THE ELECTROPHYSIOLOGICAL CHARACTERISTICS OF THE INTEROCEPTIVE REFLEX ARC

COMMUNICATION 3. CHARACTERISTICS OF THE REGIONAL VASCULAR REFLEXES ARISING IN RESPONSE TO STIMULATION OF THE MERCHANORECPTORS OF THE URINARY BLADDER

T. S. Lagutina

Laboratory of General Physiology (Head, Academician V. N. Chernigovskii), Institute of Normal and Pathological Physiology (Director, Active Member AMN SSSR V. V. Parin) of the AMN SSSR, Moscow
(Presented by Academician V. N. Chernigovskii)
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 53, No. 4, pp. 25-29, April, 1962
Original article submitted April 13, 1961

Several investigations have shown that the changes in the arterial pressure arising under the influence of stimulation of the interoceptors are accompanied by various changes in the activity of the sympathetic nerves and in the tone of the peripheral vessels [2-6, 8, 9, 10]. We have shown by stimulation of the mechanoreceptors of the urinary bladder that a definite relationship exists between the thresholds of development and the character of the changes in the effector impulses in various sympathetic nerves and the strength of stimulation and the degree of functional and anatomical closeness of the reacting region to the stimulated zone [2-5].

The lowest of all thresholds of appearance of these changes was in the efferent nerves passing to the stimulated organ itself (in our case—the threshold of development of changes in the flow of impulses to the vessels of the urinary bladder along the hypogastric nerve). Three phases of changes are found in the hypogastric nerves as the filling of the bladder proceeds: inhibition of impulses in response to weak stimuli, intensification during average stimuli, and inhibition again during strong stimuli. Changes arise in the renal nerve with a higher threshold of stimulation of the bladder receptors, and in this case only the first two phases of the changes are observed as the stimulation increases in strength: inhibition and intensification of the flow of impulses. In regions even more remote in functional and anatomical respects—in the cutaneous nerve of the thigh and the cervical sympathetic trunk—the threshold of the changes is higher still; in response to all effective strengths of stimulation the first phase—inhibition of the flow of efferent impulses—is observed.

If, however, we start from the generally accepted idea that the changes in the arterial pressure are the result of changes in the peripheral resistance in all the vessels, we must investigate how the principle we have established is carried out in other vascular fields.

In order to obtain a fuller picture of the redistribution of activity in the different parts of the sympathetic nervous system in response to different strengths of stimulation of the mechanoreceptors of the urinary bladder, we investigated the changes in the flow of efferent impulses in the intestinal, splenic, and cardiac sympathetic nerves, i.e., the impulses to the vascular fields capable of exerting a considerable influence on the systemic arterial pressure.

EXPERIMENTAL METHOD

We carried out 37 experiments on cats under ether-urethane anesthesia. The flow of efferent impulses was recorded on a two-channel cathode-ray oscillograph through an amplifier. The tracing of the impulses was synchronized with the tracing of the blood pressure and the pressure inside the urinary bladder on the kymograph. The cardiac branches leaving the right and left stellate ganglia were mobilized at the level of the second intercostal space, and placed in buried electrodes attached to the chest wall, after which the chest was closed and natural respiration reestablished. The experimental technique is described in detail in a previous communication [4].

EXPERIMENTAL RESULTS

In all three nerves (intestinal, splenic, cardiac) a background activity was observed in the absence of stimulation, which was either regular or grouped into volleys, synchronous with the pulse of respiration (Fig. 1a, Fig. 2a).

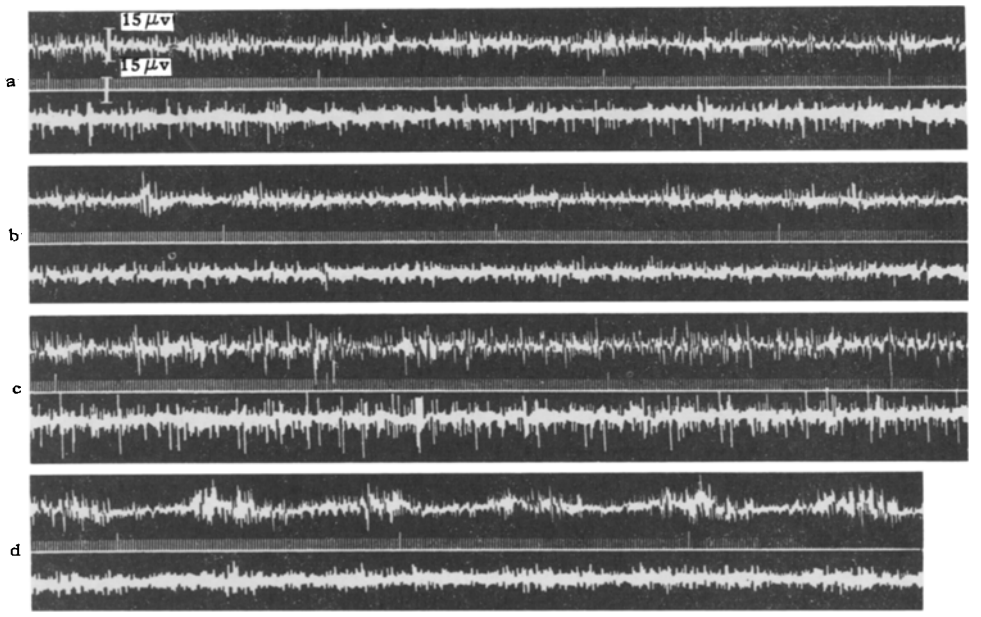

Fig. 1. Changes in the flow of efferent impulses in the splenic and intestinal nerves in response to different strengths of stimulation of the mechanoreceptors of the urinary bladder. a) Background activity in both nerves when the bladder was empty; b) intravesical pressure 10 mm Hg; flow of impulses in both nerves inhibited; c) intravesical pressure 20 mm Hg; increased flow of impulses in both nerves; d) intravesical pressure 150 mm Hg; increased flow of impulses in the splenic nerve and inhibition in the intestinal. Significance of the curves (from above down): flow of impulses in the central end of the splenic nerve; time marker (0.01 second); flow of impulses in the central end of the intestinal nerve.

The changes in background activity in response to stimulation of the bladder receptors appear at different thresholds, and the character of these changes corresponding to different strengths of stimulation may sometimes be opposite, although this prevents their general pattern from being studied.

Slight filling of the bladder caused depression of the flow of efferent impulses in the splenic and, in particular, in the intestinal nerves (Fig. 1b). With still weaker stimulation the activity in the splenic nerve was unchanged while that in the intestinal nerve was slightly depressed. With an increase in the strength of stimulation there was an increase in the flow of impulses in both nerves (Fig. 1c), and the increase took place in the intestinal nerve at a lower threshold than in the splenic nerve. A further increase in the stimulation to considerable strengths, 3 or 4 times greater than the threshold strength for a reflex change in blood pressure, again caused depression in the intestinal nerve; in the splenic nerve as before an increase in the flow of efferent impulses was observed, although it was less marked (Fig. 1d) than during the action of weaker stimuli (Fig. 1c).

Thus the flow of efferent impulses in the intestinal nerve passed through the same three phases of changes as the strength of stimulation was increased as did that in the hypogastric nerve [2-5]. The threshold of development of the changes and the threshold of the change from one phase to another were, however, slightly higher for the intestinal than from the hypogastric nerve. In the splenic nerve two phases of changes in the flow of efferent impulses were observed, i.e., they were similar in character to the changes in efferent impulses in the renal nerve.

When the flow of efferent impulses in the cardiac sympathetic branches from the stellate ganglion was recorded, changes in the background flow were observed in response to average strengths of stimulation of the mechanoreceptors of the bladder, and these took the form of inhibition (Fig. 2b). Only after a considerable intravesical

pressure (60-150 mm Hg in different experiments) had been produced could an increase in the flow of efferent impulses be observed in the cardiac branches. In some cases no increase in the flow of efferent impulses was observed in the cardiac branches even when stronger stimuli were applied, just as in the cutaneous and the cervical sympathetic nerves.

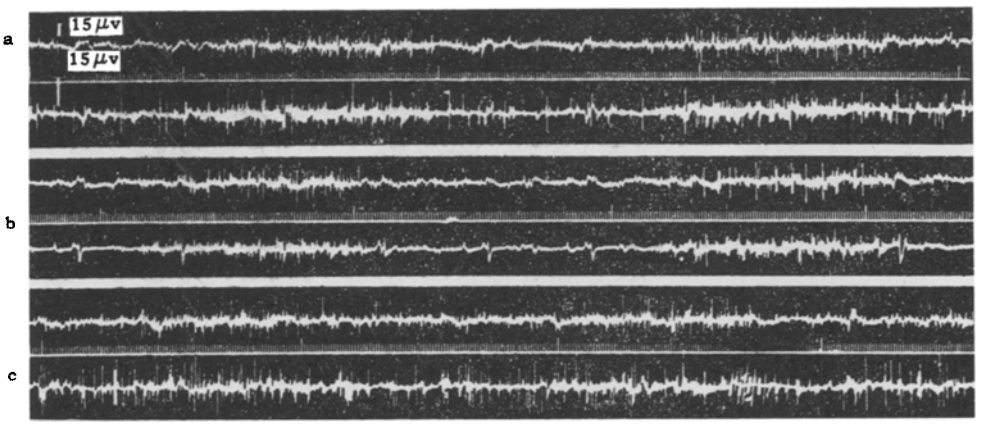

Fig. 2. Changes in the flow of efferent impulses in the cardiac nerves in response to different strengths of stimulation of the mechanoreceptors of the bladder. a) Background activity in both nerves when the bladder was empty; b) intravesical pressure 56 mm Hg; flow of impulses in both nerves inhibited; c) intravesical pressure 150 mm Hg; increased flow of impulses in both nerves. Significance of the curves (from above down): flow of impulses in the central end of the left cardiac nerve; time marker (0.01 second); flow of impulses in the central end of the right cardiac nerve.

Data showing the correlation between the changes in the flow of efferent impulses in all the nerves tested, and the flow of afferent impulses causing these changes and the changes in the general blood pressure are shown in Fig. 3.

It may be seen from Fig. 3 that as the intensity of the flow of afferent impulses increased uniformly, the flow of efferent impulses in the different sympathetic nerves and, consequently, the tone of the different peripheral vessels were modified to different degrees. In the hypogastric and intestinal nerves the flow of efferent impulses was depressed in response to strengths of stimulation not causing a rise in the general arterial pressure (in 20% of experiments a slight fall of 10-15 mm Hg in the general blood pressure was observed during the action of these strengths). An increase in the flow of impulses in the hypogastric nerve began at strengths of stimulation which were subthreshold for the pressor reflex on the general arterial pressure. In the intestinal nerve the transition from inhibition to increase of the flow of impulses coincided in most experiments with the appearance of a pressor reaction of the arterial pressure. With still stronger stimuli, which ceased to produce any further increase in arterial pressure, the flow of efferent impulses in the hypogastric and intestinal nerves was again depressed, and sometimes it disappeared completely. In the intestinal nerve this depression appeared at a higher threshold than in the hypogastric nerve.

In all the remaining nerves the third phase was not as a rule observed, evidently because of the increase in the threshold of appearance of the preceding phases of the change in the flow of efferent impulses. In the cardiac sympathetic nerves the threshold of appearance of the first phase was even higher than in the splenic nerve; consequently, the second phase appeared only in response to very strong stimulation. In the cervical sympathetic trunk and in the cutaneous nerve of the thigh, in which the characteristic depression of the first phase arose in response to strong stimulation, even very strong stimulation as a rule caused no increase in the flow of impulses characteristic of the second phase.

In all the efferent nerves investigated a very slight increase in the flow of impulses could sometimes be observed in response to strengths of stimulation below the threshold value for the appearance of the depression which we called the first phase of the reaction.

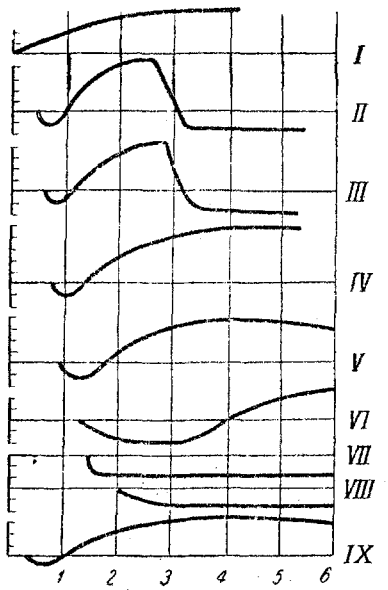

Fig. 3. The effect of stimulation of the mechanoreceptors of the urinary bladder on the flow of afferent (pelvic nerve) and efferent impulses in sympathetic nerves and on the magnitude of the reflex rise in the general blood pressure. Along the axis of absicissas—strengths of stimulation of the mechanoreceptors of the bladder in relative units (the unit is taken to be the strength of stimulation causing a threshold change in the general blood pressure), along the axis of ordinates—I) number of afferent impulses per second; II, III, IV, V, VI, VII, VIII) flow of efferent impulses (as a percentage of the initial level) in the hypogastric, intestinal, renal, splenic, cardiac, and cutaneous nerves and the cervical sympathetic trunk respectively; IX) changes in the general blood pressure (in mm Hg).

We conclude from these results that as the strength of interoceptive stimulation increases, and as the intensity of a uniform flow of afferent impulses increases the flow of efferent impulses to the vessels of the stimulated organ and of the organs most closely connected with it in a functional and anatomical respect passes through at least three phases of changes: depression, intensification, and depression. In the nerves transmitting impulses to the more distant vascular fields, the threshold of appearance of each of these phases is increased, as result of which the number of phases is reduced.

The different changes in the vascular tone of the various organs arising in these circumstances are evidently aimed primarily at the redistribution of the blood. The changes in the general blood pressure are incidental, and possibly undesirable consequences of this redistribution of vascular tone, although they may be of definite importance in the first stages of the redistribution. Characteristically, during continued stimulation of the urinary bladder, the blood pressure rapidly returns to its initial level [3, 7], although the flow of afferent impulses continues to appear [1, 3].

The vasodilator or vasoconstrictor effect in a particular vascular field is determined, so far as can be judged from the results described, by the intensity of the flow of functionally uniform afferent impulses reaching certain effector formations of the central nervous stystem. The character of the effect depends on the intensity of stimulation of the receptors and on the degree of functional closeness of the effector and the stimulated zone.

SUMMARY

Acute experiments were performed on cats. A study was made of the changes occurring in the efferent impulsation in the intestinal, splenic and cardiac sympathetic nerves in stimulation of mechanoceptors of the urinary bladder by stimuli of various intensity. The data obtained were compared with the results of analogous experiments published earlier, in which efferent impulsation was recorded in the hypogastric, renal and cutaneous nerves and in the cervical sympathetic trunk. The thresholds of appearance of impulsation changes in different nerves depended on the degree of the functional distance of the area investigated from the site of stimulation. The thresholds increase in the following order: hypogastric nerve, intestinal, renal, splenic, cardiac, cutaneous cervical sympathetic trunk. With the rise of stimulation intensity of the urinary bladder mechanoceptors the efferent impulsation in the hypogastric and intestinal nerve undergo three phase changes: depression, intensification, and depression of the impulsation. The number of phases decreases with increasing distance of the area from the site of stimulation. In the renal, splenic and cardiac nerves two first phases are observed, whereas in the cutaneous nerve and the cervical sympathetic trunk—only the first one.

LITERATURE CITED

1. N. A. Adamovich, Transactions of the I. P. Pavlov Institute of Physiology [in Russian], Moscow-Leningrad (1954), Vol. 3, p. 490.
2. T. S. Lagutina, Abstracts of Proceedings of a Conference on the Electrophysiology of the Central Nervous System [in Russian], Leningrad (1957), p. 75.
3. T. S. Lagutina, The Electrophysiological Characteristics of the Interoceptive Reflex Arc [in Russian], Candidate Dissertation, Moscow (1958).
4. T. S. Lagutina, Byull. Éksper. Biol. (1959), No. 1, p. 3.
5. T. S. Lagutina, In Problems in Electrophysiology and Encephalography [in Russian], Moscow-Leningrad (1960), p. 291.

6. N. K. Saradzhiev, Fiziol. Zh. SSSR (1959), 45, No. 1, p. 65.
7. A. M. Ugolev, V. M. Khayutin, and V. N. Chernigovskii, Fiziol. Zh. SSSR (1960), No. 1, p. 117.
8. V. V. Frol'kis and I. V. Shchegoleva, Byull. Éksper. Biol. (1960), No. 10, p. 7.
9. V. M. Khayutin and V. L. Tsaturov, Byull. Éksper. Biol. (1959), No. 2, p. 17.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
