INSTRUMENT FOR INVESTIGATING REGULATION OF CARDIAC OUTPUT WITH AUTOMATIC PRESSURE STABILIZATION OF LEFT VENTRICULAR OUTFLOW

M. M. Povzhitkov

UDC 612.172

It is of great theoretical and practical importance to know what is the principal controllable parameter in the circulatory system: the cardiac output or the arterial pressure [1-3]. A great obstacle in the way of finding the answer to this question is the tremendous variety of the factors, sometimes working in opposite directions, concerned with the regulation of the arterial pressure level and the size of the cardiac output.

In the present article an automatic following device for stabilizing pressure at the outlet from the left ventricle is described. At the same time, the instrument records the magnitude of the cardiac output and the total peripheral resistance of the systemic vessels during perfusion of the whole body with a constant volume of the animal's own blood.

EXPERIMENTAL METHOD

Experiments were carried out on cats under urethane–chloralose anesthesia. After tracheotomy and transfer of the animal to artificial respiration the internal mammary arteries and 2-4 intercostal arteries were ligated. The thorax was opened through a wide transverse incision through the sternum in the third interspace. The hila of the lungs were irrigated with 0.5% procaine solution. To prevent the blood from clotting, heparin (5000 units) was injected into the femoral vein.

A soft clamp was applied to the inferior vena cava at the hilum of the right lung. The thoracic aorta was ligated at the level of the hilum of the left lung and glass cannulas connected to a reservoir-collector (1, Fig. 1) were introduced into the proximal and distal segments. At this stage of the operation, blood from the arch of the aorta entered this reservoir, and then passed through a constant-delivery pump system (2, Fig. 1) into the descending aorta. The innominate and the right subclavian arteries were ligated in turn at their point of branching from the arch of the aorta and cannulas were inserted into their cranial ends, through which blood from the pump system entered the upper half of the body. At this stage of the operation, the whole of the systemic circulation was perfused except the coronary system. The minute volume of perfusion was maintained constant. The blood circulating in the blood system was constantly warmed to the animal's body temperature by means of a coil (3, Fig. 1) connected to an ultrathermostat.

The working of the pump was so adjusted that it provided a perfusion pressure in the systemic circulation and also a pressure in the reservoir-collector equal to the original systemic arterial pressure. In these conditions the pressure in the reservoir collector is a function of the magnitude of the cardiac output and of the resistance of the system.

$$Q = \frac{P}{R_1 + R_2},$$

where Q is the blood pumped in unit time, P is the pressure, R_1 is the resistance of the system, and R_2 is the resistance at the outlet from the left ventricle. These relationships are valid, however, in certain conditions: if, with an increase in the cardiac output, a pressure higher than the intraventricular systolic pressure is not created in the reservoir, and if the cardiac output is not reduced so much that the perfusion pump begins to suck blood actively from the left ventricle, which inevitably leads to a severe disturbance

---

Laboratory of Circulatory Physiology, A. A. Bogomolets Institute of Physiology, Academy of Sciences of the UkrSSR, Kiev (Presented by Active Member of the Academy of Medical Sciences of the USSR A. P. Nikolaev). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 64, No. 9, pp. 113-115, September, 1967. Original article submitted March 5, 1966.

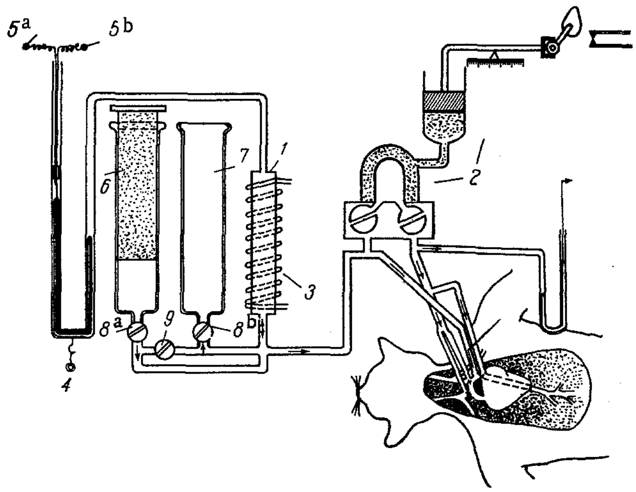

Fig. 1. Diagram of apparatus. Explanation in text.

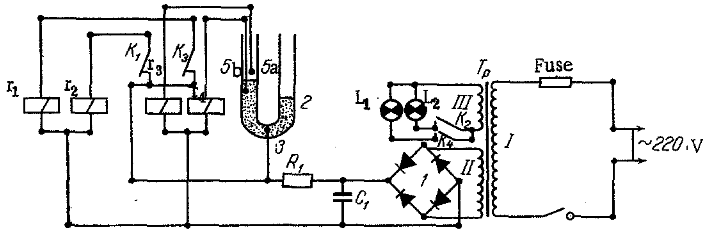

Fig. 2. Electrical circuit of recording apparatus. Power transformer (Tp): winding I) power, 220 V; winding II) 27 V, for supplying the RT-40 relays (r_1, r_2); winding III) 6 V, for supplying the RSM-2 relays (r_3, r_4). Contacts of the RSM-2 relays K_2 and K_4 are used for switching on the pilot lamps L_1 and L_2 and the electromagnetic markers. The type EGTs capacitor C_1 is 1000 μF, 30 V. Resistor R_1 is 200 Ω, 2 W. 1) Rectifier consisting of a type D7Zh diode; 2) mercury manometer; 3) fixed contact; 5a, 5b) movable contacts.

of the hemodynamics within the heart and of the circulation in the system of the coronary vessels.

For this reason, the main reservoir-collector is connected to an automatic regulating system consisting of a mercury manometer with one fixed (4) and two movable (5) contacts (see Fig. 1), a graduated reservoir with a piston filled with lead (6), and an open graduated reservoir (7). These reservoirs are joined by rubber tubes passing beneath the valves of an electromagnetic relay (8) to the reservoir-collector. A pilot lamp is also mounted on the switchboard of the apparatus. The electrical circuit of the apparatus is shown in Fig. 2.

The operation of the apparatus is as follows. In the initial working position contact 5b (see Fig. 1) is immersed in mercury, the level of which in one limb of the manometer corresponds to the pressure in the reservoir-collector; both valves of the relay are closed. With an increase in cardiac output the pressure in the reservoir-collector and manometer rises, contact 5a is closed, the valve of relay 8b opens, and blood enters the reservoir 7 until the pressure in the reservoir returns to its initial level. With a decrease in the cardiac output the pressure in the reservoir-collector and manometer falls, contact 5b is opened, the valve of relay 8a opens, and blood from reservoir 6 flows into the reservoir-collector until the original pressure therein is restored. If necessary, by means of the tap 9, blood is passed from one reservoir into the other, and also into the animal's venous system. The time of opening of the valves of the relay and the level of the perfusion pressure in the systemic circulation are recorded on kymograph paper.

By means of the apparatus described, the pressure at the outlet from the left ventricle may be kept practically constant automatically.

If the output of the perfusion pump is at a certain level and the valves of the relays open at a certain time (in the case of a constant velocity of entry of blood into the graduated cylinders and from them into the system), the magnitude of the cardiac output per unit time, and its changes during various procedures on the animal, can be determined relatively accurately, while the pressure at the outlet of the left ventricle and the total peripheral resistance to the blood flow in the systemic circulation remain constant.

The apparatus may be used for analogous investigations of the cardiac output from the right ventricle and also for stabilizing the venous return. Investigations may be carried out with the chest open or closed.

LITERATURE CITED

1. V. M. Khayutin, Vasomotor Reflexes, Moscow (1964).
2. L. L. Shik, in the book: The Oxygen Regime of the Organism and Its Regulation (1965).
3. A. C. Guyton, Circulatory Physiology Cardiac Output and Its Regulation, Philadelphia (1963).