THE BONE MARROW ROUTE FOR INJECTING FLUIDS AND DRUGS INTO THE GENERAL CIRCULATION * †

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The scientific use of fluids in the treatment of disease is a comparatively recent advance in medical practice. In the course of the last forty years, the principle of injecting solutions into the veins, under the skin, and into the muscles has been recognized as an extremely important one in the proper care of many patients. The variety of routes for the administration of parenteral fluids at present is great and satisfies the needs of most situations. However, there are circumstances when the technics in common use are unsatisfactory or impossible. For this reason, another technic for the administration of parenteral fluids will be discussed with the idea of providing an additional method for introducing fluids into the general circulation. The bone marrow is suggested as an additional portal of entry into the blood stream. It must be emphasized that the intramedullary route for fluid therapy is not designed to supplant the other well known methods, but to complement them.

In 1940 Tocantins (1) first described the administration of fluids into the general circulation via bone marrow. Well controlled animal experiments demonstrated that the injection of blood, glucose solution and dyes into the bone marrow of the tibia resulted in effective absorption of these substances into the general circulation. In the same year he described with O'Neill (2) 14 clinical cases in which blood, plasma or saline was injected into the sternal bone marrow of adults and the marrow of the tibia and femur in infants. Amounts ranging from 100 to 1050 cc. were given in one and one half to sixteen hours. Satisfactory absorption was observed in all cases without local or general complications. In 1941 (3), these authors reported the results of fifty-two administrations of different fluids into the bone marrow of 40 patients and described in detail their equipment and technic. They pointed out the advantages of the method and cautioned against the use of hypertonic or other irritating solutions because of their possible deleterious effects on bone or bone marrow.

Recently a slight modification of the Tocantins technic was described, together with an anatomical discussion of the rationale of the use of the sternal marrow for fluid therapy and a summary of early ex-

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perience with the method (4). The indications for infusions into bone marrow have been suggested but will be reviewed briefly. This technic is of particular value for patients where administration of fluid into the general circulation is required who have veins difficult or impossible to cannulate. Veins are frequently inaccessible after widespread burns, profound peripheral circulatory collapse, anasarca, and in very young patients. In addition, long periods of continued fluid therapy frequently produce thromboses of veins with the attendant possibility of infection or embolism. In all such instances the administration of saline, plasma or blood may be imperative and can be performed conveniently and effectively into the bone marrow with minimal risk. The technic is useful also in restless, excited or delirious patients who may dislodge an intravenous needle but cannot move a sternal needle with its firm fixation in situ without support. The needs of military medicine with the widespread treatment of shock by doctors inexperienced with such therapy during or after combat may be readily met if bone marrow administration of fluids is employed. The advantage of this method, together with the simplicity of the technic and the ordinary equipment required, recommends the use of the bone marrow for parenteral fluid and drug therapy as a valuable new aid to the therapeutic armamentarium of the anesthetist, surgeon and all physicians who may be required to administer such therapy in emergencies. Interestingly the sternal marrow puncture with the equipment used for parenteral therapy has been found convenient and useful for obtaining bone marrow for hematological purposes.

Because of their anatomical features the sternum is the bone of choice in adults and the tibia and femur in young children. The anatomy of the sternum with reference to its adaptability for bone marrow infusions has been recorded elsewhere (4). The salient points are reviewed here. On theoretical grounds, a portal of entry for the injection of fluid into the general circulation should meet the requirements of accessibility, rapid absorption and no untoward effects. The sternum meets these demands. It is subcutaneous, with a thin compact bony outer surface, and relatively easy to pierce with a needle. Its ample, spongy marrow and rich, venous drainage provide for rapid absorption into the general circulation, and with care in executing the necessary maneuvers, is without dangerous sequelae.

The technic for the administration of fluid into the sternum is not complicated (3, 4). The necessary equipment is a syringe, a special sternal needle, a hypodermic needle and 1 per cent procaine solution. The needles recommended are the wide bore B-D Luer-lok type (1.5 mm. in diameter), with accurately ground stylets. The shaft, exclusive of the hub, is 3 cm. long for adults, with a short (4 mm.) bevel and a sharp point and cutting edges. The Tocantins needle manufactured by the George P. Pilling & Son Company is more elaborate, being in four parts: a needle with a wide wing top, having a ball guard which

slides along the shaft to fix the needle after it is in place, another indwelling needle for marrow aspiration, a stylet and a curved adapter. This needle is manufactured in four sizes. The latter is convenient and satisfactory but not essential for using the method properly.

The needle is inserted into the lower part of the manubrium or the upper part of the body, because the spongy bone layer is usually thickest at this point. An important adjunct to the painless insertion of the sternal needle is the use of an intradermal wheal and infiltration of the periosteum with procaine. The needle is then inserted in the midline through the anesthetized skin and periosteum until firm contact is made with the cortex. The point of the needle is then directed cephalad at an angle of 30 degrees with the anterior chest wall, and a steady burrowing pressure is made on the hub of the needle against the sternum. When the needle pierces the compact bone and enters the spongy marrow, a sudden diminution in resistance is felt. If performed properly, a conscious patient feels no pain during the manipulations and has no complaints except a feeling of pressure in the chest. The exact depth of the shaft depends on the individual, but usually 2–2½ cm. of the shaft is below the skin surface. The needle is firmly fixed in position without additional support, and the area is treated as a sterile field. Strict asepsis is urged in carrying out the procedure. The actual position of the needle in situ and the characteristics of the marrow are shown in figure 1, a photograph of a sternal needle in place in the adult sternum.

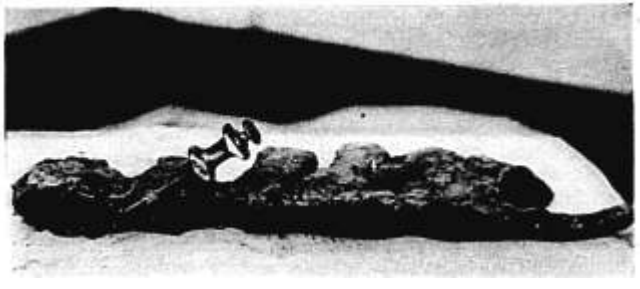

FIG. 1. A sagittal section of the adult sternum with the needle properly placed to deliver fluids into the marrow cavity.

After the needle is inserted the stylet is removed and air and marrow contents are immediately aspirated by withdrawing the plunger of an attached syringe until marrow contents are seen. This maneuver is slightly painful. The needle is incorrectly placed if marrow contents are not obtained. After the needle is cleared by the injection of sterile saline solution it is attached at once to the fluid container by sterile

rubber tubing from which all air is completely expelled at a height of at least 3 feet above the sternum. The rate of fluid flow by gravity is adjusted to suit the needs of the patient by a simple adjustable pinch clamp as commonly used in intravenous fluid therapy. After several hours, the needle may become partially occluded if marrow contents enter it due to a decreased pressure in the tubing. The needle may be cleared in situ by reinserting the stylet, removing it and then injecting fluid under slight pressure.

Osteomyelitis, septicemia or superficial infection over the site of puncture contraindicates its use. The several possible harmful sequelae from bone marrow fluid therapy are remote if proper precautions are followed, i.e., the aspiration test for marrow contents and the employment of aseptic technic. However, if the needle is in the pleural space, air may be aspirated, or if in a great vessel, fresh blood is detectable during the aspiration test. Osteomyelitis and subcutaneous infection may be possible complications avoided with proper care. Piercing the lower bony plate of the sternum is the most serious complication and constitutes the single observed objection to the use of the sternum for parenteral fluids. An accident here has emphasized the importance of following the recommended technic and exercising care not only in placing the needle but in performing the necessary tests to assure its proper position. During splenectomy for thrombocytopenic purpura in a 20 year old white female, a sternal bone marrow infusion was requested. The patient was in position, properly draped for surgery and operation was in progress. It was impractical to insert the needle in the manner described above because of interference with the surgical team. The needle was placed into the body of the sternum with the point directed caudad instead of cephalad. The usual aspiration test was performed and a small amount of marrow obtained. Five per cent glucose in normal saline was administered. For twelve hours postoperatively the patient's condition was satisfactory. Then, suddenly she became dyspneic and cyanotic and expired within a few minutes. Postmortem aspiration of the pleural spaces obtained about 2 liters of fluid which was found to contain almost 5 per cent glucose. Autopsy was not completed.

Five and 10 per cent glucose in saline, plasma and whole blood have been administered to patients by bone marrow infusion with entirely satisfactory results, without discomfort and with no restriction of movement. It will be of interest to describe in detail cases to illustrate the different types of fluid given, the length of time of administration and the results obtained.

Case 1.—(Conventional Parenteral Fluid Therapy.) A colored female, aged 42, with pulmonary tuberculosis and right therapeutic pneumothorax was subjected to hysterectomy. Five days postoperatively, intestinal obstruction developed from adhesions and a high ileostomy was performed. Subsequently, large amounts of fluid were lost via the ileostomy and the patient was unable to

retain fluid by mouth. All available veins were thrombosed due to previous use for parenteral fluids. For six days the patient was given fluids by sternal infusion including 5 per cent glucose in saline, normal saline, whole blood and plasma amounting to 14,750 cc. for the entire period. Such therapy resulted in rehydration. Surgery was repeated, the ileostomy was excluded and the bowel continuity restored. The patient was discharged improved with normal gastrointestinal function. There is little doubt that the ability to maintain the water and salt balance and plasma protein level of this patient by sternal infusion was the factor that permitted a surgical cure. This patient developed a subcutaneous abscess over the site of puncture due to careless asepsis which responded in a few days to simple incision and drainage.

Case 2.—A 43 year old white female in profound coma following the ingestion of a large amount of nembutal in a suicide attempt was hospitalized. She was in peripheral circulatory failure with veins too collapsed to cannulate conveniently. Fluids were given intrasternally with satisfactory circulatory response in a few hours. Six hours after admission she emerged from coma and was markedly excited, but the administration of fluid was uninterrupted because of the secure position of the needle and its inaccessibility to the patient. Complete recovery followed.

Tocantins warned against the use of irritative or hypertonic solutions by the intramedullary route (1). However, it was thought advisable to ascertain the effectiveness of drug therapy via the bone marrow and the effect of drugs on the sternal marrow itself as determined by x-ray and examination of the peripheral blood. Marrow smears were not performed. Two cases are presented by way of illustration.

Case 3.—(Drug Therapy Intrasternally.) An irrational 38 year old white male was admitted with lobar pneumonia and alcoholic delirium tremens. Necessary fluid therapy was given intrasternally. Here again the needle was not disturbed by an excited patient. Six grams of sodium sulfapyridine was dissolved in 2000 cc. of normal saline and given over a period of eleven hours. Sixteen hours after the start of the infusion the venous blood level of sulfapyridine was 3.0 mg. per cent, indicating adequate absorption of a diluted drug into the general circulation. There was no change in the sternum on x-ray and the peripheral blood picture was consonant with the disease process going on and showed no other pathological features.

Case 4.—A 59 year old white male with hypertension and luetic heart disease in chronic congestive heart failure was used to demonstrate the effect of an undiluted drug given intrasternally. One cc. of mercupurin was given, and digitalis or other diuretic drugs were not given until the effect of the drug had been ascertained. There was a satisfactory diuresis and weight loss with no x-ray changes in the sternum or peripheral blood changes.

Until more adequate marrow studies are completed, irritative or hypertonic drugs must be used with caution. The material cited is simply an indication that drugs which are ordinarily given intravenously produce their usual pharmacological responses when given by sternum, and produce no grossly harmful effects as determined by x-ray of the sternum and examination of the capillary blood.

ANESTHESIA

Anesthetic drugs may be injected into the bone marrow as well as intravenously. Five per cent sodium pentothal was administered intrasternally to a 64 year old woman who was undergoing a bilateral trephine for subdural hematoma. Pain responses disappeared at once. Ten cc. was then injected in four minutes and Cheyne-Stokes breathing, hypotension and bradycardia resulted. It is therefore possible to administer anesthetic drugs ordinarily given by vein into the sternal marrow with the production of anesthesia in therapeutic doses and toxic manifestations in overdose. There was no opportunity to study the blood picture or the sternum of this patient.

STUDIES ON CIRCULATION TIME

Material injected into the sternal bone marrow is presumably absorbed in toto into the general circulation. Its rate of absorption in animals has been shown to be rapid by Tocantins (1). The question of relative rates of absorption of fluid into the general circulation from bone marrow as compared with the intravenous route has not been answered. Studies on circulation time were therefore performed on man with two generally accepted tests. The "macasol" and the cyanide tests were used on each patient. It should be reemphasized that no attempt was made to establish normal values for sternal circulation time. The entire procedure was constructed to compare rates of absorption of substances from the bone marrow of the sternum and the antecubital vein of each patient, employing the end points of circulation time tests as a pharmacological indicator of the presence of the drugs at definite places in the blood stream. The administration of macasol and 2 per cent sodium cyanide had no discernible deleterious effects upon the sternal marrow or the general circulation.

The circulation time was determined for 7 patients. In the macasol test, the values after sternal injection were slightly but not significantly less than those following intravenous injection. A comparison of the figures follows:

AVERAGE CIRCULATION TIME IN SECONDS

	Throat	Abdomen	Perineum
Vein	12.9	21.7	20.5
Sternum	10.4	20.2	18.

These figures indicate that material is absorbed from the sternal marrow at least as rapidly as by vein. The cyanide test indicated that absorption from the sternum into the general circulation may be more rapid than by vein, since the average end point after intravenous in-

jection was fifteen and five-tenths seconds and after sternal injection was only eleven and four-tenths seconds.

The intramedullary administration of fluids has been suggested as possibly the method of choice in infants or very young children for whom the intravenous route may be difficult or inconvenient. The tibia is the bone of choice in these patients since the cortex is easy to penetrate and the marrow content is abundant. The technic for inserting the needle is similar to that for adults. The elected site of puncture is the antero-medial surface of the tibia 3 cm. below the epiphysis with the point of the needle pointing toward the foot. An interesting case illustrates the use of this method in infancy:

An 8 month old infant was admitted with the diagnosis of bronchopneumonia, diarrhea of three days' duration, and severe dehydration. The patient was hyperpneic and cyanotic. Intravenous fluid therapy was impossible without mutilating procedures. Five hundred cc. of Hartman's solution was given into the tibial bone marrow in twelve hours. This was followed by 120 cc. of citrated blood. The patient improved markedly and was rehydrated with a restoration of normal acid-base balance. The patient slept comfortably during the procedure.

SUMMARY

Various aspects of the technic originated by Tocantins and the use of the bone marrow as a route for parenteral fluids, drug therapy and anesthesia have been outlined and illustrative case reports appended. Intravenous and marrow cavity circulation time tests are described. The method is recommended in indicated cases as a valuable aid in the administration of these substances.

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REFERENCES

1. Tocantins, L. M.: Rapid Absorption of Substances Injected into Bone Marrow, Proc. Soc. Exper. Biol. & Med. 45: 292–296 (Oct.) 1940.
2. Tocantins, L. M., and O'Neill, J. F.: Infusions of Blood and Other Fluids into General Circulation Via the Bone Marrow, Proc. Soc. Exper. Biol. & Med. 45: 782–783 (Dec.) 1940.
3. Tocantins, L. M., and O'Neill, J. F.: Infusions of Blood and Other Fluids into General Circulation Via the Bone Marrow, Surg. Gynec. & Obst. 73: 281–287 (Sept.) 1941.
4. Papper, E. M., and Rovenstine, E. A.: The Utility of the Marrow of the Sternum for Parenteral Fluid Therapy, War Med., to be published.

The American Medical Association will hold its Scientific Assembly and Exhibit in Atlantic City, New Jersey, from June 8 to 12, 1942, inclusive. The Section on Anesthesiology will consist of three half-day sessions on June 10, 11 and 12, beginning at 2:00 p.m. There will be exhibits on Anesthesia among the Scientific Exhibits at the meeting. Headquarters for anesthetists will be the Ritz-Carlton Hotel.