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Review

Clinical Management of Intraosseous Access in Adults in Critical Situations for Health Professionals

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Abstract: There are health professionals who are unaware of the ideal management of the intraosseous route, despite the fact that it has been scientifically considered an alternative to the peripheral venous route when the patient is in critical condition. Thanks to continuous development, there has been a need to provide emergency services with materials that manage to provide satisfactory care, despite the difficulties faced by health personnel. Objectives: The objective of this systematic bibliographic review is to update the theoretical and practical knowledge and strategies for the insertion and proper management of the intraosseous route as an emergency vascular access for nursing professionals. Data sources, study eligibility criteria: The search for the articles was carried out in various scientific databases with the help of a search string (January 2015 and May 2021), which combined the keywords and Boolean operators. Study appraisal and synthesis methods: Eighteen articles were chosen after a review of 1920 database articles, following the application of the inclusion and exclusion criteria. Results: Intraosseous infusion is an effective and safe technique, which increases patient survival. Therefore, it is of crucial importance that all nursing professionals know how to handle the different intraosseous devices in situations in which it is not possible to achieve immediate peripheral venous access. Conclusions and implications of key findings: It is of great need to have devices or fast and effective alternatives that allow us to develop safe interventions by health professionals.

Keywords: intraosseous access; emergencies; adult

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1. Introduction

Intraosseous injection (IO) is a technique indicated in life-threatening situations for both adult and pediatric patients, in which the infusion of medications or liquids cannot be delayed in time, and due to age or circulatory collapse, vascular access cannot be achieved in about 60–90 s, with a maximum of up to three puncture attempts. Above all, it is used in patients in a state of shock who need to be administered blood, crystalloids, or colloids in situations of anaphylaxis, severe burns, obesity, status epilepticus, trapped, dehydrated, multiple trauma, altered level of consciousness, etc. It is an effective technique and easily accessible, with minimal complications at the time of insertion [1]. The American Heart Association (AHA) and the European Resuscitation Council (ERC) of 2015 recommended the intraosseous route after the peripheral route and prior to the central venous route, in cases of difficulty or delay in venous cannulation [1,2]. On the part of nurses, it is essential to carry out rapid action, in order to reduce the probability of morbidity and mortality and favor the recovery of the patient [1–4]. Nursing professionals can perform intraosseous insertion since this technique was approved and is reflected in the NIC code 2303 "Administration of intraosseous medication" by inserting a needle through the bone with the aim of administering fluids, blood, or medications [1].

Anatomically, the main support of the human body is the skeletal system. This is responsible for the protection of internal organs, locomotion, support, and stabilization. We can classify bones into four different categories: long (e.g., the tibia and humerus), short (e.g., the phalanges), flat (e.g., the sternum), and irregular (e.g., the vertebrae) [1,4]. The bone is divided into three main parts: the epiphysis, the diaphysis, and the process. The epiphysis is made up of spongy tissue in the center where the red marrow is located, which contains the blood cells responsible for developing the body's immune defenses. The metaphysis is the junction area of the epiphysis and the diaphysis and in it is the growth plate. The diaphysis is the internal part of the bone and in it we can find the yellow marrow formed by lipids. The apophysis is the protruding part of the bone that communicates with another bone or muscle, the endosteum forms the inner thin membranous lining of the bone cavity, and the periosteum is the membrane that covers the external face of the bone and the internal osteogenic layer [1,4].

The medullary cavity of the long bones of the human body is a network rich in sinusoid capillaries that allows the access of drugs and fluids to the blood circulation, with a speed similar to that of a peripheral venous access, in which they drain into a large central venous sinus that communicates with the general venous circulation through the emissary and nutritional veins. This venous sinus does not collapse even in situations in which the patient is in cardiorespiratory arrest due to the presence of spicules in the medullary cavity and the hardness of the compact bone [4]. The infusion rate will vary depending on the device used, the caliber, the chosen puncture site, and the external pressure exerted [4].

Physiologically, the bone begins to grow and ossify from the epiphysis to the diaphysis. Between them is the epiphyseal or growth plate that will stop growing when said plate turns into bone. Over time, the bone marrow becomes less vascularized yellow bone marrow. Therefore, the insertion sites are not the same in adult and pediatric patients. Generally, IO vascular access catheters are placed at the proximal and distal ends of long bones, because compact bone is thinner and has a greater abundance of cancellous bone [5,6]. Anatomically, in the medullary space of the bone we can find red and yellow bone marrow, apart from a hypercoagulable fibrin mesh. Between them, they form a thick substance that offers resistance to the infusion of blood. Therefore, it is necessary to perform a rapid wash with physiological saline at 9% and begin with the administration of medications and fluids. Depending on the insertion site, fluids drain into the proximal humerus and drains into the axillary vein, the proximal tibia drains into the popliteal vein, the distal tibia drains into the greater saphenous vein, and the sternum drains into the internal mammary veins and azygos [6–9]. Before channeling an intraosseous route, we must pay attention to the age of the patient and the pathology, always remembering the contraindications. The patient has the right to know what we are going to do and what to expect, in relation to pain, noise caused by the devices, or other sensations [10–14].

The anatomical sites of insertion in adults are the proximal humerus, distal and proximal tibia, sternum, and iliac crest. The proximal humerus is the first choice in adults, provided there are clear anatomical landmarks. Recent studies reveal that with this location, we can achieve higher infusion rates, less pain on insertion, and greater drug bioavailability. We can achieve flows of up to 5 L/h, since medications and fluids reach the right atrium in just 3 s [10–14]. In the proximal tibia, we can achieve fluid volumes of 1 L/h under pressure. The patient's leg should be extended, and the insertion point is located 3 cm, about 2 finger widths, just below the patella, and about 2 cm medial along the flat aspect of the tibia [12]. At the distal tibia, the patient's leg should be extended, and the insertion point is 1–2 cm proximal to the base of the medial malleolus at its midline (3 cm above the crest of the malleolus). [12]. The sternal access allows us to reach the central venous circulation due to its proximity through the mammary glands. The advantage of this access is that it reaches a maximum concentration in the blood with a time similar to that of drugs injected through a central line. The EZ IO T.A.L.O.N device is designed to be placed on the sternum. It is not indicated if the patient requires CPR, since cardiac massage cannot be performed [10–14].

For insertion in the iliac crest, we will place the patient in lateral decubitus to achieve better access. The puncture site is on the inferior aspect of the dorso-iliac spine [13].

Several studies understand with respect to the different IO access devices, that manual intraosseous needles were the first to be used. Among them, the most used are the Jamshidi/Illinois needle, the Sur-Fast needle, and the Dieckmannnn. They are the simplest and cheapest [1].

The Cook Dieckmannn intraosseous needle is composed of a thick metal needle in the shape of a pyramid for adults and a pencil-shaped needle for children and infants (Figure 1). Apart from the needle, it has a sear and a handle, which allows us to exert force on it to cross the cortex of the bone and access its interior. This needle has a black mark located 1 cm from the tip of the catheter, which will be the visual reference point. The needle is inserted perpendicular to the joint. The insertion of this type of needle is carried out by pressure, with a slight rotational movement to penetrate the cortex of the adult patient [1–3].

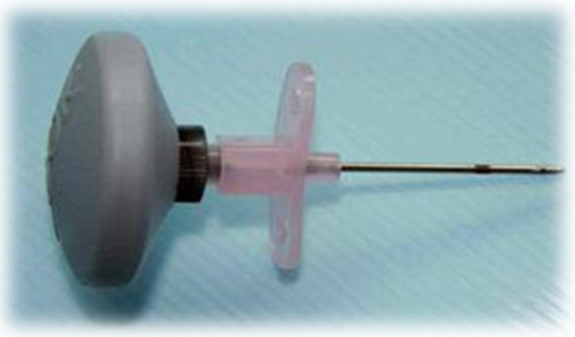


Figure 1. Cook Dieckmannn intraosseous needle. Source: *NPunto Magazine*, 2019 (1).

Among the devices for placement by firing, we can distinguish those intended for sternal access (FAST) and those that are not (BIG) [1,2]. The FAST I device (First Access for Shock and Trauma) creates a channel that allows the administration of fluids through the sternum (Figure 2). It is a set of needles around a central unit that is attached to a Luer-Lock type connector. The kit contains an introducer, a line extension system, an adhesive patch, a protective dome, and a dressing to disinfect the skin [1].

Figure 2. FAST 1 intraosseous device. Source: *Pubmed*, 2016 (15).

The intraosseous infusion gun, or Bone Injection Gun (BIG), is for single use (Figure 3). It consists of a spring, a trigger that fires the pre-assembled catheter, and a compact system with a safety pin. This device can be used in hard cortical bones, but the length of the needle can be conditioned due to the variability of the thickness of the chosen puncture site [1].

Figure 3. BIG intraosseous device. Source: *Journal of Anales de Pediatría*, 2015 (13).

The main advantages are the ease of learning the technique, the speed in channeling a vascular access (less than 1 min), the high success rate (>90%) in trained personnel, the guarantee it offers for the administration of fluids and drugs, and the safety it shows as it is a non-collapsible route, especially in situations of cardiorespiratory arrest or shock [11,13]. Furthermore, there is the possibility of obtaining a blood sample through the IO and the ease in recognizing the anatomical landmarks that serve as a guide to locate the puncture site [14,15]. Any drug or solution that can be administered intravenously can be administered intraosseously in the same dose or quantity [16,17]. It has been scientifically proven that the serum levels and efficacy are equivalent to those achieved via the peripheral or central route in both adults and children [11–18].

The general objective of this work is to update the theoretical and practical strategy of the insertion and proper management of the intraosseous route as an emergency vascular access for health professionals.

2. Materials and Methods

The preparation of this work was carried out through a systematic bibliographic review of the articles found by searching the following databases: Medline/Pubmed, Research Care, Elsevier/Embase, Scopus, and Google Scholar. To find the best possible scientific evidence, a series of inclusion and exclusion criteria were applied.

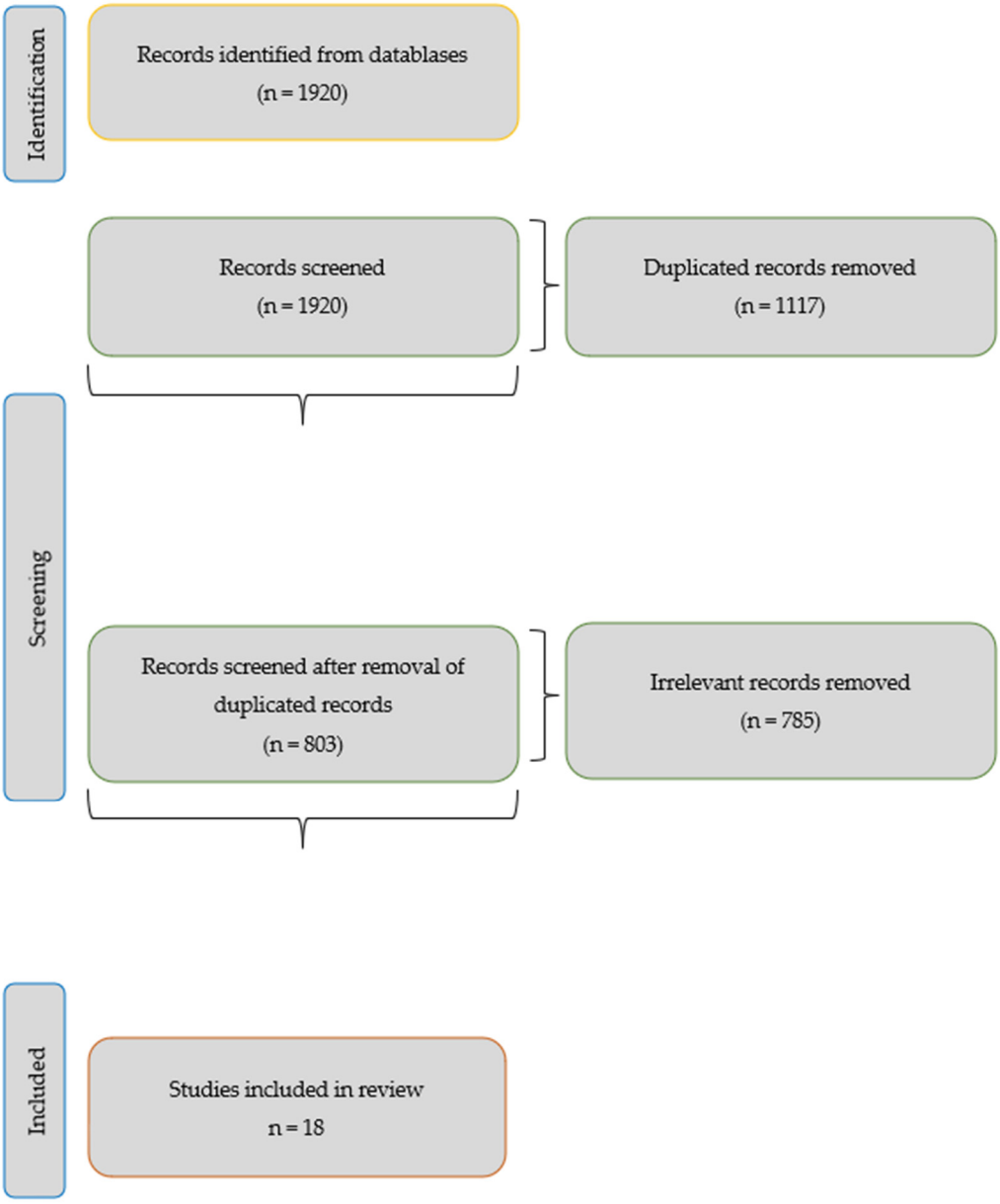
The keywords for this review are: intraosseous access; emergencies; and adult. To carry out the bibliographic search, different keywords in English were used, such as: "intraosseous access", "emergencies", "intraosseous access", and "adult". These have been validated by the DeCS and MeSH. Once selected, the corresponding Boolean operators were used: AND/OR, as well as the necessary parentheses and quotation marks. The final search string is as follows: ("Intraosseous Access") AND ("adult"). The criteria that were taken into account for the selection of the relevant studies were the following. Inclusion criteria: the period between 2015 and 2021; article type: article review and article research; field: nursing; English language; sample in adult population; and studies that provide scientific evidence justified by the level of indexing of articles in journals according to the latest certainties. Exclusion criteria: articles prior to 2015; language: not English; studies in which the population was minors; studies that do not provide scientific evidence justified by the level of indexing of articles in journals according to the latest certainties.

For the methodological evaluation of the individual studies and the detection of possible biases, the evaluation was carried out using the PEDro Evaluation Scale. This scale consists of 11 items, providing one point for each element that is fulfilled. The articles that obtained a score of 9–10 points have an excellent quality, those between 6 and 8 points have a good quality, those that obtained 4–5 points have an intermediate quality, and, finally, those articles that obtained less than 4 points have a poor methodological quality article [19].

The Scottish Intercollegiate Guidelines Network classification was used in the data analysis and assessment of the levels of evidence, which focused on the quantitative analysis of systematic reviews and the reduction of systematic error. Although it took into account the quality of the methodology, it did not assess the scientific or technological reality of the recommendations [20].

3. Results

The research question was constructed following the PICO format (Population/patient, Intervention, Comparator, and Outcomes/Outcomes). Detailed as in adult patients (P), intraosseous access (I) is a better option compared to intravenous access for the administration of fluids and medications in critical situations (C), in order to achieve greater survival and effectiveness (0) (Scheme 1).



Scheme 1. Flow diagram.

Below is a table that shows the search strategy used to select the 18 articles selected from the 6 databases, following the criteria of identified studies, duplicate studies, title,

abstract, full text, and valid studies of a definitive nature (Table 1). The total number of valid articles is summarized in Appendix A.

Table 1. Databases consulted.

Item Criteria	Medline/Pubmed	Google Scholar	Research Care	Elsevier/Embase	Scopus	Total
Identified	484	297	315	367	457	1920
Duplicates	293	214	124	255	321	1117
Title	45	21	19	28	30	143
Abstract	39	17	18	26	29	129
Text complete	36	15	14	25	27	117
Valid	6	2	3	4	3	18

According to detailed studies, to determine effective nursing health activities in the use of the intraosseous route, nursing professionals can administer intraosseous medication according to IAS 2303 [1–4]. In the management of health care, it is essential to carry out a rapid intervention, in order to reduce the probability of morbidity and mortality and favor the recovery of the patient [3,4]. The appropriate intraosseous device must be chosen for the insertion site and the patient's situation [5–8]. To describe the benefits and harms of using an intraosseous access compared to venous access, [2,4] both the localization and insertion techniques of the IO are simple [5–7]. The percentage of complications is minimal (<1%) [8–11]. Any drug or solution that can be administered intravenously can be administered intraosseously, in the same dose or quantity [11,12]. IO offers faster cannulation of a vascular access and a higher percentage of successes in trained personnel [13–15]. A disadvantage is the high costs of needles and intraosseous games [15–17]. According to studies, in order to assess the knowledge and experience that healthcare professionals have regarding the use of the intraosseous route, at present, it continues to be an underused route in emergency situations, despite all the good possibilities it has [17,18]. A comprehensive training and education program, with regularly updated sessions, should allow for rapid and reliable placement of the IO device with proper management and monitoring [18].

4. Discussion

Faminu F. shows that the absence of immediate venous access can lead to increased morbidity and mortality in patients [1,6]. Authors such as Janneth R., argue that IO should only be used in situations involving a vital emergency and for a limited time, when venous access is inaccessible and it is a temporary measure until a venous line is achieved [6,11]. Some indicated situations in which an intraosseous route is acceptable are severe bleeding, cardiorespiratory arrest, dehydration, shock, trapped, multiple traumas, severe edema, hypovolemia, sepsis, severe burns, and poisoning, among others. In cases in which the patient is conscious, local anesthesia will be used in the puncture site [1,6,11].

Méndez García J.L., Garagatti Oliveira C., and Janneth R. endorse that the contraindications of the intraosseous route are situations in which this technique should be avoided due to the high probability of complications [4,11]. To do this, we must assess whether the benefits outweigh the risks before acting [6,7]. Therefore, the IO route cannot be used in fractured or punctured bones. In the case of suspected proximal and distal tibia fracture, it is completely contraindicated as they share a common pathway within the bone. On the other hand, if the femur is fractured but the tibia is not, the insertion in the tibia can be performed. Furthermore, we cannot use IO in bones with osteoporosis, osteogenesis, with a history of surgery or prostheses, cellulitis, areas with necrotic tissue or burns, or areas with bone tumors or osteomyelitis. In addition, the aforementioned authors confirm that IO in the lower limb extremities is totally contraindicated in patients with severe abdominal trauma and previously punctured bones [4,9,11]. Distal femur IO is feasible and associated with similar measured performance parameters to other IO sites in adult out-of-hospital cardiac resuscitation for basic and advanced life support personnel [21].

Rodil Díaz J.A. and Taboada Martínez M.L. have shown with a success of 88–95% that the proximal and distal tibia are easily accessible areas, because there is not much fat between the skin and periosteum, becoming a good option for obese patients [1]. Tan et al., observed in a study of 42 patients, 20 with access in the proximal tibia and 22 with access in the distal tibia, that the flow rate of the saline solution administered was higher in the proximal tibia compared to the distal one [7], while Pasley et al., confirmed that the flow velocity in the sternal route was 1.6 times higher than the humeral one, and 3.1 times higher than the tibial one [8].

Montez D.F. et al., in a study of healthy adult volunteers, injected contrast medium through the proximal humerus and captured with fluoroscopy as it entered the heart. The mean time to reach the contrast in the superior vena cava and the right atrium was 2.42 s [9].

According to Petitpas F. et al., complications are infrequent (<1%), since the main problems are due to the lack of experience of the healthcare personnel who perform the technique. The most frequent are due to fluid extravasation around the puncture site, bone fracture, growth plate injury, bone infection, appearance of compartment syndrome when crossing two cortices, or that the bone marrow and fibrin mesh have decreased flow [15]. Petitpas F., et al., also assures that intraosseous insertion should be limited to a few hours until venous access is achieved, without exceeding 24 h. If, after 24 h, we still need to use the intraosseous device, we must insert another in a different area and remove the previous one, since fluids after 24 h may leak. In the cases of infiltration, we will be forced to interrupt the infusion, remove the device, and perform the procedure in another area [15].

Afzali M. et al., include that teaching intraosseous access insertion to students in cadaver courses is an excellent way to introduce early training skills. Additionally, allowing sufficient time for the repetition of the technique leads to an improvement in safety. Therefore, adding these activities in the curricula would increase the competences of each of the students. It is concluded that by attending the IO insertion workshops, a greater degree of confidence is gained than by observing the technique through videos or lectures [18]. Manrique Martínez et al., understand with respect to the different IO access devices, that manual intraosseous needles were the first to be used. Among them, the most used are the Jamshidi/Illinois needle, the Sur-Fast needle, and the Dieckmannnn. They are the simplest and cheapest. Among the devices for placement by firing, we can distinguish those intended for sternal access (FAST) and those that are not (BIG). Fast devices are discouraged when they may interfere with emergency cricothyrotomy or resuscitation maneuvers. Instead, they are very useful in multi-casualty accidents [13].

Median insertion time with EZ-IO was 15 s compared to 20 s with the FAST-Responder. Insertion complications recorded with the EZ-IO included extravasation, aspiration failure, and insertion time >30 s. With the use of the FAST-Responder, complications such as user failure (12.5%) and insertion time > 30 s (12.5%) were reported. Regarding flow, we found that 35.1% of EZ-IO inserts experienced poor flow and required a pressure bag. With the FAST-Responder, flow was reported as very good or good in 85.7% and no inserts had poor flow [18,21,22] (Table 2).

Table 2. Differences between intraosseous access devices.

Methodology for Placement of Intraosseous Access	Devices	Mechanism of Action	Fixation	Duration of Use	Approximate time of Application	Price (Euros)
Mannual pressure	COOK	Pressure and rotation on the crust.	Requires fixing.	One use	20 s	60 z
	FAST	Manubrio-sternal perpendicular pressure.	Needs protection by dome.	One use	50 s	126.67 z
By means of impact or firing devices	BIG	Spring shot.	Needs fixing.	One use	17 s	63.20 z
Using an electric drill	EZ-IO	The motor works like a drill and the needle works like a drill. The needle is coupled with a magnet.	It does not need fixing.	One use	10 s	Motor: 418.18 z Needles: 140.58 z

According to the evidence documented by Montez D. et al., motorized drill systems are made of non-porous, fluid resistant plastic. Whenever we are not going to use the drill, we have to place the trigger guard to avoid total consumption of the battery and a discharge. The red light will indicate that there is 10% battery left. They are not designed to be opened, so the batteries are not replaceable [12]. Manrique Martínez shows that the IO should be performed sterile with previous hand washing. To avoid infections, it is convenient to surround the intraosseous needle with a sterile dressing, disinfect the area every 4–6 h, and replace the dressing when it is dirty or wet. Additionally, he shows that the removal of the intraosseous device must be performed by a qualified professional [13]. Although IO is reserved for emergencies and critical care conditions, there are documented cases of quadriplegic patients for many years due to progressive spinal muscular atrophy and refractory disease. IO access was used for palliative sedation with propofol in a home care setting [23].

Regarding the limitations of the study, although the results obtained are conclusive in response to the objectives of the study, larger samples could yield more conclusive results. The heterogeneity between the studies means that the results found should be taken with caution. Given the paucity of published clinical trials, it is difficult to address and see how these techniques affect patients comprehensively, therefore justifying the conduct of future research.

5. Conclusions

With this review, we update the evidence of the theoretical and practical knowledge and strategy for the application of the insertion and proper management of the intraosseous route as an emergency vascular access. We show that the proximal humerus bone is the first option in adults. Through this criterion, we achieve higher infusion rates, less pain on insertion, and greater drug bioavailability. The flow velocity is greater in the proximal tibia bone than in the distal tibia bone. As for the sternal access, this allows us to reach the central venous circulation due to its proximity through the mammary glands. Regarding the technical materials, the EZ IO T.A.L.O.N device is designed to be placed on the sternum and is the one that presents the best efficiency in application time.

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Abbreviations

IO	Ankle-brachial index test
PALS	Pediatric Advanced Life Support
ERC	European Resuscitation Council
AHA	American Heart Association
BIG	Bon Injection Gun
FAST	First Access for Shock and Trauma

Appendix A. Selected Scientific Articles Table

Authors; Year	Type of Study	Patients	Conclusion
Rodil et al., 2019	Systematic review.	11 studies of between 15 and 105 adult participants.	Resuscitation therapy with low-titer cold-stored O-positive whole blood is the cornerstone of military resuscitation in hemorrhagic shock. Over the past 19 years, improved patient outcomes have demonstrated the importance of this intervention in the management of shock. Intraosseous placement of the iliac crest is an alternative when peripheral sites, such as the humeral head and tibia, are not available options. To date, no study has explored the administration of LTCSO + WB through an IO iliac crest in the military prehospital setting. Contingency procedures for vascular access are necessary for victims with severe trauma to all four extremities, and the iliac crest is a viable option. The literature supports situational advantages over other peripheral IO sites.
Dabrowska et al., 2017	Systematic review.	28 studies.	Today, intraosseous access is not only an alternative method for administration of pharmacotherapy or fluids, but it is also often used in life-threatening conditions. Although previously it was a method commonly used in pediatrics or in the military, for several years it has been advocated as the primary access point for patients in a critical condition. While this applies mainly to children, it may also include adults in a hospital setting, as well as in the emergency department. Often times it is used when intravenous access is difficult or the patient is seriously ill. Many scientific circles at the American Heart Association and European Resuscitation Council approve this method.
Baadh et al., 2016	Systematic review.	35 studies.	Intraosseous access provides a fast, efficient, and safe alternative to central and peripheral venous access in the critically ill patient. Compared with traditional central venous access in the emergency setting, intraosseous cannulation is more likely to be successful on the first try and requires much less time. As such, the use of intraosseous devices by first responders is becoming more common.
Méndez García et al., 2018	Systematic review.	14 studies.	Obtaining a vascular access quickly and efficiently during the care of a patient in a very serious condition or in an immediate vital emergency situation is transcendental in order to be able to administer drugs and fluids adequately and effectively to try to reverse the critical state we find ourselves in. This technique can be applied by both medicine and nursing staff, although in the vast majority of cases, it is the nursing staff who are in charge of carrying it out within the work in coordination with the emergency team.

Authors; Year	Type of Study	Patients	Conclusion
Píriz Campos et al., 2016	Systematic review.	7 studies.	Distal femur intraosseous vasculature was feasible and associated with similar measured performance parameters to other sites of intraosseous vasculature in adult out-of-hospital cardiac resuscitation for basic and advanced life support personnel.
Faminu, 2015	Systematic review.	14 studies.	Healthcare professionals should weigh the advantages and disadvantages of intraosseous vascular access devices, especially if these devices are no longer used in their unit of care. Journal articles, specific book chapters, and educational materials provided by intraosseous device manufacturers help professionals decide if this technology is appropriate for the patients they care for. In healthcare centers where intraosseous vascular access devices are already being used, regular assessments of the competency of professionals are essential to maintain a low rate of complications.
Tan et al., 2015	Observational study.	22 patients were recruited, with 20 proximal tibial and 22 distal tibial insertions.	Flow rates are significantly faster in the proximal tibia compared with the distal tibia. In addition, flow rates with pressure bags are significantly faster than without pressure bags in both groups.
Pasley et al., 2015	Observational study.	For 16 cadavers over a 5-min bolus infusion.	This is the first study comparing the rate of flow at the three most clinically used adult IO infusion sites in an adult human cadaver model. Our results showed that the sternal site for IO access provided the most consistent and highest flow rate compared with the humeral and tibial insertion sites. The average flow rate in the sternum was 1.6 times greater than in the humerus, and 3.1 times greater than in the tibia.
Montez et al., 2015	Observational study.	Seven subjects had contrast injected through the right PHIO catheter.	The mean elapsed time from appearance of contrast from the type of the IO catheter to appearance at the superior vena cava was less than 3 s, suggesting that use of PHIO vascular access as the first line of access should be considered when urgent access is needed, and rapid administration of drugs or fluids is required.
Perez Rojano, 2018	Systematic review.	51 studies.	Intraosseous access is a safe and effective technique to help increase patient survival. It is of vital importance that nursing professionals in the outpatient setting know and manage the technique and the different devices for intraosseous access as an alternative when immediate peripheral venous access is not possible.
Janneth, 2019	Systematic review.	20 studies.	The intraosseous route allows a drug administration route to be channeled directly to the medullary cavity inside the bone. This technique can be used in emergency situations, predominantly in the hospital setting with critical patients, when a peripheral route has not been achieved after three attempts or ninety seconds, with a low complication rate. Knowledge and management of the different devices for intraosseous use is essential for their correct use, thus increasing patient safety and the effectiveness of the treatment administered to reduce complications until being transferred to a specialized center.
Montez et al., 2017	Systematic review.	285 articles.	All IO vascular access products are designed to deliver fluids and medications through the IO space. Devices fall into three basic categories: manual, impact-driven/spring-loaded, and semi-automatic devices. The EZ-IO® Device is the only battery-powered device on the market. Several research studies and review articles have examined comparative clinical data among various IO devices on the market.
Manrique Martínez et al., 2015	Systematic review.	30 studies.	IO access is a fast, easy to learn, and safe route for the patient, which can help save many lives in those emergency situations when another venous line cannot be cannulated. It has been shown that with adequate theoretical-practical training for health professionals, such as that taught in advanced and instrumentalized CPR courses, sufficient learning is achieved for most to be able to install an IO pathway successfully in a short time.

Authors; Year	Type of Study	Patients	Conclusion
Battaloglu et al., 2017	Systematic review.	21 studies.	The need for prehospital resuscitative hysterotomy and perimortem caesarean section is rare. The procedures can be daunting and clinically challenging for practitioners. Maternal death can be prevented by swift and decisive action. This guideline serves to inform prehospital practitioners about conducting maternal resuscitation following cardiac arrest, provides an evidence-based framework to support decision making, and highlights areas for improvement in prehospital care.
Petitpas et al., 2016	Systematic review.	49 studies.	Indications for IO infusion use in adults requiring urgent parenteral access and having difficult intravenous access are increasing. Physicians working in emergency departments or intensive care units should learn the procedures for catheter insertion and maintenance, the contraindications of the technique, and the possibilities this access offers.
Overbaugh et al., 2015	Observational study.	24 subjects completed the study.	Preliminary results indicate that IO vascular access can be safely maintained for a period up to 48 h without risk of osteomyelitis or other serious adverse events. Extended dwell time and increased IO access utilization could result in the avoidance of serious complications and costs associated with peripherally inserted central catheters (PICC lines), as well as femoral, subclavian, and internal jugular central venous catheters being placed due to difficult vascular access, when central venous access may not be clinically necessary. Using additional analgesics for IO infusion pain management may be more effective than the current standard of only administering lidocaine into the IO space.
Calvo Quirós, 2016	Systematic review.	14 studies.	There are emergency situations where obtaining vascular access can be difficult, late, and frustrating. Health professionals not familiar with the techniques and who do not use these procedures frequently, generally fail or take longer to perform them, or in certain cases where it is impossible to channel the usual vascular accesses for various reasons, in the case of children, add to the fact that anxiety and urgency make it technically more difficult to place a venous access in very seriously ill patients.
Afzali et al., 2017	Systematic review.	19 studies.	Teaching procedural skills to medical students and other novice learners in cadaver courses is an excellent way to introduce early skill training and allow time for spaced repetition for learners to obtain deliberate practice and improve patient safety. Adding these skills to the existing curriculum, e.g., by implementing them in the anatomy dissection course and other resuscitation courses already present at many medical schools, demonstrates a feasible and inexpensive implementation strategy.

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