screenings in the 80's the automation of follow up. J Med System 1988, 12: 89-96.
19. Studney DR. Monitoring quality by computers. Group Practice J 1980, 3: 10-12.
20. Hendrikson G, Kovner. Effects of computers of nursing resources use. Group Practice J 1980, 3: 15-19.
21. Barnett Dxplain. An evolving decision support system. JAMA 1987, 1: 258.
22. Bhave SY. Interactive technology in the field of medical education. Bombay Hosp J 1991, 33: (in press).

INTRAOSSEOUS INFUSION

Sunit C. Singhi

In critically ill children rapid establishment of an intravenous (IV) access is vital. However, efforts at setting up an IV line in a peripheral vein may fail in 5-6% or get delayed beyond 5 minutes in about one-fourth to one third of such children(1,2). Intraosseous (IO) access may be of value in such circumstances as an alternative route for delivery of fluid and medication. Use of this route was first proposed in 1922(3,4), and gained rapid acceptance for routine infusion of saline, glucose and blood by 1940s and 1950s(5,6). However, with the advent of better IV technique it was relegated to relative obscurity despite the fact that the ease and simplicity of technique would appear to make it ideal for use in emergency situation. The technique is now experiencing a resurgence(7). Recent reports and reviews suggest its use in pediatric emergency situation such as cardio-respiratory arrest, shock, *etc.* when IV access is difficult(8-10). The American Heart Association in its Life Support Course recommends use of IO route when IV access can not be readily established(11).

From the Department of Pediatrics, Postgraduate Institute of Medical Education and Research, Chandigarh 160 012.

Reprint requests: Dr. Sunit Singhi, Additional Professor, Pediatric Emergencies and Intensive Care, P.G.I.M.E.R., Chandigarh 160 012.

Anatomical Basis

Basically IO infusion is intravenous infusion through rich network of venous sinusoids of medullary cavity of the bone. The network is supported by a bony matrix and therefore, does not collapse even in shock. The venous sinusoids drain into the venous canal and then through nutrient and emissary veins into systemic circulation. Thus, substances infused in the bone marrow are almost immediately absorbed into the circulation.

Technique

The actual technique is simple and easily mastered and has been reviewed recently(9,12). All it requires is a needle with a stylet which is sturdy enough to penetrate the bony cortex. Although many specialized needles have been developed for this procedure the standard bone marrow needles or heavier gauge (14-18 size) spinal needles are good enough. The most preferred site is on the flat anteromedial surface of proximal tibia, 1-2 cm below the tibial tubercle. Other sites are distal tibia and distal femur (*Fig.*). Detailed steps in setting an IO infusion are as follows: After restraining the leg, skin is cleansed with an antiseptic (spirit and iodine/betadine) and local anesthesia is administered. The needle is inserted perpendicularly to the

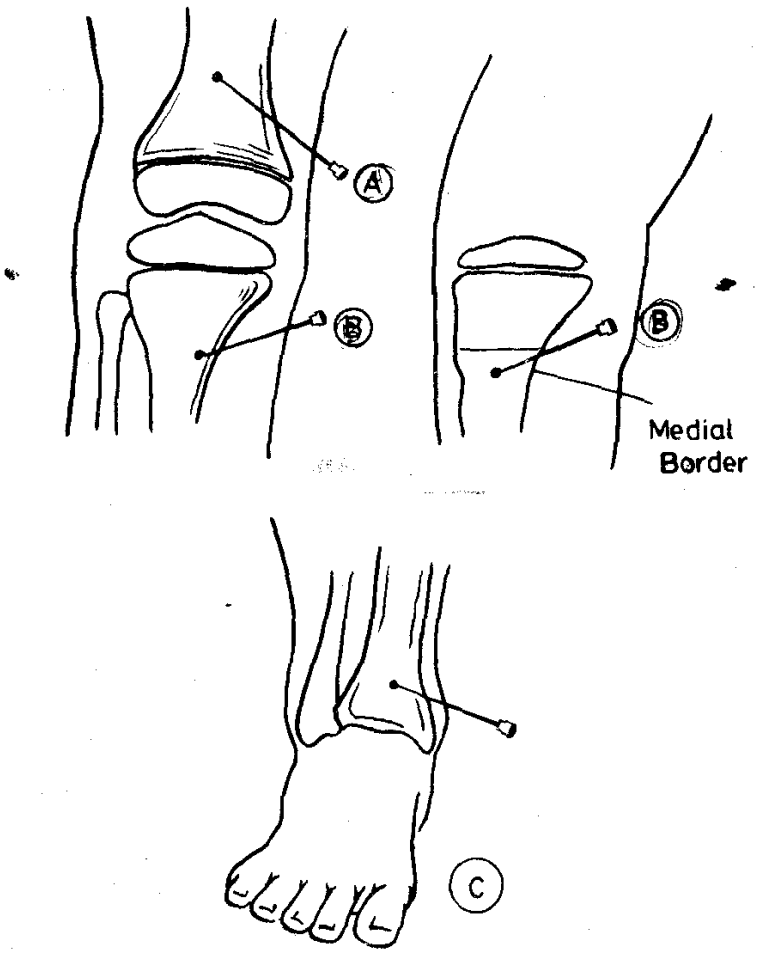

Fig. Sites for insertion of intraosseous needle.

A. *Lower end of femur: 2-3 cm above the external condyles in midline.*
B. *Upper end of tibia: on the antero-medial surface, 1-2 cm below the centre-point of the horizontal line connecting tibial tuberosity and medial border.*
C. *Lower end of tibia: on medial surface proximal to medial malleolus.*

skin, to reach the periosteum and then directed at an angle of 60 degrees inferiorly, with the bevel pointing away from the epiphyseal plate and the joint space. It is advanced further with firm pressure and rotary motion until the marrow is penetrated. This is indicated by a loss of resistance after the needle passes through the bony cortex and the needle standing upright without support. Insertion of needle to a depth of 1 cm is usually adequate as the distances from the skin through the cortex is rarely more than 1 cm in an infant or child.

The position can be confirmed by freely aspirating blood or marrow contents in a saline filled syringe. Sometimes it is difficult to aspirate bone marrow contents. In these cases if the needle is firmly in place, indicating it has penetrated the cortex, 2 or 3 ml sterile saline may be infused slowly while palpating the limb for extravasation. If the flow is free and there is no extravasation, the needle is inside the bone marrow. This procedure will also clear the probable plugging of needle with bone marrow contents.

Any standard intravenous tubing is attached to the needle for infusion of fluids and drugs. The infusion may be run in by

gravity, with the fluid bottle 4 to 6 feet above the patient.

After the infusion is over the needle is rotated slightly to loosen it and withdrawn immediately. A sterile pad is placed on the puncture site and firm pressure is applied for about 5 minutes to allow the blood to clot and form a seal. A sterile dressing is done which is changed daily for next 2 days. Follow up examination is advised if there is local pain or swelling.

Clinical Usage and Limitations

Recent studies have shown a wide range of clinical usefulness of intraosseous infusion for the emergency physician including fluid resuscitation and drug therapy. Successful resuscitation from complete asystole has been reported using intraosseous route as the sole source of drug administration(13). For volume resuscitation in hypovolemic patients, fluid may be administered in the marrow cavity at rate of 0.6-11 ml/min with gravity and at higher rates with added pressure(9). Adequate venous access and rapid fluid resuscitation can be achieved through this route even in children with severe burns(4).

The drugs that have been effectively administered through this route in emergency situation are hypertonic glucose, sodium bicarbonate, atropine, epinepherine, antibiotics, phenytoin, succinylcholine, insulin, glucose and sodium pentothal(15-21). Dosages of drugs administered through IO route are the same as that for IV route. No adjustment in the dosage may be required(20-22). As a generalization, serum levels of drugs administered through IO route tend to be elevated longer but the peak levels are not usually as high as those administered through central venous line.

Bone marrow aspirate obtained before the infusion may be used for various laboratory studies such as blood chemistry, blood gas assay, bacterial culture, *etc.*(23). However, hematological data on blood samples obtained shortly after IO infusion must be interpreted with caution(24,25).

IO infusion should be confined to those emergencies in which IV access can not be established without significant loss of time and its use be limited to a few hours for emergency drug and fluid therapy during cardiopulmonary resuscitation and hypovolemic or other shock. As soon as possible a peripheral or central venous line should be established for further infusions of fluids, blood, plasma and drugs. It is not advisable to use IO route for routine and maintenance fluid therapy because of the risk of infection. It is contraindicated in patients with fractured bone, in areas of cellulitis and infected burns, and in patients with osteogenesis imperfecta and osteoporosis.

Complications

The common complication is leakage of fluid into subcutaneous tissues. Local infection and cellulitis occur infrequently and osteomyelitis rarely. In a review of 4270 cases reported between 1942 and 1977 infection rate was only 0.6%; most of these children had needle in for a long time(8,9). Animal studies have shown no evidence of adverse effects on bone and growth plate(21). Nevertheless, the potential exists for the development of osteomyelitis, fat embolism, epiphyseal damage and piercing of both sides of cortex. The only deaths that were reportedly associated with the technique occurred when sternal approach was used(8).

Success Rate

Available data suggests that physicians are successful in establishing intraosseous

access in 80% of children with cardio-pulmonary arrest(9,27). The success rate in establishing an IO access does not differ significantly with the type of needles used. Wagner and McCabe found that second year residents were able to establish an IO infusion in randomly assigned limb of an anesthetized piglet with similar success rates, whether they used hypodermic, spinal, bone-marrow or specialized IO needles(28).

Seigler *et al.* have recently shown that in a field situation, paramedics can do it successfully in 77% instances in pediatric patients with cardiopulmonary arrest(29). These paramedics who had received only 3 hours training were able to perform the procedure in majority of patients in less than one minute.

To end, intraosseous infusion can be a life saving procedure in collapsed children with a success rate of 90-95%. It should be resorted to in children with life threatening emergencies such as shock, hypovolemia due to severe dehydration and cardiopulmonary arrest, in whom efforts at IV access have not succeeded in first 5 minutes. Research is needed on the safety and efficacy of the technique for rapid replacement of circulating volume in severely dehydrated children at the level of small hospitals in our set up. Further research on the kinetics of various resuscitation drugs administered by this route and their efficacy, as well as long term effects of the procedure on bone marrow is also required.

REFERENCES

1. Rossetti V. Thompson BM, Aprahamian C, *et al.* Difficulty and delay in intravenous access in pediatric arrests. Ann Emerg Med 1984, 13: 406.
2. Kanter RK, Zimmerman JJ, Strauss RH, Stockel KA. Pediatric emergency intravenous access: evaluation of a protocol. Am J Dis Child 1986, 140: 132-133.
3. Drinker CH, Drinker KR, Lund CC. Circulation in mammalian bone marrow with especial reference concerned in movement of red blood cells from bone marrow into circulating blood as disclosed by perfusion of tibia of dog and by injection of bone marrow in rabbit and cat. Am J Physiol 1922, 62: 1-92.
4. Doan CA. Circulation of bone marrow. Contrib Embroyol 1922, 14: 27.
5. Heinild S, Sondergaard T, Tudvad F. Bone marrow infusions in childhood: Experiences from a thousand infusions. J Pediatr 1947, 30: 400-411.
6. Pillar S. Re-emphasis on bone marrow as a medium for administration of fluid. N Engl J Med 1954, 251: 846-851.
7. Valdes MM. Intraosseous fluid administration in emergencies. Lancet 1977, 30: 400-411.
8. Rosetti VA, Thompson BMN, Miller J, *et al.* Intraosseous infusion: an alternative route of pediatric vascular access. Ann Emerg Med 1985, 14: 885-888.
9. Spivey WH. Intraosseous infusions. J Pediatr 1987, 111: 639-643.
10. Hodge D. Intraosseous infusions: A review. Pediatr Emerg Care 1985, 1: 215-218.
11. Standards and guidelines for cardiopulmonary (CPR) resuscitation and emergency cardiac care (ECC), Part V. Pediatric advanced life support. JAMA 1986, 255: 2964-2969.
12. Mofenson HC, Tascone A, Caraccio TR. Guideline for intraosseous infusions. J Emerg Med 1988, 6: 143-146.
13. Sacchatti AD, Linkenheimerr R, Lieberman M, Haviland P, Kryszczak LB. Intraosseous drug administration: successful resuscitation from asystole. Ped Emerg Care 1989, 5: 97-98.

14. Goldstein B, Doody D, Briggs S. Emergency introsseous infusion in severely burned children. Pediatr Emerg Care 1990, 6: 195-197.

15. Neish SR, Macon MG, Moore JWM, Graeber GM. Inrtaosseus infusion of hypertonic glucose and dopamine. Am J Dis Child 1988, 142: 878-880.

16. Spivey WH, Lathers CM, Malone DR, *et al*. Comparison of intraosseous, central and peripheal routes of sodium bicarbonate administration during CPR in pigs. Ann Emerg Med 1985, 14: 1135-1140.

17. Berg RA. Emergency infusion of catecholamines into bone marrow. Am J Dis Child 1984, 138: 810-811.

18. McNarama RM, Spivey WH, Unger HD, Malone DR. Emergency applications of intraosseous infusion. J Emerg Med 1987, 5: 97-101.

19. Walsh-Kelly CM, Bereus RJ, Glaeser PW, *et al*. Intraosseous infusion of phenytoin. Am J Emerg Med 1986, 4: 523-524.

20. Prete MR, Hannan CJ, Burkle FM. Plasma atropine concentrations via intravenous, endotracheal, and intraosseous administration. Am J Emerg Med 1987, 5: 101-104.

21. Moore GP, Pace SA, Busby.W. Comparison of intraosseous, intramuscular and intravenous administration of succinylcholine. Pediatr Emerg Care 1989, 5: 209-210.

22. Orlowski JP, Porembka DT, Gallagher JM, *et al*. Comparison study of intraosseous, central intravenous, and peripheral intravenous infusion of emergency drugs. Am J Dis Child 990, 144: 112-117.

23. Orlowski JP, Porembka DT, Gallagher JM. Bone marrow as a source of laboratory studies. Ann Emerg Med 1989, 18: 1348-1351.

24. Ros SP, McMannis SI, Kowal-Vern A, Zeller WP, Hurley RM. Hematologic effects of intraosseous infusion. Pediatr Emerg Care 1990, 6: 232 (Abstract).

25. Joffe M. Blasts in peripheral blood with intraosseous infusion. Pediatr Emerg Care 1990, 6: 106-107.

26. Brickman KR, Rega P, Koltz M, *et al*. Analysis of growth plate abnormalities following intraosseous infusion through proximal tibial epiphysis in pigs. Ann Emerg Med 1988, 17: 121-123.

27. Iseron KV, Criss E. Intraosseous infusion: A useable technique. Am J Emerg Med 1986, 4: 540-542.

28. Wagner, MB, McCabe JB. A comparison of four techniques to establish intraosseous infusion. Pediatr Emerg Care 1988, 4: 87-91.

29. Seigler RS, Trecklenburg FW, Shealy R. Prehospital intraosseous infusion by emergency medical service personnel: A prospective study. Pediatrics 1989, 84: 173-177.