need not be similar in volume, expansion, or degree of elasticity. With solutions which react strongly with rubber, such a series system can be applied to deliver fluid at a given rate from an inelastic reservoir made of cellophane or viscose tubing.

Variations in pressure on the intake side of the apparatus can be made to regulate delivery to any given percentage by proper selection of the total pressure within the system. With thin walled tubing, variations of pressure up to 50% are in the physiological range. Thus, where the total delivery pressure is 50 mm Hg, variation of 10.0 mm in the circulatory system would cause a change of 20% in the rate of delivery. If however, the delivery pressure is 1200 mm, the variation in rate due to this will be less than 1%.

The apparatus is superior to gravity drip in several respects. It can be placed in a light canvas harness on an experimental animal to deliver fluids over a long period during which the animal is at complete liberty. Delivery rates are variable over a range from 20 cc per minute to 0.08 cc per minute with only a minor change in the rubber stock used for the inside container.

Summary. 1. Various combinations of self-contained delivery units for the administration of fluid at regular rates are described, and the limits of usefulness of these units are delineated.

2. Combinations of such units to permit the administration of various types of fluids, including those likely to destroy the elasticity of rubber, are described.

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17270. Apparatus for Cross Transfusion.

PETER SALISBURY.* (Introduced by Harry Goldblatt.)

From the Institute for Medical Research, Cedars of Lebanon Hospital, Los Angeles, Calif.

Cross transfusion, the exchange of blood between a donor and a patient, which results in continuous mixing of the blood of two bodies, may be used in conditions such as uremia, resulting from acute renal insufficiency from a variety of causes, and in the treatment of other non-transmissible diseases.

The ideal requirements of a method for successful cross transfusion are: 1. Exchange of blood at a rate which may be varied from 0.5 to 10 liters per hour. 2. No chemical changes or hemolysis occurring in the transmitted blood. 3. Accurate measurement of the transferred blood. 4. Automatic equalization of the amounts of blood transferred in both directions. 5. The use of venous blood only, because donors and patients cannot be expected to sacrifice arteries every time that this procedure is applied.

In the past, cross transfusion has been applied in a variety of ways, none of which has been completely satisfactory. The method of paired arterial-venous anastomosis does not permit measurement of the exchanged blood and is obviously unsuitable. The multiple syringe method and the bottle method are tedious, slow and prone to introduce airborne infections. Pumps which operate on the "leaky valve" principle exhibit fluctuations in output which are proportional to the resistance encountered by the outflow. The worm pump (Pennell) and the roller pump (DeBakey) methods hemolyze at least 0.1% of the transferred blood and do not measure the transferred blood with sufficient accuracy. Although 0.1% of hemolysis is a tolerably small amount for ordinary direct transfusions of about 500 cc, yet, when quantities up to 50,000 cc are involved, the amount of hemolysis caused by such pumps may prove injurious.

This report deals with a new device which satisfies the above criteria for a safe, efficient

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and easily managed method for cross transfusion.

The device consists of 4 units. 1. Suitable double lumen intravenous plastic cannulae. 2. A motor driven blood pump. 3. Bubble traps. 4. Metering and equalizing unit.

1. *The intravenous catheter.* Blood is withdrawn from and administered to the patient and donor through specially made intravenous catheters. These consist of extruded plastic double lumen tubes of an oval outer shape with an inside diameter of 2.5 mm for each conduit. The outside diameters of the catheters are 2.8 x 4 mm. The tip of the catheter is such as to provide for an outflow end protruding about 2″ from the intake. The tip of the catheter is equipped with a thin finger-like projection which serves as a guide, the end of which terminates in a round, plastic-coated lead shot. The intake opening is fashioned with an overhanging lip which tends to prevent occlusion of the intake opening by the walls of the veins, by valves or by clots. The catheter is inserted into a vein and is pushed cardiad until the tip lies in the superior or inferior vena cava. The intake opening is upstream from the output opening and therefore no blood which is discharged through the output opening is aspirated through the intake opening when the rate of flow in the vein exceeds the rate of intake into the catheter. In our experience, this catheter has performed well. It carried an adequate volume of blood. Clotting is prevented by the intravenous injection of 1-2 mg heparin per pound of body weight and the catheter may be left *in situ,* without excessive reactions, for days at a time.

2. *The pump* (Fig. 1) propels blood by applying negative pressure to the catheter intake channel and imparting a positive pressure to the withdrawn blood. A simple commercially available pure gum rubber tube (1) is laid in a receiving channel and is then raised to connect with the outside valves (2,4) and compression unit (3). The valves and compression unit are actuated by a motor driven shaft (5) which is ground to provide cams (6) and eccentrics (7) which operate the valves and the compression unit respectively. In this manner when the "intake"

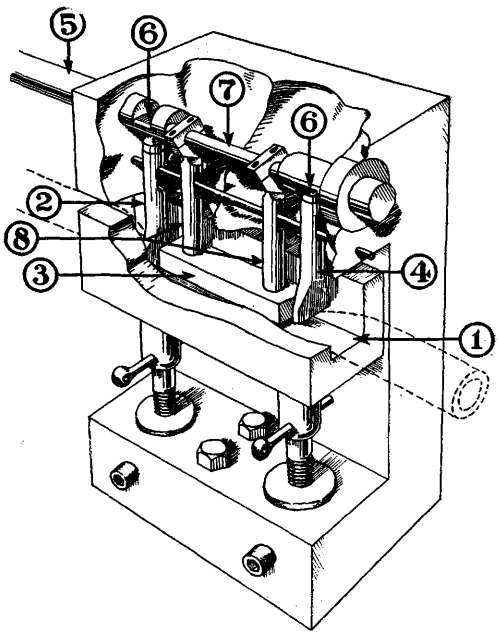

FIG. 1.
Blood pump.

valve (2) is "down" the "outlet" valve (4) "up" and the compression bar (3) comes down, the tube will be compressed and blood will be forced forward. When the "outlet" valve is "down" the "intake" valve "up" and the compression bar is raised, blood is aspirated into the tube. The tube is occluded only at the relatively short segments where it is compressed by the valves; the excursion of the compression unit is adjusted to compress the tube, but not to squeeze it. This precaution has eliminated hemolysis. The pump requires a minimum of attention, such as an occasional lubrication of the moving parts with glycerin. It is possible to change the stroke volume by using tubes of different sizes and by raising or lowering the receiving channel. The minute volume can also be controlled by adjusting the speed of the drive shaft and can be adjusted to between 10 and 1000 cc per minute.

The pump used here consists of 2 identical devices, mounted in opposite directions, of equal dimensions, and adjustment which provide an excellent means of effecting cross transfusion of equal amounts of blood. Small gas bubbles may form occasionally in the

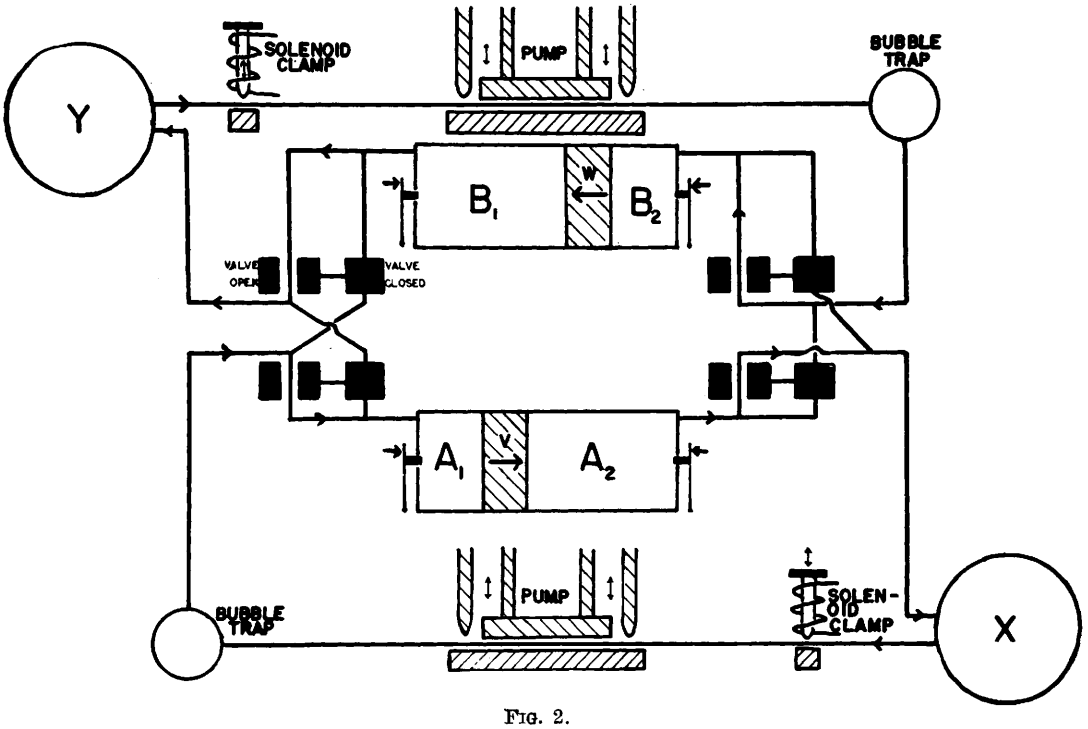

FIG. 2.
Diagram of blood flow in the cross transfusion apparatus.

blood because of the negative pressure exerted by the pump when it is withdrawing blood from the vein. Also, variations in stroke volume of the pump may occur because of changes in pressure in the intake channel, which are possibly caused by a reduction of the effective size of the intake opening. These two sources of error are corrected by bubble traps and a measuring and equalizing unit described below.

3. *Bubble traps.* These consist of 2 upright, cylindrical plastic chambers, one inch in diameter and 3½″ in height. Blood flows into one end of a chamber, near the top, and flows out at the bottom, allowing any air bubbles contained in it to collect at the top. Near the top of the cylinder there is a flexible plastic membrane which forms the floor of another plastic chamber which is filled with air and transmits variations in pressure to a U-type mercury manometer. Just underneath the plastic membrane there is a vent-like opening, to allow for adjustment of the blood level within the bubble trap and for the introduction of liquids into the bloodstream.

This device removes all but the very smallest air bubbles, allows for the constant indication of pressure and the administration of anticoagulants, drugs, etc., to either bloodstream during the experiment.

4. *The meter.* (Fig. 2) The metering unit receives blood into cylindrical chambers A1 and B2 from bodies of the subjects X and Y. As the blood is pumped into chambers A1 and B2, two floating plastic pistons, V and W, move toward the opposite ends of the chambers and expel the contents of chambers A2 and B1 into bodies X and Y respectively. At the end of the excursion of the floating pistons a micro-switch mechanism provides for the activation of solenoid clamps which stop the flow of blood to whichever chamber has been filled. When both chambers are filled, a valve mechanism is moved by means of a motor. As soon as the movement of the valve-changing mechanism is completed the solenoid clamps are released and blood again

flows into the measuring chambers. Blood from animal X is is now pumped into chamber B1 instead of Chamber A1, thereby expelling into animal X the blood from animal Y which had been collected in chamber B2 during the preceding cycle. The number of changes of the valve mechanism is recorded automatically on a meter and provides an easy and convenient way of determining mean blood flow and total amount exchanged. The volume of the chambers is 50 cc each.

This arrangement has the following advantages: It measures and equalizes the flow of blood in both directions automatically. It provides for simultaneous withdrawal and administration of equal amounts of blood. The accuracy of the registration of blood flow is about ± 1-3 cc in 10,000 cc, depending upon the fit of the piston and on the pressure differential in the two circuits. The device has been found completely satisfactory in experiments involving the exchange of a total, to date, of 500,000 cc of blood in both animals and human beings. The amount of heparin needed to prevent coagulation is within the clinically acceptable limits. Hemolysis does not occur if the pump is properly adjusted. Cross transfusion itself has proved to be a safe, efficient and relatively easy procedure, when performed with the apparatus described above. No fatalities attributable to the procedure itself have occurred.

Summary. A safe, effective and easily controlled apparatus for cross transfusion is described.

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17271. Vasomotor Reactions in the Mesenteric and Serosal Capillary Bed During Fright and Violent Muscular Activity.*

RICHARD E. LEE†

From Department of Pharmacology, College of Medicine, Syracuse University, Syracuse, N. Y.

Recently, technics were devised for painless exposure, with local anesthesia, of the guinea pig mesentery and gut and its maintenance in a warmed chamber where the capillary bed could be observed continuously with the microscope.[1] This permitted study of peripheral vasomotor reactions, and vascular responses to drugs without possible variables introduced by general anesthesia. In addition, the fact that the animal studied was fully conscious afforded the opportunity to witness the behavior of terminal arterioles and capillaries in this splanchnic area during various emotional states and spontaneous muscular activity.

Methods. Studies were made on 20 animals receiving a normal well supplemented diet, and on 21 animals in moderately advanced Vitamin C deficiency after 3-4 weeks on a standard scorbutogenic diet. The apparatus and diet have been described previously.[1] In brief, it includes holding a trained animal under light restraint, with cautious painless exposure of the mesentery and gut via a denervated or procaine field block in the flank. The preparation is maintained in a suitable warm chamber and continuously bathed with a drip solution of warmed buffered Ringer-gelatin solution, while being observed under the microscope.

Results. A. Animals receiving a "normal" diet. The changes found in the capillary bed of this splanchnic region in the control animals could be divided into 2 major categories. The

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† Present address: Department of Medicine, Cornell University Medical College, New York Hospital, New York.

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