REGULATION OF DIAMETER OF THE FEMORAL ARTERY DURING CHANGES IN VELOCITY OF PERFUSION

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KEY WORDS: femoral artery; stabilized pressure; perfusion solutions.

The lumen of the main artery of the limb [1], of an individual muscle [2], and also of the skin, intestine, and thyroid gland [7] was shown previously to be controlled by the velocity of the blood flow along it. The mechanisms of this local response of the arteries are unknown. According to one hypothesis, blood contains a substance (or substances) capable of relaxing myocytes, and with an increase in the velocity of the blood flow the supply of this substance to the arterial wall is increased and the artery dilates.

To study the validity of this hypothesis it was necessary to determine whether the response of dilatation of the arteries is preserved in the absence of blood, i.e., whether this reaction can arise in response to an increase in the rate of flow of the perfusion solution. The investigation described below was devoted to a study of this problem.

EXPERIMENTAL METHOD

Experiments were carried out on 11 cats weighing from 2.4 to 3.8 kg, anesthetized with urethane and chloralose (0.6 and 0.04 g/kg, respectively). The experimental scheme is shown in Fig. 1. A segment of the left femoral artery (FA) was isolated and its diameter measured by means of a capacitive displacement transducer [3] as described previously [1]. All large branches leaving the left FA were ligated. A segment of the right femoral vein was dissected in order to form an arteriovenous shunt. Next, after laparotomy the left iliac artery was isolated from the bifurcation of the aorta as far as the inguinal ligament. The central end of the divided left external iliac artery was connected by means of a cannula with the outlet tube of a PN-3 perfusion pump [6]. The outlet tube of the pump was connected to a 3-way cannula (Fig. 1, 8), introduced into the peripheral end of the iliac artery approximately as far as the level of the inguinal ligament. A cannula was introduced into the left FA before giving off a. saphena, and blood from this cannula flowed into the trunk D2M transducer of an RKÉ-1 electromagnetic flowmeter [5], from which it passed through the hydraulic throttle of an automatic pressure stabilization system [4] into the right femoral vein. The inner nickel tube of the 3-way cannula was connected to an electromanometer, the transducer of the system stabilizing pressure in FA. Pulsations of perfusion pressure caused by operation of the pump were smoothed by means of air dampers. The left FA was irrigated with Tyrode solution, the temperature of which in the wound was maintained at 34.5-36°C. The state of the animals was monitored by measuring the pressure in the carotid artery. The diameter of FA, the blood flow through it, and the pressure in its lumen were recorded on two KSP-4 two-channel automatic potentiometers.

By increasing the output of the pump, the presence and magnitude of a response of FA to the increase in the velocity of blood flow was determined under conditions of virtually unchanged pressure in the lumen of the artery (control period of the experiment). The tube running from the throttle to the vein was then disconnected from the vein and the inlet tube of the pump was connected to a thermostatically controlled flask, containing perfusion fluid, and for a few minutes the system and the artery were washed free from blood (the perfusion fluid during this period drained away). The tube carrying blood-free perfusion fluid from FA was then lowered into the same flask, creating a closed perfusion system. The temperature of the perfusion fluid on entry into FA was maintained at 37°C. In the next, principal period of the experiment, the rate of flow of perfusion fluid through FA was increased from time

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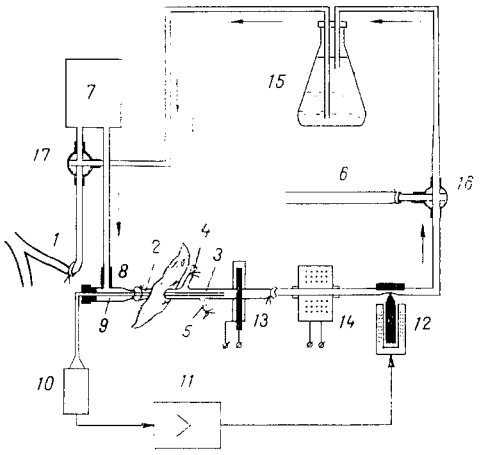

Fig. 1. Scheme of experiments. 1) Central end of divided external iliac artery; 2) peripheral end of the same artery; 3) FA; 4) a. profunda femoris; 5) lateral circumflex FA; 6) femoral vein; 7) perfusion pump; 8) 3-way cannula; 9) thin nickel tube connecting lumen of artery with electromanometer; 10) electromanometer transducer; 11) amplifier; 12) electrodynamic system and hydraulic throttle; 13) capacitive transducer of external diameter of FA; 14) transducer of electromagnetic blood flowmeter; 15) thermostatically controlled flask with perfusion solution; 16, 17) 3-way cocks (their position corresponds to perfusion of the artery with solution). Arrows indicate direction of flow of fluid.

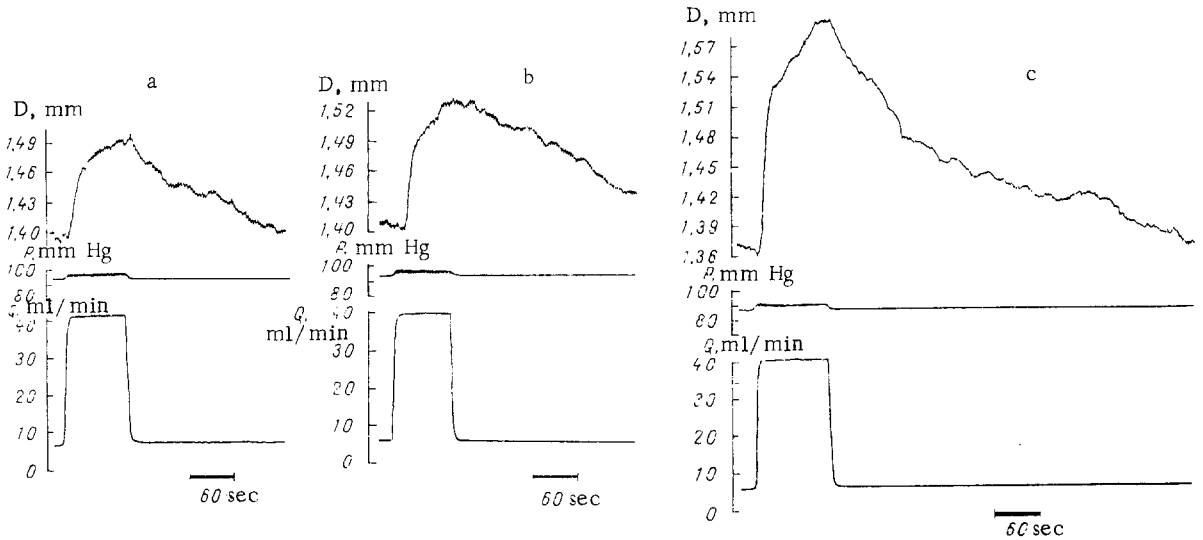

Fig. 2. Dilatation of FA with an increase in velocity of flow of blood (a) and Krebs–Henseleit solution (b), containing 4% albumin and 7% dextran, and of the same solution to which pituitrin was added in the rate of 0.05 i.u./100 ml (c). From top to bottom: diameter, D (in mm), pressure (P, in mm Hg), rate of flow (Q, in ml/min). Time marker 60 sec.

to time by increasing the output of the pump, and changes in its diameter were recorded, while the pressure in the artery remained virtually unchanged once again.

FA was perfused with Tyrode and Krebs–Henseleit solutions, with the addition of 1-4% bovine serum albumin which, according to some evidence [8], helps to preserve both the mechanisms of myogenic regulation of the vessels and their sensitivity to vasoactive substances of endogenous origin. To increase the viscosity of the solutions in them, usually 5-10% of

dry dextran (mol. wt. $6 \cdot 10^4$-$9 \cdot 10^4$) or 3-4% gelatin was added. In two experiments the perfusion fluid was a ready-made solution of rheopolyglucin.

EXPERIMENTAL RESULTS

Traces of responses of FA of the same animal in the control (a) and principal (b) periods of the experiment are illustrated in Fig. 2. An increase in the rate of flow of both blood and perfusion fluid led to dilatation of FA, the diameter of which increased in the first case by 7.6% and in the second by 8.4% (in both cases the rate of flow increased from 7 to 40 ml/min). However, during perfusion of FA with the solution, its constriction after the end of the procedure took place more slowly than in the case of perfusion with blood. If, however, 0.05-0.5 i.u. pituitrin was added to 100 ml of the solution, the amplitude of the response of FA rose sharply and the rate of dilatation and constriction of the artery increased appreciably (Fig. 2c).

In some experiments the beginning of perfusion with the solution was marked by the fact that FA, while responding by dilatation to the same increase in the rate of flow of solution as during perfusion with blood, did not return at the end of the procedure to its initial diameter. As a result of several such procedures the diameter of FA was considerably increased and the response was extinguished. If pituitrin was added in these experiments at the rate of 0.05-0.5 i.u. to 100 ml of solution, the artery constricted and its diameter returned to the original value, and later the responses to an increase in the rate of flow continued to be reproduced consistently.

The responses of FA to an increase in the rate of flow of perfusion solution (containing pituitrin or not) could be reproduced for 5-6 h; in 3 experiments we repeatedly evoked a response during 3 h after the animal's death.

Regulation of the lumen of FA by the rate of flow of fluid through it thus is preserved for a long time when the artery is perfused with salt solution containing albumin and dextran or gelatin. This fact contradicts the view that dilatation of FA arises in response to an increase in the transport of a certain substance from the blood, which either relaxes myocytes itself or promotes the formation of such substances in the vessel wall. The only such substance could be albumin, although the response of FA still persists (admittedly only for a short time) during perfusion of the artery with salt solution not containing albumin.

It must be specially emphasized that pituitrin likewise is not a substance that is essential for regulation of the lumen of arteries by the rate of flow of fluid, for arteries remain capable of regulating their diameter for a long time during perfusion with solutions not containing pituitrin. However pituitrin, or more probably one of its components, namely vasopressin, contributes to making regulation of the diameter of arteries by the rate of flow of fluid more effective. Intra-arterial injection of pituitrin during perfusion of FA with blood, just as during perfusion with solutions, leads to an increase in amplitude of the reactions and velocities of dilatation and constriction of FA.

It can be postulated that dilatation of arteries in response to an increase in the rate of flow of fluid is connected with an increase in the rate of elution of a certain substance present (or synthesized) in it from the vessel wall, which keeps the myocytes in a state of contraction. However, this hypothesis is unlikely to be true because during prolonged perfusion with solutions the precursor substances of this vasoconstrictor agent do not enter the vessel wall, and its reserves in the wall cannot be infinite.

Meanwhile the suggestion has been put forward [2, 9] that regulation of the diameter of arteries during changes in the rate of flow of fluid is effected through the degree of shear stress on the inner surface of the wall. To determine the validity of this hypothesis it is necessary to discover whether arteries respond by dilatation to an increase in viscosity of the liquid flowing through them when the rate of flow remains unchanged. The fact that the reaction of FA to a change in the rate of flow can be reproduced for a long time to perfusion solutions means that such experiments can be undertaken.

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TIME COURSE OF LYMPH PRESSURE IN SOMATIC AND MESENTERIC LYMPHATICS AT REST AND AT THE PEAK OF DIGESTION

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In this investigation the time course of lymph pressure in the popliteal and mesenteric lymph nodes and their efferent lymphatics was studied in 20 intact dogs when the drained organs were in a state of physiological rest and also, in the case of the mesenteric nodes, at the peak of digestion.

EXPERIMENTAL METHOD

The hydrodynamic lymph pressure was measured by means of a pressure transducer developed by E. P. Voityuk, the sensitive element of which is a profiled silicon membrane, 36-60 μ thick, on which a tensoresistive Wheatstone bridge with temperature stabilization elements is formed by means of planar diffusion technology [1]. The transducer has the following parameters: dynamic range 0-200 mm Hg, sensitivity 1 mV/mm Hg, zero drift ≤1%/°C, nonlinearity ≤1%. The intrinsic frequency of mechanical resonance is 20 kHz, and with a fluorine plastic catheter with internal diameter of 1 mm and length 20 cm it is 300 Hz. The pressure recording chamber, one wall of which is formed by the membrane with resistance strain gauges, communicates with an injection needle through the fluorine plastic catheter. This space is filled with physiological saline containing heparin. The lymph pressure in the lymphatic space to be studied, into which the needle is inserted, was thus transmitted through the liquid to the membrane of the transducer. Unbalance of the Wheatstone bridge, proportional to pressure changes, was recorded in the form of strain graphs.

The lymph pressure was recorded in this way for periods of 30 sec, separated by intervals of 2 min. Observations on each organ were made for between 30 and 60 min. The blood pressure in the external iliac artery was recorded synchronously by means of another transducer, and respiration was recorded by an MT-64 thermistor. The injection needle connected to the transducer was inserted into the lymph node to a depth of 2 mm. The two cases in which subcapsular bleeding was observed, resulting in high values of the pressure inside the node, were excluded from the study. A much more frequent complication was entry of the needle into the connective-tissue hilar body. In such cases the pressure record corresponded to a uniform curve characteristic of that obtained when the transducer needle was inserted into the perinodal cellular tissue.

If the pressure curve recorded with the needle inserted into the perinodal cellular tissue (control) was similar to that recorded with the needle inside the node, the latter was discarded. Operative access to the lymph nodes was obtained under morphine—thiopental anes-

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