CHANGES IN THE SYNAPTIC ENDINGS ON NERVE CELLS AND ON THE CAPILLARY WALLS OF THE SPINAL CORD IN DOGS WITH ACUTE RADIATION SICKNESS

I. D. Lev

Department of Normal Anatomy (Head—Corresponding Member AMN SSSR Prof. B. A. Dolgo-Saburov*), S. M. Kirov Order of Lenin Military Medical Academy, Leningrad

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In recent years the physiological and clinical observations indicating the high sensitivity of the nervous system to the influence of ionizing radiation have been augmented by morphological data.

Many facts demonstrating the injury to the nerve cells of various divisions of the brain, the spinal and sympathetic ganglia, the receptors and nerve fibers have been presented by V. V. Portugalov [13] and co-workers.

A. D. Zurabashvili and B. R. Naneishvili [8] studied the stage of certain divisions of the brain and spinal cord of irradiated dogs and monkeys and concluded that the central nervous system is very sensitive to x rays. They found hyperimpregnation of the synaptic structures, which they called "irritation."

By investigating the spinal cord of rats irradiated with a dose of 450-600r, we [11] found a series of reactive changes (hypertrophy, destruction) of the axo-somatic, axo-dendritic and axo-vasal (to use Dolgo-Saburov's terminology [1-7]) synaptic structures. Intact synaptic formations were also found at the same time, a feature which depended, in our opinion, on their initial functional state, and was an expression of the plastic properties of the nervous system.

The widespread involvement of the nervous system (the brain and spinal cord, the spinal ganglia) in the pathological process of radiation sickness was reported by V. P. Kurkovskii [9], who singled out in particular the vascular lesions (hemorrhages, diapedesis).

The injurious action of whole-body and local irradiation on nerve tissue has also been shown by several foreigh workers (Hicks and Montgomery [19], Arnold, et al., [16], McLaurin and Bailey [20], Bering and Bailey [17]).

The changes in the synaptic structures on the bodies and processes of nerve cells of irradiated animals, however, have been studied only by few workers [8,11].

In the present investigation we studied the changes in the axo-somatic, axo-dendritic and, in particular, the axo-vasal synaptic endings in the spinal cord of dogs suffering from acute radiation sickness.

* Deceased.

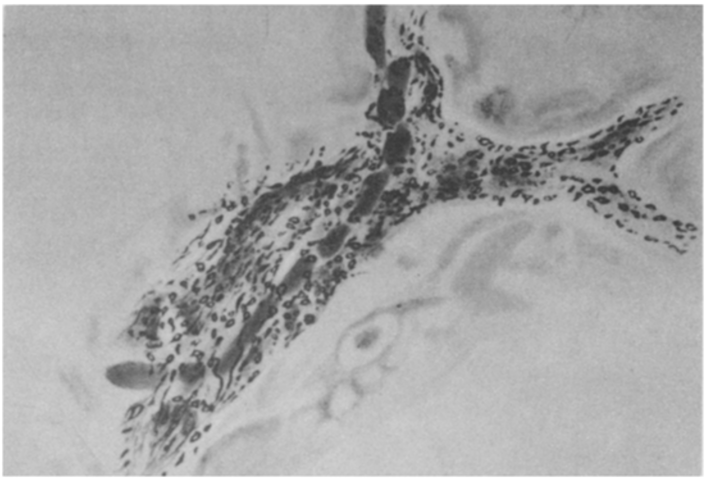

Fig. 1. Lumbar enlargement of the spinal cord. Synaptic structures on the body and processes of the nerve cell and on the walls of a capillary. Impregnated by the Golgi-Deinek method. Immersion.

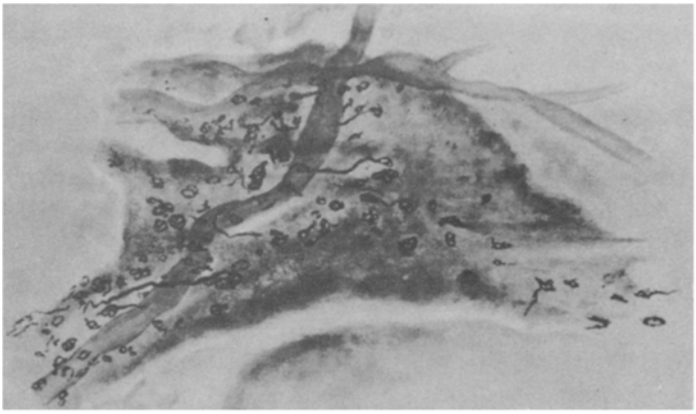

Fig. 2. Cervical enlargement of the spinal cord. Hypertrophic synaptic structures on the body and processes of the nerve cell and on the capillary walls. Impregnation by the Golgi-Deinek method. Immersion.

METHOD

The material used in the investigation consisted of the spinal cord of five adult dogs subjected to irradiation in a dose of 450 r (185 kv, 15 ma, filter 0.5 mm Cu, skin-focus distance 120 cm). The state of acute radiation sickness was diagnosed by blood counts and clinicophysiological observations. The animals died on the 9th-11th day after irradiation, i.e., at the height of the disease.

Fragments of spinal cord were taken from the cervical and lumbar enlargements and also from the thoracic segment, and were treated by the Golgi-Deinek method, and embedded in celloidin. Sections were cut to a thickness of 22-24 μ in three mutually perpendicular directions, and the capillaries were counterstained with acid fuchsin.

RESULTS

The grey matter in the region of the cervical and lumbar enlargements is known to be the richest in nerve cells; here there is correspondingly a more intensive development of the network of blood vessels, in close topo-

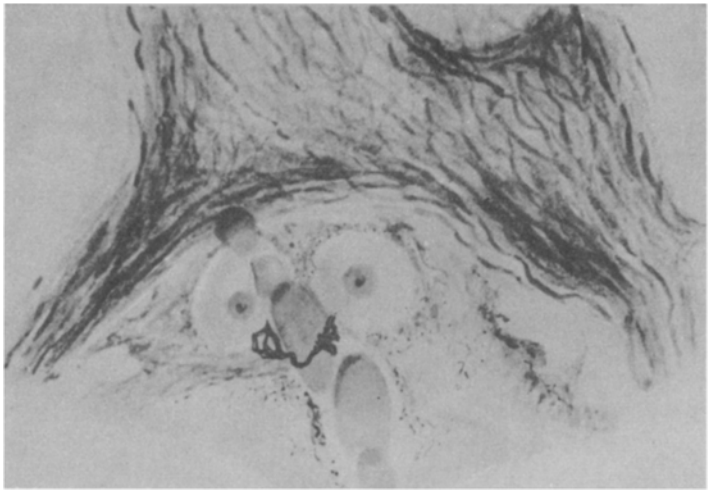

Fig. 3. Lumbar enlargement of the spinal cord. Hypertrophy and commencing destruction of the synaptic ending in the wall of a capillary. Impregnation by the Golgi-Deinek method. Immersion.

graphical relationship to the nerve cells [10]. In the plane of the transverse section of the grey matter a larger number of vessels is to be found within the limits of the motor nuclei of the anterior horns. We therefore concentrated our attention in particular on the study of the reactive changes in the synaptic structures, especially the axo-vasal, in these divisions of the grey matter of the spinal cord.

The reaction of the synaptic structures on the nerve cells and surrounding capillaries to ionizing radiation takes various forms: an increase in their argyrophilia, changes in their shape (deformation), hypertrophy, signs of destruction and disintegration. Synaptic structures began to show themselves in numbers not observed in normal conditions. Synaptic loops or, more rarely, boutons, sometimes supplied with small afferent fibers, were literally strewn over the body of the nerve cell and its process, and were distributed in the walls of the capillaries surrounding the neuron. These capillaries bore the most varied topographical relationships to the nerve cells, sometimes penetrating their body (Fig. 1) or surrounding the root of a dendrite, forming a wide plate or lamella. Another indication of the increased argyrophilia was the abundance of visible presynaptic fibers, often convoluted and with varicosities.

It is not yet possible to point to any morphological features distinguishing the synaptic structures distributed on the nerve cells from the analogous structures on the capillary walls. This fact may be interpreted as a sign of the common origin of these contact apparatuses, which is also suggested by the pattern of division of the afferent nerve fiber into two branches, terminating separately on the neuron and the capillary wall [7], i.e., the multiplication of the nerve conductors. Loops are also found, joined together in dumb-bell fashion.

In the dogs suffering from acute radiation sickness deformed synaptic loops were very often found; distinguished by their polymorphism (round, oval, rhomboidal, triangular, quadrilateral, with irregular outlines and so on). These changes affected both axo-somatic, axo-dendritic and axo-vasal synaptic structures (Fig. 2).

Another type of reaction is hypertrophy of the contact apparatuses. In these cases a sharp increase in the diameter of the loops could be observed (from 2 to 10 times) over their original size, their outline became thickened and the loops themselves more widely separated. This was usually associated with a reduction in the total number of synaptic structures on the neuron. Deformation and hypertrophy also affected the axo-vasal synaptic structures (Fig. 2); thickened and convoluted afferent fibers were often in this situation.

The destruction which affected part of the contact apparatuses was shown by loss of continuity of the loops, the appearance of vascuoles in the boutons, and by disintegration of the terminal structures (Fig. 3). The final stage of this process was the accumulation of granules, forming figures bearing a distant resemblance to loops with afferent fibers.

The findings described, in our opinion, reflect different stages of the reactive condition of the synaptic structures in response to the action of an extremely inadequate stimulus, and are not the expression of the "vital process of development and death of the ending," first described by Weber in 1945, and recently by Charvat [18].

The deformation and destruction of the contact apparatuses led to some decrease in their total number. Nevertheless, the increase in the number of synaptic structures which we observed as a result of the enhanced argyrophilia cannot be regarded as merely the more complete manifestation of already existing structures. In the present state of our knowledge it may be postulated that under the influence of ionizing radiation excessive growth of synaptic structures—i.e., hyperplasia—may take place. Grounds for this hypothesis are provided by the fact that new processes and new branches and endings develop in the course of activity of the neuron. This may also occur in radiation sickness, which leads, as we know, not only to degeneration of the various structures, but also to their possible regeneration [12].

Side by side with synaptic structures on the neurons and capillaries exhibiting the described changes, unchanged structures were often encountered. This is not surprising, for the radiosensitivity of both the nervous and the contact apparatuses of communication depends on their functional state, which may vary.

The ability of the irradiated animal (almost to the time of death from acute radiation sickness) to perform locomotor and other activities involving the participation of the nerve cells of the spinal cord suggests that the compensatory mechanisms of the nervous system are intact. The plasticity of these mechanisms may evidently be dependent on the presence of intact neurons, with synaptic structures on them and on the capillaries, among the damaged neurons.

It may be concluded from these investigations that reactive changes are observed in the axo-somatic, axo-dendritic and axo-vasal structures in the spinal cord of dogs suffering from acute radiation sickness.

These reactive changes appear in various forms: the affinity of the synaptic structures for silver salts is increased (argyrophilia), and deformation, hypertrophy and even destruction of part of the synaptic structures take place. Some synaptic structures, remaining morphologically intact, evidently retain their functional powers and enable the compensatory properties of the nervous system to be brought into play in irradiated animals.

SUMMARY

In dogs suffering from acute radiation sickness (the irradiation dose being 450 r) the reaction of synaptic formations in cells and capillary walls consists of two phenomena: a) increased affinity of the synaptic structure for silver (increased argyrophilia); they are detected in numbers, greater than under normal conditions; b) deformation, hypertrophy and destruction of synaptic formations.

The picture of the reactively changed synaptic endings is variable. The presence of intact structures on neurons and capillaries points to the plasticity of the nervous system providing an optimal level of vital processes under given conditions of existence.

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