EFFECT OF RADIATION ON MECHANISM OF TRANSMISSION OF EXCITATION IN GANGLIA OF THE AUTONOMIC NERVOUS SYSTEM

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Local irradiation of the superior cervical and inferior mesenteric sympathetic ganglia in doses of 800-2500 rad caused inhibition of ganglionic transmission (after irradiation in a dose of 800 rad a transient period of facilitation of transmission was observed). The excitability of the presynaptic endings was reduced, the excitability of the cholinergic structures of the ganglion cells to acetylcholine was lowered, the cholinesterase activity of the ganglion tissue was diminished, and the acetylcholine concentration in the tissue was increased.

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Various effects arising in response to whole-body [1, 2, 4, etc.) and to local [3, 5, 8, 10] irradiation in the autonomic nervous system of animals has been described. However, only a few reports have dealt with the immediate action of radiation on the sympathetic ganglion [6, 7], and no attempt has been made to study the disturbances of the mechanism of transmission of nervous impulses in the ganglion.

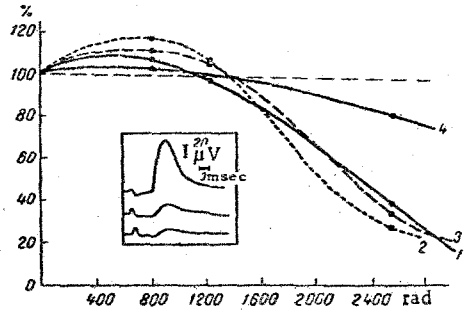

Fig. 1. Dynamics of electrophysiological characteristics of superior cervical sympathetic (SCSG) and inferior mesenteric (IMSG) ganglia of a cat with an increase in the dose of irradiation. 1) Lability; 2) reactivity of cholinergic structures of ganglia to acetylcholine; 3) postactivation potentiation; 4) antidromic responses. Abscissa: dose of irradiation (in rad), ordinate: changes (in percent). Inset: evoked potentials of postganglionic fibers of SCSG (frequency of stimulation 20/sec); top curve before irradiation, middle curve 40 min after irradiation in dose of 800 rad; bottom curve 40 min after irradiation in dose of 2500 rad.

We have studied the main steps of synaptic transmission, including the mediator link, and the functional state of the ganglion cells after exposure of sympathetic ganglia to various doses of local irradiation. The test objects were the superior cervical sympathetic (SCSG) and inferior mesenteric (IMSG) ganglia of the cat.

EXPERIMENTAL METHOD

Experiments were carried out on 30 cats. The preganglionic trunks of the SCSG and IMSG were stimulated by pulses of supramaximal strength and variable frequency. The biopotentials of the postganglionic fibers were recorded for 20-60 min after the end of irradiation. The phenomenon of postactivation potentiation was used as the criterion of the excitatory properties of the presynaptic structures. The state of the cholinergic structures of the ganglion cells was judged from their reaction to acetylcholine (20 μg) which was injected into the inferior mesenteric artery supplying blood to the IMSG. The initial value of the electrophysiological characteristics was taken as 100% and the dynamics of all indices expressed as ratios of their initial value. The results of the investigations were subjected to statistical analysis by the method of correlated series.

Parallel to the electrophysiological investigations the content of acetylcholine and the cholinesterase activity of the

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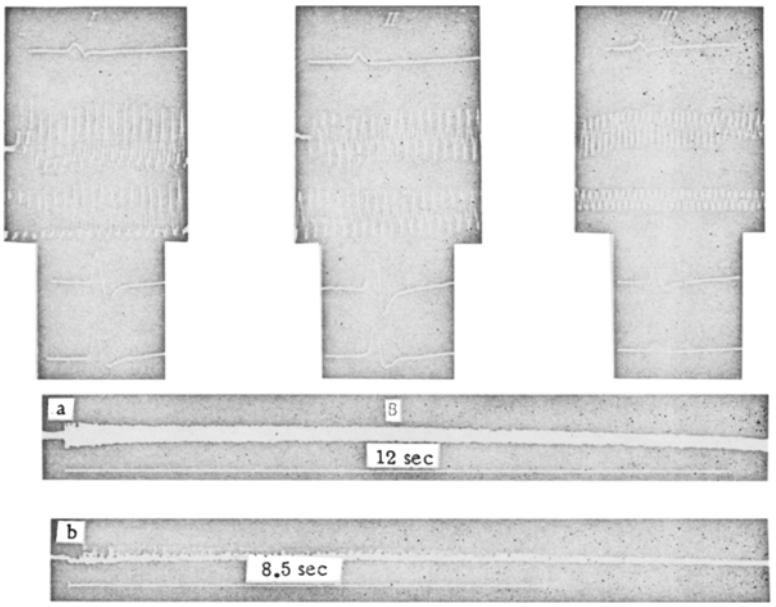

Fig. 2. Postactivation potentiation in SCSG evoked by stimulation for 10 sec at a frequency of 30/sec (A), and potentials of postganglionic fibers of IMSG during stimulation of preganglionic trunk at a frequency of 40/sec (B). In A (from top to bottom): responses before tetanization, during tetanization, and 1 and 30 sec after end of tetanization. I) Before irradiation; II) after irradiation in dose of 800 rad; III) after irradiation in dose of 2500 rad. In B: a) before irradiation; b) after irradiation in dose of 2500 rad. Time from beginning of stimulation until decrease in amplitude by two-thirds of initial value marked beneath oscillograms.

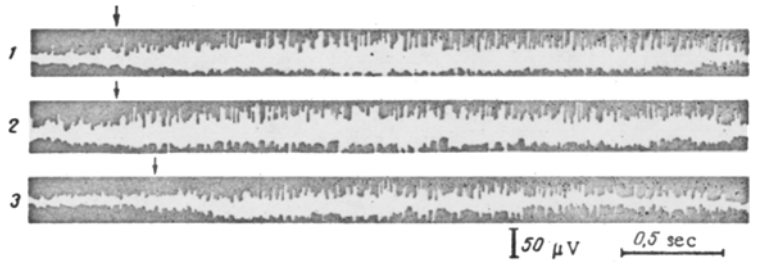

Fig. 3. Bioelectrical activity of IMSG after injection of 20 μg acetylcholine into the inferior mesenteric artery. 1) Control; 2) 20 min after irradiation in dose of 800 rad; 3) 20 min after irradiation in dose of 2500 rad. Moment of injection of acetylcholine indicated by an arrow.

ganglion tissue were determined. The ganglia were removed after doses of irradiation of 800, 1200, and 2500 rad. During investigation of the SCSG, the unirradiated ganglion on the opposite side was used as control. The acetylcholine content in the ganglia was determined by Corsten's method [9]; frog's lungs were used as test objects. Cholinesterase activity was determined by potentiometric titration.

Single local irradiation of the ganglia was carried out on the RUM-11 x-ray apparatus and also by means of β-particles (Sr^{90} β-applicator).

TABLE 1. Effect of Irradiation on Acetylcholine Content and Cholinesterase Activity of Ganglion

Index	Ganglion	Dose of irradiation					
		800 rad		1200 rad		2500 rad	
		Time after irradiation (in min)					
		20	60	20	60	20	60
Cholinesterase activity (in μg/g moist weight)	Control	0.64 ± 0.03	0.61 ± 0.02	0.62 ± 0.01	0.60 ± 0.02	0.63 ± 0.03	0.63 ± 0.04
	Irradiated	0.53 ± 0.02	0.55 ± 0.04	0.52 ± 0.03	0.50 ± 0.04	0.47 ± 0.03	0.43 ± 0.03
Acetylcholine content (in μg/g moist weight)	Control	0.32 ± 0.12	0.33 ± 0.12	0.42 ± 0.14	0.38 ± 0.16	0.13 ± 0.09	0.18 ± 0.03
	Irradiated	1.19 ± 0.48	1.24 ± 0.65	1.36 ± 0.32	1.44 0.29	0.48 ± 0.16	0.71 ± 0.14

EXPERIMENTAL RESULTS

Ionizing radiation caused definite changes in bioelectrical activity of the ganglion fibers. As the dose of irradiation increased, progressive depression of the spontaneous bioelectrical activity of the postganglionic nerve trunks was observed, while the amplitude and frequency of impulses in the preganglionic nerve fibers remained unchanged, indicating that radiation affects synaptic transmission more than conduction along the nerve fiber.

Marked facilitation of ganglionic transmission was observed 20 min after the end of irradiation in a dose of 800 rad, as shown by an increase in the amplitude of the potentials evoked by submaximal stimulation of the preganglionic nerve trunks, and also by an increase in the excitability and frequency characteristics of bioelectrical activity of the ganglia (Fig. 1). After this brief phase of facilitation (10 min), inhibition of ganglionic transmission was observed.

In the case of irradiation in a dose of 1200-2500 rad, deterioration of all electrophysiological indices was observed invariably from the beginning of recording. The excitability fell (threshold increased from 1.26 ± 0.3 to 1.58 ± 0.26 V, lability fell from 70-80 to 40-50 pulses/sec, functional stability fell by 40%), and the scatter of the values of the electrophysiological characteristics increased. Analysis of the functional state of individual synaptic structures revealed a marked decrease in the excitatory properties of the presynaptic endings, as shown by weakening of the post-tetanic activation phenomenon (Fig. 2), and also a decrease in excitability of the cholinergic structures of the ganglion cells to acetylcholine (Fig. 3).

The results of determination of acetylcholine and the cholinesterase activity are given in Table 1, showing that irradiation in a dose of 800-2500 rad increased the acetylcholine content and decreased the cholinesterase activity.

The results of the electrophysiological and biochemical investigations revealed a complex relationship between the various links of synaptic transmission in the autonomic ganglion. Within a certain dose range inactivation of cholinesterase and the increase in acetylcholine content probably do not give rise to an immediate and marked disorganization of the finely balanced process of synaptic transmission. A further increase in the quantity of mediator and inhbition of reactivity of the cholinergic membranes of the ganglion cells produce depression of transmission of nervous impulses through the autonomic ganglion.

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