INTRAOSSEOUS ACCESS – A CLASSICAL METHOD FOR VASCULAR ACCESS THAT REGAINS AN IMPORTANT ROLE AS RESUSCITATION TOOL

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ABSTRACT

75-80% of life threatening situations, with unexpected arrest, are documented out of hospital (1). This situation generates frequently a difficult resuscitation. Main cause for failure is delay in gaining vascular access for fluid and drug delivery (2). Intraosseous access (IO) is used for treatment in patients without a previously placed intravenous line that experience abrupt-onset life threatening situations (3).
Authors revisit data from initial development of this method and document the role of IO access as a valuable tool during resuscitation according to European Resuscitation Council Guidelines 2010 (4). Particular aspects of technique, improvisations and real life trouble shooting issues are presented from a single pediatric Emergency Department experience.

Keywords: intraosseous access, resuscitation

INDICATIONS AND CONTRAINDICATIONS FOR IO ACCESS

Although it was thought that IO is not suitable for newborn children, recent data document success in extremely premature children. There was published a case of IO placement in a 515 gram newborn child (5).

IO access is not a substitute for an IV line in children with difficult venous line placement! Children with non-severe diseases that are not in a life-threatening situation can benefit of a pediatric vascular surgical department expertise (venous cut-down technique, over-the-wire Seldinger technique for CVC, etc.).

Patients without vascular access that require urgently medication, during resuscitation can receive some active drugs via non-venous routes like endotracheal or intraosseous (6).

Endotracheal route has a major drawback: does not allow boluses of fluid during resuscitation. Hydrophilic drugs are not deliverable via ET tube. In the ET tube we can give only 3-5 ml normal saline in order to push, downstream to alveoli small amounts of drugs used during arrest situations: adrenaline, lidocaine, atropine and naloxone. These drugs are lipophilic and are able to cross alveolocapillary barrier. Endotracheal route is not allowed for delivery of blood and blood products.

In a critically sick patient that requires large amounts of fluid or other medication than adrenaline, lidocaine, atropine and naloxone, a rapid and reasonable alternative is IO line placement. An attempt for IO should be made after three failures of an IV line placement or these attempts last more than 90 seconds in a dying patient.

Indications for an IO line placement are, according to PALS criteria (6):

1. Cardiac arrest
2. Status epilepticus
3. Decompensated shock

Were published IO line placements in patients with extreme metabolic abnormalities that could have generated in a short time one of the 3 situations listed as major indications: severe hypoglycemia (7), life-threatening hypokalemia (8), etc.

IO placement has only 3 absolute contraindications (9):

1. Fracture of long bones in respective segment of limb (actual or recent). In patients with femoral

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fracture should be avoided ipsilateral IO tibia placement (10)

2. Severe bone diseases: osteogenesis imperfecta, osteopetrosis (11)

3. Recent femoral or saphenal venous cut-down in the same limb.

This procedure can be done with caution even in those children with minor local burns or wounds (12), or even with skin infection (13). After procedure can be injected locally an antibiotic, in order to prevent osteomyelitis.

This vascular approach should be used as a temporary route for central circulation not a "definitive" one (9). In many cases a simple bolus (20 ml/kg normal saline IO push), produces a volemic expansion significant enough to facilitate a peripheral or central venous access.

DEVELOPMENT OF METHOD

Efficient IO access was described first time in 1922 by Drinker and Lund (14). Previously were published two papers with unconvincing results: Drinker and Drinker (15) describe particular aspects of bone marrow sinus circulation in dog and Hernald documents 982 IO attempts, with fatal outcome in 964 cases (16).

In 1934 Josefson publishes (17) a paper with positive results of IO method in children.

Tocantins and O'Neil perform in 1941 several experiments regarding bone marrow grafting in a rabbit model. They are puzzled by finding that out of 5 ml normal saline (NS) infused at proximal extremity of femoral bone only 2 ml were distally recovered (18). Because no local signs of extravasation were found, authors concluded that NS has been shifted by absorption to systemic circulation my means of emissary veins. This accidental discovery encourages them to continue studies regarding blood transfusion via IO access.

Authors used seven rabbits in whom they inflicted an acute posthaemorrhagic anemia, by aspiration of 20% of total blood volume. 24 hours later, by IO access placed in proximal tibia they transfused an equivalent amount of blood with a constant rate 5-7 ml/minute. 4 of 7 rabbits had a rapid favorable outcome with complete correction of anemia. 2 had also favorable outcome but at a slower rate and one expired because of haemopericard (was drawn initially by cardiac puncture, this maneuver could have been the probable cause of hemopericardium).

Tocantins, O'Neil and Jones published results of IO infusion *of other non-blood fluids (19)*. 4 rabbits received insulin until hypoglycemic seizures were present and a hypertonic glucose solution (25-30%) was infused by intraosseous route. Rapid improvement was observed in all rabbits that received glucose and no response in the only rabbit that did not receive glucose. Time to reach central circulation was documented by injecting various dyes IO. Time to central circulation was 10 seconds on average.

In other rabbits, authors documented circulation from sternal cavity to central circulation via internal mammary vein, by IO infusion of mercury in sternum and performing series of radiographs.

Tocantins and O'Neil present 14 patients, with 16 successful IO infusions (out of 17 attempts), with various solutions: blood, plasma, NS, glucose solutions. Variable amounts were delivered, up to 1050 ml, at a rate of 0.4- 9 ml/minute. IO placement was sternum in adults, and distal extremity of femoral bone or proximal extremity of tibia, in the two infants of this group (20).

Same authors describe complications of IO infusion (21). A very severe complication is mediastinal penetration, by transfixation. Hamilton Bailey develops a special trocar for sternal puncture and publishes his discovery (22) in *British Medical Journal.*

Macht proves that epinephrine can be delivered via IO route in 1943 (23).

In 1941 in *Journal of Pediatrics* IO access is presented as a common procedure: "Bone marrow infusions as a routine procedure in children" (24). Arebeiter and Greengard present tibia approach as the best option in infants (25). Behr publishes in *Lancet* data about IO continuous infusion in infants (26). Gunz and Dean present data about blood transfusion in infants in *BMJ* (27).

Heinild and Sondergaard are authors of a paper from 1947, which presents an impressive experience with IO infusion in more than thousand patients (28).

When butterfly needles were developed IO access was less and less used. The only paper in an important journal, regarding IO, is Pilar's, in 1954 (29). Since '60s, when plastic catheters became the preferred approach in children, IO access was occasionally used.

In 1983, Henry Turkel sends a letter to the editor of *American Journal of Diseases in Children*, concerning a case of a child that succumbed after a massive blood loss post-tonsillectomy (30). He is questioning the delay of shock correction because of impossible access to peripheral or central veins. In the last two decades IO access was included in

standard protocols for resuscitation like PALS or APLS (31,32).

Use of this procedure was revisited, in USA, when *Textbook of Pediatric Emergency Medicine,* was published in 1983 with Ludwig S. and Fleisher G. as editors. *Textbook of Pediatric Emergency Procedures,* edited by Henreting FM and King CK in 1997 is the first volume of procedures dedicated to this age group. Chapter 20 written by Dee Hodge III is dedicated to IO access and infusion (33).

In 1999, Lavis is discussing IO role in adults and stated that the more data are collected the more we see that this method is the same (34), referring to Tocantins's group findings from the early '40s.

In last 20 years more than 400 papers on IO access were published. In *Textbook of Advanced Pediatric Life Support* is stated that IO approach is first option for a rapid vascular access, in children younger than 6 years, during resuscitation for life-threatening situations (35).

LANDMARKS

IO access is frequently performed at anterior and medial aspect of proximal tibia 1-2 cm below tuberosity. We can start this procedure by finding tibial tuberosity and then we move distally 1-2 cm and 1-2 cm to the medial aspect of tibia in order to avoid tibial crest. With this movement we avoid tibial growth plate lesion (if IO access if performed just near tibial tuberosity) and transfixation (if IO access if performed to close to tibial crest we can miss the typical «escape» sensation associated with penetration in medullary channel of tibia and we can transfixate the bone).

In extreme emergencies, IO access can be performed at any level of the anterior and medial aspect of tibia, preferably in a proximal location in infants and toddlers (in order to decrease risk of malpositioning the needle – at this level there is a sensible wider surface of tibia) or in a distal location in older children and adults (in order to allow a more facile penetration due to a thinner cortical bone at this level).

IO penetration can be performed also in calcaneus (newborn children), in distal femoral bone, in iliac crest, in spine of scapula or in sternum (in adults).

INSERTION TECHNIQUE

Maneuver should be performed in an aseptic way, if possible. Two types of insertion are available, either manual or instrumental insertion with mechanic devices (screwdriver type, like EZ IO, or pistol type, like BIG or FAST1).

Insertion can be performed immediately without any preparations in patients that fulfill absolute indication for use of IO access, because all these patients have abolished consciousness and pain perception. In rare situations when a patient has some level of consciousness retained we can use local anesthetic in soft tissues and at periosteal level (lidocaine 1%).

Manual insertion can be performed with firm and continuous rotatory movements. Pressure on needle should be moderate in such way that penetration is generated by drilling movements and not by direct puncture of bone. Gradual pressure applied on the needle will be decreased when crepitation are felt – these document location of the tip of needle in the spongeous part of bone. Almost immediately it is perceived an escape sensation because the needle plunges in the medullar cavity of tibia for 2-3 mm. Needle positioning will be evaluated by aspiration of bone marrow in a 20 cc syringe that is partially filled with NS (5 ml normal saline 0.9%). If no bone marrow is aspirated than we will leave unsupported the syringe for a few seconds. If this partial-filled syringe will stay unsupported in a solid position than at least one cortical bone surface is penetrated. In order to avoid over-penetration we will push forcefully the 5 ml NS and we will observe a possible swelling in popliteal fossa or around needle (36). If no significant swelling is documented and free flowing of NS is present than we have a correct penetration. After confirmation of correct location of IO needle we will connect a tubing to a pump-syringe. Tubing should be taped to the leg and draped with a sterile gauze in order to avoid dislodgement of needle in case of movement (seizures, regaining consciousness post resuscitation) (Fig. 1).

One should avoid repeated connection and reconnection of syringe directly to IO needle because of dislodgement risk or enlargement of bone penetration orifice with backflow of fluid injected with pressure. If we do not have a dedicated IO needle (Fig. 2) we can use improvisations like Jamshidi bone marrow aspiration needles (Fig. 3) or lumbar puncture needles for adults 16G or thicker (Fig. 4). This approach with lumbar puncture needles was studied in our hospital and was proven as non-inferior to conventional IO access (44).

Mechanic insertion can be performed with prior selection of depth penetration. For screwdriver type (EZ IO) we can choose the short 15 mm pediatric needle (for children 3-39 kg weight) and for the

FIGURE 1. *IO access with lumbar puncture needle placed in proximal tibia. Newborn child that was treated for septic shock with boluses of normal saline via intraosseous infusion. Connection tube fixation was performed in order to avoid traction on IO needle.*

FIGURE 2. *Cook IO needle (from 45)*

FIGURE 3. *6 years old patient, after successful resuscitation for cardio-respiratory arrest. Jamshidi type needle (for sternal bone marrow aspiration) placed in distal right tibia.*

pistol type we should rotate stopper until we reach expected depth value (43).

FIGURE 4. *IO access placed in Emergency department of IOMC. A 16G caliber lumbar puncture needle for adults was used after a failed attempt in contralateral tibia (performed in other hospital).*

In case of failed penetration we should extract needle and attempt a new insertion in contralateral tibia (Fig. 4). In extreme cases, when insertion is not possible in opposite leg, we can relocate the IO needle at a minimal distance of at least 2 cm from initial orifice.

IO needle will be kept in place as short as possible. We will terminate IO infusion only when a reliable vascular access is gained. In patients that are supposed to be transferred because of a critical situation, IO needle will be kept in place for the whole duration of transport, because IO system is vibration-resistant and allows significant pressure variation (situations encountered during ambulance or helicopter transport).

SIDE EFFECTS

Technique is generally a safe one, without serious side effects (37). In a personal series of patients we reported a single case of osteomyelitis (6 years old boy successfully resuscitated for prehospital arrest) out-of 54 IO placed needles (1.85%). Literature data present beside infectious risk (38), the peripheral necrosis risk due to extravasation of calcium salts (39) or due to compartment syndrome. There were no descriptions of significant embolism of bone marrow during IO infusions in human subjects.

In mechanically driven IO insertions (like EZ IO or BIG devices), method has virtually no significant side effects (40). Same remarkable efficacy seems to be present in a sternal device (FAST 1) frequently used military medicine (41).

In author's experience (42) IO access method, both manual and mechanical techniques represents

a very fast strategy for vascular access in critical situations. It can be placed faster and easier than a central venous catheter. IO line allows very high pressure during vascular refill and can provide a huge flow, significantly greater than any peripheral IV line. IO access is stable with vibrations so it qualifies as an excellent option for vascular access during transport of critical children.

IO method remains an actual and efficient life-saving strategy, and is included in all modern resuscitation protocols.

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