humerus, anterior and posterior pelvis, calcaneus, and clavicle.[23,24] For newborns and infants, the proximal and distal tibial routes should be considered the most ideal sites.[1,25] The rationale for preferring the tibial route during resuscitation or other critical situations stems from ease of access, site familiarity, as well as distance from the primary efforts of chest compressions and airway management. In patients who have not developed a palpable tibial tuberosity (generally those less than three years of age), the proximal tibial site is determined by finding the location two finger widths (approximately 15–20 mm) distal to the patella and then medially along the flat aspect of the tibia. The distal tibial site is found by identifying the location two finger widths proximal to the medial malleolus and then again along the medial, flat aspect of the tibia. A good reminder is to think "big toe—IO" to ensure placement on the medial aspect of the patient's leg (Figure 3).[1,14,25]

FIGURE 5 ■ Cook IO needle.

Courtesy of Cook Medical, www.cookmedical.com

FIGURE 6 ■ Stabilization of IO device.



Courtesy of WaisMed, www.waismed.com

FIGURE 7 ■ Aspiration of bone marrow from tibial IO.

Courtesy of WaisMed, www.waismed.com

Some older case reports in the literature describe the use of spinal and butterfly needles for IO placement. However, the majority of the articles in the literature refer to using "traditional" IO needles such as the Jamshidi (Cardinal Health, Dublin, Ohio) or the Cook (Cook Medical, Bloomington, Indiana) (Figures 4 and 5).[26] These devices are placed using a twisting motion until a change in resistance (commonly called a "pop" or "give") is felt. Insertion (after local anesthesia if the baby is conscious or responsive to pain) should be made at a 90-degree angle to the bone. There is no evidence to suggest the need for a 10- to 15-degree slant away from the growth plate. This myth continues to permeate the literature, but is not supported in IO-related radiologic reviews.[25] Further, angling the IO on insertion can lead to difficulty with both initial stabilization and subsequent use. Although the needle should be "self-supporting," continuous stabilization of the device with tape and possibly gauze is recommended (Figure 6).[1,14,18,25] The stylet is then removed, and attempts at aspirating a small amount of bone marrow can be made. A section of extension tubing, preflushed with normal saline, is secured to the IO needle so that fluids or medications can be administered.

During the insertion of any IO device, it is crucial to secure the area manually to minimize motion during insertion. Also, with placement in the tibia or femur, a small towel, but never the practitioner's hand, can be placed under the insertion site because inadvertent movement, excessive pressure or force, or even slipping could result in the device's either missing the intended location or going through the patient's leg and entering the practitioner's hand.[4,6,22,23,27]

VERIFICATION OF PLACEMENT

A review of the literature identified several ways to confirm proper initial placement of the IO device. With traditional IO insertion devices such as the Cook or the Jamshidi needles, a "pop" or "give" can be felt as the needle set passes into the spongy, or cancellous, bone. In pediatric and adult patients, the needle should be able to "stand at attention" without assistance because it is supported by the hard bony cortex. In neonates, however, with their smaller and thinner bones, it is crucial to ensure that the IO device is always stabilized to prevent inadvertent dislodgment and extravasation.

After initial placement of the IO device, bone marrow can often be aspirated and sent for laboratory studies such as complete blood count, blood culture, and chemistries (Figure 7).[1] However, the absence of bone marrow aspirate is not necessarily an indication of an improperly inserted IO needle.

An initial fluid flush of a few milliliters of saline should push easily. Although initial radiographs and repeated measurements of the extremity and or extremity circumferential pressure can be done to determine appropriate placement (Figure 8), there is no substitute for careful and regular clinical examinations of the site for swelling or bleeding. This is especially important during and after each fluid bolus or medication administration and should be continued throughout the time that the IO device is in place. Assessment should include palpation of the soft tissue surrounding the device, aspiration, and evaluation of distal circulation. Swollen tissues can be an early sign of infiltration.[1,14,28]

REMOVAL TECHNIQUE

IO infusion should be limited to providing emergency vascular access, and the device should be removed once the patient has secure, alternative vascular access (such as a peripheral or a central line) in place. The IO needle can then be gently removed in 90- to 180-degree back-and-forth rotational movements from the bone, and a light sterile gauze or other dressing can be placed over the site.[14] After the IO device is removed, the site must be monitored for any evidence of bleeding, swelling, or signs of infiltration.

COMPLICATIONS

Although the literature does not substantiate this concern, the most feared complication of IO device placement seems

FIGURE 8 ■ X-ray of tibia with IO in place.

Courtesy of WaisMed, www.waismed.com

FIGURE 9 ■ EZ-IO PD.

Courtesy of Vidacare, www.vidacare.com

to be osteomyelitis. When sterile technique is utilized for IO placement, however, and the IO is removed promptly when acceptable peripheral/central access is obtained, the rate of osteomyelitis is quite low.[29–31] Although osteomyelitis is reported primarily in case reports, in the largest study detailing 4,200 cases of IO placement in infants and children, osteomyelitis was seen in 0.6 percent of cases, occurring only when the infusion continued for a prolonged period of over 24 hours or if the patient was bacteremic at the time of infusion.[30]

Fat emboli that occur as a result of the introduction of the needle into the bone marrow[4,32,33] and inhibition of bone growth,[34] though theoretical concerns and possibilities, have not been shown to be of clinical consequence post–IO device placement. Bone fractures have been reported in pediatric patients after IO placements; however, they also are very rare and are generally associated with poor technique and excessive insertion pressure.[1]

Another possible complication of IO infusions—and in our experience, a bigger concern than osteomyelitis—is compartment syndrome, which is an acute increase in swelling and tissue pressures most commonly seen in the extremities (although it may also occur in the abdomen). The resultant decrease in perfusion to the surrounding or distal areas may have serious consequences. Compartment syndrome can result from the infiltration of fluids into the subcutaneous tissues, either with the initial misplacement of the IO needle or even hours later. Remember that IVs are placed through skin and a vascular wall, both of which "give a little." IOs are placed through bone, which doesn't and therefore unavoidable tiny movements will eventually cause the point of insertion to enlarge. Regular and repeated assessments of the site and surrounding tissues can greatly decrease the potential for compartment syndrome to occur. During these assessments, infiltration or extravasation can be identified at the early stages and the IO device promptly removed. There are only a small number of pediatric and adult case reports and anecdotal stories of this complication occurring with the infiltration of fluids and resuscitation medications, with none specifically in neonates. However, if not detected early, emergency fasciotomies and even amputations have been required post–IO compartment syndrome.[1,35]

IO DEVICES: A NEW GENERATION

For decades, medical professionals used traditional IO needles. However, recent equipment innovations have proved to be remarkably effective, user friendly, and safe. The bone injection gun (WaisMed Ltd., Houston, Texas) has been in use for ten years and the EZ-IO PD (Vidacare, San

FIGURE 10 ■ Bone injection gun.

Courtesy of WaisMed, www.waismed.com

Antonio, Texas) for a year. With the introduction of this new generation of devices, IO infusion has exploded as a means of obtaining emergency venous access, not only in the pediatric population, but also with infant and adult patients.[22] Several infant and pediatric studies (approximately 175 patients over two years, with the smallest infant weighing 1.5 kg) as well as adult IO studies with these newer IO devices found the complication rate to be 0 percent with a nearly 100 percent successful initial placement rate.[5,24,36–38]

EZ-IO Bone Drill

The EZ-IO (Vidacare, San Antonio, Texas) is a reusable battery-powered orthopedic drill that comes with single-use specialized sterile IO needles to be attached to the drill (Figure 9). Vidacare originally introduced the system for adult IO access (EZ-IO AD) and has recently introduced a pediatric model as well (EZ-IO PD). Although the published research on this device focuses primarily on its use in adults (patients weighing >40 kg), in several countries, including the U.S., the U.K., Africa, and Australia, there have now been substantial company-reported uses of the EZ-IO AD and EZ-IO PD in infants, children, and adults in prehospital and emergency department environments. To date, however, nothing has been published concerning use of the device specifically with neonates.[23,36,37,39]

Bone Injection Gun

The bone injection gun (WaisMed Ltd., Hertzeliya, Israel) infant/pediatric and adult models are spring-loaded IO devices (Figure 10). The practitioner simply "pulls the trigger," and the IO is inserted to a predetermined depth, which can be adjusted for the age of the patient. The caregiver needs simply to know the patient's age in years (0–3 [0.5–1 cm depth], 3–6 [1–1.5 cm depth], 6–12 [1.5 cm depth]) and to set the adjustment feature for the applicable age span, and the IO will be inserted to the appropriate depth.[23,40–46] For newborn patients, turning the device to the "0" line allows the needle to be inserted 0.5 cm. For a one year old, the device should be dialed 1/3 above the "0–3" line, while a five year old should have the device dialed 2/3 above the "3–6" line. For the past ten years, in more than 30 countries, including the U.S., the U.K., Israel, the Netherlands, and Germany, WaisMed reports that neonatal/pediatric intensive care units and delivery rooms, as well as emergency departments and emergency medical services agencies, have been using the device for placement of IOs in newborns, children, and adults, when conventional access could not quickly be obtained.[5,24,38,46]

NURSING IMPLICATIONS

IO infusions require ongoing assessment to ensure that the device is functioning appropriately. Assessment of IO and IV sites is quite similar. As with the IV route, an IO infusion may infiltrate into the surrounding subcutaneous tissues. It is essential to closely monitor and frequently palpate the surface area surrounding the device for swelling, discoloration, or pitting edema. Fluid in the extravascular space will collect at the lowest point, so it is important to palpate on the posterior surface of the leg and under the gauze for signs of infiltration. IO devices may be saline locked with a 5–10 ml flush of saline given every four to six hours.

As in the IV route, resistance to flow of fluids or medications and pump pressure alarms may indicate device misplacement. High infusion rates and hypertonic solutions may lead more quickly to infiltration. Any change in condition or failure of the patient to respond to resuscitative therapies may indicate that the device is not functioning—and calls for immediate inspection and evaluation of the IO site and device.

IO devices are now more neonate friendly, and needle sizes that suit the size of patients managed within the scope of neonatal practice are available. Because of the experience and expertise of their staffs, pediatric intensive care units and emergency departments are excellent resources for assistance in choosing a device that is best suited for neonates.

The infrequency with which IO infusion is required does not support training and ongoing competency evaluation for a large group of nurses. However, units might consider training a core group of experienced bedside or advanced practice nurses in insertion technique. Care of the infant requiring IO infusion might be included as part of annual NICU competencies.

CONCLUSION

A sound evidence-based practice using IO access in the neonate will likely never be possible because IV access is obtained in nearly all delivery room and neonatal intensive care situations where access is required. As a result, it is doubtful there will ever be a large randomized clinical trial to study this issue. The International Liaison Committee on Resuscitation did not address the use of neonatal IO access in its most recent recommendations, likely because the current literature on the topic is limited primarily to case reports.[47]

Despite the paucity of evidence, there appears to be a place as an emergency procedure for the IO technique for establishing access in the neonate, especially in older NICU patients or newborns presenting to the NICU in cardiovascular collapse. The IO procedure can be performed quickly, preventing delays in resuscitation that may occur when repeated IV access attempts are required. In summary, in the majority of NICU patients, IV access can be obtained whether via the peripheral or the umbilical venous route. However, in situations where an infant presents with cardiovascular collapse and traditional IV access is not successful, establishing IO access can be life-saving.[1,4]

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