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## Vascular access through the intraosseous route in pediatric emergencies

*Acesso vascular por via intraóssea em emergências pediátricas*

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### ABSTRACT

Obtaining venous access in critically ill children is an essential procedure to restore blood volume and administer drugs during pediatric emergencies. The first option for vascular access is through a peripheral vein puncture. If this route cannot be used or if a prolonged period of access is necessary, then the intraosseous route is an effective option for rapid and safe venous access. The present work is a descriptive and exploratory literature review. The study's aim was to describe the techniques, professional responsibilities, and care related to obtaining venous access via the intraosseous route in pediatric emergencies. We selected 22 articles (published between 2000 and 2011) that were available in the Latin American and Caribbean Health Sciences (LILACS) and MEDLINE databases and the SciELO electronic library, in addition to the

current protocol of cardiopulmonary resuscitation from the American Heart Association (2010). After the literature search, data were pooled and grouped into the following categories of analysis: historical aspects and physiological principles; indications, benefits, and contraindications; professional assignments; technical principles; care during the access; and possible complications. The results of the present study revealed that the intraosseous route is considered the main secondary option for vascular access during the emergency response because the technique is quick and easily executed, presents several non-collapsible puncture sites, and enables the rapid and effective administration of drugs and fluid replacement.

**Keywords:** Infusions, intraosseous/methods; Infusions, intraosseous/instrumentation; Emergency nursing; Critical care/methods; Child

### INTRODUCTION

Venous puncture is an essential procedure for administering fluids and medications during pediatric emergencies. This procedure is technically more difficult in children because of their anatomy and hemodynamic responses to severe pathological processes.<sup>(1,2)</sup>

For critically ill children, the intraosseous route is quick and safe because it involves non-collapsible vascular access - unlike the peripheral veins, which undergo vasoconstriction during clinical and traumatic situations, leading to shock that prevents puncture and maintenance of an appropriate route for treatment. It is possible through the intraosseous route to infuse medications, electrolyte solutions, and blood products directly into the venous plexus bone, in which the absorption and duration of action are the

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same as with peripheral or central venous access.<sup>(3,4)</sup>

Some studies have revealed that intraosseous puncture is successful in over 90% of the cases for which there is a clinical indication. Furthermore, the average time to perform the puncture is less than 2 minutes when performed by an experienced professional with the suitable material. Thus, intraosseous access is increasingly becoming a good alternative to fluid infusion after the failure of peripheral venous access.<sup>(1,5,6)</sup>

Despite the well-defined indication for intraosseous access in pediatric emergencies, it is noteworthy that this subject is rarely addressed in the Brazilian scientific literature and the field of graduate health science. Consequently, questions regarding the technique, professional tasks, and care related to intraosseous puncture in pediatric emergencies might arise.

From this perspective, the current study is relevant due to the lack of national publications regarding intraosseous venous access in pediatric patients; the aim is to provide important scientific information so that emergency room professionals may perform this procedure safely and effectively.

Therefore, the purpose of this review is to describe the technical principles, professional assignments, and care related to using the intraosseous route for vascular access during pediatric emergencies.

## METHODS

The current study is categorized as a descriptive and exploratory literature review.

To accomplish the goals of the present investigation, articles were selected from the international literature published in English, Portuguese, or Spanish. We used abstracts that were available in the Virtual Health Library (VHL) - specifically in the Latin American and Caribbean Health Sciences (LILACS) and MEDLINE databases - and the Scientific Electronic Library Online (SciELO). A search was also conducted for books in the collection of the Centro Universitário Una in Belo Horizonte (MG-Brazil) and for documents published by boards of nursing and medicine; in addition, the current protocol of the American Heart Association (AHA) for treating cardiopulmonary arrest and cardiovascular emergencies, which was published in 2010, was used. For the article search, the following keywords were used, based on the Health Science Descriptors (DeCS/BIREME): “Intraosseous infusion,” “pediatrics,” “nursing,” “emergency nursing,” and

“intensive care.” To identify the research materials, a period of 11 years (2000 to 2011) was used to obtain the most current information on the topic.

To select the articles, the following exclusion criteria were considered: dissertations and doctoral theses (due to the time scheduled), duplicate publications in the databases, and animal research. Consequently, 283 summary articles were read, and 22 articles were selected. Twenty articles were selected from MEDLINE, 1 article was selected from SciELO, and 1 article was selected from the LILACS database.

The data were collected using the following procedure of Gil:<sup>(7)</sup> (a) exploratory reading; (b) selective reading of the title and summary to identify articles relevant to the purpose of the study; (c) analytical reading to sort the information found in the articles; and (d) interpretative reading, aimed to understand the selected material and the construction of the theoretical framework for analysis.

Thus, the articles that were retrieved from the literature were analytically read, with subsequent highlighting of key points that were arranged as they appeared in the texts.

The presentation of the results and discussion of the data were descriptively categorized as follows: historical aspects and physiological principles; indications, benefits, and contraindications; professional assignments; technical principles; care during the access; and possible complications. This form of presentation was chosen to provide the reader with greater clarity in assessing the applicability of the study.

## RESULTS

### General aspects

The intraosseous route for vascular access is not a recently developed procedure, having been first described in 1922. Its most widespread use occurred in the 1940s, when the technique was introduced for routine care in medical emergencies and during World War II, for treating severely injured patients.<sup>(8-11)</sup>

A decade later, in 1950, the use of the intraosseous route was reduced due to the introduction of new catheters for venous puncture (catheters on needles). However, in mid-1980, the use of intraosseous vascular access started to increase in pediatric patients because of the simplicity of the procedure, new scientific studies, the recommendations of the AHA, and the availability of new technologies.<sup>(9-11)</sup>

The infusion of fluids through the intraosseous route

became possible because the bone is richly vascularized, especially in its red bone marrow. Blood vessels enter the bone through the periosteum, passing through the compact bone via the perforating holes or Volkmann canals and Haversian canals that run longitudinally through the bone. Adjacent to this region, there are plates, which are rigid spaces that have gaps with small canaliculi. Upon reaching the spongy bone, the vessels traverse macroscopic spaces between the trabeculae, which are filled with red bone marrow, until reaching the spinal canal medullary cavity.<sup>(11,12)</sup>

The connections between the segments form a network of branches, which allows oxygen and nutrients to be transferred to the bone cells as well as products and excretions to be drained back into the bloodstream.<sup>(11-13)</sup>

Through the intraosseous route, infused fluids and medications can reach the bloodstream quickly and without loss during the absorption process.<sup>(3,11,14)</sup>

During pediatric emergency treatment, venous access is a priority. Obtaining peripheral venous access in children may be impossible or too time-consuming due to anatomical and physiological characteristics, such as increased thickness of the subcutaneous adipose tissue, the presence of small-caliber vessels, and difficulty accessing large-caliber vessels (e.g., jugular and subclavian veins). During severe pathological conditions (such as cardiopulmonary arrest, septic and hypovolemic shock, prolonged status epilepticus, and severe dehydration), reduction of the circulating blood volume, vasoconstriction, and collapse of peripheral vessels may occur. These events, together or separately, significantly contribute to the difficulty of venipuncture.<sup>(2,15)</sup>

In such circumstances, other access routes for infusion of fluids and medications may be used. However, these routes present greater risks and disadvantages compared with the intraosseous route because they are invasive procedures and require

greater technical skill. Central venous access, for example, consists of a time-consuming technique that is more complex than the intraosseous route, making it not feasible for cardiopulmonary resuscitation. In this case, the endotracheal route would be another possibility for drug administration. However, several studies have demonstrated that absorption through this route is incomplete and inconsistent, few drugs can be administered, several side effects may be observed, and fluid replacement is not possible.<sup>(1)</sup>

Compared with central and peripheral venous access, the intraosseous route has several advantages (Table 1). The only limitation of this technique is the maximum duration of the access, which is 24 hours.<sup>(16)</sup>

For these reasons, intraosseous access is indicated as the first alternative for fluid infusion after failure to gain peripheral venous access (Table 2). In addition to providing non-collapsible access, which is minimally affected by the hemodynamic state of the patient, intraosseous access is also considered a rapidly and easily implemented technique that may be used for fluid replacement and the administration

**Table 2 - Most important indications for intraosseous access associated with the clinical care sectors.**

Care sector	Most important indications
Intensive care unit	Admission of patients without the possibility of peripheral vascular access; multiple organ failure; acute respiratory syndrome; acute renal or hepatic failure; bleeding that requires rapid fluid replacement; disseminated intravascular coagulation; severe hemodynamic disorders
Emergency service	Cardiopulmonary resuscitation; patients with difficult peripheral access that require the administration of fluids and drugs, such as polytrauma care and cardiac or respiratory failure; exogenous poisoning
Surgical center	Loss of peripheral access during surgery; complicated peripheral access for emergency surgery
Pre-hospital care	Polytrauma care; cardiopulmonary resuscitation; inability to access peripheral puncture sites in patients in shock or with severe hemodynamic disturbances

Modified from Vizcarra C, Clum S. Intraosseous route as alternative access for infusion therapy. *J Infus Nurs.* 2010;33(3):162-74. Erratum in *J Infus Nurs.* 2011;34(2):123.<sup>(11)</sup>

**Table 1 - Characteristic of the main access routes in pediatric patients.<sup>(16)</sup>**

	Intraosseous access	Subclavian vein	Femoral vein	Internal jugular vein	External jugular vein	Axillary vein	Venous dissection
Access route during emergency treatment	++++	++	+++	++	+++	+	++
Ease of performing the technique	++++	++	+++	++	+++	+	+
Infection	+	++	++	++	+	+	++
Thrombosis	0	+	++	+	+	+	++++
Other complications	+	++	+	+	0	+	0
Appropriate for long-term use	0	+++	++	++	+	+	0
Appropriate for short-term use	++++	++	+++	+++	++	+++	++

0 - no effect/not applicable/no risk; ++++ - higher effect/most used/high risk; + - lower effect/less used/low risk.

**Table 3** - Most commons medications for intraosseous administration.<sup>(3)</sup>

<b>Analgesics, anesthetics, anticonvulsants, and sedatives</b>	<b>Antibiotics</b>	<b>Fluids</b>	<b>Neuromuscular blockers</b>	<b>Resuscitation medications</b>	<b>Others</b>
Fentanyl	Amikacin	Blood Components	Atracurium	Adenosine	Antitoxins
Ketamine	Ampicillin	Glucose	Pancuronium	Adrenaline	Contrast
Lorazepam	Ceftriaxone	Ringer's Lactate Solution	Rocuronium	Atropine	Dexamethasone
Midazolam	Clindamycin	Isotonic and hypertonic saline	Succinylcholine	Calcium Chloride	Diazoxide
Morphine	Gentamicin		Vecuronium	Digoxin	Heparin
Phenobarbital	Sulfadiazine			Dobutamine	Insulin
Phenytoin	Vancomycin			Dopamine	Methylene blue
Propofol				Isoproterenol	Methylprednisolone
				Lidocaine	Prostaglandins
				Noradrenaline	Vitamins
				Sodium bicarbonate solution (diluted)	
				Vasopressin	

of various medications, including drugs specified for cardiopulmonary arrest (Table 3). Furthermore, this pathway allows enables the collection of blood for laboratory tests.<sup>(1-3,13,17)</sup>

The absorption and bioavailability of several intravenous drugs are equivalent when administered through intraosseous access.<sup>(3,10,18)</sup> Pharmacokinetic studies of morphine sulfate<sup>(4)</sup> administered intraosseously versus intravascularly have demonstrated the similarity between the two routes.

Considering these advantages, the AHA stated in its 2010 guidelines that if it is impossible to obtain peripheral venous access (first option), then the intraosseous route should be the second-choice technique for obtaining venous access.<sup>(19)</sup>

Intraosseous puncture for fluid and medication infusions should not be obtained (absolute contraindication) in cases with recent fractures or punctures of the bone at the site of access. In other situations, such as osteogenesis imperfecta, severe osteoporosis, osteomyelitis, cellulitis, or infection of the puncture site, physicians should consider the risk/benefit ratio (relative contraindication). Sternal puncture is contraindicated in children due to the possibility of serious complications, such as transfixation, fracture, hemothorax, and cardiac or large-caliber-vessel injury.<sup>(3,8,11,15,18)</sup>

Intraosseous access should always be performed by a trained and qualified professional. In Brazil, doctors and nurses are allowed by their respective councils to execute this procedure because these professionals are qualified to insert and manipulate intraosseous devices. The indication for the procedure is a medical decision.<sup>(20-22)</sup>

Well-defined protocols and continual training of medical and nursing staff regarding proper handling of the general apparatus and identification of the specific

device used in the procedures are essential for effective and safe care of patients undergoing intraosseous venous access.<sup>(3,22)</sup>

An important aspect for the success of this procedure is the necessity for continuing education for the health staff.<sup>(23)</sup> Molin et al.<sup>(24)</sup> determined that the lack of training and knowledge of the technique influenced the rate of its use in hospitals in Denmark.

As demonstrated by Pfister et al.,<sup>(17)</sup> the training of physicians and non-physicians improved the success rate in obtaining intraosseous access. In their study, the rate of success for obtaining intraosseous access with no more than 3 attempts was 100% for professionals who had received training. However, the success rate was lower, at 77%, before training. Thus, the training of professionals performing this technique is crucial for effectively executing the procedure without harming the patient.

### Technical principles

The preferable puncture sites in children for intraosseous access are the proximal tibia (the site may be located by placing a finger 1 cm below the tibial tuberosity and then sliding the finger 1 cm medially), the distal tibia (2 cm above the medial malleolus), and the distal femur. The humerus and calcaneus may also be used. The proximal tibia is the most commonly indicated puncture site because of the thin layer of skin that covers the anterior region of this bone and because this site would not interfere with cardiopulmonary arrest procedures, such as chest compressions and invasive respiratory access for ventilation.<sup>(15,22,25)</sup>

Several devices may be used for intraosseous puncture, and they are classified as manual and new-generation devices (Table 4). The manual devices are inserted into the puncture site using manual pressure exerted by the operator; for this procedure, specific

needles are available.<sup>(9,10,15,22,26)</sup> Because of the risk of needle obstruction during insertion, devices that do not have indwelling trocars should not be used.<sup>(11)</sup>

Automatic insertion devices, or new-generation devices, are placed on the puncture site and enter the spinal canal using the force of an internal spring inside the device; other devices consist of an electric bone punch, in which the needle is inserted into the medullary canal at high speeds. Both devices control the distance of insertion and use needles of various sizes.<sup>(9,10,23,26)</sup>

These new devices have advantages over the manual ones because the former provide faster access and a higher degree of safety during the puncture. In addition, the risks of fractures or of transfixing the spinal canal are minimized if the instructions are carefully followed.<sup>(1,3)</sup>

To compare the technical precision between these devices, Hartholt et al.<sup>(27)</sup> studied the results of punctures with 2 intraosseous access devices (the Jamshidi® 15G and BIG® 15G and 18G needle), verifying that the needle for manual insertion did not yield any adverse events during 12 punctures, while the automatic insertion device yielded 3 adverse events (1 extravasation, 1 malposition, and 1 needle displacement) during 11 punctures.

In the study conducted by Schwartz et al.,<sup>(6)</sup> the BIG® device was used, and the success rate was 87.2% (47 total punctures: 41 successful and 6 unsuccessful) in the pediatric population.

To ensure the correct use of each device, the site for which they are indicated must be examined (Table 5) to determine whether it can be used in a pediatric patient.<sup>(9)</sup>

During intraosseous access, conscious patients or patients with preservation of pain perception by the central nervous system can experience pain; in these cases, the administration of local anesthetics into the subcutaneous tissue and the intraosseous infusion of lidocaine (see the table below) are indicated before

**Table 5 - Insertion sites and intraosseous access devices.<sup>(9)</sup>**

Site	Adult	Children	Devices
Sternum	✓	0	Manual, FAST 1®
Humeral head	✓	0	Manual, BIG®, EZ-IO®
Distal radius	✓	0	Manual
Distal ulna	✓	0	Manual
Iliac crest	✓	0	Manual
Distal femur	✓	✓	Manual, BIG®, EZ-IO®
Proximal tibia	✓	✓	Manual, BIG®, EZ-IO®
Distal tibia	✓	✓	Manual, BIG®, EZ-IO®

starting fluid infusion. Unconscious patients who do not respond to pain, as in cases of cardiac arrest, do not require this procedure.<sup>(11)</sup>

**Care and possible complications of the access**

The maximum amount of time that venous access via the intraosseous route should remain in the patient is 24 hours. However, it is recommended that it remain only for the period necessary to address the emergency and obtain a more permanent vascular access (central or peripheral access) to reduce the risk of infusion-related complications caused by the intraosseous route. Within this period, several precautions should be taken to avoid complications (Table 6).<sup>(3,22)</sup>

As with all invasive procedures, the intraosseous route also can yield complications. The occurrence of adverse events during the use of this pathway is less than 1%. Recent studies have reported complication rates of approximately 0.6% and have demonstrated that the extravasation and infiltration of administered fluids are the most frequent adverse events.<sup>(9,11)</sup>

The complications are related to each other, and the causes of some may be associated with unfamiliarity with the technique, as in infiltration (which occurs due to extravasation of fluids) and fractures (which are related to errors during execution of the technique). Other complications, such as osteomyelitis, sepsis, cellulitis, and abscess, are related to failures regarding aseptic techniques for puncture or manipulation of the

**Table 4 - Devices for intraosseous puncture.<sup>(9)</sup>**

Devices	Description	Method of insertion	Products
Manual	Steel needle with a removable trocar to prevent plugging of the needle by bone fragments	Manual insertion in the medullary space, controlled by the operator	IO Jamshidi® ( <i>Care Fusion</i> ) Needle; IO Cook® Needle ( <i>Cook Medical</i> )
Automatic	Impact	Steel trocar needle, operated by a spring	Upon being triggered, the device automatically inserts the trocar needle into the spinal canal via spring tension.
	Electric	Steel trocar needle, battery-operated power driver	Upon being triggered, the device is inserted into the medullary canal via spinning (the device resembles an orthopedic drill bit)

**Table 6 - Care during intraosseous access, along with its justifications.<sup>(3,21)</sup>**

Care	Justification
Define the injection site and the appropriate apparatus.	There are devices specific for different puncture sites.
Use aseptic techniques for insertion and removal of the needle and handling apparatus.	To prevent puncture-site infection, osteomyelitis, and sepsis
Fix the needle, as well as the stents and catheters.	To avoid the needle being pulled out, preventing loss of access, leakage, and damage to the tissue and bone
Use a continuous infusion pump for fluids, drugs, and blood components.	To ensure the continuity and rate of infusion, which are not maintained by gravity. Furthermore, as in the intravenous route, the alarms of infusion pumps may indicate obstruction of the apparatus, which may suggest infiltration.
Inject a 10 ml bolus of physiological saline (0.9%) every 4 hours.	To prevent clogging of the device, the discontinuity of infusion, and loss of the access.
Verify the operation and permeability of the apparatus.	To avoid clogging of the apparatus and its consequences, such as loss of access and disruption of the infusion, which would compromise the patient's health.
Evaluate the presence of edema, erythema, and hypersensitivity at the puncture site after removing the needle.	To enable the early detection and treatment of complications, such as bleeding and infiltration
Apply an occlusive, sterile-gauze dressing to the puncture site using aseptic technique.	To prevent contamination and reduce the risk of infection at the puncture site
Support professional training and establish protocols for the procedure.	To increase the chances of success of the procedure, to instruct professionals regarding their responsibilities in clinically managing the access, and to provide safe and effective patient care

devices. Compartment syndrome and tissue necrosis are related to extravasation of fluids. Fat embolism might also occur, although no cases have been reported in the literature because the bone marrow in children has little or no fat.<sup>(2,3,11,14,15,23)</sup>

According to Coronel Carvajal<sup>(2)</sup> and Lane and Guimarães,<sup>(15)</sup> injury to the growth plate may occur. However, DeBoer et al.<sup>(3)</sup> state that this is only a theoretical concern, without any clinical evidence.

Early detection and rapid treatment are key factors for preventing these complications from generating larger lesions in the patient (Table 7). To prevent such adverse events, it is essential to follow the protocol carefully, with adequate antisepsis and proper handling of the apparatus being critical, both at the time of insertion and the withdrawal of the needle. Splinting and immobilizing the punctured limb may reduce the risks of fracture, needle dislocation, and extravasation.<sup>(2,3,15)</sup>

**Table 7 - Managing the major complications related to intraosseous access.<sup>(11)</sup>**

Complications	Treatments
Extravasation	Remove the device, elevate the limb, and apply a cold compress to the puncture site
Osteomyelitis	Remove the device within 24 hours. Initiate antibiotic therapy (as prescribed by the physician) to treat the osteomyelitis
Compartment syndrome	Remove the device, elevate the limb, apply a cold compress to the puncture site, and consult the surgeon (fasciotomy and removal of necrotic tissue are required in severe cases)
Fat embolism	No specific treatment (no cases have been reported in the literature for pediatric patients)

### CLOSING REMARKS

Currently, the intraosseous route is accepted as a safe alternative for venous access because it provides several sites for non-collapsible puncture. Consequently, intraosseous access is indicated for the most severely ill children, except in clinical situations where the technique is not feasible (as previously described) or where the risk/benefit ratio is disadvantageous.

Intraosseous access is a rapidly and easily executed technique that saves time during emergency care; consequently, it enables the staff to pay closer attention to other procedures that are equally important for severely ill patients. Ultimately, use of the intraosseous route may increase the chances for a faster and more complete recovery of the child.

Despite the advantages and benefits associated with intraosseous access, its use remains underexplored in clinical practice. This fact might be explained by emergency health professionals' lack of knowledge and appropriate training on the subject.

The results of the present study show that the available published information predominantly addresses the indications, contraindications, and complications of the procedure, as well as the technique for its execution. Most of the articles discuss the technical aspects related to the moment of the puncture access. By contrast, few studies discuss the management of infusion through this route and the maintenance of access, which may be because most of these articles were published by physicians (20 articles published by physicians and 6 by nurses), although the technique is generally the

responsibility of the nurses and their teams.

The majority of the articles analyzed in the literature are reviews. There were no experimental studies that addressed the major complications and their incidence rates, the age and morbidity of children undergoing this procedure, and the difficulties encountered in performing this technique or establishing protocols and training on the subject.

This study met its goal of describing the technical principles, responsibilities, and professional care in obtaining venous access via the intraosseous route in pediatric emergencies, in addition to contributing to the dissemination of the procedure and the provision of support to professionals working in emergency rooms.

The necessity for additional studies on this subject is emphasized, and they would enable the procedure to gain popularity. Such studies are also necessary to produce concrete scientific support for the establishment of guidelines and protocols regarding the relevant indications, techniques, and professional responsibilities, in addition to defining the appropriate materials or devices based on each type of clinical situation encountered.

## RESUMO

A obtenção do acesso venoso em crianças gravemente enfermas é um procedimento essencial para o restabelecimento

da volemia e a administração de fármacos nas emergências pediátricas. A primeira opção para obtenção de acesso vascular é pela punção de uma veia periférica. Quando essa via não pode ser utilizada ou sua obtenção se torna demorada, a via intraóssea consiste em efetiva opção para obtenção de um acesso venoso rápido e seguro. O presente estudo possui caráter descritivo e exploratório, realizado por meio de pesquisa bibliográfica, com o objetivo de descrever os princípios técnicos, as atribuições profissionais e os cuidados relacionados à obtenção do acesso venoso pela via intraóssea em emergências pediátricas. Foram selecionados 22 artigos disponibilizados nas bases de dados LILACS e MEDLINE e na biblioteca eletrônica SciELO, publicados entre o período de 2000 a 2011, além do protocolo vigente de ressuscitação cardiopulmonar da *American Heart Association*, de 2010. Após a leitura das publicações, os dados foram agrupados, possibilitando a construção de cinco categorias de análise: aspectos históricos e princípios fisiológicos; indicações, vantagens e contraindicações; atribuições dos profissionais; princípios técnicos; cuidados com o acesso; e possíveis complicações. Os resultados desse estudo mostraram que a via intraóssea consolida-se, hoje, como uma segunda opção de acesso vascular no atendimento a emergências, por ser uma técnica de fácil e rápida execução, apresentar vários sítios de punção não colapsáveis e permitir que a administração de fármacos e a reposição volêmica sejam rápidas e eficazes.

**Descritores:** Infusões intraósseas/métodos; Infusões intraósseas/instrumentação Enfermagem em emergência; Cuidados críticos/métodos; Criança

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