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Emergency Intraosseous Fluid and Drug Administration

MICHAEL R. GUNDERSON, REMT-P[1] and MICHAEL BROWN, REMT-P[2]

Establishing a route for fluid and drug administration is an important task in managing patients requiring advanced life support. The inability to secure an IV during an emergency can seriously delay what might be life saving therapy. This problem can be particularly acute in the field, where clinical privileges for venous access usually do not include central routes, due to the higher potential for serious complications and limited EMS agency access to appropriate clinical training in central venous procedures.

Other fluid and medication routes are available, but have significant limitations. The endotracheal route requires that the patient be intubated and will only accommodate a limited number of commonly accepted drugs, to include naloxone, atropine, diazepam, epinephrine and lidocaine. In general, endotracheal drugs should be lipid soluble and relatively non-irritating (1). The intracardiac route will accept most any drug, but the patient must be in arrest. The intracardiac injection has a high potential for complications and must interrupt chest compressions (2). Sublingual, subcutaneous, transdermal, intramuscular and rectal administration routes are only viable when perfusion to those tissues are sufficient to promptly absorb medications and carry them to the central vascular circuit.

There is an evolving rediscovery in the emergency and critical care community of a previously developed medication route via the rich venous network of the bone marrow, commonly called the intraosseous route.

HISTORICAL DEVELOPMENT

The idea of intraosseous infusion dates back to 1922 in the works of Drinker (3) and Doan (4), describing the circulation of blood through marrow. Drinker suggested the marrow as a potential route for blood transfusion. Diagnostic puncture of the sternum to obtain marrow samples was described by Arinkin (5) and cited by Josefson as the original basis for his use of sternal injection of liver extracts to treat anemia (6). Josefson speculated about the bone marrow as a route for administration of other drugs. He also discovered a serious complication potential with inadvertent sternal perforation and undetected pleural infusion. He suggested use of the tibia as another marrow infusion site.

Dr. Leandro Tocantins of Philadelphia played a major role in bringing this new technique to the attention of the medical community. In 1936, the seeds for Tocantins' later work were planted while he was performing bone marrow transplant experiments in which he noticed significant loss of fluids injected in rabbit femurs. Local tissue examination did not reveal any signs of infiltration. Absorption by the vascular system was implicated (7).

Research by Benda and colleagues, published in 1937 (8,9) and 1940 (10), demonstrated rapid migration of bacteria and other substances into the venous circulation and lungs following sternal injection. In 1940, Henning (11) experimented with sternal injections of radiopaque fluids, dextrose and blood in persons with circulatory collapse and concluded that it would be a good route for transfusions to battlefield casualties.

The team of Tocantins and O'Neil collaborated in several widely cited studies of intraosseous infusion (12-21). Their work included an experiment where mercury was infused into the humeri and tibias of an infant, showing systemic distribution by full body fluoroscopy (7). Congo red dye infused into the tibia was found in the heart 10 seconds after injection (12). Seizures secondary to hypoglycemia were successfully treated with a tibial infusion of glucose (12). Tocantins refined the procedure with development of special equipment (13-14) and published on use of the intraosseous technique in pediatrics (15-16).

Following a surge of publications in the 1940's and 1950's (22-56), intraosseous infusion fell from common use with the introduction of improved intravenous methods, including the indwelling plastic IV catheter.

Contemporary interest in the intraosseous route reappeared in 1977 with a publication by Valdez recounting his "discovery" and 15 cases of intraosseous fluid and medication delivery (57). In 1979, Shoor published on an animal study where flow rates with pressure infusion and the general pharmacokinetics of intraosseous therapy where described (58). In the 1980's, the volume of publication on the topic of intraosseous infusion is growing (59-81).

CLINICAL ANATOMY

The clinical anatomy of the tibia will be described, as it is the most common site for intraosseous infusion.

1 *Senior Consultant, Emergency Medical Resources, Inc., Paramedic, Palm Harbor Fire Department, Pinellas County EMS, President, Acute Care Foundation; Tampa, Florida*

2 *Senior Paramedic, Hillsborough County EMS Contributing Editor, Tampa Bay EMS Journal; Tampa, Florida*

The tibia is a superficial long bone which contains a significant marrow cavity, even at birth. The marrow of the tibia, as well as other bones, is contained in its intramedullary space. Its spongy marrow tissue contains a dense network of blood filled sinuses. These venous sinuses interconnect to drain out of the bone through emissary veins. These in turn drain into the popliteal veins (Figure 1).

The spongy semi-rigid marrow tissue surrounding the sinuses do not collapse with hypotension, as do peripheral veins. Thus, they are consistently accessible in the critically ill or injured patient.

The long bones, such as the tibia, femur, and humerus, have a delicate layer of tissue at the distal and proximal ends called the epiphyseal plates (Figure 1). These structures are responsible for longitudinal bone growth. Therefore, introduction of any needle into these long bones must be particularly cautious to avoid the epiphyseal plates and thereby avoid disruption of normal bone growth. On the tibia, the proximal epiphyseal plate is located just proximal to the tibial tuberosity. Proximal introduction of an intraosseous needle is therefore angled slightly caudad, to minimize risk of epiphyseal contact. On the distal tibia around the malleolus, the needle is directed slightly cephalad to avoid the distal epiphyseal plate. These same principals hold true for the femur and humerus. The mid-shaft of long bones are usually not utilized because the neck of the bone near either end is wider and has a larger marrow cavity, making success more likely. Further, the mid-shaft has more yellow marrow, in contrast to the red marrow at the ends. The yellow marrow has a higher theoretical potential for fat embolism, although Tocantins reports that the work of Harris and Bolle indicates this risk to be minimal (7).

INDICATIONS

The intraosseous route should be considered as a second line route for drug therapy in an emergency situation. Although the procedure might also be used in less urgent situations, the contemporary short and long term complication rates and marrow reactions to many modern drugs are not well documented. Rapid emergency fluid replacement in the adult may not be practical by the intraosseous route. The maximum flow rates by gravity and by pressure infusion (300 mm Hg) are approximately 10 milliliters per minute and 40 milliliters per minute, respectively (58). These rates are probably inadequate for serious hemorrhage in the adult, but may still be useful in children.

The literature sites osteopetrosis (a condition of excessive bone calcification which causes spontaneous fractures - also called Albers-Schonberg disease) and osteogenesis imperfecta (defective bone matrix with propensity for fracture) as general contraindications (64,66). Fresh or recently fractured bones must not be used to avoid subcutaneous extravasation (66).

EQUIPMENT

The procedure will require skin antiseptic, tape, IV fluid and administration set, and a suitable needle. The needle used for intraosseous access should be stiff, large bore (at least 18 gauge) and include a stylette. Needles without stylettes may be used if other more suitable needles are not available. To clear bone particles that might occlude the lumen of a plain needle, a smaller and longer needle may be inserted into it through the hub.

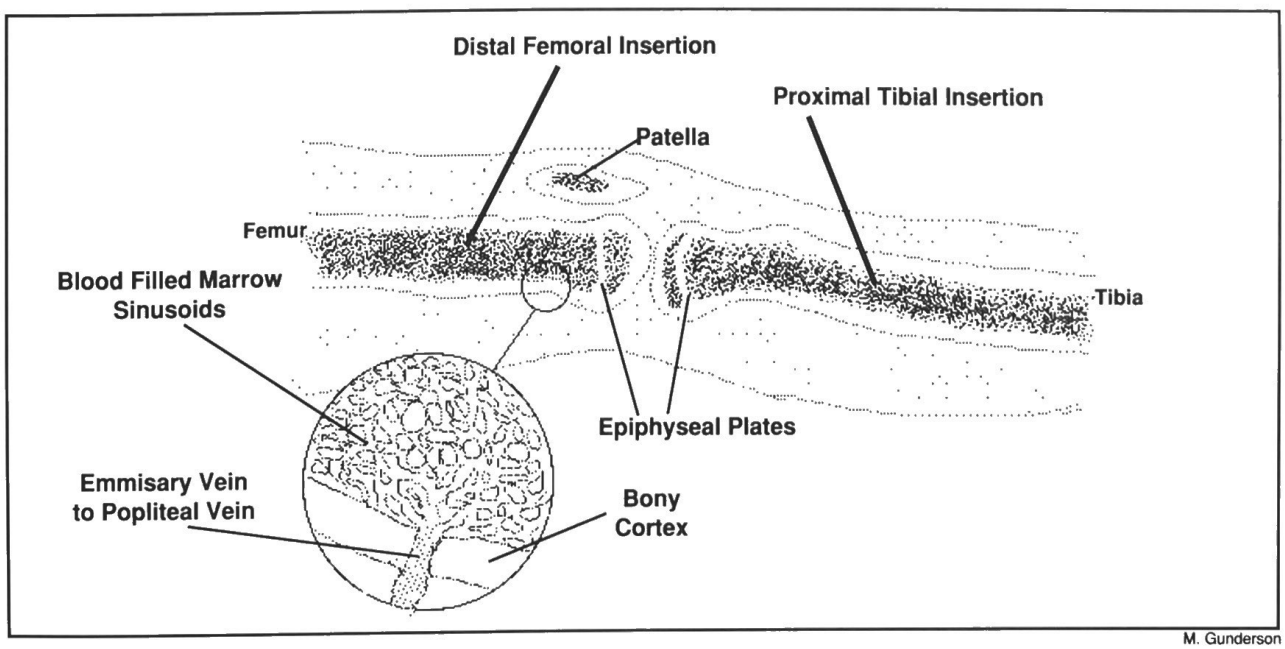

Figure 1 - Clinical Anatomy for Tibial and Femoral Approaches to Intraosseous Infusion

Bone marrow aspiration needles are commonly used for the intraosseous procedure, including the Osgood and Rosenthal varieties. The modified Illinois aspiration needle (Figure 2) is currently in use by the Fairfax, Maryland EMS agency (66,67). That needle seems to be very well suited for the procedure. It has a collar which can be adjusted after insertion to prevent the needle from going too deep and thereby reducing the risk of perforating the bone. It is also a disposable item. The Rosenthal and Osgood needles are non-disposable with a cost of approximately thirty-five dollars each.

SITE SELECTION

There are many potential sites. In general, any superficially accessible bone with significant marrow cavities may be utilized. Particular caution should be used in children and adolescents to avoid disruption of the epiphyseal area of long bones, so normal bone growth will not be disturbed (65). The literature most frequently mentions the sternum, tibia, femur and humerus as suitable targets.

The sternum provides an adequate marrow cavity only after three years of age. There is a potential for causing dangerous accumulation of fluids in the chest if there is leakage from either the primary site, previous sternal sites where access was unsuccessful, or from inadvertent sternal perforation (56).

The proximal tibia appears to have a consensus of favor in the literature we have reviewed. It is suitable for patients of most any age and has a minimum potential for complication, so long as the epiphyseal area is avoided in younger patients. The point of needle insertion should avoid areas with cellulitis and infections. The complications of osteomyelitis and iatrogenic infection are much higher when the intraosseous line is utilized for more than 24 hours (64).

Should the procedure be used in a trauma patient requiring the use of the MAST garment, a femoral or proximal tibial site would interfere with MAST placement. In such cases, the malleolus or humerus may be preferable. Infusion from the malleolus to flow up through the tibia within the MAST garment should theoretically not be a factor limiting infusion flow rates. However, the effect of the MAST on flow out of the tibia via emissary veins and into the popliteal veins has not been studied.

PROCEDURE

The principles of the technique are similar for all sites, but this discussion will use the proximal tibial site to describe specifics.

The best detailed description we found for tibial access was offered by Friery and Weiner (66). Using a modified Illinois aspiration needle, the needle is inserted at a point even with or slightly inferior to the tibial tuberosity. The point of

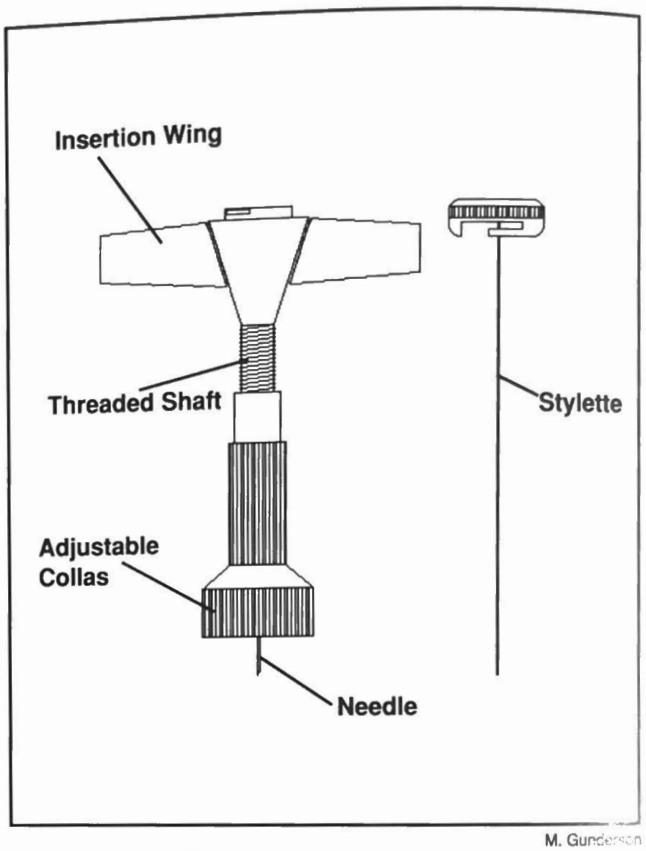

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Figure 2 - Modified Illinois Aspiration Needle

insertion should be slightly medial on the leg to give a be[illegible] exposure of the marrow cavity (Figure 3). External rota[illegible] of the leg will provide proper positioning.

If the patient is awake, local anesthesia may be prov[illegible] by a wheal of lidocaine infiltrated along the intended in[illegible] tion pathway, to include the periosteum where bone pene[illegible] tion will be made.

The needle is inserted in two steps. The first is thro[illegible] the soft tissues to bring the point of the needle against [illegible] bone. The second step uses a firm twisting motion to pe[illegible] trate through the bony cortex and into the marrow cavity, as indicated by a break in resistance as the needle tip "pops" into place. The stylette is removed and replaced with a syringe containing 5 cc of intravenous fluid. Blood and marrow may be freely aspirated if the tip of the needle is properly inserted into the marrow. However, aspiration is reported to be very uncomfortable in the awake patient, so limit aspiration to 1 ml in confirming placement. The 5 ml of IV fluid can be injected to help clear the lumen and tip of bone fragments. The IV fluid administration set should be attached and opened as soon as possible to prevent clotting. If this is delayed, reinsert the stylette.

The modified Illinois needle features a circular collar that may be screwed down around the outside of the needle until firmly against the skin to prevent inadvertently deeper penetration. Tape may then secure the entire assembly in place.

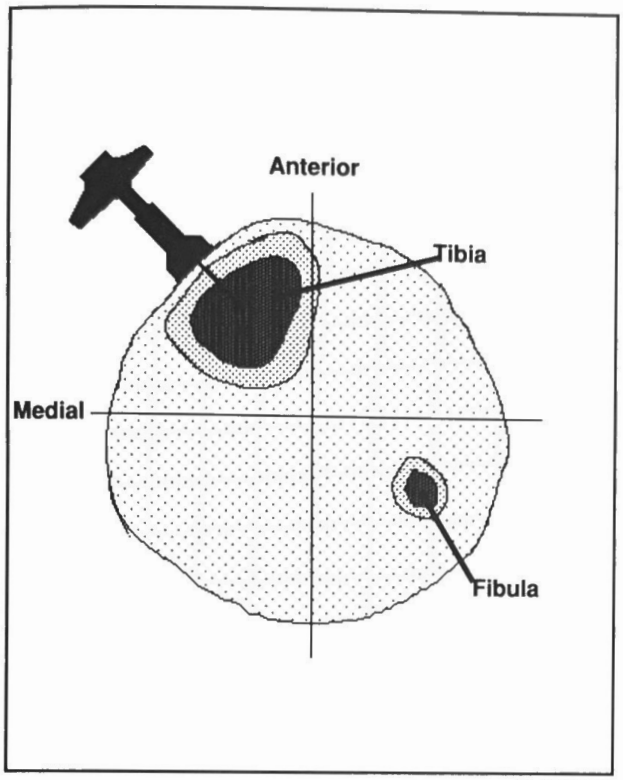

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Figure 3 - Angle of Insertion for Proximal Tibial Approach

DISCUSSION

There are several issues that appear to be unresolved with this procedure.

Use of intraosseous infusion for adult trauma victims may offer a faster and more consistently accessible route for fluid replacement, for both crystalloids and blood. However, the pressure infusion studies of Shoor in an animal model found flow rates of only 41 ml per minute (2460 ml per hour) with a 300 mm Hg infusion pressure level (59). This would probably be inadequate for an adult with a serious hemorrhage. Studies have not been identified which have examined the potentials of multiple simultaneous pressurized intraosseous infusions, in the same or multiple bones.

The contemporary literature does not provide a study of long term complications of the procedure, particularly in children. Further, the short and long term effects on the bone and marrow of many drugs now used in emergency and critical care have not been identified.

In the prehospital arena, we are not able to locate publications which document complication rates, attempts and time required for placement, or responses to medications given via the intraosseous route. Complication rates, attempts, and times may vary with the site and equipment utilized.

SUMMARY

The intraosseous route for fluid and medication delivery is a practical alternative in an emergency setting when other routes of peripheral IV access are not available. It may be particularly useful in the field, where central venous procedures are not widely utilized. While pediatric cases are most often cited as candidates for the procedure due to their inherent problems in venous access, the method appears to be equally practical and efficacious in adults. Further study is needed to clarify the optimal equipment and sites for the procedure. Contemporary statistics on overall complication rates and local tissue reactions to current emergency and critical care medications are lacking.

REFEREE COMMENTARY

Harold F. Sherman, M.D. *(Trauma/Critical Care Fellow, Tampa General Hospital; Clinical Associate in Surgery, University of South Florida; Tampa, FL)* - The technique discused here is interesting and probably some applications in unique settings. Yet it seems largely to be a method currently looking for its niche.

In an era of increasing emphasis on a 'scoop and run' field approach to trauma, especially in an urban setting, another time-consuming technique to infuse inadequte amounts of fluid seems superfluous. Regarding the use of this technique in the pre-hospital treatment of acute medical illnesses, the authors state quite clearly that studies of drug absorption by and drug effects on marrow are yet to be done. Within these constraints, it is difficult to accept the statement that this technique is "...practical and efficacious.."

While there may be unique and specific situations within the prehospital setting, including the emergency department, where this procedure could or should be used on a controlled trial basis, I can imagine little immediate role in the pre-hopital setting for intraosseous infusion. I look forward to more clinical trials exploring the areas of drug absorption, fluid flow rates, complication rates, and long term effects.

Richard Weibley, M.D. *(Assistant Professor of Pediatric Critical Care, University of South Florida; Tampa, FL)* - Gunderson and Brown have wriiten a comprehensive and and valuable review article on intraosseous fluid and drug administratyion. They clearly outline its conceptualization, disappearance with improved intravascular techniques of the 1950's and subsequent reemergence two decades later. This is primarily because of the needed emergence of prehopital care and the ability to treat patient who previoulsy died.

Gunderson and Brown also nicely describe the anatomical sites, necessary equipment and acceptabvle techniques. Hopefully, after reading the article, those who have not utilized this modality will reconsider when the indication arises.

Finally, Gunderson and Brown discuss the the need for research documenting both the efficacy and long-term complications.

As with so many techniques in medicine, the intraosseous route appears to be a rediscovery of the wheel - what goes around comes around.

Thomas J. Abrunzo, M.S., M.D., F.A.A.P., F.A.C.E.P. *(Chief, Section of Pediatric Emergency Medicine, All Children's Hospital / Bayfront Medical Center; St. Petersburg, FL)* - There's "good news" and "bad news" regarding emergency intraosseous infusion, particularly for the pediatric patient. The paper by Gunderson and Brown outlines the situation well.

The "good news" is that this technique is time-tested, requires simple, inexpensive equipment, is easy to learn and is potentially life-saving.

The "bad news" is the unknown; there is not data to document safety and efficacy versus other venous access techniques in specific emergency situations. As is the case so often in pediatrics, there is not a simple approach or response to the variety of pediatric arrest or pre-arrest conditions. One must be quick to individualize therapy. Similarly, one needs to evaluate intraosseous infusion in such common but pathophysiologicall disparate situations as: multiple trauma with skeletal fractures, respiratory failure, isolated head injuries, status epilepticus, septicemia/becteremia.

A multitude of questions emerge: Are fat and/or marrow embolism a significant problem with high pressure, high volume infusion versus low pressure, low volume medication infusion? Does septicemia significantly increase the occurence of osteomyelitis? Should the risk of osteomyelitis constitute a relative contraindication? With lower extremity and pelvic fracture, are the humeral and sternal sites as easily used? Ae the complications significantly increased? Are volume and medication uptake rates the same in full cardiopulmonary arrest as compared to some of the above pre-arrest conditions?

Should emergency intraosseous infusion be advocated for the prehospital setting in the absence of data on comparative efficacy and complications? Present data suggest that the cost-benefit comparason, as best as we can tell, is skewed heavily on the benefit side. I therefore strongly believe that the technique should be studied and used by prehospital caregivers, with the following, specific admonitions:

- The provider should develop and rehearse a time-directed protocol based on patient severity.
- A plastic-jacketed steel needle with adjustable shaft should be used to minimize difficulty and complications of insertion.
- The infusion site should be swithched to a more conventional site as sonn as patient status allows.
- The provider should facilitate collection of data regarding protocol implementation, acute results and long term follow-up.

Mr. Gunderson's reply - All of the reviewers have appropriately reemphisized that there are still many unknowns concerning the intraosseous route, particularly on long term effects to the marrow. I believe Dr. Abrunzo puts these concerns in proper perspective in terms of a cost - benefit comparison. The possible risks of epiphyseal, marrow and fat emboli complications must be balanced against the possible benefits that early fluid and drug administration can provide in pre-arrest and arrest conditions. The evidence indicates that these possible risks are indeed genuine. However, these studies also support use of the intraosseous technique, despite these risks, due to a relatively low incidence of such complications.

From a conservative perspective, the intraosseous route might be implemented in the emergency department and prehospital environments under well defined research protocols. Those protocols should be designed to minimize the potential for complications, as Dr. Abrunzo suggests, with an optimal needle and a switch to a conventional IV as soon as possible. Rigorous data collection should be mandatory. The fluids and drugs used in these early applications might be limited to those of a less innocuous nature, such as crystalloids, blood and some specific drugs for which there is experience reported in the literature. It's hard to turn one's back on the considerable experience and favorable cases that have been published. The potentials of this route for the patient in extremis with vascular collapse should encourage us to conduct these studies and see if those potentials can be realized. I thank the reviewers for their critique. Their comments will be helpful to those who will pursue research in this area.

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