ON REGENERATION OF THE CEREBRAL CORTEX

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Up until lately, it has been considered impossible for the cortex of the cerebral hemispheres to undergo regeneration. However, investigations have been published in the last few years, testifying to the possibility of structural regeneration on the part of areas in the occipital cortex and even the entire hemisphere, in animals in their first month of life [2, 5]. L. V. Polezhaev and co-workers [6] studied this question in detail, on several subjects, using experimental-morphological methods. By maintaining certain conditions (removal of less than the full cortical thickness, cleansing the wound of blood, and preserving the membranes of the brain), they observed formation of new nerve tissue, which, in the young animals, completely filled in the defect. According to the data of the authors, the new tissue differed from the old in its smaller number of neural and neuroglial cells, and its different arrangement of layers.

B. N. Klosovskii and G. A. Vasil'ev [4], repeating the described experiments, obtained a negative result. According to their data, upon removal of visual and motor areas of the cortex, the appearance of brain tissue regeneration is created due to the growth and closing in of neighboring regions. For the formation of new tissue, there must be division of the nerve cells; it is possible to observe karyokinesis in the areas adjacent to the injured section only on the 3rd day after the operation [1, 7]. Subsequently, one does not observe either karyokinetic or straight division. In addition, the investigation of N. F. Kastrikin [3] did not corroborate the presence of mitotic division of the neurons in the rat cortex, described by Syui Tszin, following mechanical injury. In his opinion, Syui Tszin mistook division of the granular spheres for division of the neurons.

We investigated retrograde degeneration of the thalamic nuclei following extirpation of the sigmoid convolutions in puppies of various ages (10 and 14 days, 2, 3 and 5 months). In connection with studying the question of whether it is possible for removed portions of the central nervous system to be regenerated, particularly the cerebral cortex, special interest was presented by the areas of extirpation in the puppies that were operated upon at ages 10 and 14 days.

EXPERIMENTAL METHODS

Data was obtained on 6 puppies. In ten day old puppies, we performed simultaneous bilateral extirpation of the cortex of the sigmoid convolutions; the animals were sacrificed 2 months after the operation. In 4 fourteen day old puppies, we extirpated the cortex of the sigmoid convolution in one hemisphere; they were sacrificed 7 months after the operation. The operation was carried out under ether narcosis. Bone in the area of the sigmoid convolution was cut apart with brain forceps. The dura mater was incised and reflected onto the bone. The brain substance was scooped out with a spoon instrument from under the pia mater, through a small incision. The wound was covered with hemostatic sponge and a layer of fibrin was placed on top. The muscles and bone were sutured. It must be noted that we did not observe the optimal conditions for nerve tissue regeneration cited by L. V. Polezhaev and co-workers. The brain of the puppies was fixed in 10% formalin; with some of the puppies, we first performed a preliminary perfusion with physiological saline, and then with 10% formalin. The material was imbedded in celloidin and frontal serial sections were prepared, 20 micra in width. The sections were stained with cresyl violet.

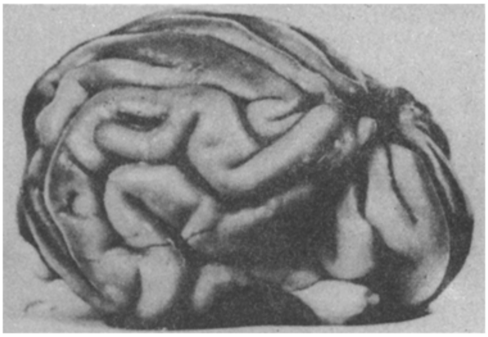

Fig. 1. Puppy brain with atypical arrangement of the sulci; they are drawn toward the defect site. Side view. The cortex of the sigmoid convolutions was extirpated in the 10 day old puppy, and the animal was then sacrificed 2 months after the operation.

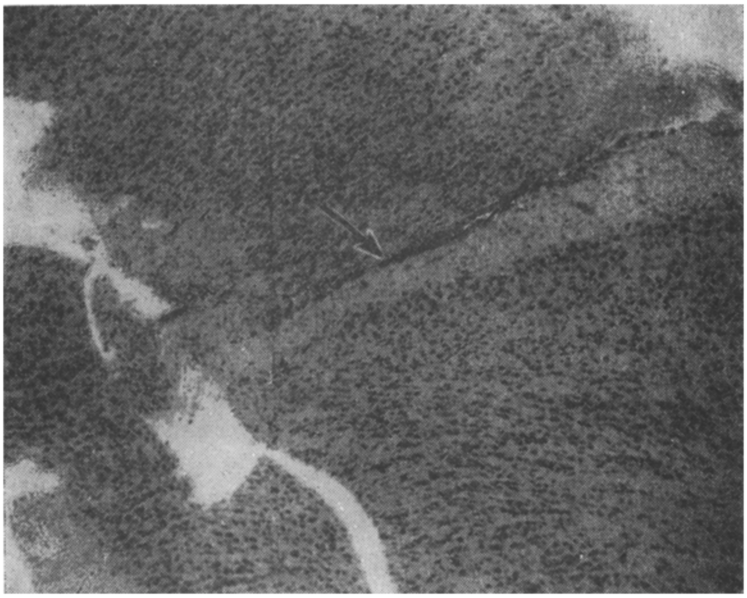

Fig. 2. Joining of the injured edge of the presplenial convolution with the uninjured lower wall of the cruciform sulcus (site of juncture denoted by arrow). The puppy was operated upon at 14 days of age, and sacrificed 7 months after the operation. Microphotograph. Stained with cresyl violet. Obj. 8, ocul. 1.

EXPERIMENTAL RESULTS

In all the puppies, the site of the defect could be clearly seen in the region of the sigmoid convolution. However, the areas of injury were significantly smaller in size than at the time of the operation, due to closing in of the defect borders secondary to brain growth. The sulci near the site of injury were arranged atypically and pulled toward the defect site (Fig. 1). In the neighboring areas we discovered several small, unknown, sulci. These structures had not been observed before in puppies 2 months of age or older.

Fig. 3. Site of defect in the cortex, filled in from the surface with atypical tissue. The cortex of the sigmoid convolution was extirpated in a 10 day old puppy, and the animal was then sacrificed 2 months after the operation. Microphotography. Stained with cresyl violet. Obj. 8, ocul. 1.

Microscopic analysis of the areas of extirpation showed that with removal of only the cortex, and absence of damage to the white matter, both edges of the defect grew toward each other and joined. The juncture could be formed both by the edges of the removed convolution alone, or the edges of different convolutions. We observed joining of an uninjured sulcus wall with the injured edge of the convolution (Fig. 2). As a result of this, a very small area of injury was seen from the surface. There was no scar tissue at the juncture site of the edges. The cortex of the joined areas was markedly changed; it lost its layering, the pyramids were abnormally oriented (the apical dendrite was directed toward the juncture of the edges), and in individual areas the cells were intensely rarefied. These changes were probably related to movement of the tissue into the defect.

In those cases where the injury was enlarged by hematoma and extended to the lateral ventricle, we observed neither closing in nor joining of the edges. Only in one puppy was the defect site filled in with tissue which, apparently, certain authors describe as regenerated tissue. It filled in the defect only from the surface, and left a cyst-like cavity under it. This tissue was clearly delineated from normal cortical tissue, and consisted of separate fragments joined with one another (Fig. 3). It differed from normal cortex by its lack of the typical layering, and had a smaller number of cells. The structure of the "new" cortex had nothing in common with the structure of the cortex in the motor area; the "new" cortex was more similar to the individual, interjoined, partially degenerated areas of cortex in the wound edges. It seems to us that in this case, as in all the others, there was no substitution of the lost brain matter with new matter, but that all that took place was growing in and joining of the neighboring areas, which created the appearance of tissue completion in the puppies.

SUMMARY

In order to ascertain the possibility of structural regeneration in the cortical areas of the cerebral hemispheres, the cortex of the sigmoid convolution was extirpated in puppies aged 10 and 14 days. These animals were then sacrificed 2 and 7 months after the operation. Their brains were fixed in 10% formalin and sections of the material were stained with cresyl violet. The site of the defect was clearly visible macroscopically. However, its size was considerably less than at the time of the operation. Due to growth of the brain, the edges of the injured area moved over the defect, closing it over and joining each other. This was quite distinct microscopically. However, where the size of the injury was enlarged by hematoma and reached the lateral ventricle, no closing in of the tissue or juncture of the edges was observed. Thus, in the opinion of the author, there was no replacement of the brain matter by new matter, but there only occurred superposition and juncture of the adjacent areas, which created the appearance of tissue regeneration.

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