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# Fiber dissection anatomy of the dorsal and ventral language pathways at the temporo–parieto–occipital junction: Implications for fiber separation surgery

## *Temporo-pariyeto-oksipital bileşkede dorsal ve ventral dil yollarının fiber diseksiyon anatomisi: Lif ayırma cerrahisi için çıkarımlar*

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## ABSTRACT

**Aim:** The temporo–parieto–occipital junction (TPOJ) represents a critical convergence zone of the dorsal and ventral language pathways. Preservation of these tracts is essential during surgery for lesions involving this region. The aim of this study is to define the microsurgical anatomy of the dorsal and ventral language pathways at the TPOJ using the fiber dissection technique and to propose a surgical strategy based on the principles of fiber separation.

**Materials and Methods:** Three formalin-fixed adult human cadaveric brains (six hemispheres) and two silicone-injected adult human cadaveric heads (four sides) were prepared using the Klingler fiber dissection technique. Stepwise microscopic dissections were performed from the cortical surface toward the deep white matter. The spatial relationships of the superior longitudinal fasciculus (SLF II–III), arcuate fasciculus (AF), inferior fronto-occipital fasciculus (IFOF), middle longitudinal fasciculus (MdLF), and extreme capsule (ExtC) were analyzed. Special attention was given to the depth, orientation, and natural separation planes between the dorsal and ventral language pathways.

**Results:** The dorsal language system, mainly composed of SLF II–III and the arcuate fasciculus, was identified in all dissections as a superficial-to-intermediate layer beneath the U-fibers. The ventral language pathways, including the IFOF, MdLF, and extreme capsule system, were observed in deeper and more medial planes throughout the dissections. Between the dorsal and ventral systems, a distinct separation corridor was consistently identified, particularly along the interface between the arcuate fasciculus and the IFOF, across different cadaveric specimens. This corridor corresponded to a potential surgical plane for fiber separation techniques.

**Conclusions:** At the TPOJ, the dorsal and ventral language pathways demonstrate a layered anatomical organization with distinct separation planes. Recognition of these natural separations may contribute to the development of fiber-preserving microsurgical strategies.

**Keywords:** Association fiber systems; fiber separation surgery; temporo–parieto–occipital junction; white matter anatomy.

## ÖZ

***Amaç:*** *Temporo-pariyeto-oksipital bileşke (TPOJ), dorsal ve ventral dil yollarının birleştiği kritik bir geçiş bölgesini temsil eder.*

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*Bu bölgeyi içeren lezyonlara yönelik cerrahi sırasında bu yolların korunması esastır. Bu çalışmanın amacı, fiber diseksiyon tekniğini kullanarak TPOJ düzeyinde dorsal ve ventral dil yollarının mikrocerrahi anatomisini tanımlamak ve lif ayırma prensiplerine dayanan bir cerrahi strateji önermektir.*

***Gereç ve Yöntem:*** *Üç adet formalinle fikse edilmiş erişkin insan kadavra beyni (altı hemisfer) ve iki adet silikon enjekte edilmiş erişkin insan kafa kadavrası (dört taraf) Klingler fiber diseksiyon tekniği kullanılarak hazırlandı. Kortikal yüzeyden derin beyaz cevhere doğru aşamalı mikroskopik diseksiyonlar gerçekleştirildi. Süperior longitudinal fasikül (SLF II–III), arkuat fasikül (AF), inferior fronto-oksipital fasikül (IFOF), middle longitudinal fasikül (MdLF) ve ekstreme kapsül (ExtC) arasındaki topografik ilişki analiz edildi. Dorsal ve ventral dil yolları arasındaki derinlik, yönelim ve doğal ayrım düzlemleri ayrıntılı değerlendirildi.*

***Bulgular:*** *Esas olarak SLF II–III ve AF'den oluşan dorsal dil sistemi, tüm diseksiyonlarda U-liflerinin altında yer alan yüzeyel–orta derinlikte bir katman olarak tanımlandı. IFOF, MdLF ve ExtC sistemini içeren ventral dil yolları ise diseksiyonlar boyunca daha derin ve daha medial düzlemlerde izlendi. Dorsal ve ventral sistemler arasında, özellikle AF ile IFOF arasındaki ara yüz boyunca, farklı kadavra örneklerinde benzer şekilde ortaya konabilen belirgin bir ayrılma koridoru gözlemlendi. Bu koridor, lif ayırma teknikleri açısından potansiyel bir cerrahi düzleme karşılık gelmekteydi.*

***Sonuç:*** *TPOJ'de dorsal ve ventral dil yolları, belirgin ayrılma düzlemleri ile düzenlenmiş katmanlı bir anatomik organizasyon gösterir. Bu doğal ayrımların tanınması, lif koruyucu mikrocerrahi stratejilerin geliştirilmesine katkı sağlayabilir.*

***Anahtar Sözcükler:*** *Asosiasyon lif sistemleri, lif ayırma cerrahisi, temporo-parieto-oksipital bileşke, ak madde anatomisi.*

**Abbreviations**

*AF = arcuate fasciculus; ExtC = extreme capsule; IFOF = inferior fronto–occipital fasciculus; MCA = middle cerebral artery; MdLF = middle longitudinal fasciculus; OR = optic radiation SLF = superior longitudinal fasciculus; TPOJ = temporo–parieto–occipital junction; UF = uncinate fasciculus.*

## INTRODUCTION

The temporo–parieto–occipital junction (TPOJ) represents one of the most complex anatomical and functional convergence zones of the human brain (1,2). Located at the intersection of the temporal, parietal, and occipital lobes, this region contains a dense network of association, commissural, and projection fibers (3). Among these, the white matter pathways involved in language processing are particularly critical, as even minor surgical injury may result in permanent functional deficits (4). Therefore, detailed knowledge of the subcortical architecture of the TPOJ is essential for planning safe and effective surgical approaches to intrinsic tumors, vascular malformations, and other lesions involving this region (1,2,4). Contemporary models of language organization emphasize the existence of two major processing streams: the dorsal and ventral language pathways (5,6). The dorsal pathway is primarily associated with phonological processing, auditory–motor integration, and speech production (5,7,8). It is mainly composed of the arcuate fasciculus (AF) and the superior longitudinal fasciculus (SLF), particularly its second and third components (9–11). These tracts connect the posterior temporal and inferior parietal regions to the frontal language areas, forming the structural basis of the classic perisylvian language network. In contrast, the ventral pathway is involved in semantic processing, lexical access, and comprehension. It includes the inferior fronto–occipital fasciculus (IFOF), the extreme capsule (ExtC) system, and the middle longitudinal fasciculus (MdLF), which connect the temporal and occipital cortices with the frontal lobe through deeper and more medial trajectories (9,12,13). The TPOJ constitutes a key intersection area where the dorsal and ventral language pathways course in close proximity within a limited anatomical space. Several tractographic and anatomical studies have demonstrated the intricate arrangement of these fiber systems and their complex interconnections (2,7). However, most existing literature has focused either on diffusion tensor imaging–based reconstructions or on general white matter anatomy, rather than on the specific spatial relationships between the dorsal and ventral language pathways at this

junction. Furthermore, the surgical implications of the layered organization of these tracts have not been sufficiently emphasized.

Fiber dissection techniques, particularly those derived from the Klingler method, have significantly advanced the understanding of white matter architecture (14,15). By enabling stepwise separation of fiber bundles according to their natural orientation, these methods provide a three-dimensional appreciation of the relationships among major association pathways. Beyond purely anatomical insights, such dissections can reveal natural cleavage planes between adjacent fiber systems. These planes are of particular interest in neurosurgery, as they may represent potential corridors for lesion removal while preserving critical functional tracts. The concept of fiber separation surgery is based on the principle that pathological tissue can be separated from surrounding white matter by applying dissection forces parallel to the orientation of the fiber bundles. This technique relies on the intrinsic structural differences between tumor tissue and normal white matter and aims to preserve functional tracts by exploiting natural anatomical planes. While this concept has been described in relation to various brain regions, its specific anatomical basis at the level of the TPOJ and within the dorsal–ventral language system remains insufficiently explored.

The present study aims to define the microsurgical anatomy of the dorsal and ventral language pathways at the TPOJ using fiber dissection in cadaveric specimens. Particular attention is given to the spatial relationships, depth, and orientation of the main language tracts, as well as to the natural separation planes between them. Based on these findings, we propose a conceptual surgical model illustrating how the layered organization of the language pathways at the TPOJ may support fiber separation strategies during surgery. This approach seeks to provide an anatomical foundation for tract-preserving microsurgical techniques in lesions involving this functionally critical region.

## MATERIALS and METHODS

### Study Design and Participants

This study was designed as a descriptive cadaveric anatomical investigation of the dorsal and ventral language pathways at the TPOJ. The study was performed on three formalin-fixed adult human cadaveric brains (six hemispheres) and two silicone-injected adult human hemisectioned cadaveric heads (four sides). All specimens were obtained through the institutional anatomical donation program and were used in accordance with institutional and ethical guidelines for cadaveric research.

### Specimen Preparation and Fiber Dissection Technique

Specimens were prepared according to a modified Klingler fiber dissection technique. After fixation, the brains were frozen at −15 °C for at least two weeks and then slowly thawed under running water prior to dissection. All dissections were performed under 4 to 40 magnifications using a Zeiss Surgical Microscope (Carl Zeiss AG, Germany). Stepwise fiber dissection was carried out from the lateral cortical surface toward the deeper white matter structures. The cortex and subcortical U-fibers were removed sequentially to expose the major association pathways at the TPOJ. Special attention was given to the identification and anatomical relationships of the dorsal language pathways, including the SLF II–III and AF, and the ventral pathways, including the IFOF, MdLF, and ExtC system. Dissections were performed in a layer-by-layer fashion to evaluate the depth, orientation, and natural separation planes between the dorsal and ventral language systems. The analysis focused on topographic relationships and reproducible dissection corridors. High-resolution photographic documentation was obtained at each stage of dissection using a digital camera (Canon EOS series; Canon Inc., Tokyo, Japan).

### Ethical Approval

This study was conducted on donated human cadaveric specimens in the Microneurosurgery Laboratory of the Department of Neurosurgery, Istanbul University–Cerrahpaşa, Cerrahpaşa Faculty of Medicine, under institutional regulations. As the study involved only cadaveric anatomical dissections and no living human participants or patient data, formal ethics committee approval was not required. All procedures were performed in accordance with institutional guidelines and the ethical principles of the Declaration of Helsinki.

## RESULTS

Stepwise fiber dissection of six hemispheres demonstrated a consistent layered organization of

the dorsal and ventral language pathways at the TPOJ (Table-1). The major association tracts could be reliably identified according to their depth, orientation, and relationship to the surrounding cortical landmarks. Despite minor interspecimen variability in cortical morphology, the subcortical fiber architecture showed reproducible anatomical patterns across all specimens.

### Superficial Cortical and Subcortical Layer

Initial dissection of the lateral cortical surface exposed the central sulcus, inferior frontal gyrus (pars orbitalis, pars triangularis, and pars opercularis), Sylvian fissure, superior temporal gyrus, supramarginal gyrus, and angular gyrus, forming the principal cortical landmarks of the perisylvian region (Figure-1A). Following removal of the cortical gray matter, short U-fibers interconnecting adjacent gyri were encountered as the most superficial white matter layer. These fibers formed a dense network between the superior temporal gyrus, supramarginal gyrus, and angular gyrus. Removal of these U-fibers exposed the first layer of long association tracts. The SLF complex was consistently identified as the most superficial long association system (Figure-1B). The SLF II and SLF III components formed a broad sheet-like structure extending from the inferior parietal region toward the frontal lobe. The SLF II was located deeper and more dorsal, coursing between the angular gyrus and dorsolateral frontal cortex, whereas the SLF III was positioned more ventrally, connecting the supramarginal gyrus with the inferior frontal region. Both components demonstrated a predominantly anteroposterior orientation and constituted the superficial portion of the dorsal language system. Temporal decortication exposed the superior, middle, and inferior temporal gyri as well as Heschl gyrus, providing additional anatomical landmarks for the deeper dissection stages (Figure-1B).

### Intermediate Dorsal Language Pathway

After gentle separation of the SLF components, the AF was identified as a deeper and more compact fiber bundle (Figure-1C). The AF followed a curved trajectory around the posterior end of the Sylvian fissure, connecting the posterior temporal cortex to the frontal opercular regions. In all specimens, the AF was located medial and slightly inferior to the SLF III fibers. The relationship between the SLF complex and the AF was consistent across hemispheres, with the AF forming a distinct intermediate layer beneath the superficial SLF system. The transition from the SLF to the AF was marked by a change in fiber orientation, as the AF formed a more compact and obliquely oriented bundle. This layered arrangement allowed separation of the SLF and AF along their natural fiber directions without disruption of the surrounding white matter. Following resection of the frontal, parietal, and temporal opercula, the insula was exposed. Removal of short association fibers in the insular region revealed the ExtC, and progressive AF dissection allowed differentiation of its dorsal and ventral components (Figure-1D).

### Dorsal–ventral Transition Zone

Following identification of the AF, deeper dissection revealed a reproducible cleavage plane between the dorsal and ventral language systems (Figure-1C, D). This transition zone was most evident at the interface between the AF and the IFOF. The AF demonstrated a curved, perisylvian trajectory, whereas the IFOF followed a long anteroposterior course through the deep white matter. This difference in orientation created a natural dissection corridor. Gentle separation along the axis of the AF allowed exposure of the deeper ventral tracts without transecting the dorsal system. This plane was consistently observed across specimens and represented a potential surgical cleavage zone between the dorsal phonological and ventral semantic pathways.

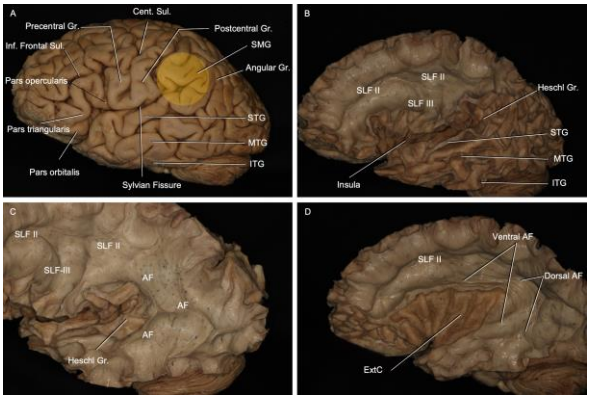


**Figure-1.** Lateral view of the left hemisphere. **A:** The central sul. separating the precentral and postcentral gyri is visible. The Sylvian fissure is prominent. At the posterior end of the fissure, the SMG, which constitutes the anterior component of the inferior parietal lobule, is observed. The superior temporal sulcus and, in its

posterior extension, the angular gr. are identified. The pars orbitalis, pars triangularis, and pars opercularis of the inferior frontal gyrus are distinguishable. **B:** In the frontoparietal region, removal of short association fibers (U-fibers) exposes the SLF II-III. The insular cortex is observed deep to the Sylvian fissure. Decortication has been performed in the temporal lobe, allowing identification of the STG, MTG, ITG, as well as Heschl gr. **C:** With additional removal of U-fibers in the temporo-occipital region, the SLF–AF complex is exposed. At the level of the posterior STG, Heschl gr. and its surrounding fiber relationships are demonstrated. **D:** Following resection of the frontal, parietal, and temporal opercula, the insula is exposed. Removal of short association fibers in the insular region renders the ExtC visible. Dissection of AF fibers allows differentiation of the dorsal and ventral components. *AF: arcuate fasciculus, Angular Gr.: angular gyrus, Cent. Sul.: central sulcus, ExtC: extreme capsule, Heschl Gr.: Heschl gyrus Inf. Frontal Sul.: inferior frontal sulcus, ITG: inferior temporal gyrus, MTG: middle temporal gyrus, Postcentral Gr.: postcentral gyrus, Precentral Gr.: precentral gyrus, SLF: superior longitudinal fasciculus, SMG: supramarginal gyrus, STG: superior temporal gyrus.*

## Deep Ventral Language Pathways

In deeper layers, the ventral association system was identified (Figure-2). In the right hemisphere, resection of the temporal operculum exposed the insular cortex and the posterior limiting sulcus. At the parieto-temporal level, transection and removal of the temporal AF segment revealed the MdLF (Figure-2A). With further dissection and preservation of the insular limiting sulci, removal of the MdLF exposed the optic radiation (OR) and the IFOF medially. In the insular region, removal of extreme capsule fibers revealed the claustrum and the external capsule. At the level of the limen insula, the UF was identified. Inferomedial to the claustrum and superior to the UF, the central IFOF fibers were consistently observed. OR fibers passing through the superior portion of the sagittal stratum were also visualized. Windows opened into the external capsule allowed visualization of the silhouette of the putamen (Figure-2B). In another specimen, in the left hemisphere, the putamen was demonstrated posteriorly through a window in the external capsule. The dorsal and ventral components of the AF and their temporal extensions were identified. The UF and the adjacent IFOF with its frontal extension were also demonstrated, highlighting the close anatomical relationship between the AF, OR, and IFOF systems (Figure-2C). After separating the AF fibers from the sagittal stratum and elevating them superiorly, the courses and spatial relationships of the UF, IFOF, and OR were clearly demonstrated (Figure-2D).

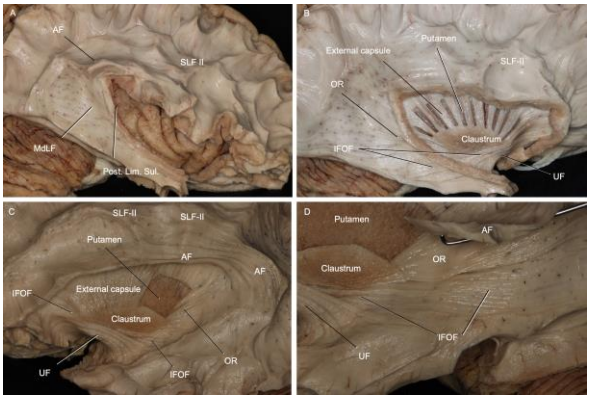


**Figure-2.** In a different specimen, the SLF–AF complex is demonstrated in the right hemisphere. **A:** Resection of the temporal operculum exposes the insular cortex, and the post. lim. sul is identified. At the parieto-temporal level, AF fibers are transected and the temporal AF segment is removed, thereby exposing the MdLF. **B:** The dissection is deepened with preservation of the limiting sulci of the insula. Following removal of the MdLF fibers, the OR and IFOF are observed medially. In the insular region, removal of ExtC fibers exposes the claustrum and the external capsule. At the level of the limen insula, the UF is demonstrated. Inferomedial to the claustrum, and superior to the UF, the central IFOF fibers are identified. OR fibers passing through the superior portion of the sagittal stratum are observed. Through windows opened into the external capsule, the silhouette of the putamen is visible. **C:** In another specimen, in the left hemisphere, the putamen is demonstrated posteriorly through a window opened into the external capsule. The dorsal and ventral components of the AF and their temporal extensions are observed. The UF and the adjacent IFOF with its frontal extension are demonstrated. The close anatomical relationship of the OR and IFOF fibers with the AF is notable. **D:** AF fibers are separated from the sagittal stratum and elevated superiorly. Following this maneuver, the courses and mutual anatomical relationships of the UF, IFOF, and OR fibers are demonstrated. *AF: arcuate fasciculus, ExtC: extreme capsule, IFOF: inferior fronto–occipital fasciculus, MdLF: middle longitudinal fasciculus, OR: optic radiation, Post. Lim. Sul.: posterior limiting sulcus, SLF: superior longitudinal fasciculus, UF = uncinate fasciculus.*

## Relationship To The Insular Region and Surgical Corridor

In specimens in which an insular approach was performed, stepwise microsurgical dissection, complemented by two silicone-injected adult cadaveric heads (four sides), demonstrated the

layered organization of the underlying association tracts along the corridor from the Sylvian fissure to the subinsular region (Figure-3). Following right-sided Sylvian fissure exposure, the superficial Sylvian vein and temporal lobe surface were identified as the initial operative landmarks (Figure-3A). Retraction of the frontal and temporal opercula exposed the insular cortex, where the M1 segment, middle cerebral artery (MCA) bifurcation, and M2 branches were visualized over the short and long insular gyri, with the central insular sulcus serving as a key cortical landmark (Figure-3B). After removal of the insular cortex, the ExtC was encountered as the first subcortical fiber layer, consisting of short association fibers running parallel to the insular surface (Figure-3C). Deeper dissection through the ExtC exposed the external capsule and claustrum, along with the ventral association tracts, including the IFOF and UF (Figure-3D). Further subinsular dissection revealed the putamen posteriorly and demonstrated the spatial relationship between the UF and the central fibers of the IFOF (Figure-3E). Throughout this sequence, the insular cortex functioned as a key surface landmark overlying the transition zone between the dorsal and ventral language systems. The SLF–AF complex was consistently located lateral and superficial to the insular region, whereas the ventral pathways, including the IFOF and ExtC system, occupied deeper and more medial planes. This stepwise exposure from the insular surface to the deep white matter reliably demonstrated the layered organization of the dorsal and ventral language pathways.

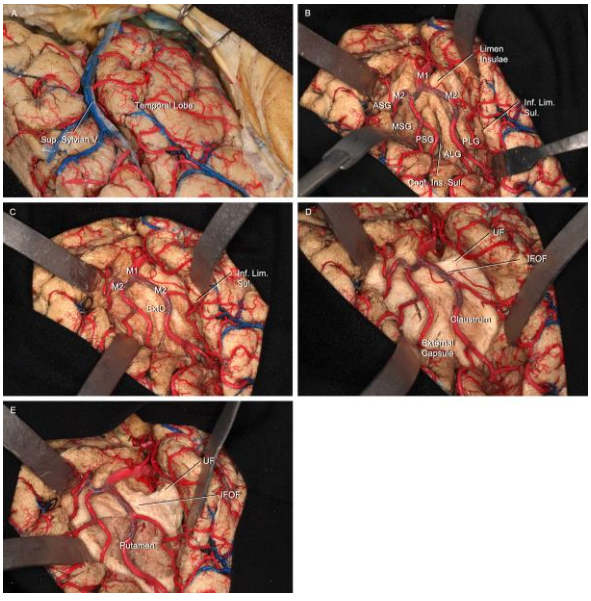


**Figure-3.** Stepwise microsurgical exposure of the insular and subinsular region through a pterional corridor. **A:** Right-sided Sylvian fissure exposure demonstrating the sup. Sylvian v. and temporal lobe surface. **B:** Cortical insular surface exposed after retraction of the frontal and temporal opercula. The M1 segment, MCA bifurcation, and M2 branches are visible over the insular cortex. The short and long insular gyri and the cent. ins.sul. are identified. **C:** After removal of the insular cortex, the ExtC is exposed, consisting of short association fibers running parallel to the insular surface. **D:** Removal of the ExtC reveals the external capsule and claustrum, along with the IFOF and UF. **E:** Further deep dissection exposes the putamen posteriorly and demonstrates the spatial relationship between the UF and IFOF within the subinsular region. *Cent. Ins. Sul.: central insular sulcus, ExtC: extreme capsule, IFOF: inferior fronto-occipital fasciculus, Inf. Lim. Sul.: inferior limiting sulcus, MCA: middle cerebral artery, Sup. Sylvian V.: superficial Sylvian vein, UF: uncinate fasciculus.*

## DISCUSSION

The TPOJ represents one of the most complex subcortical convergence zones of the human brain. This region contains a dense intersection of long association pathways responsible for phonological processing, semantic integration, and higher-order cognitive functions (1,16,17). In the present study, stepwise fiber dissection of brain hemispheres demonstrated a consistent layered organization of the dorsal and ventral language pathways at the TPOJ. The SLF complex and AF formed the superficial and intermediate components of the dorsal system, while the IFOF, MdLF, and ExtC system occupied deeper and more medial planes (Table-1) (2,10,18). Most importantly, a reproducible cleavage plane was identified between the AF and IFOF, corresponding to the transition between the dorsal and ventral language pathways (1,16,19). This anatomical configuration provides a structural basis for fiber separation strategies in lesions involving this critical functional region.

Modern models of language organization emphasize a dual-stream architecture (20–22). The dorsal pathway, primarily represented by the AF and SLF II–III, is involved in phonological processing, auditory–motor integration, and speech production (10,20,21). In contrast, the ventral pathway, including the IFOF, ExtC, and MdLF, is associated with semantic processing, lexical access, and comprehension (16,20,22). Several tractographic and anatomical studies have described these systems independently; however, fewer studies have focused on their

spatial relationships at the TPOJ. The present fiber dissection findings demonstrate that these two functional systems are not only anatomically distinct but also arranged in a consistent layered configuration, with a clear transition zone between them.

The SLF complex was consistently encountered as the most superficial long association system after removal of the U-fibers. This observation aligns with previous anatomical and tractographic studies, which describe the SLF as a broad dorsal pathway connecting the inferior parietal and frontal regions (10,23,24). Beneath this superficial layer, the AF was identified as a compact, curved bundle arching around the posterior Sylvian fissure (9,10,23). The distinct orientation and compact structure of the AF created a natural boundary between the superficial SLF system and the deeper ventral tracts. One of the most important findings of this study was the consistent identification of a cleavage plane between the AF and the IFOF. The AF demonstrated a curved, perisylvian trajectory, whereas the IFOF followed a long, anteroposterior course through the deep white matter. The difference in fiber orientation and depth created a reproducible anatomical corridor between these systems. From a surgical perspective, this interface represents a potential corridor for lesion removal while preserving both dorsal and ventral language pathways. The concept of fiber separation surgery is based on the principle that pathological tissue can be separated from adjacent white matter by applying forces parallel to the orientation of fiber bundles (2,25). This technique relies on the structural differences between tumor tissue and normal white matter and exploits natural cleavage planes between fiber systems. While this principle has been described in various brain regions, its anatomical basis at the level of the TPOJ has not been clearly defined. The present findings provide anatomical support for this concept by demonstrating a consistent separation plane between the dorsal and ventral language pathways.

The relationship between the insular cortex and the underlying language pathways also has important surgical implications. In the present dissections, the insular surface represented a key anatomical landmark overlying the transition zone between the dorsal and ventral systems. After removal of the opercular cortex, the SLF and AF were encountered as superficial and intermediate layers lateral to the insula, whereas the IFOF and ExtC were located deeper and more medially (9,26,27). This layered arrangement suggests that the insular corridor provides a natural surgical route toward the ventral language pathways while preserving the dorsal system, provided that dissection follows the natural fiber orientations. These findings have practical implications for surgeries involving intrinsic tumors or vascular lesions of the TPOJ. Traditional transcortical approaches may risk direct injury to critical language tracts if the layered organization of the white matter is not recognized. In contrast, a fiber-oriented dissection strategy that respects the natural cleavage planes between dorsal and ventral systems may allow safer lesion removal. In particular, the AF–IFOF interface may serve as a reproducible surgical corridor in selected cases.

Despite these insights, several limitations of the present study should be acknowledged. First, the study was performed on a limited number of cadaveric specimens, and individual variability in white matter anatomy cannot be completely excluded. Second, the findings are based on anatomical dissections and do not include functional or intraoperative mapping data. Therefore, the functional significance of the observed cleavage planes must be interpreted cautiously. Third, no quantitative morphometric measurements were performed, as the focus of the study was on qualitative anatomical relationships and reproducible dissection planes. Nevertheless, the present study provides a focused anatomical analysis of the dorsal and ventral language pathways at the TPOJ and highlights the presence of consistent separation planes between these systems. These findings support the concept of fiber separation surgery and emphasize the importance of understanding the layered organization of language pathways during surgical planning. Future studies combining fiber dissection, tractography, and intraoperative functional mapping may further refine these anatomical concepts and their clinical applications.

## CONCLUSION

The TPOJ contains a complex convergence of dorsal and ventral language pathways arranged in a consistent layered configuration. Fiber dissection demonstrated that the SLF and AF form the superficial and intermediate components of the dorsal system, whereas the IFOF, MdLF, and ExtC system occupy deeper and more medial planes. A reproducible cleavage corridor was

identified between the AF and the IFOF, corresponding to the transition between the dorsal and ventral language streams. This natural separation plane provides an anatomical basis for fiber-preserving surgical strategies. Understanding the layered organization of these pathways may facilitate safer microsurgical approaches to lesions involving the TPOJ and support the application of fiber separation principles in language-eloquent regions.

**Ethical approval:** This study was conducted on donated human cadaveric specimens in the Microneurosurgery Laboratory of the Department of Neurosurgery, Istanbul University–Cerrahpaşa, Cerrahpaşa Faculty of Medicine, under institutional regulations. As the study involved only cadaveric anatomical dissections and no living human participants or patient data, formal ethics committee approval was not required. All procedures were performed in accordance with institutional guidelines and the ethical principles of the Declaration of Helsinki.

**Conflict of interest:** The authors declare no competing financial interests and no sources of funding and support, including any for equipment and medications.

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**Table-1.** Anatomical and surgical characteristics of the dorsal and ventral language pathways at the TPOJ.

| Pathway | Main Tracts | Cortical Connections | Functional Role | Relative Depth | Fiber Orientation | Surgical Relevance |
|---|---|---|---|---|---|---|
| **Superficial layer** | U-fibers | Adjacent gyri at TPOJ | Local cortical integration | Most superficial | Short, curved intergyral fibers | First layer encountered after corticotomy |
| **Dorsal language pathway (superficial)** | SLF II–III | Inferior parietal lobule to frontal cortex | Phonological processing, articulation, attention | Superficial long association layer | Anteroposterior | Initial dorsal system exposed during dissection |
| **Dorsal language pathway (intermediate)** | AF | Posterior temporal cortex to inferior frontal gyrus | Auditory–motor integration, speech production | Intermediate depth | Curved, perisylvian trajectory | Key tract to preserve during dorsal pathway surgery |
| **Transition zone** | AF–IFOF interface | Between dorsal and ventral systems | Functional boundary between phonological and semantic streams | Intermediate-to-deep | Crossing fiber orientations | Natural cleavage plane for fiber separation surgery |
| **Ventral language pathway (deep)** | IFOF | Occipital and posterior temporal cortex to frontal lobe | Semantic processing, lexical access | Deep | Long anteroposterior fibers | Major ventral tract at risk in deep TPOJ lesions |
| **Ventral language pathway (deep)** | MdLF | Superior temporal gyrus to inferior parietal lobule | Language comprehension, auditory integration | Deep | Anteroposterior | Secondary ventral tract encountered after AF separation |
| **Ventral association system** | ExtC | Temporal cortex to inferior frontal region | Semantic and ventral language connectivity | Deep and medial | Short-to-medium association fibers | Anatomical landmark in insular surgical corridor |

## References


1. De Benedictis A, Duffau H, Paradiso B, Grandi E, Balbi S, Granieri E, et al. Anatomo-functional study of the temporo-parieto-occipital region: Dissection, tractographic and brain mapping evidence from a neurosurgical perspective. J Anat 2014;225(2):132-51.
2. Biceroglu H, Karadag A. Neuroanatomical aspects of the temporo-parieto-occipital junction and new surgical strategy to preserve the associated tracts in junctional lesion surgery: Fiber separation technique. Turk Neurosurg 2019;29(6):864-74.
3. Shekari E, Nozari N. A narrative review of the anatomy and function of the white matter tracts in language production and comprehension. Front Hum Neurosci 2023;17:1139292.
4. Martino J, da Silva-Freitas R, Caballero H, Marco de Lucas E, García-Porrero JA, Vázquez-Barquero A. Fiber dissection and diffusion tensor imaging tractography study of the temporoparietal fiber intersection area. Neurosurgery 2013;72(Suppl Operative):87-97.
5. Chang EF, Raygor KP, Berger MS. Contemporary model of language organization: an overview for neurosurgeons. J Neurosurg 2015;122(2):250-61.
6. Dick AS, Bernal B, Tremblay P. The language connectome. Neuroscientist 2014;20(5):453-67.
7. Saur D, Kreher BW, Schnell S, Kümmerer D, Kellmeyer P, Vry MS, et al. Ventral and dorsal pathways for language. Proc Natl Acad Sci U S A 2008;105(46):18035-40.
8. Rauschecker JP. Ventral and dorsal streams in the evolution of speech and language. Front Evol Neurosci 2012;4:7.
9. Yagmurlu K, Vlasak AL, Rhoton AL. Three-dimensional topographic fiber tract anatomy of the cerebrum. Neurosurgery 2015;11(Suppl 2):274-305.
10. Yagmurlu K, Middlebrooks EH, Tanriover N, Rhoton AL. Fiber tracts of the dorsal language stream in the human brain. J Neurosurg 2016;124(5):1396-405.
11. Perron M, Theaud G, Descoteaux M, Tremblay P. The frontotemporal organization of the arcuate fasciculus and its relationship with speech perception in young and older amateur singers and non-singers. Hum Brain Mapp 2021;42(10):3058-76.
12. Oğlin V, Orhun Ö, Quiñones-Hinojosa A, Middlebrooks EH, Çevik OM, Usseli Mİ, et al. Topographic anatomy of the lateral surface of the parietal lobe and its relationship with white matter tracts. Front Neuroanat 2024;18:1458989.
13. Giampiccolo D, Herbet G, Duffau H. The inferior fronto-occipital fasciculus: bridging phylogeny, ontogeny and functional anatomy. Brain 2025;148(5):1507-25.
14. Dziedzic TA, Balasa A, Jeżewski MP, Michałowski Ł, Marchel A. White matter dissection with the Klingler technique: a literature review. Brain Struct Funct 2021;226(1):13-47.
15. Da Costa MDS, Braga VL, Yagmurlu K, Centeno RS, Cavalheiro S, Chaddad-Neto F. A technical guide for fiber tract dissection of the internal capsule. Turk Neurosurg 2018;28(6):934-9.
16. Martino J, Brogna C, Robles SG, Vergani F, Duffau H. Anatomic dissection of the inferior fronto-occipital fasciculus revisited in the lights of brain stimulation data. Cortex 2010;46(5):691-9.
17. Burks JD, Boettcher LB, Conner AK, Glenn CA, Bonney PA, Baker CM, et al. White matter connections of the inferior parietal lobule: a study of surgical anatomy. Brain Behav 2017;7(4):e00640.
18. Sarubbo S, De Benedictis A, Maldonado IL, Basso G, Duffau H. Frontal terminations for the inferior fronto-occipital fascicle: anatomical dissection, DTI study and functional considerations on a multi-component bundle. Brain Struct Funct 2013;218(1):21-37.
19. Axer H, Klingner CM, Prescher A. Fiber anatomy of dorsal and ventral language streams. Brain Lang 2013;127(2):192-204.
20. Hickok G, Poeppel D. The cortical organization of speech processing. Nat Rev Neurosci 2007;8(5):393-402.
21. Hickok G. The functional neuroanatomy of language. Phys Life Rev 2009;6(3):121-43.
22. Duffau H, Moritz-Gasser S, Mandonnet E. A re-examination of neural basis of language processing: proposal of a dynamic hodotopical model from data provided by brain stimulation mapping during picture naming. Brain Lang 2014;131:1-10.
23. Martino J, De Lucas EM. Subcortical anatomy of the lateral association fascicles of the brain: a review. Clin Anat 2014;27(4):563-9.

24. Makris N, Pandya DN. The extreme capsule in humans and rethinking of the language circuitry. Brain Struct Funct 2009;213(3):343-58.
25. Duffau H. The anatomo-functional connectivity of language revisited. Neuropsychologia 2008;46(4):927-34.
26. Tanriover N, Rhoton AL, Kawashima M, Ulm AJ, Yasuda A. Microsurgical anatomy of the insula and the sylvian fissure. J Neurosurg 2004;100(5):891-922.
27. Türe U, Yaşargil DCH, Al-Mefty O, Yaşargil MG. Topographic anatomy of the insular region. J Neurosurg 1999;90(4):720-33.