Intraosseous Vascular Access for Alert Patients

When IV access fails, IO access offers a rapid, safe, and effective alternative.

OVERVIEW: Nurses are often faced with the challenge of starting an IV line in a patient who is dehydrated, has suffered trauma, or is in shock. Even the efforts of the most skilled clinician may fail, while valuable time is lost. Intraosseous access is a rapid, safe, and effective route for delivering fluids and medications, and is recommended by numerous professional and specialty organizations for both pediatric and adult patients. Yet many clinicians remain unaware of the procedure. This article outlines the procedure and devices used, describes support for use in the literature, and discusses various considerations and nursing implications.

Keywords: emergency care, intraosseous access, intraosseous infusion

Emma Jolley, a three-year-old girl, presented to the ED with her parents after experiencing three days of fever, nausea, vomiting, and diarrhea. (This case is a composite based on two similar cases in our experience.) Emma was alert but pale, with a central capillary refill time of three to four seconds. Her weight was 15 kg (33 lbs.) and her vital signs were as follows: temperature, 100.8°F (38.2°C); heart rate, 148 beats per minute; respiratory rate, 26 breaths per minute; and blood pressure, 78/50 mmHg. The ED physician assessed her and ordered typical laboratory tests for an ill child, including complete blood count, electrolyte levels, and blood cultures. Because she was obviously dehydrated, an IV fluid bolus of 20 mL/kg of warmed normal saline was ordered.

Emma was clearly very ill and the staff knew she could deteriorate quickly. The ED nurse made two attempts to start an IV line without success. Emma was not only dehydrated but also had nonvisible, nonpalpable veins. A pediatric nurse specialist was called to assist but was also unsuccessful. Despite the nurses' best efforts, the unsuccessful attempts to start an IV line and waiting for the specialist's arrival had consumed valuable time, and now the patient's stability was compromised. Eighty minutes after vital signs were first assessed, her skin was beginning to mottle, her hypotension had worsened, and her heart rate had increased to 170 beats per minute.

An immediate fluid bolus was required to prevent progression from compensated shock to decompensated shock. But there was one problem: Emma was awake. Although her level of consciousness had decreased, she was still somewhat alert and responsive. Intraosseous (IO) access—via the intraosseous vasculature—was the next alternative route, but there were concerns. Could such access be attempted on a patient who wasn't unconscious? Would the parents understand why a hole was going to be drilled into the bone of their child's leg? Would the procedure be painful? The patient's condition was rapidly worsening. The decision was made to immediately place an IO needle in the proximal tibia using an IO power driver (see Figure 1), which was the hospital's standard method for establishing IO vascular access. Although the hospital also had manual insertion devices, it was determined that placement using the power driver would be less traumatic, especially for a semiconscious patient, as less manual pressure is required for placement.

As this case suggests, nurses are often faced with the challenge of starting an IV line in a dehydrated patient whose veins are difficult to visualize. Gaining IV access can also be complex when the patient

has suffered trauma or is in shock. Even the efforts of the most skilled clinician may fail, while valuable time is lost—and this may be compounded if the institution has no guideline limiting the number of IV attempts that should be made before another route is tried. It's reasonable for nurses to consider the use of IO access in patients who are awake and not in a resuscitative state in order to prevent clinical deterioration.

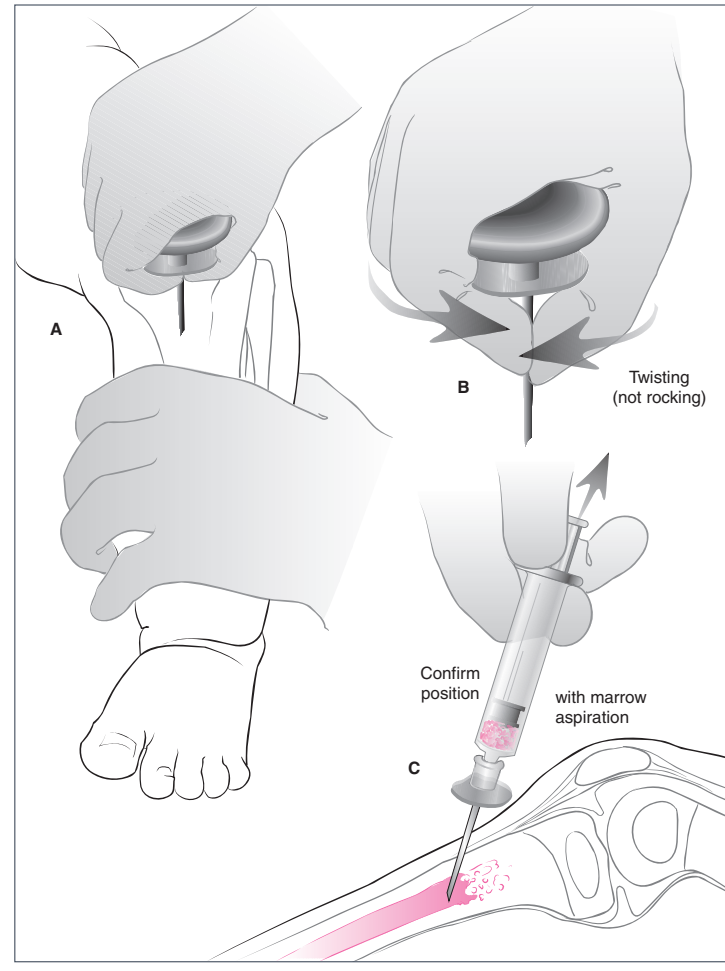
WHAT IS INTRAOSSEOUS ACCESS?

The IO space includes the spongy interior of a bone's epiphyses and the medullary cavity of the diaphysis. This space contains thousands of tiny blood vessels that rapidly absorb any fluids or medications and transport these substances to the central circulation. Unlike peripheral veins, the IO space is unlikely to collapse in response to shock, trauma, or dehydration (unless the bone itself is compromised). For this reason it's sometimes referred to as a "noncollapsible vein."[1]

Various methods of gaining access to the IO space are available. Manual insertion devices (see Figures 2 and 3) permit the insertion of a hollow steel needle, which has a removable trocar to prevent it from becoming plugged with bone fragments. The device handle allows the clinician to push and twist the needle through the periosteum. Manually inserted needles are often used in younger pediatric patients because a child's bones are still soft enough to permit easy placement; they are difficult, if not impossible, to use on adolescents and adults, whose bones have calcified. A second method involves using a spring-loaded mechanism (see Figure 4), which generates enough direct force to drive a sharpened needle into the medullary cavity. The third method involves using a power driver to drill the needle into the IO space with a rotary motion. These last two methods can be performed on pediatric and adult patients.

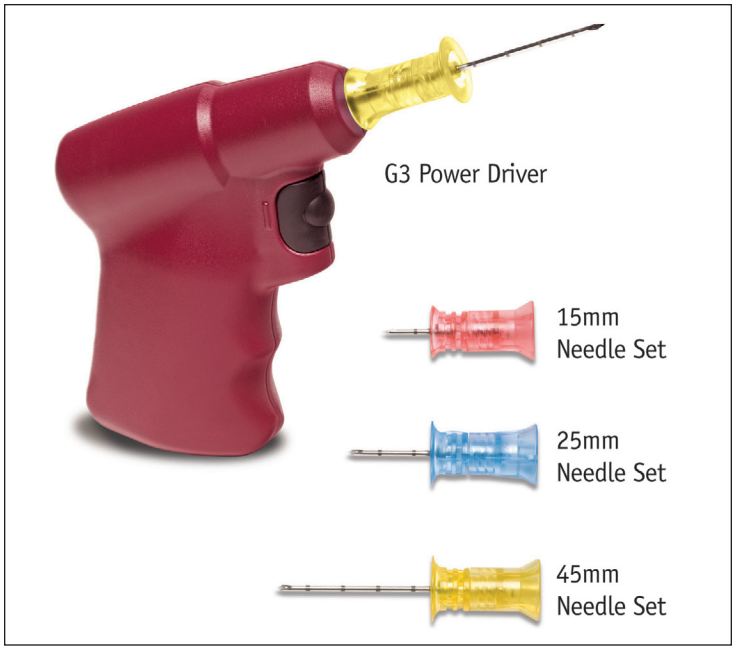
Watch a video demonstration of the placement of an IO needle in the proximal tibia using an IO power driver at http://links.lww.com/AJN/A50.

In pediatric patients, the preferred placement site is the medial proximal tibia, approximately 1 to 2 cm below the tibial tuberosity.[2] Other possible placement sites include the distal femur, the distal tibia directly above the medial malleolus, and the humeral head; and in adults, the sternum and distal radius.[2] In adults, the humeral head placement is becoming more commonplace; studies suggest that this site may offer superior flow rates and that pain there is better tolerated by alert patients.[3,4] Each IO insertion device has been approved by the U.S. Food and Drug Administration for particular sites, and different institutions may have specific protocols for placement sites. It's important for the clinician to be aware of these approvals and protocols in order to ensure appropriate placement.



An example of a manual pediatric intraosseous needle insertion. A. The needle is angled slightly away from the joint space or, as more recent sources have recommended, perpendicular to the bone. B. A back-and-forth "screwing" motion is used to insert the needle. ("Rocking" the needle from side to side results in enlargement of the puncture site and extravasation of infused fluid.) C. Intramedullary placement is confirmed by aspirating marrow. Reprinted with permission from King C, et al. *Textbook of Pediatric Emergency Procedures*. 2nd ed. Philadelphia: Lippincott Williams and Wilkins; 2007.

Figure 1. The EZ-IO Intraosseous Infusion System power driver and needles. Photo courtesy of the Vidacare Corporation.



Once the IO needle has been placed, it can be used in the same manner as an IV catheter for delivering drugs, fluids, and blood products. A correctly placed IO catheter will sit firmly on the bone and will not move. It's often suggested that bone marrow be aspirated immediately after insertion to verify correct placement; but the withdrawal of marrow isn't always attainable. And while the aspiration of bone marrow contents signifies that the catheter is in the marrow space, blood return might not occur even with proper placement.[2] With any IO catheter, it's essential that caregivers monitor the site frequently for extravasation, which is evidenced by swelling of the surrounding tissues.

Because of the relatively dense structure of the IO space, flow rates through an IO catheter are slower than they would be through most peripheral IV catheters. Fluids often will not flow freely through the IO needle. An IV pressure bag or pump can be used to ensure adequate flow.

HISTORY AND SUPPORT FOR USE

History. The use of IO access is not new. C. K. Drinker, a physician at Harvard University, and colleagues first reported IO infusion in 1922, when they inspected sternum circulation in small mammals and established that fluids infused into the bone marrow were absorbed into the central circulation.[5] (Indeed, current research suggests that fluids and drugs administered via the IO route reach the central circulation as fast as those given via central venous catheters.[6]) During World War II, IO access was widely used to resuscitate military patients who were dying of hemorrhagic shock; but after the war its use declined.[1] In 1988, the American Heart Association (AHA) prompted renewed interest in IO access by including it as standard in its pediatric advanced life support (PALS) guidelines. Since then, the AHA has continued to recommend the use of IO access earlier in the care of critical patients. In 2005, the AHA revised its guidelines to recommend IO access whenever IV access can't be quickly achieved in a critically ill pediatric or adult patient.[7,8]

Support in the literature. Numerous studies in adult patients have shown that IO needle insertion is fast and effective.[3,9-13] In a study of adults undergoing resuscitation, Leidel and colleagues found that IO cannulation was a significantly faster and more successful method for establishing vascular access than central venous catheterization.[13] In another study, Lamhaut and colleagues found that IO access could be gained significantly faster than peripheral IV access (mean time, 50 ± 9 seconds and 70 ± 30 seconds, respectively).[14] And Paxton and colleagues compared three access methods—peripheral IV, central venous catheterization, and IO using a power driver—and found that IO cannulation yielded significantly faster results and higher success rates.[3]

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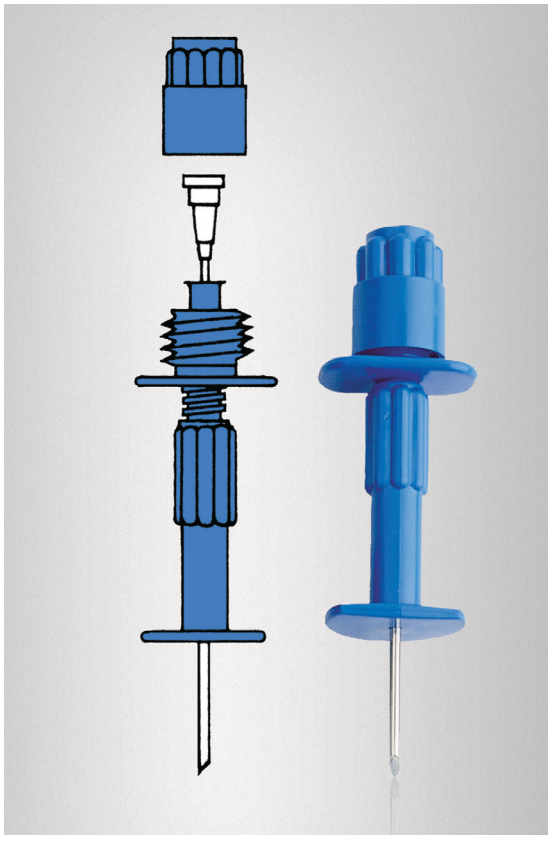
Similar findings have been reported in pediatric patients. A study using an IO power driver to achieve vascular access resulted in successful insertion and infusion in 94% of the young patients.[15] Insertion time was 10 seconds or less in 77% of the one-attempt successful cases. Other pediatric studies have reported first-attempt successful insertion rates of between 81% and 100%.[16,17]

Recommendations from professional associations. The AHA and the American Academy of

Figure 2. The Jamshidi Intraosseous Needle, a manual infusion device. Photo courtesy of CareFusion Corporation or one of its subsidiaries, 2010. All rights reserved.



Pediatrics recognize IO cannulation as a simple and effective mode of establishing vascular access in pediatric and adult patients.[18-20] They note that IO access offers clinicians a rapid, safe, and effective route for delivering fluids and medications. Current PALS recommendations include using IO access as the "initial vascular access attempted" in "circumstances [such as] cardiac arrest or severe shock with severe vasoconstriction" and when peripheral IV access "cannot be readily obtained in a child with compensated or hypotensive shock."[18]

Both the Emergency Nurses Association (ENA) and the American Association of Critical-Care Nurses (AACN) have endorsed an Infusion Nurses Society (INS) position paper stating that "a qualified registered nurse may insert, maintain, and remove IO access devices. Intraosseous access should be considered if IV access cannot be obtained, and substantial concern exists for increased morbidity or even mortality in the patient from not obtaining treatment."[21-23] And the American College of Emergency Physicians (ACEP) has issued a statement recognizing the need for alternative modes of vascular access in the ED, including IO access.[24]

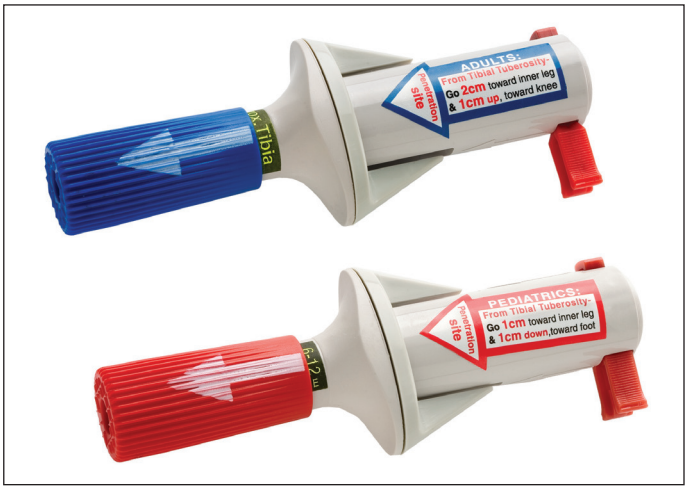
CONSIDERATIONS AND POSSIBLE COMPLICATIONS

Serious complications related to the use of IO access are rare.[2] IO access should not be attempted on any bone with a suspected fracture, nor in a bone in which IO access was recently attempted (within the last 24 to 48 hours). Extravasation of fluids or medications can result from movement or accidental dislodgment of the needle or from repeated IO attempts at the same site.[25] These extravasated substances can be harmful to tissues and may lead to the development of compartment syndrome.[2, 25] Clinicians must be careful to protect and reassess the patency of the insertion site and monitor the patient for any signs of compartment syndrome. The infused IV fluids swell the patient's muscle compartments and affect arterial and venous blood flow. Because IO access requires the use of an IV pressure bag or pump to overcome the inherent arterial pressure in the IO space,[26] it's vital that nurses continue to monitor and reassess access sites for patency and signs of extravasation.

As with any IV insertion, there is a risk of infection, either at the insertion site or in the bone. The same protocols and precautions used to prevent infections with peripheral IV access should also be used with IO access. Reported instances of osteomyelitis or IO site infections have been few. One review of 30 studies involving more than 4,000 patients found that osteomyelitis occurred in fewer than 0.6% of IO insertions.[27] Study findings indicate that osteomyelitis can be prevented if the IO needle is removed within 24 hours of insertion, which is a current standard of care for IO access.[1, 28, 29]

Figure 3. The Cook Intraosseous Infusion Needle, a manual infusion device. Permission for use granted by Cook Medical Incorporated, Bloomington, IN.

Figure 4. The B.I.G. (bone injection gun), a spring-loaded device. Adult (blue) and pediatric (red) models are shown. Photo courtesy of PerSys Medical.



Pain. Any decision to use IO access must consider the patient's ability to tolerate the procedure. The pain of IO needle insertion, which stimulates nociceptors in the skin and periosteum, is typically no more than that of a peripheral IV stick.[30] But the infusion of fluids into the medullary space, which contains many pressure-sensitive nerve fibers, can cause more severe pain.[4, 30] Fortunately, studies have shown that pain can be controlled with the use of 2% preservative-free lidocaine injected slowly through the IO device.[2, 4, 26]

The use of IO lidocaine in children. Before administering lidocaine to pediatric patients, certain factors should be considered. A history of nonfebrile seizures in a patient should prompt the clinician to weigh the potential benefits and risks of lidocaine use. The drug is known to lower the seizure threshold and may increase the risk of seizure in children with a history of seizure or acute seizure activity.[31, 32] That said, the dosage recommended for use in the pediatric IO space is well below the maximum,[33] as is the case for adults.[4] Thus a history of seizure is a consideration, but not a contraindication, for the use of IO lidocaine. [The authors' facility has developed an IO lidocaine dosing chart; for more information, contact the authors.]

CASE REVISITED

When the IO needle was inserted, Emma showed no withdrawal reflex, and a pain score of 0 was noted using the Face, Legs, Activity, Cry, and Consolability (FLACC) pain assessment scale.[34] (The FLACC scale evaluates pain in five categories for a possible total score of 0 [no pain] to 10 [worst pain]). As the initial flush was administered, the patient exhibited a pain score of 6 on the FLACC scale, grimacing and drawing up her legs and arching her back. At the time of treatment, the hospital had no guideline for the use of IO lidocaine before the administration of fluids via IO access to a conscious patient. Because of Emma's critical state, there wasn't time for the staff to investigate appropriate IO lidocaine dosing; it was imperative that the fluid boluses be given quickly. The most significant pain appeared to occur upon infusion of the initial IV flush and seemed to decrease during administration of the first fluid bolus. After this bolus, her pain score decreased to 2.

After receiving three boluses of 20 mL/kg warm normal saline, Emma's heart rate dropped to 110 beats per minute, her blood pressure returned to within normal range, and her capillary refill time decreased to less than two seconds. Her respiratory rate dropped to 20 breaths per minute and her temperature decreased to 100.4°F (38°C). She became more alert and responsive. Although she required a 24-hour hospitalization for observation, she recovered from her dehydration with no long-lasting effects.

LOOKING AHEAD

Despite recommendations from numerous specialty organizations, including the AHA, the ENA, the AACN, the INS, and the ACEP, IO access remains underutilized.[35] A recent literature review found that reasons for this include lack of awareness, lack of guidelines, lack of proper training, and lack of proper equipment.[35] Nurses must be actively engaged in efforts to further the acceptance and use of IO access devices. Such efforts are more likely to succeed when a department has an "IO champion" who can support and train nursing staff, persuade physicians and others who may be hesitant about using IO access, and maintain staff competency in the use of the devices. It's also essential that institutions develop protocols and guidelines for IO vascular access. At our hospital, the two similar cases prompted the development of a protocol for the administration of lidocaine to conscious patients who need pain control during IO infusions. The experience also led to improvements in our processes for establishing access in acutely ill patients. For example, clinicians monitor time closely when attempting IV access in patients

IO access should not be attempted on any bone with a suspected fracture.

who are deteriorating, and will attempt IO access sooner. ▼

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