

Compartment Syndrome of the Leg After Intraosseous Infusion: Guidelines for Prevention, Early Detection, and Treatment

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Obtaining adequate vascular access in the multiply injured or critically ill pediatric patient can be very difficult. Options for gaining access to the venous circulation include peripheral percutaneous cannulation, intraosseous (IO) infusion, percutaneous central venous access, and peripheral venous cutdown. If percutaneous access is not achieved after 2 attempts, consideration should be given to IO infusion or peripheral venous cutdown. Percutaneous central venous cannulation is not routinely used for primary access for resuscitation in adult trauma patients and should not be used as such in pediatric trauma patients.

IO infusion is an expedient, safe, and reliable method of administering fluids and medications during resuscitation.¹⁻³ However, potential complications associated with IO infusion include osteomyelitis, cellulitis, fracture at IO-line site, compartment syndrome, and fat embolism.⁴⁻¹⁰

Although compartment syndrome is a rare complication of IO-line placement, this case report illustrates that it can occur. This report also emphasizes that, with proper technique, attention to detail, and serial monitoring of the involved limb, compartment syndrome and other potential complications can be avoided.

We have obtained the patient's guardian's informed, written consent to publish the case report.

CASE REPORT

At an outside hospital, a 2-year-old boy underwent emergent exploratory laparotomy for hemoperitoneum and pneumoperitoneum secondary to child abuse. A right tibial IO needle was inserted for the resuscitation, and percutaneous femoral venous access was attained. The IO needle was removed in the operating room before the laparotomy. Exploration revealed separation of the stom-

ach from the duodenum at the pyloroduodenal junction, hepatic injury, traumatic pancreatitis involving the body of the pancreas, ischemic transverse colon with avulsion of the mesentery, and a retroperitoneal right colonic injury. A damage control laparotomy was performed because the patient was hypothermic and coagulopathic. The right and proximal transverse areas of the colon were resected, the stomach was stapled closed, the duodenum was oversewn, and a drain was placed in the right upper quadrant. The patient was then transferred to a level I pediatric trauma center for further resuscitation and management.

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After warming and correction of the coagulopathy, the next day he underwent reexploration of the abdomen with subsequent gastrojejunostomy, ileostomy, and subclavian vein central line placement. At this time, the femoral venous line was discontinued. There was no evidence of arterial injury or hematoma, and distal pulses were palpable and symmetric. (Of note, the patient was positioned supine for all abdominal surgeries.) Approximately 10 hours later, the right calf was noted to be firm and tense. Radiographic examination revealed mild soft-tissue swelling and no evidence of fracture associated with the prior IO-line placement. The orthopedic surgery service was consulted, and, after clinical examination, compartment pressures were found to be 50 mm Hg anteriorly and 40 mm Hg in the deep posterior compartment. The patient was urgently taken to the operating room for a 4-compartment fasciotomy of the right leg. The muscles in all 4 compartments were found to be pink and viable, though there was moderate edema in the subcutaneous tissues. The medial and lateral wounds were closed in a delayed fashion 6 days later. Five months after surgery, the patient was ambulating without assistance.

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DISCUSSION

Use of the IO route has become an integral part of pediatric emergency medicine and critical care. Several series have shown that the IO route in emergent situations is safe, reliable, efficacious, and easily used in both the prehospital and hospital settings.^{1,3,11,12} During IO infusion, the rich vasculature of long bones is used to transport fluids and medications to the central circulation. Sinusoids within the marrow of long bones function as rigid conduits that do not collapse in the presence of hypovolemia. Blood passes into the venous channels of the medulla and then leaves the bone through nutrient or emissary veins entering the general circulation.

With practice, this technique can be easily mastered by physicians, nurses, paramedics, and other skilled technicians.¹¹ IO needles should not be placed at fractured extremities because extravasation will occur at fracture sites. The tibia and distal femur are recommended sites in infants and children younger than 6 years. These sites are easily identified by topical landmarks, and the bones are

Bilateral leg compartment syndrome was reported in a patient who had an IO line moved from the right side to the left side after the right leg became progressively swollen after 20 minutes of fluid infusion.⁸ The left leg became similarly swollen and tense after 2 hours of infusion. Mean compartment pressures were 65 to 70 mm Hg, and a standard 4-compartment fasciotomy was performed on both legs. All muscles responded to electrical stimulus and appeared to be viable. A 1-month-old infant was reported to develop a pulseless right foot after an IO was placed in the right tibia, covered with bandages for 2 days, and then removed when presumed to be nonfunctioning.⁵ Three days later, the right lower extremity became progressively swollen, and a fasciotomy was performed after compartment pressures were found to be elevated. The musculature had a dark appearance without response to electrocautery. No improvement in limb viability was noted over the ensuing 5 days, and a below-the-knee amputation was performed.

“To recognize possible extravasation, the [needle] site should be closely monitored the first 10 to 15 minutes after infusion is started.”

superficially located. Needles inserted in these locations traverse tissue planes devoid of important structures, and the marrow cavity is relatively large. These sites are also physically removed from other resuscitative efforts, such as airway management and chest compressions. The preferred site is the proximal tibia; insertion is performed 1 to 3 cm below the tibial tuberosity on the flat anteromedial surface of the tibia. The needle is directed caudally, away from the growth plate. In children older than 5 years, the proximal tibia cortex is relatively difficult to penetrate, and the distal tibia is approached 2 to 3 cm above the medial malleolus posterior to the saphenous vein on the palpable flat surface of the bone. The needle is directed cranially away from the growth plate. Secure vascular access should be obtained before the functioning IO needle is removed.

Despite its efficacy and success, the IO route has several potential complications. Cellulitis, the most common complication, can be treated with antibiotics and local skin care. Incidence of osteomyelitis associated with IO insertion has been reported to be as low as 0.6%.¹ Fracture at the IO site is an extremely rare occurrence, and the theoretical concern for fat embolization has never been reported. One case of popliteal arterial thrombosis after IO-line placement has been reported.⁴

Compartment syndrome as a complication of IO insertion has been previously reported.^{5,6,8-10,13} Moscati and Moore⁹ reported the case of a 3-month-old child who developed compartment syndrome of the left leg after 2 hours of emergency resuscitation. Subsequent fasciotomy found the muscles of all 4 compartments to be nonviable, and a through-the-knee amputation was performed.

The exact etiology of compartment syndrome in our patient remains unknown. Prolonged positioning, iatrogenic arterial injury, and fluid extravasation were all potential causes. The patient was never in a lithotomy position, and there was no evidence of arterial injury from a femoral venous line, which makes the first 2 possibilities less likely. We speculate that the condition resulted primarily from extravasation of fluid into the muscular compartments because of edema in the subcutaneous tissues at the time of fasciotomy. The potential causes for this extravasation include incomplete penetration of the cortex, penetration of the needle through the posterior aspect of the cortex, extravasation through a previous IO puncture site, and extravasation through the foramina of the nutrient vessel.⁸

Precautionary measures that reduce the incidence of compartment syndrome and allow for its early recognition include correct placement of the IO line to reduce the amount of fluid extravasation. A fresh, large-bore needle should be used to facilitate bone penetration, prevent blockage of the lumen, and withstand bending forces. Multiple breaches of the cortex should be avoided, and the needle should be passed only through the near cortex. Aspiration of marrow contents confirms accurate placement, and free flow of fluid into the osseous cavity should be noted. Plain radiographs can also be used to confirm placement. If improper placement is confirmed, and the cortex has been breached, the site should be well dressed, and insertion can be attempted at another site.

It is important that the affected limb be immobilized during use of the IO line to prevent dislodgement of a properly placed needle. The cannula should be secured to the extremity with a noncircumferential dressing to prevent

venous constriction. However, the IO apparatus should be secured to the extremity; the needle site itself should be exposed to allow for close inspection. To recognize possible extravasation, the site should be closely monitored the first 10 to 15 minutes after infusion is started. Documentation should include start and stop times, rate, and volume of fluid infused. Physical examination may be difficult or impossible in very young patients or in patients with altered mental status. Frequent objective neurovascular examinations should be performed and documented, including motor and sensory testing, assessment of distal pulses, capillary refill, and palpation of adjacent compartments. If possible, the circumference of the extremity at the level of the IO site should be measured serially. When a young child in extremis is being treated, health care providers typically focus on cardiopulmonary resuscitation. Although not immediately life-threatening, IO-line complications can be associated with extensive morbidity. The IO line and extremity should be monitored with the interval recording of vital signs. If there is any concern that compartment syndrome is developing, the IO line should be removed immediately, and the appropriate surgical or orthopedic service should be consulted.

In summary, we present our patient's case to emphasize that, though it is a rare complication, compartment syndrome can occur after IO-line placement. Proper placement technique and serial monitoring of the involved extremity are of the utmost importance. Adhering to these guidelines may prevent this complication or allow for early recognition. Urgent surgical consultation and wide, 4-compartment

fasciotomy are warranted when the index of suspicion for compartment syndrome is high.

AUTHORS' DISCLOSURE STATEMENT

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.
