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A SEARCH FOR CENTRIFUGAL OPTIC FIBERS IN THE CAT

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ABSTRACT

H. Lin and W. R. Ingram (1973) *A Search for Centrifugal Optic Fibers in the Cat.* Bull. Inst. Zool., Academia Sinica **12**(3): 51-57. Cats were used throughout. Stereotaxic electrolytic lesions were produced in one or more of the following neural entities: the dorsal lateral geniculate nucleus, pulvinar, pretectum and superior colliculus. Extensive unilateral ablation of the visual cortex was also performed. After survival periods of 7-21 days, the brains were processed with the Nauta method. In the corresponding primary optic pathways axonal degeneration could be demonstrated only in the areas shared with supraoptic commissures and in a limited sector of the central terminal portion of the homolateral optic tract near the lesion. No degeneration could be ascribed to *efferent* (*centrifugal*) optic fibers. These findings, coupled with tests related to the hypothalamus, mesencephalic reticular formation, accessory optic system and ventral lateral geniculate nucleus as reported elsewhere, do not support the existence of efferent optic fibers in the mammal.

The problem of *efferent* (*centrifugal*) optic fibers in mammals has long been controversial (14-16; Lin and Ingram, to be published). While their existence is in serious doubt, possible central origins have nevertheless been suggested. Anatomical experiments involving the destruction of such origins have hinted positive identification of presumable efferent Wallerian degeneration in the peripheral optic pathways [4,10,25].

We have systematically tested all presumed origins of optic efferents proposed in the literature for the mammal, with consistently negative results. These areas included the dorsal lateral geniculate nucleus, superior colliculus, pulvinar-pretectum complex and the visual cortex. Experiments with other possible sources of centrifugal optic fibers such as the hypothalamus[14], mesencephalic tegmentum and accessory optic system[15], as well as the ventral lateral geniculate (Lin and Ingram, to be published) are reported elsewhere.

MATERIALS AND METHODS

Sixteen adult cats were operated on under Nembutal anesthesia. All operations were unilateral and on the left side. Stereotaxic electrolytic lesions were placed in one or more of the following subcortical visual centers of 15 cats: the dorsal lateral geniculate, superior colliculus and the pretectum-pulvinar complex. Electrodes were inserted vertically. In most cases, several lesions were made in a given structure, and the electrodes were moved up and down to ensure extensive damage to the neural entities under consideration. The animals were maintained postoperatively for 7-21 days. For each visual structure mentioned above there was at least one animal which had a relatively long survival (14 days or more) in

view of the suggestion that it might take no less than 10 days for the cat efferent optic fibers to undergo Wallerian disintegration[14~16]. For the remaining cat (14 days of survival) subtotal ablation of the primary and association visual cortex was done by aspiration. Postoperative care was observed to minimize pain and discomfort to the animals.

After the aforementioned intervals, the cats were killed with ether and the brains perfused with saline, followed by fixation with 10% formolsaline solution. Except for cat 65, whose brain was cut parasagittally, frozen frontal sections of 30 microns were processed with the Nauta method[14]. Special efforts were made to bring out maximal axonal degradation, or the alternating sections were passed through the potassium permanganate solution for varying intervals, in the hope of revealing at least some disintegrated fibers which might be present in the distal optic pathways. Nissl preparations were routinely available for the assessment of brain damage.

RESULTS

The lesions varied in location and size in different cats. They were either well confined to the neural structures to be tested or also encroached upon adjacent brain tissue, including the brachium of the superior colliculus, the branch of the optic tract on either side of the ventral lateral geniculate, and the mesencephalic tegmentum (Fig. 1). Cortical necrosis and electrode tracks were also rather extensive. These should

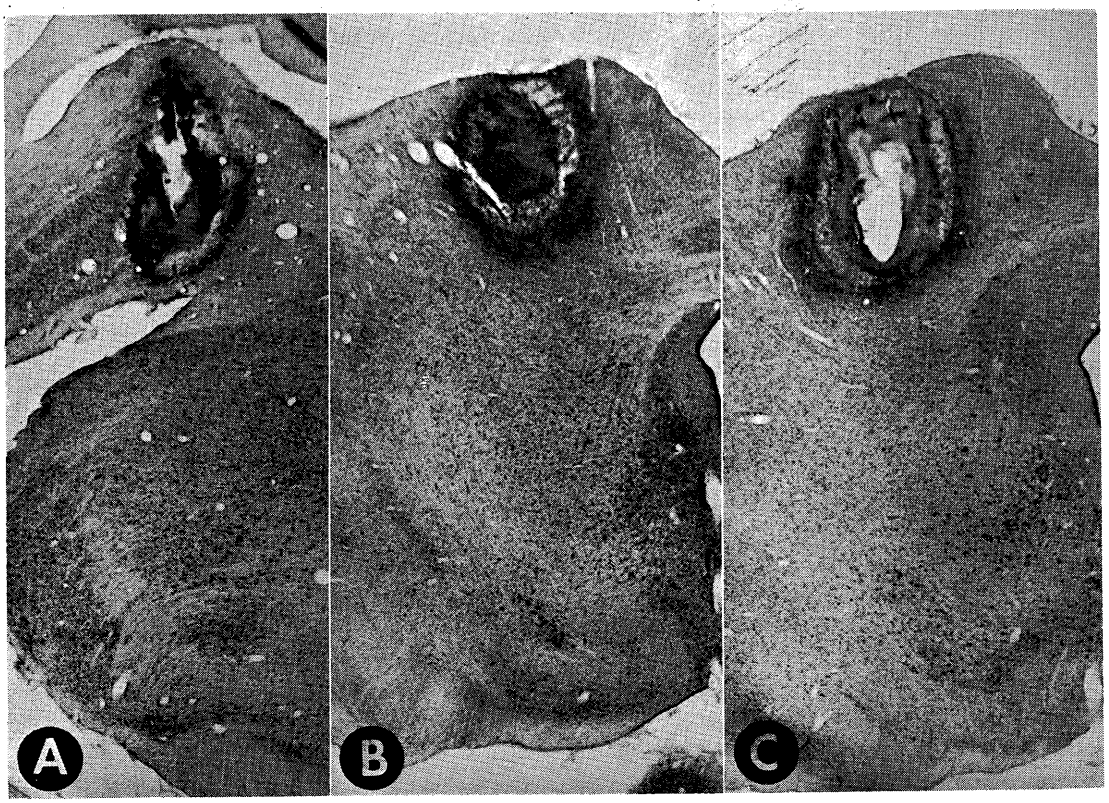

Fig. 1. Examples of unilateral lesions on the left side in a cat brain. (A): In the dorsal lateral geniculate nucleus. (B): In the pretectum. (C): In the superior colliculus. Frontal sections, cresyl violet stain. ×4.

pose no complication since we are concerned only with the question of any Wallerian degeneration of centrifugal optic fibers.

Since fibers of supraoptic commissures intermingle with primary optic pathways to some extent[4,18] and were observed to degenerate in most of our cats, they should be defined. These fibers interconnect the two hemispheres after crossing the midline just ventral to the third ventricle. The exact sources and terminations are in great dispute and need not concern us here. The pertinent point is their topographical relationship to the visual pathways. Some of these fibers could pass along the dorsomedial portion of the optic tract and the dorsoposterior aspect of the optic chiasm to join the contralateral tract[4,18]. The major portions of the optic chiasm and tracts as well as optic nerves will for reason of simplicity be designated as the optic pathways proper in the following presentation.

In cats with lesions exclusively in the dorsal lateral geniculate or with visuocortical ablation, no axonal deterioration could be seen in the optic pathways proper, except in the immediate vicinity of the lesions, nor in the supraoptic decussations. For the other cats, degeneration in the optic pathways shared with supraoptic commissures was obvious whereas the main portions were free from degeneration (Fig. 2) except in the area just distal to the lesions (Fig. 3). In each instance, axonal degradation was traced for a short distance in the central (terminal) portions of the homolateral optic tract fibers next to the lesions (Fig. 3). The degeneration in such fibers was either limited to the branches of the tract or extended slightly below the ventral lateral geniculate (Fig. 3). In no circumstance were we able to follow this disintegration into the optic nerve. Thus there was no deterioration involving optic efferents in any of our cats.

DISCUSSION

Failure to demonstrate axonal breakdown in the distal optic pathways proper (Fig. 2) following brain lesions, despite relatively long survival times, could not be due to faults of the staining

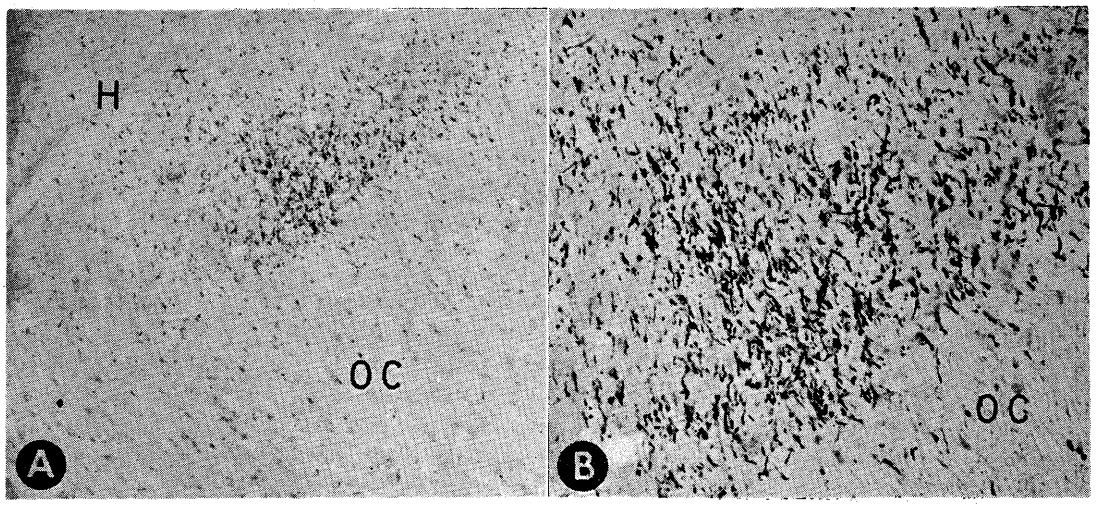

Fig. 2. Nauta preparation of a brain section of cat 65 (14-day survival) which had lesions in the dorsal lateral geniculate nucleus and pulvinar. Parasagittal section, oriented rostrally toward the right and dorsally toward the top. (A): Axonal degeneration of supraoptic commissures which lie partly in the hypothalamus (H) above and the optic chiasm (OC) below, at this level. ×75. (B): Higher power view of the degeneration in the supraoptic commissures. ×190.

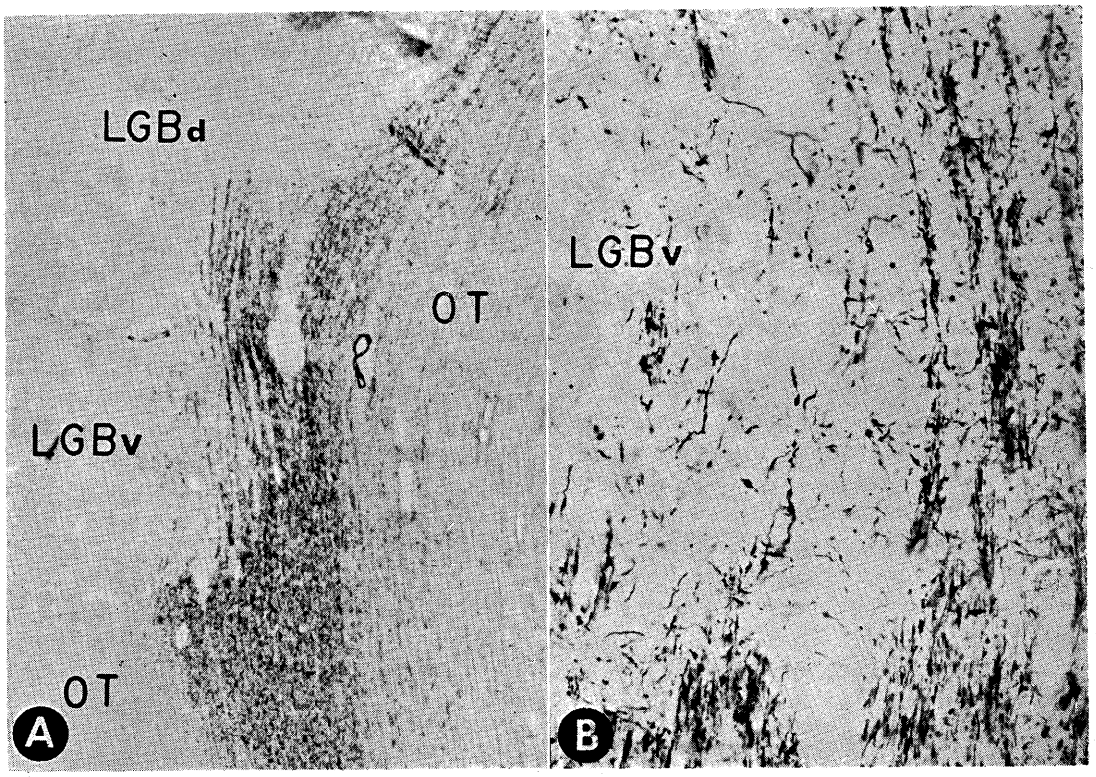

Fig. 3. Nauta preparation of a brain section of a cat (14-day survival) with lesions in the dorsal lateral geniculate nucleus (LGBd) and adjacent areas. Coronal section. (A): Part of the lesion is seen in the LGBd at top. There is a band of profuse degeneration in the central portion of the optic tract (OT) in the middle of the field. Some degeneration is also present in the ventral lateral geniculate (LGBv) and in the central portions of the OT on each side of the degeneration band. ×30. (B): Higher magnification of the OT band of degeneration just ventrolateral to the LGBv. ×190.

technique, because definite local degeneration was invariably noted in the areas adjacent to the lesions (Fig. 3) and electrode tracks, and also in some other brain areas. The only likely explanation for this failure is the absence of efferent optic fibers, or the latter are not impregnated by the Nauta method. Another report (Lin and Ingram, to be published) using several silver impregnation procedures, including the Nauta process employed here, has shown that the temporal and spatial distribution of degradation in the optic pathways proper distal to the lesions are directly related to the lengths of postoperative durations and to the nearness of lesions to the retina. Such findings indicate that retrograde degeneration of *afferent* (*centripetal*) optic fibers may occur while optic efferents are not demonstrated (Lin and Ingram, to be published).

The limited distribution of degeneration in central parts of the optic tract and its branches peripheral to the lesions (Fig. 3) could be explained on nonmutually exclusive bases. Projection fibers of nonretinal origins could traverse such regions[21,27]. Traumatic disturbance could occur in afferent optic fibers for a short distance (16; Lin and Ingram, to be published). Third

possibility is that of retrograde deterioration of optic afferents. Because of the longer distance of lesions from the retina in comparison to the optic tract or nerve incision (16; Lin and Ingram, to be published) retrograde disintegration failed to spread[1].

It could be argued that the present lesions did not destroy all branches of optic afferents[24,26] and thus retrograde degeneration could not progress retinopetally beyond the branching points[1]. Granted this possibility despite our extensive lesions which in many cases damaged several optic centers (Fig. 1), it does not satisfactorily explain the lack of devolution in more distal parts of the optic pathways proper. Certainly not all afferents give rise to collateral ramifications to different optic terminations[26]. Besides, many of our lesions destroyed the branches of the optic tract proximal to the branching points of most, if not all, retinofugal fibers (Fig. 2). The lack of complete retrograde degeneration was probably due to the longer distance from the retina or insufficient deterioration time, or both.

Von Monakow (1889, cited in 2, 19) described cellular degeneration in the rabbit superior colliculus after eye enucleation and suggested that it was owing to retrograde reaction of optic efferents. The same conclusion was derived by others for the colliculus and dorsal lateral geniculate from work on the cat and rat[25]. There was no evidence that such degeneration was actually retrograde rather than transsynaptic, as pointed out by others[2,19]. Besides, several recent workers have specifically noted no appreciable cellular changes in the colliculus in similar experiments[22,28] or in clinical cases[9]. Von Gudden (1870) and Von Monakow (1889) presumably saw orthograde degeneration of optic efferents after collicular extirpation in young rabbits and cats[1,8], an observation questioned by Munzer and Wiener (1902, quoted in 8) and could be due to retrograde devolution of optic afferents[1]. Edinger (1911, cited in 8) noted in the same forms fibers passing from the colliculus into the optic nerve of an enucleated eye, which could be no more than optic afferents "preserved" after such an operation (14, 16, for discussion).

Cragg[4] guardedly concluded that centrifugal optic fibers might come from the superior colliculus and dorsolateral thalamus in the rabbit in experiments similar to ours. He admitted that "the methods of Nauta and Glees have given no more than suggestive evidence of degenerating centrifugal fibers to the retina . . . only one or two degeneration fibers could be identified in each section of the optic nerve or retina in the most favorable preparation after survival periods of 14 days or more." Such random degeneration should be rightfully ignored[6,27] particularly in view of the bulk of staining artifacts "sometimes giving the observer an impression that he was seeing a degenerated nerve fiber"[4]. Furthermore, Cragg[4] failed to explain why overt degeneration was seen in the distal optic nerve segment only 10 days after crushing it, as compared to 14 days or more after brain lesions, if he were really dealing with Wallerian disintegration of centrifugal ones. Such discrepancy in the onset of axonal breakdown could be better accounted for by the retrograde decay of optic afferents (16; Lin and Ingram, to be published). Similar brain lesion studies in various species could not confirm Cragg's results[1,18,21,27]. Our own experimental data were also negative (Fig. 2).

Recently, Honjin *et al.*, Wolter and associates (14, 16, for refs.), Sacks and Lindenberg[23] saw some persisting fibers in the optic pathways in ophthalmological or experimental cases with optic nerve severance and thought that these could come from the dorsal lateral geniculate and superior colliculus among other brain centers. These studies have been discussed as involving probable misconception[14,16]. Holmes[11] studied the remaining brain of a dog long after bilateral hemispherectomy and implied that the geniculate contained cells whose axons passed to the retina. He seemed to base the idea on "a few cells" persisting in this nucleus. The existing literature shows that the corresponding cell atrophy might or might not be complete in similarly but unilaterally prepared specimens[17,20]. There is no reason to believe that retrograde and transsynaptic

cellular atrophy should be complete in the dorsal lateral geniculate of adult animals after such an operation, in the presence of internuncial cells and connections to and from other subcortical entities[18,17,25], including the retina. It is to be noted that there were still neurons remaining in the geniculate in clinical cases of bilateral optic atrophy with or without persisting optic fibers[9,12,23].

Certain anatomical studies have favored the presence of direct corticoretinal efferents after visuocortical lesions[10,25]. The retrograde transsynaptic degeneration which could occur after occipital lesions[1,5] should be envisaged. Gorikov[7] thought normal fibers in the optic nerve subsequent to enucleation could originate from the cortex. As discussed before, such "normal" fibers were likely "preserved" afferents. Others using current silver techniques could not demonstrate efferent Wallerian degradation of corticoretinal fibers[3,4]. Our cat with visuocortical ablation and every other cat having parts of the cortex damaged by electrode passage also failed to offer confirmation.

It seems fair to conclude that while the existence of centrifugal optic fibers in the mammal is dubious (14-16; Lin and Ingram, to be published) suggestions as to their origins are even less tenable. We should point out that lesion studies supporting optic efferents are relatively few and equivocal, and should perhaps be rejected. On the other hand, it is possible that many investigators did not find any evidence for such axons and hence refrained from discussing the problem. Our quotation of negative studies was restricted to only some of those from which definite information was available in description and/or diagram. The present and other reports (14, 15; Lin and Ingram, to be published) have tested every pertinent neural structure but failed to support any as the source of centrifugal optic fibers. Thus, the latter probably do not exist or, if they do, can not be revealed by the silver methods.

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貓離心視纖維之探索

林宏民 W.R. Ingram

哺乳類之視神經纖維係由網膜通往大腦，通稱向心視纖維。可是近百年來文獻中一再出現另有一種視纖維存在之說。據云此種纖維由大腦通往網膜，亦即所謂離心視纖維也。作者等在一系列實驗中將貓腦中可能發出此種所謂離心視纖維之部位加以破壞，然後用 Nauta 鍍銀法觀察視覺通路中神經萎壞變化之情形。本文實驗結果再度證明哺乳類之離心視纖維極可能根本不存在。