Three-Dimensional Anatomy of the White Matter Fibers of the Temporal Lobe: Surgical Implications

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BACKGROUND: **The aim of this work is to describe in detail the complex 3-dimensional organization of the white matter of the temporal lobe and discuss the surgical implications of the approaches to lesions located into the mesial temporal region and within the temporal horn and the atrium of the lateral ventricles.**

METHODS: **Sixteen human cerebral hemispheres fixed in a 10% formalin solution for at least 40 days were studied. After removal of the arachnoid membrane, the hemispheres were frozen at −15°C for at least 14 days, and the Klingler technique, which consists of the microscopic dissection and progressive identification of white matter fibers, was performed.**

RESULTS: **The dissection allowed us to appreciate the topographical organization of the white matter of the temporal lobe identifying the most important association, projection, and commissural fasciculi. The dissection from the lateral side allowed the progressive visualization of the superior longitudinal fasciculus and its components, the extreme and external capsule, the uncinate fasciculus, the inferior fronto-occipital fasciculus, the anterior commissure, the internal capsule, and the optic radiations. The dissection was completed from the inferior and medial side for identification of the cingulum and the fornix.**

CONCLUSIONS: **The complex 3-dimensional organization of the white matter substance of the temporal lobe is characterized by 2 main systems of boundaries: the sagittal stratum and the temporal stem. Their knowledge is essential for the appropriate treatment of pathologies localized in this region as demonstrated by the 2 clinical cases presented in this work.**

INTRODUCTION

The temporal lobe is one of the regions of great neurosurgical interest in regard to its complex anatomical organization and the large number of diseases localized in its context. Cerebral aneurysms, arteriovenous malformations, cavernomas, brain gliomas, and traumatic pathology potentially can occur in the temporal lobe. In addition, its mesial portion, in relation to a complex cytoarchitectonic organization, is the source of origin for drug-resistant epilepsies. A detailed knowledge of the surgical anatomy of the temporal lobe is essential to treat pathologies located in regions of difficult surgical access to limit the risk of damaging functionally important structures.[1,2]

The aim of this work is to describe in detail the complex but at the same time magnificent 3-dimensional organization of the white matter of the temporal lobe through the Klingler dissection. This technique is based on the freezing of previously formalin-fixed brains. The aqueous formalin solution penetrates little or not at all into the myelinated fibers but instead remains between the fibers. Consequently, when the brain is frozen, ice forms between the fibers. Because the volume of water increases by about 10% when it solidifies into ice, the fibers thus separate from each other. This loosening up of the brain substance facilitates dissection.[3-7] This technique allows the identification of the countless white matter tracts that underlie in this area by providing a clear overview of the topographical relationships of the

Key words
- Extreme capsule
- Internal capsule
- Meyer loop
- Superior longitudinal fasciculus
- Temporal lobe
- Three-dimensional anatomy
- White matter

Abbreviations and Acronyms

AVM: Arteriovenous malformation
MRI: Magnetic resonance imaging
SLF: Superior longitudinal fasciculus

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Table 1. Demographic Data

Patient	Sex	Age, years	Cause of Death
1	Male	52	Cardiac death
2	Male	66	Cardiac death
3	Female	48	Polytrauma
4	Female	59	Neoplasm
5	Male	70	Pulmonary embolism
6	Female	73	Cardiac death
7	Male	62	Neoplasm
8	Male	68	Pulmonary embolism

individual fiber bundles. After we examine the complex topographical organization of the white matter of the temporal lobe and the clinical consequences of injury of each identified bundle, we discuss the surgical implications of the approaches to lesions located into the mesial temporal region and within the temporal horn and the atrium of the lateral ventricles.

MATERIALS AND METHODS

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Sixteen human cerebral hemispheres were fixed in a 10% formalin solution for at least 40 days (demographics data are summarized in Table 1). The first step was the removal of the arachnoidal and vascular structures under microscopic magnification. The hemispheres were frozen at −15°C for at least 14 days, and dissections were carried out through different-sized wooden spatulas. The anatomic dissection started with a detailed study of each hemispheric surface according to the technique described by Türe et al.[8] The study was then continued through an extensive dissection from the basal surface to reach the floor of the temporal horn. An extensive dissection from the medial surface to identify the cingulate sulcus until the parahippocampal gyrus was then performed. Eventually, after we removed the ependymal layer, it was possible to identify the origin of optic radiation at the level of the pulvinar and of the lateral geniculate body. Other structures belonging to the "temporal stem," including the Meyer loop, the amygdala, and the anterior commissure, also were identified.

The dissections performed, although meticulous and precise, did not always allow us to identify all the fibers constituting the sagittal stratum. Although the objective of our study is to describe the anatomy of the white matter substance of the temporal lobe, the exposition of the fibers of this region required a more extensive dissection also involving other fiber bundles located in the adjacent areas. The images were obtained with a Nikon D40 camera and the following lenses: AF-S Nikkor 18–15 mm 1: 3.5–5.6 GII ED and AF-S VR Micro-Nikkor 105 mm f/2.8 G (Nikon Corp., Sendai, Japan).

Table 2. Spatial Relationships of the Main Fiber Boundless with Some Specific Anatomic Landmarks

	Maximum, mm	Minimum, mm	Mean, mm	SD
F2/F3ls-SLFh	25	22	23.8	0.81568
T1/T2 pls-SLFv	25	20	22.7	1.43386
PFPT-SLFar	28	25	26.3	1.06394
U-Mlap	23	22	22.5	0.5164
T1/T2 ls-ORlm	23.3	21.7	22.2	1.02364
TP-Mlap	29	27.8	28.2	0.38101
Ml-Th	5.2	3	4.3	0.72131

F2/F3ls-SLFh, distance between the cortical surface of the middle and inferior frontal gyri and horizontal part of the superior longitudinal fasciculus; T1/T2 pls-SLFv, distance between the cortical surface of the posterior portion of the superior and middle temporal gyri transition and the vertical tract of the superior longitudinal fasciculus; PFPT-SLFar, distance between the cortical surface of the prefrontal and posterior temporal region with the arcuate segment of the superior longitudinal fasciculus; U-Mlap, distance between the uncus and the apex of the Meyer loop; T1/T2 ls-ORlm, distance between the lateral surface of the superior/middle temporal gyri and lateral margin of the optic radiation; TP-Mlap, distance between the temporal pole and the apex of the Meyer loop; Ml-Th, relationship of the Meyer loop with the temporal horn.

Measurements

Spatial relationships of the main fiber boundless (superior longitudinal fasciculus, Optic radiations) with some specific anatomic landmarks were analyzed by performing microscopic measurements through the use of dedicated instrumentation (Table 2). Measurements performed included the following:

- the distance between the cortical surface of the middle and inferior frontal gyri and horizontal part of the superior longitudinal fasciculus;
- the distance between the cortical surface of the posterior portion of the superior and middle temporal gyri transition and the vertical tract of the superior longitudinal fasciculus;
- the distance between the cortical surface of the prefrontal and posterior temporal region with the arcuate segment of the superior longitudinal fasciculus;
- the distance between the uncus and the apex of the Meyer loop;
- the distance between the lateral surface of the superior/middle temporal gyri and lateral margin of the optic radiation;
- the distance between the temporal pole and the apex of the Meyer's loop;
- the relationship of the Meyer loop with the temporal horn; and
- the length of the optic radiations.

No differences of statistical significance were observed between the left and the right hemispheres. Two illustrative cases of patients harboring lesions of the temporal lobe are presented in the second part of the Results section.