INTRA-OSSEOUS ACCESS (EZ-IO®) FOR RESUSCITATION: UK MILITARY COMBAT EXPERIENCE

Cooper BR[1], Mahoney PF[2], Hodgetts TJ[2], Mellor A[3]

[1]212 Field Hospital RAMC(V), [2]Royal Centre for Defence Medicine, [3]Ministry of Defence Hospital Unit Northallerton

Conflict of interest:

Colonel Hodgetts is Defence Consultant Adviser in Emergency Medicine and is responsible for recommending the intraosseous devices for use by Defence Medical Services: he has no financial interest in any of these devices.

Captain Cooper, Lieutenant Colonel Mahoney and Surgeon Commander Mellor have no conflict of interest.

Abstract

Military trauma produces predominantly blast and fragmentation injury, commonly resulting in haemorrhagic shock. Injury patterns to limbs are such that the conventional sites for venous cannulation may be unsuitable. The EZ-IO® (Vidacare®, San Antonio) system is one of a number of novel products designed for intraosseous (IO) access in adults or children. In three months of combat casualty care in Helmand Province, Afghanistan, the UK Defence Medical Services used EZ-IO® for emergency vascular access on 26 patients (16 adults; 10 children). 23/26 patients had IO access obtained in the emergency department; 3/26 had pre-hospital IO access within a tactically flying helicopter. A total of 32 needles were inserted, with 97% effective function. IO needles were used to administer fluid (crystalloid, packed red cells and fresh frozen plasma) and drugs (analgesics, cardiac arrest drugs, antibiotics, drugs for both rapid sequence induction and maintenance of anaesthesia). No complication of infection was noted, but pain was observed in responsive patients with the pain of infusion exceeding that of the underlying injuries in 3 cases.

Introduction

The UK Joint Forces Medical Group mission in Afghanistan 2007 has been to provide appropriate medical care for NATO and Afghan coalition forces within the area of joint operations. This medical care can be provided to civilians if they are injured as a result of these operations or it is deemed that they have a life or limb threatening condition.

Rapid circulatory access in trauma cases is required for fluid resuscitation, analgesia, antibiotics and in some cases rapid sequence induction (RSI) of anaesthesia. Peripheral cannulation as a primary circulatory access route is frequently difficult due to hypovolaemic shock and peripheral venous shutdown. Injury patterns to limbs sustained by patients from combat wounding mechanisms, combined with environmental and tactical conditions, are such that the traditional sites for peripheral venous cannulation in the forearm may be unsuitable (for example, multiple penetrating injuries) or technically difficult (for example, in a moving vehicle platform with limited ambient light). In these situations the intraosseous route can be utilised with substantial clinical effect.

The intraosseous route as a form of access to the central circulation has been utilised clinically for over 70 years [1]. During the 1930's and 1940's intraosseous access was used extensively in emergency situations in adults and a sternal puncture kit was a common component in emergency medical supplies during World War II [2]. The technique faded out of clinical use in the following 40 years, but re-emerged in the 1980's as a technique for venous access in paediatric emergencies. Contemporary military operations have stimulated the development and adoption of intra-osseous access as a technique in adult resuscitation.

The EZ-IO® system (Vidacare, San Antonio, USA) is one of a number of innovative products for intraosseous access. This system was introduced into UK DMS in December 2006, together with the FAST1™ sternal intraosseous device (Pyng Medical Corporation, Richmond, Canada). FAST1™ had been evaluated operationally in Afghanistan since April 2006. This report concentrates on the use of the EZ-IO® system in both the pre-hospital and emergency department settings for medical emergencies and major trauma encountered by UK Defence Medical Services in Helmand Province, Afghanistan, between April and July 2007.

EZ-IO® system

EZ-IO® system consists of a battery powered disposable drill (estimated 1000 uses); a bevelled, hollow needle with a cutting needle central trocar; and a short connection tube (with one way valve) for fluid/drug administration. There are two needle sizes: one for adults (over 40 kg; blue hub) and a shorter needle for children (3-39kg; pink hub).

The insertion point is just below and medial to the tibial tuberosity on the upper flat aspect of the adult or child tibia (Figure 1): insertion can be achieved within a matter of seconds. EZ-IO® can also be inserted into the lateral aspect of the humeral head. A manual version of the system is available.

Contraindications are rare, but EZ-IO® should not be inserted into a fractured bone (to avoid extravasation into soft tissues) or where there is obvious infection at the insertion site. Training in its use within UK DMS is provided on the Battlefield Advanced Trauma Life Support Course [3], which is attended by relevant medical personnel prior to deployment to the operational environment. Training equipment is also available within the theatre of operations to encourage continuation training.

Corresponding Author: Lieutenant Colonel P Mahoney RAMC Defence Professor of Anaesthesia, Department of Military Anaesthesia & Critical Care, Birmingham Research Park, Vincent Drive, Birmingham B15 2SQ

E: peterfmahoney@aol.com

T: 0121 415 8848

Figure 1: Insertion of EZ-IO® into adult tibia

Case Series

26 patients were treated with 32 intra-osseous needles over a 3 month period. 22 needles were inserted in adult patients and 10 needles in children aged 2-10 years old. 23/26 patients had needles inserted in the emergency department; 3/26 patients had needles inserted pre-hospital during helicopter flight to hospital.

All insertions were in the upper medial tibia. 25/26 patients had suffered trauma (including traumatic cardiac arrest); 1/26 was a severe methanol poisoning (Afghani). 31/32 (97%) needles were functional and effective for fluid and/or drug administration.

The Abbreviated Injury Scale 2005 (US Military) was used to code the injuries of the trauma patients. The median Injury Severity Score (ISS) was 17; the median New Injury Severity Score (NISS) was 34. NISS is recognised to be a more representative measure of injury severity as it will take account of more than one injury in the same body region [4]. In 3 patients the ISS was maximal (75).

The intraosseous access was used to deliver crystalloid, packed red cells and fresh frozen plasma (Table 1 and Figure 2); it was also used to deliver analgesic drugs, cardiac arrest drugs, antibiotics and drugs for both raid sequence induction and maintenance of anaesthesia (Table 2).

Type of Fluid	Uses in adults	Uses in children
Crystalloid*	15	6
Packed Red Cells	1	2
Fresh Frozen Plasma	1	0

Table 1: Fluid administration through the intraosseous route
**Normal Saline and/or Hartmann's Solution*

Figure 2: Delivery of blood products in critical trauma by the intraosseous route

Type of Medication	Uses in adults	Uses in children
Morphine	2	1
Ketamine	5	2
Midazolam	1	0
Fentanyl	1	1
Propafol	2	1
Suxamethonium	2	2
Vecuronium	2	0
Antibiotics**	3	1
Adrenaline 1:10,000	2	1
Atropine	1	0
Recombinant fVIIa	1	0

Table 2: Drug administration through the intraosseous route
***Benzylpenicillin and flucloxacillin*

No complications of subsequent insertion site infection were recorded. However, pain was noted when pushing drugs or fluid in responsive patients. On three occasions the pain from fluid administration was observed to be causing more distress than the pain from the traumatic injuries.

There were two issues relating to the robustness of the device. In one paediatric patient the needle was bent during transfer and had to be removed; in one adult patient the plastic hub snapped off leaving the needle in-situ.

In 2 cases additional to the 32 needle insertions, the trocar was erroneously inserted without the needle: specifically, the hollow needle was unintentionally left behind within the rigid plastic packaging. This was considered to result from the trocar working free from its associated hollow needle during handling in the supply chain (the trocar is retained by a screw thread): the problem has been reported to the manufacturer.

Figure 3: Easi IO drill and 9mm

Discussion

The intraosseous route for obtaining vascular access is taught on both the Advanced Trauma Life Support [5] and Advanced Paediatric Life Support [6] provider courses and yet it is rarely utilised in UK civilian trauma practice.

Smith et al [7] scrutinised 23,489 paediatric trauma cases between 1988 and 2003 within the Trauma Audit and Research Network. From these, 129 (0.55%) cases had intraosseous access recorded as an intervention. Lavis et al [8] undertook a questionnaire study of 559 Emergency Departments in the UK to establish the opinion and practice relating to intraosseous infusion in adult resuscitation. 74% of the respondents were aware that intraosseous infusion could be used in adult resuscitation, while only 7% used the technique.

It is recognised that delays and failure to obtain venous access can cause major limitations to pre-hospital resuscitation [9] and that intraosseous access provides an effective alternative. In a

prospective, multi centre trial, Davidoff et al [10] measured the success rate of emergency medical professionals in the insertion of the EZ-IO® needle in 250 eligible patients. The study results indicated a 97% success rate for device insertion and function for the administration of fluids and/or drugs.

Frascone et al [11] evaluated provider performance for obtaining intraosseous access with two intraosseous devices in two sequential field trials. 89 FAST1™ and 89 EZ-IO® insertions were completed between February 2000 and December 2005. 64/89 (72%) insertions of FAST1™ were successful, and 78/89 (87%) insertions of the EZ-IO® were successful, identifying significantly greater success with EZ-IO® ($p = 0.009$). Providers using the FAST1™ attempted more IV insertions prior to using the IO device than the providers using the EZ-IO® (2.6 vs. 2.0, $p = 0.005$). However, from the UK military perspective these devices are not mutually exclusive and both have been supplied, with appropriate training, to advanced pre-hospital care and emergency medicine providers. The rationale is that multiple ballistic or fragmentation limb injuries are common and may preclude the use of EZ-IO®: in this circumstance the one area of the body that is likely to be uninjured is the area behind the ceramic body armour plate and, specifically, the sternum.

In this case series of intraosseous use, insertions were performed by doctors, paramedics and ED nurses who had undergone the training package before deployment or whilst in the theatre of operations. All users were questioned and reported the system was easy to use and landmarks easy to identify. A box splint was often used to protect the IO needle insertion site and the needle being inadvertently dislodged (Figure 4); however, an attraction for the military pre-hospital environment is how secure the IO needle is when placed in the upper tibia when compared to the vulnerability of a peripheral venous cannula.

Figure 4: Use of a box splint to protect the IO insertion site

Anaesthesia was successfully induced via this route in two adults and two children; additionally, cardiac arrest drugs were administered to two adults and one child. Drugs, blood products and fluid have all been shown to be delivered with acceptable rates of flow via the intraosseous route when administered under pressure [12] and there is a documented low complication rate [6]. Case reports suggest the most common complication is osteomyelitis [13] and localised cellulitis, although the continuous major trauma audit process that operates in field hospitals (MACE, Major Trauma Audit for Clinical Effectiveness) has not identified any infection. Compartment syndrome [14] is also reported after fluid administration, but occurrence is rare.

The complication of pain during fluid administration was also demonstrated by Davidoff et al [8] who noted the average pain upon fluid infusion was rated as '5' on a modified Visual Analogue Scale (1-10) in patients with a Glasgow Coma Score of greater than 8 (36 patients).

Conclusion

The experience of the UK Defence Medical Services in Afghanistan has demonstrated that the EZ-IO® system has been a key intervention in the resuscitation and treatment of the critically injured. It has allowed prompt administration of analgesia, sedation, anaesthetic drugs, fluid and blood across a spectrum of age groups when conventional intravenous access is impractical or unsuccessful.

Intraosseous access using the EZ-IO® system is a simple technique that can be performed rapidly even in the most challenging pre-hospital environments (a tactically flying military helicopter: personal experience of the authors) and has rapidly become absorbed into the culture of the UK DMS. The speed of obtaining vascular access coupled with the high success rate makes it a primary access route for drug and/or fluid resuscitation in cardiac arrest (any cause) in adults or children in the hospital or pre-hospital setting.

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