STRUCTURAL AND FUNCTIONAL CHANGES IN THALAMIC RELAY NUCLEI IN SENSORY DEPRIVATION

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The problem of resistance of brain centers under conditions of sensory deprivation is an urgent task in both experimental and practical medicine. Experimental models on animals not only reveal pathological changes in the nervous system at the molecular and ultrastructural levels, but they also enable the time course of their development to be studied, and this is important for practical medicine.

EXPERIMENTAL METHOD

Light-optical and electron-microscopic investigations were made of the brain of 16 adult cats 5 days, 4 months, and 1 year after operation. Neurosurgical operations of division of the left optic tract (OT) and hemisection of the tegmentum mesencephali (HSTM) were carried out by Lyubimov's method [2]. Neurons were counted in Nissl preparations by drawing all the neurons under immersion. The average neuron density was calculated by standard methods. Ultrathin sections were studied on Hitachi HI-II and Philips microscopes.

EXPERIMENTAL RESULTS

The results obtained during chronic experiments on adult cats revealed several characteristic changes in the visual (lateral geniculate body – LGB) and somatosensory (ventrobasal nuclear complex – VB) thalamic relay nuclei after deafferentation: due to division of OT and, correspondingly, HSTM. These sensory subcortical centers have a very complex synaptoarchitectonics: a large set of synaptic endings (axodendritic, axo-somatic, axo-axonal, etc.), an irregular distribution of synapses, and the presence of intricate glomerular complexes and complex synaptic junctions (axo-axo-dendritic, axo-dendro-axonal, dendro-dendro-axonal) [1].

After division of the optic tract LGB is deprived of its principal classical afferent input, and tegmental hemisection of the brain stem also leads to blocking of the classical somatosensory channels for VB. Quantitative analysis of the neuronal composition of these formations 1 year after division of the classical afferent connections showed that no cells had disappeared in LGB (Fig. 1a, b), and no transneuronal degeneration of neurons likewise was found in VB. Thus under conditions of deafferentation of the classical channels, these subcortical relay centers preserved the stability of their cytoarchitectonic structure.

At the ultrastructural level, redistribution of functional activity between the affected and intact axons, which is expressed as the appearance of individual axo-dendro-axonal synapses with two types of axonal endings, took place in VB in the early stages (5-7 days after the operation): synapses of the first type were densely packed with synaptic vesicles, those of the second type showed evidence of pale degeneration. Both types of endings formed junctions with a central dendrite,

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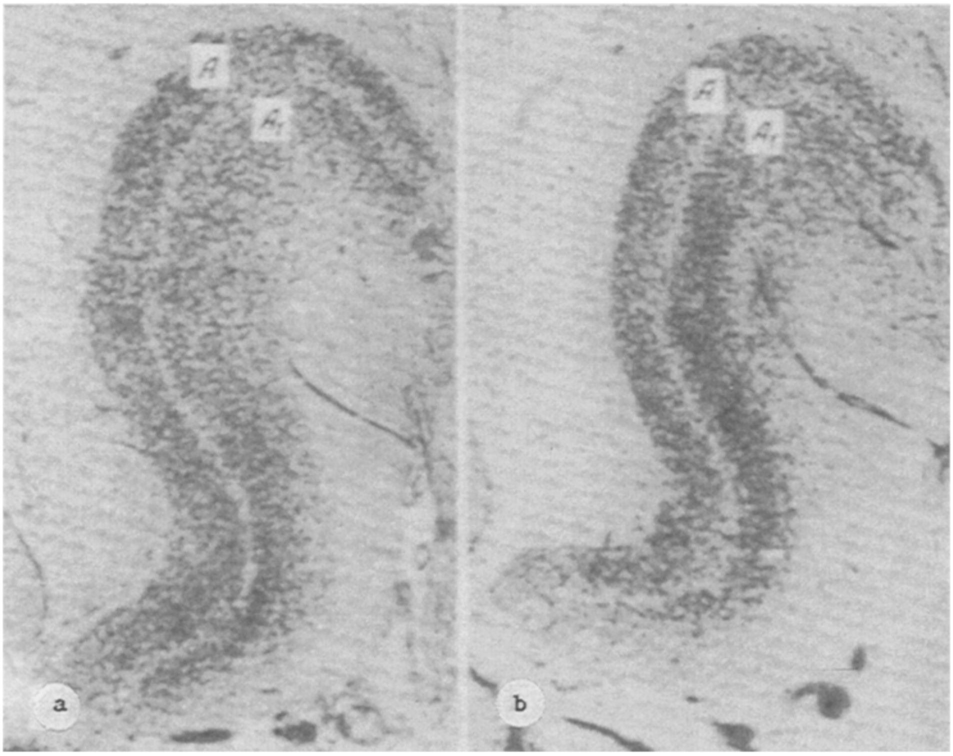

Fig. 1. Sagittal sections through brain of cat surviving 1 year after division of left optic tract: a) right LGB, b) left LGB, A, A1) layers of LGB (photomicrograph, staining by Nissl's method, 40×).

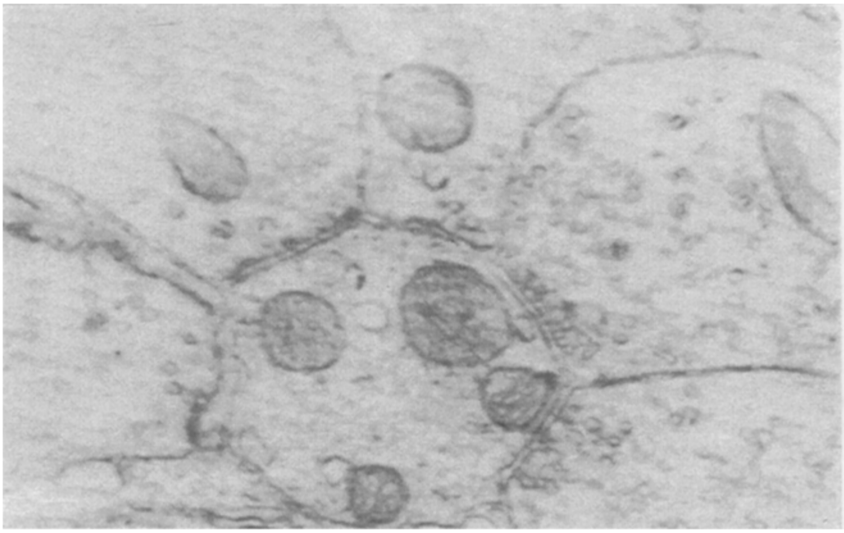

Fig. 2. Synaptic glomerulus of VB 5 days after operation of HSTM. 30,000×.

in which small round mitochondria with two or three widened cristae (juvenile forms) were grouped close to the synaptic cleft of an active axon. Juvenile forms of mitochondria, and also concentrations of glycogen in the processes of nerve cells are signs that a neuron, under sensory deprivation conditions, is in a new energy-related state, and is evidence of the existence of intracellular compensation (Fig. 2). The integrity of synaptic endings of glomerular type 4 months after the operation suggests the presence of integrative forms of information processing, taking place in accordance with the same structural principle as in intact animals. Electron-microscopic investigation of LGB 5 days and 4 months after division of OT revealed integrity of several synaptic glomeruli, based on central retino-geniculate fiber, forming junctions with dendrites of LGB cells and an axo-axonal junction with an ending of the cortico-geniculate fiber. This is evidence of possible structural reserves in the deafferented center.

Structural changes in the thalamic relay centers described under conditions of sensodeprivation lead not only to integrity of the neuronal composition of the centers themselves, but also, as behavioral studies have shown, to preservation of their functional capacity. In animals 1 month after HSTM restoration of kinesthetic sensitivity was already taking place, specifically restoration of the conditioned instrumental food reflex of the deafferented limb [3], whereas in cats 2-3 months after division of OT partial recovery of the corresponding, visual fields was taking place [4]. According to electrophysiological data [2], compensatory processes in LGB and YB under sensory deprivation conditions can be attributed not only to structural reorganization of the brain center itself, but also to mobilization of additional sources of afferent impulsation, namely: for VB – extralemniscal nonclassical connections of the dorsal columns of the spinal cord, and for LGB – transcommissural afferent visual channels (transcallosal and transcollicular).

By using this complex approach to the study of structural and functional reorganization of subcortical centers under sensory deprivation conditions, involving behavioral, electrophysiological, light-optical, and electron-microscopic methods of investigation, it is possible to detect not only specific changes, but also the number of characteristic differences in the changes taking place in the thalamic nuclei and also in the organization of the somatosensory and visual systems as whole.

The main conclusion to be drawn from this investigation is that subcortical sensory thalamic centers of LGB and YB, under conditions of blocking of their classical sensory channels, preserve the stability of their cytoarchitectonic structure through plastic changes not only in the brain centers themselves, but also in the sensory system as a whole, through mobilization of additional nonclassical afferent channels conveying visual and somatosensory information.

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