STRUCTURAL CHANGES OF THE VISUAL ANALYZER OF MONKEYS AFTER EXTIRPATION OF THE OCCIPITAL LOBES

L. V. Koroleva

Laboratory of Physiology and Pathology of Higher Nervous Activity
(Head, Professor N. I. Lagutina), Institute of Experimental Pathology and Therapy
(Professor B. A. Papin), AMN SSSR, Sukhumi
(Presented by Active Member AMN SSSR A. V. Lebedinskii)
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In experiments on monkeys it has been shown that after extirpation of the occipital lobes conditioned reflexes to light stimuli may be preserved [3,4,11,12], and stable differentiation in terms of light intensity may occur in the young [4]. The question has arisen as to what cerebral structures are involved in the formation of the temporary association with the light stimulus in monkeys from whom the occipital lobes have been removed.

According to published reports extirpation of the occipital lobes from primates causes retrograde degeneration of the external geniculate body [6,9,10,13,14,15], and of the pulvinar of the thalamus [7,8,13,14,15]. Some investigators have categorically denied the degeneration of the superior quadrigemina in such animals.

We have found no reports describing changes in the subcortical structures of the visual analyzer of apes operated at an early age. The present investigation deals with this question.

EXPERIMENTAL METHOD

The experiments were made on hamadryl apes from which the occipital cortex, comprising Brodman's areas 17, 18, and 19, and the underlying white matter had been removed; the operation was performed at 4 days, $1\frac{1}{2}$ months, or 3 years. The animals were killed 10 months or $1\frac{1}{2}$ years after the operation. The brain was stained by the method of Nissl and Spielmeyer. A small number of preparations were stained in Luxol-blue, and counterstained with hematoxylin.

EXPERIMENTAL RESULTS

As shown in Fig. 1 the remaining portions of the brain failed to cause any regeneration of the extirpated portions.

The visual areas of the cortex were removed almost entirely from three animals. At the site of the incision there was a scar made up of glial and connective tissue. There was no scar in the animals operated at the age of four days. When the operation was performed on one side only there was an asymmetry in the position of the gyri of the operated and intact hemispheres.

Extirpation of the occipital lobes caused degeneration of the external geniculate bodies. Their nerve cells degenerated, and no division into layers could be made out; there was a proliferation of the glia (Fig. 2). When the occipital lobes were extirpated from adult animals the external geniculate bodies underwent complete cellular degeneration, involving reduction in the size of the nucleus. In the external geniculate bodies of animals operated at four days or $1\frac{1}{2}$ months, the nerve cells were preserved and did not degenerate; the nuclei maintained the same size as in control animals. When the extirpation was unilateral the ipsilateral external geniculate body degenerated, while the e.g.b. of the intact side showed no changes (Fig. 3).

In the pulvinar of the thalamus nerve cells were lost and were replaced by proliferating glia in the lateral and lower portions (classification of Ol'shevskii for the macaque rhesus monkey). The cells of the medial nucleus of the pulvinar were also somewhat reduced in number. The greater the age of the operated animal the greater was the extent of the degeneration.

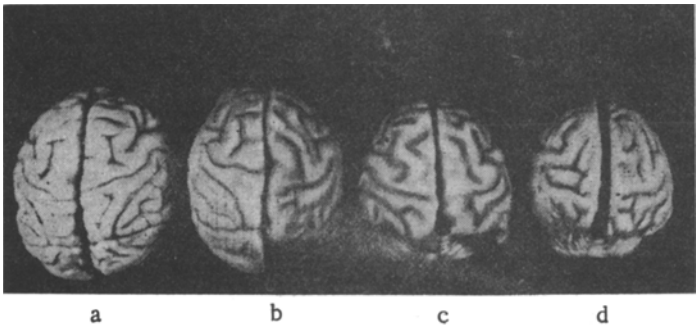

Fig. 1. Brain of monkeys from the dorsal surface. a) Normal; b) after removal of the right occipital lobe at the age of $1\frac{1}{2}$ months; c) after bilateral extirpation at the age of 4-20 days. d) after removal of the occipital lobes at the age of 3 years (brain photographed after fixation in alcohol).

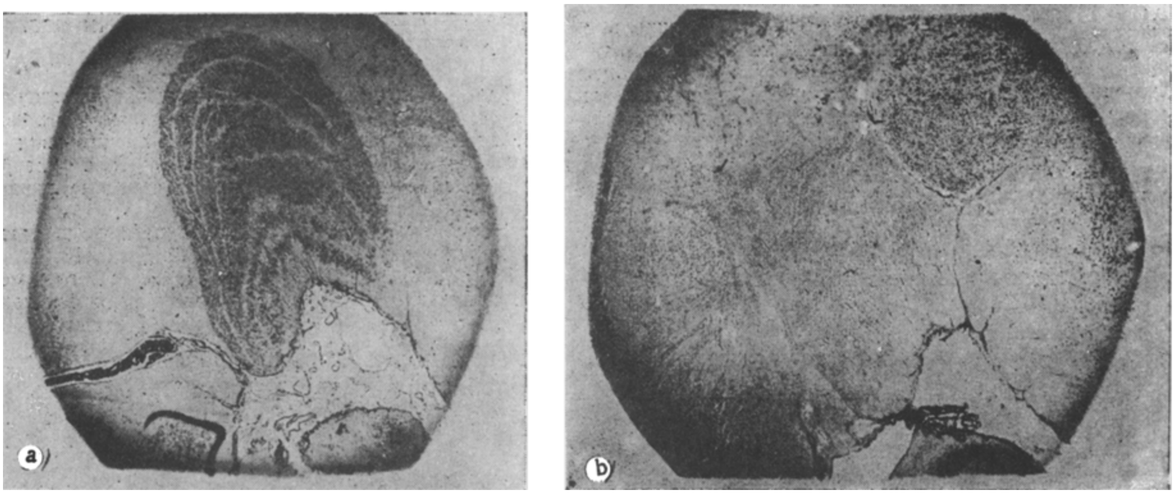

Fig. 2. External geniculate body. a) Normal; b) after extirpation of the occipital lobes at the age of 4-20 days. Nissl stain. Magnification × 8.

Fig. 3. External geniculate body of monkeys after extirpation of the occipital lobe at the age of $1\frac{1}{2}$ months. Nissl stain. Magnification × 3.

When we investigated the fibers it was found that there was degeneration of the association pathways running to the remains of the occipital lobes, of the middle temporal, cingulate, and hippocampal gyri. There was also degeneration of the commissural pathways running into the fornix and of the more caudal portions of the corpus callosum (splenium and truncus), there was also degeneration of the projection fibers running to the inferior portion of the internal capsule, of the capsule of the external geniculate body, of the geniculate body itself, and of the pulvinar of the thalamus. There was diffuse degeneration in the optic tracts. When occipital lobe extirpation was unilateral degeneration was found in the ipsilateral optic tract. In this case degeneration of the fibers of the corpus callosum occurred only in the intact hemisphere.

The results of our investigations showed that there is no morphological recovery of the extirpated occipital lobes in animals of various ages, and our findings do not agree with those obtained in experiments on other animals [1,2]. The results quoted above [14,15] concerning the greater vulnerability of the external geniculate body to removal of the occipital lobes from apes has been confirmed by our experiments. Like other authors [15] we found degeneration in the ipsilateral geniculate body occurring as a result of unilateral extirpation of the occipital lobes. Degeneration of the lower and the lateral portions of the pulvinar indicated apparently its close relationship with visual function. The most considerable changes of all these structures caused by extirpation of the occipital lobes were in the adult animals, but in all cases the superior corpora quadrigemina were not affected.

When we compare our results concerning the structural changes of the cortical and subcortical structures of the visual analyzer occurring as a result of extirpation of the occipital lobes with changes in the conditioned reflexes in response to light stimulation under corresponding conditions [3,4,11,12], we have reason to suppose that the simple analysis of light stimuli is brought about by the remaining subcortical structures of the visual analyzer. However, we cannot exclude the possibility that in the differentiation of intensity of illumination cortical structures, particularly the cortex of the frontal lobes may be involved; evidence in this direction is obtained from the results of electroencephalographic studies [5]. Apparently the greater plasticity of the nervous system at early stages of development makes it possible for the young apes to produce a more effective functional compensation of damage to the visual cortex.

SUMMARY

After uni- or bilateral extirpation of the occipital lobes from Papia hamadryas of different ages a study was made of the structure of the visual analyzer after the brains had been stained by Nissl and Shpielmayer's method. No regeneration of the extirpated portion occurred even in young monkeys which had undergone the operation at the age of 4 or 5 days. With bilateral extirpation there was a degeneration of both external geniculate bodies, of the pulvinar of the thalamus, optic tracts, and of the caudal portions of the corpus calosum; when the extirpation was unilateral the degeneration of the structures we have mentioned occurred ipsilaterally. Degenerative changes of subcortical structures were less pronounced in the young monkeys.

LITERATURE CITED

1. N. N. Dzidzishvili, Abstracts of reports of the 2nd Transcausian conference of physiologists, biochemists, and pharmacologists, Tbilisi, p. 103 (1956).
2. A. B. Kogan and T. V. Ivannikova, Byull. éksper. biol., 3, pp. 6-9 (1955).
3. L. V. Koroleva and N. I. Lagutina, Abstracts and reports of the 3rd scientific conference on evolutionary physiology, p. 103, Leningrad (1961).
4. L. V. Koroleva, in the book: Contributions to the 14th conference of physiologists of Southern RSFSR, p. 144, Krasnodar (1962).
5. N. I. Lagutina, T. G. Urmancheeva, and L. V. Koroleva, Fiziol. zh. SSSR, 4, 419 (1963).
6. B. Brouwer and W. P. C. Zeeman, Brain, 49, 1 (1926).
7. K. L. Chow, J. comp. Neurol., 93, 313 (1950).
8. W. E. L. Clark and D. W. C. Northfield, Brain, 60, 126 (1937).
9. W. E. L. Clark, Anat. 75, 419 (1941).
10. H. B. Klüver, in the book: Biological Symposia, 7, 253, Lancaster (1942).
11. D. G. Marquis and E. R. Hilgard, Fiziol. zh. SSSR, 21, 5-6, 778 (1936).
12. Idem, Brain, 60, 1 (1937).
13. M. Mishkin and K. H. Pribram, J. comp. physiol. Psychol., 47, 14 (1954).
14. S. Polyak, J. comp. Neurol. 57, 541 (1933).
15. Idem, The Vertebrate Visual System, Chicago (1957).
16. Uoker (1936) quoted by M. M. Kurepin. Trans. of the Moscow Town Pedagogical Inst., 24, 2, 209 (1953).