A METHOD OF MEASURING THE MINUTE VOLUME OF THE HEART

I. E. Kisin

From the Laboratory of Special Pharmacology (Head — Active Member AMN SSSR V. V. Zakusov) of the Institute of Pharmacology and Chemotherapy (Director — Active Member AMN SSSR V. V. Zakusov) of the AMN SSSR, Moscow

(Received June 6, 1958. Presented by Active Member AMN SSSR V. V. Zakusov)

The methods most widely used for determining the minute volume of the heart are Fick's direct method and a method based on measurement of the rate of dilution of a dye [1, 3, 5]. These methods enable measurement of the minute volume during both acute and chronic experiments; they are, however, very complicated and laborious. There are simpler methods which are based on the direct measurement of the volume of blood flowing through the heart. For this purpose a flowmeter is used, by means of which the volume rate of the blood flow is measured in the venae cavae [4], the aorta [2, 7] or the pulmonary artery [6].

In the present communication we describe a method of measurement of the minute volume of the heart which requires no special apparatus. The method involves measurements of the volume rate of the blood flow in the pulmonary artery. The low level of the blood pressure, and the possibility of measuring the whole quantity of blood flowing through the heart, including the blood from the coronary vessels, makes the pulmonary artery the most suitable place for measurement of the minute volume.

A suitable animal in which to measure the minute volume is a cat weighing 3-4 kg. Under nembutal anesthesia, and with artificial respiration, thoracotomy is performed. To prevent clotting of the blood, heparin (1000-1500 units/kg) is injected into the animals. The pulmonary artery is separated from the surrounding tissues and two cannulas are inserted through an incision in its wall: one into the central, the other into the peripheral end of the artery. The pulmonary artery must not be clamped for longer than 30-40 seconds during insertion of the cannulas if fibrillation of the heart is to be avoided.

The cannulae to be inserted into the pulmonary artery are made of polyvinyl chloride tubing. The narrowest point of the cannula must be not less than 3 mm in diameter; this is necessary to reduce the resistance to the flow of blood. Because the length of the pulmonary artery in the cat does not exceed 1.5-2.0 cm, the ends of the cannulae designed for insertion into the artery are made short — 4-5 mm. After the cannulae have been inserted into the pulmonary artery, the blood at once begins to flow into a special apparatus designed to measure periodically the volume rate of the blood flow (Fig. 1).

As will be seen in Fig. 1, the blood entering the cannula inserted into the central end of the artery passes along the tubes 4 and 1 and is returned into the peripheral part of the pulmonary artery. The clamp which is situated on tubes 1, 2 and 3, under these circumstances is in position I.

When the clamp is moved to position II, blood cannot enter the tube 1, but is directed along tube 3 into a rubber balloon, situated in the reservoir C. The balloon is distended and displaces water from the reservoir C into the glaa tube B. In this way the float, to which is attached a pen, is raised, and a sloping line is traced on the moving drum of the kymograph. The minute volume is determined from the angle which this makes with the base line.

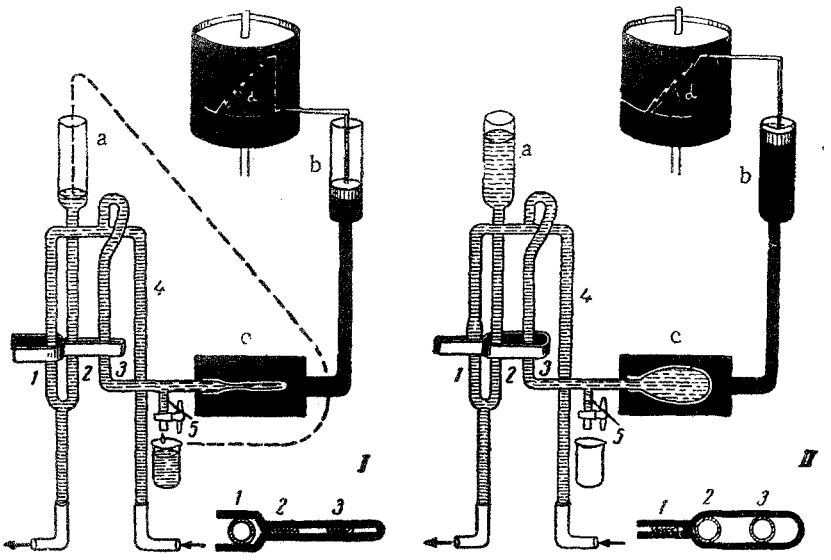

Fig. 1. Scheme of the method of determining the minute volume. For description see text.

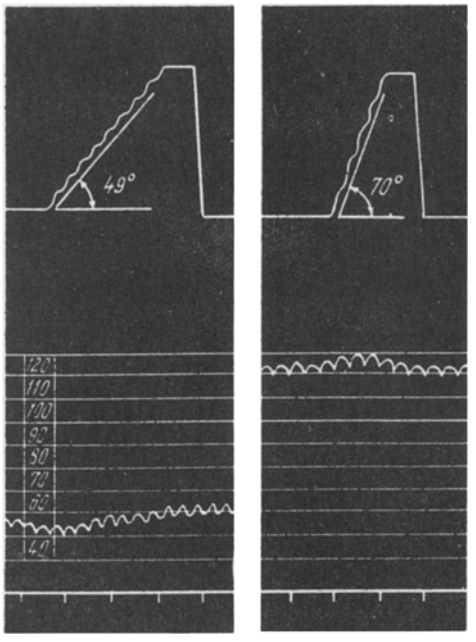

Fig. 2. Measurement of the minute volume before (a) and after (b) injection of adrenalin in a dose of 50 γ / kg.

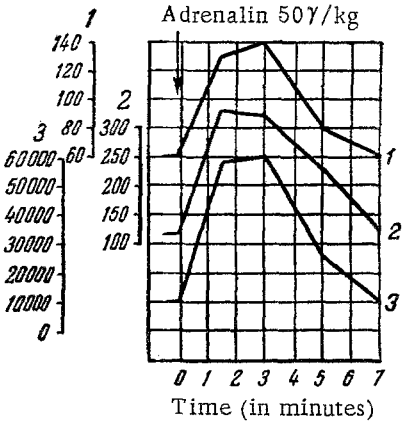

Fig. 3. The effect of adrenalin on the minute volume and the work of the heart. 1) Arterial pressure in mm Hg; 2) minute volume in ml/ min; 3) work of the heart in g/ cm/ min.

In order to compensate for the cessation of the blood flow to the lungs, at the same time as blood enters the reservoir C, blood from the reservoir A is directed along the tube 2 into the peripheral end of the pulmonary artery. The reservoir A, like the tube B, is at a height above the level of the heart corresponding to the mean value of the pressure in the pulmonary artery of the cat (20-25 cm).

The length of time taken to determine the volume velocity of the blood flow in the pulmonary artery is 1.5-3.0 seconds on each occasion. During this time 4-6 ml of blood enters the recervoir C. At the end of this time, the clamp is moved back again to position I. The blood filling the rubber balloon flows out through the tube 5 and is taken into recervoir A.

The minute volume is calculated from the formula

$$M = (AVt)\,tgd,$$

where A is the scale of magnification of the elevation of the float and pen in ml/cm; V is the velocity of movement of the drum of the kymograph in cm/sec; t – time in seconds.

In our experiments the values A and V were constant (A = 2 ml/cm, V = 1 cm/sec), and during measurement of the minute volume, t was also constant and equal to 60 seconds, hence

$$M = Ctgd,$$

$$C = AVt = 2 \cdot 1 \cdot 60 = 120.$$

The determination of the minute volume thus resolves itself into finding the tangent of the angle formed by the sloping line which is traced when the float and pen are raised (Fig. 2).

In our experiments the minute volume was 30-50 ml/kg body weight of the cat.

In Fig. 3 are shown curves of the minute volume and the work of the left heart, obtained by means of the method described. The work of the left heart is calculated from the formula

$$A = 13.6\,MP$$

where A is the work of the heart in g/cm/min; M is the minute volume in ml/min and P is the systolic arterial pressure in cm Hg.

SUMMARY

A method of measuring the minute heart volume requiring no special instruments is presented. The minute volume is determined by direct measurement of the blood flow volume velocity in the pulmonary artery. A special device for the periodical determination of the blood flow volume velocity is described.

LITERATURE CITED

[1] A. Gournand, Federation Proc. 4, 207-212 (1945).

[2] R. W. Eckstein, M. Stroud, C. V. Dowling et al., Federation Proc. 8, 38. Cited by Suly a. Gregg (1949).

[3] S. R. Gilford, D. E. Gregg, O. W. Shadle et al., Rev. Scient. Instr. 24, 696-702 (1953).

[4] D. E. Gregg and R. E. Shipley, Am. J. Physiol. 142, 44-51 (1944).

[5] W. F. Hamilton, Federation Proc. 4, 183-195 (1954).

[6] R. D. Seely and D. E. Gregg, Proc. Soc. Exper. Biol. a. Med. 73, 269-270 (1950).

[7] R. Wegria, C. W. Frank, G. A. Misrahy et al., Proc. Soc. Exper. Biol. a. Med. 74, 551-552 (1950).