REACTIONS OF BLOOD VESSELS OF SKELETAL MUSCLES AND CHANGES IN THE FLOW OF SYMPATHETIC IMPULSES TO THEM DURING STIMULATION OF THE PELVIC ORGANS (RECTUM AND BLADDER)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 57, No. 2,
pp. 24-28, February, 1964
Original article submitted December 15, 1962

Previous investigations have demonstrated a definite pattern of inclusion of various parts of the sympathetic nervous system and vascular fields into the reaction in response to stimulation of the mechanicoreceptors of the bladder and rectum. The thresholds of appearance of changes in the flow of impulses in the various nerves were dependent on the degree of functional communication between the tested region and the site of stimulation. With an increase in the strength of stimulation the flow of efferent impulses to the subjacent regions was weakened by the action of weak stimuli, strengthened by the action of moderate stimuli, and again weakened by the action of very strong stimuli. In regions less intensively connected with the site of stimulation, as a result of the raising of the thresholds the last phase of the changes, and in the most remote regions the second phase also, could not be observed.

It was concluded from these findings that the vessels of different parts of the body part in the formation of the general reaction of the blood pressure in the body as a whole. It was not discovered, however, what part the skeletal muscles play in this reaction. It is generally accepted that the vascular bed of the skeletal muscles constitutes a considerable part of the vascular system, and according to some writers [7] it plays a leading role in determining the character of the changes in the general blood pressure, In the present study the peripheral resistance of the vessels of the limb muscles of the cat and the flow of sympathetic impulses to these vessels were investigated.

EXPERIMENTAL METHOD

Thirty experiments were performed on cats anesthetized with urethane (1 g/kg intravenously). The mechanicoreceptors of the bladder were stimulated by filling the organ with air under a definite pressure. To stimulate the mechanicoreceptors of the rectum, a rubber finger-stall was fixed inside the organ and filled with air at a definite pressure. Stimulation of these two organs was carried out in turn. Recordings were made of the pressure in the carotid artery and the intravesical and intrarectal pressures (mercury manometer). At the same time, by means of buried electrodes, the action potentials in the branches of the tibial nerve were recorded on a cathode-ray oscillograph through an ac amplifier, the frequency characteristic of which was linear between 0.3 and 2000 cps. In another series of experiments the blood flow through the skeletal muscles of the fore and hind limbs was investigated (cutaneous arteries in both cases were ligated). The reactions of the vessels were judged by the change in their resistance to a constant flow of blood maintained by a perfusion pump, as described previously in the literature [6]. To avoid artefacts from developing as a result of compression of the veins draining the hind limbs during inflation of the rectum, the blood flowing from the femoral vein was collected in a receiver and then injected into the jugular vein.

EXPERIMENTAL RESULTS

In the first series of experiments the changes in the blood flow in the muscles of the fore and hind limbs during stimulation of the mechanicoreceptors of the bladder and rectum with different intensities were investigated.

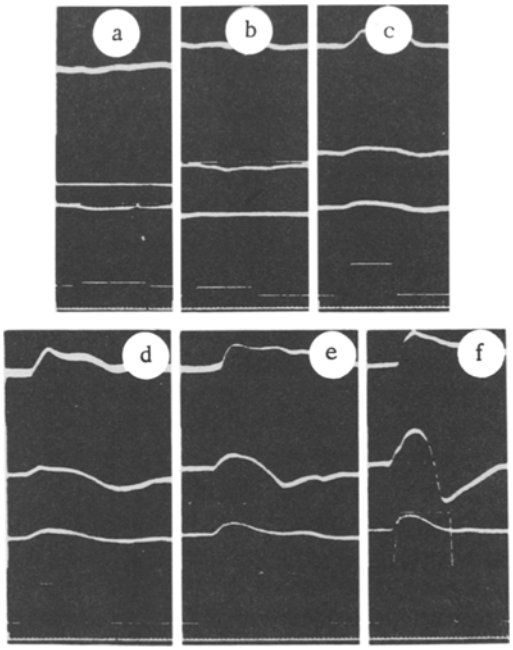

Fig. 1. Changes in general blood pressure and peripheral resistance of the vessels of the muscles of the fore and hind limbs under the influence of stimulation of different intensities of stimulation of the mechanicoreceptors of the bladder. a) Intravesical pressure 5 mm; b) 8 mm; c) 41 mm; d) 54 mm; e) 66 mm; f) 140 mm Hg. Significance of curves (from top to bottom): general blood pressure in carotid artery; peripheral resistance in brachial artery; peripheral resistance in femoral artery; pressure in stimulated organ; time marker (5 sec).

The resistance of the vessels of both limbs fell, i.e., vasodilatation was observed, in response to weak stimulation of the mechanicoreceptors of the bladder (Fig. 1, a, b), and vasoconstriction took place in response to moderate and strong stimulation (Fig. 1, c-f). The change from the first reaction to the second took place in the hind limb in response to a lesser degree of distension of the bladder (see Fig. 1,b) than in the forelimb (see Fig. 1, c). During stimulation of the rectum the vessels of the hind and fore limbs dilated in response not only to weak, but also to moderately strong stimulation (Fig. 2, a). During the action of very strong stimulation of the rectum the vessels of the hind limb, as a rule, were constricted whereas the vessels of the forelimb continued to dilate (Fig. 2,b). A further increase in the strength of stimulation in 60% of the experiments caused constriction of the vessels of the forelimb (Fig. 2,c); in 40% of the experiments the change of the reaction of vasodilatation into one of vasoconstriction was not observed. So far as the dilatation of the blood vessels of the limb muscles, arising (Fig. 1) immediately after vasoconstriction, is concerned this took place in some (about 50%) of the experiments in response to strong stimulation of the bladder and rectum. As previous experiments showed [5], this secondary effect is caused by humoral agents and by procedures directed against the carotic sinus and the aortic reflexogenic zones.

Hence, stimulation of the mechanicoreceptors of both the bladder and rectum caused dilatation of the limb vessels in response to weaker, and constriction in response to stronger stimuli. The vessels of the hind limbs reacted with lower thresholds of stimulation than the vessels of the fore limbs. The same relationship was observed in respect of the change of the vasomotor reactions to constrictor. The difference between the effects of stimulation of the mechanicoreceptors of the bladder and rectum was that in order to obtain equal reactions weaker stimulation of the bladder than of the rectum was required.

In the second series of experiments the changes in the flow of sympathetic impulses to the vessels of the muscles of the hind limbs were investigated. For this purpose the ventral roots were divided unilaterally in the animal from the 5th lumbar to the 1st sacral segments, containing the motor fibers to this limb. Potentials were recorded in the central segment of the slender twig of the tibial nerve in which, as a result of this procedure, only the sympathetic fibers running in the 10-12th thoracic and 1st-3rd lumbar ventral roots remained active. In some experiments the potentials in the central segment of the twig of the tibial nerve in the opposite limb were recorded at the same time, the ventral roots being still intact on this side. In this way the activity of the somatic and sympathetic fibers could be compared. Greater amplification was needed to demonstrate the latter than the former. This is because the great majority of fibers in these nerves are somatic, which by-pass the activity of the small number of sympathetic fibers.

One of the experiments in which the activity of the sympathetic fibers was recorded during different intensities of stimulation of the bladder and rectum is illustrated in Fig. 3. During slight inflation of the bladder, when the pressure inside the viscus was 5 mm Hg, the flow of sympathetic impulses to the limb was diminished. If the same pressure was created inside the rectum there was no visible change in the flow of impulses (Fig. 3, b). An increase in the intravesical pressure to 10 mm Hg caused an increased flow of impulses, but the same pressure inside the rectum inhibited the flow of sympathetic impulses (Fig. 3,c). A still greater increase in the intravesical pressure (in this case to 60 mm Hg) led, as before, to an increase in the flow of impulses to the vessels of the muscles of the hind limbs. The creation of the same pressure in the rectum also increased the flow of impulses (Fig. 3, d).

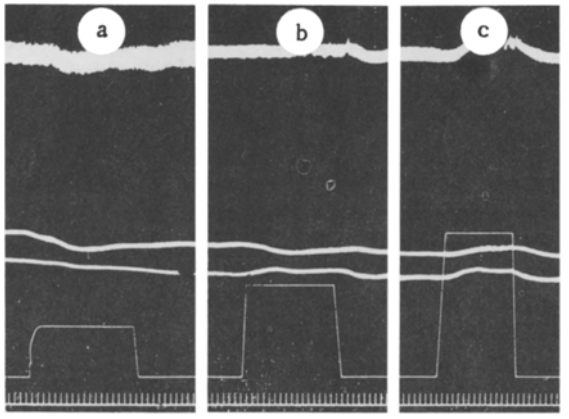

Fig. 2. Changes in general blood pressure and peripheral resistance of the vessels of the muscles of the fore and hind limbs under the influence of stimulation of different intensities of the mechanicoreceptors of the rectum. a) Intrarectal pressure 52 mm, b) 92 mm, c) 145 mm Hg. Significance of curves as in Fig. 1.

Hence, the flow of sympathetic impulses regulating the tone of the vessels of the hind limbs is diminished in response to weaker stimulation of the mechanicoreceptors of the bladder and rectum and is increased in response to stronger stimulation. The thresholds of appearance of the changes in the flow of impulses, like the thresholds of the change from the reaction of inhibition to the reaction of stimulation, are lower during stimulation of the bladder than of the rectum.

The changes in the flow of somatic impulses also were biphasic in character, i.e., inhibition was observed in response to weak stimulation and an increase in flow in response to stronger stimulation of the mechanicoreceptors of the bladder and rectum. However, the thresholds of appearance of the changes in the flow of somatic impulses and the thresholds of the change from inhibition to stimulation of the flow did not coincide, as a rule, with the character of the changes in the flow of sympathetic impulses to the same stimuli. Consequently, the principles governing the changes in the flow of sympathetic impulses to the vessels of the hind limbs are basically identical with those governing the changes in the tone of these vessels in response to stimulation of the mechanicoreceptors of the bladder and rectum. During a weakening of the flow of impulses in the sympathetic pathways dilatation was observed, and during a strengthening of the flow, on the other hand, vasoconstriction of the limb vessels took place.

The changes in the sympathetic impulses flowing to the forelimbs could not be studied, for the sympathetic and spinal fibers composing the nerves to the forelimbs leave by the same spinal roots. However, there is no reason to suppose that the relationships between the flow of sympathetic impulses and the changes in the peripheral resistance of the vessels should differ in the forelimbs during the production of the vasomotor reactions described above from those in the hind limbs.

The results of these experiments demonstrate that the reflex weakening of the efferent flow of sympathetic impulses as a result of stimulation of the receptors of the bladder and rectum leads to a decrease in the peripheral resistance of the vessels, whereas an incrase in this flow of impulses is accompanied by an increase in the peripheral resistance. This confirms the conclusion which we obtained previously by comparing the changes in the flow of sympathetic impulses to certain internal organs with the changes in the blood flow in these organs [1]. Comparison

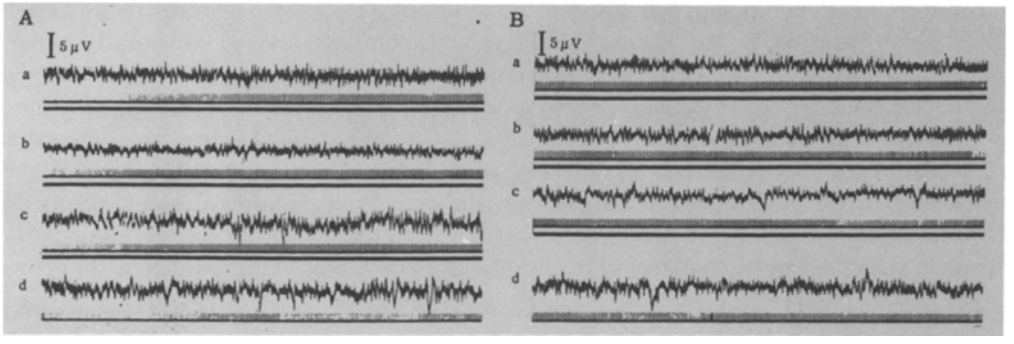

Fig. 3. Changes in the flow of efferent impulses in a twig of the tibial nerve (ventral roots from L5 to S1 inclusive divided on this side) with different strengths of stimulation of the mechanicoreceptors of the bladder (A) and rectum (B). a (A and B) – background activity of tibial nerve; b(A) – intravesical pressure 5 mm Hg: efferent impulses inhibited; b (B) – intrarectal pressure 5 mm Hg; efferent impulses unchanged; c (A) – intravesical pressure 10 mm; increased flow of impulses; c (B) – intrarectal pressure 10 mm; flow of impulses inhibited; d – intravesical pressure (A) and intrarectal pressure (B) 60 mm: flow of impulses increased in both cases. Significance of curves from top to bottom: time marker (0.01 sec), action potentials in central segment of the twig of the tibial nerve.

between the results described in the present paper and those obtained previously [1-4] gives the following. The strengths of stimulation at which the above-mentioned changes in the flow of impulses take place and a weakening of the flow is replaced by a strengthening of the flow during stimulation of the mechanicoreceptors of the bladder and rectum are rather higher for the vessels of the muscles of the hind limbs than for the vessels of the small intestine and slightly lower than for the renal vessels. In the case of the vessels of the forelimb muscles, they are rather higher than for the splenic vessels, but lower than for the vessels of the heart, and, moreover, during stimulation of the rectum in 50% of cases no change of the inhibitory reaction into a stimulating reaction was observed in the cardiac nerves. In relation to the skeletal muscles of the forelimbs, this change was not observed in 40% of cases.

Hence, the vessels of the skeletal muscles do not play an exclusive role in the development of the composite reactions of the blood pressure to stimulation of the mechanicoreceptors of the bladder and rectum, but they occupy a definite place among the other groups of vessels. Likewise their reactions, especially the reactions of the forelimb vessels, may not coincide with the reaction of the general blood pressure, but they obey a common rule: they develop the more intesively and have lower thresholds, the closer their connection functionally and anatomically with the site of stimulation. In this respect our conclusions are close to V. M. Khayutin's ideas [7]. However, Khayutin considers that the vascular reflexes elicited from the mechanicoreceptors of the bladder, like those from the tissue receptors, begin with vasoconstriction even with stimulation of threshold strength. This difference cannot be attributed to differences in the method of anesthesia, for in certain experiments we, like Khayutin, used chloralose-urethane anesthesia and this did not affect the results. It appears that the difference between our results and those of Khayutin may be partly explained by the fact that in our experiments the mechanicoreceptors of organs were stimulated, and in most of Khayutin's experiments electrical stimulation of nerves was used. In our experiments functionally opposite results could be obtained from the same receptor zone (bladder or rectum). The character of the reflex changes in the blood vessels of the skeletal muscles (constriction or dilatation) was determined by the strength of stimulation of the mechanicoreceptors of the bladder or rectum. Weak stimulation caused dilatation of the limb vessels, but strong, on the other hand, was accompanied by a constrictor effect. These varied effects were brought about by a decrease or, conversely, an increase in the intensity of flow of vasomotor impulses respectively.

SUMMARY

As demonstrated in acute experiments on cats, stimulation of the mechanoreceptors of the bladder and rectum caused vasodilation in the extremities in response to weaker stimuli and vasoconstriction in response to stronger. Vessels of posterior extremities reacted to weaker stimuli than did those of the anterior. Sympathetic impulsation controlling the vascular tone of posterior extremities was inhibited in response to weaker stimulation of mechanoceptors of the bladder and of rectum and increased in response to stronger stimuli. The difference between the effects of stimulation of the bladder and rectum was that, to obtain equal reactions, stimuli of lesser intensity were required in the case of the bladder than of the rectum. In the formation of blood pressure reactions in response to stimulation of the vesical and rectal mechanoceptors the skeletal muscle vessels did not occupy any exclusive position among the vessels of the various parts of the body.

LITERATURE CITED

1. T. S. Lagutina, The electrophysiological characteristics of the interoceptive reflex arc, Candidate dissertation, Moscow (1958).
2. T. S. Lagutina, Byull. éksper. biol., 1, 3 (1959).
3. T. S. Lagutina, Problems in Electrophysiology and Encephalography [in Russian], p. 291, Moscow-Leningrad (1960).
4. T. S. Lagutina, Byull. éksper. biol., 4, 25 (1962).
5. I. M. Rodionov and V. P. Kulagina, Hypertension, Atherosclerosis, Coronary Insufficiency, Abstracts of Proceedings of the 12th Scientific Session of the Institute of Therapy, AMN SSSR [in Russian], p. 5, Moscow, (1961).
6. V. M. Khayutin, V. M. Danchakov, and V. L. Tsaturov, Byull. éksper. biol., 2, 117 (1958).
7. V. M. Khayutin, The functional organization of vasomotor reflexes, Doctorate dissertation, Moscow (1962).