ELECTROPHYSIOLOGICAL INVESTIGATION OF THE FLOW OF IMPULSES IN THE DEPRESSOR NERVE DURING THE ACTION OF IONIZING RADIATION

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In previous experiments on various species of animals (rabbits, cats, dogs) an increase in the tone of the vagus nerve center was observed during the first days after the action of ionizing radiation. One of the ways by which the constant tonic activity of the cardiac center of the vagus nerve is maintained is known to be by a stream of afferent impulses from the interoceptors of the blood vessels, especially of the aorta and carotid sinus. According to M. N. Livanov [3], the initial reactions of the central nervous system to ionizing radiation are mainly dependent on influences from the periphery and above all from the interoceptors of the internal organs. Consequently, the study of the effect of ionizing radiation on the functional state of the receptor zone of the aorta is of great practical as well as theoretical interest.

The afferent impulsation of the aortic nerve in radiation sickness has been the subject of only few investigations. A. N. Balashova [1], for example, observed that in rabbits after whole-body irradiation with γ-rays in a dose of 400 r changes took place in the amplitude and frequency of the action potentials of the depressor nerve, and these changes exhibited a succession of phases. Additional stimulation of the aortic receptor zone of the irradiated rabbit by increasing the oxygen concentration in the inspired air led to the development of paradoxical phenomena and of inhibitory states in this zone. However, the flow of impulses before and after irradiation was not compared by Balashova in the same animal.

The amplitude and frequency of the action potentials of the depressor nerve are known to show considerable individual variation, so that in the present investigation the potentials of the depressor nerve were recorded in the same animal before and after irradiation.

EXPERIMENTAL METHOD

Experiments were carried out on 15 cats and 10 rabbits anesthetized with urethane (1.0-1.5 g/kg intravenously). The potentials were picked up by means of ordinary silver electrodes with a distance of 3-4 mm between the poles, and recorded by a four-beam cathode-ray oscillograph using a type TsBNK amplifier. At the same time as the nerve potentials were recorded, the respiratory movements of the chest, the ECG, the time marker and, in some experiments, the general blood pressure were registered on photographic film.

Before irradiation the flow of impulses was recorded from the central and peripheral ends of the left depressor nerve which had been divided. The animals than received whole-body irradiation on a type RUM-3 apparatus under the following conditions: voltage 180 kV, current 15 mA, filters 0.5 mm Cu and 1 mm Al, focus distance 60 cm, dose rate 18.7 r/min. The total dose received by the cats was 550 r, and by the rabbits 800-1000r. Recordings were taken from the same nerves under the same conditions 10 and 30 min and 1, 2, and 4 h after irradiation.

EXPERIMENTAL RESULTS

The bioelectrical activity in the peripheral end of the depressor nerve of healthy animals, as many workers have shown, is periodic in character: the pressure receptors of the aorta respond to every systolic discharge of blood by volleys of nervous impulses which subside during diastole of the heart; a dicrotic grouping (rhythmic impulsation) is also frequently observed in rabbits at this period.

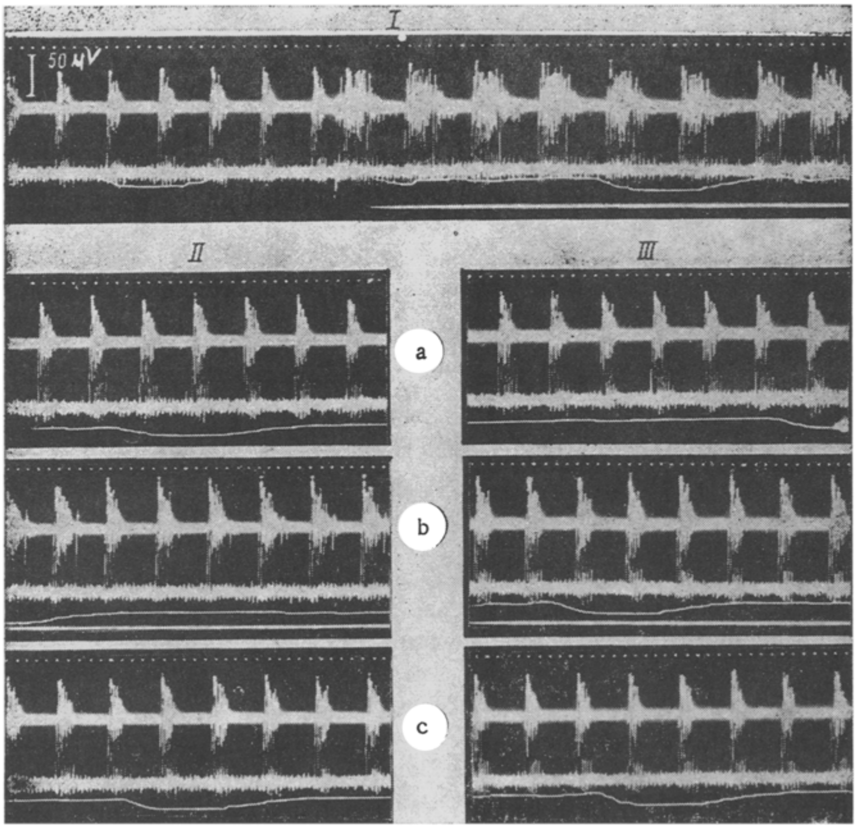

Fig. 1. Changes in the grouped impulses in the peripheral and central segments of the depressor nerve of a cat during the action of adrenalin (I), compression of the ipsilateral (II), and contralateral carotid artery (III). a) background; b) during compression of the artery; c) after removal of the clamp. Significance of the curves (from above down): time marker (0.05 sec); impulses in peripheral segment; impulses in central end; pneumogram, and marker of stimulation.

The flow of impulses in the central end of the depressor nerve has not been studied so completely. Holmes [6] pointed out that the central end of the depressor nerve in cats contains a small number of afferent fibers from the pressure receptors of the carotid sinus. M. I. Vinogradova [2] found that the electrical activity of the fibers in the central end of the aortic nerve in cats is sometimes characterized by clearly defined grouping in rhythm with the pulse. In experiments on cats we also observed a rhythmic flow of impulses, but we also recorded a continuous flow of impulses in which no rhythmic grouping could be distinguished. In the central end of the depressor nerve of rabbits only the continuous flow of impulses could be observed.

These investigations showed that the first type of impulses of electrical activity (in rhythmic groups) in the central end of the depressor nerve in cats is similar in nature to the flow of impulses in the peripheral end. This hypothesis is conformed by the following facts. Firstly, both series of impulses appear almost at identical times in each systolic period (Fig. 2, I), approximately 50 millisec after the QRS complex; secondly, the reaction to the intravenous injection of 0.2 ml of 0.1% adrenalin solution causes a simultaneous increase in the amplitude of the impulses in both segments of the nerve (Fig. 1, I, b). If the common carotid artery were clamped on the left side (on the side from which the impulses were recorded), while the impulses grew stronger in the peripheral end they died away in the central end. Immediately after removal of the clamp the impulses reappeared, and their amplitude was greater than initially. We did not observe any such changes in the impulses when the carotid artery on the opposite side was compressed (Fig. 1, II, III).

Hence it may be supposed that the rhythmic flow of impulses in the central end belongs to the afferent fibers of the vascular receptors lying above the point of compression of the common carotid artery, more expecially in the carotid sinus [6].

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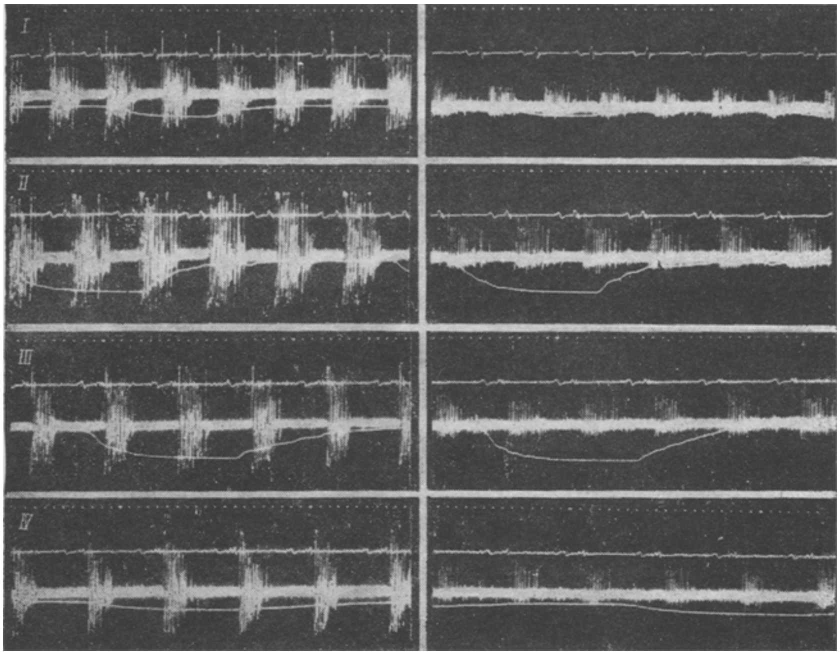

Fig. 2. Changes in the grouped impulses in the peripheral (a) and central (b) segments of the depressor nerve of a cat before irradiation (I) and 10 min (II), 30 min (III), and 1 h (IV) after irradiation. Significance of the curves (from above down): time marker (0.05 sec); ECG; impulses in nerve; pneumogram.

a b

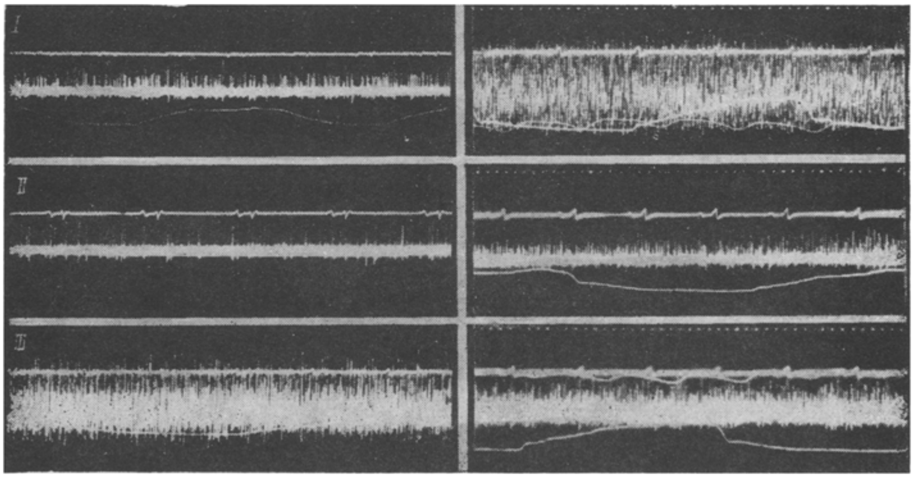

Fig. 3. Changes in the continuous flow of impulses in the central segment of the depressor nerve of a cat before irradiation (I) and 10 min (II) and 1.5 h (III) after irradiation, in association with a low (a) and high (b) background activity. Remainder of legend as in Fig. 2.

For the moment the nature of the continuous flow of impulses in uncertain. According to reports in the literature [5] the neurons of the autonomic efferent fibers of the depressor nerve lie in the ganglion nodosum. These neurons may possible by the source of the second type of impulsation in the central end, although as yet we have no evidence that this suggestion is correct.

Immediately after irradiation the amplitude of the impulses in the peripheral end of the depressor nerve increased in most of the cats and rabbits, after which it fell gradually for a period of 1-2 h (Fig. 2, a).

The changes in the flow of impulses of the first type in the central end were similar to the changes in the impulses in the peripheral end (Fig. 2, b); the impulses of the second type, however, increased in amplitude to an even greater degree immediately after irradiation than the afferent impulses (Fig. 3, a). Meanwhile, if a very high background activity was present, irradiation caused it to die away (Fig. 3, b). At the same time the amplitude of the impulses in the peripheral end increased.

In the rabbits the amplitude of the impulses in the central end of the depressor nerve also increased immediately after irradiation, while in some experiments impulses appeared which were not recorded before irradiation.

In one experiment, besides impulses grouped together in rhythm with the pulse, a continuous flow of impulses was also recorded in the central end of the depressor nerve of a cat. After irradiation these continuous impulses grew so much in amplitude that it was difficult to distinguish the rhythmic groups. Two hours after irradiation the continuous impulses disappeared, but the impulses of the first type persisted. It appears that the neural apparatuses (receptors or neurons) associated with the impulses of the second type are less resistant than the pressure receptors of the arch of the aorta and carotid sinus, and undergo more marked changes after irradiation.

It should be emphasized that not only did the blood pressure level not rise under these circumstances, but that it actually fell. Other workers observed the same. Brooks and Gerstner [4], who discovered a fall in the blood pressure of rabbits, whether anesthetized with urethane or unanesthetized, actually in the course of irradiation concluded that urethane anesthesia does not prevent early hypotension.

The relationships between the flow of impulses in the depressor nerve and the blood pressure are normally stable. If the latter rises the amplitude of the impulses in the depressor nerve increases, and if the pressure rises considerably (for example, after adrenalin) the volleys of nervous impulses may merge to give a continuous rhythm. After irradiation the regulating function of the pressure receptors of the arch of the aorta and carotid sinus is evidently disturbed. As our experiments showed, after irradiation the flow of afferent impulses from these zones increased in amplitude, notwithstanding the fall in blood pressure.

In another series of experiments conducted on rabbits at later periods (on the 7th-8th day after irradiation), an even more marked disturbance of the functional state of these receptors was observed. When the general blood pressure was raised by compression of the carotid arteries, in some cases instead of the expected strengthening of pressure-receptor activity in the depressor nerve, weakening of this activity was observed, and sometimes individual groups of impulses were lost. This fact suggests that in radiation sickness the lability of the pressure receptors of the arch of the aorta is reduced.

Irradiation thus leads to functional changes in the receptor apparatus of the vascular system. This is evidently one of the factors causing changes in the functional state of the vagus nerve center and hemodynamic disorders during the action of ionizing radiation on the body.

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