MORPHOLOGICAL ANALYSIS OF THE CORTEX AND SOME SUBCORTICAL FORMATIONS AFTER DIVISION OF THE INTERNAL CAPSULE

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In connection with the numerous investigations conducted on animals and involving removal of the cerebral cortex, there is considerable interest in the problem of the character of the morphological changes taking place in such animals in other parts of the central nervous system. Physiologists usually describe such animals as decorticated, without always paying heed to the structural changes developing in the subcortical formations after removal of the cerebral cortex.

It is reported in the literature [1, 2, 5-7] that important secondary changes arise in the structures of the diencephalon of animals after removal of the cortex, and they undergo intensive degeneration. Some authors [5] have accordingly concluded that such animals should be regarded as being "hypothalamic."

The object of the present investigation was to study certain subcortical formations after exclusion of the cerebral cortex (the neocortex) and basal ganglia (strio-pallidary formations) from the lower levels of the brain by division of the internal capsule, a method developed by M. M. Khananashvili [3, 4]. The structure of the cortex thus excluded was also studied.

EXPERIMENTAL METHOD

The operation which was performed has many advantages over extirpation of the cortex: it is less traumatic and causes less interference with the blood supply to the brain. At the same time, it allows the total or almost total exclusion of the neocortex from the other portions of the brain. Morphological studies were made of the brains of two dogs after bilateral division of the internal capsule and the brains of two cats after unilateral division of the internal capsule. In one of these cats (No. 20) the corpus callosum also was divided (in order to exclude the influence of the opposite hemisphere). The cats survived for 1.5 months after the operation, one dog live 3 months (Lisichka) and the other 6 months (Rem).

The brain of each animal was treated by Nissl's method. Horizontal sections were cut.

EXPERIMENTAL RESULTS

The investigation showed that in both cats all subdivisions of the internal capsule (anterior limb, genu, and posterior limb) had been completely divided at all levels (Fig. 1). In addition, during the operation, when the approach to the internal capsule was being made, a small area (10-15 mm^2) of the cortex and the underlying white matter of the presplenial gyrus was destroyed.

In cat No. 11 the section was made in such a way that the caudate nucleus was excluded along with the cortex. By doing so, both these structures were completely departed from the thalamus and the other subcortical structures. In cat No. 20 the section cut through a small area of the body of the caudate nucleus, leaving behind one part connected with the cortex and the other connected with the thalamus.

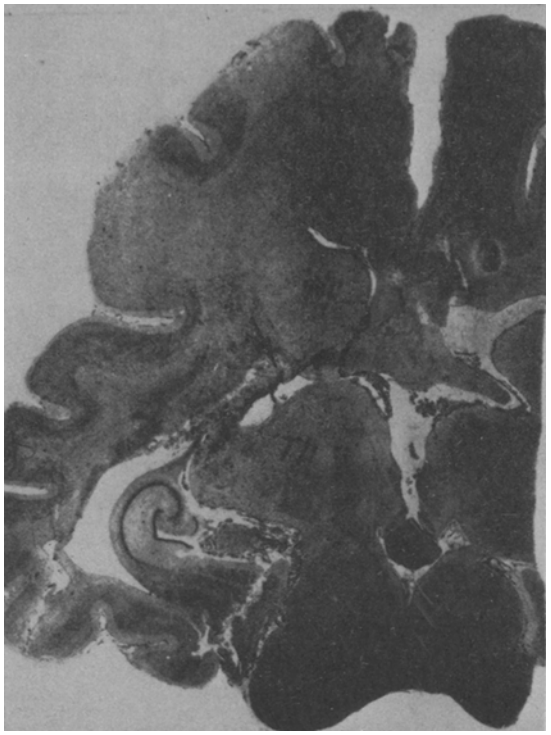

Fig. 1. Line of division of internal capsule in cat No. 11. Th) Thalamus; Nc) caudate nucleus; arrow) line of division. Loupe. Nissl's method. 3 ×.

The most marked structural changes were observed in these cats in the nuclei of the thalamus and metathalamus. Nearly all the nerve cells in the nuclei of the anterior, ventral, and lateral groups, a large proportion of the cells in the medial group of nuclei, and some cells of the nuclei of the midline were absent and replaced by neuroglia (Fig. 2). In the nuclei of the midline the two habenular nuclei, the cells of the paraventricular nucleus, and the rhomboid nucleus were completely intact. Part of the cells in the dorso-medial and reticular nuclei also were intact. In the lateral geniculate body nearly all the large and most of the middle-sized and small cells were absent and replaced by neuroglia. In the medial geniculate body also, most of the ganglion cells had died. No changes could be seen in the cells of the hypothalamus and mesencephalon.

The study of the brain of the dog Rem showed that all parts of the internal capsule were completely divided bilaterally at all levels of the horizontal sections. Significant changes were observed in the nuclei of the thalamus: almost total degeneration of the cells was observed on both sides in the anterior nuclei and the nuclei of the lateral, ventral and medial groups (Fig. 3). Solitary cells remained in the region of the central-lateral nucleus, both habenular nuclei, and the reticular nucleus and a few were distributed along the midline. Many ganglion cells were absent in the lateral and medial geniculate bodies, although in the former many cells remained intact. In the hypothalamus and mesencephalon no loss of nerve cells was observed.

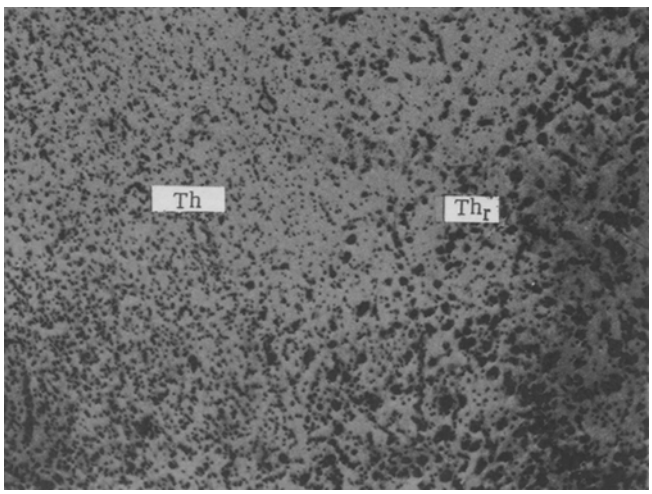

Fig. 2. Area at the border of the left (side of operation) and right (normal) halves of the thalamus in cat No. 20. Normal nerve cells are seen on the right; many nerve cells are replaced by neuroglia on the left. Th) Left half of thalamus; Th_r) right half of thalamus. Photomicrograph. Nissl's method. 90 ×.

Fig. 3. Right half of thalamus in the dog Rem. Degeneration of various groups of nuclei. Legends as in Fig. 1. Photomicrograph. Nissl's method. 10 ×.

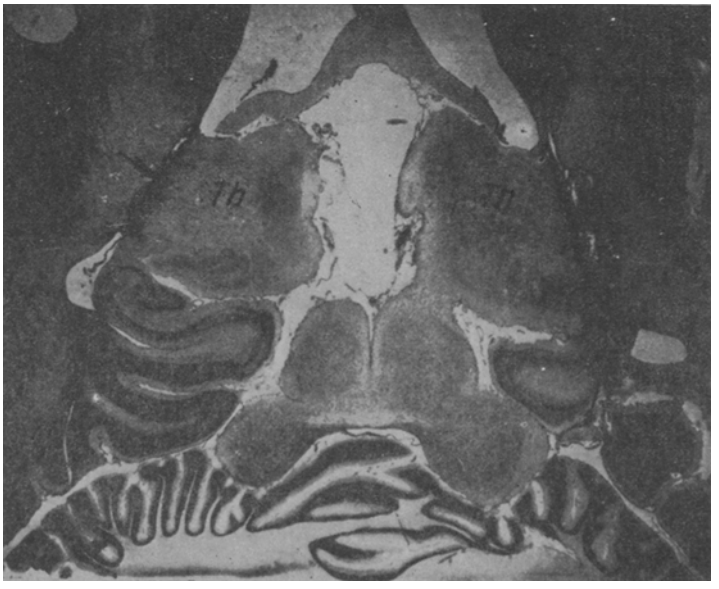

Fig. 4. Line of division of internal capsule on both sides in the dog Lisichka. Legend as in Figs. 1 and 3. Loupe. Nissl's method. 3 ×.

Investigation of the brain of the dog Lisichka showed that all parts of the internal capsule at all levels in the left hemisphere had completely degenerated, while in the right a small bundle of fibers of the anterior limb remained intact at the ventral levels of the horizontal sections. Having gone through the internal capsule, the incision continued more posteriorly, dividing part of the cortex of the rhinencephalon from the neocortex (Fig. 4). In the left hemisphere, where the internal capsule had completely degenerated, considerable retrograde degeneration was observed to have taken place in the nuclei of the anterior, lateral, ventral, and medial groups, and in some nuclei of the midline of the thalamus. Similar degeneration was observed in the lateral and medial geniculate bodies. A few cells remained intact in the medial group of nuclei (central-lateral, dorso-medial), and all the cells in the habenular nuclei and some cells in the reticular nuclei were preserved. On the side of incomplete division, cells remained in the antero-ventral, dorso-medial, and reticular nuclei, and in part of the anterior portion of the lateral and the medial division of the ventral nucleus. The habenular cells and cells in the region of the midline were intact. In the hypothalamus and mesencephalon no significant changes affecting the nerve cells were detected.

The study of all the cortical zones of the neocortex and of the rhinencephalon of the cats and dogs showed that the structure of the cortex (its arrangement in layers, the number of nerve cells and their state) remained basically unchanged. However, in the motor cortex, especially in the cats, degeneration of the large pyramidal cells in layer V of the cortex could be observed. This is a particularly interesting fact because it shows that the cells of the cortex do not undergo degeneration, if the pial blood supply is intact, even after division of all the afferent and efferent projection pathways of the neocortex. At the same time it may be supposed that the cortical cells continue to interact through the short association fibers which were mainly preserved after the operation.

The investigation of the caudate nucleus, the putamen, the globus pallidus, the amygdaloid nucleus, and the claustrum in the cats and dogs revealed no substantial changes in the cell structure of these formation. Only in the brain of the dog Rem and of cat No. 11 was primary degeneration of the caudate nucleus and the medial part of the globus pallidus observed.

Hence, the study of the subcortical structures in animals after division of the internal capsule showed that the most marked changes, amounting in some cases to complete degeneration of whole groups of nuclei (anterior, lateral, ventral, and medial), were observed in the thalamic and metathalamic structures. In the adjacent subcortex (strio-pallidary structures), the hypothalamus and the mesencephalon no changes in the cells were seen. The cells of the cerebral cortex were relatively intact. Consequently, taking the facts described above into account, not only was the cortex (neocortex) excluded in these animals, but the thalamus had also degenerated. The animals could therefore be regarded as "hypothalamic" but with preservation of individual nonspecific nuclei of the thalamus (reticular nucleus, etc.).

SUMMARY

A study was made on certain subcortical formations and the cortex of cats and dogs after severing the internal capsule, which leads to disconnection of the cortex of the cerebral hemispheres (neocortex) with the basal ganglia (strio-pallidal formations) from the underlying regions of the brain. The most severe changes, to the degree of complete degeneration of the majority of cells, were noted in the thalamus, with preservation of the nerve cells in strio-pallidal formations, the hypothalamus, the midbrain, and with a relative retention of the cortical cells of the cerebral hemispheres. Therefore, such animals can be regarded as animals not only with an excluded cortex but also with a degenerated thalamus, i.e., as "hypothalamic" animals having retained isolated nonspecific nuclei of the thalamus.

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