EARLY ULTRASTRUCTURAL CHANGES IN AXODENDRITIC SYNAPSES OF THE RAT SENSOMOTOR CORTEX AFTER HIGH DOSES OF FAST NEUTRON IRRADIATION

A. A. Abdrakhmanov

UDC 616-001.28-036.11-07:616.831.091

KEY WORDS: sensomotor cortex, synaptic ultrastructure, neutron irradiation, early post-radiation changes.

In the early stages after whole-body irradiation with high doses of ionizing radiation ultrastructural changes associated with changes in metabolic activity and function of neurons take place in the CNS [1, 2, 5, 8].

This paper describes the results of a study of ultrastructural changes in interneuronal synapses (SY), which develop during the 24 h after irradiation and which largely determine the character of subsequent development of the pathological process.

EXPERIMENTAL METHOD

Male Wistar rats weighing 180-210 g were subjected to whole-body irradiation with fast neutrons in the vertical channel of a VVR/M reactor in a dose of 10 Gy, with a total dose range of 0.35 Gy/min. Ionization chambers were used for dosimetry [6]. The animals were killed by decapitation 15 min and 1, 3, 6, and 24 h after irradiation (5 rats in each experimental group). Control animals (5 rats) were subjected to "mock" irradiation. Pieces of brain tissue from the sensomotor cortex were treated by the usual method [1]. Ultrathin sections through layer V of the cortex were examined in JEM-100B (Japan) and Tesla BS-613 (Czechoslovakia) electron microscopes. Morphometric analysis of the ultrastructure of the axodendritic SY was undertaken on electron micrographs with a final magnification of 45,000, by the method of [4]. Altogether 60 SY were studied from each group of animals. The significance of differences between the numerical results was estimated by Student's t test.

EXPERIMENTAL RESULTS

The ultrastructure of SY 15 days after irradiation showed no change in the electron-optical density of the presynaptic endings (PSE) and by well marked "active" zones (AZ). Most mitochondria (M) in PSE had increased electron-optical density and the ultrastructure of their cristae was preserved. The total number of synaptic vesicles (SV) was greater than in the control (Fig. 1a; Table 1). The degree of concentration of vesicles was increased around AZ, and the number and length of AZ and the width of the postsynaptic condensation (PSC). Most SV were pale, round agranular vesicles, but single granular vesicles also were present. The ultrastructure of the postsynaptic part of the interneuronal synapses (dendrites, spines) showed no appreciable changes.

During the first 6 h after irradiation the cytoplasmic matrix of PSE became lighter and the M in them swelled (Fig. 1b). There were fewer SV in PSE (Table 1) and the vesicles were either uniformly distributed or they formed small groups away from the presynaptic membrane. The degree of concentration of SV near AZ and also the proportion of the area of PSE occupied by SV were reduced. Individual vesicles were reduced in size, the vesicles were oval in shape, and some of them had indistinct outlines. In some PSE, although all components of SY were present, there were no SV. Electron-dense finely granular material was observed in PSE of this kind, and according to some workers [3] this may be the result of disintegration of SV. Although the length of AZ remained the same as in the control, the width of PSC was

Department of Morphology, Institute of Experimental Medicine, Academy of Medical Sciences of the USSR, Leningrad. Radiobiology Group, Institute of Nuclear Physics, Academy of Sciences of the Kazakh SSR, Alma-Ata. (Presented by Academician of the Academy of Medical Sciences of the USSSR D. S. Sarkisov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 104, No. 12, pp. 734-736, December, 1987. Original article submitted December 10, 1986.

0007-4888/87/0012-1743$12.50

TABLE 1. Morphometric Parameters of Postradiation Changes in Ultrastructure of Axodendritic SY in Rat Sensomotor Cortex (in conventional units; $X \pm S_x^-$)

Parameter studied	Control	Time after irradiation, h				
		0,25	1	3	6	24
Number of SV in PSE	1,94±0,17	3,00±0,21***	1,67±0,15	1,78±0,19	1,28±0,08**	2,28±0,16
Degree of concentration of SV near AZ	1,67±0,16	2,07±0,11*	1,57±0,13	1,67±0,17	1,27±0,07*	1,71±0,07
Action of area of terminal occupied by SV	2,06±0,15	2,40±0,13	1,43±0,12**	1,63±0,15*	1,30±0,11***	1,74±0,10
Number of AZ	1,06±0,05	1,40±0,13*	1,25±0,09	1,22±0,11	1,10±0,05	1,05±0,04
Length of AZ	1,28±0,11	1,93±0,15***	1,29±0,09	1,33±0,11	1,33±0,10	1,36±0,09
Width of PSC	1,67±0,14	2,33±0,12***	1,29±0,08*	1,20±0,07**	1,21±0,07**	1,21±0,05**
Number of M in PSE	0,28±0,13	0,73±0,30	0,57±0,27	0,56±0,17	0,24±0,08	0,26±0,07
Area of cross section of terminal	1,44±0,20	2,00±0,27	1,67±0,21	1,89±0,20	1,82±0,21	1,86±0,12

Legend. *p < 0.05, **p < 0.01, ***p < 0.001, compared with control.

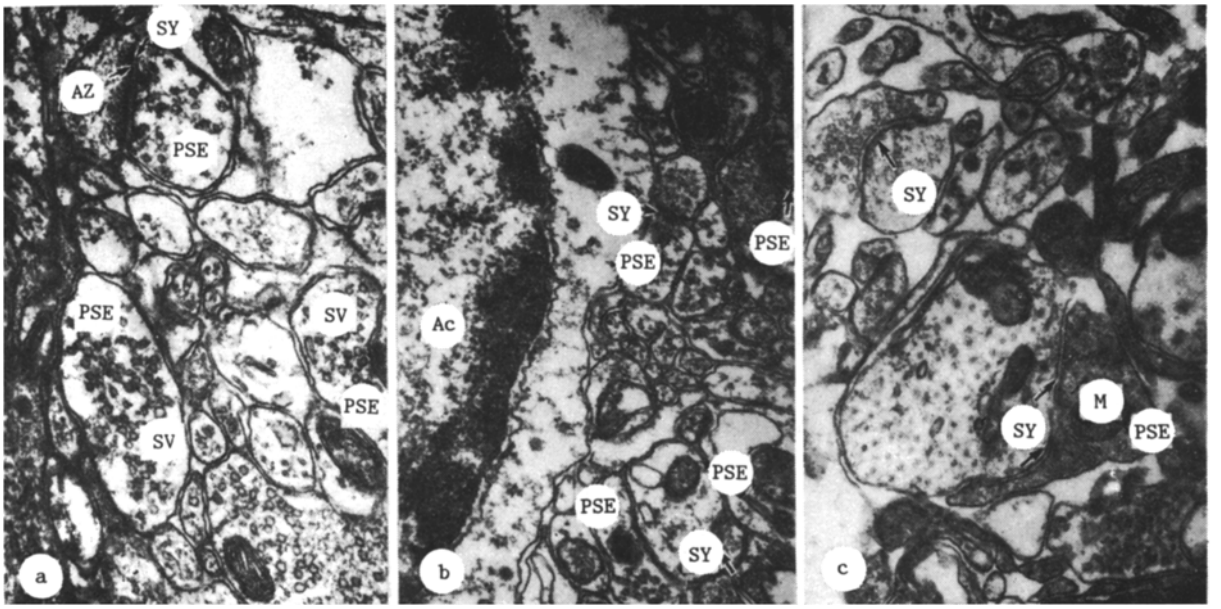

Fig. 1. Ultrastructure of axodendritic SY in rat sensomotor cortex soon after whole-body neutron irradiation in a dose of 10 Gy. a) 15 min (34,000 ×); b) 6 h (26,000 ×); c) 24 h (30,000 ×) after irradiation. Ac) Astrocyte.

reduced (Table 1). Mitochondria with signs of swelling appeared in PSE, and some of them showed fragmentation of their cristae and vacuolation. Single vacuoles appeared in a few PSE. The matrix of the dendrites was more translucent.

After 24 h two types of changes in the ultrastructure of PSE were observed (Fig. 1c). In most of them the electron-optical density was reduced (the "pale" type of reaction). Some M showed signs of swelling and fragmentation of their cristae, and vacuolation of individual M took place. Although the total number of SV in PSE and the degree of concentration of SV near AZ were greater than at the previous time of observation, the length of AZ and width of PSC were not greater than 6 h after irradiation (Table 1). Individual PSE contained vacuoles of various sizes, bounded by an elementary membrane. Other PSE showed condensation of their cytoplasm with increased electron-optical density (the "dark" type of reaction). The SY were surrounded by swollen processes of astrocytes and the intercellular spaces in the neuropil were widened and deformed.

After irradiation, ultrastructural changes in interneuronal SY thus follow a definite time course, marked by an initial (after 15 min) increase in the number of SV in PSE, an increase in the degree of concentration of SV near AZ, and an increase in the length of AZ and the width of PSC. The quantitative ultrastructural changes observed in SY, according to some authorities [3, 4, 8, 9], are evidence of activation of synaptic processes. During later

observations, these quantitative parameters gradually diminish (Table 1). The character of the ultrastructural changes in SY during this period can be regarded as the morphological basis of reduction of synaptic activity [3, 7, 9].

On the whole, the ultrastructural changes observed in SY after irradiation can be classed as nonspecific and include various forms of pathological transformation of PSE similar to those described by other workers after exposure of the CNS to various harmful factors [3].

The results may be evidence that changes in the condition of function of SY take place after irradiation. In particular, the absence of SV in some SCE indicate a reduction in the total number of functioning SY.

At all times of the investigation, besides SY exhibiting ultrastructural changes, others were found which were either intact or only very slightly changed. This indicates that interneuronal SY differ in their sensitivity to the action of ionizing radiation, possibly on account of regional or chemical differences between, or differences in the type of nerve cells, their processes, and synapses.

Although most axodendritic SY are highly sensitive to the action of neutron irradiation, as shown by their early ultrastructural changes, as a whole they also possess definite resistance to the action of this factor (the absence of gross destructive changes in SY at all times of observation). It is evidently this feature which determines the morphological basis of the early response of the CNS to irradiation.

LITERATURE CITED

1. A. A. Abdrakhmanov, A. A. Kachurin, V. F. Mashanskii, et al., Radiobiologiya, 25, No. 3, 338 (1985).
2. A. A. Abdrakhmanov, A. A. Kachurin, V. F. Mashanskii, et al., Byull. Éksp. Biol. Med., No. 5, 622 (1985).
3. N. N. Bogolepov, Ultrastructure of Synapses under Normal and Pathological Conditions [in Russian], Moscow (1975).
4. E. V. Loseva and S. B. Stefanov, Byull. Éksp. Biol. Med., No. 5, 112 (1983).
5. A. G. Sverdlov, Biological Action of Neutrons and Chemical Protection [in Russian], Leningrad (1974).
6. V. P. Tumanov, Arkh. Patol., 36, No. 9, 32 (1984).
7. K. Akert, M. Cuenod, and H. Moor, Brain Res., 25, No. 2, 255 (1971).
8. F. E. D'Amelio, L. M. Kraft, E. D. D'Amelio, et al., J. Hirnforsch., 24, No. 5, 479 (1983).
9. M. Gavelova and T. Badonic, Z. mikr.-anat. Forsch., 98, No. 2, 277 (1984).