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ELECTRON-AUTORADIOGRAPHIC ANALYSIS OF PROJECTIONS OF SOMATOSENSORY CORTICAL AREAS I AND II IN THE POSTERIOR VENTRAL NUCLEUS OF THE THALAMUS

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Differences in the organization of corticofugal fibers arising from somatosensory cortical areas I (S_I) and II (S_{II}) were detected by electron-microscopic autoradiography in the posterior ventral nucleus (NVP) of the thalamus. The distribution of corticofugal fibers from the corresponding zones of the two somatosensory cortical areas within NVP differs. Endings of both types of fibers form synaptic contacts chiefly with distal dendrites of relay cells of NVP and much less frequently with dendrites of Golgi type II interneurons. No direct convergence of fibers arising from the two somatosensory areas on single cells of NVP was observed.

KEY WORDS: corticofugal fibers; somatosensory cortical areas; posterior ventral nucleus of the thalamus; degeneration; autoradiography; electron microscopy.

Previous electrophysiological investigations showed that somatosensory cortical areas I and II differ in their influence on the relay neurons of the posterior ventral nucleus (NVP) of the thalamus, the axons of which run to somatosensory cortical area I [3-5]. The modulating effect of the somatosensory cortical areas is manifested particularly clearly in relation to the transmission of afferent signals [3] and the formation of trace processes which develop in NVP after the passage of an afferent impulse [4].

The nature of the morphological substrate responsible for differences in the character of cortical control over the mechanism of transmission of signals through the thalamic relay from the two somatosensory areas has not yet been explained. To study these problems the investigation described below was undertaken.

EXPERIMENTAL METHOD

Experiments were carried out on 36 cats weighing 2.5-4 kg. An autoradiographic method was used in the experiments of series I. Leucine-^{3}H, in a concentration of 100 μCi/μl, was injected into the zone of representation of the forelimb in somatosensory area I (S_I) of the cortex (six cats) and somatosensory area II (S_{II}) of

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the cortex (five cats). The microinjection of isotope was given by a Hamilton's syringe at four points in each particular area four times in the course of 5 min.

In the experiments of series II the method of electron microscopy was used to study degenerating terminals of corticofugal fibers. For this purpose, thermocoagulation of the zone of representation of the forelimb in area S_I (five cats) and area S_{II} of the cortex (four cats) was carried out.

In the experiments of series III a combination of the two previous methods was used. In seven cats the area of representation of the forelimb in cortical area S_I was coagulated and leucine-^{3}H was injected at the same time into the corresponding zone of cortical area S_{II}. In nine cats coagulation of area S_{II} was accompanied by injection of leucine-^{3}H into cortical area S_I.

The animals were killed 66 h later under anesthesia during intravital perfusion through the heart. Pieces of brain forming the anterior, middle, and posterior parts of the ipsilateral and contralateral NVP of the thalamus were additionally fixed in the perfusion solutions and, after dehydration, were embedded in Araldite. Ultrathin sections were cut from the material obtained from the animals of series II and these were studied in the IEM-100 B electron microscope. Sections for light autoradiography by the Kopriwa – Leblond method [12] and for electron-microscopic autoradiography by Granboulan's method [8] were cut from the blocks obtained from the animals of series I and III. The semithin sections for light autoradiography were coated with Ilford K-5 liquid photographic emulsion. After development in Kodak D19 developer and fixation in 30% thiosulfate solution, the track autoradiographs were stained with toluidine blue and examined in the light microscope. The number of grains of silver above the neuropil was determined for each 3200 μ^2 of section. Ultrathin sections, before coating with photographic emulsion, were stained with uranyl acetate and lead citrate by Reynolds' method [16]. The ultrathin sections were exposed for 4-8 months. After development, the ultrathin sections were examined in the IEM-100B electron microscope.

EXPERIMENTAL RESULTS

After injection of leucine-^{3}H into the zone of representation of the forelimbs in area S_I the largest number of grains of silver was found in the middle part of the lateral nucleus of NVP (n. VPL), where the forelimb is represented. The mean number of grains above a standard area here was 78 per 3200 μ^2. The largest number of grains observed in some regions of the middle part of n. VPL was 90 per 3200 μ^2. The number of grains of silver in the anterior and posterior parts of NVP (n. VPL ant., n. VPL post.) fell sharply, and in the medial nucleus of NVP (n. VPL) and in the contralateral n. VPL it did not exceed the spontaneous activity. The large number of grains of silver in the middle part of n. VPL is evidence that comparatively many corticofugal fibers originating in the zone of representation of the forelimb in cortical area S_I terminate in this part of NVP. Very low activity was observed in different parts of NVP after injection of labeled leucine into the zone of representation of the forelimb in cortical area S_{II}. This indicates that comparatively few corticofugal fibers from area S_{II} terminate in NVP. The largest number of grains of silver (20 per 3200 μ^2) was observed in the posterior part of NVP (n. VPL post.), whereas in the anterior and middle parts of the nucleus it was only 13-14 per 3200 μ^2.

Consequently, the results showing that the zone of representation of the forelimb in cortical area S_{II} sends most of its fibers to the caudal portions of NVP agree with results obtained by other methods [1, 2, 6, 10].

The topographical distribution of corticofugal fibers arising from the corresponding somatotopic zones of the two cortical somatosensory areas differed within NVP but the character of their endings was identical. Endings of both types of fibers corresponded to Guillery's type "RS" profiles [7], which have small, dark axon terminals with densely packed, round synaptic vesicles. In the glomeruli surrounded by a capsule composed of processes of glial cells, degenerating endings were very rarely seen, in agreement with the observations of Jones and Powell [9]. Most of the synapses formed by degenerating corticofugal endings were axodendritic contacts. Axosomatic contacts were rare. Most of the axodendritic synapses formed by degenerating endings were contacts on the surface of dendrites of relay cells (Fig. 1A). Synapses between corticofugal fibers and Guillery's "F_2" profiles were less frequently seen [7]. These profiles are considered to be dendritic profiles of Golgi type II interneurons [12]. The terminals of corticofugal fibers were always the presynaptic components of the synapses.

Within NVP overlapping of the terminals of the corticofugal fibers arising from the corresponding somatotopically organized zones of the two somatosensory cortical areas was slight. By electron-microscopic autoradiography and investigation of degenerating terminals, corticofugal fibers originating in the two cortical somatosensory areas could be labeled simultaneously but differently and, consequently, they could be distin-

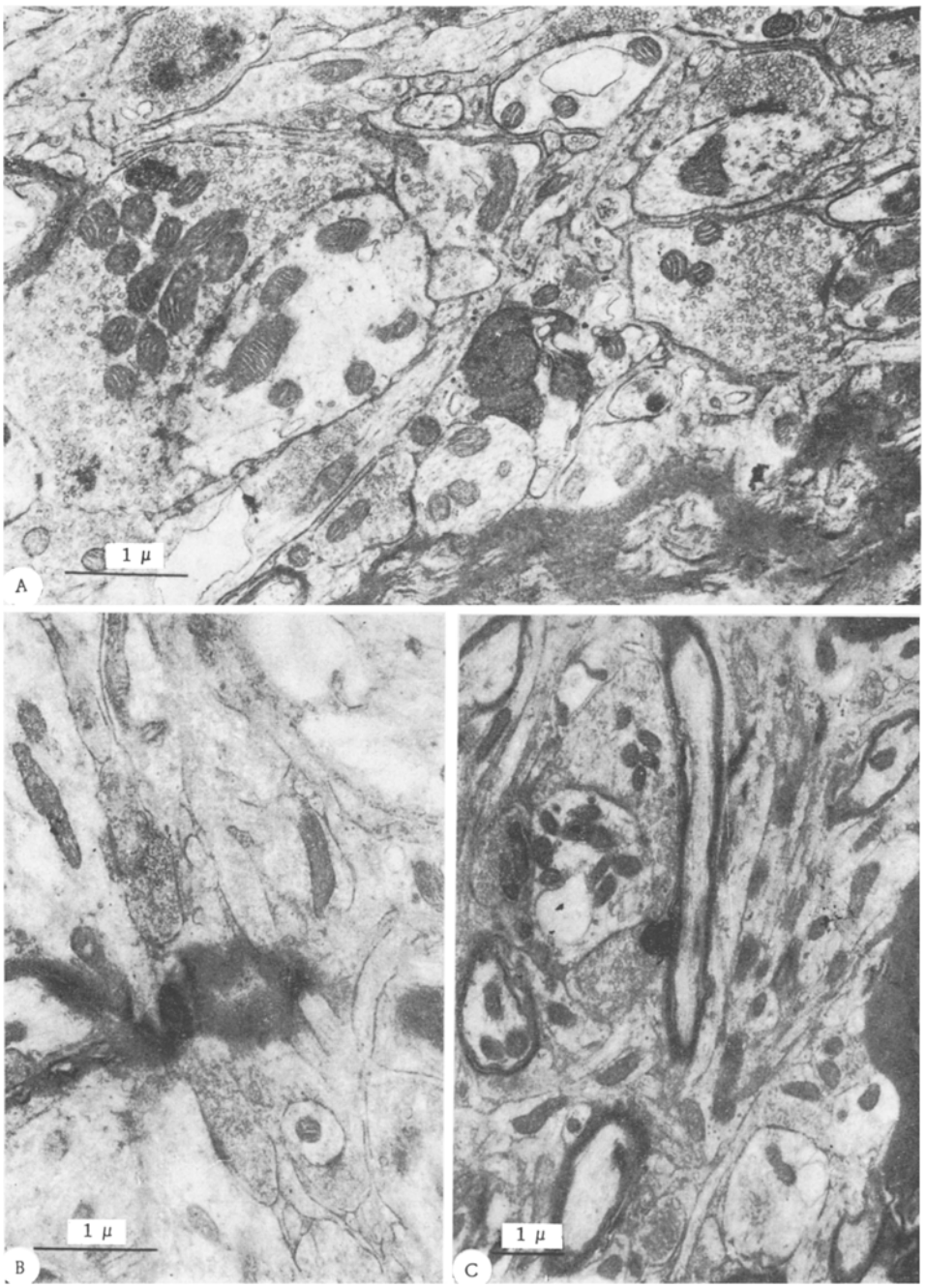

Fig. 1. Electron micrographs of posterior lobe of ventral hypothalamic nucleus (NVP): A) anterior part of NVP after coagulation of somatosensory cortical area II (degenerating synapse on dendrite of relay cell of NVP can be seen in the center). B, C) Autoradiographs of posterior part of NVP after injection of leucine-^{3}H into somatosensory cortical area I and coagulation of somatosensory cortical area II (synapse formed by autoradiographically labeled cortical axon terminal on dendrite of relay cell in NVP can be seen in the center).

guished from each other in the same preparation. In one part of NVP fibers arising from cortical area S_I degenerated as the result of coagulation of that area, whereas the corticofugal fibers from area S_{II} were labeled with the isotope. In preparations from the other series of experiments, fibers from area S_I were identified by their autoradiographic grains, whereas fibers from area S_{II} showed signs of degeneration as the result of coagulation of area S_{II} (Fig. 1B, C). No direct convergence of corticofugal fibers arising from the two areas of the cortex could be observed by this method on single neurons of NVP. However, this does not rule out the possibility of such convergence, but merely indicates that if it existed it was quantitatively on a very small scale.

The morphological observations described above confirm the writers' view [4] that during transmission of the afferent signal the influence of cortical area S_I on the relay neurons of NVP is exhibited directly. Meanwhile, the phasic, facilitatory influence of cortical area S_{II} is manifested indirectly, through other, most probably reticular, structures, for the number of endings of corticofugal fibers arising from cortical area S_{II} is extremely small in that part of NVP where these relay neurons are located in the nucleus.

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ULTRASTRUCTURAL MECHANISMS OF SEROTONIN DEMYELINATION

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The effect of serotonin on the ultrastructure of the white matter in the CNS of dogs was studied. Intracisternal injection of the amine (6 μg in 0.1 ml physiological saline) led to considerable disturbances in the myelin and glia in regions of the white matter of the spinal cord adjacent to the cerebrospinal fluid channels. Loss of the regular structure and separation of the lamellae of the myelin with rupture and lysis of the myelin sheath and demyelination were observed. Vacuolar degeneration was observed in the oligodendrocytes; the astrocytes were virtually unchanged. After local intracerebral injection of the amine (2 μg in 0.01 ml physiological saline) similar disturbances developed in the white matter of the cerebral hemispheres, but with features of an inflammatory reaction in the late stages of the investigation. In control animals which received injections of physiological saline, changes appeared later and only in the gliocytes. It is concluded that serotonin has the property of injuring myelin and glia.

KEY WORDS: serotonin; ultrastructure of the CNS; myelin; glia; demyelination.

An important role in the pathogenesis of allergic demyelination is played by the intensity and character of the liberation and inactivation of biogenic amines, notably serotonin [2-5]. In the course of experimental allergic encephalomyelitis serotonin has been shown to escape from the brain into the cerebrospinal fluid; on the other hand, intravenous injection of small doses of serotonin into dogs after immunization with encephalito-

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