A REGIONAL PERFUSION PUMP WITH AUTOMATIC PRESSURE STABILIZATION IN THE MAIN ARTERY OF THE ORGAN

A. A. Moibenko, L. A. Grabovskii, and P. P. Stoletnii

UDC 615.38-033.84:611.13-72:615.473

Kinematic and electrical systems of a two-channel perfusion apparatus with an automatic regulating device for automatic perfusion of the vessels of an investigated organ are described. The level of the perfusion pressure is stabilized and simultaneous recordings can be made of the blood pressure and flow on a kymograph.

* * *

Quantitative analysis of changes in the resistance of the vessels to the blood flow can be undertaken either by measuring changes in perfusion pressure when the blood flow is stabilized or by measuring changes in the blood flow when the pressure in the perfused region is stabilized. The method of recording changes in vascular resistance during perfusion with a constant minute volume has become firmly established in experimental practice following the work of V. M. Khayutin [2-4]. The method of measuring changes in hydraulic resistance during changes in blood flow have not been widely adopted because of the absence of perfusion pumps providing for automatic stabilization of pressure and continuous recording of the arterial blood inflow into the organ. The various perfusion systems hitherto suggested [1, 5, 7] do not fully meet these requirements.

The suggested pump is built on the basis of a resistograph as made by the experimental design workshops at the A. A. Bogomolets Institute of Physiology, and unlike other perfusion systems it can work on either a constant output or a constant pressure regime. In the latter case, besides recording the perfusion pressure, the blood flow in the main artery of the organ is recorded continuously on a kymograph. The

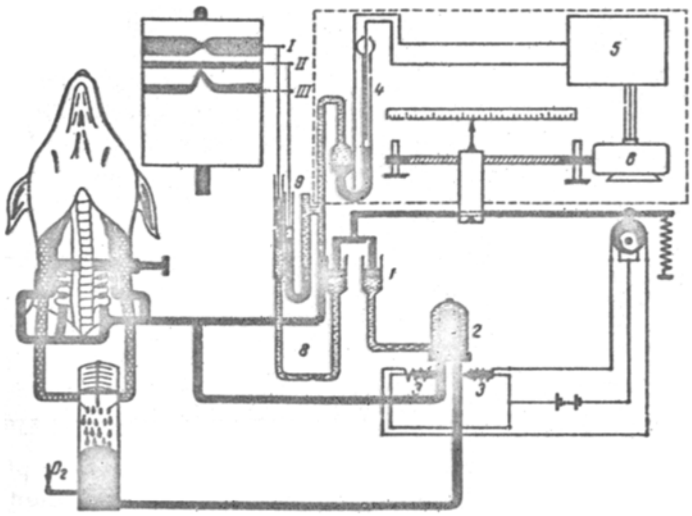

Fig. 1. General diagram of the apparatus. Explanation in text.

Department of Pathology of the Circulation, A. A. Bogomolets' Institute of Physiology, Academy of Sciences of the Ukrainian SSR, Kiev (Presented by Active Member of the Academy of Medical Sciences of the USSR N. N. Gorev). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 66, No. 7, pp. 113-116, July, 1968. Original article submitted April 20, 1967.

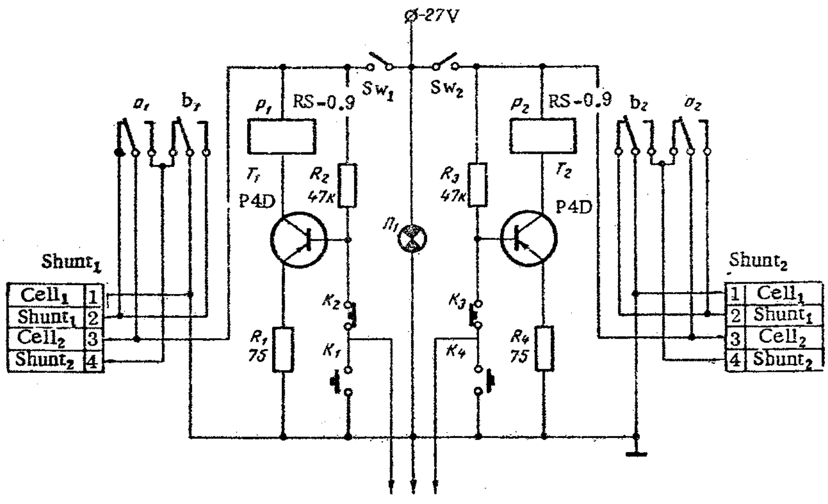

Fig. 2. Theoretical electrical circuit of two-channel commutative element. P_1, P_2) electromagnetic relays. a_1, b_1, a_2, b_2) contacts of relays; t_1, t_2) transistors. Connections to reversible electric motors; K_1, K_2, K_3, K_4) limit switches.

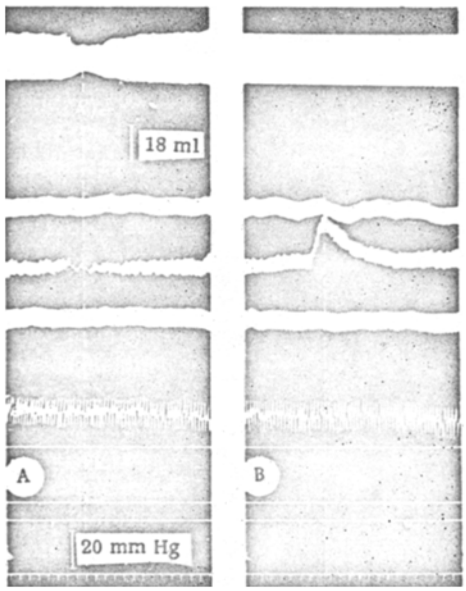

Fig. 3. Reaction of coronary vessels to intracoronary injection of 1 μg hypertensin, recorded under conditions of automatic pressure stabilization (A) and of output stabilization (B). From top to bottom: output of pump–volume of blood flow in circumflex branch of left coronary artery, resistogram of cerebral vessels, general arterial pressure, zero lines of manometers, marker of stimulation, and time marker (10 sec). The lines of the stimulation and time markers are also zero lines of manometers.

perfusion regimes can be quickly interchanged in the course of the experiment and no additional manipulations are necessary other than inclusion or exclusion of the automatic regulating system.

The perfusion apparatus (Fig. 1) consists of a pumping system, including a plunger pump (1), connected hydraulically with a delivery unit (2) through which the blood flow is directed by means of valves (3), an automatic regulating system (4–6), and a recording system (8).

The output of the pump is continuously recorded on the kymograph as vertical lines whose length correspond to the movements of the working plunger—the stroke volume of the pump. The connection between the output pen and the plunger of the pump is effected by mechanical or hydraulic transmission.

The automatic device regulating pressure, should deviations occur, consists of the following components: 1) a sensitive element determining the actual value of the parameter to be controlled—the perfusion pressure—at a given moment; 2) a master element bringing the perfusion pressures to the required level; 3) a commutative element (5) altering the working regime of the system depending on the character of deviation of the momentary value of the perfusion pressure from the assigned value; 4) an operative element (a RED-6 reversing electric motor; Fig. 1). In assembling the apparatus the sensitive and master elements are combined into a pressure detector, PD (4). This consists of a V-shaped mercury manometer with amplifier and two (moving and static) contacts which are closed or open by changes in the mercury level. By displacement of the moving contacts the perfusion pressure can be established at the required level.

By changing the diameter of the mercury manometer and the mass of mercury in it, optimal agreement between the time constant of the element of the automatic regulating system can be obtained, which increases the stability of the system and facilitates work with the apparatus under astatic conditions. The pressure detector is connected in parallel with the control mercury manometer (9), and both reflect the pressure at the output of the pump. An essential condition is that the inertia of the working and control manometers must be equal.

The theoretical electrical circuit of the two-channel commutative element is given in Fig. 2. Each channel includes an electromagnetic relay, which can switch the winding of the reversible electric motor, depending on the signal arriving from the PD, to turn its rotor in the corresponding direction, and a transistorized amplifier. The latter amplifies the current passing through the contacts of the PD to a value sufficient to operate the relay. To avoid overheating of the PD contacts the current through them must not exceed 0.3-0.5 mA.

Depending on changes in perfusion pressure relative to the assigned level, the PD contacts may be either closed or open. Correspondingly, the transistor will be either nonconducting, in which case the relay does not operate, or open, in which the case the relay operates. The direction of rotation of the motor, the position of the moving carriage, and consequently the output of the pump change correspondingly.

Since the pump works on a pulsating regime (100 pulsations/min), operation of the automatic regulating system takes place twice in the course of each working cycle of the pump, for an increase in pressure in the delivery phase leads to closure of the PD contacts and a lowering of pressure in the suction phase causes them to open. If the resistance at the output of the pump remains unchanged, the time of closing and opening of the PD contacts and of the change in output of the pump in either direction will correspondingly be equal, and the system is in dynamic equilibrium maintaining the mean value of the perfusion pressure unchanged.

An increase in resistance to the blood flow in the perfused region leads to an initial increase in pressure. During each working cycle of the pump the time of closing of the PD contacts will be greater than the time of their opening. Accordingly, the decrease in output of the pump will exceed its increase. The dynamic equilibrium of the system is shifted toward a decrease in output of the perfusion pump and is established at new values of output and resistance. The opposite changes take place when the resistance to the blood flow is decreased.

Examples of reactions of the coronary vessels when perfused under conditions of automatic pressure stabilization (A) and constant output (B), are given in Fig. 3. The automatic regulating system ensures satisfactory stabilization of the perfusion pressure. Quantitative analysis of the vasomotor reaction in the first case is based on changes in the output of the pump supplying blood to the coronary vessels. The hydraulic resistance during perfusion of the organ always increased more with automatic pressure stabilization (R_1) in vasoconstrictor reactions than during perfusion at constant output (method of resistography, R_2). In the kymograms given, for instance, injection of equal doses of hypertensin (1 μg) into the coronary blood flow increased the resistance of the vessels in the first case by 89%, but in the second by only 17% of the initial level. This difference, also observed by other investigators [6], is due to the absence of the stretching effect of the increased intravascular pressure in the first case and to its presence during resistography.

LITERATURE CITED

1. I. E. Kisin, Byull. Éksp. Biol. i Med., No. 12, 95 (1964).
2. V. M. Khayutin, V. M. Donchakov, and V. L. Tsaturov, Byull. Éksp. Biol. i Med., No. 2, 117 (1958).
3. V. M. Khayutin, Vasomotor Reflexes [in Russian], Moscow (1964).
4. V. M. Khayutin, Fiziol. Zh. SSSR, No. 9, 1152 (1966).

5. F. Ballhatcher, F. Ives, and F. R. Winton, J. Physiol. (London), 132, 32 (1956).
6. A. C. Burton and R. H. Stinson, J. Physiol. (London), 153, 290 (1960).
7. H. D. Green, A. B. Denison, Jr., L. Franklin, et al., J. Lab. Clin. Med., 36, 485 (1950).