STRUCTURAL CHANGES IN THE CENTRAL NERVOUS SYSTEM UNDER THE INFLUENCE OF A PERMANENT MAGNETIC FIELD

M. S. Abdullakhozhdaeva and S. R. Razykov

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An urgent problem in modern magnetobiology is the study of the effect of permanent magnetic fields (PMF) on CNS. Its urgency is dictated by the necessity of an up-to-date evaluation of the biological action of both natural and artificial magnetic fields. Neurophysiological investigations have shown that magnetic fields alter the electrical activity of the brain and disturb processes of skill formation and processes of information storage and recall in the CNS [8, 9]. The study of the neurological status of persons exposed for long times to magnetic fields has revealed disturbances of function, clinical manifestations of which can be reduced to three symptom-complexes: 1) a peripheral vasovegetative syndrome; 2) an asthenovegetative syndrome; 3) a mixed syndrome [5]. However, the morphological substrate of these physiological disturbances in the CNS under the influence of PMF has been inadequately studied [1, 2, 7]. Many matters connected with the mechanism of action of the PMF on the CNS remained unexplained.

This paper describes the results of a study of the response of neurons, astrocytes, and synapses of the postcentral and precentral areas of the rat cerebral cortex during exposure to PMF, for these microstructures are ascribed an important role in the integrative activity of the CNS, in processes of distribution and storage of incoming information.

EXPERIMENTAL METHOD

Experiments were carried out on 48 male albino rats weighing 200-250 g. The animals were exposed to a PMF once for 1 h (group 1) or repeatedly, for 1 h daily for 15 and 30 days altogether (groups 2 and 3 respectively). Animals of group 4 were killed 10 days after the 30th exposure to PMF. The control group (5) consisted of eight intact animals. The induction of the PMF was chosen to be 50 mT, which is that most frequently found under production conditions. Material for electron microscopy was fixed by perfusion with glutaraldehyde followed by postfixation in OsO_4, then dehydrated and embedded in Epon by the usual method. Sections were cut on the LKB-3 ultramicrotome and examined in the ÉMV-100L electron microscope. A three-dimensional stereometric analysis was carried out on the basis of photomicrographs, using a linear integration system [3, 4, 6]. The arithmetic mean volume of mitochondria of the rough endoplasmic reticulum (RER) and of the lamellar apparatus (LA) was calculated (Table 1).

EXPERIMENTAL RESULTS

Electron-microscopic study of the cerebral cortex of rats exposed to PMF showed that structural changes are observed within a few hours of exposure in neurons, astrocytes, and synapses, and their intensity increases with the frequency of exposure. For instance, after a single exposure to PMF changes which can be characterized as reactive were found in microstructures of the zones studied. In neurons there was an increase in area of the karyoplasm on account of invagination of the nuclear membrane, together with widening of the nuclear pores, hypertrophy of the nucleolus, and also moderate swelling of the mitochondria and hyperplasia of membrane profiles of RER and LA, which was confirmed by the significant increase in volume of these organelles (Table 1). In the astrocytes moderate swelling of the nucleus and fragmentation and ectopia of the nucleolus were observed. Increased osmiophilia of the active sites was found in the axodendritic synapses of both zones.

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TABLE 1. Stereometric Characteristics of Organelles in Neurons of Precentral (Pre) and Postcentral (Post) Cortical Areas of Rats Exposed to PMF in a Dose of 50 mT (M ± σ, %)

Group of animals	Area	V_M	V_{RER}	V_{LA}
1.	Post	20,17±3,93 (7,86)	22,61±4,03 (8,06)	10,83±3,04 (6,09)
	Pre	21,82±3,98 (7,87)	19,76±3,82 (7,65)	9,61±2,89 (5,78)
2.	Post	25,73±4,28 (8,56)	22,37±4,07 (8,16)	15,14±3,51 (7,02)
	Pre	25,86±4,29 (8,55)	20,36±3,96 (7,89)	13,61±3,35 (6,72)
3.	Post	31,36±4,55 (9,09)	24,18±4,19 (8,39)	13,71±3,37 (6,74)
	Pre	32,43±4,59 (10,27)	22,65±4,10 (8,31)	12,63±3,26 (6,31)
4.	Post	19,75±3,90 (7,80)	21,13±4,00 (8,00)	10,05±2,94 (5,89)
	Pre	20,14±3,93 (7,81)	19,81±3,91 (7,80)	9,56±2,88 (5,76)
5. (control)	Post	18,21±3,74 (7,54)	20,43±3,96 (7,83)	11,74±3,11 (6,23)
	Pre	19,67±3,86 (7,83)	17,32±3,71 (7,45)	8,58 ± 2,75 (5,56)

Note. V_M) Volume of mitochondria; V_{RER}) volume of organelles of rough endoplasmic reticulum; V_{LA}) volume of organelles of lamellar apparatus. Absolute error of measurements shown in parentheses.

After 15 exposures to PMF swelling of the nucleus was observed in individual cortical neurons. Swollen mitochondria with lysis of their cristae and translucency of the matrix could be seen in the cytoplasm (Fig. 1). There was a marked increase in volume of the organelles. Changes in the astrocytes (swelling of the nucleus, a decrease in the number of membrane profiles of the RER, widening of the profiles, swelling of mitochondria with lipoid degeneration of some of them) indicate a marked reaction of the astrocytes to 15 exposures to PMF. Condensation of synaptic vesicles near the presynaptic terminal and irregular thickening of the post-synaptic membrane were observed in the synapses.

After 30 exposures to PMF changes indicating lowering of functional activity were found in both neurons and astrocytes. In nerve cells, for instance, swelling of the nucleus was observed. The RER consisted of single shortened tubules, disorganization was observed in the mitochondria, and in some of them lysis of the cristae and translucency of the matrix were visible (Fig. 2). Many lipofuscin granules were seen in the cytoplasm of the astrocytes (Fig. 3).

The active zone of the synapses was reduced in size, synaptic vesicles were fewer in number, and they were undergoing aggregation.

On the whole, if the ultrastructural changes in neurons and astrocytes are compared, it will be noted that the astrocytes began to respond to the magnetic fields after neurons, but

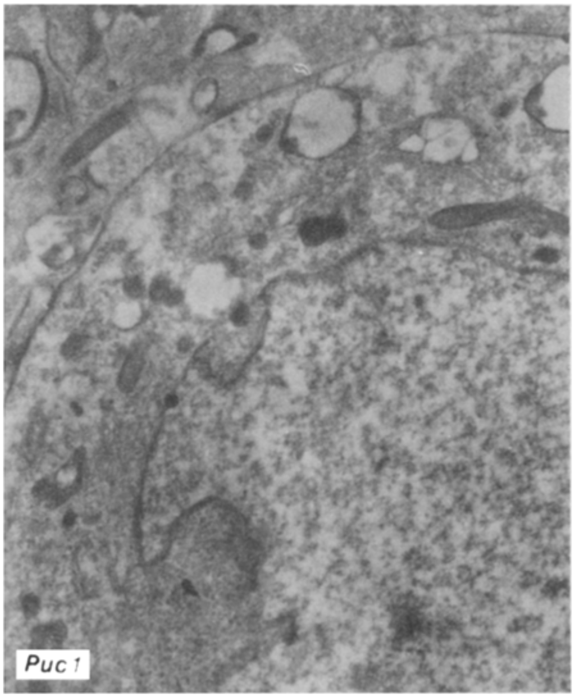

Fig. 1. Swelling of mitochondria with focal and total lysis of cristae, marked hypertrophy and hyperplasia of elements of LA in cytoplasm of cortical neurons (15 exposures to PMF; 40,000×).

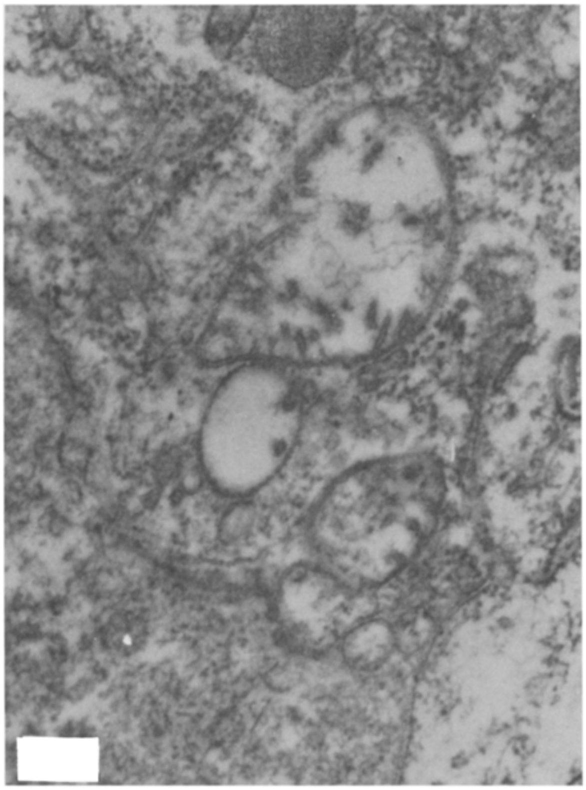

Fig. 2

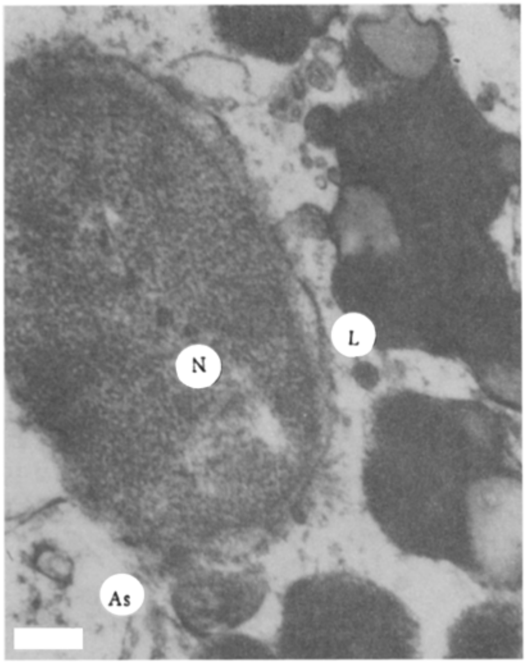

Fig. 3

Fig. 2. Mitochondria in state of swelling with disorganization of cristae; lysis developing in individual cristae (30 exposures to PMF; 50,000×).

Fig. 3. Marked increase in number of lysosomes (L) and lipofuscin bodies in astrocytes (As) (30 exposures to PMF; 60,000×).

the degree of dystrophic changes in them was quite severe. In these investigations exposure to PMF once and 15 times led to the development of structural changes, which lie at the basis of the increased functional activity of the microstructures described above, whereas 30 exposures led to structural changes indicating a disturbance of this activity.

The results of the study of reversibility of the structural changes 10 days after exposure to PMF show the development of marked repair processes, restoring the normal ultrastructures of the organelles and their relative volumes (Table 1), evidence of the high capacity of the intracellular regenerative mechanisms in the CNS.

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