CHARACTER OF THE EFFERENT IMPULSES IN THE POSTGANGLIONIC FIBERS OF THE SPLANCHNIC NERVE DURING VASOCONSTRICTOR AND VASODILATOR REACTIONS IN THE ABDOMINAL ORGANS

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Stimulation of the effector pathways of the sympathetic nervous system is followed by both constriction and dilatation of the vessels for the ear [12], the posterior extremities [7, 11, 13, 14], the abdominal viscera [8, 9, 10], and other organs. We have shown that variations in the frequency and strength of stimulation of the peripheral end of the splanchnic nerve cause functionally opposite vasomotor effects in the abdominal organs: dilatation with relatively low frequencies and strengths of stimulation and constriction with higher frequencies and strengths.

The object of the present investigation was to study the changes in the stream of efferent impulses flowing to the vessels of the intestine, kidney, and spleen accompanying changes, as indicated above, in the parameters of electrical stimulation of the preganglionic fibers of the splanchnic nerve.

EXPERIMENTAL METHODS

Fifteen acute experiments were conducted on cats anesthetized with ether and urethane. The efferent impulses to the vessels of the kidney, intestine, and spleen were recorded in the central ends of the divided renal, mesenteric, and splenic nerves, consisting of postganglionic fibers of the ganglion of the solar plexus. The recordings were made on an Alvar three-channel Myocathograph. Buried electrodes were used to pick up the potentials. The peripheral end of the preliminarily divided greater splanchnic nerve on the left side was stimulated by means of a "Neurovar" stimulator. The right greater splanchnic nerve also was divided. The nerve was stimulated at frequencies varying from 0.5 to 20 cps. The strength of stimulation ranged from 0.5 to 10 V. The duration of the individual pulse of stimulating current was constant (1 millisec). The total duration of stimulation with all variations of frequency and strength also was constant (3 sec).

EXPERIMENTAL RESULTS

In the initial state the mesenteric, renal, and splenic branches of the splanchnic nerve exhibited background activity. In the mesenteric nerve this took the form of a continuous stream of impulses (Fig. 1A, 2), whereas in the renal nerve it consisted of a series of discrete bursts (Fig. 1A, 1). Bursts of impulses also were observed in the splenic nerve (Fig. 1A, 3).

Stimulation of the peripheral end of the splanchnic nerve with a frequency of 0.5 cps and a strength of 2 V caused no changes in the background activity in these nerves, or was accompanied by a slight decrease in its intensity (Fig. 1B).

During stimulation at a frequency of 2 cps and constant strength of 2 V, an increase in the frequency of the impulses in the renal and splenic nerves was observed (Fig. 1C). As a quantitative index if the postganglionic nervous activity we determined the mean power of the impulses [3], given by the product of the square of the mean amplitude of the impulses and the number of impulses in the given segment of the electroneurogram. The power of the impulses in this case, compared with the background level taken as 100%, was 123% in the renal and 109%

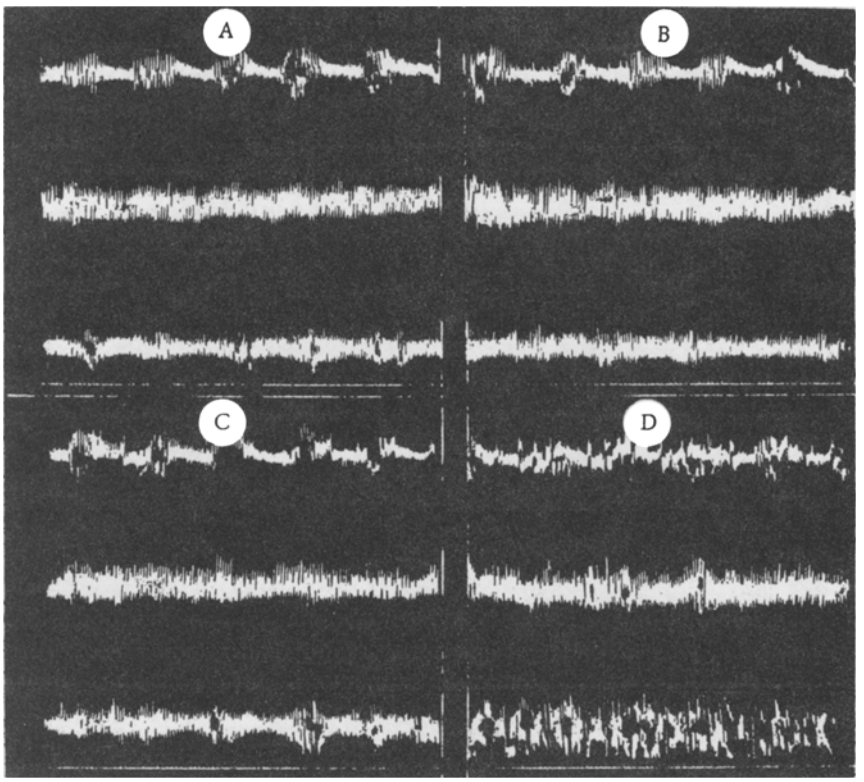

Fig. 1. Changes in efferent impulses in renal (1), mesenteric (2), and splenic (3) nerves during stimulation of the peripheral end of the greater splanchnic nerve at different frequencies (constant strength 2 V, duration of stimulating pulse 1 millisec): A) before stimulation; B) at a frequency of 0.5 cps; C) at a frequency of 2 cps; D) at a frequency of 10 cps. Time marker 0.02 sec.

in the splenic nerve. In this particular case the impulses in the mesenteric nerve were indistinguishable from the background activity.

A still greater increase in the frequency of the oscillations in the electroneurogram was obtained during stimulation of the splanchnic nerve at a frequency of 10 cps. The bursts of impulses found in the renal and splenic nerves in normal conditions were replaced during stimulation by an almost continuous stream of impulses (Fig. 1D). The power of the impulses at this frequency of stimulation was 179% in the renal nerve, 147% in the mesenteric, and 189% in the splenic nerve in relation to the power of the background impulses in the corresponding nerves.

Changes in the postganglionic impulses were also observed when the strength of stimulation of the splanchnic nerve was varied. The results of one such experiment are given in Fig. 2. The frequency of stimulation (5 cps), the total duration of stimulation (3 sec) and the duration of each stimulating pulse (1 millisec) remained constant. In these conditions stimulation with a strength of 1 V caused a slight weakening of the impulses: the mean amplitude of the impulses in the renal nerve fell from 8.5 to 7.5 mm, and in the splenic nerve from 7.1 to 6.5 mm. The changes in the amplitude of the impulses in the mesenteric nerve were insignificant (Fig. 2B). The power of the impulses in the renal nerve was 73%, in the mesenteric nerve 76%, and in the splenic nerve 82% of the power of the background impulses.

Conversely, stimulation in a strength of 3 V caused an increase in the power of the impulses in the renal nerve to 107%, in the splenic nerve to 118%, and in the mesenteric nerve to 109% (Fig. 2C). A further increase in the amplitude and power of the impulses took place during stimulation in a strength of 5 V. The mean amplitude of the renal impulses was not 8.9 mm, the mesenteric 12 mm, and the splenic 8.7 mm, and the corresponding increases in their power were 13, 26, and 42% (Fig. 2D).

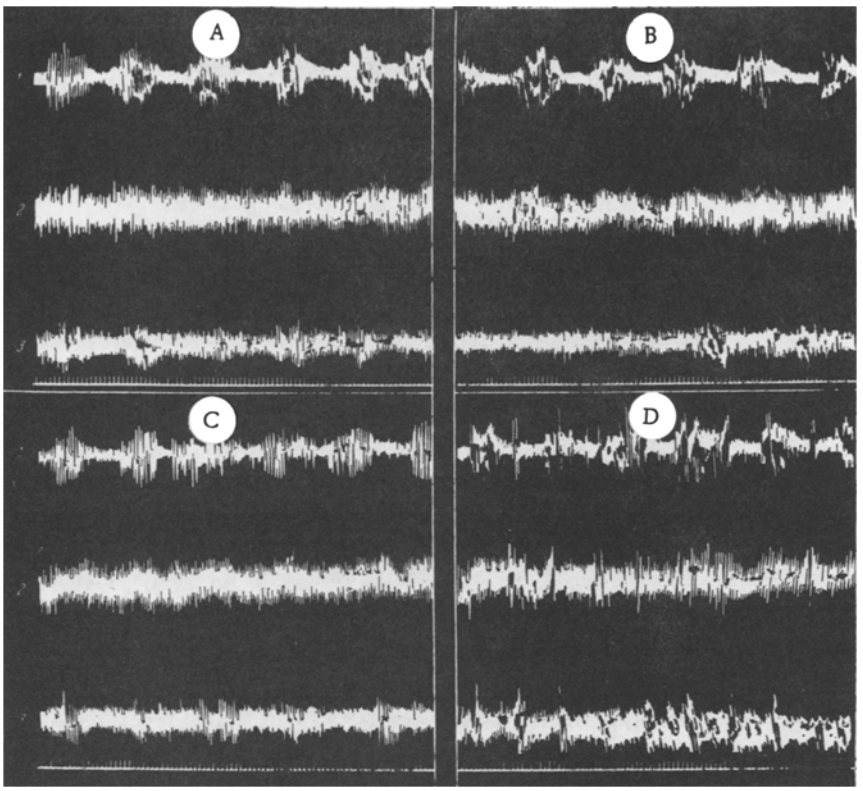

Fig. 2. Changes in the flow of efferent impulses in the renal (1), mesenteric (2), and splenic (3) nerves during stimulation of the peripheral end of the divided greater splanchnic nerve at different strengths (constant frequency 5 cps, duration of stimulating pulse 1 millisec). A) Before stimulation; B) at a strength of 1 V; C) at a strength of 3 V; D) at a strength of 5 V. Time marker 0.02 sec.

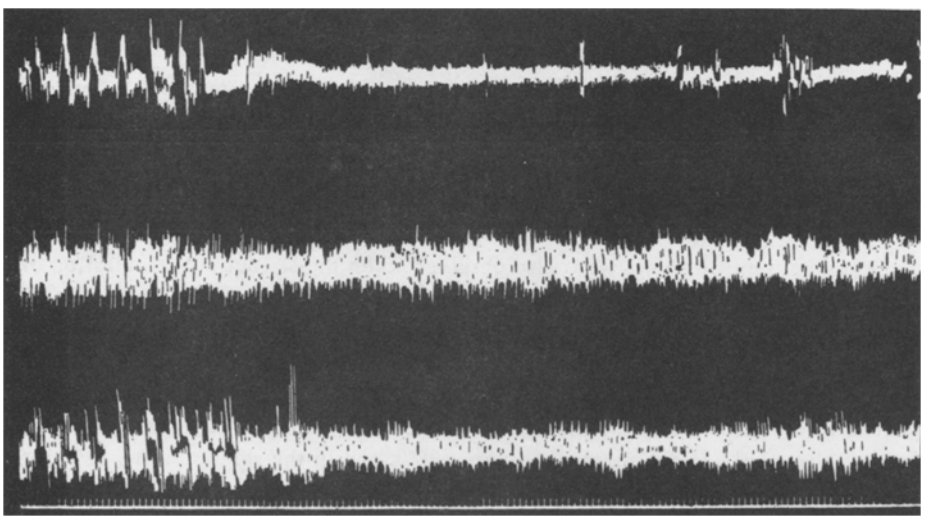

Fig. 3. Weakening of efferent impulses in the renal (1), mesenteric (2), and splenic (3) nerves after cessation of stimulation of the peripheral end of the greater splanchnic nerve at a frequency of 10 cps (strength 2 V, duration of stimulating pulse 1 millisec). Time marker 0.02 sec.

Cessation of the relatively strong and fast stimulation of the peripheral end of the splanchnic nerve was often accompanied by weakening, and sometimes by total disappearance of the impulses in the postganglionic fibers of the renal, mesenteric, and splenic nerves. It is clear from Fig. 3 that cessation of stimulation of the splanchnic nerve in a frequency of 10 cps, a strength of 2 V, and a duration of the stimulating pulse of 1 millisec caused a weakening of the flow of impulses for 1-3 sec. Subsequently the initial impulse activity was gradually restored.

It has been shown [1] that the limiting frequency of the stimulation reproducible by the synapses of the ganglion of the solar plexus without transformation is 15-20/sec. In our experiments, as pointed out above, frequencies of stimulation below this limit were used. However, the results indicate that during the transmission of excitation each individual impulse is not passed across from the preganglionic fibers to the postganglionic; on the contrary the preganglionic impulses modify the intrinsic impulse activity of the postganglionic neurons, and this modification in the activity of the postganglionic elements is dependent on the quantitative parameters of the nervous impulses present in the preganglionic nervous pathways. Our experimental results demonstrate that a change occurs in the background impulse activity of the postganglionic fibers of the splanchnic nerve during stimulation of its preganglionic fibers. Under these circumstances, low frequencies and strengths of stimulation either do not cause significant changes in this activity, or they weaken it, whereas higher frequencies and strengths of stimulation cause an increase in the power of the bursts of impulses directed towards the effector organs.

Having regard to the qualitatively different effects previously obtained on the blood vessels of the abdominal organs, we may suppose that vasodilatation is associated with a weakening of the flow of impulses to the effector organ, whereas vasoconstriction results from an increase in the strength and frequency of the impulse activity. Some support for this hypothesis is given by experiments in which cessation of stimulation of the spanchnic nerve is relatively high frequencies and strengths was followed by disappearance or weakening of the impulses, corresponding to the period of relaxation of the smooth muscle of the vessles. This replacement of a constrictor by a dilator effect was sometimes observed during the recording of the vasomotor reactions of the abdominal organs during stimulation of the peripheral end of the splanchnic nerve.

The hypotheses put forward in this article are confirmed by the results of experiments by B. S. Kulaev and T. S. Lagutina [2, 3-6]. These workers varied the intensity of the afferent flow of impulses and showed that a change in the intensity of the effector impulses corresponds to a change in the vascular tone: in all conditions causing weakening of the efferent impulses, vasodilatation was observed in the region investigated; in conditions causing strengthening of the flow of impulses, vasoconstriction was observed.

It may therefore be considered that vasoconstrictor and vasodilator effects are caused by differences in the intensity of stimulation of the preganglionic fibers of the splanchnic nerve and by corresponding quantitative changes in the final impulse activity in the postganglionic vasomotor fibers.

SUMMARY

Recording of efferent impulsation in the central ends of the mesenteric, renal and splenic nerves has made it possible to establish the presence of a background impulse activity in all three nerves. Following stimulation of the peripheral end of the greater splanchnic nerve the impulse activity in these nerves changed in accordance with the frequency and strength of the stimulation. It may be considered that vasoconstrictor and vasodilator effects are dependent upon the stimulation intensity of preganglionic fibers of the splanchnic nerve, and concomitant quantitative changes in the terminal impulsation of the postganglionic vasomotor fibers.

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