THE TRIGEMINAL NERVE AND THE CERVICAL SYMPATHETIC GANGLIA IN THE INNERVATION OF THE CEREBRAL ARTERIES

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The nervous system plays the leading part in reflex regulation of the cerebral circulation. For a correct understanding of the physiology of this process a knowledge of the sources of innervation of the cerebral vessels is also required, and these problems have not been adequately investigated.

All authors admit the involvement of the cervical sympathetic ganglia in the innervation of the cerebral vessels, and this innervation has been confirmed experimentally [6, 7]. However there is a divergence of opinion concerning the part played by the cranial nerves. Stohr [9] maintains that nerves III, VI, IX, X, XI, and XII are involved; B. N. Klosovskii [4] invokes nerves III, IV, VI, VII, VIII, IX, and X. D. D. Shelep claims III, VI, and X, while S. N. Boyarinova and N. D. Dovgyallo [3] point to nerves III, IX, X, XI, and XII. B. N. Klosovskii [4] considers that the trigeminal nerve supplies the sensory innervation of the cerebral vessels. However, this idea has not been confirmed experimentally. Other authors [1, 8] have also described the trigeminal nerve as involved in the innervation of the cerebral vessels.

In the Central Scientific Research Laboratory of our Institute experimental investigations have also been made on the involvement of the trigeminal nerve and the superior cervical sympathetic ganglion in the innervation of the cerebral arteries.

EXPERIMENTAL METHOD

In one group of cats the branches of the trigeminal were divided intracranially at the point where they leave the Gasserian ganglion; the superior cervical sympathetic ganglion was removed from another group of cats. A histological study was then made of the regeneration of nerve fibers along the wall of the cerebral arteries 24, 48, 72 h after the operation.

The Gasserian ganglion was approached by the method described by Oksman [5]. Oksman himself and other authors [2] have destroyed the Gasserian ganglion by thermocautery. We however preferred to divide the branches of the trigeminal to avoid the toxic influence of the disintegration of the products formed by the cautery, which might affect the nervous elements of the cerebral arteries. The superior cervical sympathetic ganglion was removed by the usual method; as a criterion of its removal we used the disappearance from view of the nicticating membrane on the operated side.

We studied the brain of 24 cats at the following times after division of the branches of the trigeminal nerve: in five cases after 24 h, in five after 48 h, and in five after 72 h; after removal of the superior cervical sympathetic ganglion in two cases the study was made after 24, and in five after 48 h. As a control we made a study of the cerebral arteries of two cats in which the branches of the trigeminal nerve were not divided, but in which a mock operation had been performed.

The brain was fixed whole in 12% neutral formalin. For our study we used the trunks and branches of the anterior, middle, and posterior cerebral arteries lying in the pia mater, lying outside the brain. We also studied

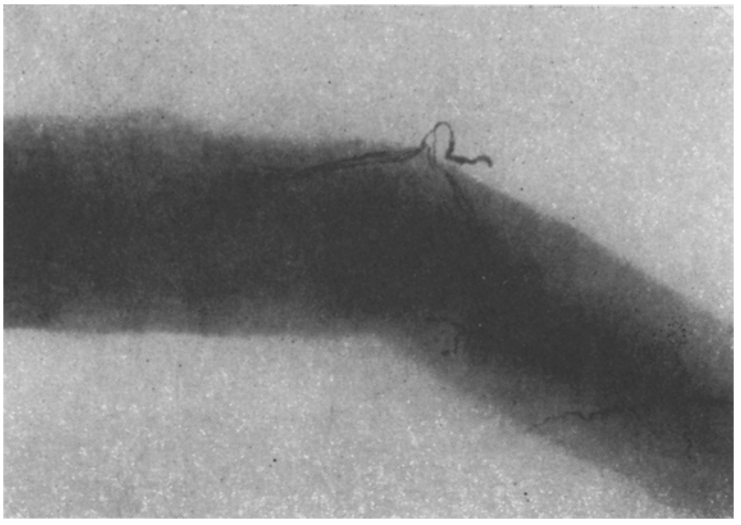

Fig. 1. Degeneration of nerve fibers on a branch of the middle cerebral artery of a cat 24 h after division of the branches of the trigeminal nerve (operated side). Micrograph. Impregnation by Bielschowsky Gros. Ocular 15×, objective 8×.

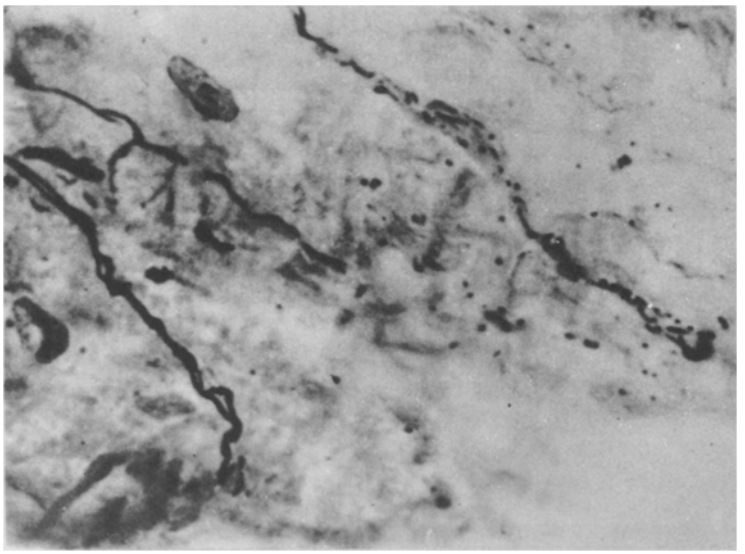

Fig. 2. Disintegration of the nerve fibers on an intracerebral vessel of a cat 48 h after removal of the superior cervical sympathetic ganglion (operated side). Micrograph. Impregnation by Bielschowsky Gros. Ocular 20×, objective 40×.

divisions and branches of the cerebral arteries lying in the brain substance itself. We would point out that in the cat the intracerebral vessels are very fine: to expose them we used hedgehog spines and a loupe on a stand giving a magnification of twenty diameters. We used intracerebral vessels from the region of the thalamus, corpus striatum, and frontal lobes.

Histological preparations were made from sections of the wall of the arterial trunks of the cerebral arteries, from pieces of pia mater with the arterial branches it contained; we also made total preparations of the intracerebral vessels. The preparations were impregnated with silver nitrate by the method of Bielschowsky Gros.

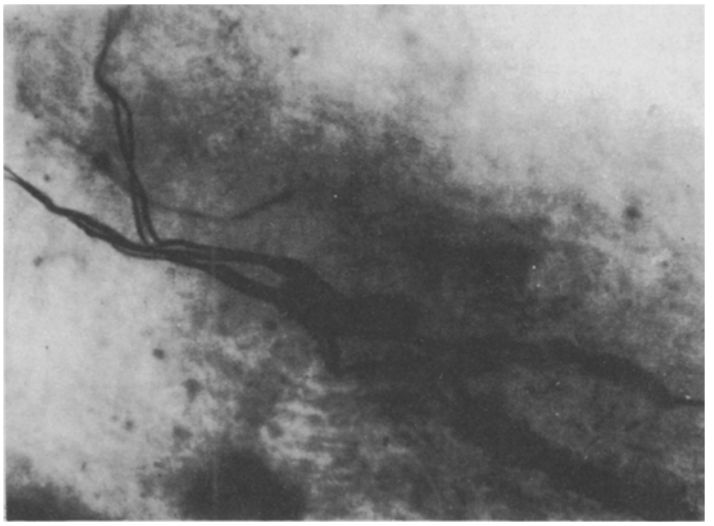

Fig. 3. "Growth cones" on the wall of the middle cerebral artery of a cat, 48 h after division of the branches of the trigeminal nerve (operated side). Micrograph. Impregnation by Bielschowsky Gros. Ocular 15×, objective 40×.

EXPERIMENTAL RESULTS

After division of the branches of the trigeminal nerve the medullated nerve fibers degenerated (undergo fragmentation and disintegration), this process taking place on the wall of the trunks and branches of the anterior, middle, and posterior cerebral arteries lying in the pia mater, i.e., lying outside the brain substance (Fig. 1).

The question which now arises is whether this degeneration is the result of the response of the nerve fibers to the operative interference. By itself the operation on the skull, especially in conjunction with the intracranial division of the branches of the trigeminal nerve constitutes a serious trauma. The answer to the question is in the negative because even 72 h after the mock operation we never found any fragmentation or disintegration of the nerve fibers on any of the preparations of the cerebral arteries; we found merely signs of their stimulation. Evidently fragmentation and disintegration of the nerve fibers on the wall of the cerebral arteries was genuinely evoked by division of the branches of the trigeminal nerve, i.e., degeneration of the nerve fibers occurred as a result of their separation from the center (from the nerve cell).

It must be emphasized that after division of the branches of the trigeminal nerve fragmentation and distintegration of the medullated nerve fibers on the wall of the trunks and branches of the anterior, middle, and posterior cerebral arteries lying in the pia mater could be found not only on the operated but also on the unoperated side. It is true that the number of degenerated fibers on the nonoperated side was much less than on the operated side. Apparently the trigeminal nerve contributes part of the innervation of the cerebral arteries on the contralateral side also.

Also, on the operated side not all the medullated nerve fibers degenerated; even in a single nerve bundle, intact fibers could be found among those which had been affected. If we postulate a bilateral innervation of the cerebral arteries by the trigeminal nerve, some of the remaining intact nerve fibers can be assumed to have originated from the trigeminal nerve of the opposite side. As has already been pointed out the remaining intact fibers originate from other cranial nerves. However because after division of the trigeminal nerve the main mass of medullated nerve fibers on the vascular wall undergoes degeneration, we must consider the trigeminal nerve to be one of the principal sources contributing to the sensory innervation of the cerebral artery.

Neither on the nonoperated nor on the operated side did we find any fragmentation or disintegration of the nerve fibers on the arterial branches lying in the brain substance (after division of the branches of the trigeminal nerve). We found only marked signs of stimulation of constant degree of the nerve fibers on both sides, an effect which was probably the result of reactive stimulation. Possibly the trigeminal nerve innervates only the trunks and branches of the cerebral arteries lying in the pia mater, and its zone of innervation does not extend to the intracerebral vessels.

After removal of the superior cervical sympathetic ganglion degeneration of the nonmyelinated nerve fibers occurred on both the trunks and branches of the anterior, middle, and posterior cerebral arteries where they lay in the pia mater, i.e., outside the brain substance; this effect occurred both on the main and subsidiary branches lying within the brain substance, and a small number of the nonmedullated nerve fibers underwent degeneration (Fig. 2).

From these facts we may conclude that the superior cervical sympathetic ganglion takes part in the innervation of the cerebral arteries, and that its zone of innervation extends as far as the intracerebral vessels. However this does not appear to be the only source of sympathetic innervation of the cerebral arteries, because a number of intact nonmedullated nerve fibers remain after removal of the ganglion.

After extirpation of the superior cervical sympathetic ganglion we found degeneration of nonmedullated fibers only on the wall of the cerebral arteries on the operated side; degeneration of the fibers on the nonoperated side was not found in any of the preparations.

In our work on degeneration of the nerve fibers after division of the branches of the trigeminal nerve we came across an interesting effect. On the wall of the trunks and branches of the anterior, middle, and posterior cerebral arteries lying in the pia mater flask-shaped swellings of the medullated nerve fibers were seen (Fig. 3). They were oval in shape, and to some extent simulated nerve cells. However they differed in their greater size and by the absence of any structural features. Such flask-shaped swellings appear to constitute an accumulation of neuroplasm, and represent the response of the nerve fibers to operative interference. Such structures have been described in the literature under the title of "growth cones," which are formed during the regeneration of nerve fibers.

SUMMARY

Experiments were carried out on cats to determine the involvement of the trigeminal nerve and superior cervical sympathetic ganglion in the innervation of the cerebral arteries. The preparations were treated by impregnation with silver nitrate by the method of Bielschowsky-Gros. After intracranial division of the branches of the trigeminal nerve, degeneration of the nerve fibers occurred only on the walls of the extracerebral trunks, and on the branches of the cerebral arteries; the effect was seen mainly on the ipsilateral and to a lesser extent on the contralateral side. After removal of the superior cervical sympathetic ganglion degeneration of this type was observed on the wall of both the extracerebral and intracerebral vessels on the operated side.

Flask-like nerve fiber swellings simulating nerve cells were found on the walls of the cerebral arteries after their denervation.

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