A PUMP FLOWMETER FOR RECORDING THE RATE OF FLOW OF THE BLOOD INTO AN ARTERY WHEN PERFUSION PRESSURE IS STABILIZED

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Previously V. L. Tsaturov and I have described a pump flowmeter; slight modifications enabled it to be used for recording of blood flow into an artery under conditions of stabilized perfusion pressure. This device is a valve pump with a dividing membrane. Expulsion of blood is achieved by introduction of fluid into the pump at a constant pressure from a Mariotte bottle.

A diagram of the construction is shown in Fig. 1. Within the working head 1 there is a thin-walled rubber cone 3, and another cone 2 of hard chlorvinyl of corresponding size having small apertures 0.2-0.3 mm in diameter. A, B, and C, are external electromagnetic valves. Tubes 7 is connected with the central end of the femoral or carotid artery, tube 5 with the peripheral end of the perfused artery. When valve A is closed and valve B is open blood from the central end of the artery passes along tube 7 and enters the rubber cone 3. The cavity of the working head 1 and of the chlorvinyl cone 2 is filled with water. Blood entering the rubber cone fills it to its maximum volume (which is limited by the internal dimensions of the stiff chlorvinyl cone); an equal quantity of water is displaced from the latter, and enters the space within the working head whence it passes into the measuring cylinder 9 through tube 6. Immediately after closure of valve B valve A opens. Then water flows along tube 4 at a certain pressure (the Mariotte bottle plays the part of the pump, because it is filled with water and raised to an appropriate height); it then enters the cavity of the working head 1 and of the chlorvinyl cone 2 displacing blood in the cone through tube 5 into the peripheral end of the artery. When valve A closes valve B opens and the cycle repeats.

Thus in one cycle of the working head an amount of blood equivalent to the amount required to increase the quantity within the rubber cone 3 from the original to the maximum volume (a volume limited by the chlorvinyl cone 2) enters the measuring cylinder. This difference is in turn determined by the amount of blood which left the cone to enter the perfused artery during the expulsion period.

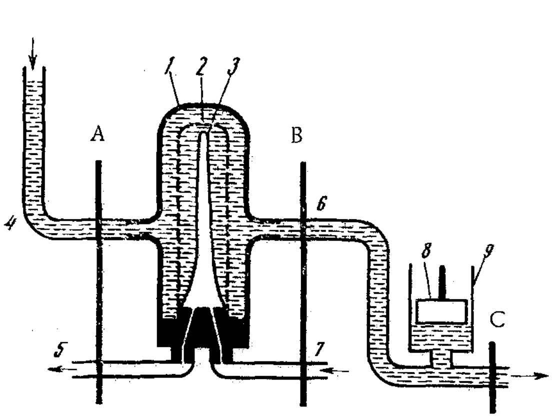

Fig. 1. Diagram of the working head and measuring cylinder of the pump flowmeter.

In order to ensure a continuous pulsatory flow of blood into the perfused artery the flowmeter pump consists of two identical heads operating successively at a rate of 24 cycles per minute. As blood enters one head it is expelled from the other, and vice versa.

Water expelled from the working heads enters the measuring cylinder 9. When valve C is closed the water raises the float in the cylinder, and the movement is recorded by means of a lever on the moving paper of a kymograph. When valve C is open water leaves the cylinder. Valve C is closed periodically for equal time intervals which are set at 20, 10, or 5 sec according to the programme of operation. Closure of valve C occurs directly before valves A and B open. Thus an amount of

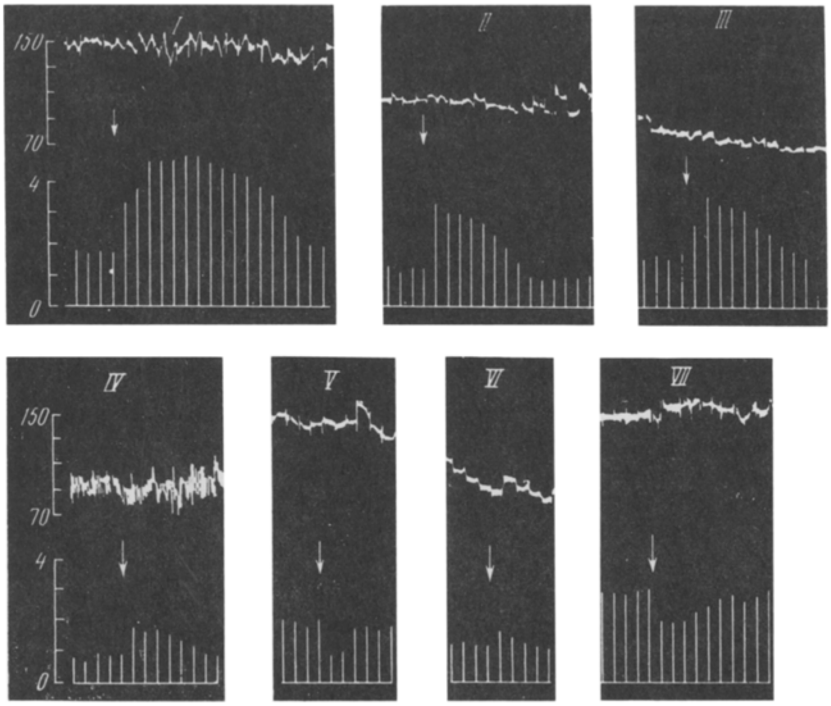

Fig. 2. Effect on the resistance of the coronary vessels of certain substances known to have an action on them. Curves, top to bottom; arterial pressure (in mm); perfusion rate (in ml/min). The perfusion rate was measured every 30 sec. The kymograph drum moved only in the intervals between measurements of perfusion rate, and therefore one measurement is indicated as a vertical line; I) intracoronary injection of 0.3 mg papaverine; II) 0.6 mg chlorazicin; III) 1 mg euphylline; IV) 0.1 mg nitroglycerine; V) 3 μg adrenalin; VI) 5 μg adrenalin; VII) 0.5 units of pituitrin.

fluid equal to the volume of blood entering the perfused artery in 8, 4, or 2 cycles (i.e., a flow of blood over a period of 20, 10, or 5 sec respectively) enters the measuring cylinder.

The time relay which defines the program of the external electromagnetic valves is mounted on a Warren motor.

By means of this pump an artery is perfused at a constant pressure which is determined by the height of the water in the Mariotte bottle supplying the inflow to the pump. The simultaneously recorded rate of flow is an index of the resistance (tone) of the vascular bed.

The pump as described here has been applied to an investigation of the influence of drugs on the resistance of the coronary vessels of the feline heart. The experiments were carried out on animals weighing 3-4 kg anaesthetized with 40 mg/kg nembutal in which the thoracic cage was opened and artificial respiration maintained. The catheter through which perfusion was effected was inserted into the first part of the curved branch of the left coronary artery. The perfusion pressure was maintained at 120 mm Hg. The blood was prevented from clotting by the injection of 1500 units/kg of heparin. Arterial pressure was recorded from the carotid artery. We used papaverine, aminophylline, nitroglycerine, chlorazicin, adrenalin, and pituitrin, drugs whose effect on the blood supply of the heart is widely known. These substances were injected into the coronary artery in amounts from 1/20 to 1/50 of the amounts which produced an effect when injected intravenously.

The experiments showed that the original perfusion rate in the circumflex branch of the left coronary artery was 3-6 ml/min. However, in most experiments for the first 5-15 min of perfusion there was a marked increase in the resistance offered by the coronary artery, as was shown by a 50-70% diminution of flow. These results agree with those of Schofield and Walker [15] who found in dogs that there was a reduction of the flow of blood through the coronary artery in the first 5-20 min of perfusion.

By means of the pump flowmeter it was found that 0.2-0.4 mg papaverine, 0.3-0.7 mg chlorazicin, 1-2 mg euphylline, or 50-100 μg nitroglycerine are effective in reducing the resistance of the coronary vessels. The most marked effect was given by papaverine, and the least by nitroglycerine. Usually 2-5 μg of adrenalin increased the resistance of the coronary vessels, but in some experiments the reverse effect was obtained. An injection of 0.2-0.6 units of pituitrin increased the resistance of the coronary vessels (Fig. 2).

The results reported here agree both with those in which records were made of the resistance of the coronary vessels measured at a constant perfusion rate [3, 4, 6, 12, 13] and in experiments in which measurements were made of the flow of blood through the coronary sinus [1, 5, 7, 8, 14].

A shortcoming of the apparatus is the small resolving power with respect to time. The minimum interval between successive recordings is 5-10 sec.

The pump flowmeter of the design described can evidently be applied to recording resistance (tone) not only in the coronary but also in other arteries.

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