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Review of the Literature on The Progress of Intraosseous Infusion in Clinical Practice

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Abstract

In emergency situations, the prognosis for the patient's outcome is determined by how quickly fluid access is established and resuscitation with fluids and drugs is administered. Because peripheral veins collapse in critically ill patients with shock, limb defects, and severe burns, it is difficult for medical staff to quickly establish insertion of a peripheral venous catheter. In recent years, the application of intraosseous infusion in early adult fluid resuscitation has received a lot of attention and investigation. However, clinical data from current large-scale clinical RCTs on intraosseous infusion and training of medical staff are insufficient. It is important that rapid and safe administration of IO infusion for parenteral access in patients with difficult venous access is possible. This article focuses mainly on a literature review of advances in the clinical application of IO.

Keywords

Intraosseous infusion; Emergency Nursing; Review.

1. INTRODUCTION

In clinical practice, treatment efficacy and patient prognosis are determined by the rapid and effective establishment of fluids/drugs access. In patients diagnosed with acute and critical conditions such as shock, severe trauma, gunshot wounds, severe dehydration, severe burns and seawater immersion injuries, rapid fluids and drugs can determine the prognosis. Common routes of infusion available to health care providers are as follows: central venous catheter, peripheral intravenous catheter and intraosseous infusion (IOI). The American Heart Association and the European Resuscitation Council recommend that IOI should be considered if venous catheterization fails twice or if the catheterization time exceeds 90 seconds[1]. In particular, IOI should be the first choice for emergency treatment of infants, severe burns or limb damage trauma when the establishment of venous access in emergency treatment. According to statistics, the average successful catheterization time of IOI was 70.04 ± 48.64 s[2]. The application of IOI in emergency treatment such as cardiac arrest and shock can significantly shorten or improve the time of blood pressure shortening, heart rate recovery time and the length of rescue room stay. In the emergency setting, the indications and application scenarios of IOI can be an effective alternative after failure of peripheral venous catheterization procedures. Emergency room or ICU staff should widely carry out IOI operation training and nursing learning.

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2. HISTORICAL BACKGROUND FOR IOI

In 1922, Drinker et al. published the first report on the physiological characteristics of the circulation of the intraosseous marrow vascular system[2]. In this article, the intramedullary vascular system was likened to a vein that never collapses. It was this statement that aroused the interest of researchers in the marrow vascular system. In 1940, Tocantins et al. first published the successful infusion of blood products as well as crystalloid fluid via the IOI route in a paediatric patient[3]. In the following decades, however, the use of IOI was limited to paediatric patients. In 2005, the American Heart Association first recommended that IOI could be used in adult cardiopulmonary resuscitation and emergency cardiovascular care scenarios. In 2011, the EZ-IO infusion system was officially approved in Europe and can be used for puncture infusion of the distal femur in children[4]. In 2015, the American Heart Association officially recommended IOI as one of the preferred alternatives to peripheral intravenous fluids in guidelines[5]. Nevertheless, IOI is far from being widely carried out in clinical practice. In the UK, although 74% of emergency physicians knew that IOI could be a possible option for infusion access, the actual application rate was only 7%[6].

3. INDICATIONS FOR IOI

3.1. Pediatric patients in emergency or critical care

The first successful clinical application of IOI is in paediatric patients. In emergency clinical care, it is more difficult to establish infusion channels in paediatric veins than in adults, due to their diameter and other reasons. IOI can effectively shorten the time it takes to establish an IV cannulation and reduce the incidence of complications.

3.2. Patients in shock

Wars, natural disasters, and car accidents may lead to a large number of clustered shock patients. To date, a large number of studies have demonstrated the superiority, efficacy and safety of IOI infusion techniques in such patients. In emergency situations, blood products, anti-shock drugs or crystalloid fluids can be administered via the IOI method. Some studies have shown that IOI can also be an effective way to monitor the results of laboratory tests such as blood group, hemoglobin concentration, and hematocrit. However, because the intraosseous environment and the peripheral venous circulation system have different characteristics, further experimental studies are needed to clarify the specific correlation between the two test indicators.

3.3. Patients in cardiac arrest

The European Resuscitation Council, in its 2018 guidelines for emergency cardiac arrest, states that IOI has definite advantages over other routes of infusion when used in emergency situations[7]. It is important to note that IOI puncture sites should be chosen that do not affect CPR operation, such as the tibia. In addition, when resuscitating with fluids through the IOI route, usage of pressure bags is required to enhance flow rate that meets emergency criteria.

3.4. Other emergencies

We may also consider IO to establish an infusion route for severe burns in patients who have difficulty establishing venous access. In addition, medical staff may also consider IOI if the peripheral venous system of an intravenous addicted patient has difficulty establishing an infusion route.

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4. CONTRAINDICATIONS FOR IOI

Contraindications to IOI include: skin and subcutaneous tissue infection at the puncture site, fractures, bone marrow infection and recent local IO puncture failure. The debate as to whether osteoporosis and osteosclerosis can be used as puncture sites for IO is inconclusive.

5. DEVICES AND INSERTION OF IOI

5.1. Manual devices

The manual device, generally used as an alternative method of puncturing when automatic devices are not available. The Dieckmann modified puncture needle is currently the most commonly used manual puncture device for IO puncture. In addition, the Bone Marrow Biopsy Puncture Needle can also be used as an alternative device for IO in emergency situations. The success rate of manual puncture devices is generally higher in children than in adults due to the soft nature of their bones.

5.2. Semi-automatic devices

There are three different types of semi-automatic IO puncture devices available: FAST, EZ-IO and BIG. There is insufficient evidence to support the effectiveness of semi-automatic devices. However, these devices are commonly used clinically to perform IO in adult patients. The FAST devices were officially approved by the US Food and Drug Administration for sternal notch puncture in 1997[8]. The use of FAST requires caution: (i) this puncture device is primarily used in adults; (ii) children <12 years of age are not recommended for this series of puncture devices; and (iii) re-puncture is not recommended if the puncture fails. Some studies have shown that IOI through the sternum is significantly faster than other puncture sites, such as the femur, humerus and tibia. However, if CRP is clinically necessary, it is not recommended to perform IO at the sternum or with the FAST puncture device.

The EZ-IO is a re-disposable IO puncture devices that can be equipped with two types of power, both of which are powered by lithium batteries, and can be repeated approximately 500-1000 times.

The BIG is a semi-automatic IO puncture device that allows the IO needle to penetrate the bone cortex by manually compressing the spring to generate kinetic energy. Demir et al. found that the BIG had a higher rate of successful puncture and a shorter operation time compared to manual puncture devices. The BIG devices are currently used in military emergency organisations and are expensive. The BIG can be used for IO access to the humerus, distal femur and tibia.

6. INSERTION OF IOI DEVICES

The choice of IO puncture site is clinically relevant. Common puncture sites include: sternum, clavicle, tibia, femur, humerus, etc. If a patient requires CRP, we would not recommend the sternal site for IO access. In addition, caution needs to be taken to ensure that the skin and subcutaneous tissues at the prepared puncture site are not infected; and that there are no fractures of the local puncture site. IO puncture sites require routine skin disinfection and aseptic draping prior to surgery.

The proximal tibia (5-10 mm medial to the proximal tibia) and the distal tibia (20 mm above the medial ankle midline) are the most commonly used puncture sites in clinical practice. The advantages of tibial puncture are the relatively high success rate of IO access and the low likelihood of IO needle dislodgement. Santos et al. compared IO puncture site success rates in adult emergency cardiac arrest patients (N = 182). The results showed that the success rate of

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the first puncture was the highest in the tibia (91%), 51% in the humerus, and only 43% in the peripheral vein[9]. Peripheral venipuncture took relatively short median time.

We recommend the humerus as the IO puncture site if there is a fracture, injury or infection in the lower limb. Humeral puncture is relatively less likely to injure the cardiopulmonary vessels and the flow of fluid for IOI infusion is high. In general for children, we usually recommend choosing the sternum or femur as the IO puncture site.

7. PHARMACOKINETICS VIA IOI

Anti-shock drugs, antibiotics, blood products and crystalloid fluids can all be safely administered via IO access. Theoretically, any drug that can be infused through a peripheral vein can be infused through IO devices. We recommend that the administration of vasoactive drugs should be followed by 10 ml of fluid or more to ensure that the vasoactive drug can enter the body circulation completely. In animal models, sternal IOI concentrations peaked at 53 seconds, tibial IOI at 107 seconds[10]. Individual clinical trials showed that the time to peak concentration following administration of morphine IOI infusion through the sacroiliac site generally paralleled that of peripheral intravenous administration.

8. SECURING OF IOI DEVICES

Once the IO needle has been successfully punctured and placed, it must be secured with special tape or appropriate fixation. Proper fixation will prevent needle displacement, dislodgement or leakage of fluid into the subcutaneous tissue. In clinical practice, some people do not use fixation devices to ensure that fluid leakage can be detected at the first time.

9. COMPLICATIONS IOI DEVICES

Complications of IO are generally less than 1%. If fluid leakage occurs at the IO puncture site, then Compartment syndrome may occur. If there is no significant leakage after IO puncture, no significant leakage tends to occur with normal or pressurised infusions. Other possible complications include conditions such as lipoembolism, osteomyelitis and skin infections. The prevention of these complications is to keep the duration of IOI application as short as possible.

10. CONCLUSIONS

IOI was first introduced into clinical practice in paediatric emergencies. Since then, the IOI technique has gradually been adopted in adult emergency resuscitation, where IOI can be used as an effective alternative to peripheral venous puncture and for patients in shock, combat trauma and cardiac arrest. At present, the rate and prevalence of IOI puncture techniques in clinical emergencies is far from adequate. Many medical and nursing staff have only theoretical knowledge of IO access. In order to make IO access more comprehensive and widespread, we need to further strengthen the training of IOI and the popularisation of IOI devices. In conclusion, IOI can be used as an efficient and safe infusion route and has very important application prospects in emergency situations, catastrophic natural disasters and combat trauma.

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