INFUSIONS OF BLOOD AND OTHER FLUIDS VIA THE BONE MARROW IN TRAUMATIC SHOCK AND OTHER FORMS OF PERIPHERAL CIRCULATORY FAILURE *

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IN FAILURE of the peripheral circulation resulting from various causes, the administration of plasma or blood is often of great benefit. When the circulatory depression is marked and of some standing it is difficult to introduce any substances into the circulation by the venous route. Several factors operate to create this difficulty. The diminution in blood flow, which in certain vessels almost amounts to stagnation, renders it difficult to bring out the peripheral veins by the usual methods. The peripheral veins themselves are collapsed because of the reduced blood volume and poor venous return. If venesection is attempted, it is sometimes, even then, not possible to enter the veins, the walls of which may be in close apposition. Even when the vein is entered, one may not be able to inject fluid rapidly; the sluggish column of blood ahead prevents a rapid drainage of injected material with the result that further forceful injection may lead, especially in children, to a "blowing out" of the vein at the puncture site. All these difficulties which are the result of peripheral circulatory failure also interfere with any attempts at re-establishing the level of the blood volume, thereby helping to perpetuate the vicious circle. Attempts to re-establish blood volume other than by the *direct* introduction of fluids into the circulation fail, because of the markedly slow absorption of such fluids by the tissues, under these abnormal conditions.

During a stage when fluids are most urgently needed, one is left without ready access to the central portion of the circulation. It has occurred to us that, under such conditions, the bone marrow offers the ideal site for the introduction of fluids until the patient has reached such a stage that the peripheral circulation is restored and access to the veins is again possible. Since the marrow veins are surrounded by a rigid envelope, they are less likely to collapse, and can probably withstand forcible injection without overdistention and leakage better than the poorly supported peripheral veins.

Substances injected into the bone marrow cavity are taken up immedi-

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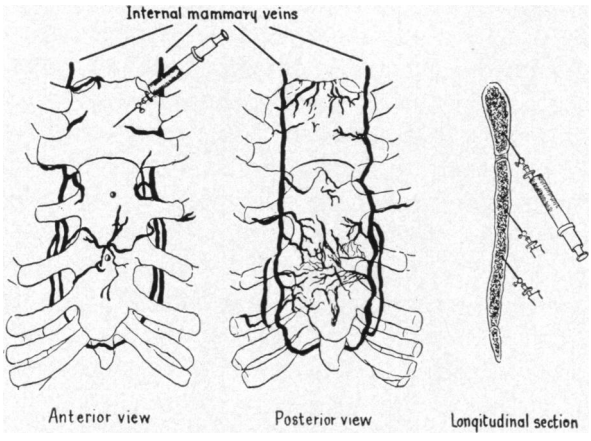
ately into the venous circulation apparently unchanged.[1] This method for giving fluids has been used in 72 patients to date, without any local or constitutional reactions.[2, 3] Experience with the method in animals having failure of the peripheral circulation due to hemorrhage[3] or in those undergoing an insulin reaction[1] impressed us with the desirability of widening the application of this method to the commonly encountered states of acute peripheral circulatory failure as observed in the operating room, in obstetric practice, in accidents, in industrial life or on the battlefield. Since our experience is limited to such incidents as are encountered in general hospital practice, this report is intended to draw the attention of those in whose hands the method may find a greater application.

Fate of Colored Solutions Injected into the Marrow Cavity of the Sternum.—If 10 cc. of green vinylite solution (a plastic material which solidifies on exposure to the air) are injected into the manubrium of the intact cadaver of an adult man, the solution leaves the marrow at once, enters the internal mammary veins and most of it is found in the form of a rubbery mass in the right auricle. The accompanying figure (Fig. 1b) illustrates the path traversed by the solution after it is injected into the sternum. Injection of dyes into a cadaver can give only an approximate idea of their spread during life, because of the absence of the circulation. The quick appearance of the dye in the auricle, however, serves to demonstrate the comparatively short distance between the sternal marrow and the right side of the heart. Rapid introduction of fluid into this side of the heart, therefore, may help to restore cardiac output during acute peripheral circulatory failure, by increasing the volume of blood returning to the central portion of the circulation.



Dissected human sternal plate after injection of green vinylite resin into the manubrium and body of the sternum

Fig. 1a (For Fig. 1b and legends see opposite page) →

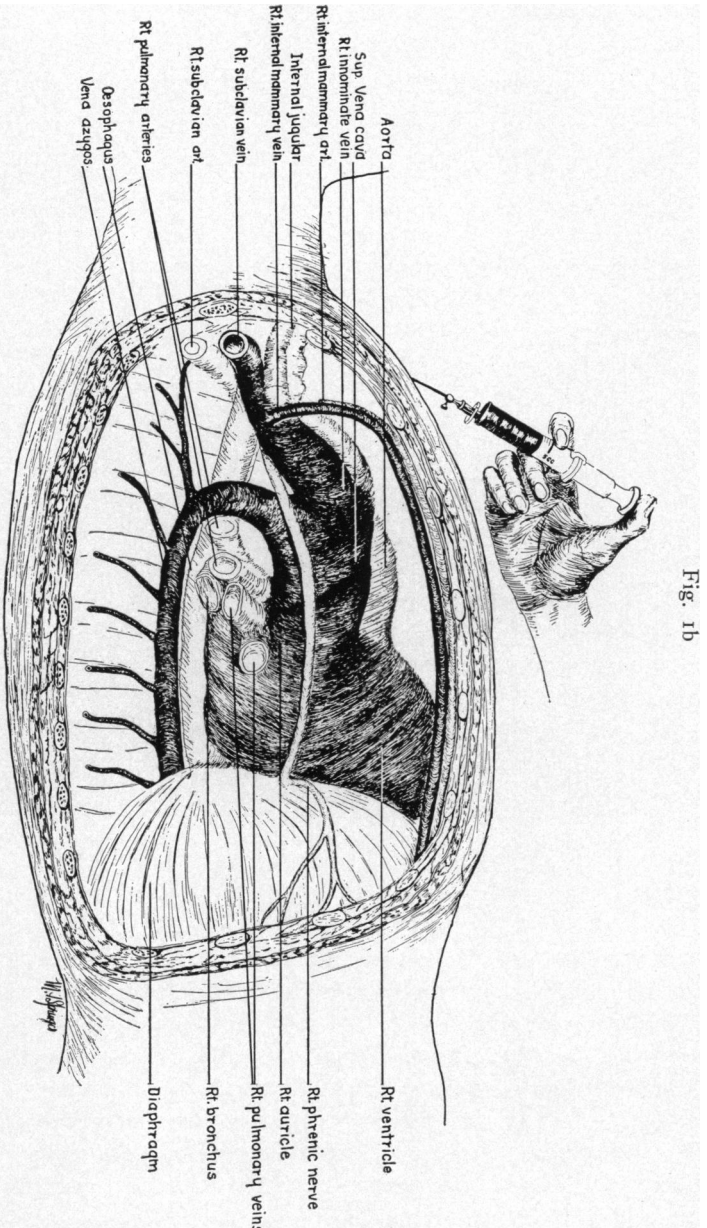


Fig. 1b

Fig. 1b—Right parasternal section of the thorax of an adult man (right lung removed). The path traversed by a green dyed solution injected into the sternal marrow cavity is indicated by the shaded vessels. Note the filling out of the vena azygos and intercostal veins, a result perhaps of the lack of resistance offered after death by the blood in that vein, and the absence of the sucking action of the right auricle.

Figure 1a (see illustration opposite page) illustrates the distribution of the dye in the retrosternal veins and the location of the needles during the injection.

Technic.—Details of the technic for introducing fluids into the sternal marrow have been described at length elsewhere.[2, 3] Only such variations in technic that may be applicable in patients with peripheral circulatory failure will be mentioned here.

After the needle has been introduced into the sternum (or tibia) and marrow has been obtained by aspiration, the syringe containing the material to be administered is inserted into the needle and the material is injected as fast as the resistance offered to it will allow. In conscious adult patients, rates of injection over 20 cc. a minute are usually accompanied by an unpleasant feeling of fulness in the sternum which passes off immediately after cessation of the injection. If it is contemplated to inject more than 50 cc. of fluid, much time may be saved by using a manually operated two-way stopcock with two thin-walled rubber tubes, one leading into the needle by means of an adapter and the other tube leading into the reservoir holding the blood, plasma or whatever fluid is to be injected (Fig. 2). By this means, it becomes unnecessary to remove the syringe from the sternal needle every time it has to be filled. If it is felt that a more rapid rate of injection is desirable than that obtained by using a single needle, two needles may be inserted at once in the sternum, one in the manubrium (above the angle of Louis) and the other 5 cm. below it, in the body of the sternum. Since the marrow cavity of the manubrium and the body of the sternum seldom communicate, it is possible to inject material through an orifice in the manubrium without its coming out of another orifice made in the body of the same bone. Care should be taken,

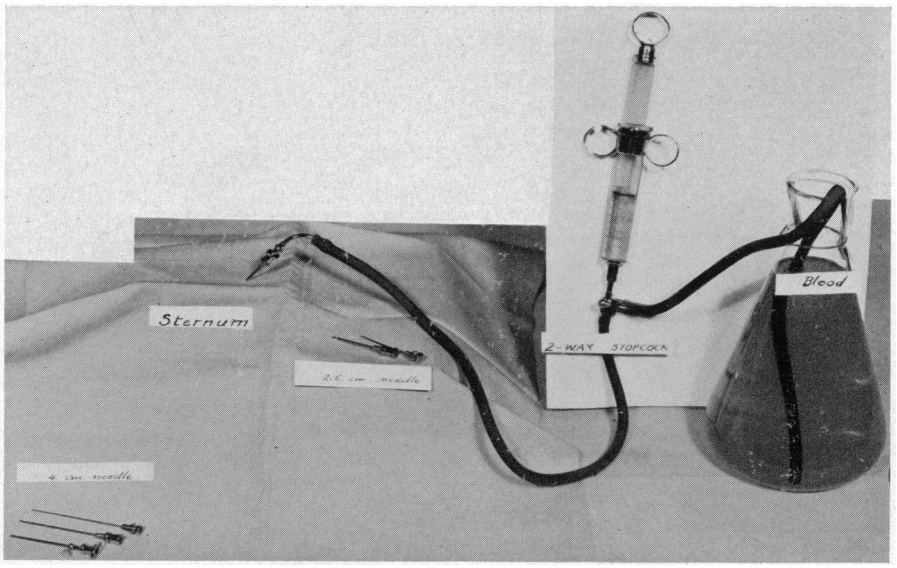


FIG. 2.—Arrangement for the rapid injection of fluids via the bone marrow. The blood may be put in a burette or inverted flask held above the level of the syringe, thus making easier to aspirate blood into it. All connections must be tight. A set such as the above, including two complete marrow infusion needles (4 and 2.5 cm. long respectively), sterilized, may be held in readiness in the central hospital sterilizing rooms or in emergency stations, for use at once when needed.

however, not to have both orifices made in the same portion of the sternum unless the fluid is going in with the same pressure through both of them. After the injection of the fluid is completed, the needle may be connected with a standard gravity infusion apparatus. If the patient has reacted from the state of collapse and the blood pressure has risen to a normal level, it may then be possible to use the peripheral veins.

The following cases illustrate the type of acute emergency in which this method finds its greatest usefulness:

Case 1.—(From the service of Dr. George J. Boines, Wilmington General Hospital, Wilmington, Del.) R. S., a white girl, age nine, had her tonsils removed on August 26, 1941, and went home the following day, apparently in good condition. On August 30, about 10 P.M., she began to vomit large amounts of blood and a few clots. During that day the child had been unable to eat anything because of pain in the throat. When admitted to the hospital she was having some bleeding in the postnasal space where a few large clots were observed. After the clots were removed, it was seen that the bleeding came from the posterior pharyngeal wall and was apparently controlled by packing. During the night the child began to bleed again and vomited many clots. Packing was again resorted to and seemed to control the bleeding. At 2:30 A.M. the child's condition became worse. She was cold, pale, and her skin was clammy. Her pulse was 170, weak and thready and her respirations 48. Stimulation was given and an attempt was made to give fluids intravenously but the veins of both arms and legs were collapsed and it was not possible to distend them by the usual methods. When, after repeated trials, it was felt that it was impossible to introduce a needle into any of the veins, the blood was given through the sternum using a marrow infusion needle. After aspirating a slight amount of blood from the sternum, the donor's blood was given through the needle. Three hundred cubic centimeters of citrated blood were infused followed by 200 cc. of normal saline solution, in two hours and 50 minutes. At 9 A.M. her temperature was 102° F., pulse 116, respirations 26. There was marked clinical improvement after the transfusion and the child was discharged three days later in good condition.

Case 2.—(From the service of Dr. Garfield Duncan, Pennsylvania Hospital, Philadelphia, Pa.) E. W., a diabetic colored woman, age 25, was in a deep coma when first observed by us. The blood sugar was 530 mg. per 100 cc. of blood. Attempts had been made to give insulin and fluids intravenously but, since the veins were collapsed, it was not possible to do it. The patient had been given several injections of insulin intramuscularly, apparently without effect. At 9 A.M. of December 30, 1940, a needle was inserted in the manubrium of the sternum and a small amount of blood-marrow mixture removed. At 9:02 A.M. 120 units of crystalline zinc insulin were injected followed by an infusion of 1,000 cc. of 5 per cent glucose at the rate of 11 cc. per minute. At 9:16 the pulse was felt at the wrist and five minutes later it was 96 per minute, regular and of fair volume. The patient came out of the stupor and answered questions. The infusion of 5 per cent glucose was continued at the regulated rate of 8 cc. per minute until the patient had received 1,500 cc. in about three hours. By 11 A.M. her circulation again began to fail but through a misunderstanding the insulin was given intramuscularly instead of through the sternal needle. She died at 12:15 P.M.*

Case 3.—(From the service of Dr. Frank R. Lock, Bowman Gray School of Medicine, Baptist Hospital, Winston-Salem, N. C.) M. H., age 45, female, white. On September 3, 1941, at 8:30 A.M. this patient underwent a perineorrhaphy and abdominal hysterectomy, under pontocaine spinal anesthesia. The operation proceeded without any complications. The patient's blood pressure was well maintained throughout, and she returned

* This case was previously reported in greater detail in Surg., Gynec., and Obst., 73, 281, September, 1941.

to her room in good condition. Between 9:45 A.M. and 1 P.M. her blood pressure declined gradually until at 1:15 a reading could not be obtained. There was no evidence of hemorrhage anywhere. At 1:30 P.M. it was possible to start an intravenous infusion of 10 per cent glucose (1,000 cc.) and 250 cc. of plasma. The impression was that the patient's peripheral circulatory collapse was probably due to pontocaine. The blood pressure remained low until the end of the infusion at 3:30 P.M. At 4 P.M. it was not possible to re-enter the veins and an infusion of 500 cc. of blood and 500 cc. of 5 per cent glucose was started through the manubrium of the sternum. While the infusion was flowing in by gravity the blood pressure dropped to zero. At this point the infusion apparatus was removed and the blood and glucose were injected through the sternum with a syringe. Between 5 and 5:20 P.M. 400 cc. of blood, 250 cc. of plasma and 500 cc. of 5 per cent glucose were injected through the sternum (total amount: 1,150 cc. in 20 minutes, or 57.5 cc. per minute). Administration of the fluid was continued by slow drip afterwards. Two doses of digifoline (five cat units) were then injected through the sternal needle. By 8:20 P.M. there were still signs of circulatory collapse, the abdomen was tense, the patient quiet and there was on palpation definite evidence of intra-abdominal hemorrhage. At 8:30 P.M. the patient was taken to the operating room and the abdomen was reopened under light ether anesthesia. There was a large amount of blood in the abdomen, coming apparently from the right broad ligament. While the vessel was being located and tied the circulation was maintained by injecting 500 cc. of blood through the sternal needle. At the end of the operation the blood pressure was 140/80; it was then possible to give 1,000 cc. of blood intravenously (Fig. 3).

Case 4.—(Reported by courtesy of Dr. Albert Davis, Camden, N. J.) M. McG., female, white, age 32, had a large pelvic abscess which ruptured while she was being moved to the hospital on October 30, 1941. At 2 P.M. of that day a celiotomy was performed; there was extensive lower abdominal peritonitis. Cigarette drains were inserted and 8 Gm. of sulfanilamide were left in the abdominal cavity. Immediately after the operation a transfusion of 500 cc. of blood intravenously and 1,000 cc. of salt solution by hypodermoclysis were given. Her condition was fair then, but by late afternoon of the next day the patient was in profound circulatory collapse; the pulse was 148, scarcely felt at the wrist, the skin was clammy, the lips cyanotic. Attempts to give her fluids by vein were unsuccessful for several hours; finally a needle was inserted into the vein but after 75 cc. of blood was given no more would run in. A marrow infusion needle was then inserted into the sternal manubrium and 425 cc. of blood was administered by gravity over a period of 75 minutes. This was followed by 250 cc. of 10 per cent glucose solution and 1,000 cc. of 5 per cent glucose, or a total of 1,675 cc. over a period of 13 and one-half hours. At the conclusion of the intramedullary infusion the patient was visibly improved and it was then possible to administer all subsequent fluids intravenously. For the following five days the patient's condition was critical but there were no more episodes of acute circulatory collapse and it was possible to give all further intravenous therapy without difficulty.

COMMENT.—Much of the medication given at present to patients with acute failure of the peripheral circulation is ineffective because it is administered by intramuscular or subcutaneous injection. Fluids, rapidly administered intravenously, are often the only means of restoring the circulation to normal. Though these principles are generally recognized, execution of the indicated measures is often made difficult or impossible by the very disorder of the circulation which requires treatment. Under these circumstances, the delay involved in locating a vein and in the attempts to introduce a needle into it, may jeopardize any chances for recovery from the acute circulatory collapse. When all required equipment is available and ready, it should be possi-

ble to start an intramedullary infusion or injection within less than three minutes after penetration of the skin by the needle. In contrast with venesection no incision of the skin or any special after-care of the wound is necessary; no veins are ligated, thereby depriving the patient of their use at some future time.

The method may be useful in the emergency treatment of mutilated patients or in those whose skin has been burned so widely as to make it impossible

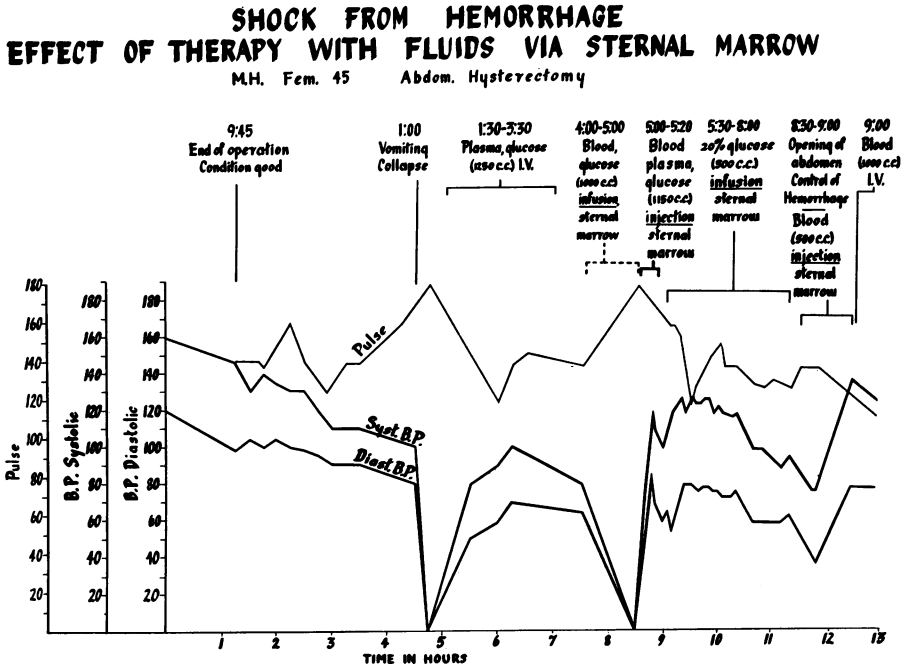


FIG. 3.—Changes in the pulse and blood pressure of M. H. (Case 3).

to use the veins of the extremities. Since the needle, once in place, remains fixed, it allows continuation of an infusion while the patient is being transported from one place to another, without fear of displacing the needle.

Even though one is working under pressure of the existing situation, the precautions enumerated in detail elsewhere[2, 3] should be strictly observed. No fluid should be injected unless marrow is clearly obtained by aspiration. Sturdy needles, preferably especially made for the purpose, should be used to minimize the danger of bending or breaking. Familiarity with the anatomic landmarks should be obtained by practice on a fresh cadaver.

SUMMARY

In four patients with acute failure of the peripheral circulation, the injection of blood, fluids or drugs via the bone marrow was followed by a prompt recovery from the state of collapse. The intramedullary route is indicated

whenever veins are not available and a rapid introduction of fluids into the central circulation is urgently needed.

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