



Pediatric Emergency Cases Managed with Intraosseous Access: Indications, Complication and Outcomes

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Abstract

Intraosseous (IO) access is an alternative way of administering fluid and drug and also taking biopsies needed for clinical and laboratory tests in cases when peripheral venous access couldn't be established. The IO route was successfully secured in all cases with a significant shorter time of vascular access insertion, shorter length of stay and reduction in mortality in IO group vs. IV group. IO access was first used in 1922. This technique was widely used during 1940's when emergency medical care was routinely needed for seriously injured patients in World War II. Since 1950's after the introduction of peripheral venous access technique IO access lost its actuality. In management of Pediatric emergencies intravascular (venous) access is prior but sometimes establishing peripheral venous access is impossible or it may take too much time because of anatomical or physiological characteristics, such as an excessive subcutaneous fatty tissue and veins with a small diameter. Vasoconstriction, reduction of circulating blood volume and peripheral venous collapse takes place during cardiopulmonary arrest, septic or hypovolemic shock and prolonged status epilepticus. This features alone or in combination can make venous catheterization impossible.

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For pediatric resuscitation, vascular access must be established quickly, often in difficult circumstances. Alternative methods of peripheral access, such as umbilical catheter, central venous lines, venous cut-down, and ultrasound guided access, may be poor options because of the patient's age or condition, the urgency of resuscitation, and/or the skill of available clinicians. Anatomically, the described site is suggested to offer a safe alternative access point for emergency infusion in severely hypovolemic newborns and infants, without the risk of damage to any anatomical structures. IO access complications are infection - cellulites, abscess, osteomyelitis and fracture. The most widespread complication is extravasation, which, if left unidentified, can cause compartment syndrome. The EZ-IO® device is easy to use and requires minimal training. These studies suggest that the EZ-IO® is an easy to use, easy to learn tool that can be used successfully in resuscitation scenarios with minimal training. It is evident that blood samples drawn immediately after intraosseous cannulation can provide accurate laboratory and blood bank data to aid in resuscitation. More recently, the pharmacokinetics of intraosseous drug delivery has been compared with central venous drug delivery.

Keyword: Intraosseous (IO) access; Venous access; Intraosseous drug delivery.

1. Introduction

Intraosseous (IO) access is an alternative way of administering fluid and drug and also taking biopsies needed for clinical and laboratory tests in cases when peripheral venous access couldn't be established. The cornerstone of emergency management of sepsis is early, goal-directed therapy. The effect of intraosseous (IO) vs. intravenous (IV) access for resuscitation of patients with septic shock admitted to pediatric intensive care unit [1]. The IO route was successfully secured in all cases with a significant shorter time of vascular access insertion, shorter length of stay and reduction in mortality in IO group vs. IV group. In pediatric emergencies, as in case of shock, the use of IO route is recommended to get rapid vascular access as soon as possible, as it revealed better outcome [1]. IO access was first used in 1922. This technique was widely used during 1940's when emergency medical care was routinely needed for seriously injured patients in World War II [9-12]. Since 1950's after the introduction of peripheral venous access technique IO access lost its actuality [11]. In management of Pediatric emergencies intravascular (venous) access is prior but sometimes establishing peripheral venous access is impossible or it may take too much time because of anatomical or physiological characteristics, such as an excessive subcutaneous fatty tissue and veins with a small diameter [11]. Vasoconstriction, reduction of circulating blood volume and peripheral venous collapse takes place during cardiopulmonary arrest, septic or hypovolemic shock and prolonged status epilepticus. This features alone or in combination can make venous catheterization impossible [11-13]. During 80's it was revealed that in pediatric emergency care peripheral venous catheterization wasn't always effective. There was a need for finding alternative way. After reviewing the literature [11] it was clear that the IO access was the only alternative way for administration of fluids and drugs fast, effectively and with minimal side effects. American Heart Association (AHA) and American Academy of Pediatrics (AAP) added pediatric and neonatal resuscitation chapter in Advanced Cardiac Life Support (ACLS) guideline in which IO access is discussed as the only alternative way for fluid and drug administration [11,16,18]. In 2009, American college of critical care medicine revised sepsis guidelines in which IO insertion is discussed as an alternative way for maintaining hemodynamic stability in children and newborns [1-3]. Some research suggests that IO access is successful in

more than 90% of cases, which is an important clinical indicator. Moreover, IO insertion is performed in less than 2 minutes if it's done by skilled professional and the equipment is of high quality [15-20]. This is why the IO access is thought as the alternative way for fluid and drug administration in complicated cases or when peripheral venous catheterization is impossible [10-15]. Intraosseous line (IO) use has been described in prehospital settings too, with some studies in the emergency department (ED). However, population-based studies describing IO line use across diverse ED and hospital settings are sparse, and the true incidence of complications remains unknown [16]. It was a retrospective cohort study using administrative data from 450 California hospitals and ED.s. Two hundred ninety-one children had IO lines placed in 90 hospitals, including 239 in the ED and 52 inpatient. There were 6,660,564 pediatric ED visits and 2,276,231 pediatric admissions, resulting in an incidence of IO line placement of 0.04 per 1000 ED visits and 0.02 per 1000 admissions. Mortality was 37% among patients with IO line placement. The most common diagnoses included cardiac arrest (34%), trauma (19%), and respiratory failure (6%). Types of hospital in which IO lines were placed included children's hospitals 14%, general hospitals 86%, and rural hospitals 7.9%. No complications were identified [16]. Intraosseous vascular access is a time-tested procedure which has been incorporated into the 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation [11-16]. Intravenous access is often difficult to achieve in shock patients, and central line placement can be time consuming. Intraosseous vascular access, however, can be achieved quickly with minimal disruption of chest compressions. Newer insertion devices are easy to use, making the intraosseous route an attractive alternative for venous access during a resuscitation event. It is critical that anesthesiologists, who are often at the forefront of patient resuscitation, understand how to properly use this potentially life-saving procedure [18]. The overall incidence of IO line use in the ED and hospital setting is low, but IO line access is used in a variety of different hospital and ED settings for high-acuity conditions. No IO line complications were identified [16]. Intraosseous (IO) access is a standard of care for pediatric emergencies in the absence of conventional intravenous access. Intraosseous needles provide access for resuscitation fluids and medications and are often placed in the emergency department [11-13-17]. However, there are no studies to date that describe the characteristics of pediatric IO needle recipients or their dispositions and outcomes. This study examined the characteristics and disposition of children following IO needle placement by prehospital and emergency room teams before being transported to a children's hospital [17]. However, of those who experienced a complication, 27% were due to infiltration of the IO needle. Of those admitted to hospital, 58% (n = 83) were ultimately discharged home. Intraosseous access provides a safe and reliable method for rapidly achieving a route for administration of medications, fluids and blood products. It is a lifesaving measure with most IO needles successfully placed by referring facilities prior to transport, with few reported complications [17]. There was a case of 2 months old critically ill child who developed cardiac arrest while securing central venous access under ultra-sonographic technique. Successful resuscitation by administering fluid and drugs through prompt establishment of intra osseous access saved the life of an infant [19]. Difficulties to establish a venous access may also occur in routine pediatric anesthesia and lead to hazardous situations. Intraosseous infusion is a well-tolerated and reliable but rarely used alternative technique in this setting. According to recent surveys, severe complications of intraosseous infusion stay a rare event [17-20]. Minor complications and problems in getting an intraosseous infusion started on the other side seem to be more common than generally announced. The EZ-IO intraosseous infusion system has received expanded EU CE mark approval for an extended dwell time of up to 72 h and for insertion in pediatric patients

in the distal femur. Key values of blood samples for laboratory analysis can be obtained with only 2 ml of blood/marrow waste and do also offer reliable values using an I-Stat point-of-care analyzer [15,20]. Most problems in using an intraosseous infusion are provider-dependent. In pediatric anesthesia, the perioperative setting should further contribute to reduce these problems. Nevertheless, regular training, thorough anatomical knowledge and prompt availability especially in the pediatric age group are paramount to get a seldom used technique work properly under pressure. More longitudinal data on large cohorts were preferable to further support the safety of the intraosseous infusion technique in pediatric patients [20,21]. Intraosseous access (IO) is becoming increasingly accepted in adult populations as an alternative to peripheral vascular access; however, there is still insufficient evidence in large patient groups supporting its use. (არა მარტო ზავშვებში)!!! IO access can be used to administer a wide variety of life-saving medications quickly, easily and with low-complication rates [11,16,18,22]. This highlights its valuable role as an alternative method of obtaining vascular access, vital when resuscitating the critically injured trauma patient [22]. Intraosseous (IO) needle placement is an alternative for patients with difficult venous access. The purpose of this retrospective study was to examine indications and outcomes associated with IO use at a Level 1 trauma center (January 2008-May 2015). Data points included demographics, time to insertion, intravenous (IV) access points, indications, infusions, hospital and intensive care unit length of stay, and mortality. Of 68 patients with IO insertion analyzed (63.2% blunt trauma, 29.4% penetrating trauma, and 7.4% medical), 56 per cent were hypotensive on arrival and 38.2 per cent asystolic. The most common indications for IO infusion were difficult IV access (69%) and rapid sequence intubation (20.6%). The median time to IO access was three minutes. IV access was gained after IO in 72.1 per cent of patients. Through IO access, 30.9 per cent patients received crystalloid, 29.4 per cent received Advanced Care Life Support (ACLS) medications, 25 per cent rapid sequence intubation medications, 20.6 per cent blood products, and 2.9 per cent seizure medications. Overall, 80.9 per cent were intubated in the Emergency Department (ED), 26.5 per cent had ED thoracotomy, and 20.6 per cent had a laparotomy. Median crystalloid infused through IO was 180 cc in pediatric patients and 1 L in adults, respectively. Extravasation, the most common complication, was experienced by 7.4 per cent of patients. In hospital mortality was 72.9 per cent. IO access should be considered when there is a need for rapid intervention requiring vascular access [24]. For the pediatric cohort, use of a semiautomatic IO access device in place of a manual device offered no statistically significant difference in first-attempt success (3.3%) or in success per attempt (13.0%). However, the rate at which IO access was used by emergency medical services providers more than tripled with use of the semiautomatic device [25]. Vascular access is a potentially life-saving procedure that is a mainstay of emergency medicine practice. There are a number of challenges associated with obtaining and maintaining vascular access, and the choice of the route of access and equipment used will depend on patient- and provider-specific factors. Timely and effective assessment and management of difficult-access patients, pain control techniques that can assist vascular access, and contraindications to each type of vascular access can be discussed [26]. Intraosseous access is a rapid and effective route of fluid and drug administration. Its use has been proven in emergency medicine, pediatrics, and the military. We aimed to assess its performance and utilization against landmark-guided central venous catheter placement during inpatient medical emergencies [27]. We found information in various scientific publications about intraosseous device training which was added to standard central venous catheter training beginning in February 2012. Intraosseous were used as primary access in cardiac arrests and secondary access if central venous catheter placement failed

during noncardiac arrest emergencies. An online survey was conducted among intraosseous and central venous catheter operators to assess their experience and any barriers to use. In this study Seventy-nine adults had central access placement from February 2012 to July 2013. Sixty were during medical emergency team calls, and 19 were cardiac arrests. Thirty-one received intraosseous device, and 48 received a central venous catheter. First-pass success was significantly higher for intraosseous than for central venous catheter (90.3 vs 37.5%; 95% CI, 80-101 vs 24-51; $p < 0.001$). Mean placement times were significantly shorter for intraosseous than for central venous catheter (1.2 vs 10.7 min; $p < 0.001$). There was a total of 33 intraosseous versus 169 central venous catheter attempts with fewer attempts on average per patient during intraosseous placement (1.1 vs 2.8; $p < 0.001$). There were three intraosseous-related complications and 22 central venous catheter-related complications. This survey showed high satisfaction with intraosseous training and operation. Among the barriers cited, timely intraosseous kit acquisition was most common [27]. It is feasible to incorporate intraosseous use during medical emergency team calls. Intraosseous had significantly higher first-pass success rates and faster placement compared with central venous catheters. Intraosseous operators reported high satisfaction and confidence in its use. Prospective randomized studies comparing intraosseous and central venous catheter are warranted [27]. For pediatric resuscitation, vascular access must be established quickly, often in difficult circumstances. Alternative methods of peripheral access, such as umbilical catheter, central venous lines, venous cut-down, and ultrasound guided access, may be poor options because of the patient's age or condition, the urgency of resuscitation, and/or the skill of available clinicians. When peripheral access fails after 3 attempts (or in 90 seconds), an intraosseous line offers emergency clinicians a fast and effective alternative for venous access in children of all ages. They can be inserted within 5 to 60 seconds, and they require little clinician experience or training and minimal equipment. The American Heart Association, the International Committee on Resuscitation, and the American College of Surgeons all recommend intraosseous line use [28]. Although contraindications include existing bone fracture or bone disease, complication rates are similar to central venous catheters. This review looks at the guide- lines, recommendations, and evidence on using intraosseous lines in pediatric patients and gives information about mechanical devices used, techniques for insertion, and possible complications [28]. Studies have shown that the venous system tends to collapse during hypovolemic shock. The use of the bone marrow space for infusions is an effective alternative, with the tibial insertion site being the norm. This study was conducted to determine a quick intraosseous infusion method that could be an alternative to the tibial route in neonates during emergency situations [20,29]. Anatomically, the described site is suggested to offer a safe alternative access point for emergency infusion in severely hypovolemic newborns and infants, without the risk of damage to any anatomical structures [29,30]. Gaining vascular access in a neonate during cardiopulmonary resuscitation is crucial and challenging. Intraosseous (IO) access can offer a fast and reliable method for achieving emergency access for fluids and drugs when venous access fails in a critically ill child. IO access can however result in rare, but serious adverse events including compartment syndrome and amputation [30-33]. There was a case resulting in leg amputation due to IO infusion in a neonate after resuscitation and therapeutic hypothermia. We compared 10 tibia X-rays in three age groups. The mean medullary diameter of the proximal tibia at the recommended site for IO access was 7 mm in neonate, 10 mm in 1- to 12-month-old infants, and 12 mm in 3- to 4-year-old children. This provides a narrow margin of safety for the correct positioning and the avoidance of dislodgement of the IO needle [10,31]. IO access complications are infection - cellulites, abscess, osteomyelitis and fracture. The most widespread

complication is extravasation, which, if left unidentified, can cause compartment syndrome [7]. IO access must be done in aseptic conditions to minimize complications. The catheter insertion site must be checked for extravasation before and after catheter insertion. Peripheral or central catheterization has to be done as soon as it's possible. The perfect time for it is 24 hours [8]. In this research it was unable to study all the complications of IO access. The most common complication of IO access is infiltration [4]. Mortality rate is still high in patients in whom IO access wasn't established before arriving to hospital (40%). We hope that mortality rate will significantly decrease with an implementation of PALS guidelines [10]. Approximately 46.8% of patients had cardiovascular and respiratory arrest in combination [12]. IO access was established in cases in which attempt of venous catheterization was unsuccessful. From this research it is obvious that most of the patients survived and discharged from clinics [10]. It is interesting that this study was conducted before the PALS 2010 guidelines were approved, in which it is indicated that IO access must be established if venous catheterization is unsuccessful. During the study they found out that IO access was widely used for fluid and drug administration in pediatric population in 1985 [5]. IO access has advantages compared to central and peripheral catheterization: 1. IO access technique was used in 46,8% of cases with respiratory and cardiovascular arrest. 2. Respiratory failure - 17.5%. 3. Cardiovascular failure - 11.2% and finally sepsis/fever/dehydration - 9.1%. The problem is that IO access can be used only for 24 hours [10]. The reason for which IO access is thought as an alternative way for peripheral catheterization is: Impossibility of peripheral venous catheterization in 53.1 % of cases, absence of perfusion in 33.6 %. Accidental removal of already established catheter in 6.3 % of cases [10]. The correct position of the IO needle should be confirmed by bone marrow aspiration and fluid bolus. Unnecessary touching of the IO needle after fixing it in place should be avoided by inserting a luer lock catheter with a three-way stop-cock for IO drug and fluid administration. Regular observation of the circulation and possible swelling of the leg should be performed. The IO administration of inotropic infusions should also be avoided after the initial resuscitation phase. When treating with therapeutic hypothermia it may be wise to remove the IO needle much earlier than the currently recommended 24 h because of the problems in peripheral circulation and its monitoring [31]. Complication rates are estimated to be low, based on small patient series, model or cadaver studies, and case reports. However, user experience with IO use in real-life emergency situations might differ from the results in the controlled environment of model studies and small patient series [33]. Survey was performed of IO use in real-life emergency situations to assess users' experiences of complications [31-33]. In users' recollection of real-life IO use, perceived complications were more frequent than usually reported from model studies. The perceived difficulties with using IO could affect the willingness of medical staff to use IO. Therefore, user experience should be addressed both in education of how to use, and research and development of IOs [33].

2. Conclusion

Intraosseous cannulation is a time-tested procedure that will play a role in the resuscitation of patients in the future. Intravenous access is often difficult to achieve in shock patients and central line placement can be time consuming. This literature review has demonstrated that intraosseous vascular access can be achieved quickly and accurately in emergency situations. Given the efficiency of insertion combined with a favorable complication profile, there is clearly a role for intraosseous vascular access in the resuscitation of critically ill patients. Therefore, emergency care doctor should become familiar with intraosseous insertion techniques and

understand how to properly use this potentially life-saving procedure. The EZ-IO® device is easy to use and requires minimal training. These studies suggest that the EZ-IO® is an easy to use, easy to learn tool that can be used successfully in resuscitation scenarios with minimal training. It is evident that blood samples drawn immediately after intraosseous cannulation can provide accurate laboratory and blood bank data to aid in resuscitation. More recently, the pharmacokinetics of intraosseous drug delivery has been compared with central venous drug delivery. As per the 2010 AHA guidelines, all Advanced Cardiac Life Support medications are administered at the same doses regardless of route. Colloids have also been effectively administered through the intraosseous route. An analysis of hydroxyethyl starch pharmacokinetics demonstrated no significant difference between intravenous and intraosseous administration.

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