17269. A Self-Contained Method for the Administration of Fluids at Regular Rates.

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The continuous administration of fluids has been of considerable importance in the study of many phases of physiological phenomena.

Certain critical limits to any system for such administration must be adhered to: (1) the rate of delivery must be linear over the range demanded by the experimental procedure; (2) the system must be reasonably foolproof and simple to adjust; and (3) the system should be compact.

For some experimental purposes a rate of flow, constant within 0.1% is necessary, and methods have been designed to meet such tolerances.[1,2] Such systems are susceptible to mechanical failure, entail considerable supervision, and though modified[3,4] to allow movement of the subject, necessitate a continuous connection between the subject and some stationary structure, not always easy to maintain for long periods in the experimental animal.

For purposes less rigorous in requirements of tolerance of rate of flow, a method has been devised with possibilities of adaptation to a multiplicity of experimental uses, allowing complete freedom of movement to the recipient of the fluid.

Construction. A glass container of suitable volume is fitted with a 2 hole rubber stopper carrying 2 short lengths of glass tubing, one of which is flanged at the lower end. Over this flanged end which lies within the container, is fitted a short length of latex rubber tubing fastened securely with silk thread. The free end of this latex tubing is also tied securely. To the second length of glass tubing is affixed a fine wire long enough to reach to the bottom of the glass container when the stopper is affixed (Fig. 1). The wire prevents tight sealing of the inflated tube to the glass wall.

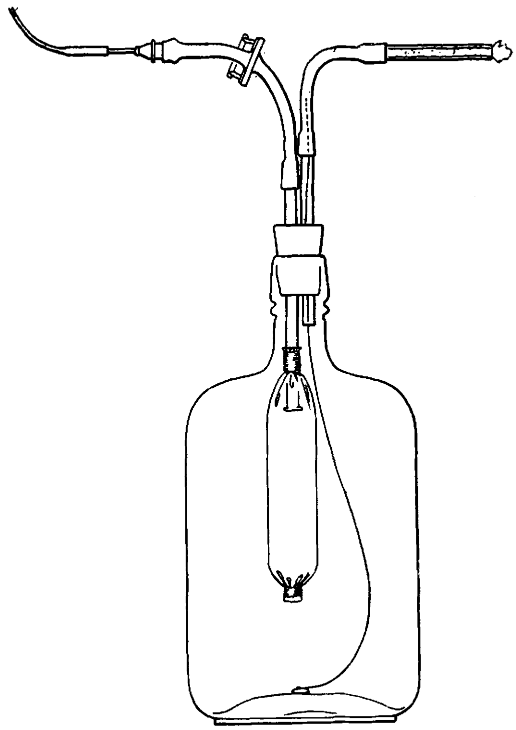

Fig. 1.
A typical delivery system shows the space relationships and mode of construction. The component parts are described in the text.

Operation. Filling. Two short lengths of rubber tubing are attached to the outer ends of the glass tubing perforating the stopper, and the stopper is fitted tightly into the neck of the glass container. Vacuum is then applied to the tube to which the wire has been attached, while the end of the tubing carrying the latex container is connected to a reservoir of fluid with which the apparatus is to be

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[1] Burn, J. H., and Dale, H. H., *J. Physiol.*, 1924, **59**, 164.

[2] Debakey, M. E., *New Orleans M. and S. J.*, 1934, **87**, 386.

[3] Jacobs, H. D. R., *J. Lab. and Clin. Med.*, 1931, **16**, 901.

[4] Stengel, A., Jr., and Vars, H. M., *J. Lab. and Clin. Med.*, 1939, **24**, 525.

TABLE I.
Typical Systems.

Size of reservoir tubing	Delivery pressure, mmHg	Length of reservoir tubing, cm	Size of polythene tubing of delivery unit: Large (needle No. 18)	Medium (needle No. 18)	Small (needle No. 23)
			Delivery rate, cc per min.		
Infusion	155	100	20	4.5	.8
Aged 1 wk.		50	22	11	1.2
Single ⅜″	16	100	5	.8	.1
Aged 1 wk.		50	8	2.1	.2
Single ⅝″	14	100	3.5	.3	.08
Aged 1 wk.		50	5	1	.1
Double ⅝″	27	100	7	1.2	.15
Aged 1 wk.		50	10	2.1	.3
Double 1″	49	100	11	3	.4
Aged 1 wk.		50	18	5	.9

''Infusion'' tubing—Rubber Latex Products, Inc., Cuyahoga Falls, Ohio.

All other rubber tubing—''Penrose'' tubing from Davol Rubber Co., Providence 2, R. I. They have recently provided us with heavier 1½″ tubing which has a delivery pressure of 41 mm single thickness and 70 mm double thickness, with comparable intermediate delivery rates.

Polythene tubing was supplied by Suprenant Electrical Insulation Company.

Large — 0.30 cm inside diam., 0.48 outside diam.
Medium—0.23 '' '' '' 0.38 '' ''
Small — 0.11 '' '' '' 0.24 '' ''

filled for delivery. The latex container is gradually distended with fluid, as the vacuum is created in the glass container, until it completely fills the bottle. The connection leading to the latex bag is then clamped off, and the apparatus is ready for delivery.

Delivery. A delivery unit of a suitable length and size of polythene tubing is connected to the clamped off tube connected to the latex bag. The needle or cannula of the delivery unit is inserted into the blood vessel or space desired and the clamp removed.

Delivery Rate. Reproducibility. The delivery rate of most of the fluid (60 to 80%) is linear, and for any given unit is constant within reasonable limits ($\pm 3\%$) on successive runs with the same resistance and with the same solution being delivered. Similar apparatus made of similar materials will reproduce rates within 6%. Ageing of the tubing in contact up to 2 weeks with the solution to be delivered produces no significant change in delivery rate with such inert solutions as physiological saline and low concentrations of organic compounds of intermediate acidity and basicity. Treatment with depyrogenizing agents such as weak bases (bicarbonate, sodium nitrite, green soap) had no effect on the delivery rate over 12 hours, but autoclaving drastically decreased the elasticity of the latex and affected the delivery rate. Sterilization for 12 hours with organic bactericides (Zephiran, Metaphen), however, had no noticeable effect.

Applications. This type of delivery unit is adaptable to many uses within a wide range of delivery rates (Table I). The desired delivery pressure may be roughly approximated by the selection of the type of tubing used in constructing the delivery unit. By using one latex container within another the arithmetic sum of their delivery pressures can be utilized. Delivery rate can be controlled most simply by increasing or decreasing the length of plastic tubing used for delivery. The rate may be slowed by increasing the viscosity of the solution, or by limiting the size of the air intake. If a relatively high viscosity fluid be admitted instead of air, the rate of delivery will be regulated by the rate of flow of the high viscosity fluid. To increase the rate of delivery, the pressure on the intake side may be increased by connecting two units in series. The latex containers 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.

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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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