ANATOMICAL CONNECTION BETWEEN THE CORTICAL AREAS OF THE SPLANCHNIC NERVE AND THE PREMOTOR, MOTOR, AND LIMBIC REGIONS IN THE CAT

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The cortical projection areas of the specific ascending interoceptor pathways have been demonstrated by the method of evoked potentials [1-3, 5-12]. However, the nature of the interneuronal connections of these zones remains largely unknown.

Nothing is known of the relation of these cortical areas, representing terminations of afferent pathways, to other central nervous structures. Here we are concerned with the nature and the number of fibers connecting the zones of primary responses with different parts of the brain, and primarily with those parts of the cortex whose stimulation or extirpation elicits autonomic effects.

In the present communication we describe a morphological investigation of the association connections of the cortical representational areas of the splanchnic nerve with the premotor, motor, and limbic regions*.

EXPERIMENTAL METHOD

The investigation was carried out on 29 adult cats by the method of terminal axon degeneration. To induce and determine the nature of the degenerating fibers in cortical areas corresponding to the first and second zones of representation of the splanchnic nerve we produced three kinds of operative interference. Extirpation resulted in the destruction of all systems of fibers. Undercutting the white matter beneath the projection areas enabled us to observe the degenerative disintegration of the radial fibers alone, i.e., of those association fibers which form part of the U-shaped and intralobular fibers. Finally deep division of the substance of the cortex in the projection areas revealed degeneration of the horizontal cortico-cortical fibers.

Localization of the cortical representation of the splanchnic nerve was made from topographical data established in terms of the primary responses [5-7]. The first zone lay in the region of the sulcus anastus, and the second in the anteriro region of gyrus ectosylvius anterior. From the map of Gurevich and Bykhovskaya the first zone corresponds to the central divisions of areas 1 and 2, and the second to the most anterior regions of area 50.

The operations were carried out under sodium amytal anesthesia under sterile conditions. After division of the soft tissues of the head an opening was trespanned in the skull and the dura opened. The white matter was undercut by an angled leucotome. To avoid damage to the cortical layers the leucotome was introduced into the brain substance in regions remote from the areas of representation. An incision was made into the cortex in the form of a circular cut extending the full depth of the cortex. The animals were killed 5, 8, and 9 days after the operation. The material was impregnated by Naut's method after the brain had first been perfused with 10% neutral formol.

A histological study was made of area 4 (motor cortex), area 6 (premotor region), and areas 32, 24, and 29 (limbic region). The cytoarchitectonic structure was studied in Nissl preparations.

EXPERIMENTAL RESULTS

Area 4. A histological study of area 4 after separate extirpation of the cortical representational areas of the

*A summary of the autonomic influences of these parts of the cerebral cortex is given in the monograph by V. N. Chernigovskii [4].

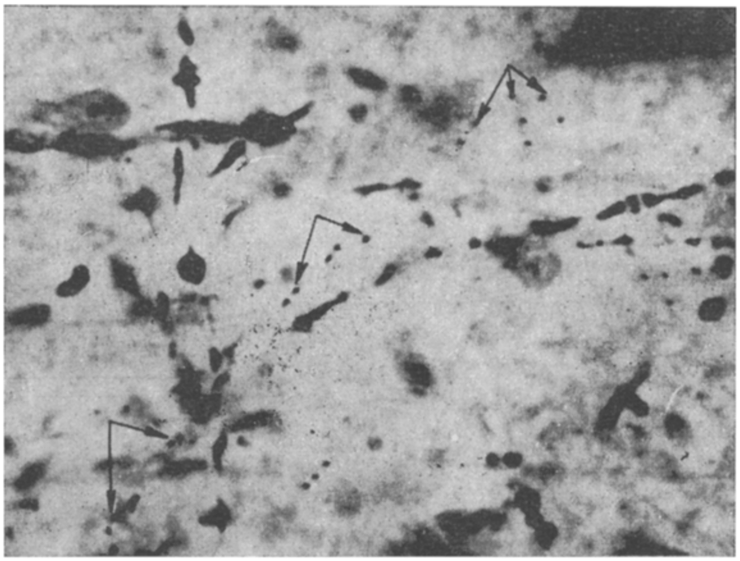

Fig. 1. Cortex of area 4 eight days after removal of the second area of representation of the splanchnic nerve. Varicosity and fragmentation of horizontal and radial fibers in the middle cortical layer. The arrows indicate regions of degeneration of the terminal portions of the fibers. Naut's impregnation. Ocular 12.5 ×. Immersion objective 60 ×.

splanchnic nerve revealed similar massive irreversible changes in the radial and horizontal systems of fibers. Degenerative changes were shown by varicose swellings, by fragmentation, and by the disintegration of thick and medium-sized fibers into granules. The preparation shown in Fig. 1 of area 4 of the cortex after extirpation of a second zone of representation of the splanchnic nerve shows a breakdown of the radial and horizontal fibers in the middle cortical regions. It is important to note that the changes in the fibers were apparent in all cortical layers except for the first. It was then found that all parts of the fibers underwent degeneration, including their terminal portions. It should be noticed that the destruction was localized to certain regions of the cortical cross section.

After undercutting the white matter beneath the cortex degenerative changes were found chiefly in the radial system of fibers. Changes in the horizontal fibers were found only occasionally and were evidently due to the fact that some of the undercut radial fibers branched within area 4 to form a T-junction.

When the first representational area of the splanchnic nerve was divided to the full depth of the cortex irreversible changes of the horizontal fibers of the middle and superficial layers of area 4 occurred. After a similar operation in area 2 of representation of the splanchnic nerve no regenerating fibers were found.

Area 6. After separate extirpation of the regions corresponding to the zones of cortical representation of the splanchnic nerve, no single type of change was found. As in the case of area 4, we found a well-marked argentophilia, varicosity, and fragmentation. At the same time the breakdown of fibers in field 6 was not so massive and affected chiefly the thick radial fibers. They could be followed from the point of emergence from the white matter as far as the middle cortical areas. Figure 2 shows one such fiber from the lower regions of the cortex of this area. Also, after removal of the first zone of representation of the splanchnic nerve, in the middle regions of the cortex of area 6 we found degenerative changes of a few horizontal fibers.

After undercutting the white matter beneath the projection areas we observed destructive changes of the thick radial fibers. After cutting through the whole thickness of the projection areas irreversible changes in the fibers took place only in cases when the circular cut damaged the cortex of the first splanchnic cortical area. Then, just as after extirpation of this region, occasional horizontal fibers passing through the middle regions of the cortex degenerated.

Area 24. A microscopical study of preparations of area 24 made after removal of the cortical projection areas of the splanchnic nerve showed irreversible changes of the thin radial fibers. These changes usually appeared in the lower and middle regions of the cortex, whereas in the first layer only the horizontal fibers were degenerate. After

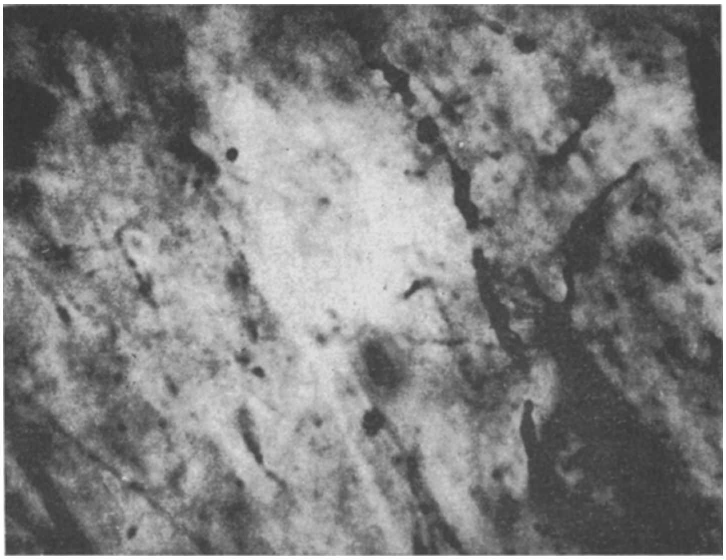

Fig. 2. Cortex of area 6 eight days after removal of the second area of representation of the splanchnic nerve. Fragmentation of an argentophil varicose fiber from the lower cortical layers. Naut's impregnation. Ocular 12.5 ×. Immersion objective 60 ×.

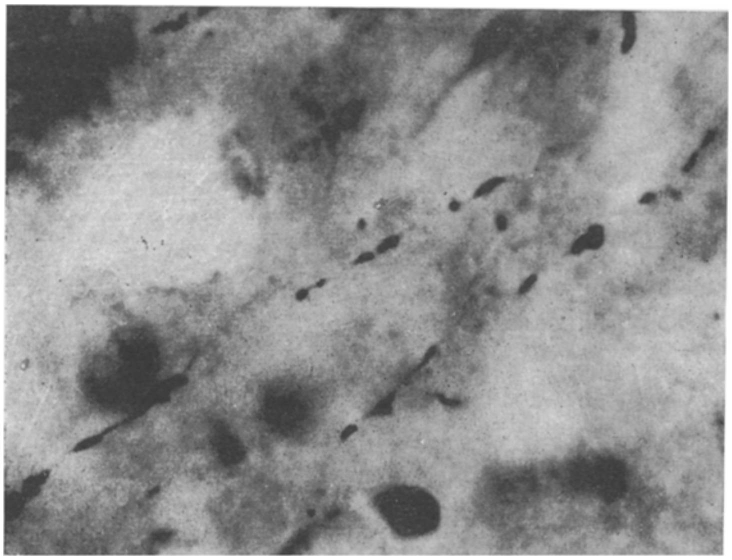

Fig. 3. Cortex of area 24 nine days after extirpation of the first area of representation of the splanchnic nerve. Varicose changes and fragmentation of the fine horizontal fibers of the first cortical layer. Naut's impregnation. Ocular 12.5 ×. Immersion objective 60 ×.

extirpation of the first projection area, the compact bundles of horizontal fibers underwent destructive changes. Irreversible changes of both these and other fibers took the form of fragmentation of the argentophil varicose fibers. In many preparations we were also able to observe degeneration of the terminal regions of the fibers. Figure 3 shows breakdown of the horizontal fibers in the first cortical layer after extirpation of the first representational area of the splanchnic nerve.

We must emphasize that despite the great similarity of the damage in the two cases, the extent of the fiber destruction 24 h after removal of an area depended on whether the first or second splanchnic cortical area had been excised. A study of histological material showed consistent features: After removal of the first area, the number of degenerated fibers was far greater than the number found after removal of the second.

When the white matter was divided beneath the cortex of the first and second projection areas of the splanchnic nerve the changes which we found affected chiefly the fine radial fibers. After making an incision through the whole depth of the cortex in the areas representing the splanchnic nerve there were no changes in the fibers.

Area 32. A study of preparations of cortical area 32 after removal of the first splanchnic cortical area revealed destructive changes affecting the fine radial fibers in the lower and middle cortical layers. They were numerous and scattered in depth thorughout the cortex.

After removal of the second splanchnic cortical area the changes were found to include only the separate radial fibers lying in the lower cortical regions. Affected fibers were always encountered in the underlying white matter.

After an incision into the white matter beneath the areas of representation of the splanchnic nerve breakdown of radially directed fibers was found. The number of degenerating fibers found after removal of the first zone exceeded the number of such fibers found after removal of the second splanchnic cortical area. No degenerative changes of the fibers in area 32 could be seen after a circular incision had been made through the whole depth of cortex.

Area 29. A microscopical study of preparations of cortical area 29 after separate extirpation of the cortical splanchnic areas revealed no denerating fibers.

Experimental morphological studies have shown that after operative interference on cortical areas corresponding to the first and second areas of splanchnic representation, degenerative changes were found in various systems of fibers in the motor cortex (area 4), premotor cortex (area 6), and in the limbic region (area 32 and 24).

The presence among the disintegrating fibers of very fine terminal fibers is evidence of their function as connections. Also, the degeneration of the radial fibers, of which a considerable proportion were terminal, confirms that there are connections between these areas.

Studies of fiber change made by undercutting the white matter beneath the cortex and by making incisions into the cortex have revealed the cause of the damage. It was found that the main portion of the fibers which make connections belong to the association systems which pass into the white matter, and only a small number of intracortical fibers connect the first cortical splanchnic area with the premotor cortex. However, most of the horizontal fibers demonstrated microscopically are derived from T-junctions of radial fibers.

A comparison of the number of degenerated fibers in the fields investigated suggests that the splanchnic cortical areas are connected with the premotor, motor, and limbic areas (anterior and middle portions), but to different extents. The most extensive connection was found between the second splanchnic cortical area and area 4. A moderate number of these connections was recorded between the first splanchnic cortical area and areas 4, 32, and 24, as well as between both projection areas and area 6, while the smallest number was found between the second splanchnic cortical area and areas 24 and 32 of the limbic region.

SUMMARY

By the method of terminal degeneration the presence of anatomical connections was established between the first and second representation zones of the splanchnic nerve and the premotor, motor and limbic areas of the cortex of large hemispheres of cat. The system of fibers detected belonged mainly to the associative routes, passing in the white matter. The quantitative characteristics of the connecting fibers is of diverse nature.

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