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Topography of the Uncinate Fascicle and Adjacent Temporal Fiber Tracts

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Summary

Neurosurgical procedures in the anterior temporal lobe are common, in which different postoperative neuropsychological deficits may occur. For the refinement of the surgical approach 10 human hemispheres were dissected using the method of dissection by Klinger, to gain more data about the fiber tracts in the anterior temporal lobe, respectively the temporal stem. The uncinate fascicle has a form like a curved dumb-bell with a thin (about 2 mm thick), fan-like arrangement of fibers in the frontal and temporal lobe. The solid portion runs in the extreme and external capsule through the limen insulae. The topography of adjacent important fiber tracts (inferior occipito-frontal fascicle, Meyer's loop, anterior commissure, inferior thalamic bundle) could be displayed. According to the resulsts possible neuropsychological deficits and surgical considerations are discussed.

Keywords: Temporal lobe; temporal stem; uncinate fascicle; neuropsychological deficits.

Introduction

Neurosurgery in the region of the anterior temporal lobe is common, i.e. tumours of the anterior and medial temporal lobe, microsurgical selective hippocampectomy and amygdalectomy[36, 40], and temporal lobectomy for epilepsy[12, 21, 27–29].

During surgery an approach through the anterior temporal lobe may be unavoidable. However, several important fiber tracts are located in the temporal stem. Despite the fact, that the role of the temporal stem with regard to neuropsychological deficits is controversialy discussed, an anterior temporal lobectomy may include the temporal stem causing an interruption of temporal connecting fibers with possible severe disturbances of memory and learning functions[14, 28, 41]. The exact anatomical topography of these fibers needs further attention to preserve them – if at all possible – during surgery. The aim of this study was to elaborate more anatomical data of the uncinate fascicle and its adjacent temporal fiber tracts in regard to anterior temporal lobe resections.

Anatomy

The name "uncinate fascicle" is derived because of the hooklike shape of the tract, which combines the three convolutions of the tip of the temporal lobe and the orbital gyri of the 3. frontal convolution[4, 6, 11, 17, 31, 37, 39] (Fig. 1).

In the literature different data about the origin and termination of the uncinate fascicle are reported. It interconnects the cortical nuclei of the amygdala[18, 32, 37], the hippocampal formation[32], the temporal pole[2, 5, 31, 37], the first temporal convolution[33] and the second temporal convolution[11] with the orbital frontal lobe[25]. The uncinate fascicle combines area 38 and area 47[2]. It is associated with the orbital (subcallosal gyrus, Gyrus rectus, posterior orbital cortex) and temporal, perirhinal areas of the mesocortex[35] (Fig. 1). Ventral fibers are said to originate in the hippocampal formation and the cortical nuclei of amygdala[18, 37], the dorsal bundle derives from the temporal pole[37].

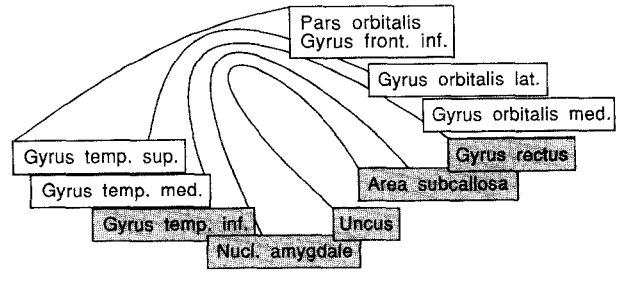

Fig. 1. Origin and termination of the dorsal (white) and ventral (grey) portions of the uncinate fascicle

The uncinate fascicle lies in the limen insulae[15, 18, 33], underneath the putamen and the claustrum[4]. The claustrum is partially imbedded in the uncinate fascicle[37]. The outer portion of the uncinate fascicle travels in the extreme capsule[4], the inner portion in the external capsule[7, 11]. The uncinate fascicle lies laterally and caudally at the lateral border of the inferior occipito-frontal fascicle and the two fiber bundles merge in this area[7, 33].

Previous descriptions have mentioned only an intermingling of all temporal fiber tracts, i.e. the anterior commissure, Meyer's loop of the optic radiation, inferior thalamic peduncle, the inferior occipito-frontal and uncinate fascicle in the temporal pole[4, 7, 11, 18, 33], which has been described exactly[1, 7, 8, 18, 22, 24]. However, no surgical topography of these fibers has been given.

Materials and Methods

10 hemispheres of formalin fixed normal adult human brains of both sexes were examined. The proportions, the three-dimensional course, origin and termination of the uncinate fascicle and its topographical relationship to the adjacent fiber systems were studied. Klingler's fiber dissection method was applied and previously described[8–10, 18, 20]. The preparation was carried out with a "Schweizer Uhrmacherpinzette" and a Zeiss operating microscope (Zeiss OPMI 1 FC) according to the recommendations of brain dissection[15, 19] (Figs. 2 and 3).

After complete removal of the arachnoid and vessels the parietal operculum was resected. Next the cortex of the temporal lobe, insula, orbital and third frontal convolution was removed with a fine spatula.

The short U-fibers of the fronto-orbital, temporal and the peri-insular cortex were plucked away. Under this layer of fibers first the anterior temporal branch of the arcuate fascicle and second the inferior occipito-frontal fascicle could be prepared. The uncinate fascicle was separated from the lateral edge of the inferior occipito-frontal fascicle. The anterior commissure was dissected through the putamen and followed to the tip of the temporal horn of the lateral ventricle. After removal of the ependyma and tapetum of the roof of the temporal horn Meyer's loop was prepared. The inferior stem of the thalamic raditation and the ventral-amygdalofugal fibers were followed from the midline to the cortical nuclei of the amygdala. Clear specimens of the uncinate fascicle could be dissected (Fig. 2).

Results

Topography and Proportions of the Uncinate Fascicle

The uncinate fascicle can be divided into a temporal, insular and frontal portion. It originates like a fan (of about 2 mm thickness) from the anterior three temporal convolutions (area 20, 38) in front of the temporal horn and the cortical nuclei of amygdala (area 28, 34, 36). All fibers unify in the anterior temporal stem in the deep white matter of the 2 nd. temporal gyrus in front of and at the level of the inferior horn. The fiber bundles form a solid fiber tract while running upward over the lateral nuclei of the amygdala toward the limen insulae (Fig. 2). It is a solid bundle of fibers between 3 and 7 mm in width and between 2 and 5 mm in height. Here the uncinate fascicle travels in the extreme and external capsule along the lateral, ventral circumference of the putamen towards the retro-orbital cortex and gyrus rectus. Its frontal fan-like portion is orientated in an horizontal plane in the gyrus rectus (area 11), the medial, retro-orbital cortex (area 12) and subcallosal area (area 25).

The ventro-medial fiber bundles connect the uncus,

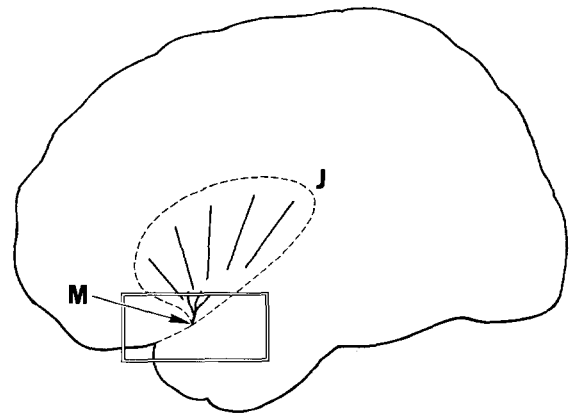

Fig. 2 A. Overview of a left hemisphere. The insula (*J*) and limen insulae with the bifurcation of the middle cerebral artery (*M*) is marked. The rectangle presents the region of interest (see B)

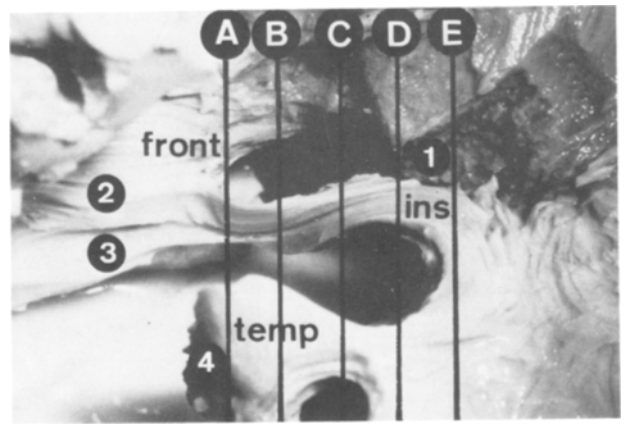

Fig. 2 B. Specimen of a left uncinate fascicle with its frontal (*front*), insular (*ins*) and temporal (*temp*) portion. *1* The lentiforme nucleus, claustrum, external and extreme capsule and the inferior occipito-frontal fascicle were removed. *2* Fibers of the uncinate fascicle in the orbital cortex, *3* in the gyrus rectus, *4* in the first temporal gyrus. The lines *A, B, C, D* and *E* represent the coronal cuts (see C)

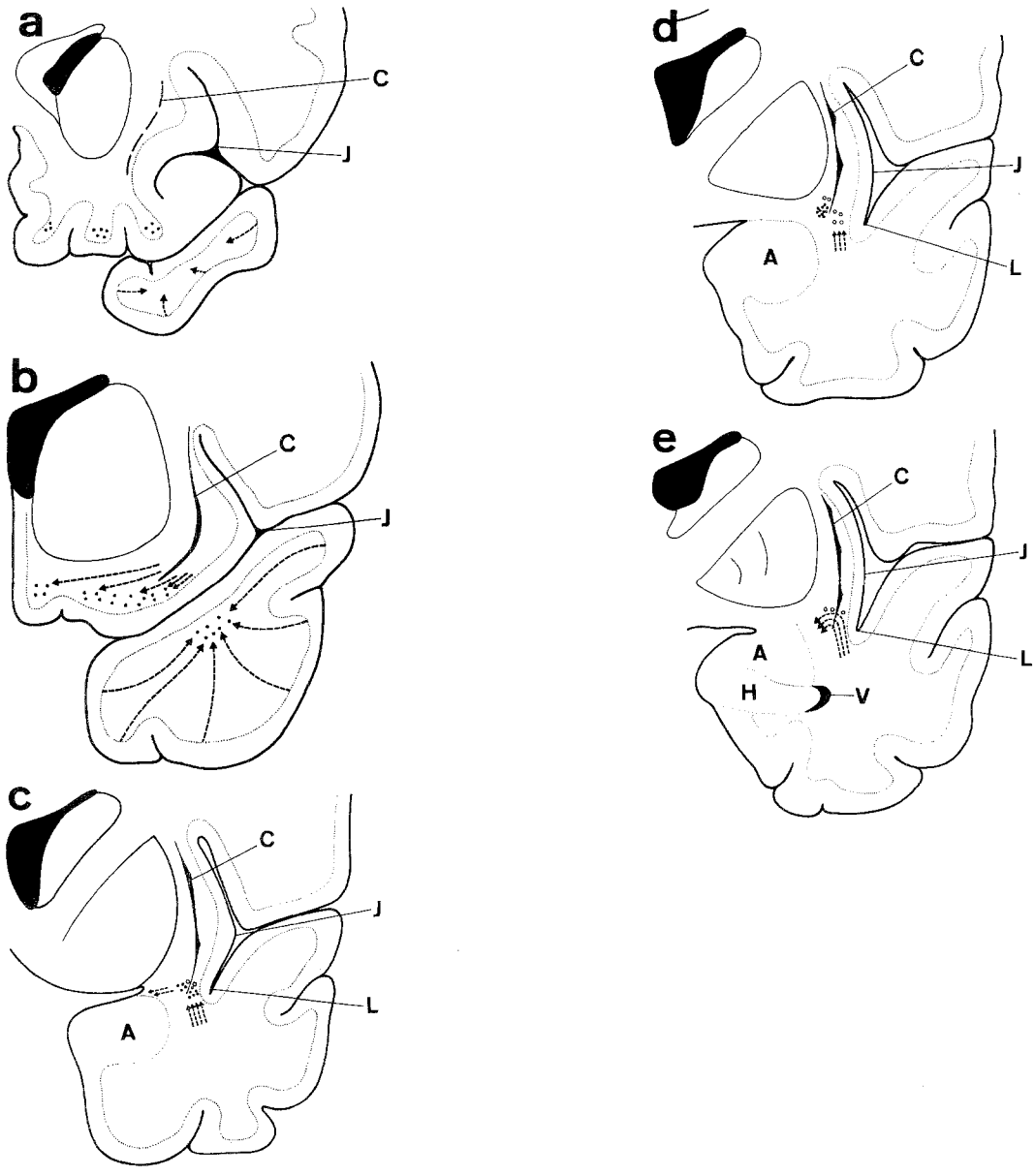

Fig. 2C. Coronal cuts through line A, B, C, D, and E (see Fig. 2B). *A* N. amygdala, *C* claustrum, *H* hippocampus, *J* insula, *L* limen insulae, *V* ventricle. a) cut through the retro-orbital cortex and most anterior temporal pole. The uncinate fascicle in the dorsal frontobasal cortex (black circles) and its fibers in the tip of the temporal lobe are shown (dashed lines). b) cut b lies 5 mm behind cut a. The fibers in the white matter of the orbital cortex are shown (black circles) and the fibers running frontally from the Limen insulae (dashed lines). The fibers deriving from the temporal pole (dashed lines) and fibers forming the solid portion running toward the limen insulae (black circles) are shown. c) Cut c lies 5 mm behind cut b. The upward running fibers in the temporal stem and horizontal frontally running fibers (dashed lines) are shown. The inferior occipito-frontal fascicle (open black circles) is shown above the uncinate fascicle (black points) in the extreme and external capsule, capping the claustrum. d) Cut d lies 5 mm behind cut c. The upward running temporal (dashed lines) and the horizontal running (black points) frontal fibers of the uncinate fascicle in the limen insulae are shown. The open circles represent the inferior occipito-frontal fascicle. e) Cut e lies 5 mm behind cut d. The turning point of the uncinate fascicle is shown (dashed lines), where the temporal fibers turn frontally. The inferior occipito-frontal fascicle is indicated by open circles

cortical nuclei of the amygdala and the tip of the third temporal convolution with the gyrus rectus and subcallosal area. The dorso-lateral bundle connects the tip of the first and second temporal convolutions with the retro-orbital cortex lateral to the gyrus rectus (Fig. 1).

Topography of the Fiber Tracts in the Temporal Pole

The uncinate fascicle, inferior occipito-frontal fascicle, Meyer's loop of the optic radiation, anterior commissure, inferior thalamic radiation and the ventral amygdalofugal fibers pass through the temporal stem.

It forms a narrow gate between the lower circular sulcus of the insula and the roof of the temporal horn in the deep white matter of the second temporal gyrus.

The inferior occipito-frontal fascicle runs in the caudal portion of the extreme and external capsule, enfolding the lower portion of the claustrum (Fig. 2). Caudally lies the uncinate fascicle. Both fiber systems show a parallel course through the limen insulae and can be separated by following their different coures, i.e. the uncinate fascicle shows its typical hooklike configuration and the inferior occipito-frontal fascicle a straight occipital course. The inferior occipito-frontal fascicle is located right above the optic radiation and travels parallel to it. In the fronto-orbital white matter the uncinate fascicle forms a layer of fibers adjacent to the lateral border of the inferior occipito-frontal fascicle without a clear limit between the two fiber systems. For better understanding of the topography of the different fibers in the anterior temporal stem their dispositions are given in the legend to Fig. 3.

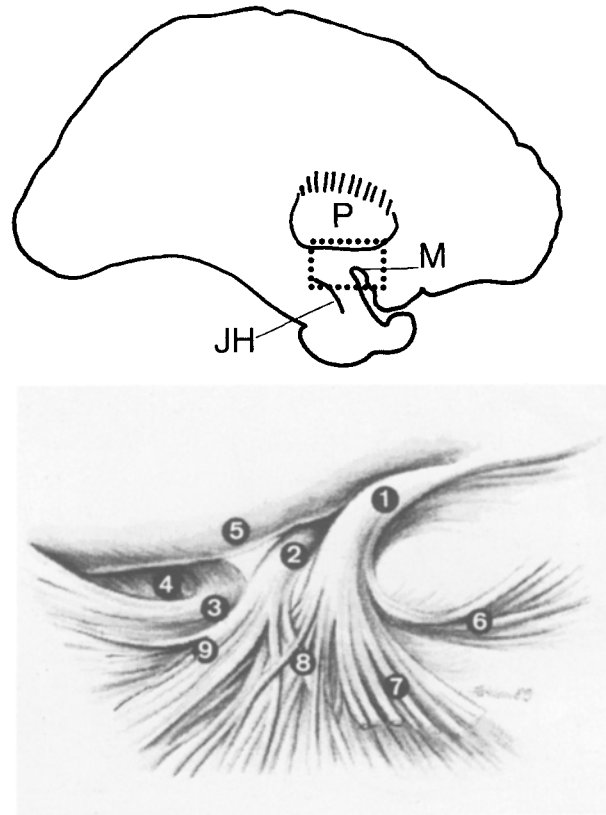

Fig. 3. Upper: Parasagittal cut through the right hemisphere and temporal stem. *P* Lentiforme nucleus, *M* limen insulae, *JH* inferior horn. The rectangle shows the region of interest (lower picture). Lower: Artist's drawing of the topography of the fiber systems in the temporal stem after removal of the inferior occipito-frontal fascicle of a specimen of the right hemisphere.
The numbers in rectangular brackets show the anatomical structures and relationships.
Meyer's loop [*3*] is found above and around the tip of the inferior horn underneath the removed inferior occipito-frontal fascicle[1, 8, 22]. The fibers of Meyer's loop [*3*] show some intermingling with the fibers of the anterior commissure [*9*]. The *variable* course of Meyer's loop [*3*] around the tip of the inferior horn was proven by the same method[8]. Opening of the ventricle tip may cause an upper homogenous quadrantanopia, which does not disturb the patient in daily life[8]. The anterior commissure [*2*] lies in the temporal stem caudally and dorsally of the uncinate fascicle [*1*]. In this further course the fibers of the anterior commissure [*2*] accompany the ventro-caudal fibers of the inferior occipito-frontal fascicle. These two fiber tracts intermingle with the fibers of Meyer's loop following its occipital course [*9*]. Also the uncinate fascicle [*1*] shows an intermingling with the anterior commissure [*8*]. In the further course the uncinate fascicle [*1*] detaches from the anterior commissure and changes its direction toward the temporal pole [*6, 7*]. The inferior thalamic radiation [*4*] passes through the sublenticular internal capsule, behind the anterior commissure [*2*] and underneath the lentiforme nucleus [*5*].

Discussion

The benefit of the method of fibre dissection used by Klingler is well documented[8–10, 18, 20]. The three dimensional course, the topography of the anterior temporal fibers and their landmarks could be studied. The accurate dissection of the fiber bundles can be difficult due to the intermingling of fibers[7, 10, 15, 33]. Fiber systems form long fiber tracts, but can be clearly distinguished from one another[7]. The cleavage of fiber systems are the result of fiber structure and not of arbitrary dissection[7]. Arbitrary fiber dissection can be avoided by finding the cleavage between fiber systems and applying traction of defined force and direction[7]. The inevitable loss of fiber substance by plucking away some fibers and shrinkage of fibers due to fixation imply, that the dimensions determined are smaller than in reality. For studies of surgical topography and proportions of fiber systems, however, this loss of substance can be neglected almost entirely.

The topography of different fiber systems in the anterior temporal stem implicates the possibility of damage during surgery. A lesion of the insular uncinate fascicle is possible, when an approach through the limen insulae is chosen for a selective amygdalectomy and hippocampectomy[36, 40].

During surgery a partial temporal pole resection may be unavoidable to again sufficient access. For the 1 st. temporal gyrus it should be limited to its white matter and not extended into the temporal stem, i.e. crossing the floor of the superior temporal sulcus. A superficial resection of the middle temporal gyrus is

recommended, sparing the temporal stem in its deep white matter in front of, above and around the tip of the inferior horn. The resection of the 3 rd. temporal gyrus should be restricted cranially to the floor of the lateral ventricle, preserving the fibers around the tip of the temporal horn. Medially the resection can be adapted according to the localization of the lesion. The *lateral* extent of anterior temporal resections should be kept as small as possible, regarding the wide variability of the speech area and risk of memory deficits in the dominant hemisphere[28, 30]. In general the resection should be limited to the depth of the superior or inferior temporal sulcus, preserving the temporal stem.

The role of the temporal stem in respect of neuropsychological functions as an assembling of different pathways is controversialy discussed in the literature[13, 14, 28, 41]. Lesions here may be responsible for severe disturbances of verbal and visual and spatial memory and learning functions[14]. Due to the damage of the temporal stem with all the efferent fiber systems of the temporal neocortex, the temporobasal, allocortical area and the cortical nuclei of the amygdala are interrupted and the temporal association cortex becomes isolated[13].

In contrast Zola-Morgan could show in monkeys, that not damage to the temporal stem, but to the mesial temporal structures (hippocampus) is responsible for amnestic deficits[41]. But he found, that "temporal stem lesions did, however, disrupt visual pattern discrimination learning, presumably as a result of damage to afferents and efferents of area TE"[3, 41].

Due to the narrow topographical arrangement of fiber systems in the anterior temporal stem one may argue, that damage here may be responsible for various cognitive deficits. Therefore we would not recommend a deep anterior temporal resection including the temporal stem because this may an impact on selective cognitive functions[16, 23, 38]. Dominant (left) temporal lobectomies produced significantly worse verbal memory[23, 26, 27, 29, 34]. Non-dominant (right) temporal lobe removal resulted in disturbed memory of visual and spatial data[23].

The landmark of the temporal stem is the 2 nd. temporal convolution or the level of the temporal horn, which corresponds to the second temporal convolution[8]. The temporal stem can be found in the depth of superior temporal sulcus medial and above the temporal horn. The uncinate fascicle and other fiber systems lies in front of, lateral and above the tip of the temporal horn, which lies 27 + 3.2 mm behind the tip of the temporal pole[8]. The limen insulae corresponds to the bifurcation of the middle cerebral artery[40]. In axial CT or MRI the limen insulae is clearly found at the antero-lateral border of the putamen. The uncinate fascicle can be localized easily with coronal CT or MR at the most inferior and anterior extreme and external capsule.

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