DIRECT REACTIONS OF THE NERVOUS SYSTEM TO IONIZING RADIATION

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We have previously suggested [8] that ionizing radiation may act as a general, nonspecific stimulus of the nervous system. This suggestion was based on the results of experiments demonstrating the direct reactions of the cerebral cortex and the reaction of the retina of animals to γ-rays emitted by Co^{60}, experiments in which a conditioned reflex was formed to γ-irradiation, and on published data [2,3,5-9,11-17]. The object of the present investigation was to verify this hypothesis.

EXPERIMENTAL METHOD

Acute experiments were carried out on sexually mature chinchilla rabbits to study the electrical activity of the depressor nerve (40 animals), the vagus and sympathetic nerves (in 10 animals each), and the intestinal branch of the splanchnic nerve (3 animals) during the period of exposure to Co γ-rays.

From 10 to 20 min before the beginning of the experiment the sympathetic, vagus, or depressor nerve was dissected in the neck of an unanesthetized rabbit. The approach to the intestinal nerve and the recording of its electrical activity were undertaken in rabbits anesthetized with ether and chloroform. Platinum wire electrodes 0.3-0.5 mm thick were applied to the nerve. The action potentials of the nerves were amplified by means of a four-stage ac amplifier and recorded on a Siemens three-loop (loop No. 5) oscillograph. The background action potentials were recorded usually for 5-10 min, after which the rabbits were totally irradiated with Co γ-rays. The animals were irradiated on an experimental γ-ray apparatus (dose rate 0.5-1.0 r/sec, duration of irradiation 5 min, total dose of radiation 150-300 r). The electrical activity of the nerves was recorded throughout the period of irradiation.

EXPERIMENTAL RESULTS

Control investigations on 10 rabbits showed that keeping the animals in the experimental conditions (without irradiation) for 30 min did not affect the flow of impulses in the nerves or weakened it slightly.

In 57 of 63 rabbits, during irradiation in a total dose of the order of several tens or units of roentgens, changes were observed in the flow of impulses in the vagus, depressor, sympathetic, and intestinal nerves. These changes took the form of an increase in the amplitude and frequency of the action potentials (Figs. 1,2,3), indicating the presence of irritation phenomena in systems connected with the investigated nerves. Further, in approximately half the animals the flow of impulses became continuous in character. Normally the discharges followed each other in groups, but during irradiation impulses were also recorded between the grouped discharges.

In some experiments the strengthened flow of impulses became weaker after cessation of the irradiation, while in others it remained slightly stronger for 5-20 min. We know that autonomic nerves contain, besides efferent fibers, a large number of afferent fibers conveying impulses from the corresponding interoceptors of the internal organs. In order to discover the role of the receptors in these reactions, in eight rabbits the impulses were recorded from the peripheral ends of divided nerves. In this case too, irradiation led to an increase in the amplitude and frequency of the action potentials in the nerves that were studied. This clearly indicates that ionizing radiation creates a state of excitation in the corresponding receptors.

What was responsible for the effect of stimulation of the various receptors in these experimental conditions? The primary chemical action of the radiation was obviously to form H and OH radicals from the excited or ionized

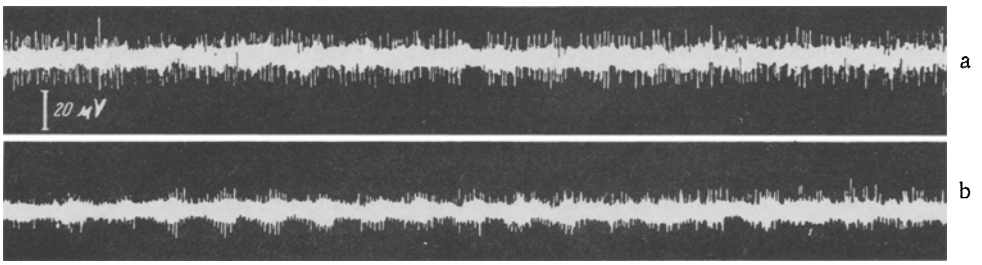

Fig. 1. Changes in the flow of impulses in the depressor nerve of the rabbit during irradiation: a) during irradiation; b) before irradiation.

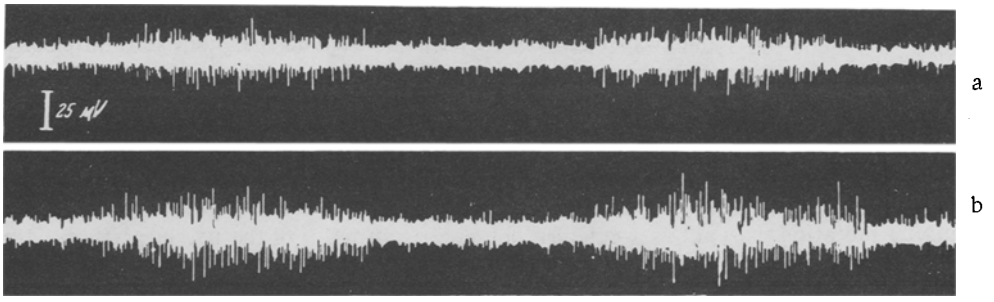

Fig. 2. Changes in the flow of impulses in the cervical sympathetic nerve of a rabbit during irradiation; a) before irradiation; b) during irradiation.

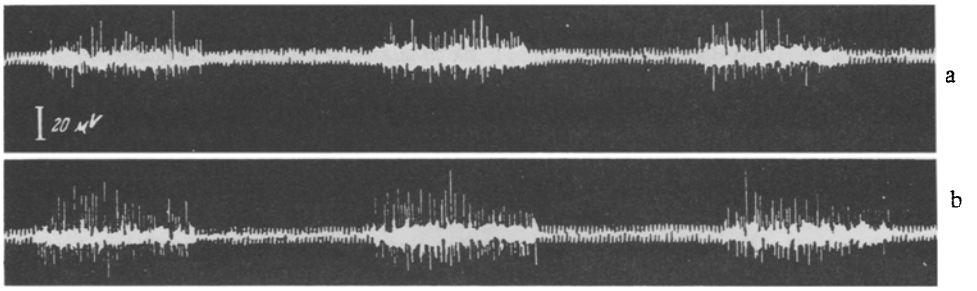

Fig. 3. Changes in the flow of impulses in the intestinal branch of the splanchnic nerve of a rabbit during irradiation; a) before irradiation; b) during irradiation.

water molecules. Free H and OH radicals have unsaturated valences, and therefore possess extremely high chemical activity, and are capable of reacting with any substance, causing oxidation or reduction. This leads to the formation of molecules of the H_2O_2 type, possessing marked oxidative properties.

The interaction between the active products of radiolysis and the biomolecules of the animal organism may modify their structure greatly or even destroy them completely. At the same time it is possible that active products may be formed which act as catalysts of biological reactions. On these grounds it may be supposed that during the action of radiation on the animal organism, in certain conditions stimulation of chemoreceptors may take place. It must be pointed out that an important role in the mechanism of the action of radiation as a stimulus is played by the ability of radiation to cause depolarization phenomena in excitable structures [1].

The most widely accepted theory of excitation, the membrane theory, takes for its starting point the fact that the onset of excitation is based on changes in the permeability of the membrane, which becomes permeable to anions. Whereas before stimulation of the cell its surface is positively charged, as a result of the escape of anions it becomes negatively charged, i.e., it is depolarized. Under these circumstances potassium, no longer held electrostatically by anions, leaves the cell to some extent on account of its lower concentration in the surrounding medium. The process of depolarization is the factor causing the onset of excitation.

What are the facts in radiobiology providing evidence of the depolarizing action of ionizing radiation? The increase in permeability caused by irradiation if firmly established. Meanwhile, it has been found [10] that potassium cations leave irradiated muscle tissue for the surrounding medium.

More direct proof of the depolarizing action of radiation on excitable structures has been obtained. It has been found [4,10] that after irradiation of a muscle in a dose of 100-1000 r an injury potential develops, as shown by the appearance of a potential difference between the irradiated and intact areas of the muscle. V. A. Muzheev stresses that the injury potential sometimes not only does not disappear after irradiation, but continues to increase. This distinguished ionizing radiation sharply from many other known irritants.

Our investigations also revealed an increased flow of impulses in the nerves for a short period after irradiation. The increased excitability of the receptors may also be regarded evidently as the result of depolarization phenomena. As a result of the increase in the excitability of the various analyzer systems by radiation, adequate stimuli which were subthreshold before irradiation may become superthreshold after irradiation and may evoke a reaction of one of the analyzers. This was confirmed by our experiments in which we observed that the excitability of the cutaneous nerves to electrical stimulation may be increased during irradiation.

Analysis of the mechanism of the action of ionizing radiation as a stimulus of the nervous system must take into account the following fact. The action of radiation on all the organs and systems of the body may lead to changes in their structure and function, which in turn may cause a reaction of the corresponding receptors.

Hence, ionizing radiation may act as a general, nonspecific stimulus of the nervous system. Impulses arising in different receptor fields under the influence of radiation do not have the significance of true signals and do not help to ensure the constancy of the internal milieu of the organism (homeostasis).

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