MEASUREMENT OF MINUTE VOLUME IN ACUTE EXPERIMENT

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One of the most convenient means of determining the minute volume in an acute experiment is to measure the amount of blood flowing through the pulmonary artery. However, to do so involves a laborious and traumatic operation. To increase the accuracy of the figures obtained it is important as far as possible to reduce the trauma involved in the early procedures (particularly those associated with manipulation of the heart itself), and to use as simple an apparatus as possible.

The most valuable of the methods proposed with this end in view is that of Kisin [1], but it suffers from serious drawbacks, of which the most important is the necessity for temporarily compressing the pulmonary artery while it is cannulated. The blood then over-fills the large veins, and unduly expands the right atrium and ventricle. With the best technic this manipulation cannot be completed within less than 30-40 sec. Our colleagues in the institute have introduced the cannula and carried out the associated compression of the pulmonary artery in not less than $1^1/_2$ - 2 min. Naturally even short hemodynamic changes evoked by compression of the pulmonary artery are not without effect on the results of the investigation.

Furthermore, after the cannula has been introduced into the pulmonary artery, even in the pauses between measurements blood passes from the heart into the lungs not along the ordinary route, but along a system of tubes, and additional resistance is introduced. This effect, in turn, influences the circulation rate and the work of the heart (blood pressure in the pulmonary artery is comparatively low, and therefore even quite a small increase in resistance leads to an appreciable change in the amount of flow).

Daly and Luck [2] measured the flow in the pulmonary artery by a Shipley and Wilson rotameter [3]. In order not to arrest the circulation during the time the pulmonary artery was compressed they first introduced through the right atrium a cannula connecting the right ventricle with the left pulmonary artery. The reverse flow of blood was prevented by a Hufnagel valve [2]. The provision of an outflow for the blood during compression of the pulmonary artery is of great importance. However, it must be remembered that this procedure necessitates direct manipulations on the heart, damage to the right auricle, and introduction of the cannula into the ventricles, measures which may influence the results of the subsequent measurements.

We have developed a method for this experiment which is free from these shortcomings (Fig. 1).

After the pulmonary artery has been exposed, while it remains intact and blood flow is maintained, the end of a vascular prosthesis of corresponding diameter is sewn to it end to side. This operation is best carried out with an atraumatic needle, though good results may be obtained with an "intestinal" needle and fine thread. Opening of the wall of the pulmonary artery does not cause any considerable hemorrhage because the opening is rapidly thrombosed. The artificial vessel must be sewn on as close as possible to the origin of the pulmonary artery, without damage to the pulmonary valve. In experiments on dogs, which are known to have a short and thick pulmonary artery, the prosthesis is best arranged as an ellipse whose long diameter lies across the pulmonary artery. In this way a large proportion of the pulmonary artery may be preserved for further manipulations.

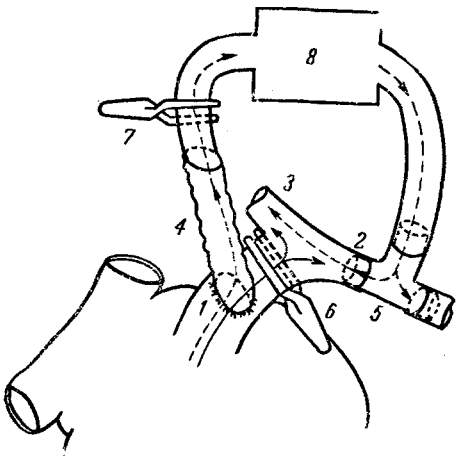

Fig. 1. Diagram of the measurement of the minute volume of the blood (first arrangement). 1) Pulmonary artery; 2) left branch of pulmonary artery; 4) vessel of artificial tissue sewn end to side at the root of the pulmonary artery; 5) T-junction introduced into the left branch of the coronary artery; 6, 7) clamps on the common trunk of the pulmonary artery and on the tube connecting the vascular prosthesis with the flowmeter; 8) flowmeter. The arrow drawn with a continuous line indicates the direction of the blood flow between measurements (clamp 6 open and clamp 7 closed); the dotted arrow indicates the direction of blood flow during measurement (clamp 6 closed, clamp 7 open).

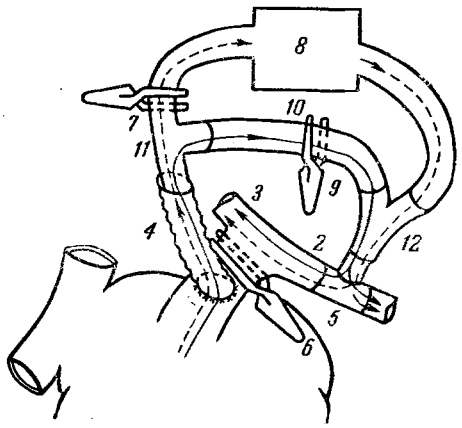

Fig. 2. Diagram of measurement of the minute volume of blood (second arrangement). 9) clamp on shunt; 10) shunt along which flow occurs in the intervals between blood-flow measurements; 11, 12) 3-way taps. Other indications as in Fig. 1. The arrow drawn with a continuous line shows the direction of blood flow between measurements (clamp 9 open and clamps 6 and 7 closed); the dotted arrow indicates the direction of blood flow during blood-flow measurement (clamp 7 open and clamps 6 and 9 closed.

Having ascertained that the artificial artery was reliably fixed in position, a short scalpel was introduced in it, and a clamp placed above. The wall of the pulmonary artery was then carefully opened, care being taken not to damage the stitching. Then while in turn first the upper and then the lower part of the artificial artery was clamped, the scalpel was removed, and a hollow tube introduced whose diameter was less than that of the attached prosthesis. The tube was expanded by a slit in the wall of the pulmonary artery and joined on so that its end entered only a little way into the aperture in the pulmonary artery. Heparin was then immediately added to the blood.

The next stage is to separate the left branch of the pulmonary artery. After the branch had been clamped close to its origin from the main trunk it was cut across. Cannulae which were short but as wide as possible were then introduced into both sides; they were connected by means of T-junction. The free end of the T-junction was closed, the clamp was removed, and circulation of the blood restored.

Any system for recording blood flow is then introduced between the tube coming from the side of the pulmonary artery and the free end of the T-junction. The measuring system is not connected until the blood flow is to be recorded. For this purpose the pulmonary artery is lightly clamped; for the rest of the time the blood flows along the normal circuit.

Sometimes when the vascular prosthesis is being sewn in position it is not possible to preserve enough of the pulmonary artery for the subsequent manipulations. In order that a result may be obtained, the 3-way tap is inserted in the tube joined to the pulmonary artery (Fig. 2, 11). The steady flow of blood is directed through one of its arms into the exit tube of the T-junction 12, and then into 1 branch of the T-junction 2 introduced into the left branch of

the pulmonary artery. The 2nd arm of T-junction 11 is used to direct the blood into the measuring apparatus. Blood returns through junctions 12 and 2.

The disadvantage of this arrangement is that in the intervals between measurements the blood makes a detour. It is then important to ensure that the tubes are short and sufficiently wide.

SUMMARY

A description is given of an untraumatic method for measuring the circulation in the pulmonary artery. A vascular prosthesis is sutured end to side into the pulmonary artery, and the blood flow is measured without previous occlusion of the pulmonary artery. During the experiment the blood follows its usual course. It flows through the "system" only during the period of measurement.

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