A Laboratory Manual for Stepwise Cerebral White Matter Fiber Dissection

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OBJECTIVE: **White matter fiber dissection is an important method in acquiring a thorough neuroanatomic knowledge for surgical practice. Previous studies have definitely improved our understanding of intrinsic brain anatomy and emphasized on the significance of this technique in modern neurosurgery. However, current literature lacks a complete and concentrated laboratory guide about the entire dissection procedure. Hence, our primary objective is to introduce a detailed laboratory manual for cerebral white matter dissection by highlighting consecutive dissection steps, and to stress important technical comments facilitating this complex procedure.**

METHODS: **Twenty adult, formalin-fixed cerebral hemispheres were included in the study. Ten specimens were dissected in the lateromedial and 10 in the mediolateral direction, respectively, using the fiber dissection technique and the microscope.**

RESULTS: **Eleven and 8 consecutive and distinctive dissection steps are recommended for the lateromedial and mediolateral dissection procedures, respectively. Photographs highlighting various anatomic landmarks accompany every step. Technical recommendations, facilitating the dissection process, are also indicated.**

CONCLUSIONS: **The fiber dissection technique, although complex and time consuming, offers a three-dimensional knowledge of intrinsic brain anatomy and architecture, thus improving both the quality of microneurosurgery and the patient's standard of care. The present anatomic study provides a thorough dissection manual to those who study brain anatomy using this technique.**

INTRODUCTION

The revival of the fiber dissection technique and its incorporation into neurosurgical education have emphasized that the detailed, three-dimensional anatomic knowledge is what ultimately navigates the surgeon in the operating theater. In addition, the firm grasp of anatomy is acquired with this method. Current functional and neuroimaging studies have contributed to the evolution of new surgical perspectives (36, 41).

Just as skull base surgery has been dramatically improved by cranial cadaveric dissections (30, 38), brain surgery has been refined from the invaluable information revealed by the white matter fiber dissection technique (17, 20, 33, 40, 41). Therefore, novice neurosurgeons must be spurred on to perform hands-on dissections in microneurosurgery laboratories to appreciate the intrinsic brain architecture and acquire an appropriate three-dimensional parenchymal knowledge for surgical practice. In addition, the necessity of a precise understanding of white matter anatomy is more needed than ever, not only due to the introduction of diffusion tensor imaging (DTI)-based tractography but also because of the propagation of several refined surgical techniques, especially regarding the field of low-grade glioma surgery (1, 2, 5, 11-13, 18, 20, 22, 28).

Hence, the aim of this study is to provide a comprehensive, stepwise laboratory guide for cerebral white matter dissection to neurosurgeons who are motivated to study brain anatomy using this method. Avoiding common and frustrating mistakes during this complex procedure saves time and brain specimens. To our knowledge, this is the first concentrated and thorough dissection manual on this topic.

METHODS

Twenty healthy, adult cerebral hemispheres were fixed in a 10%–15% formalin solution for a minimum period of 6 weeks. Subsequently, the specimens were washed under running water and the arachnoid membrane and vessels were carefully removed. The

Key words
- Dissection manual
- Fiber dissection technique
- White matter anatomy
- White matter dissection

Abbreviations and Acronyms
DTI: Diffusion tensor imaging

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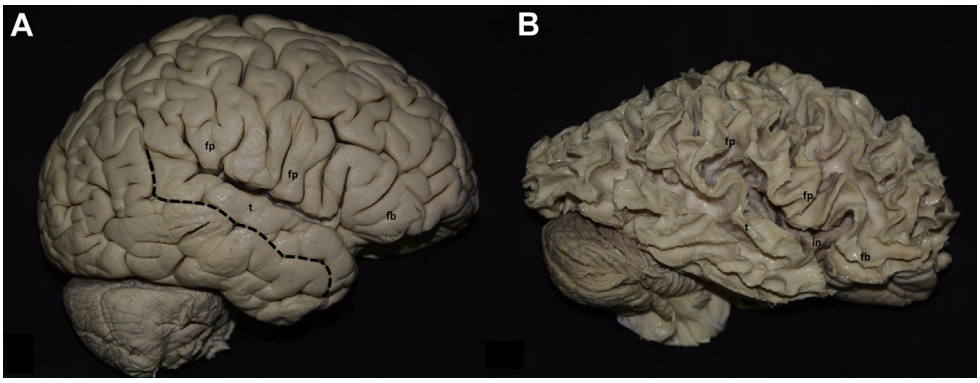

Figure 1. (**A**) Photo of a right cerebral hemisphere after removing the arachnoid membrane and vessels. The *black dotted line* marks the superior temporal sulcus through which the lateromedial dissection begins. Frontoorbital, frontoparietal, and temporal operculum are indicated. (**B**) "U" fibers are disclosed. Removing the gray matter of the operculum requires special attention so that insular surface anatomy is preserved. fb, frontoorbital operculum; fp, frontoparietal operculum; in, insula; t, temporal operculum.

specimen were then refrigerated at temperatures between −10° and −15°C for at least 15 days and were allowed to thaw under water for several hours (freeze-thaw procedure) (15, 16).

All the specimens were investigated using the fiber dissection technique (15, 16) and the microscope (OPMI Plus; Carl Zeiss, Jena, Germany) in a stepwise fashion. Initially, 10 hemispheres were dissected, starting from the lateral cerebral surface and proceeding medially, until the ventricular ependyma was encountered. The remaining 10 hemispheres were dissected in the opposite direction, starting from the medial cerebral surface and advancing laterally, until the head and body of the caudate nucleus were revealed.

Our primary dissection tools were fine metallic periosteal dissectors, various sized anatomic forceps, and microsurgical scissors, as we found them easier and more precise in handling than the traditional wooden spatulas.

Before starting the dissection of each specimen, the anatomy of the lateral, medial, and basal cerebral surface was carefully studied (31, 32). Numerous digital photographs were taken, with and without flash, and were reviewed in relation to previous reports and anatomic atlases of cerebral white matter (17, 23, 37, 42). Interestingly, we noticed that, in some occasions, the photos without flash delineated the fiber tract anatomy more precisely. It must be emphasized that all the photos included in the study were not edited by any image processing software, thus resembling closely the actual fiber tract anatomy and configuration encountered during the dissections.

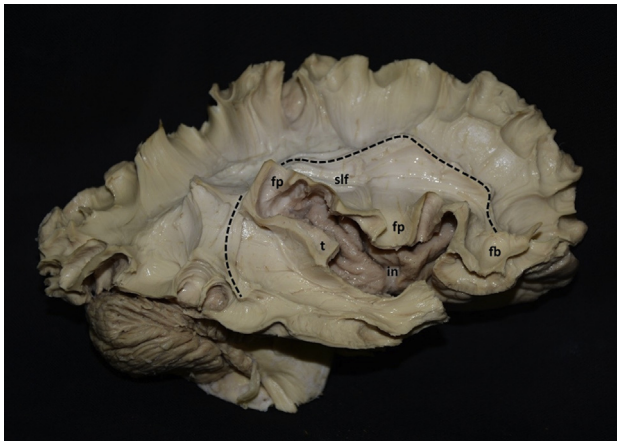

Figure 2. The superior longitudinal fasciculus is exposed by removing the "U" fibers. The white matter of the operculum is left intact. The *black dotted line* represents the configuration of the superior longitudinal fasciculus. fb, frontoorbital operculum; fp, frontoparietal operculum; in, insula; slf, superior longitudinal fasciculus; t, temporal operculum.

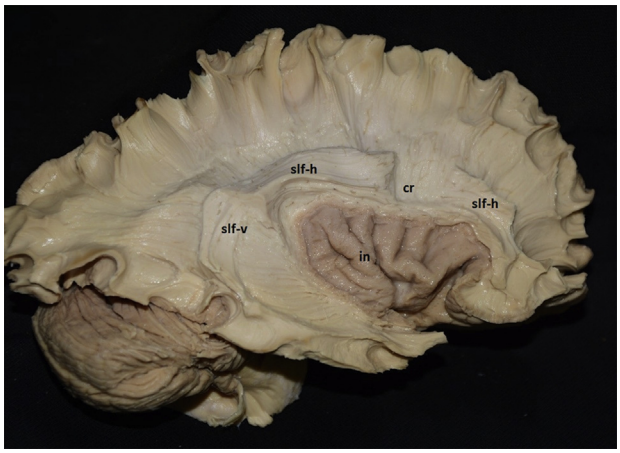

Figure 3. The insular surface anatomy and superior longitudinal fasciculus are demonstrated. A small cut is made to the frontal part of the superior longitudinal fasciculus to expose the underlying fibers of corona radiata. cr, corona radiata; in, insula; slf-h, horizontal segment of superior longitudinal fasciculus; slf-v, vertical segment of superior longitudinal fasciculus.

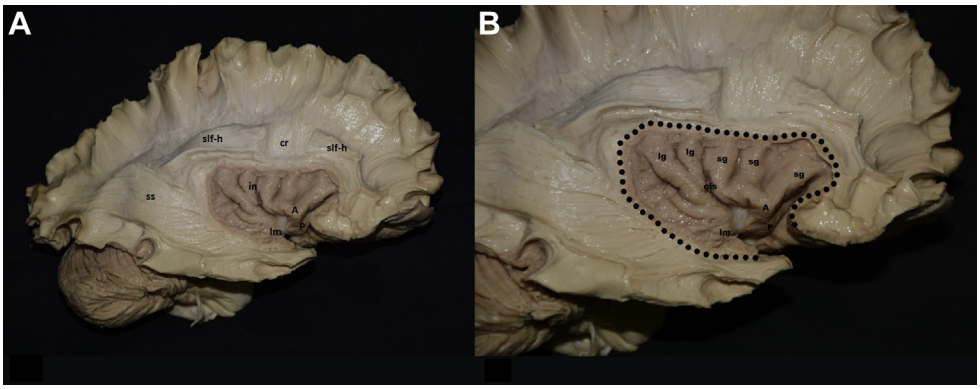

Figure 4. (**A**) The vertical part of the superior longitudinal fasciculus has been removed and the entire sagittal stratum is revealed. (**B**) The insular surface anatomy in more detail. The periinsular sulcus, marked with the *black dots*, demarcates the boundary between the insula and the overlying operculum. A, insular apex; cis, central insular sulcus; cr, corona radiata; in, insula; lg, long gyrus; lm, limen insula; P, insular pole; sg, short gyrus; slf-h, horizontal segment of superior longitudinal fasciculus; ss, sagittal stratum.

RESULTS

Eleven and 8 consecutive, distinctive steps are highlighted for the lateromedial and mediolateral dissection of the cerebral white matter, respectively. Furthermore, important technical aspects that facilitate the entire process are delineated.

Lateral-to-Medial Dissection

Eleven steps are recommended for the lateral-to-medial dissection process. Figures 1–11 show the stepwise lateromedial dissection of a right cerebral hemisphere. Specifically:

Step 1. Remove the cerebral surface gray matter, starting from the depth of the superior temporal sulcus and gradually extend the dissection to the entire lateral surface (37). Peel away the gray matter of the operculum cautiously to preserve the insular surface anatomy. "U" fibers (i.e., the connective fibers between the adjacent cerebral gyri) are disclosed at the end of this step (Figure 1).

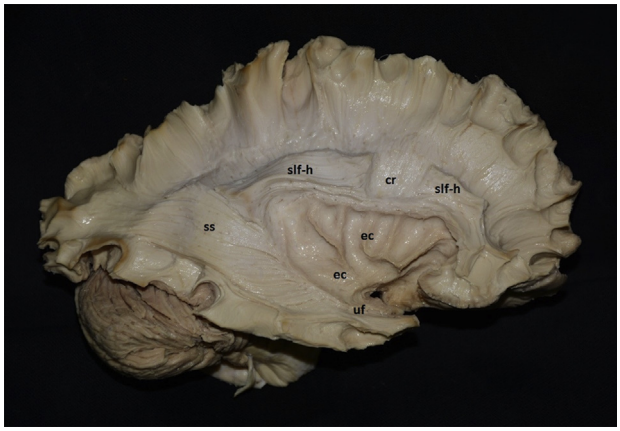

Figure 5. The gray matter of the insula has been removed and the fibers of the extreme capsule are depicted. Notice the superficial layer of the uncinate fasciculus at the level of the limen insula. cr, corona radiata; ec, extreme capsule; slf-h, horizontal segment superior longitudinal fasciculus; ss, sagittal stratum; uf, uncinate fasciculus.

Step 2. Progressively dissect the "U" fibers, beginning from the level of the middle frontal gyrus, to reveal the superior longitudinal fasciculus. It is recommended to preserve the white matter of the operculum as the fibers of the superior longitudinal fasciculus can easily be disrupted (Figure 2).

Step 3. Cut the white matter of the operculum with fine scissors, starting from the temporal part, to expose the insula. Gradual dissection discloses the superior longitudinal fasciculus more accurately (Figure 3).

Step 4. Appreciate the insular surface anatomy (i.e., short and long gyri, insular pole, insular apex, limen insula) (34, 36). Removing the vertical part of the superior longitudinal fasciculus exposes a group of horizontal fibers (i.e., the sagittal stratum) situated in the posterior temporal and occipital areas. This compact bundle comprises the fibers of the occipitofrontal fasciculus, anterior commissure, inferior longitudinal fasciculus, and retrolenticular part of the internal capsule (Figure 4) (12, 37).

Step 5. Peel away the gray matter of the insula until its connective fibers, which constitute the superficial layer of the extreme capsule, are evident. Removing the gray matter of the limen insula, in particular, exposes the superficial layer of the uncinate fasciculus, which is essentially a part of the extreme capsule at this level (Figure 5) (10, 12).

Step 6. Dissecting the extreme capsule reveals the ventral part of the external capsule. At the level of the insular apex the claustrum becomes apparent, whereas at the level of the limen insula the occipitofrontal and uncinate fasciculi are depicted. Actually, these

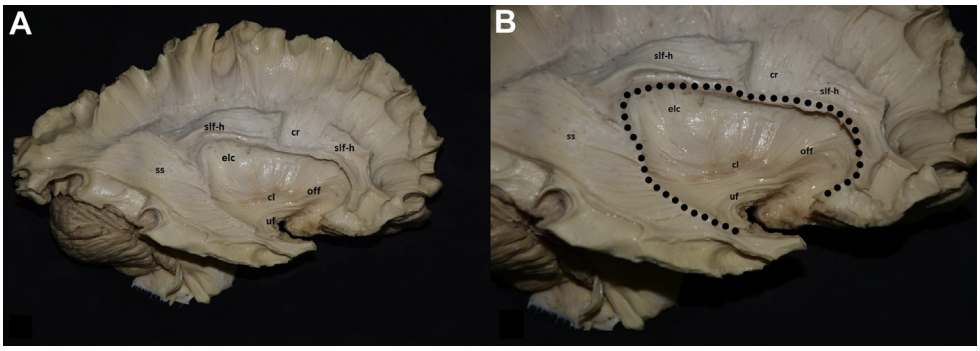

Figure 6. (**A**) The fibers of the extreme capsule have been cautiously removed. The underlying external capsule along with the claustrum, uncinate and occipitofrontal fasciculi are demonstrated. (**B**) A close-up photo delineating in more detail the anatomy and the fiber direction of the white matter pathways. Notice the intermingling of the occipitofrontal fasciculus with the sagittal stratum at the level of the inferior part of the periinsular sulcus. The *dotted line* depicts the level of the periinsular sulcus. cl, claustrum; cr, corona radiata; elc, external capsule; off, occipitofrontal fasciculus; slf-h, horizontal segment of superior longitudinal fasciculus; ss, sagittal stratum; uf, uncinate fasciculus.

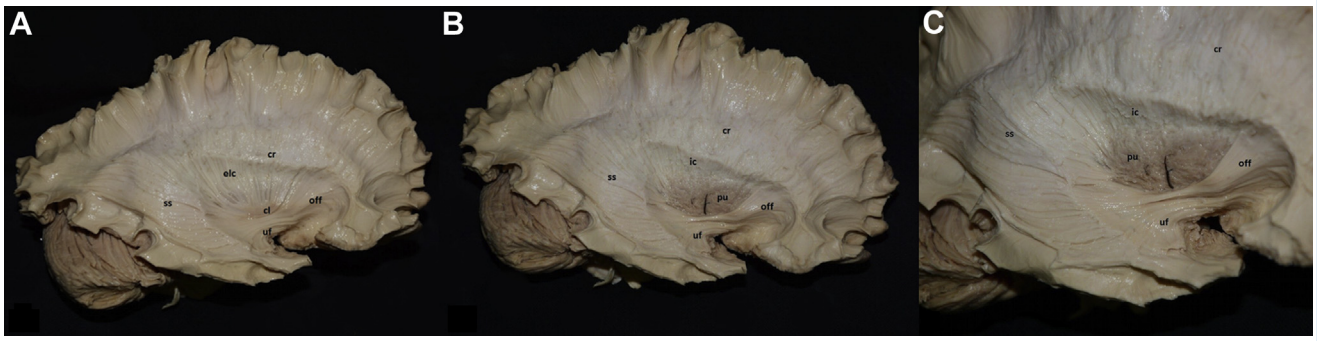

Figure 7. (**A**) The remaining part of the superior longitudinal fasciculus has been removed. Notice the intermingling of the external capsule with the sagittal stratum and corona radiata at this level. (**B**) Removing the external capsule along with the claustrum discloses the lateral part of the internal capsule at the periphery and the putamen centrally. The uncinate and occipitofrontal fasciculi are left intact. (**C**) This anterolateral close-up photo delineates the continuity of corona radiata, sagittal stratum, and internal capsule. Observe the intermingling of the fibers of the occipitofrontal fasciculus with the sagittal stratum. cl, claustrum; cr, corona radiata; elc, external capsule fibers; ic, internal capsule; off, occipitofrontal fasciculus; pu, putamen with a lenticulostriate artery in the middle; ss, sagittal stratum; uf, uncinate fasciculus.

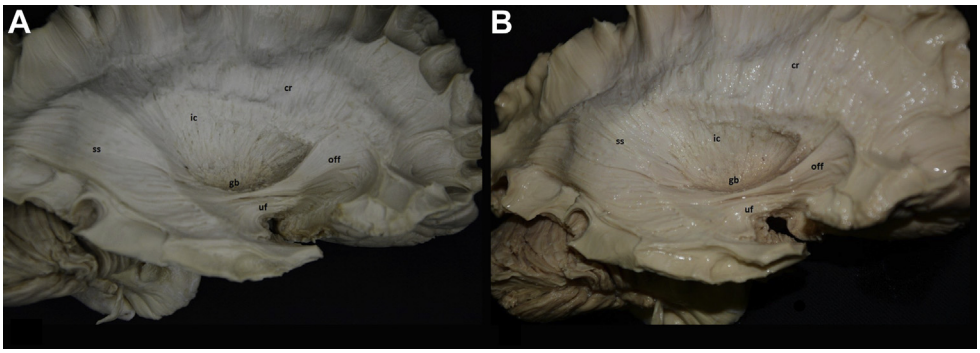

Figure 8. (**A**) A photo without flash to demonstrate the gray matter of the globus pallidus more accurately. (**B**) Anterolateral close-up photo demonstrating the continuity of the internal capsule, corona radiata, and sagittal stratum at this level. cr, corona radiata; gb, globus pallidus; ic, internal capsule; off, occipitofrontal fasciculus; ss, sagittal stratum; uf, uncinate fasciculus.

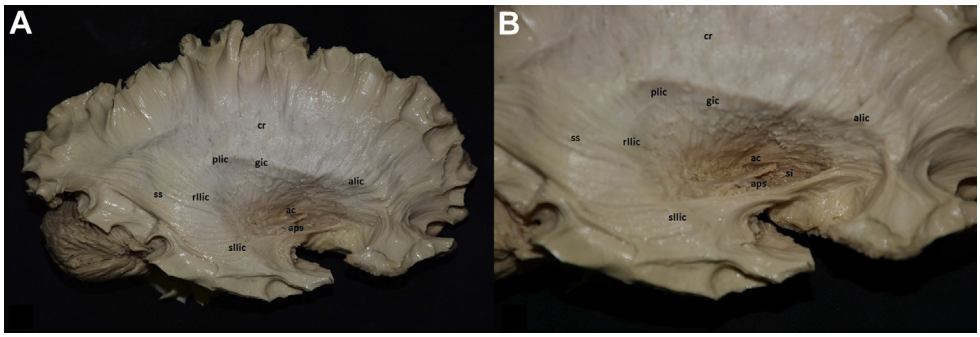

Figure 9. (**A**) The anterior commissure and anterior perforated substance are depicted. Observe the intermingling of the fibers of the retrolenticular and sublenticular parts of the internal capsule with the sagittal stratum. (**B**) A close-up photo demonstrating the anterior commissure, anterior perforated substance, and substantia innominata. All the parts, limbs of the internal capsule are clearly evident. ac, anterior commissure; alic, anterior limb of internal capsule; aps, anterior perforated substance; cr, corona radiata; gic, genu of internal capsule; plic, posterior limb of internal capsule; rllic, retrolenticular limb of internal capsule; sllic, sublenticular limb of internal capsule; si, substantia innominata; ss, sagittal stratum.

white matter pathways are parts of the external capsule at the level of the limen insula (Figure 6) (12, 37).

Step 7. Remove the remaining part of the superior longitudinal fasciculus along with the fibers of the external capsule. Gradual dissection of the external capsule aids in the removal of the claustrum (13). The lateral part of the putamen and internal capsule are disclosed centrally and at the periphery, respectively. It must be stressed that the large white matter pathways of corona radiata and sagittal stratum are essentially in continuity without a point of demarcation distinguishing them. Also, the external and internal capsules merge with these white mater pathways to form a single entity (Figure 7) (12, 13).

Step 8. Dissect the putamen, which has a spongy consistency, and identify the firm density of the globus pallidus. A very thin band of white matter between these two central core nuclei—the external medullary lamina—is usually not properly demonstrated. Occipitofrontal and uncinate fasciculi are left in place (Figure 8).

Step 9. Dissect the fibers of the occipitofrontal fasciculus and carefully expose, at the anterior and basal surface of the globus pallidus, the anterior commissure. Inferior to the anterior commissure, the anterior perforated substance and the substantia innominata are identified. Extensive dissection of the globus pallidus reveals all parts of the internal capsule. It must be noted that the sublenticular part of the internal capsule contains the

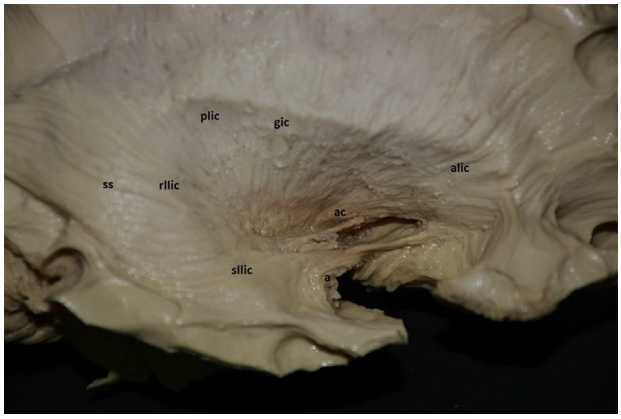

Figure 10. Substantia innominata and uncinate fasciculus are carefully removed. The anterior commissure and amygdala are clearly depicted. a, amygdala; ac, anterior commissure; alic, anterior limb of internal capsule; gic, genu of internal capsule; plic, posterior limb of internal capsule; rllic, retrolenticular limb of internal capsule; sllic, sublenticular limb of internal capsule; ss, sagittal stratum.

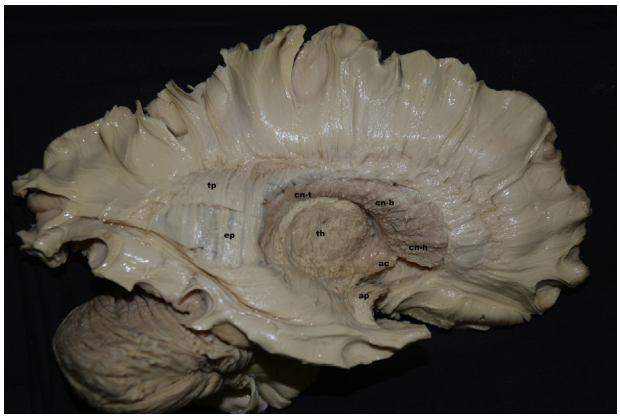

Figure 11. A photo showing the thalamus, caudate nucleus, ansa peduncularis, tapetal fibers, and ventricular ependyma at the end of the lateral to medial dissection. ac, anterior commissure; ap, ansa peduncularis; cn-b, body of caudate nucleus; cn-h, head of caudate nucleus; cn-t, tail of caudate nucleus; ep, ventricular ependyma; th, thalamus; tp, tapetum.

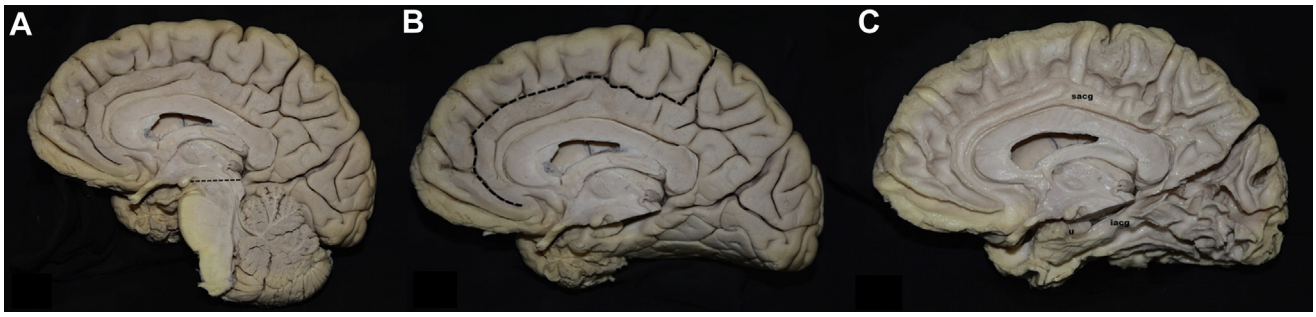

Figure 12. (**A**) Medial surface of a right cerebral hemisphere after removal of the arachnoid membrane and vessels. The axial cut, running from the level of the superior colliculus to the ipsilateral mammillary body, to remove the brainstem and cerebellum, is shown with the *black dotted line*. (**B**) Appreciate the medial surface anatomy. The *dotted line* indicates the cingulate sulcus through which the dissection is recommended to start. (**C**) A photo demonstrating the "U" fibers and the superior and inferior arms of the cingulum. Uncus remains intact. iacg, inferior arm of cingulum; sacg, superior arm of cingulum; u, uncus.

anterior optic bundle fibers (i.e., Meyers loop), whereas the retrolenticular part comprises the middle and posterior optic bundles (**Figure 9**) (9, 12, 25, 26, 29, 33).

Step 10. Gradual resection of the fibers of the uncinate and the occipitofrontal fasciculi expose the amygdala, which forms the anterior part and roof of the temporal horn. Removal of the gray matter of the substantia innominata demonstrates the anterior commissure more accurately (**Figure 10**).

Step 11. Meticulously dissect the internal capsule so that the caudate nucleus—head and body—as well as the thalamus become visible. The so-called ansa peduncularis, connecting the amygdaloid nuclei to the hypothalamus, thalamus, and septal region, is also apparent (12, 20). Dissection of the sagittal stratum reveals the fibers of the tapetum. Removing the tapetum reveals the ependyma of the lateral ventricle (**Figure 11**).

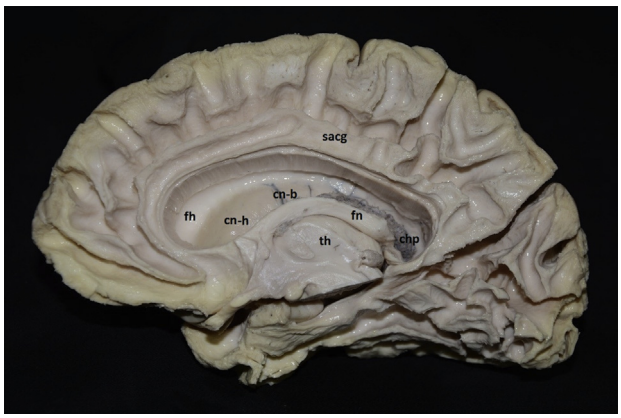

Figure 13. The corpus callosum has been resected so that the intraventricular and paraventricular structures can be studied. chp, choroid plexus; cn, caudate nucleus; fh, frontal horn; fn, fornix; sacg, superior arm of cingulum; th, thalamus.

Medial-to-Lateral Dissection

Eight consecutive steps are recommended for the medial-to-lateral dissection process. **Figures 12–19** demonstrate the stepwise mediolateral dissection of a right cerebral hemisphere. Specifically:

Step 1. Before beginning the dissection, it is mandatory to remove the cerebellum and brainstem with an axial cut running from the level of the superior colliculus to the mammillary body, as shown in **Figure 12A**. Then, peel away the gray matter of the medial cerebral surface starting from the depth of the anterior part of the cingulate sulcus and gradually extend posteriorly to the precuneus (42). Dissect the cuneus along with the lingual and parahippocampal gyri; preserve the uncus. Attention must be paid to the dissection of the cingulum, as it is easily disrupted, especially in its inferior arm i.e. the parahippocampal gyrus. At the end of this procedure, the so-called "U" fibers (i.e., the connective fibers between adjacent cerebral gyri and their connections to the superior and inferior arms of the cingulum) become apparent (**Figure 12**).

Step 2. Resect the corpus callosum leaving a thin strip of it attached to the cingulum. This is accomplished with a curvilinear cut, running from the rostrum to the splenium, using a No. 15 blade scalpel. Pay attention to preserving the anatomy of the intra ventricular and paraventricular structures. This maneuver exposes the ventricular ependyma, head and body of caudate nucleus, choroid plexus (attached to the choroid fissure), and ipsilateral fornix (**Figure 13**).

Step 3. Dissect the "U" fibers and the white matter of the superior arm of the cingulum to reveal the radiating fibers of the corpus callosum, consisting of the minor and major forceps anteriorly and posteriorly, respectively. The occipital horn of the ventricle is entered and inspected. Bear in mind that the floor of the occipital horn is composed of optic radiation fibers (25, 26, 33). The inferior arm of the cingulum is left intact (**Figure 14A**).

Step 4. Dissect the medial thalamic and hypothalamic surface, starting from the level of the mammillary body to expose the

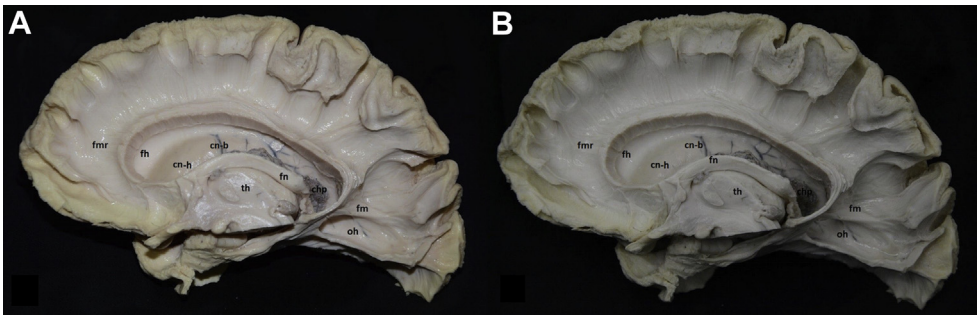

Figure 14. (**A**) "U" fibers and the superior arm of cingulum have been dissected away revealing the forceps minor and major. The occipital horn of the lateral ventricle has also been entered. Notice that the roof of the occipital horn is formed by the forceps major. (**B**) The same photo but without flash demonstrates more accurately the direction of delicate fiber tracts such as these of forceps minor. chp, choroid plexus; cn-b, body of caudate nucleus; cn-h, head of caudate nucleus; fh, frontal horn; fm, forceps major; fmr, forceps minor; fn, fornix; oh, occipital horn; th, thalamus.

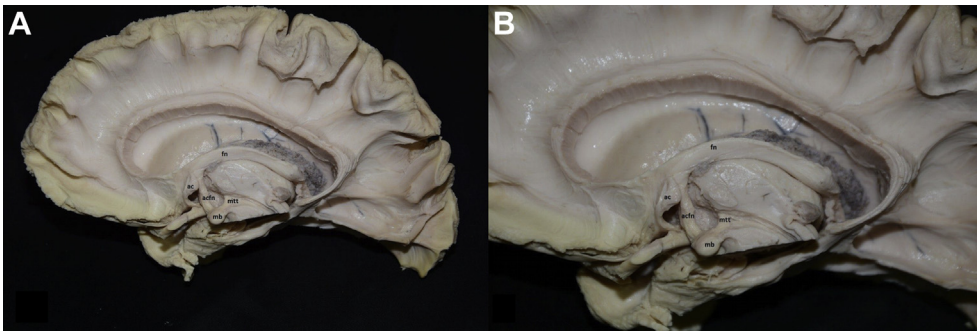

Figure 15. (**A**) The mammillothalamic tract and the anterior column of the fornix are disclosed. Appreciate the complex relationship between the anterior column of the fornix, the anterior commissure, and the mammillary body. (**B**) A close-up photo of this dissection step demonstrates how the anterior column of the fornix courses prominently behind the anterior commissure. To reveal adequately this part of the fornix, the hypothalamus must be carefully dissected. ac, anterior commissure; acfn, anterior column of fornix; fn, fornix; mb, mammillary body; mtt, mammillothalamic tract.

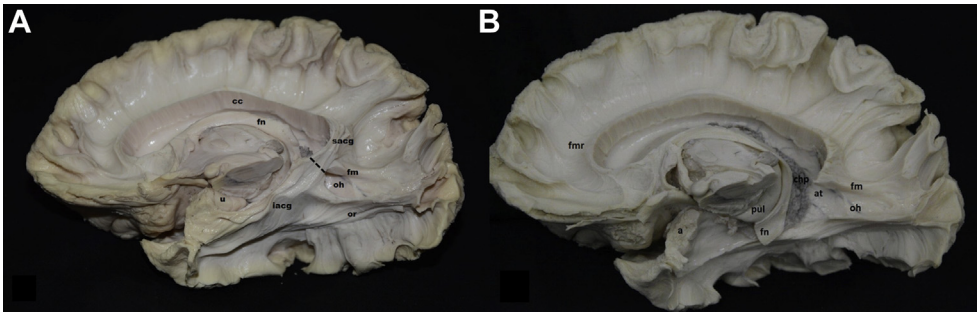

Figure 16. (**A**) Inferolateral view of the same cerebral hemisphere showing with the *black dotted line* the cut below the level of forcep major to remove the inferior arm of the cingulum. Notice that the floor of the occipital horn consists of fibers of the optic radiation. (**B**) Inferolateral view showing the amygdala, fornix, choroid plexus, forceps major, ventricular compartments, thalamic surfaces, and pulvinar. The ependyma of the ventricle is not dissected. Oblique views are necessary for the comprehensive understanding of the complex regional anatomy. This photo is without flash to better depict the gray matter of the amygdala. a, amygdale; at, atrium; cc, corpus callosum; chp, choroid plexus; fm, forceps major; fmr, forceps minor; fn, fornix; iacg, inferior arm of cingulum; oh, occipital horn; or, optic radiation; pul, pulvinar; sacg, superior arm of cingulum; u, uncus.

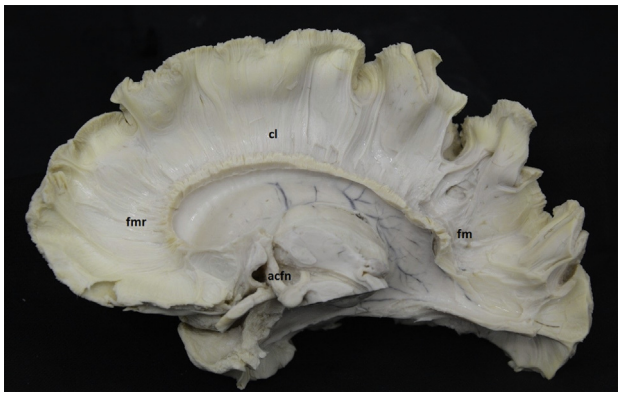

Figure 17. The fornix and choroid plexus have been removed. The fibers of the corpus callosum radiating to the entire hemisphere are demonstrated. Photos without flash delineate more accurately the direction and extension of the callosal radiations. Ventricular ependyma remains intact. clr, callosal radiations; fm, forceps major; fmr, forceps minor.

mammillothalamic tract (3) and the anterior column of the fornix (i.e., the connection of the hippocampal formation with the mammillary body—part of the Papez circuit) (24). Appreciate the "rigid" consistency of the thalamic substance, in contrast to that of the hypothalamus (Figure 15).

Step 5. Transect the inferior arm of the cingulum just below the level of the forceps major and remove it along with the hippocampal formation, fasciolar, and dentate gyri, yet preserving the fornix (8). It is important to dissect free the hippocampal formation from the collateral eminence to complete this step (42). The temporal horn is now completely exposed and the uncal cortex can now be peeled away until the amygdala is encountered. The complex anatomic relationship between the fornix, the choroid plexus, and the thalamus can be studied and recorded (Figure 16).

Step 6. Remove the fornix, sparing its anterior column, along with the choroid plexus. Gradually dissect the fibers of the corpus callosum, which constitute the callosal radiations, and appreciate the direction and extent of this complex fiber system (Figure 17) (27).

Step 7. Resect the remaining part of the corpus callosum, using a No. 15 blade scalpel, until the level of the splenium and carefully peel the ventricular ependyma from the frontal horn and the body of the lateral ventricle. The atrial, occipital, and temporal ependyma is preserved. As a result, the gray matter of the head and the body of the caudate nucleus is exposed. The forceps major and the remaining part of the splenium are preserved to demonstrate more precisely the direction and orientation of the fibers of the tapetum in the next step (Figure 18).

Step 8. Further dissecting the ependyma of the atrium, occipital, and temporal horn reveals the fibers of the tapetum, the tail of the caudate nucleus, and the stria terminalis. Notice the stria terminalis coursing medially to the tail of the caudate nucleus and the fibers of the tapetum arching over the lateral walls of the atrium and temporal horn. The tapetum is mainly formed by the splenial callosal radiations (Figure 19) (3, 42).

Technical Recommendations

(1) We recommend the use of double fine metallic periosteal dissectors, various sized anatomic forceps, and microsurgical scissors instead of the traditional wooden spatulas, since the precision of the dissection process was improved (Figure 20).

(2) Using the microscope is a cornerstone in improving the quality of the dissections. Furthermore, we recommend the microscope lamp brightness to be adjusted to a medium level as this helps in identifying and preserving elegant fiber tracts.

(3) Photographs were taken with and without a flash. In some instances the anatomy is more accurately demonstrated without the flash. This is particularly true for the globus

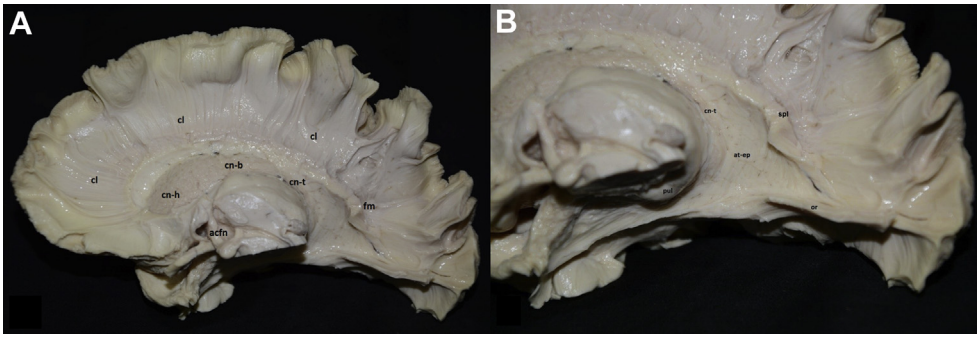

Figure 18. (**A**) The ependyma of the frontal horn and body of the lateral ventricle is carefully dissected, revealing the head and body of the caudate nucleus. The callosal radiations and forceps major are also apparent. (**B**) A photo zooming in the atrial ependyma, which remains intact. Notice the tail of the caudate nucleus and the pulvinar. It must be emphasized that the floor of the occipital horn consists of optic radiation fibers. at-ep, atrial ependyma; clr, callosal radiations; cn-b, body of caudate nucleus; cn-h, head of caudate nucleus; cn-t, tail of caudate nucleus; fm, forceps major; or, optic radiation; pul, pulvinar; spl, splenium.

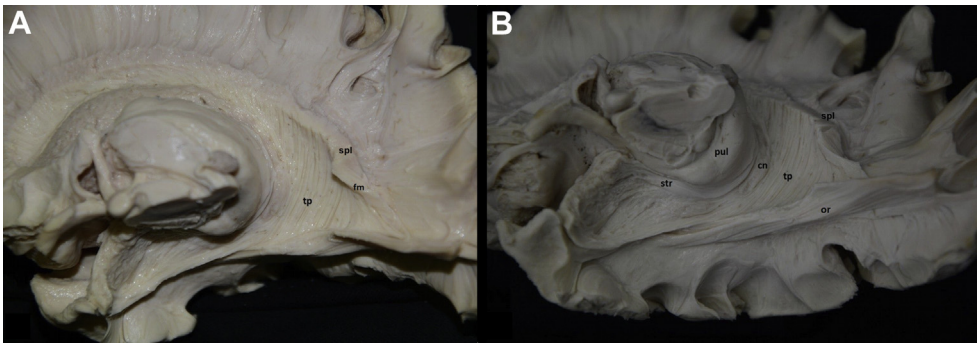

Figure 19. (**A**) A close-up photo focusing on the fibers of the tapetum. Notice the tapetum originating from the splenium of the corpus callosum and arching over the lateral wall of the atrium. (**B**) Inferior view of the same specimen. Observe the anatomic relationship between the stria terminalis and the tail of the caudate nucleus. Also notice the direction and extension of the fibers of the tapetum to the lateral wall of the atrium and temporal horn. cn, caudate nucleus; fm, forceps major; or, optic radiation; pul, pulvinar; spl, splenium; str, stria terminalis; tp, tapetum.

pallidus, the cingulum, the forceps minor, the callosal radiations, and the tapetum (Figures 8A, 14B, 16B, 17, 19B).

(4) Take photographs using different views of the specimen. As a result the complex regional anatomy and the direction of several fiber tracts can be more accurately delineated.

(5) Immerse the specimen in water regularly to retain its elasticity. This contributes to a smoother dissection.

(6) Before proceeding to the next dissection step, review the relevant anatomy using neuroanatomic atlases. Having a roadmap will save time and brain specimens.

DISCUSSION

This study provides a simplified, but concentrated, laboratory guide to cerebral white matter dissection. It consists of distinctive, consecutive steps and technical comments regarding the handling of special fiber tracts and anatomic structures. Eleven and 8 steps are proposed for the lateromedial and mediolateral fiber dissection procedure respectively, thus organizing this complex and time-consuming method of studying brain anatomy. The specific technical recommendations are stressed, improve the quality of the dissections, and contribute to the proper acquisition of anatomic data through photographs.

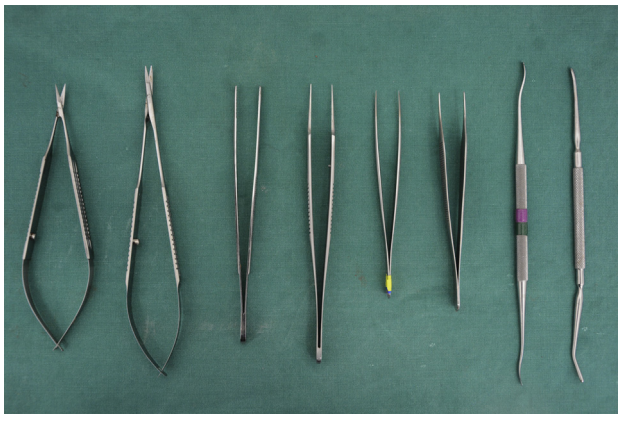

Figure 20. Recommended dissection instruments.

Although previous studies have improved our understanding about the cerebral white matter and fiber tract anatomy (3, 12, 29, 37, 41), they are scattered throughout the neurosurgical literature and do not provide the reader with a thorough, step-by-step, laboratory guide for the entire dissection process. To our knowledge, the present study is the first concentrated anatomic report that actually acts as a manual for this topic, thus orientating the novice neurosurgeon by making the whole procedure straightforward.

The Significance of the Fiber Dissection Technique in the Era of Modern Neurosurgery

Optimal treatment of patients harboring intraparenchymal lesions is a demanding task. Dissemination and/or invasion of the pathology to neighboring structures (19), localization, surgical exposure, maximal resectability with preserved neurological function, and postoperative assessment, in terms of results and additional therapies, are consecutive distinctive steps that should be carefully tailored for every patient. In this context, modern neuroimaging with special magnetic resonance imaging sequences, DTI-based tractography, and neuronavigation (11-13, 18, 22, 28) should be integrated with the profound anatomic knowledge of the brain parenchyma acquired through cadaveric white matter dissections.

The fiber dissection technique is a scientific procedure that aims at providing the neurosurgeon with a simultaneous, 3-dimensional knowledge of gray and white matter anatomy. Therefore, it is crucial in the formation of a proper intellectual concept of the accurate intrinsic brain architecture. Consequently, one can correlate brain surface anatomic landmarks with deeper fiber tracts in the laboratory setting and resemble this procedure when performing live surgeries. This is of utmost importance as in real operative settings the fiber tracts, which are so nicely revealed during brain cadaveric dissections, are not apparent. Hence, it is

this firm grasp of anatomy that enables the neurosurgeon to form a mental picture of the operative field to achieve safe intraoperative brain dissections and optimize the surgical exposure in each case.

Performing wide craniotomies to identify and correlate brain surface anatomic landmarks with underlying fiber tracts and, furthermore, planning the optimal surgical trajectory so as to access a lesion avoiding, if possible, eloquent white mater pathways are some of the obvious repercussions of laboratory investigation to everyday operative practice. This meticulous surgical attitude is invaluable when treating lesions located at the so-called central core of the brain (3, 31), the insula (34, 36), and the medial temporal region (35) in which the relationship between the operative corridor and the regional anatomy is highly complex.

In addition, the evolution of surgical approaches and the modification of current ones require not only profound theoretical knowledge but also practical laboratory work, before these techniques can be extrapolated to real operative settings. The transition from Spencer's anteromedial temporal lobectomy (39) to more refined surgical alternatives in treating epilepsy, such as Yasargil's transsylvian, translimen selective amygdalohippocambectomy (40), or selective subtemporal amygdalohippocambectomy through the collateral sulcus (14), is undoubtedly based on anatomic studies. In addition, the introduction of the transverse section of the anterior part of the corpus callosum during the interhemispheric transcallosal approach (21), as an elegant variant of the standard callosotomy, is another example of incorporating laboratory investigation into surgical practice.

Apart from the surgical standpoint, the enrichment of the fiber dissection technique with evidence arising from studies using intraoperative subcortical stimulation during awake glioma surgery and DTI is revealing new, eloquent white matter pathways, previously unrecognized, such as the inferior fronto-occipital fasciculus and its role in speech recognition (5). These novel findings improve our insight into the anatomofunctional brain architecture and plasticity (4, 6, 7).

Although brain anatomy has often been described with schematic drawings and illustrations, spatial understanding is not a simple intellectual process, as one has to postulate a 3-dimensional structure based in a 2-dimensional image. Even with the evolution of 3-dimensional images, the detailed and precise anatomic knowledge can only be obtained with hands-on cadaveric dissections (3). Hence, studying the intrinsic brain anatomy with the aid of white matter dissection remains a cornerstone in improving our understanding on the perplexing relationship between cortical and subcortical structures.

CONCLUSIONS

Fiber dissection is an invaluable method for acquiring profound neuroanatomic knowledge. In conjunction with modern neuroimaging and functional studies, it can enrich our understanding about the complex intrinsic brain architecture and furthermore contribute to the refinement of surgical approaches or even to the introduction of new ones. In this context, novice neurosurgeons should be encouraged to perform brain dissections in microneurosurgery laboratories as a part of their standard training program. The current study provides a concentrated and simplified dissection guide for this purpose.

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