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Laboratory Investigation

A Understanding of the Temporal Stem

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Objective : There has been inconsistency about definition of the temporal stem despite of several descriptions demonstrating its microanatomy using fiber dissection and/or diffusion tensor tractography. This study was designed to clarify three dimensional configurations of the temporal stem.
Methods : The fronto-temporal regions of several formalin-fixed human cerebral hemispheres were dissected under an operating microscope using the fiber dissection technique. The consecutive coronal cuts of the dissected specimens were made to define the relationships of white matter tracts comprising the temporal stem and the subcortical gray matters (thalamus, caudate nucleus, amygdala) with inferior limiting (circular) sulcus of insula.
Results : The inferior limiting sulcus of insula, limen insulae, medial sylvian groove, and caudate nucleus/amygdala were more appropriate anatomical structures than the roof/dorso-lateral wall of the temporal horn and lateral geniculate body which were used to describe previously for delineating the temporal stem. The particular space located inside the line connecting the inferior limiting sulcus of insula, limen insulae, medial sylvian groove/amygdala, and tail of caudate nucleus could be documented. This space included the extreme capsule, uncinate fasciculus, inferior occipito-frontal fasciculus, anterior commissure, ansa peduncularis, and inferior thalamic peduncle including optic radiations, whereas the stria terminalis, cingulum, fimbria, and inferior longitudinal fiber of the temporal lobe were not passing through this space. Also, this continued posteriorly along the caudate nucleus and limiting sulcus of the insula.
Conclusion : The temporal stem is white matter fibers passing through a particular space of the temporal lobe located inside the line connecting the inferior limiting sulcus of insula, limen insulae, medial sylvian groove/amygdala, and tail of caudate nucleus. The three dimensional configurations of the temporal stem are expected to give the very useful anatomical and surgical insights in the temporal lobe.

KEY WORDS : Anatomy · Fiber dissection · Temporal stem.

INTRODUCTION

The term of temporal stem seems to have derived from the pictorial appearance of the structure on coronal sections of the brain and was initiated by Horel[8]. It has been considered to have an important role as a reciprocal route of tumor, infection, seizure spread, and a number of disorders including amnesia, traumatic brain injury, Alzheimer disease because of a bridge between the temporal lobe and other regions of the brain[12]. Recently, diffusion tensor imaging tractography and fiber dissection technique which has been very helpful to understand the white matter fibers of the brain, were used to describe the temporal stem[4,5,12,17,18,22,23]. However, the anatomical definition of the temporal stem has shown the inconsistency as in the existing descriptions by several authors. This study was designed to clarify three dimensional configurations of the temporal stem using fiber dissection and to show a different view with regard to its anatomical borders.

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MATERIALS AND METHODS

The several cerebral hemispheres were fixed in formalin solution for at least 2 months after removing the cerebral vessels and leptomeninges under the microscope. Then, the specimens were kept frozen at the temperature of -15 Celsius for 2 weeks. Before dissection, the brains were immersed in water for thawing. This freezing process was derived from Klingler who thought that the formalin ice crystals at high concentrations between the fibers were expanding and separating them, so it could facilitate the dissection of fiber bundles[13,14]. The region around the inferior limiting (cir-

cular) sulcus of insula and roof of temporal horn were dissected in a stepwise fashion. The consecutive coronal cuts of the dissected specimens were taken to observe the white and subcortical gray matters of the temporal lobe around the inferior limiting sulcus.

RESULTS

Outer surface of the temporal stem (Fig. 1)

The removal of the short, long arcuate fibers and cortex of frontal, parietal, occipital, and temporal operculums around the sylvian fissure revealed the insula, limen insulae, limiting sulcus of insula and the superior longitudinal fasciculus which was located deep to the middle frontal gyrus, inferior parietal lobule, and middle temporal gyrus. The removal of insular cortex and dorsal extreme capsule revealed the remaining ventral extreme capsule, claustrum and external capsule. The removal of extreme capsule, claustrum, and external capsule showed the putamen, corona radiata, inferior occipito-frontal fasciculus, and uncinate fasciculus. The inferior occipito-frontal fasciculus was located immediately superior to the uncinate fasciculus. The removal of the superior longitudinal fasciculus and inferior occipito-frontal fasciculus showed the whole corona radiata and the anterior commissure passing through the base of the putamen proceeded to the temporal lobe. The further removal of the uncinate fasciculus and anterior commissure revealed amygdala, an inferior part of the putamen hidden beneath the lateral extension of the anterior commissure. Also, the unique striations of Meyer's loop, anterior bundles of the optic radiations arising from the lateral geniculate body was directed forward on the temporal horn and then followed backward at the tip of the temporal horn. The removal of putamen, corona radiata and inferior thalamic peduncle including optic radiations revealed the tapetum, caudate nucleus, amygdala, stria terminalis, globus pallidus, thalamus, and internal capsule that separated the lenticular nucleus from the caudate nucleus/thalamus. The stria terminalis arising from amygdala proceeded in the groove between the thalamus and caudate nucleus. The removal of the globus pallidus revealed the ansa peduncularis fibers passing to the septal area. The ansa peduncularis curved outside the internal capsule and was located below the anterior commissure.

Inner surface of the temporal stem (Fig. 2)

The fusiform gyrus, parahippocampal gyrus, hippocampus, fimbria and choroid plexus were removed to observe the tail of the caudate nucleus of the temporal horn roof, amygdala and lateral geniculate body. The amygdala located at the tip of the temporal horn seemed to be connected with tail of the caudate nucleus. The further dissection was performed to see the amygdala and optic radiations arising from the lateral geniculate body. The medial sylvian groove, postero-lateral margin of the anterior perforated substance, was located superior to the amygdala and uncus.

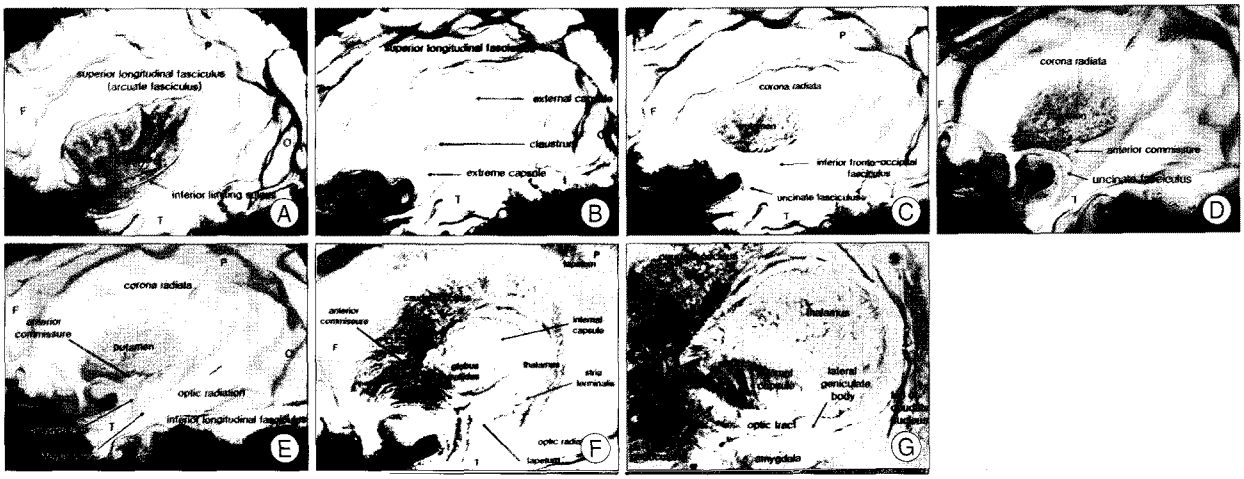

Fig. 1. The removal of the short, long arcuate fibers and the cortex of frontal, parietal, occipital, and temporal operculums around the sylvian fissure reveals the insula, limen insulae, inferior limiting (circular) sulcus of insula and the superior longitudinal fasciculus. The curved line with red color represents the limiting (circular) sulcus of insula (A). The removal of insular cortex and dorsal extreme capsule reveals the remaining ventral extreme capsule, claustrum and external capsule (B). The removal of extreme capsule, claustrum, and external capsule shows the putamen, corona radiata, inferior occipito-frontal fasciculus, and uncinate fasciculus (C). The removal of the superior longitudinal fasciculus and inferior occipito-frontal fasciculus shows the whole corona radiata and the anterior commissure proceeding to the temporal lobe (D). The removal of the uncinate fasciculus and anterior commissure reveals the amygdala, a part of putamen hidden beneath the extension of the anterior commissure. Also, the unique striations of Meyer's loop, anterior bundles of the optic radiations arising from the lateral geniculate body was observed (E). The removal of the putamen, corona radiata and inferior thalamic peduncle including optic radiations reveals the tapetum, caudate nucleus, amygdala, stria terminalis, globus pallidus, thalamus, and internal capsule (F). The removal of the globus pallidus reveals that the ansa peduncularis fibers passing to the septal area curves outside the internal capsule. The anterior commissure is reflected (G).

Coronal planes of the temporal stem (Fig. 3)

The consecutive coronal cuts of the dissected specimens were made to observe the relationships of white matter tracts passing between the inferior limiting sulcus of insula and roof of the temporal horn with the subcortical gray matters (lenticular nucleus, thalamus, caudate nucleus, amygdala). At the level of the limen insulae, the inferior limiting sulcus of insula, limen insulae, and medial sylvian groove were obvious and consecutive. At the mid-level bet-ween limen insulae and lateral geniculate body, the white matter fibers passing between the inferior limiting sulcus of insula and roof of the temporal horn were seen and the amygdala/tail of caudate nucleus and inferior limiting sulcus of insula were obvious. At the level of the lateral geniculate body, same structural relationships as shown in the previous coronal cut were also observed. Both the inferior limiting sulcus of insula and tail of caudate nucleus continued posteriorly.

The lateral geniculate body was a structure located outside the temporal lobe. The space positioned inside the line connecting the inferior limiting sulcus of insula, limen insulae, medial sylvian groove/amygdada, and tail of caudate nucleus included the extreme capsule, uncinate fasciculus, inferior occipito-frontal fasciculus, anterior commissure, ansa peduncularis, and inferior thalamic peduncle including optic radiations. On the other hand, the stria terminalis, cingulum, fimbria, and inferior longitudinal fibers of the temporal lobe were not passing through this space. Also, it was continuous posteriorly along the caudate nucleus and limiting (circular) sulcus of insula.

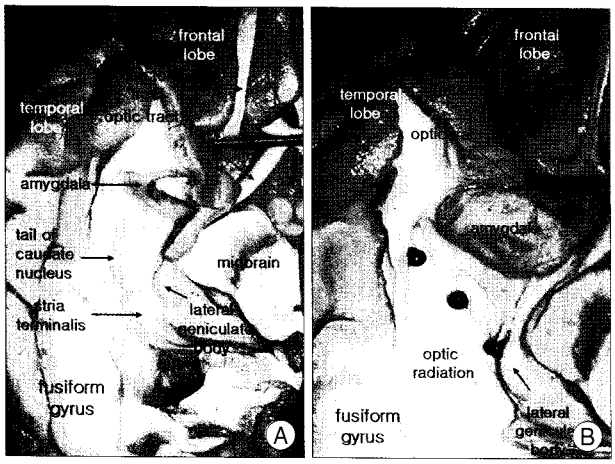

Fig. 2. The fusiform gyrus, parahippocampal gyrus, hippocampus, fimbria and choroid plexus were removed to observe the tail of the caudate nucleus through the transparent ependymal layer of roof of the temporal horn. The amygdala located at the tip of the temporal horn is connected with tail of the caudate nucleus (A). The further dissection was performed to see the amygdala and optic radiations arising from the lateral geniculate body (B).

DISCUSSION

With respect to the temporal stem, there has been an inconsistency about its definition. Horel[8] referred to it as a thin band of white matter forming a bridge between the temporal lobe and brain stem. Since then, the temporal stem has been frequently used. Cirillo et al.[2] stated the temporal stem as white matter representing connections between temporal cortex/amygdala and orbital frontal cortex, striatum, and thalamus. Ebeling and von Cramon[5] described the temporal stem as narrow gate between roof of the temporal horn and lower circular sulcus in the white matter of the temporal lobe and that it included the anterior commissure, uncinate fasciculus, inferior occipito-frontal fasciculus, Meyer's loop of optic radiations, and inferior thalamic fibers. On the other hand, Duvernoy[3,4] described it in a slightly different way as the narrow lamina of white matter between the temporal horn and superior temporal sulcus,

Fig. 3. Two dissected specimens with different stage showing the level of three consecutive coronal cuts (inset). At the level of the limen insula, the inferior limiting sulcus, limen insulae, and medial sylvian groove are obvious and consecutive (A). At the second level of coronal cuts, the white matter fibers passing between the inferior limiting sulcus and roof of the temporal horn are observed. The amygdala/tail of caudate nucleus, and inferior limiting sulcus are also obvious (B). At the level of the lateral geniculate body, same structural relationships as shown in the previous coronal cut are observed. Both the inferior limiting sulcus and tail of caudate nucleus proceed posteriorly (C).

extending from the level of the amygdala to the level of the lateral geniculate body. Kier et al.[12] stated that anterior and posterior extents of the temporal stem were uncinate fasciculus and Meyer's loop/inferior occipito-frontal fasciculus. Wang et al.[22] insisted that the temporal stem begins at the limen insulae and ends at the postero-inferior insular point on the inferior limiting sulcus. In the study of Peuskens et al.[18], it is described that the temporal stem forms the junction of the anterior temporal lobe and thalamus, brain stem, and the frontal lobe and connects the polymodal association areas in the anterior temporal lobe with the frontal lobe, basal forebrain, thalamus, and contralateral temporal lobe. To our knowledges, Ebeling and Cramon's description seems to have been cited more frequently[12,17,22]. However, Yasargil et al.[23] insisted that the temporal stem is ambiguous anatomical term. They stated that it gives the impression of only connection of the entire temporal lobe and reducing the multidimensional, multidirectional, and the multimodular activities in the temporal lobe. We also agree with them in part. In this study, we found that the lateral geniculate body was located outside the temporal lobe, the inferior limiting sulcus of insula was continuous to the remainder of the whole limiting sulcus, and the roof/dorso-lateral wall itself of the temporal horn was a curved plane, not a discernable structure to point out. Also, the temporal horn continued to the remaining lateral ventricle. We thought that the ambiguity of the temporal stem was due to lack of obvious anatomical structures to clarify the temporal stem and the posterior continuation of inferior limiting sulcus of insula. Therefore, it is possible that the temporal stem is white matter fibers passing through the particular space of the temporal lobe located inside the line connecting the inferior limiting sulcus of insula, limen insulae, medial sylvian groove/amygdala, and tail of caudate nucleus. However, it is not certain whether the temporal stem may be the inferior part of its posterior continuation along the limiting sulcus of insula and caudate nucleus. From the viewpoint of our description about the temporal stem, the extreme capsule, uncinate fasciculus, inferior occipito-frontal fasciculus, anterior commissure, ansa peduncularis, and inferior thalamic peduncle including optic radiations were included in the temporal stem. Peltier et al.[17] demonstrated that the ventral portion of the corpus callosal radiation seemed to belong to the temporal stem although we did not verify that. The stria terminalis, cingulum, fimbria, and inferior longitudinal fibers of the temporal lobe were not passing through the temporal stem. And, it is considered that the further studies on the posterior extension of temporal stem are necessary. The temporal stem composed of several white matter tracts has been known to have an intimate relation with learning, spatial, visual, and verbal functions[1,5-12,15,16,19-21,24]. It can be a route for tumor, infection, and seizure spread[12]. And also the temporal stem used to be a direct surgical route in the trans-sylvian approach. This approach can minimize the temporal neocortical damages, retraction injuries, and the injuries of the Meyer's loop[24] although some fibers comprising the temporal stem can be interrupted to various degrees. We could also verify the anatomical and clinical significances of the temporal stem through the fiber dissections.

CONCLUSION

The temporal stem is white matter fibers passing through the particular space of temporal lobe, located inside the line connecting the inferior limiting sulcus of insula, limen insulae, medial sylvian groove/amygdala, and tail of caudate nucleus. The several perplexing fibers comprising the temporal stem communicate with frontal lobe, corpus striatum, thalamus, hypothalamus, contralateral temporal lobe, and septal region through the temporal stem. The idea that the temporal stem may be the inferior part of its posterior continuation along the limiting (cicular) sulcus of insula and caudate nucleus needs the further studies.

References

1. Bigler ED, Anderson CV, Blatter DD : Temporal lobe morphology in normal aging and traumatic brain injury. **AJNR Am J Neuroradiol 23** : 255-266, 2002
2. Cirillo RA, Horel JA, George PJ : Lesions of the anterior temporal stem and the performance of delayed match-to-sample and visual discriminations in monkeys. **Behav Brain Res 34** : 55-69, 1989
3. Duvernoy HM : **The human brain stem and cerebellum : Surface, Structure, Vascularization, and Three-Dimensional Sectional Anatomy with MRI.** Vienna : Springer-Verlag, 1995, pp266-295
4. Duvernoy HM : **The human brain, surface, blood supply, and three dimensional sectional anatomy, 2nd ed.** Vienna : Springer-Verlag, 1999, pp122-143
5. Ebeling U, von Cramon D : Topography of the uncinate fascicle and adjacent temporal fiber tracts. **Acta Neurochir (Wien) 115** : 143-148, 1992
6. Fernández-Miranda JC, Rhoton AL Jr, Alvarez-Linera J, Kakizawa Y, Choi C, de Oliveira EP : Three-dimensional microsurgical and tractographic anatomy of the white matter of the human brain. **Neurosurgery 62** : 989-1026; discussion 1026-1028, 2008
7. Gaffan D, Easton A, Parker A : Interaction of inferior temporal cortex with frontal cortex and basal forebrain : double dissociation in strategy implementation and associative learning. **J Neurosci 22** : 7288-7296, 2002
8. Horel JA : The neuroanatomy of amnesia. A critique of the hippocampal memory hypothesis. **Brain 103** : 403-445, 1978
9. Hughes TS, Abou-Khalil B, Lavin PJ, Fakhoury T, Blumenkopf B, Donahue SP : Visual field defects after temporal lobe resection : a prospective quantitative analysis. **Neurology 53** : 167-172, 1999
10. Kantarci K, Jack CR Jr, Xu YC, Campeau NG, O'Brien PC, Smith GE, et al : Mild cognitive impairment and Alzheimer disease : regional diffusivity of water. **Radiology 219** : 101-107, 2001
11. Kantarci K, Shin C, Britton JW, So EL, Cascino GD, Jack CR Jr :

Comparative diagnostic utility of 1H MRS and DWI in evaluation of temporal lobe epilepsy. **Neurology 58** : 1745-1753, 2002
12. Kier EL, Staib LH, Davis LM, Bronen RA : MR imaging of the temporal stem : anatomic dissection tractography of the uncinate fasciculus, inferior occipitofrontal fasciculus, and Meyer's loop of the optic radiation. **AJNR Am J Neuroradiol 25** : 677-691, 2004
13. Klingler J : Erleichterung der makroskopischen praparation des Gehirns durch den Gefrierprozess. **Schweiz Arch Neurol Psychiatr 36** : 247-256, 1935
14. Klingler J, Gloor P : The connections of the amygdala and of the anterior temporal cortex in the human brain. **J Comp Neurol 115** : 333-369, 1960
15. Maclean CJ, Gaffian D, Baker HF, Ridley RM : Visual discrimination learning impairments produced by combined transections of the anterior temporal stem, amydala and fornix in marmoset monkeys. **Brain Res 888** : 34-50, 2001
16. Nagata S, Sasaki T : The transsylvian trans-limen insular approach to the crural, ambient and interpeduncular cisterns. **Acta Neurochir (Wien) 147** : 863-869, 2005
17. Peltier J, Verclytte S, Delmaire C, Pruvo JP, Godefroy O, Le Gars DL : Microsurgical anatomy of the temporal stem : clinical relevance and correlations with diffusion tensor imaging fiber tracking. **J Neurosurg 112** : 1033-1038, 2009
18. Peuskens D, van Loon J, van Calenbergh F, van den Bergh R, Goffin J, Plets C : Anatomy of the anterior temporal lobe and the frontotemporal region demonstrated by fiber dissection. **Neurosurgery 55** : 1174-1184, 2004
19. Rhoton AL Jr : The Cerebrum. **Neurosurgery 51** : S1-S51, 2002
20. Rubino PA, Rhoton AL Jr , Tong X, Oliveira E : Three-dimensional relationships of the optic radiation. **Neurosurgery 57** : 219-227; discussion 219-227, 2005
21. Taoka T, Sakamoto M, Iwasaki S, Nakagawa H, Fukusumi A, Hirohashi S, et al. : Diffusion tensor imaging in cases with visual field defect after anterior temporal lobectomy. **AJNR Am J Neuroradiol 26** : 797-803, 2005
22. Wang F, Sun T, Gang XG, Liu NJ : Diffusion tensor tractography of the temporal stem on the inferior limiting sulcus. **J Neurosurg 108** : 775-781, 2008
23. Yasargil MG, Türe U, Yasargil DHC : Impact of temporal lobe surgery. **J Neurosurg 101** : 725-738, 2004
24. Yaşargil MG, Wieser HG, Valavanis A, von Ammon K, Roth P : Surgery and results of selective amygdala-hippocampectomy in one hundred patients with nonlesional limbic epilepsy. **Neurosurg Clin N Am 4** : 243-261, 1993