CORTICOTHALAMIC CONNECTIONS IN THE PROJECTION SYSTEM OF THE PELVIC NERVE

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Electrophysiological investigations on specific projection systems in the animal brain have shown that somatic sensation is relayed in the ventroposterior (VP) nucleus of the thalamus, and that within this nucleus there is fairly definite somatotopic arrangement of afferent systems [13]. The projection from this nucleus is in the somatosensory cortex, where again there is somatotopic distribution of sensation [14].

Anatomical investigations on connections between somatosensory cortex and thalamus have shown that corticofugal fibers run from these cortical fields to the thalamic structures which actually send the projection fibers to the cortex [4, 11].

It follows, therefore, that thalamocortical systems are linked by two-way projections.

It has recently been shown that visceral sensation is also represented in the ventroposterior nucleus of the thalamus and in the somatosensory cortex. The projection zones of pelvic and splanchnic nerves are organized in the same way as somatic zones in ventroposterior nucleus and sensory cortex [2, 3, 5, 6, 8].

There is practically nothing in the literature on the existence of corticofugal connections in the projections of visceral afferent systems or on their topography in relation to any particular thalamic nuclei. An attempt at morphological analysis of such corticothalamic connections is now described.

METHOD

It was decided to study the afferent projection system of the most studied visceral nerve, the pelvic nerve.

The investigations were carried out on cats. First of all, the projection zone of the pelvic nerve and its center of greatest activity were defined in somatosensory field I of the cortex by the evoked potential method with unipolar leads (nembutal anesthesia) [5]. The contralateral pelvic nerve was stimulated with single rectangular pulses.

When the projection zone had been defined, an area not exceeding 2-3 mm^2 was thermocoagulated. To avoid damage to the white substance of the cortex, the tip of the thermocoagulator was fixed in the manipulator of a stereotaxic apparatus and introduced into the cortex to a depth of not more than 1.8-2.0 mm. When the postoperative period was not completely satisfactory, the animal was excluded from the experiments.

The animals were killed 7-9 days after the operation by intravital perfusion of the brain with 10 per cent neutral formalin in normal saline.

Serial frontal sections of the brain (30 μ thick) were prepared by the Nauta and Gygax method [19], which gives selective impregnation of degenerated fibers and their preterminals. The preparations thus present a clear picture of the bundles of fibers which have degenerated, their course and their terminations.

Topographical details of the frontal sections of the thalamic nuclei were pinpointed from the stereotaxic atlas of Jasper and Ajmone-Marsan [10].

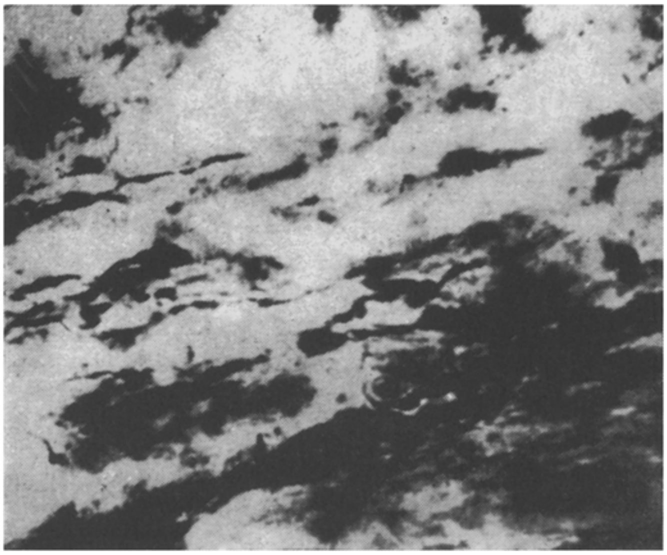

Fig. 1. Degeneration of nerve fibers in internal capsule (isolated bundlesof fragmented fibers). Frontal section at level 9-10 mm anterior to the zero frontal plane. Nauta-Gygax method. ×750.

RESULTS

A compact bundle of degenerated fibers, coming from the coagulated area in the cortex, was seen in the posterior limb of the internal capsule, nearer to the region of the reticular nucleus of the thalamus. These fibers constituted about half the volume of the still normal fibers in this part of the internal capsule (Fig. 1).

The next structure in which fairly distinct areas of degeneration could be seen was the reticular nucleus of the thalamus.

The nucleus had the characteristic reticular structure and was situated in the anterolateral part of the thalamus. Towards its caudal extremity, it extended round the lateral geniculate body and ventroposterior nucleus in the form of a falciform band.

The cells of the reticular nucleus were scattered diffusely among groups of fibers. In this area the degenerated fibers appeared as varicose fragmented fibers of various thicknesses (Fig. 2). There were stout drop-like fragments and delicate separated fibrils. The visible preterminals of some of the degenerated fibers proved that at any rate some of these fibers ended in the reticular nucleus, and thus formed a system of corticofugal (descending) connections linking this nucleus with area I of the sensory cortex. The remaining group of degenerated fibers apparently did not end in the nucleus but continued on towards the ventroposterior nucleus.

The degeneration was particularly distinct and striking in the ventroposterior nucleus. This is one of the largest structures in the thalamus and is part of the system of specific relays. It is situated between the group of lateral nuclei and the centrum medianum. The ansa medialis passes below it.

The degenerated fibers were seen as closely set, deeply staining fragments and granules (Fig. 3). It was sometimes difficult to trace the course of the degenerated fibers as these had broken down into numerous discrete fragments. In some cases, however, fibers which had not broken down distally could be seen going directly to cells.

Numerous intact fibers of various sizes, running in various directions, could be seen in the corresponding part of the ventroposterior nucleus in the opposite half of the thalamus (on the side opposite to the coagulated area). Altered fibers could be seen here and there, but this may have been the result of general trauma associated with the brain operation.

The picture in this area did not differ from that presented by similarly treated preparations from the brain of an intact cat.

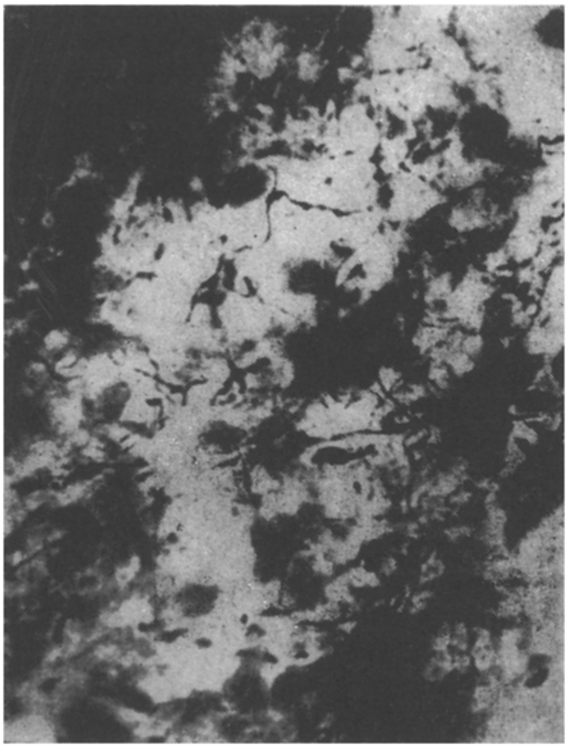

Fig. 2. Degenerative changes in fibers in reticular nucleus of thalamus showing different stages of breakdown; varicose and drop-like fragments; degenerated preterminals can be seen. Nauta and Gygax method. x750.

The picture of degeneration was altogether different in the posterior ventral nucleus on the side of the coagulated cortex. The number of degenerated fibers was incomparably greater and bundles of such fibers could be seen in almost all parts of the nucleus.

The number of degenerated fibers in the dorsolateral part of the ventroposterior nucleus greatly exceeded the numbers seen in other parts (see Fig. 3). This group of fibers formed a compact bundle and the degenerated preterminals could be seen making contact with neurones in this part of the nucleus.

Electrophysiological analysis of primary responses indicates that the lemniscal pathways of the pelvic nerve terminate in this part of the nucleus [2]; this area, therefore, constitutes the projection of the pelvic nerve in the lateral part of the ventroposterior nucleus. It gives origin to a third neurone which goes to the thalamocortical projection in field I of the somatosensory cortex, and this is therefore the cortical projection zone of the pelvic nerve [5].

The posterior ventral nucleus of the thalamus thus contained a large compact group of degenerated fibers concentrated in one particular zone, in addition to the smaller isolated groups of similarly degenerated fibers, scattered throughout the nucleus (see Fig. 3).

The large area of degenerated fibers may be termed the center of maximum degeneration, on analogy with the center of maximum activity observed when evoked potentials were recorded from this area on stimulation of the pelvic nerve. The visible degeneration of preterminals of these corticothalamic fibers is evidence that the coagulated area of cortex is connected with this same part of the ventral nucleus, which means that the cortical projection zone of the pelvic nerve and its thalamic relay in the ventral nucleus are linked by both ascending and descending connections. The descending corticofugal connections, however, have a distribution which extends beyond the circumscribed projection zone of the pelvic nerve in the nucleus. These relationships are apparently a reflection of extensive overlapping of different afferent systems in both cortex and nucleus. The number of degenerated fibers diminished with increasing distance from the main center and, consequently, there were correspondingly diminishing numbers of neurones with which the terminals of these fibers came into contact. All or at any rate most neurones within the central area, which are projected in the cortical field indicated, would appear to have return connections from the same cortical field.

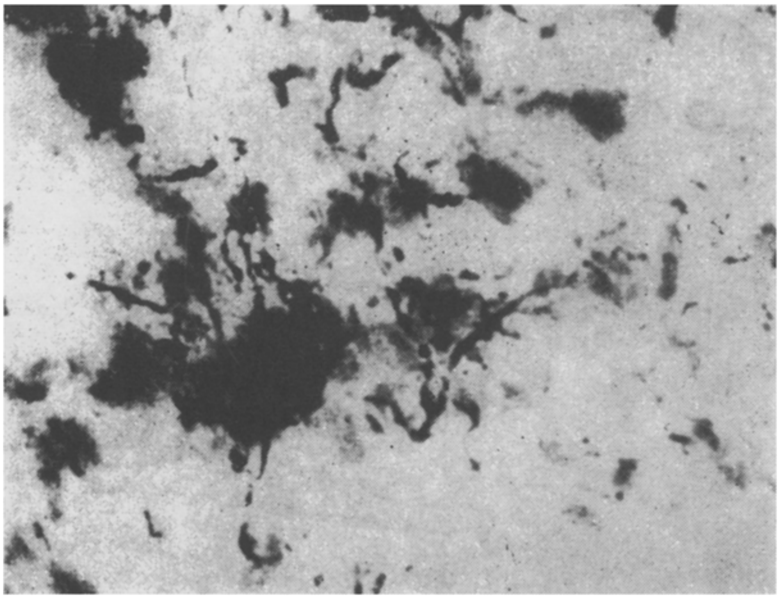

Fig. 3. Breakdown of nerve fibers in postero-ventral nucleus. Cell outlines with near by breaking down preterminal fibers can be seen; Nauta and Gygax method. ×750.

It is, of course, possible that these local return connections within the specific thalamocortical projection system of a particular afferent system (in this case, that of the pelvic nerve) are also the morphological substrate for what have been termed the corticothalamic feedback networks [7, 9]. Degenerated fibers, it should be noted, were also found in other thalamic nuclei, such as the ventrolateral part of the dorsomedial nucleus, ventromedial and paracentral nuclei.

The existence of feedback connections in various structures of the central nervous system has been discussed by many research workers recently [1]. These feedback connections are considered to be essential elements in the system of mechanisms responsible for analysis of afferent signals.

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