

HISTORICAL NOTE

Discovery of the intraosseous route for fluid administration

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Abstract

One of the many problems in the resuscitation of the shocked patient is how to gain access to the circulation to provide fluids or drugs. Since the 1830s fluids have been administered intravenously. Intravenous access is not always possible in the very shocked patient. An alternative, used in the first world war, was the rectal route. This has rarely been used on a large scale since. Just before the outbreak of the second world war a chance discovery resulted in the development of intraosseous infusions of fluid and drugs. From its discovery it was used in adults and children. For many years it seemed to be ignored in adult resuscitation, but there are now signs of renewed interest in the technique. This brief review traces the discovery of the intraosseous route to put the current developments into a historical context.

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Recently Lavis reported using the intraosseous route to give drugs and fluids to four adult trauma patients, in whom it was impossible to secure venous access quickly.¹ As the author noted, this route of access to the circulation has been used in adults in the recent past, but it does not feature in the main emergency care training courses. Intraosseous infusions are well established in paediatric resuscitation, but, as this historical note will show, the intraosseous route was discovered more than 50 years ago, and at that time was used predominantly in adults.

In 1936, during experiments on bone marrow transplantation in rabbits, Tocantins and O'Neill noticed that if 5 ml of saline were injected into the proximal end of the marrow cavity of a long bone only 2 ml were recovered at the distal end. As they found no evidence of fluid infiltration into the local tissues they concluded that the saline had been absorbed into the systemic circulation.² This incidental finding led to the idea of intraosseous, or intramedullary, infusion.

To investigate this further Tocantins conducted a series of ingenious studies.³ His first

experiments were to see if blood volume could be replaced by the intraosseous route. Seven rabbits were subjected to a 20% total blood volume haemorrhage by cardiac aspiration. Twenty four hours later they were given an equal volume of blood via a needle inserted into the upper tibia, at a rate of 5–7 ml/min. Within 24 hours four of the animals had returned to their pre-haemorrhage haemoglobin concentration. Two recovered within 48 hours, and one died of a haemopericardium. His next study involved making four rabbits hypoglycaemic, to the point of convulsions, by giving them insulin, and then injecting them with intraosseous dextrose (25%–30%). The rabbits recovered. One rabbit, which was not treated, died. To assess the speed of fluid absorption dye was injected into the marrow cavity and serial blood samples taken by cardiac aspiration. Within 10 seconds of injection into the marrow cavity the dye had reached the heart. By injecting mercury into a rabbit tibia and taking radiographs he showed that fluid was absorbed into the venous circulation. This was confirmed by injecting mercury into the sternum of a female patient and finding the mercury in the internal mammary vein. Finally he tried a gravity infusion of fluid into the sternum of three male patients.

The success of these experiments prompted a clinical trial in 14 patients, including two children under the age of 1.⁴ No adverse reactions were seen in 16 successful infusions (from 17 attempts), with various solutions (citrate blood, plasma, glucose, and saline). Up to 1050 ml of fluid were given at infusion rates of 0.4–9 ml/min. In a further trial in 1941, 40 patients (14–80 years) were given 52 intraosseous infusions.² The sites most commonly used were the body of the sternum or the manubrium, and in infants the distal femoral or the proximal tibial metaphysis, as the marrow in the sternum was thought to be inadequately developed.

The site of sternal puncture was midway between the angle of Louis and the xiphoid process. Procaine was injected into the skin, subcutaneous tissues, and periosteum. The needle used appears to have been a double needle with a stylet. This was inserted vertically, bevel up, and pushed into the periosteum, by twisting, “until a good foothold is

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obtained". To penetrate the anterior plate of the sternum the needle was lowered to make a 30 degree angle with the skin and pushed in with a semiroatory motion. After penetrating the bone the stylet was removed, a syringe attached and bone marrow aspirated through the inner needle to confirm the position. The inner needle was then withdrawn and flushed with saline. The inner needle was then "reinserted in the outer needle while alternately aspirating and injecting salt solution ... to remove air from the lumen of the outer needle". Saline was then injected into the outer needle, which was then connected up to the gravity infusion apparatus.

The authors suggested practice on cadavers as the best way to acquire a feel for penetration of the sternum. They recognised three causes for failing to aspirate a blood-marrow mixture, (1) not entering the marrow cavity, (2) marrow infiltration with fibrous tissue, or bone proliferation, and (3) the distal opening of the needle lying against a spicule of bone, in which case rotation of the needle might clear the obstruction. They also suggested equipping the outer needle with an adjustable guard to protect against mediastinal puncture. Avoiding air embolism was thought very important, especially in children.

Up to 2000 ml of fluid (blood, plasma, glucose, or saline) could be given by gravity infusion or by injection. Injection rates of up to 43 ml/min could be achieved, but these were only recommended in cases of severe shock. The route was not suitable for hypertonic solutions, and they found no evidence of fat embolism. The infusion needle could be left in situ for up to 30 hours.

One of the advantages of the intraosseous route was that it was open even in the most shocked casualty, or the smallest infant. Tocantins *et al* used intraosseous infusions of

citratated blood, successfully, in a 7 week old infant with pyloric stenosis.⁵ Another advantage became apparent during the blitz. In 1944 Hamilton Bailey wrote, "Sternal puncture can be carried out in a comparatively poor light—a most important consideration under black-out conditions".⁶ He inserted the needle just above the manubriogladiolar junction rather than the body of the sternum, using a Witts needle. The major drawback with sternal puncture was the risk of going through the sternum and into the mediastinum, with possibly fatal consequences. Recognising this problem Hamilton Bailey went on to design a special sternal trocar with a guard to make it impossible to enter the mediastinum.⁷

So, from a chance observation in the laboratory, and the exigencies of wartime casualty resuscitation, was intraosseous infusion born. But, as with many other medical discoveries, it seems to have been forgotten and then rediscovered. Now its main use is in paediatric resuscitation, but as Lavis points out, it can still, and maybe should, have a much greater role in adults.

"Plus ça change, plus ça reste la même chose".

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