CENTRIFUGAL AND CENTRIPETAL FIBERS IN THE OPTIC NERVES*

N. G. Gorikov

UDC 611.831.2-018.83-086

Unilateral and bilateral enucleation was carried out on dogs and cats. Thin medullated fibers were found intact after bilateral enucleation in and above the chiasma and in the optic nerves, and it was concluded from the formation of bulbs of growth in the central stumps of these fibers that the optic nerves contain efferent (centrifugal) fibers. It is postulated that the direct connection between the internal membranes of the eyes and the occipital cortex and with each other is effected by unbroken thin nerve fibers.

* * *

Different views are held on this problem in the literature. Some workers [8, 9, 14, 15], for instance, consider that the optic nerves contain receptor fibers, the cell bodies of which lie outside the retina. Biryuchkov [1] found degenerating fibers of this type in animals after enucleation of the eyes, reaching the cortex without internuncial (subcortical) neurons.

Recent investigations [10, 16-19, 21, 22, 25] have demonstrated the presence of centrifugal effector fibers in the optic nerves, which were in fact discovered in the last [6] and at the beginning of the present century [23, 24]. However, this has not been confirmed universally [20].

EXPERIMENTAL METHOD

The investigation described below was purely experimental in character. It was carried out on adult animals (18 dogs and cats) subjected to unilateral and bilateral enucleation of the eyes. The animals were sacrificed on the 3rd-28th day after the operation. Material was fixed in 10% neutral formalin and acetone. Frozen sections, 15-25 μ in thickness, were stained with Sudan black and for acid phosphatase by Gomori's method, and the impregnation methods of Bielschowsky, Rasskazova, and Nauta were also used.

EXPERIMENTAL RESULTS

Unilateral Enucleation of the Eye

Changes in the Nerve on the Side of Enucleation. In sections impregnated by Nauta's method and stained for acid phosphatase, a mass of degenerating fibers could be seen in the proximal division of the optic nerve on the side of enucleation. By the use of Bielschowsky's method and the same stain for acid phosphatases, along with degenerating fibers, intact thin nerve fibers could also be seen, as a rule running in small bundles (Fig. 1C). Bulbs of growth nesting centrally in the stump, could be observed at their ends by the 8th-11th day (Fig. 1A, B). Later the bulbs of growth in the central stump became less numerous, on account of their spread along Buengner's bands in a cranial direction.

* Presented on April 18, 1967, at a Scientific Conference of Stavropol' Medical Institute reviewing work done in 1965-1966.

Department of Histology and Embryology, Stavropol' Medical Institute. (Presented by Academician of the Academy of Medical Sciences of the USSR A. P. Avtsyn.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 68, No. 10, pp. 101-105, October, 1969. Original article submitted May 28, 1966.

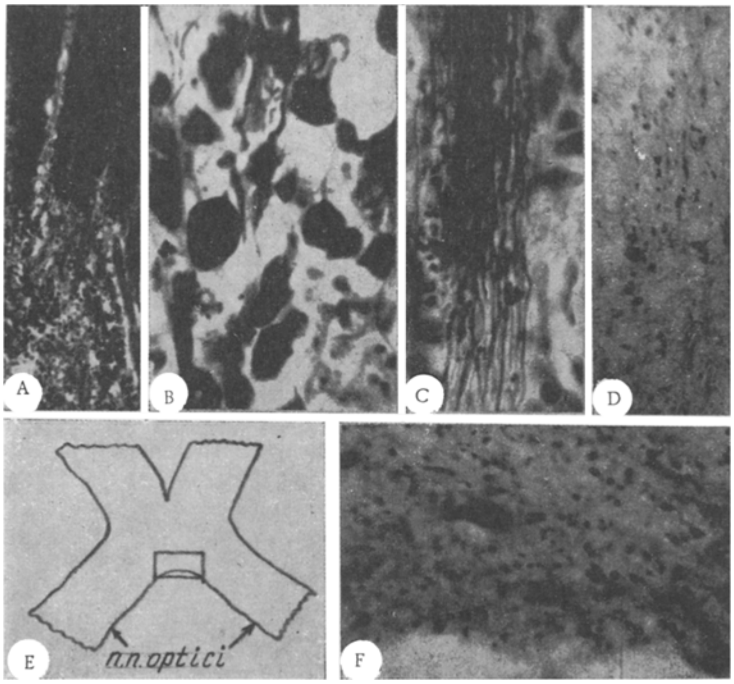

Fig. 1. Cat. Enucleation of right eye, 11 days after operation. A, B) Central stump: nesting bulbs of growth can be seen; C) proximal part of right optic nerve: intact thin nerve fibers, arranged in bundles, are visible among degenerating fibers; D) left (intact) optic nerve: degeneration of thin nerve fibers can be seen; E, F) chiasma of dog after unilateral enucleation: degenerating nerve fibers can be seen passing anterior third from the nerve on the side of enucleation into the intact optic nerve. A, B, C) Impregnation by Bielschowsky's method; D, F) impregnation by Nauta's method. A) 56 ×; B, C, D) 420 ×; F) 630 ×.

In sections stained with Sudan black, intact thin medullated fibers, also consisting of small bundles were also seen in the proximal segment of the optic nerve.

Changes in the Intact (controlateral) Nerve. Microscopic investigation of the intact optic nerve showed that in addition to a mass of normal fibers, degenerating nerve fibers could also be clearly seen in sections stained for acid phosphatase and impregnated by Nauta's method (Fig. 1D).

Why is degeneration of fibers observed in the intact nerves? Different views on this problem have been and are still held in the literature. One of the most widely held views is that of Plechkova [11], who regards degenerative changes in the intact (contralateral) nerves, like changes in other parts of the nervous system, as "reflected changes [13], or as the result of the body's reaction to injury to a peripheral nerve, manifested as a "neurogenic degenerative process" remote from the injured nerve, including in the intact nerve.

The study of histological sections obtained from unilaterally enucleated animals showed that the degenerating fibers are very thin (with a thin myelin sheath), and they enter the intact nerve by following a well-defined morphological path, namely through the optic chiasma in its anterior third (Fig. 1E, F).

It was natural to suggest that the cell bodies whose degenerating axons enter the intact nerve lie in the retina of the enucleated eye. This has also been postulated by Dzugaeva [5] and others. Other workers [11], however, deny the existence of this connection.

Two important conclusions follow from the data obtained by unilateral enucleation: 1) the existence of bulbs of growth nesting in the central stump of the optic nerve, and the arrangement of thin nerve fibers in

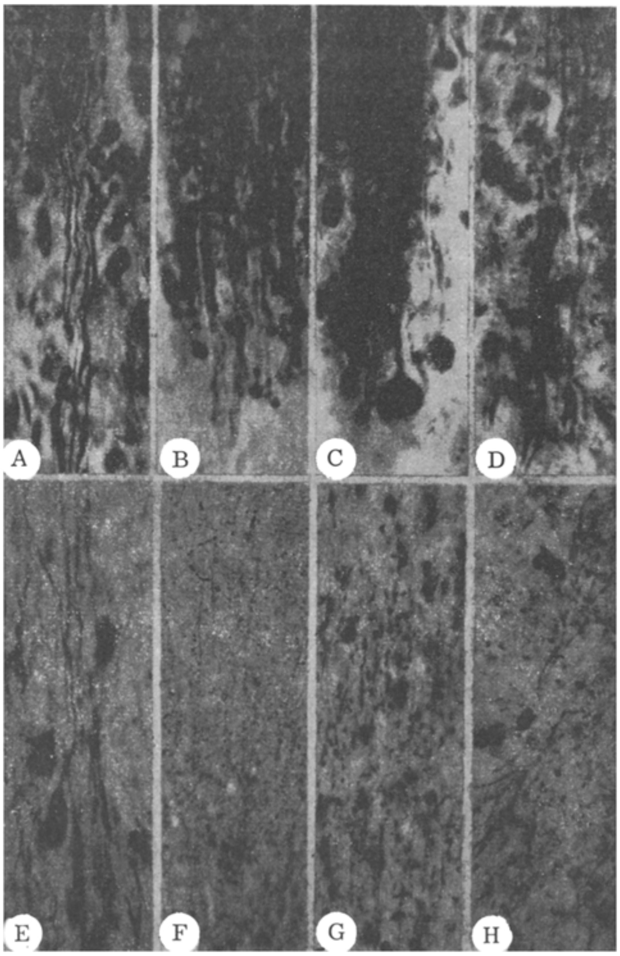

Fig. 2. Cat. Bilateral enucleation, 11 days after operation. Proximal segment of right (A, B) and left (D) optic nerve. Intact thin (A, D) medullated (B) fibers, running in bundles, are visible among degenerating fibers. Region of the right (C) and left (E) central stump: nesting of bulbs of growth can be seen in them. F, G, H) Corresponding section of left cerebral cortex (area 17); F) general view (gray matter above, white matter below). Degeneration of thin nerve fibers in cortical white (G) and gray (H) matter. A, C, D, E) Impregnation by Bielschowsky's method; B) Sudan black; F, G, H) impregnation by Nauta's method. A, B, C, D, E, G, H) 420 ×; F) 21 ×.

groups in the proximal segments of the optic nerve, confirming that the cell bodies from which these fibers arise lie above the point of division, and consequently they are either in the retina of the intact eye or in the central nervous system; 2) degenerating thin medullated nerve fibers pass from one optic nerve into the other via the anterior portion of the chiasma following unilateral enucleation, presumably indicating that their trophic centers lie in the retina of the enucleated eye.

Bilateral Enucleation of the Eyes

The first quick glance at the histological sections shows that all fibers in the proximal segment degenerated. However, a careful study of the sections through the optic nerves, layer by layer, revealed bulbs of growth in both central stumps, nesting in the same characteristic position as after unilateral enucleation (Fig. 2C, E). A minute study of the proximal segments of both optic nerves in sections impregnated by Bielschowsky's method and stained for acid phosphatase and with Sudan black also showed that they contain thin (Fig. 2A, D) medullated (Fig. 2B) nerve fibers, with bulbs of growth as mentioned above on their ends.

There were fewer intact fibers, and consequently, fewer bulbs of growth in the central stumps than after unilateral enucleation.

Neurohistological investigation of the optic tract and chiasma and higher levels of the optic system showed that after bilateral enucleation the thin nerve fibers with a tendency to join into small bundles along their course persisted there.

The results of bilateral enucleation thus confirm the view that nerve fibers remaining intact in the optic nerves and chiasma have trophic centers located in the central nervous system.

Finally, the last question: is it correct that there is a direct link between the retina and cerebral cortex, as Biryuchkov [1] and others believe? Examination of this material confirms the fact that from the 9th-11th day after enucleation in sections impregnated by Nauta's method, degeneration of thin nerve fibers is found in the occipital cortex in areas 17 and 18 of dogs and cats, predominantly in the polymorphic layer of the cortex and subjacent white matter (Fig. 2F, G, H). Unilateral enucleation gives rise to a symmetrical picture of degeneration in both hemispheres.

The following preliminary conclusions can thus be drawn from the facts described above.

1. The uniform pattern of arrangement of intact thin medullated fibers (grouped into bundles) in the proximal segments of the optic nerve and the presence of a uniform nesting arrangement of bulbs of growth in the central stump after unilateral and bilateral enucleation suggest that the cell bodies whose processes

remain intact in the chiasma and optic nerve and give rise to bulbs of growth in the central stump after these enucleations are located in the central nervous system, and not in the retina of the intact eye.

2. A direct connection certainly exists between the two eyes through thin medullated nerve fibers in the optic nerves.

3. It may be postulated that after unilateral enucleation, recurrent fibers (fibers of the "afferent feedback") [2-4], which evidently are the structures responsible for involvement of the second eye in inflammation in sympathetic ophthalmia, degenerate after unilateral enucleation in the chiasma and the intact optic nerve, and also in the cerebral cortex.

What is the character of the contacts and what is the functional significance of these fibers pursuing such a long path: central nervous system, retinas of both eyes, cerebral cortex? On the question of contacts it is natural to postulate an "en passant" innervation in the retinas as was described by Lavrov [7] as long ago as in 1941. The physiological importance of these "afferent feedback" fibers is presumably that they convey information concerning the state of metabolism in the interstitial tissues of the internal membranes of the eye to the visual cortex. This hypothesis requires careful physiological and morphological verification.

LITERATURE CITED

1. Yu. V. Biryuchkov, in: Problems in Morphology of the Nervous System [in Russian], Moscow (1966), p. 4.
2. N. G. Gorikov, in: Problems in Gerontology and Geriatrics [in Russian], Stavropol' (1965), p. 441.
3. N. G. Gorikov, in: Problems in Theoretical and Practical Medicine [in Russian], Élista (1965), p. 50.
4. N. G. Gorikov, in: Problems in Morphology and Clinial Medicine [in Russian], Élista (1965), p. 24.
5. S. B. Dzugaeva, Proceedings of the 7th All-Union Congress of Anatomists, Histologists, and Embryologists [in Russian], Tbilisi (1966), p. 333.
6. A. S. Dogel', Arch. Mikr. Anat., 44, 662 (1895).
7. K. A. Lavrov, Terminal Divisions of the Peripheral Nervous System [in Russian], Rostov-na-Donu (1941).
8. É. F. Levkoeva, K. I. Golubeva, and A. L. Prigozhina, Oftal'mol. Zh., No. 1, 3 (1953).
9. É. F. Levkoeva, A. L. Prigozhina, and K. I. Golubeva, Oftal'mol. Zh. No. 3, 174 (1954).
10. A. S. Novokhatskii, in: Problems in Neuroophthalmology [in Russian], Vol. 11-12, Khar'kov (1963), p. 59.
11. E. K. Plechkova, Reaction of the Nervous System of an Organism to Chronic Injury to a Peripheral Nerve [in Russian], Moscow (1961).
12. E. Zh. Tron, Cited by Yu. V. Biryuchkov.
13. L. I. Falin, Some Unsolved Problems in the Morphology and Physiology of Secondary Degeneration of Peripheral Nerves [in Russian], Moscow (1954).
14. S. A. Shibkova, in: Problems in Morphology of the Nervous System [in Russian], Leningrad (1956), p. 92.
15. S. A. Shibkova, Arkh. Anat., No. 2, 39 (1960).
16. E. G. Shkol'nik-Yarros, Abstracts of Proceedings of a Conference on Interneuronal Connections [in Russian], Leningrad (1955), p. 23.
17. E. G. Shkol'nik-Yarros, Zh. Vyssh. Nervn. Deyat., No. 1, 123 (1958).
18. E. G. Shkol'nik-Yarros, Zh. Vyssh. Nervn. Deyat., No. 4, 680 (1961).
19. E. G. Shkol'nik-Yarros, Neurons and Interneuronal Connections. The Central Optic System [in Russian], Leningrad (1965).
20. G. S. Brindley and D. J. Hamasaki, J. Physiol. (London), 184, 444 (1966).
21. R. D. Lund, Exper. Neurol., 15, 100 (1965).
22. R. R. Pfister and J. R. Wolter, Neurology (Minneapolis), 13, 38 (1963).
23. S. Ramón y Cajal, Anat. Anz., 4, 3 (1889).
24. S. Ramón y Cajal, Histologie du Système Nerveux de l'Homme et des Vertèbres, Paris (1909), Vol. 1; (1911), Vol. 2.
25. J. R. Wolter and R. R. Knoblich, Brit. J. Ophthalm., 49, 246 (1965).