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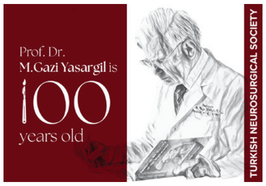

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Anatomical Segmentation and Connectivity of the Uncinate Fasciculus

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ABSTRACT

AIM: To provide a detailed anatomical segmentation of the uncinate fasciculus (UF) and to identify its cortical and subcortical connections using complementary white matter dissection and diffusion-weighted imaging tractography techniques.

MATERIAL and METHODS: Human cadaveric cerebral hemsipheres were used to perform fiber dissections of the UF using the Klingler technique. The tract was anatomically segmented based on its spatial relationships with surrounding structures. In parallel, high-resolution diffusion MRI data from healthy subjects were analyzed using deterministic tractography methods to reconstruct the UF and validate the anatomical segmentation.

RESULTS: Dissection studies revealed three distinct segments of the UF—temporal, insular, and frontal—based on their anatomical trajectories. Tractography findings supported this segmentation and demonstrated specific patterns of connectivity: the temporal segment connected the anterior temporal lobe to the amygdala and insula; the insular segment traversed the limen insulae; and the frontal segment projected to Brodmann areas 10, 11, 47, as well as the anterior cingulate cortex. These findings were consistent across all subjects.

CONCLUSION: This study presents a novel three-segment model of the UF, integrating findings from both dissections and tractography. The identified connectivity patterns enhance our understanding of frontal-temporal network organization and provide valuable insights for neurosurgical approaches and neuropsychiatric research.

KEYWORDS: Uncinate Fasciculus, Uncinate pole, Cingulate pole, Fiber dissection, White matter, Tractography

ABBREVIATIONS: AC: Anterior commissure, **AF:** Arcuate fasciculus, **ALS:** Anterior limiting sulci, **APS:** Anterior perforated substance, **DWI:** Diffusion-weighted imaging, **EC:** External capsule, **IFOF:** Inferior fronto-occipital fasciculus, **ILF:** Inferior longitudinal fasciculus, **ILS:** Inferior limiting sulci, **NAc:** Nucleus accumbens, **SI:** Substantia innominata, **SLF:** Superior longitudinal fasciculus, **SLS:** Superior limiting sulci, **UF:** uncinate fasciculus

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INTRODUCTION

The uncinate fasciculus (UF), initially described by Johann Christian Reil in 1809 as a "broad band bridging the frontal and temporal lobes," has undergone significant conceptual refinements over time (32). Later, Karl Burdach further characterized it as "curved fibers extending laterally and basally from the frontal region of the external capsule" (32). As a major association pathway linking medial temporal regions to the dorsolateral prefrontal cortex, the UF plays a pivotal role in higher-order cognitive functions, including episodic memory — particularly the encoding of temporal and spatial contexts — as well as in lexical retrieval of semantic knowledge. Beyond its contributions to memory, the UF is fundamental to social and emotional regulation by connecting limbic and paralimbic structures, thus influencing decision-making processes and behavioral control mechanisms (5,8,13,25,33).

Anatomically, the UF constitutes a direct, monosynaptic, long association tract that bridges the frontoorbital cortex with the anterior temporal lobe (10). Despite considerable research efforts, a definitive consensus on the precise cortical terminations of the UF remains elusive (2,14,22). Its central location within the brain's architecture renders it critical for cognitive-emotional integration and implicates it in various neuropsychiatric and developmental disorders (14,32). The fascicle is also frequently interrupted during surgeries in and around the region of insula and the transylvian approaches to the mesial temporal lobe (1,37). The UF is also affected by traumatic brain injuries, owing to its connections with both frontal and temporal regions (17,20).

Given its complex anatomical organization, diverse cortical projections, and prominent clinical relevance, achieving a more refined understanding of the internal architecture of the UF is imperative. Although previous studies have attempted to delineate its segmentation, ambiguities regarding its precise internal structure persist. Accordingly, the present study seeks to advance the anatomical comprehension of the UF by thoroughly analyzing its fiber composition and cortical terminations using complementary methodologies: white matter dissection and diffusion-weighted imaging (DWI) tractography.

MATERIAL and METHODS

Twelve human hemispheres were fixed in a 10% formalin solution for a minimum of two months, following the fixation technique originally described by Klingler (18). Following fixation, the arachnoid mater, pia mater, and vascular structures were removed under a Zeiss surgical microscope (Carl Zeiss AG, Oberkochen, Germany). The specimens were then frozen at -16°C for a minimum of three weeks. Prior to dissection, they were thawed in running tap water for one hour and subsequently stored in a 70% ethanol solution between procedures. Microsurgical dissections were conducted under magnifications ranging from x4 to x40 using a Zeiss surgical microscope and a Rhoton microsurgical instrument set. The fiber dissection proceeded systematically from lateral to medial and from inferior to superior orientations. At each step, the spatial relationships between the UF fibers and surrounding neuroanatomical structures were carefully examined. High-resolution photographs were captured at each stage using a Canon EOS 550D DSLR camera equipped with a fixed 100 mm macro lens, mounted on a professional Manfrotto tripod.

Diffusion tractography was performed utilizing DSI Studio software (http://dsi-studio.labsolver.org) with DWI data derived from the Human Connectome Project, encompassing a cohort of 1065 healthy individuals. A deterministic tractography algorithm was applied, with anisotropy and angular thresholds randomly varied within standardized parameters. A multishell diffusion acquisition strategy was employed with b-values set at 990, 1985, and 2980 s/mm^2. DWI was sampled isotropically at 2.0 mm resolution, with a diffusion sampling length ratio of 1.7. A deterministic tractography algorithm was used for fiber tracking. Only fibers ranging from 10 mm to 200 mm in length were included; shorter or excessively long tracts were excluded. A total of 16 iterations of tract refinement were conducted to eliminate spurious trajectories, ensuring anatomical accuracy in fiber reconstruction.

RESULTS

Lateral to Medial Dissection of the Uncinate Fasciculus: Insular Segmentation and Revealing Insular Relationships

Following periinsular decortication in the left hemisphere, two prominent superficial long association fibers in the periinsular area were revealed. These were the superior longitudinal fasciculus (SLF), which travels above the Sylvian fissure and the insula to provide frontoparietal connections, and the arcuate fasciculus (AF), which surrounds the Sylvian fissure and insula to establish frontotemporal connections (Figure 1A).

Following removal of the opercular association fibers, the anterior, superior, and inferior limiting sulci (ALS, SLS, and ILS) of the insula were clearly identified (Figure 1A, B). The claustrum, located at the apex of the insula, along with the external capsule (EC), was exposed. The EC comprises a dorsal portion formed by claustrocortical fibers and a ventral portion formed by fibers of the UF and the inferior fronto-occipital fasciculus (IFOF). The IFOF courses between the frontal and occipital cortical regions, while the UF provides long-range frontotemporal connectivity (Figures 1A, B; 3A, B) (34).

Based on the boundaries formed by the ALS and ILS, we segmented the UF into frontal, insular, and temporal parts (Table I). The insular segment of the UF is located lateral to the anterior perforated substance (APS) and the substantia innominata (SI), at the level of the limen insula (11,29). This segment forms the lateral boundary of the SI. The anterior boundary of the SI is formed by the internal capsule. Its posterior boundary is formed by the anterior commissure, coursing from anteromedial to posterolateral (Figures 1E, F; 3B, C).

After removal of the ventral AF, located dorsal to the ILS, the IFOF, which coursed toward the sagittal stratum, was visualized along with the fibers of the temporal segment of the UF projecting toward the temporal lobe (Figure 1C, D). The posterior boundary of the insular segment of the UF was defined by the AC and ILS, specifically where the AC and IFOF converge

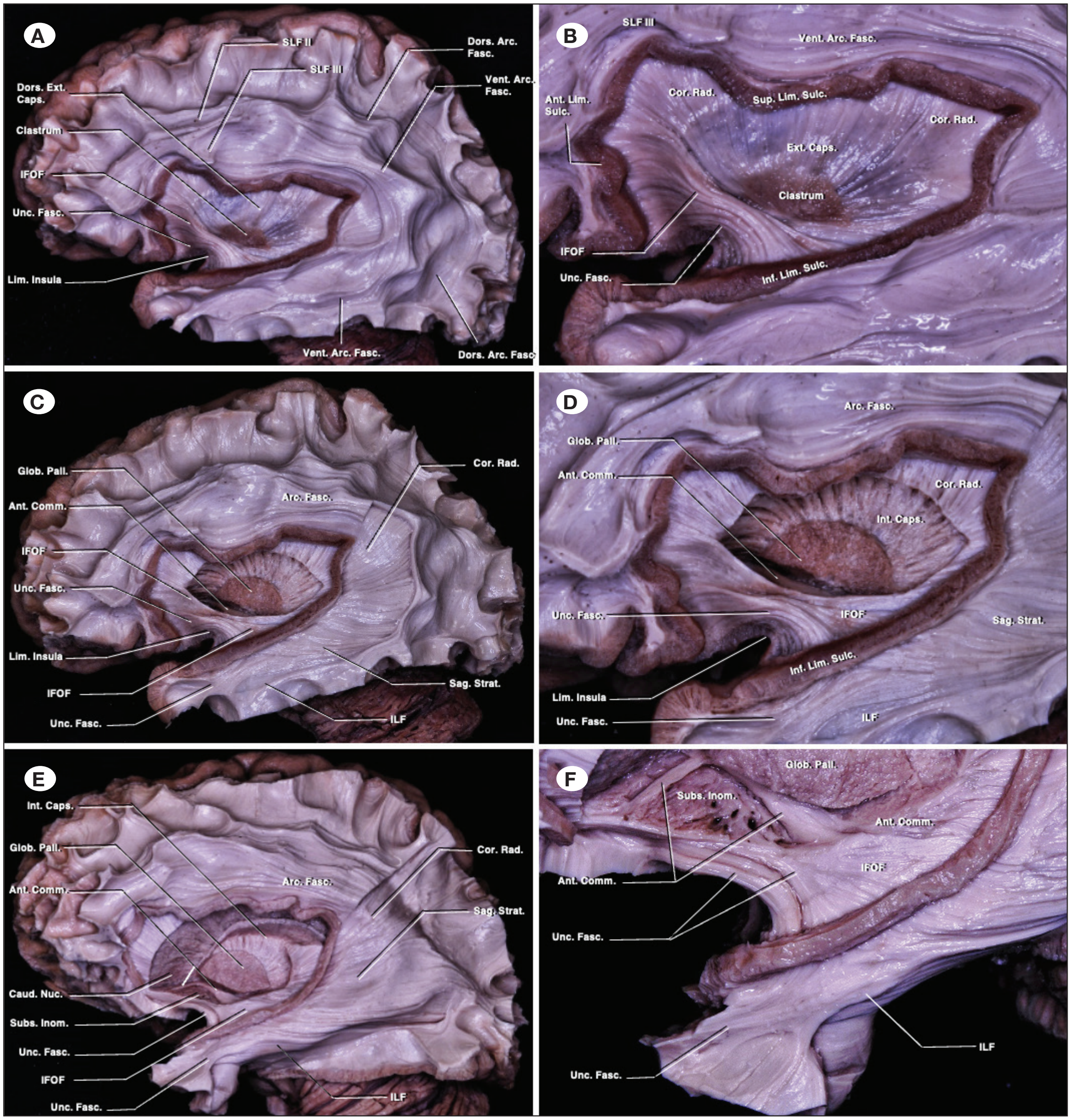

Figure 1: Gradual lateral to medial fiber dissection on the left cerebral hemisphere. **A)** Initial white matter dissection of the periinsular and insular region. SLF II runs between the middle frontal gyrus and the angular gyrus, whereas SLF III courses along the frontoparietal operculum between the pars orbitalis and the supramarginal gyrus. The ventral AF originates from the middle temporal gyrus, passes through the supramarginal gyrus, and projects to the inferior frontal gyrus. In contrast, the dorsal AF begins in the middle and inferior temporal gyri, traverses the angular gyrus, and also projects to the inferior frontal gyrus. **B)** Removal of the opercular cortex reveals the EC, formed dorsally by claustrocortical fibers and ventrally by the IFOF and UF. The claustrum is exposed at the apex of the insula. The dorsal EC, located around the SLS, merges with internal capsule fibers and contributes to the corona radiata by passing deep to the SLF and AF. The main trunks of the UF and IFOF were revealed at the level of the limen insula and the insular apex. **C, D)** With further dissection, the ventral AF has been removed, revealing the IFOF and UF passing beneath the ALS and ILS. The AC, GP, and internal capsule are also identified. Continued dissection exposes the sagittal stratum, showing the IFOF coursing posteriorly and the UF curving anteroinferiorly toward the temporal lobe. **E, F)** The anterior limb of the internal capsule is resected to better visualize the UF trajectory. The posterior limb of the AC and adjacent GP are exposed. The convergence of the AC, UF, and IFOF at the level of the ILS is observed. Deeper structures, including the caudate nucleus, SI, and internal capsule are revealed.

Table I: Anatomical Segmentation and Structural Relationships of the Uncinate Fasciculus (UF)

Segment	Subdivision	Anatomical Boundaries	Neighboring Structures	Cortical Connections / Pathways
Frontal Segment	Anterolateral UF	Lateral to olfactory sulcus	Lateral & posterior orbital gyri, pars orbitalis	Orbitofrontal cortex, anterior insula
	Dorsomedial UF	Medial to olfactory sulcus, beneath medial orbital gyrus	Gyrus rectus, nucleus accumbens, anterior-ventral cingulum	Gyrus rectus, medial orbitofrontal cortex, cingulate pole
Insular Segment	Anterolateral UF	Between ALS and ILS; lateral to substantia innominata	Anterior perforated substance, external capsule, insular apex	Frontal-insular transition zone; contributes to frontotemporal connectivity
	Dorsomedial UF	Medial portion of insular segment, lateral to anterior commissure	Substantia innominata, deep insular white matter	Projects medially toward mesial temporal structures
Temporal Segment	Anterolateral UF	Lateral to collateral sulcus	Temporal pole, inferior longitudinal fasciculus	Temporal pole, inferior temporal gyrus
	Dorsomedial UF	Medial to collateral sulcus	Parahippocampal gyrus, amygdala, cingulum	Amygdala, parahippocampal gyrus; merges with cingulum at the uncinate pole
Uncinate Pole	Convergence zone	Inferolateral to the amygdala	Amygdala, anterior temporal lobe, dorsomedial UF, cingulum bundle	Intersection of cingulum and dorsomedial UF; potential hub for temporolimbic connectivity

***ALS:** Anterior limiting sulci, **ILS:** Inferior limiting sulci.*

into the sagittal stratum. The ALS constituted the boundary between the frontal and insular segments of the UF (Figure 1D), corresponding to the most anterolateral portion of the AC (Figure 1F).

In the lateral dissection, after looping around, the temporal segment of the UF followed an anterolateral course as it traveled with the inferior longitudinal fasciculus (ILF) toward the temporal pole (Figures 1F, 3A). Deep to the SI and IFOF fibers, the dorsomedial UF fibers disappeared toward the mesial temporal area (Figure 1F).

The insular segment of the UF was further divided based on the direction of the fibers. The more lateral group was defined as the anterolateral UF, while the more medial group was defined as the dorsomedial UF (Figure 1D, E, F) (Table I).

Inferior to Superior Dissection of the Uncinate Fasciculus: Frontal and Temporal Segmentation and Revealing the Cingulate and Uncinate Pole

Following decortication of the frontoorbital area, inferior frontal gyrus, and limen insula from the basal surface, the frontal cortical structures were exposed. In the frontoorbital region, composed of the the anterior, lateral, medial, and posterior orbital gyri, was separated from the gyrus rectus via the olfactory sulcus (Figure 2A).

Fibers of the insular segment of the UF extend toward the frontal segment from the deep portion of the ALS, which constitutes the anterior boundary of the limen insula and is ventrally related to the APS. The frontal segment of the UF extends laterally from the olfactory sulcus and distributes in the orbitofrontal cortex anterior to the medial and lateral olfactory striaes. It was observed to have two distinct layers, displaying long anterolateral and short dorsomedial courses (Figures 2A, 2B; 3D). Based on this frontal distribution, the UF was segmented into the anterolateral UF and dorsomedial UF (2).

The anterolateral UF separates from the dorsomedial fibers and projects to the lateral, anterior, and posterior orbital gyri, as well as to the pars orbitalis. The dorsomedial UF turns medially at the frontal base, courses beneath the olfactory sulcus within the medial orbital gyrus, and reaches the gyrus rectus. At the posterior part of the prefrontal cortex, near the septal area, the region referred to by Yasargil as the “cingulate pole” is located (36). Here, the dorsomedial segment of the UF intersects with the ventral extension of the cingulum bundle (Figures 2B; 3E, F, G). Before merging with the cingulum, dorsomedial UF fibers course over the medial and inferior surfaces of the NAc, sending fibers to it (2).

On the inferior surface of the hemisphere, the parahippocampal gyrus, collateral sulcus, and inferior temporal gyrus were dissected (Figure 2). The temporal segment of the UF, turning toward the temporal pole from the depth of the ILS, diverges into the dorsomedial UF medially and anterolateral UF laterally relative to the collateral sulcus. The anterolateral UF fibers that travel lateral to the collateral sulcus terminate in the temporal pole alongside the ILF, which connects the visual areas of the occipital lobe to the inferior temporal gyrus (Figures 1F; 2A, B) (34). Medial to the collateral sulcus, the dorsomedial UF was observed extending toward the parahippocampal gyrus and the amygdala (Figure 2C, D).

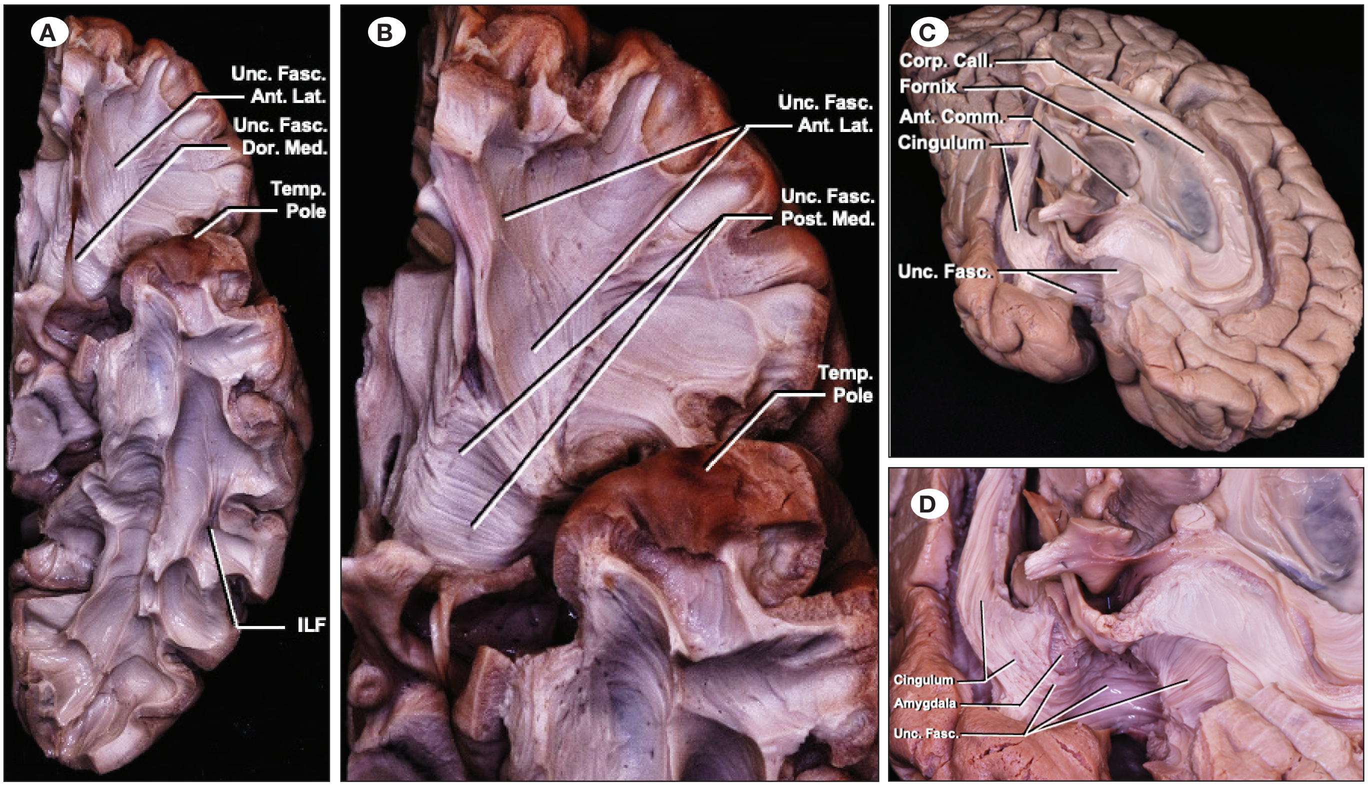

Figure 2: Inferior to superior dissection of the UF on the left cerebral hemisphere, illustrating frontal and temporal segmentations and their anatomical targets. **A)** After decortication of the ventral surface, the orbitofrontal cortex and temporal pole are exposed. The anterolateral UF is visualized projecting toward the anterior, lateral, and posterior orbital gyri. The dorsomedial UF courses medially beneath the olfactory sulcus, toward the gyrus rectus and septal area. **B)** Continued dissection at a deeper level shows both UF components projecting from the ALS. The anterolateral UF is directed laterally to the orbital gyri, while the dorsomedial UF extends medially to the gyrus rectus and septal cortex. The temporal segment of the UF is visualized turning around the limen insula toward the temporal pole. **C)** The AC, corpus callosum, and fornix are revealed medially. The dorsomedial UF fibers intersect with the anterior cingulum bundle near the so-called “cingulate pole” at the subcallosal area. The convergence of these limbic structures is noted anterior to the septal area. **D)** The terminal portions of the dorsomedial UF fibers are shown approaching the amygdala and parahippocampal gyrus. The uncinate pole is illustrated as the junction point of the dorsomedial UF and the cingulum, deep to the uncus and adjacent to the mesial temporal lobe structures.

Within the depth of the parahippocampal gyrus, extending from the isthmus of the cingulate gyrus to the anterior temporal pole, lie the fibers of the cingulum bundle, which connect the medial frontal and parietal areas to the medial temporal lobe (Figure 2C, D) (2,31). The cingulum and dorsomedial UF fibers converge inferolaterally to the amygdala, forming the uncinate pole (Figures 2D; 3E, F, G).

DISCUSSION

The UF is a long association fiber tract that exhibits a characteristic hook-like trajectory around the limen insula. It forms cortico-cortical connections between the subcallosal area, gyrus rectus, pars orbitalis, and frontoorbital cortex with the superior, middle, and inferior temporal gyri, as well as the anterior portions of the uncus (2,10,15,22,27,28,32). Dejerine was the first to describe not only the classical hook-shaped fibers of the UF but also fibers that appear flattened or even reversed in orientation (9). We define the UF as a ventral limbic pathway that connects the rostral, inferior, ventral, and medial temporal regions with the medial and orbital frontal cortices. Furthermore, our findings support recent discussions suggesting that the UF is not solely composed of hook-shaped fibers, but also includes segments that reverse direction within the orbitofrontal and parahippocampal cortices. The primary focus is to provide a detailed anatomical segmentation of the UF by evaluating the frontal and temporal cortical termination sites in relation to their functional associations.

Building upon the classification proposed by Ebeling and Cramon, we refined the anatomical boundaries of the compact UF trunk based on its relationship to the ILS (10). Accordingly, we defined three main segments: frontal, insular, and temporal. Each segment was further subdivided into dorsomedial and anterolateral components, based on their orientation and cortical termination patterns beyond the limiting sulci (Table I).

Cortical fibers associated with the claustrum, known as the EC fibers, are divided into dorsal and ventral components. The dorsal EC consists of claustrocortical fibers, while the ventral EC is composed of the UF and IFOF (12). The dorsal EC

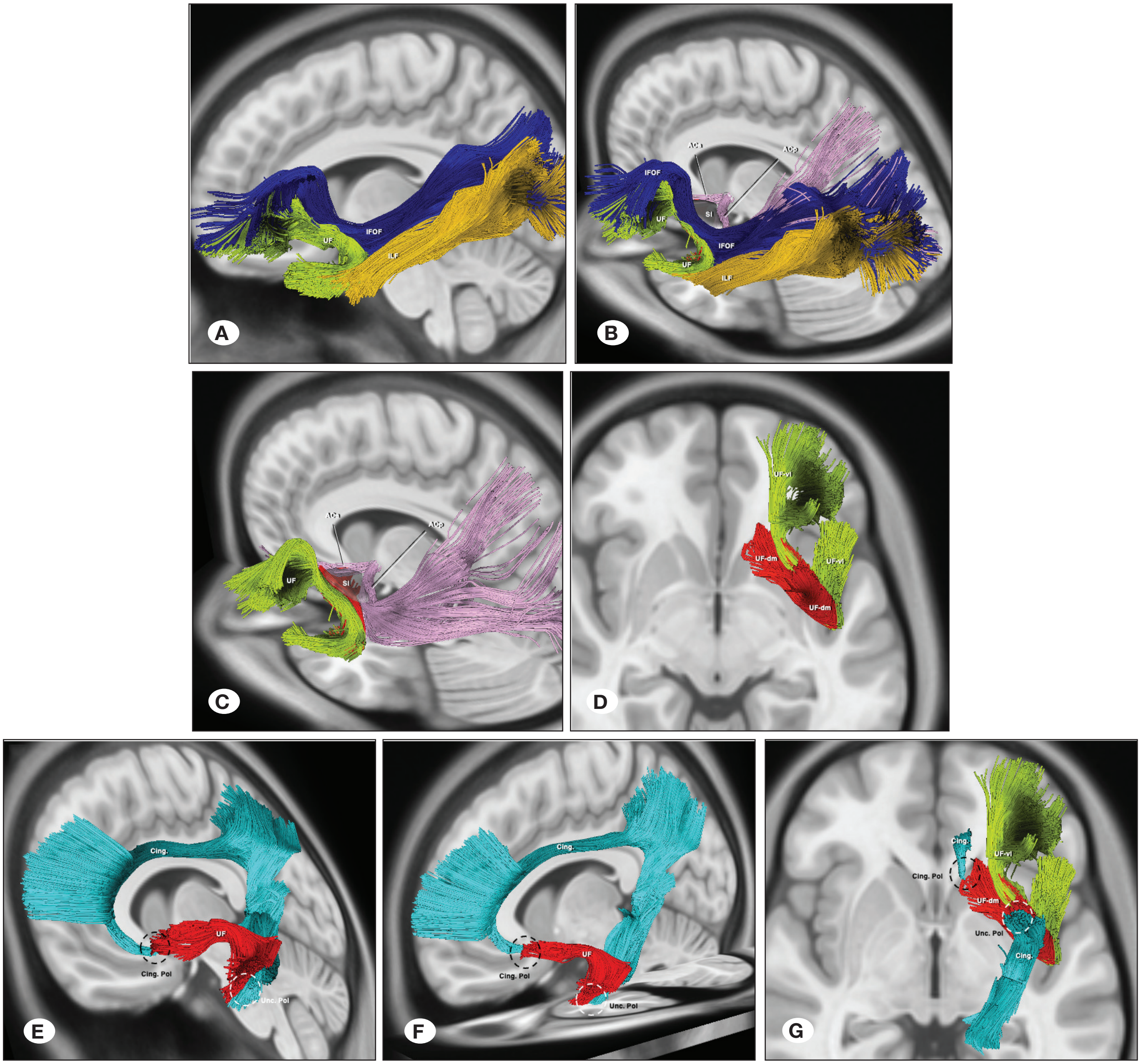

Figure 3: DWI tractography images derived from healthy subjects to assess the integrity of the fiber dissection results and display relevant UF connections on the left cerebral hemisphere. All tracts were generated using deterministic tractography with analysis performed in DSI Studio. The anisotropy threshold was randomly selected, and the angular threshold was randomly varied between 15° and 90°. Step size was randomly set between 0.5 and 1.5 voxels. **A)** Left medial view showing the ILF, IFOF, and UF **B)** Slightly deeper dissection reveals the anterior and posterior limbs of the AC (ACa and ACp, respectively), situated between the SI and ventral striatum. The dorsomedial UF courses medially and superiorly, **C)** IFOF was removed. The ventrolateral UF and dorsomedial UF are clearly distinguished by their orientation around the limen insula and SI. **D)** The ventrolateral and the dorsomedial UF viewed from below. The dorsomedial UF fibers approach the medial temporal lobe, while the anterolateral UF courses laterally toward the temporal pole, running parallel to the ILF. **C, D)** The dorsomedial UF courses medially and inferiorly, in contrast to the more lateral and superior anterolateral UF fibers that extend toward the temporal pole. **E, F, G:** The anatomical convergence of the dorsomedial UF fibers with the anterior cingulum is shown at both poles: the cingulate pole at the frontal base and the uncinate pole at the temporal base. These two anatomical hubs represent critical junctions in the limbic circuitry. **G)** Basal view illustrating the relationship between the UF and cingulum.

includes long association fibers that connect the claustrum with cortical regions ranging from the supplementary motor area anteriorly to the posterior parts of the parietal lobe (12). These fibers merge with the internal capsule in the region of the SLS, contributing to the corona radiata (Figure 1). The ventral EC is formed dorsally by the IFOF and ventrally by the UF (12). The IFOF comprises fronto-occipital association fibers that connect the middle and inferior frontal gyri (particularly the pars orbitalis and pars triangularis) with the posterior parietal and occipital lobes (12,14). In our study, we demonstrated the compact arrangement of these tracts at the insular apex, with the IFOF occupying the superior position and extending fronto-occipitally, and the UF located inferiorly with a frontotemporal course (Figure 1). As the UF fibers course toward the temporal pole and mesial temporal region, they diverge from the IFOF at the level of the ILS, turning anteroinferiorly. Notably, this region also corresponds to the area where AC fibers and IFOF fibers interdigitate to form the sagittal stratum. The insular segment of the UF occupies the insular apex as a compact fiber bundle, situated between the APS and the extreme capsule (10,32).

Previous studies have described that the inferior and medial fibers of the UF course rostrally between the APS and the putamen, while its lateral fibers intermingle with fibers from the genu of the corpus callosum, projecting into the frontoorbital and lateral frontal lobes (32). Based on our lateral to medial dissections, the first fibers encountered were the anterolateral UF bundle of the insular segment, which extended from the temporal pole to the lateral, anterior, and posterior orbital gyri, as well as the pars orbitalis (2). Deeper dissection revealed another group of fibers located adjacent to the SI and APS, forming the dorsomedial UF bundle. These fibers originated in the mesial temporal region and coursed toward the gyrus rectus, septal area, and NAc (2). Adopting the segmentation proposed by Ebeling and Cramon into temporal, insular, and frontal components, we further classified the insular segment of the UF into anterolateral and dorsomedial subcomponents (Table I) (10).

Recent studies have demonstrated that the frontal cortical terminations of the UF extend beyond the traditionally accepted orbitofrontal cortex and pars orbitalis, encompassing a broader area of the frontal lobe (22). In a previous study, we reported that the UF projects to the frontoorbital area, septal area, NAc, and the superolateral frontal lobe (2). Hau et al. further described UF projections to widespread regions of the lateral prefrontal cortices, including the superior, middle, and inferior frontal gyri (15). Leng et al. documented terminations in the middle frontal gyrus, pars orbitalis, and pars triangularis (21), while Liakos et al. observed projections to the posterior orbital lobule, pars orbitalis, gyrus rectus, and subgenual area (22). In our current study, we show that UF fibers diverge into distinct trajectories within the frontal lobe, originating from the ALS to reach various cortical targets (2). As the distance from the APS increases, the anterolateral UF of the insular segment, located in its lateral compartment, follow a relatively straight horizontal course toward the anterior, lateral, and posterior orbital gyri, as well as the pars orbitalis (Figure 1). In contrast, the dorsomedial fibers located in the medial compartment of the insular segment change their orientation along the ALS, curving anteriorly and medially as they extend. These dorsomedial fibers have a shorter trajectory than the anterolateral fibers and project to the gyrus rectus, septal area, and NAc (Figure 2).

Early studies have described the terminations of the UF predominantly in the temporal pole, as well as in the superior and middle temporal gyri, fusiform gyrus, and entorhinal cortex (9,10). Additionally, several investigations have reported UF projections to the cingulate gyrus and amygdala (6,7,19,33). However, Hau et al. did not identify these projections in their dissections and suggested that such discrepancies might be attributable to the presence of adjacent pathways, such as amygdalo-temporal or amygdalo-prefrontal tracts, that may have been misattributed to the UF (16). We demonstrated that the insular segment of the UF, as defined in our study, curves from the level of the ILS and proceeds toward the temporal pole, amygdala, and medial temporal areas. Martino et al. reported that the anterior boundary of the optic radiation, located beneath the ILS, coincides with the transition point between the UF and IFOF (24). We confirmed that from the level of the ILS—the point marking the transition between the IFOF and UF—the insular segment of the UF curves into two distinct trajectories, which we define as the temporal segment of the UF. Among these, the anterolateral UF fibers project toward the temporal pole, while the dorsomedial UF fibers course medially toward the medial temporal region (Figures 1, 2).

The limbic system, comprising white matter pathways that mediate cortical and corticocortical connections involved in memory, emotion, and behavior regulation, is anatomically represented by the cingulate cortex, orbitofrontal cortex, hippocampus, amygdala, NAc, thalamic nuclei, and mammillary bodies (4). The cingulum and the UF constitute the dorsal and ventral limbs of the limbic axis, respectively (32). As a dorsal limbic pathway, the cingulum bundle connects the frontal, parietal, and cingulate cortices with the ventral temporal cortex. It is implicated in memory processing, decision-making, and emotional regulation, with the left cingulum particularly associated with intellectual performance and cognitive functioning (23,26,31). On the other hand, the UF serves as the most lateral component of the ventral limbic stream, connecting the rostral, inferotemporal, and ventral temporal cortices with medial and orbital frontal areas (2,26,32). UF has been associated with multimodal sensory integration, behavior inhibition modulated by the reward–pleasure system, and visual memory (14). Together, the cingulum and UF form an alternative limbic circuit resembling the Papez circuit, encircling nearly the entire medial hemisphere (2). This circuit is completed at two key junctions, previously described as the *“cingulate pole”* by Yasargil and the *“uncinate pole”* by Baydin et al. (2,35). In our study, we observed that the cingulum merges with the anteromedial fibers of the UF on the dorsomedial surface of the uncus in close association with the amygdala, thereby forming the uncinate pole. Furthermore, we identified the cingulate pole, defined by Yasargil as the convergence zone between the subcallosal and paracingulate cortices and the posterior prefrontal cortex, where the cingulum and dorsomedial UF fibers intersect deep to the gyrus rectus and septal area, medial to the NAc (Figures 2, 3).

Additionally, our results support the existence of amygdalo-accumbens connections mediated by dorsomedial UF fibers, consistent with previous reports describing the amygdalo-accumbens pathway (Figures 2, 3) (3,30).

CONCLUSION

In this study, we provided a detailed anatomical segmentation of the UF through combined white matter dissection and tractography. We demonstrated that the UF can be systematically divided into frontal, insular, and temporal segments, each with distinct dorsomedial and anterolateral subcomponents based on their cortical trajectories and anatomical relationships. Our findings not only refine the classical descriptions of the UF but also emphasize its critical role within the limbic system, highlighting its contributions to the integration of emotional, cognitive, and behavioral processes. By elucidating the internal organization and cortical terminations of the UF, this study offers a valuable framework for understanding its involvement in both normal brain function and a variety of neurological and psychiatric disorders.

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Ethical approval is not applicable for this article (https://trdizin.gov.tr/wp-content/uploads/2022/04/TRDizin_etik_ilkeleri_akis_semasi.pdf).

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Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: SSB, OB, NT

Data collection: SSB, OB, BK

Analysis and interpretation of results: OB, OH

Draft manuscript preparation: SSB, OB, BK, OH

Critical revision of the article: SSB, NT

Other (study supervision, fundings, materials, etc...): NT

All authors (SSB, OB, BK, OH, NT) reviewed the results and approved the final version of the manuscript.

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