Thorax (1966), **21**, 382.

A pump unit for perfusion of the coronary vessels

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Coronary perfusion can be achieved in a variety of ways, but many of them have disadvantages.

1. We do not always know with sufficient certainty whether coronary perfusion is efficient or not.
2. The output of each coronary cannula is insufficiently known.
3. The pressure in the system is variable.
4. It is not always possible to prevent the pressure in the system from rising excessively.
5. The addition of the responsibility for separate coronary perfusion to his other duties is often too much for the perfusionist.
6. The pumps that are generally used are too large to be arranged without difficulty in a suitable position.

The apparatus to be described was evolved with these disadvantages in mind. It is smaller and seems to be less complicated than the device described by Bosher, Edwards, and Pois (1964).

DESCRIPTION OF THE UNIT

The external dimensions were kept as small as possible so that the unit can be used with any heart–lung apparatus (Fig. 1). The unit measurements are: length, 41 cm.; width, 37 cm.; total height, 60 cm.; priming volume, 500 ml. (heat exchanger included).

The blood derives from the arterial line of the heart–lung apparatus beyond the heat exchanger. It passes a small, separate heat exchanger and is then distributed over two pumps (right and left). The output of each pump is continuously variable from 0 to 600 ml./minute. Each pump propels its blood into a small reservoir for pressure readings. The air-pressure above the blood level in each reservoir is read from a dial manometer, which also controls the automatic device activating or inactivating the pump in question. For this purpose the manometer dial carries an adjustable segment. The segment covers a dial area representing a pressure difference of 50 mm. Hg. If the indicator of the manometer moves past this segment, then the pump in question is inactivated and not reactivated until the pressure diminishes by 50 mm. Hg, which is the other border of the segment. Since the pump tubing is of standard diameter, the output of each pump can be read directly from a tachometer.

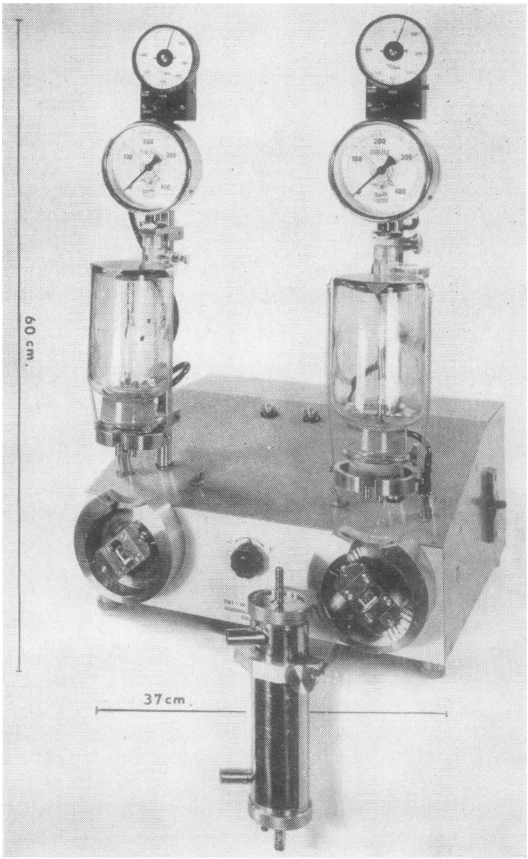

FIG. 1. *The pump unit.*

ACTION PRINCIPLE OF THE PUMP UNIT

In the feedline, a certain pressure prevails which is exerted by the arterial pump of the heart–lung apparatus. When the pumps of the coronary perfusion apparatus are switched on, the reservoirs can be filled. This is achieved by opening a valve below each manometer, which allows the reservoir to fill without building up pressure. The corresponding coronary cannula is clamped off by the surgeon. When the level in the reservoir is sufficiently high, the valve is closed while the pump is allowed to continue until it automatically stops (when the predetermined perfusion pressure is attained). The pressure is predetermined with the aid of the adjustable dial segment. During filling, the output of the pumps is adjusted to a value slightly exceeding the expected flow in order to prevent the reservoir from emptying when perfusion starts.

Everything is now ready to start coronary perfusion. For the actual starting, the surgeon removes the clamp from the cannula and waits until this has filled. The clamp is then applied again, and the cannula is inserted. If after opening the clamp there is an adequate flow, the pump in question immediately begins to operate. The pump speed is then adjusted so that the indicator, within the limits of the dial segment, travels gradually towards the end of the segment. As it reaches the end, the pump is automatically inactivated, and the indicator must travel back to the beginning of the segment. Once it is back at the beginning, the pump is activated again. If the indicator fails to travel back, so that the pump is not reactivated after a short while, then there is no perfusion. The perfusionist must then ascertain whether the surgeon has clamped the cannula in question. If not, he must warn him about a possible obstruction of the ostium or the coronary artery or about a possible kinking of the catheter. The surgeon need not constantly remember to state whether at a given moment he wants coronary perfusion on or off. This is automatically recorded by the manometer, and there is no risk of the pressure mounting to a dangerous level.

The blood for coronary perfusion can be separately cooled. For re-warming, it is sufficient to switch off the small heat-exchanger, whereupon the blood will assume the temperature of the large heat-exchanger.

In an emergency the pumps can be driven manually.

This apparatus has so far been used in more than 70 cases.

EXPERIMENTAL DATA

In experiments with the pump unit described above the following tubings were used :

From the arterial line to the heat exchanger: PVC with an internal diameter of 8 mm.

From the reservoir to the coronary catheter: PVC with an internal diameter of 6 mm.

In the pump: Silastic (Dow Corning, Mich., U.S.A.) with an internal diameter of 6 mm.

We used disposable coronary catheters of the Rygg-Kyvsgaard type, sizes 1, 2, and 3.

When this system is filled with citrated human blood the resistance at various flows can be read from the diagrams in Fig. 2. In these circumstances haemolysis after four hours' circulation via a reser-

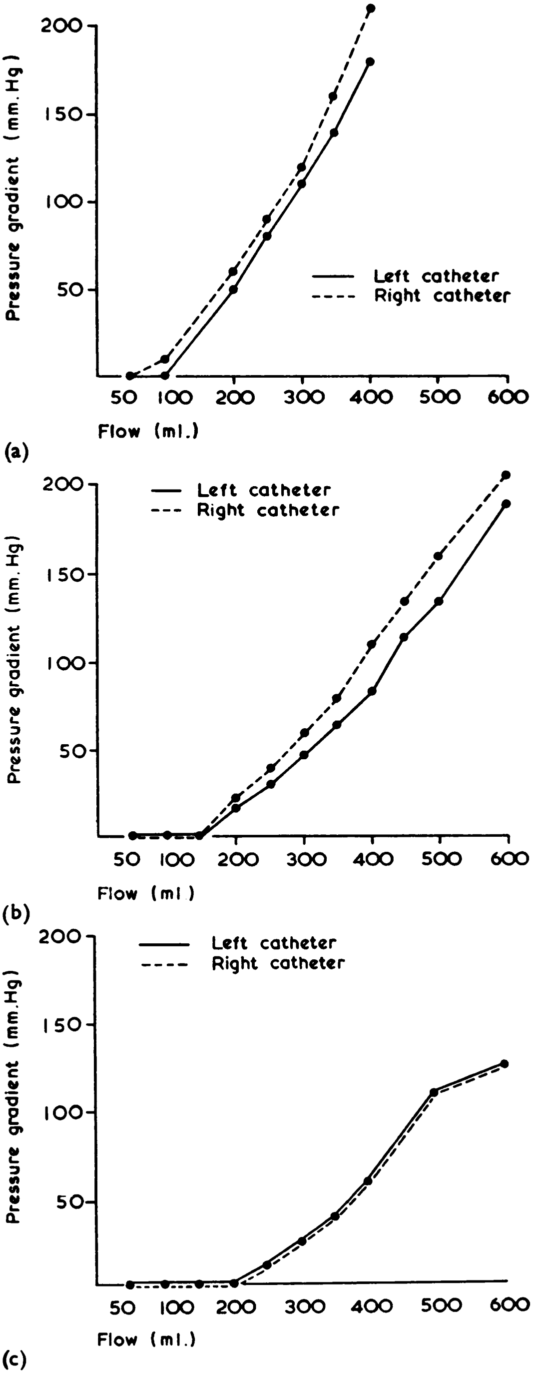

FIG. 2. *Perfusion using Rygg-Kyvsgaard catheters (a) size 1, ±1.5 mm. internal diameter; (b) size 2, ±2 mm. internal diameter; and (c) size 3, ±2.5 mm. internal diameter.*

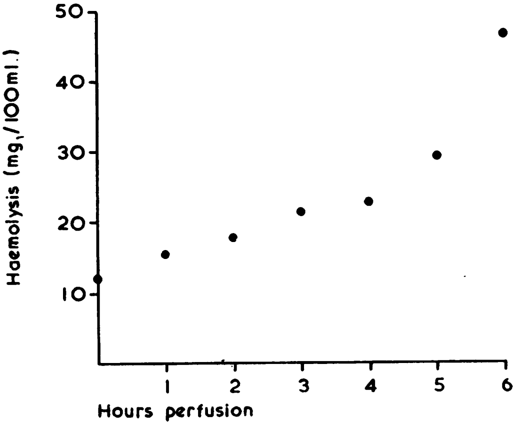

FIG. 3. *Haemolysis.*

voir is inconsiderable. In Fig. 3 haemolysis is plotted against time.

This pump unit has been used in five animal experiments in which the aortic valve was replaced; defibrillation was easy. The duration of coronary perfusion varied from 50 to 95 minutes in the various experiments.

SUMMARY

An apparatus for coronary perfusion is described which has the following advantages:

1. Reliability and simplicity of operation.
2. Semi-automatic regulation of flow and pressure.
3. Direct flow and pressure readings.
4. Very small dimensions, making possible the use of the unit in any arrangement of extracorporeal circulation.
5. Easier handling of coronary perfusion by the perfusionist as well as the surgeon.

REFERENCE

Bosher, L. H., Edwards, J. F., and Pois, A. J. (1964). An automatic coronary perfusion system for clinical application. *J. thorac. cardiovasc. Surg.*, **47**, 254.