The Medial and Lateral Lemnisci: Anatomically Adjoined But Functionally Distinct Fiber Tracts

Ruben Rodríguez-Mena and Uğur Türe

■ OBJECTIVE: **The dense and complex distribution of neural structures in the brainstem makes it challenging to understand their real configuration. We used the fiber microdissection technique to show the course of the medial and lateral lemnisci within the brainstem. Although these structures seem anatomically alike, they are functionally distinct.**

■ METHODS: **Fifteen human brainstems and 8 brain hemispheres (formalin-fixed and previously frozen) were dissected and studied under the operating microscope by applying the fiber microdissection technique.**

■ RESULTS: **We delineated and described the medial and lateral lemnisci, noting their gross elaborate arrangement. These structures are intimately compact and closely related to one another in their common trajectory through the tegmenta of the pons and midbrain. However, we were not able to identify the exact origin and termination of their fibers or the accurate delimitation between the medial lemniscus, spinothalamic tract, and lateral lemniscus along their course in the brainstem.**

■ CONCLUSIONS: **Using the fiber microdissection technique, we were able to define a general perspective of the topography and architecture of the medial and lateral lemnisci in the brainstem. This perspective should be incorporated into interpretations of magnetic resonance imaging techniques, recognizing both their benefits and limitations. It should also be applied to surgical planning and strategies to achieve a safer and more precise microsurgical procedure.**

INTRODUCTION

The white matter of the brainstem consists of strands of fiber systems contained in numerous ascending and descending tracts. Some of these systems pass throughout the whole length of the white matter, having their origin in the spinal cord or cerebral cortex, respectively. Others originate or terminate within the brainstem nuclei. The density of the nuclei and tracts distributed along the narrow confines of the brainstem results in a complexity of anatomic organization and neural function.

Despite being neighboring white matter bundles in the brainstem and assigned similar names, the medial and lateral lemnisci are completely unrelated in their function. The medial lemniscus constitutes an important sensory conduction pathway conveying tactile and proprioceptive information to the cortex, whereas the lateral lemniscus comprises a main link in the auditory system.[1-5]

Histologic techniques used for normal and degenerated fiber tracts have provided valuable data and improved our understanding of the organization of the white matter, especially within the brainstem. However, from a surgical point of view, the fiber microdissection technique constitutes the best method to acquire accurate knowledge of the general arrangement of the internal structures of the brain and brainstem,[6-20] with the advantage of a more appropriate discernment of the three-dimensional relationships and courses of the white matter, following a step-by-step technique.

To this end, we used the fiber microdissection technique to show the medial and lateral lemnisci along their trajectory in the brainstem and provide a clear visualization of the gross appearance and configuration of these fiber tracts, which can assist surgeons who operate on intrinsic or extrinsic brainstem lesions.

METHODS

Fifteen human brainstems and 8 brain hemispheres (formalin-fixed and previously frozen) were dissected and studied under an

Key words
- Brainstem
- Fiber microdissection technique
- Lateral lemniscus
- Medial lemniscus
- White matter anatomy

Abbreviations and Acronyms
DTT: Diffusion tensor tractography
MRI: Magnetic resonance imaging

Department of Neurosurgery, Yeditepe University School of Medicine, Kozyatagi Kadikoy, Istanbul, Turkey

To whom correspondence should be addressed: Uğur Türe, M.D.
[E-mail: drture@yahoo.com]

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operating microscope through the fiber microdissection technique, which has been extensively described elsewhere.[12,13,16,17,20] Detailed microdissection of the most minute fiber bundles requires an operating microscope, fine watchmaker's forceps, and a pressure-regulated surgical suction system. Brain dissection began at the lateral aspect of the hemisphere, according to the method recommended previously,[16,17] whereas brainstem and cerebellar dissection started at the superior surface of the cerebellum and proceeded toward the midbrain (mesencephalon), pons, and medulla oblongata in a stepwise manner. In 5 brainstem specimens, several axial cuts were made to determine the disposition of the medial and lateral lemnisci at different levels. Each stage of the dissection was photographed (Nikon D7000 camera; AF-S VR Micro- Nikkor 105 mm f/2.8 G IF-ED lens [Nikon Corp., Melville, New York, USA]).

RESULTS

Dissection begins on the lateral surface of the cerebral hemisphere in a step-by-step fashion until the hidden pyramid-shaped insula is revealed. Next, the cerebral structures surrounding the anterior, superior, and inferior peri-insular sulci are removed. The insula is an important anatomic landmark because of its intimate relation to deeper white matter fibers, the basal ganglia, and the lateral ventricle (Figure 1A).

Dissection progresses over the superior and lateral aspects of the vermis and cerebellar hemisphere, with removal of the cerebellar cortex covering the lingula, the central lobule with its wing, the culmen with the anterior quadrangular lobule, the declive with the posterior quadrangular lobule, and the folium with the superior semilunar lobule. This maneuver exposes the narrow underlying white matter laminae of the cerebellar folia as projections of the white matter of the cerebellum.

After the cerebellar folia are removed, the middle cerebellar peduncle radiations, most of which arise from the contralateral pons, are seen running in a posterior and medial direction. These radiations terminate in a large area of cerebellar lobules, except for the nodulus and flocculus. Dissection of the radiating fibers of the middle cerebellar peduncle exposes the inferior cerebellar peduncle fibers, which course from lateral to medial and anterior to posterior directions, in an oblique trajectory to the cortex of the vermis and, to a lesser extent, to that on the cerebellar hemisphere. The inferior cerebellar peduncle, connecting the dorsolateral medulla and the cerebellum, passes upward to form part of the lateral wall of the fourth ventricle, and then turns backward and enters the cerebellum between the superior and middle cerebellar peduncles, where it can be carefully exposed and clearly differentiated. Both middle and inferior cerebellar peduncle fibers cover the superior surface of the dentate nucleus, which is exposed after further dissection. The dentate nucleus consists of well-defined, islandlike, almost parallel bars of gray matter separated from each other by shallow grooves filled with white matter. Fibers from the dentate nucleus collect in its hilus and, combined with fibers from the emboliform and globose cerebellar nuclei, compose the superior cerebellar peduncle. This peduncle follows an anterior and superior direction and elongates under the fibers of the lateral lemniscus and the inferior colliculus on its way to the tegmentum of the midbrain (Figure 1B). In its origin, it constitutes part of the upper lateral wall of the fourth ventricle, medial to the inferior cerebellar peduncle. It then ascends to help form the roof of the fourth ventricle conjointly with the superior medullary velum and its homologous portion from the contralateral side.

On the lateral surface of the tegmentum of the midbrain, posterior to the lateral mesencephalic sulcus and anterior to the superior cerebellar peduncle, the tectospinal tract is recognized as a superficial thin fiber layer. This structure establishes an efferent connection from the superior colliculus that descends and proceeds to the lateral part of the tegmentum of the pons. Its removal uncovers a group of fibers ascending in an oblique trajectory superficial and ventral to the fibers of the superior cerebellar peduncle, some of which reach the inferior colliculus, whereas the rest continue under the brachium of the inferior colliculus. These fibers, from posterior to anterior, are the lateral lemniscus, the spinothalamic tract, and some fibers from the dorsolateral part of the medial lemniscus. All of these entities are in their most superficial location in the brainstem (Figure 1B).

With the fiber microdissection technique, it was not possible to define the limits between these fiber bundles because they appear as a group, sharing similar sizes and trajectories in the lateral tegmentum of the midbrain. The lateral lemniscus ends at the inferior colliculus, and the spinothalamic tract continues with the medial lemniscus, both shifting dorsally beneath the brachium of the inferior colliculus, to their destination in the thalamus. In only in a few cases were we able to discern the final course of the anterior (ventral) spinocerebellar tract (Gower tract) over the surface of the superior cerebellar peduncle, adjacent to the tegmentum of the midbrain. Here, it stands alongside the posterior border of the lateral lemniscus, before it enters the cerebellum, increasing the complexity of anatomic features of the white matter in this area (Figure 2A). This tract, which originates at the base of the posterior horn and zona intermedia throughout the lumbosacral segments of the spinal cord, ascends through the medulla oblongata and tegmentum of the pons. It then curves sharply in a dorsal direction along the rostral border of the trigeminal motor nucleus and enters the cerebellum.

Dissection continues in the insula with removal of the cortex and the underlying extreme capsule, claustrum, and external capsule, including the remaining fibers of the occipitofrontal and uncinate fasciculi in the region of the limen insula.[16] Then, the putamen is exposed with the corona radiata at its periphery and the lateral extensions of the anterior commissure passing through the basal portion of the lenticular nucleus, perpendicular to the optic tract. The lateral extensions of the anterior commissure, along with the fibers of the ansa peduncularis (located inferior and parallel to the anterior commissure and within the anterior perforated substance), are severed and removed. Fibers from the posterior limb of the internal capsule, including the sublentiform portion of the internal capsule, are revealed. Further removal of the corona radiata exposes the periphery of the head, body, and tail of the caudate nucleus, as well as the caudolenticular gray matter that traverses the internal capsule and connects the more superficial putamen with the deep-situated caudate nucleus (Figure 1C).

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