138. *Thalamo-Cortical Organization of the Auditory System in the Cat*

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The topical organization of the cortical projections of the medial geniculate body (MGB) is not well established. Most of the anatomical investigations on this subject have used the method of retrograde cell degeneration. This method, however, is not suitable for tracing cortical projections of MGB, which are considered to contain abundant collateral branchings. The present study is an attempt to study the cortical projections of MGB in the cat with the use of the Nauta and Gyax²⁾ silver technique, laying particular emphasis on the topical relation of these projections.

Material and methods. Unilateral electrolytic lesions were placed stereotaxically in various portions of the left MGB in 12 cats. The electrode was inserted obliquely through the right cerebral hemisphere to effect the lesion on the left side in all cats except in cat 4, where the electrode was introduced vertically through the ipsilateral hemisphere. After survival periods of 7 days the animals were sacrificed, under Nembutal anesthesia, by intracarotid perfusion with normal saline followed by a solution of 10% neutral formalin. The brains were fixed in 10% neutral formalin for one month, sectioned serially at 40 μ in the transverse plane, and every fourth section was impregnated by the Nauta and Gyax²⁾ method. The terminology employed for thalamic nuclei was that of Niimi and Kuwahara.³⁾ The auditory areas were defined according to the cytoarchitectonic study of Rose.⁴⁾

Results. The anterior and middle portions of the principal part of MGB project fibers massively to the middle ectosylvian gyrus (primary auditory area, AI), including the lateral bank of the middle suprasylvian sulcus (suprasylvian fringe area, SF), and the most dorsal parts of the sylvian and anterior ectosylvian gyri (secondary auditory area, AII) in an orderly manner anteroposteriorly and dorsoventrally (cats 9, 6, 10, 11, 12, 7, 5). The most anterior portion of the principal part projects to the most rostral part of AI (cat 9), and the middle portion to the posterior part of AI (cats 10, 7, 11, 12). The large lesion in the anterior and middle portions of the principal

Fig. 1. Showing the extent of the cortical degeneration (A—D) and the lesions in the medial geniculate body (E, F) in cats 9, 6, 11 and 10. In this and subsequent figures, heavy degeneration is indicated by solid black, moderate degeneration by oblique hatching and light degeneration by stipple. The lesions are shown on transverse sections (E) and on an orthogonal reconstruction of the medial geniculate body viewed from lateral (F). The numbers indicate cat numbers. ANT: anterior, POST: posterior, MGB: medial geniculate body, MGM: magnocellular part of MGB, MGP: principal part of MGB.

part leads to degeneration in almost the entire extent of AI (cats 6, 5). It is possible that the lesion in the anterior and middle portions of MGB interrupts the fibers from more posterior portions of MGB, since most of the fibers from MGB first run rostrally through the nucleus and gradually migrate laterally to enter the internal capsule. On the other hand, the dorsomedial portion of the principal part projects fibers to the lateral bank and lip of the suprasylvian sulcus, the suprasylvian fringe area (cats 9, 10). The dorsolateral and lateral portion sends fibers to the dorsal part of AI (cats 6, 7), while the ventrolateral portion gives off fibers to the middle and ventral

Fig. 2. Showing the extent of the cortical degeneration (A—D) and the lesions in MGB (E, F) in cats 12, 7, 4 and 8.

part of AI (cats 12, 5). The most ventral portion projects largely to the ventral part of AI (cat 11). In addition to the main projections, the anterior and middle portions of the principal part project to the dorsal part of anterior sylvian gyrus, the insular area.

The posterior portion of the principal part of MGB sends marked projections to the dorsal part of the posterior ectosylvian gyrus (posterior ectosylvian area, Ep) and the most posterior part of AI (cats 2, 7, 4, 8). It gives off a moderate number of fibers to the limited posterior parts of AII and of the posterior sylvian gyrus. In some cases, it also projects fibers to the anteroventral part of Ep (cats 7, 4). The projection of the principal part of the caudal MGB to the dorsal part of Ep may indicate the anteroposterior organization, in that the anterior, middle and posterior portions of the principal part project to the corresponding portion of the dorsal part of Ep (cats 2, 7, 4, 8). The topical organization appears to exist also in the dorso-ventral dimension. The dorsal portion of the principal part of the

Fig. 3. Showing the extent of the cortical degeneration (A—D) and the lesions in MGB (E, F) in cats 5, 2, 1 and 3.

caudal MGB projects fibers to the lateral bank of the middle supra-sylvian sulcus and the most dorsal part of Ep (cats 2, 8); the more ventrolateral portion sends fibers to the most dorsal part of Ep (cat 7); and the lateral portion gives off fibers to the dorsal part of Ep (cat 4). It is worthy to note that fibers from the principal part of MGB to Ep are composed of relatively fine fibers.

The magnocellular part of MGB projects fibers profusely to AII and the adjoining parts of AI and of Ep (cats 2, 1, 3). The magnocellular part, except for its posterior extremity, sends fibers also to the anterior sylvian gyrus. The anterior pole of the magnocellular part may project fibers to the most rostral part of AII in the anterior ectosylvian gyrus (cat 9). The middle portion of the magnocellular part projects to the middle part of AII (cat 2), the middle and posterior portions send fibers to the middle and caudal part of AII (cat 1), and the most posterior portion to the caudal and most caudal part of AII and the adjacent portion of Ep (cat 3). These data suggest

strongly an anteroposterior organization of the cortical projection of the magnocellular part of MGB.

According to our results, localized lesions anywhere in the principal part of MGB cause diffuse scattering of degenerated fibers in almost the entire extent of the auditory cortex (AI, AII, Ep and the dorsal part of the insulo-temporal region), in addition to localized dense degeneration. In cases with lesions involving the magnocellular part, the area of scattered diffuse degeneration in the auditory cortex tends to spread further anteriorly and ventrally to include the secondary sensory areas (SII), the face area of the primary sensory area (SI) and the insulo-temporal area except for the anterior part of the posterior sylvian gyrus. On the other hand, the site and extent of heavy and moderate cortical degeneration varies with the position and size of the lesions in MGB, as mentioned above. Thus, MGB can be said to have both localized and diffuse projections to the auditory cortex.

The sporadic degeneration in the suprasylvian and lateral gyri is regarded as resulting from damage to the corpus callosum, since no degeneration is detected in these gyri in cats without injury to the corpus callosum.

The laminar distribution of degenerated fibers in the cortex is found in all layers except in layer II, where only fibers of passage are discernible. Degenerated fibers terminate most profusely in layer IV. In cases with lesions in the anterior and middle portions of the principal part, a few degenerated fibers are encountered in the superficial portion of layer I in the severely affected part of AI (cats 9, 13, 6, 11, 12). When the lesions are present in the posterior portion of the principal part, some degenerated axons and preterminals are constantly seen in layer I of the markedly affected part of Ep (cats 10, 7, 4, 8). More marked degeneration is found in layer I of the severely affected portions of AII, AI and Ep in cases with lesions in the magnocellular part (cats 5, 2, 1, 3).

Discussion. It has been known that the anterior part of MGB projects to AI.^{1),5)} However, there has been no definite information about the projection of MGB to AII and Ep. Although some authors suggested the projection of the magnocellular part to AII (Waller,⁶⁾ Woolsey and Walzl⁸⁾), Rose and Woolsey⁵⁾ found that lesions within AII or Ep did not cause undoubted retrograde changes either in the principal division or in the magnocellular division of MGB. Wilson and Cragg⁷⁾ emphasized a continuous distribution of fibers from MGB to the cortex, in contrast to the localized projection of the lateral geniculate body. Our results revealed that MGB has both localized and diffuse cortical projections.

Summary. The anterior and middle portions of the principal part of MGB have heavy projections to AI, including SF, and the adjoining portion of AII, which are organized topically in both anteroposterior and dorsoventral dimensions. It also projects fibers to the insular area in the anterior sylvian gyrus. The posterior portion of the principal part sends fibers massively to the dorsal portion of Ep and the most posterior part of AI. These projections appear to be organized in a topical manner anteroposteriorly and dorsoventrally. It gives off a fair number of fibers to limited caudal parts of the sylvian and posterior sylvian gyri. In addition, the principal part of MGB tends to project sporadic fibers diffusely to AI, AII, Ep, SF and the dorsal part of the insulo-temporal region. The magnocellular part of MGB sends marked projections to AII and the adjoining parts of AI and of Ep in an orderly manner in the anteroposterior dimension. Its major portion, except for the caudal extremity, projects fibers to the insular area. The magnocellular part also tends to send scattered fibers to the cortex which covers SII, including the third auditory area (AIII), the face area of SI and most of the insulo-temporal area, in addition to the auditory cortex in the ectosylvian and sylvian gyri.

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