AUTOMATIC PRESSURE STABILIZATION IN LARGE ARTERIES DURING CHANGES IN BLOOD FLOW

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During the study of mechanical properties of arteries and the regulation of their lumen *in situ* [1, 2], it may be necessary to create a pressure in an artery under investigation which differs from the animal's arterial pressure, and which must at the same time be kept constant over a wide range of values of the blood flow through the vessel. Some experimental situations also require the pressure in an artery to be changed while the blood flow through it remains constant.

Sometimes pressure stabilization during changes in the blood flow in an artery is brought about manually: The resistance of rubber tubes connected in series with the artery is adjusted by means of screw clamps [1]. However, in this method several attempts must be made beforehand to choose the resistance of the tubes which will allow the necessary blood flow. The pressure established in the artery likewise must not, in principle, exceed the animal's arterial pressure. A "Starling's resistance" – a thin-walled collapsible rubber tube, enclosed in a chamber and its diameter controlled by compressed air [5, 7], is also used for pressure stabilization. By means of a "Starling's resistance," connected in series with a constant delivery perfusion pump, it is possible to create any level of pressure in an artery (either higher or lower than the animal's arterial pressure). The arterial pressure can be changed by changing the pressure of the air compressing the tube. However, in this method pressure is stabilized not in the artery itself, but at the point where the "Starling's resistance" is connected. Accordingly, during changes in the blood flow, the pressure in the artery will change a little. The regional perfusion pressure stabilizer described in [6] also has the same disadvantage.

The system devised by the present writers is free from the above drawbacks and can be used to stabilize pressure directly in a vessel under investigation, during changes in the blood flow through it, and also to create any desired pressure in an artery. Blood from any large artery enters the perfusion pump [3, 4] 1 (Fig. 1), which pumps it into the artery 2, the properties of which are being studied. A lateral branch of this artery is connected to an electromanometer 3, which serves as sensor for the pressure stabilization system. (The pressure can be measured also in the lumen of the artery by introducing a thin metal tube into it, through a T-tube, as shown in Fig. 2.) The artery is connected to a thin-walled rubber tube 4. Its cross-section and, consequently, the resistance to the blood flow through it can be varied, for part of this tube consists of a hydraulic throttle 5, with electrodynamic control (Fig. 3). Blood from tube 4 enters the vein 6.

A functional diagram of the pressure stabilization system is shown in Fig. 1. The signal from the electromanometer 3 is led to the amplifier 7 and the voltage from its output (V) is led to the comparison cell 8, where it is compared with the assigned voltage (U), proportional to the stabilization pressure (P_{st}). The error signal (V – U) is led to the amplifier 9, the load on which is the winding of the electrodynamic system that measures the hydraulic resistance of the throttle (Fig. 3). The electrodynamic system of the RPCh-2 ink-writing recording instrument was used. (A magnet and voice coil with centering washer can also be used.)

When, as a result of an increase in blood flow, the pressure P rises above the assigned value P_{st}, the framework of the electrodynamic system, moving in a magnetic gap, increases the

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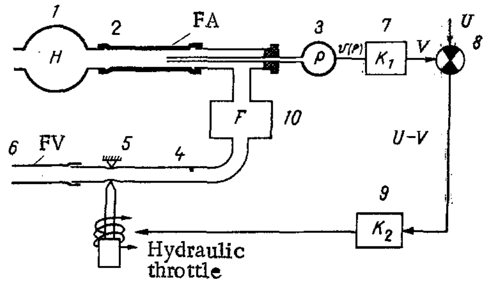

Fig. 1

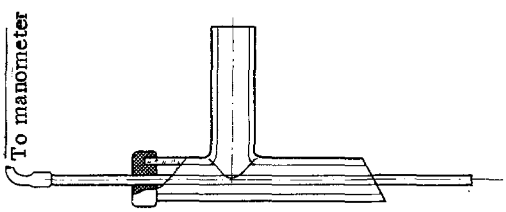

Fig. 2

Fig. 1. Functional diagram of the pressure stabilization system. 1) Perfusion pump; 2) femoral artery; 3) electromanometer; 4) rubber tube; 5) hydraulic throttle; 6) femoral vein; 7) pressure signal amplifier; 8) comparison cell; 9) power amplifier; 10) sensor of electromagnetic flowmeter.

Fig. 2. Diagram of 3-way cannula for measuring pressure in lumen of artery.

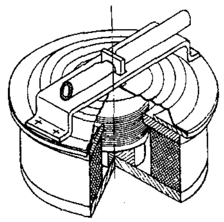

Fig. 3. Diagram of hydraulic throttle.

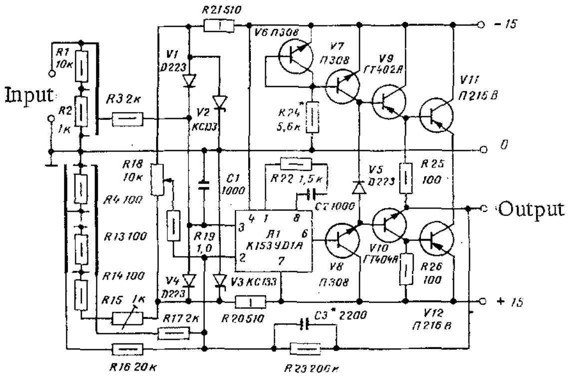

Fig. 4. Circuit of power amplifier.

area of cross-section of the rubber tube, and this reduces its resistance and so causes the pressure to fall to the stabilized level P_{st}. Conversely, if P falls below the assigned value (for example, if the blood flow decreases or the artery dilates), the area of cross-section of the rubber tube is reduced and the pressure rises. In addition, if the assigned value of P_{st} rises or falls, the electrodynamic system alters the area of cross section of the tube so that the pressure in the artery rises or falls correspondingly; under these circumstances, the blood flow remains unchanged. Operation of the stabilizer demands that all side branches of the artery except that through which the electromanometer is connected are ligated.

The circuit of the amplifier controlling the electrodynamic system is given in Fig. 4. To provide for a coefficient of pressure stabilization of 5%, the amplification factor (K2) (Fig. 1, 9) must not be below 100. The amplifier is powered by a stabilized source of ±15 V with pulsations of not more than 0.2 V with a current of under 2 A. The voltage (U) assigning the stabilization pressure is set by the switches S2 (coarse) and S3 (fine). The amplifier is matched with the pressure sensor by means of the input attenuator S1 and the fine adjustment resistor R26. The initial displacement of the input voltage of the amplifier is regulated by the resistor R13. The input resistance of the amplifier is not less than 7 kΩ. The output voltage of the amplifier is between 0 and ±12 V, and the current in the winding of the throttle does not exceed 3 A. Transistors T3 and T4 must stand on radiators with a total area of not less than 3 dm^2. With high pulsations of voltage in the power circuit, the stabilitrons D2 and D4 must be shunted by electrolytic capacitors of 100-200 μF. To suppress pulsations in the hydraulic system, an integrating RC circuit with time constant of 0.1 sec can be connected into the feedback circuit of the amplifier (in series with R6).

Trials of the system in experiments on the cat femoral artery showed that it ensures pressure stabilization at any level from 10 to 200 mm Hg. The blood flow through the artery may vary under these circumstances from 1 ml/min to the value of P/R (P_{st} denotes stabilization

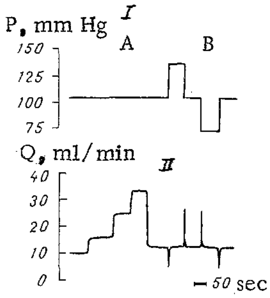

Fig. 5. Pressure (I) and blood flow (II) in cat's femoral artery. A) Pressure unchanged during changes in blood flow; B) changes of pressure with constant blood flow.

pressure, R the hydraulic resistance of the artery and tubes when the throttle is completely open (a trace of the pressure in the femoral artery during changes in blood flow is given in Fig. 5). In experiments with a pressure of 100 mm Hg the maximal blood flow was about 50 ml/min.

In addition, this system can also be used to perfuse an organ with blood with stabilization of pressure at the entry into its main artery. For this purpose, by means of a 3-way tube the hydraulic throttle must be connected parallel to the vascular network of the organ, and the third limb of the 3 way-tube is connected to the pump (the output of the pump should be set at above the highest expected flow rate for dilator reactions). The outlet pipe of the throttle is connected to a vein. During dilatation of the blood vessels of the organ, the area of cross section of the throttle decreases and a larger volume of blood will enter the organ. Conversely, during vasoconstrictor reactions, less blood will enter the organ because an increase in the area of cross-section of the throttle will divert part of the blood volume into the venous system, a sufficient amount of it ensuring that the pressure at the entry into the main artery of the organ is maintained at the assigned level.

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