White Fiber Dissection of Brain: Safety of Different Commonly Used Transcortical Microsurgical Approaches to Ventricles in Relation to Damage of the Internal Capsule and Other White Fiber Tract: A Cadaveric Study

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Objectives: This study was conducted to analyze the safety of transcortical (frontal, parietal, and temporal transcortical approaches to the ventricles) approaches with respect to damage caused to the internal capsule and other white fiber tracts by conducting sequential white fiber dissection of the brain in cadaver.

Methods: Eight formalin-fixed cerebral hemispheres were dissected for visualizing white fibers under operating microscope by the Klinger technique and their association with the basal ganglia and other related structures were studied. A standard middle temporal gyrus incision was made with a sharp knife and was deepened perpendicular to the surface to reach the temporal horn. By using the Klinger technique 11 formalin-fixed cerebral hemispheres were dissected for visualizing optic radiation under the microscope and was examined for any damage caused to optic radiation. A standard middle frontal gyrus incision was made and was deepened inferio-medially with an angle of 20 degrees to the sagittal plane to reach the lateral ventricle. Another incision on the superior parietal lobule was made and was deepened inferio-medially with an angle of 25 degrees to the perpendicular plane to reach the atrium of lateral ventricle. Another set of 6 formalin-fixed cerebral hemispheres was dissected and examined for any damage caused to the internal capsule and other white fiber tracts.

Results: Internal capsule was dissected completely and its association with the surrounding structures were shown. No damage of any part of the internal capsule including optic radiation was found with the middle frontal, superior parietal lobule, and middle temporal gyrus transcortical approaches to the ventricles.

Conclusions: Commonly used transcortical approaches to the ventricles are relatively safe with respect to causing damage to the internal capsule.

Key Words: internal capsule, white fiber dissection, microsurgical anatomy, middle temporal gyrus, amygdalohippocampectomy, transcortical approaches to the ventricles

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Although the gross anatomy of the brain has been studied by anatomists and clinicians, the intrinsic 3-dimensional microanatomic study of the complex fibers of the white matter is still somewhat neglected. Very few publications regarding this topic are available. Recently, in Rhoton's masterpiece, "The supratentorial cranial space: microsurgical anatomy and surgical approaches"—supplement of *Neurosurgery*, some beautiful dissection pictures showing the internal fasciculus can be appreciated.[1] As the radiologic and microneurosurgical techniques become increasingly precise, in order to continue this microneurosurgical development, the knowledge of 3-dimensional microanatomy of the internal capsule and other white fiber tract of the brain is essential for the management of various intrinsic neoplastic, vascular, and intraventricular lesions and other pathologic brain lesions that can produce clinical symptoms and signs by involving the parts of the internal capsule and other white fiber tracts or by exerting pressure over them. In fact, in the studies and management of the intrinsic brain lesion, such as the gliomas, the 3-dimensional microanatomy of the white matter tract is more important compared with the anatomy of the sulci.[2] In the management of intraventricular lesions, transparenchymal approaches are commonly used. Possibility of causing damage to the white fibers in such approaches (ie, frontal and parietal transcortical approaches to the lateral and third ventricle) is an important fact that should be always kept in the mind of the surgeon. Different extents of a temporal lobectomy is needed in different pathologic conditions including temporal lobe epilepsy. During surgery, it is almost impossible to differentiate the optic radiation from other white fibers.[3–5] There may be variable visual defects due to damage to the optic radiation after temporal lobe surgeries.[6–8] Amygdalohippocampectomy for intractable temporal lobe epilepsy is a common and reliable surgery for the management of epilepsy. Although it can be accomplished through several approaches ,[9–13] the middle temporal gyrus approach is a usual approach. Thus, safety of this approach with respect to causing damage to optic radiation along with anterior and lateral extension of optic radiation is an important issue.

The knowledge and experience gained from this technique can be applied to the microneurosurgical procedures. Three-dimensional microneuroanatomic description of the internal capsule and other white fibers will not only help the neurosurgeon but also the neurologist, neuropathologist, and the neuroradiologist. At the same time, this study can assess the nature of white fiber damage in different transcortical microsurgical approaches to the lateral ventricle. This type of cadaveric study is relatively rare in the literature.

MATERIALS AND METHODS

White Fiber Dissection

Eight cerebral hemispheres that were formalinated (10% formalin) for 3 to 6 months were taken for dissection of the internal capsule in the department of Neurosurgery, King Edward Memorial Hospital, Parel, Mumbai, India and the department of Anatomy, Dhaka Medical College, Dhaka, Bangladesh. The formalinated brains were preserved in refrigerator for 4 weeks before commencement of dissection. The internal capsule was dissected out using the Klingler fiber dissection method under the operating microscope. Dissection was carried out using bamboo-made small spatulas with different sized tip, ice-cream sticks, and surgical dissector.

The dissection was initiated at the supero-lateral surfaces of the cerebral hemispheres.

Supero-Lateral Dissection

The supero-lateral surface of each cerebral hemisphere is markedly convex and fits into the corresponding half of the skull vault (Figs. 1–5). Under the microscope, the gray matter over the supero-lateral surface was removed. The U-patterned short association fibers were identified under the gray matter that were dissected out and removed. The insula was opened up by removing the lips bordering the lateral sulcus and its rami. These lips are known as the pars orbitalis, pars triangularis, and pars opercularis. After their removal, the insula appears as a triangular eminence that is marked by a number of sulci and gyri (Fig. 1). The insular gray matter was removed revealing a number of sulci, one of which in the central sulcus of the insula is deep and prominent compared with the rest. Again, the "U" fibers of the insula gyri were visualized and the circular sulcus of the insula that surrounds the entire insula except at limen insulae were visualized as well. Thus, the entire gray matter of the whole cerebral hemisphere was removed revealing the "U" short-association fibers of the white matter underneath.

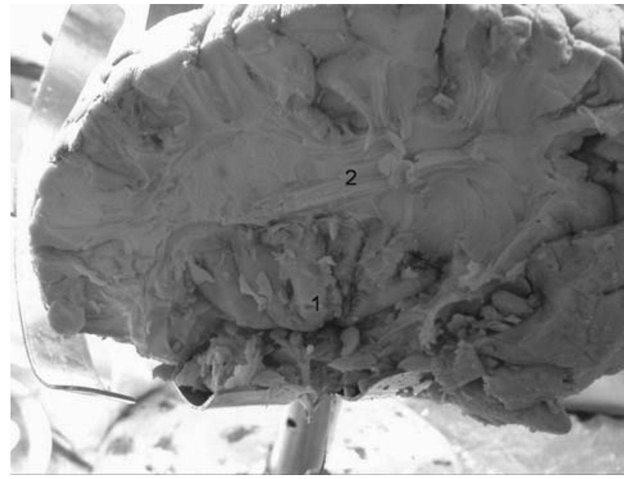

FIGURE 1. Dissection made from lateral surface. Operculum is removed to expose insula at the floor of the lateral sulcus. 1 indicates insula; 2, superior longitudinal fasciculi (partially removed).

The "U" short-association fibers of the insula and surrounding areas of the frontal parietal, occipital, and temporal lobes were removed to expose extreme capsule that is a thin sheet of white fibers that lies under the insula and external to the claustrum. Claustrum is a thin layer of gray matter exposed by removing the extreme capsule. External capsule that is a white matter sheet lies outside the lentiform nucleus (Fig. 2). It is thicker and more prominent compared with the extreme capsule. After dissection and removal of the external capsule fibers, lentiform nucleus was exposed. Anterio-inferio-lateral to the lentiform nucleus the U-shaped uncinate fascicle was dissected out that connects the frontal and temporal lobes through the limen insula, and some fibers from this region join the external capsule and optic radiation; actually

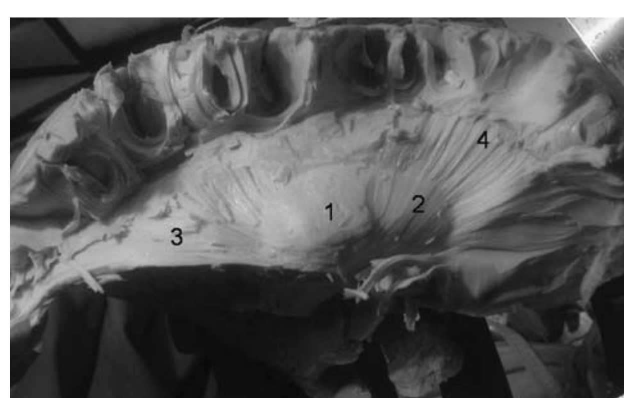

FIGURE 2. Dissection made on the lateral cerebral surface (continued), superior longitudinal fascicle, insula, extreme capsule, claustrum, and part of external capsule removed. 1 indicates lentiform nucleus; 2, external capsule; 3, optic radiation; 4, corona radiata.

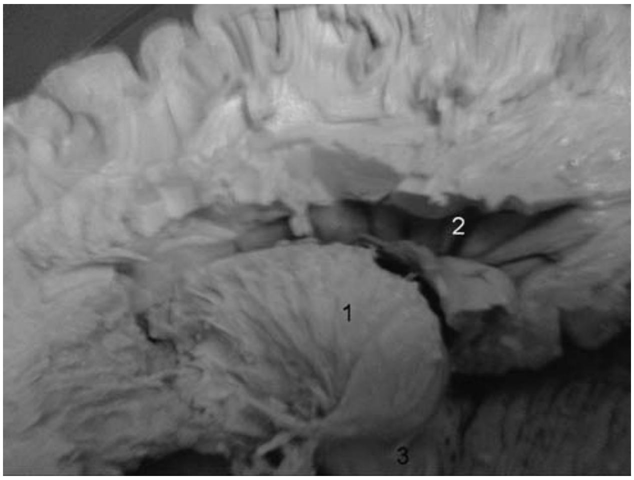

FIGURE 3. Dissection made on the lateral surface (continued). Lentiform nucleus removed to expose internal capsule (1). Internal capsule (1) continued below with crus cerebri (3). Corona radiate and part of caudate nucleus removed to expose lateral ventricle (2).

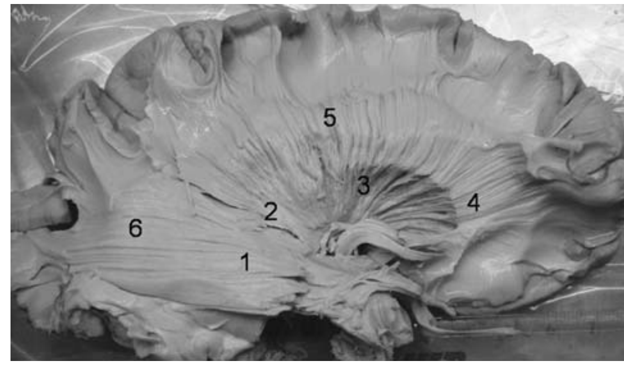

FIGURE 5. Complete exposure of the internal capsule from the lateral surface. 1 indicates retro and sublentiform part of the internal capsule; 2, posterior limb; 3, genu; 4, anterior limb of internal capsule; 5, corona radiate; 6, posterior part of optic radiation.

these fibers are so-called inferior longitudinal fascicle that connects the frontal, parietal, and occipital lobes. Anterior end of the optic radiation lies just posterior to the uncinate fascicle in the roof of the temporal horn of the lateral ventricle. Then the superior longitudinal fasciculus, the largest of the bundles, is located along the upper and lateral border of the lentiform nucleus and insula was dissected out. It arches backward from the frontal lobe lateral to the internal capsule and through the parietal to the occipital lobe, where it arches downward and forward to reach the temporal lobe. It interconnects widely frontal, parietal, occipital, and temporal lobes by its short and long fibers. After dissection and removal of the superior longitudinal fascicle and the lentiform nucleus, corona radiate and internal capsule were exposed and dissected out completely including optic radiation up to the cerebral peduncle (Figs. 3–5). Thereafter, a portion of the internal capsule and adjacent caudate nucleus was removed to open the lateral ventricle, and medial connection of the internal capsule was studied (Fig. 3).

Inferior Surface Dissection

The lamina terminalis was identified and removed, and then anterio-inferior portion of the hypothalamus (anterior portion of the lateral wall of the third ventricle) was removed to expose the anterior margin and anterior part of the internal capsule. Anterior commissure was identified at the superior attachment of the lamina terminalis and dissected laterally up to the anterior temporal lobe. Most of the temporal lobe was removed to expose the optic radiation, optic tract, and hippocampus (Fig. 6).

Medial Surface Dissection

On the medial surface of the cerebral hemisphere mammillary body was identified and then mammillothalamic tract was dissected out on the lateral wall of the third ventricle up to the anterior group of thalamic nucleus. The fibers from the anterior thalamic nuclei (anterior thalamic radiation) were dissected out lateral to the head of the caudate nuclei. This anterior thalamic

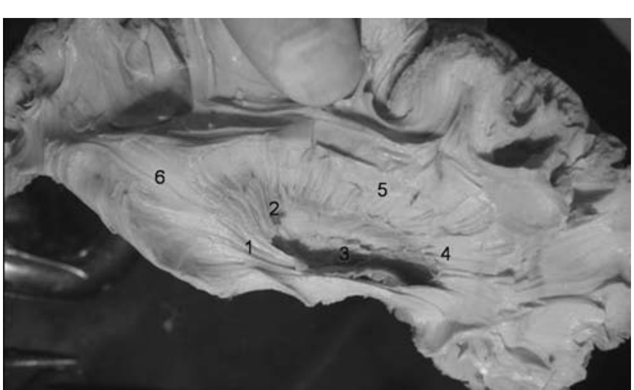

FIGURE 4. Exposure of internal capsule from lateral surface. 1 indicates retro and sublentiform part of the internal capsule; 2, posterior limb; 3, genu; 4, anterior limb of internal capsule; 5, corona radiate; 6, posterior part of optic radiation.

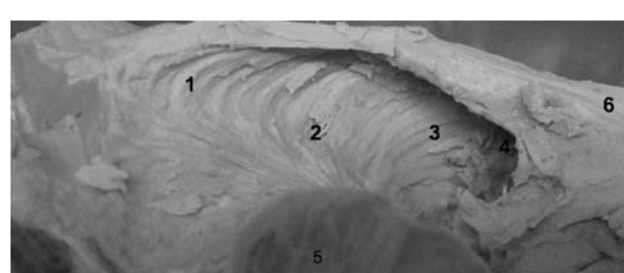

FIGURE 6. Exposure of the internal capsule through the roof of the temporal horn of the lateral ventricle (retro and sublentiform part of internal capsule that form optic radiation). 1, 2, 3 indicates retro and sublenticular part of the internal capsule; 4, temporal horn of the lateral ventricle; 5, midbrain; 6, optic radiation (seen on lateral surface).

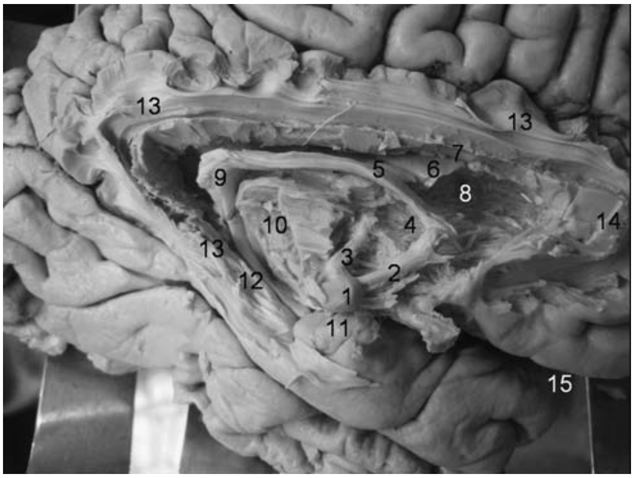

FIGURE 7. Exposure of the internal capsule from the medial cerebral surface (partial dissection). Part of caudate nucleus removed and medial surface of the anterior limb of internal capsule (anterior thalamic radiation) is seen. In dissection various parts of papez circuit is also seen after removal of the brain stem, cerebellum, and part of the thalamus and caudate nucleus. 1 indicates Mamillary body; 2, post commissural fornix; 3, mamillothalamic tract; 4, anterior thalamic nuclei; 5, body of fornix; 6, stria terminalis; 7, caudate nucleus; 8, anterior thalamic radiation; 9, crus fornix; 10, fimbria fornix; 11, uncus; 12, parahippocampal gyrus; 13, cingulum; 14, rostrum of corpus callosum; 15, temporal pole.

radiation joins to the anterior limb of the internal capsule (Fig. 7). By removing the body of the caudate nucleus, superior and posterior thalamic radiations were dissected out that join the posterior limb of the internal capsule.

Transcortical Middle Temporal Gyrus Approach to the Temporal Horn

Eleven cerebral hemispheres that were formalinated for 3 to 6 months were taken for dissection of optic radiation. The optic radiation was dissected out using the Klinger fiber dissection method under the operating microscope (Fig. 8). Dissection was carried out using bamboo-made small spatula and surgical dissector. Dissection was initiated from the lateral and inferior surfaces of the cerebral hemisphere. After removal of the gray mater, short and long association fibers, superior longitudinal fascicle, extreme capsule, claustrum, external capsule, and lantiform nucleus of the internal capsule were reached. The sublentiform and retrolentiform optic radiations were identified and dissected up to the occipital cortex. Thereafter, a 2 cm long anterior-posterior incision was made on the middle of the middle temporal gyrus extending from a point 3 cm posterior to the temporal pole. The incision was continued perpendicularly to the surface up to the temporal horn of the lateral ventricle (Fig. 9). Further, after removing the lower part of the temporal lobe and floor of the temporal horn, we exposed the roof from below (Fig. 10) and performed stepwise dissection of the optic radiation from the lateral geniculate body to the

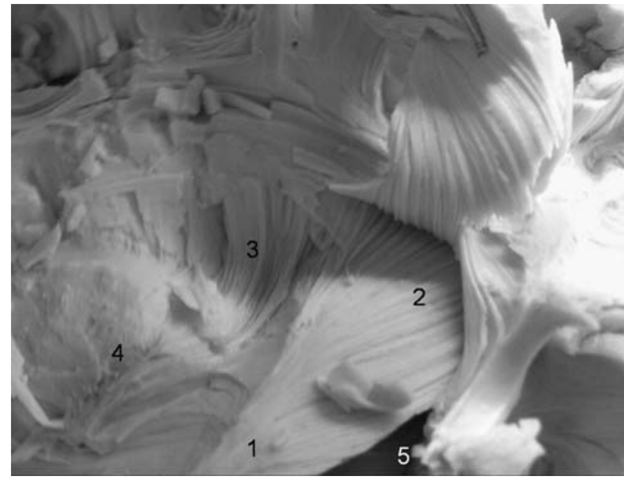

FIGURE 8. Dissection of the optic radiation. 1 indicates Meyer loop; 2, middle and posterior bundle of optic radiation; 3, internal capsule; 4, lentiform nucleus; 5, hippocampus in the temporal horn.

visual area. Temporal pole, amygdala, and hippocampus were preserved. Anterior and lateral extensions of the optic radiation were studied. It was noted whether any damage was made to the optic radiation by the middle temporal gyrus incision. The distances between anterior limit of the optic radiation, anterior end of the temporal horn (Fig. 9), head of the hippocampus, and the temporal pole were noted.

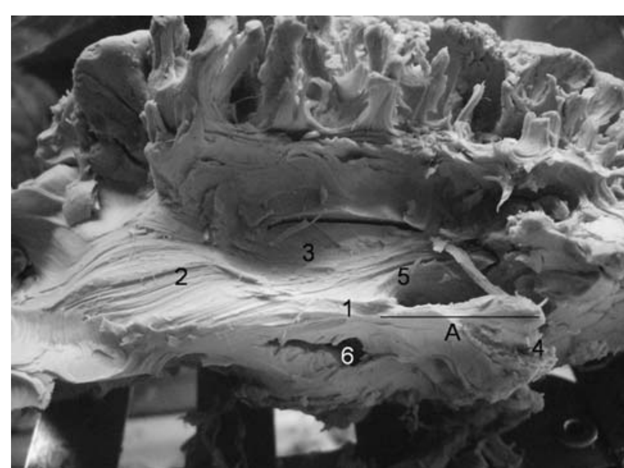

FIGURE 9. Complete dissection of the optic radiation with opening on the lateral wall of the temporal horn through the middle temporal gyrus incision. A indicates distance between the Meyer loop and the temporal pole; 1, Meyer loop; 2, middle and posterior bundle of optic radiation; 3, external capsule; 4, temporal pole; 5, uncinate fascicle; 6, hippocampus in the temporal horn seen through the opening on the lateral wall of temporal horn made by middle temporal gyrus incision.

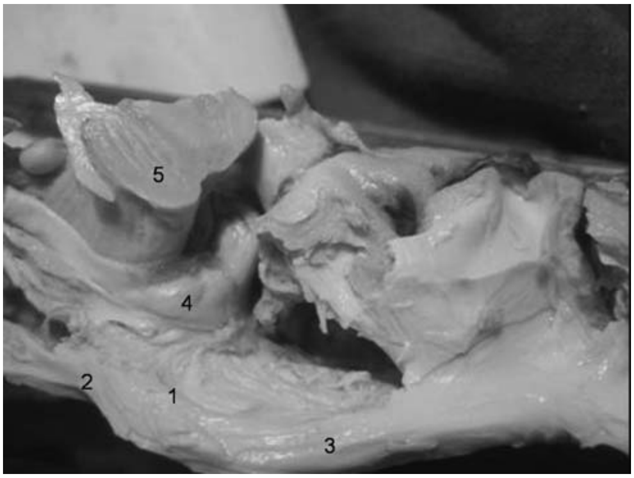

FIGURE 10. Inferior view of the roof of the temporal horn; ependymal and tapetal layers are removed and optic radiation was dissected out. 1, Meyer loop; 2, uncinate fascicle; 3, optic radiation; 4, lateral geniculate body; 5, midbrain.

Middle Frontal Gyrus and Superior Parietal Lobule Transcortical Approaches to the Lateral Ventricle

A 2-cm long anterior-posterior incision on the middle frontal gyrus 2 cm anterior from the precentral sulcus was made with a sharp knife. The incision was deepened inferio-medially with an angle of 20 degrees to the sagittal plane to reach the lateral ventricle at the junction of its body and the frontal horn (Fig. 11). Another 2 cm long anterior-posterior incision on superior parietal lobule 2 cm posterior from the postcentral sulcus was made with a sharp knife (Fig. 11). The incision was deepened inferio-medially with an angle of 20 degrees to the perpendicular plane to reach the lateral ventricle at the atrium of the lateral ventricle. By using the Klinger fiber dissection method, 6 formalin-fixed cerebral hemispheres were dissected for visualizing white fibers under the microscope. An examination was conducted to find out the effects of the incisions made to the white fiber tracts of the brain and also to study which white fiber bundle was damaged by the incision with its extension (Figs. 12–16).

FIGURE 11. Incisions made on the cortical surface of the brain for transcortical approaches to lateral ventricle. A, indicates incision on superior parietal lobule and B, incision on middle frontal gyrus.

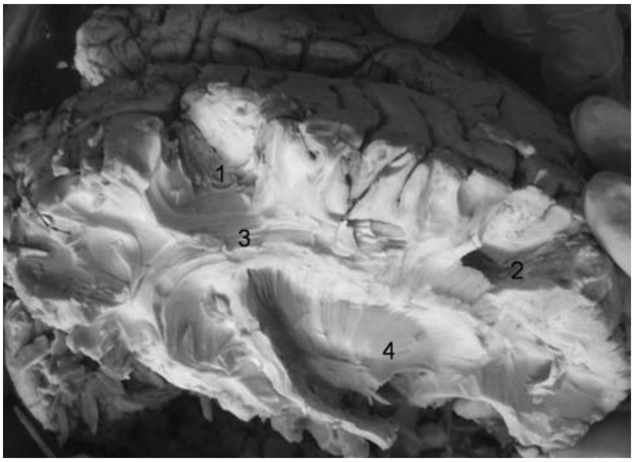

FIGURE 12. White fibers dissection of the brain; white fibers relation with the transcortical incision made to the ventricle. 1 indicates transparietal incision; 2, transfrontal incision; 3, superior longitudinal fascicle; 4, external capsule.

RESULTS

The projection fibers that form the internal capsule arising from almost all parts of the cerebral cortex pass down. Above the level of upper border of the lentiform nucleus, these fibers are arranged in a radiating pattern, and, hence, they are called the corona radiate (Figs. 2–5). The corona lies caudally continuous with the internal capsule, where these fibers are densely packed. The fibers of the internal capsule are arranged more densely to continue below as crus cerebri (cerebral peduncle). The internal capsule is bound laterally by the lentiform nucleus and medially by the caudate nucleus and the thalamus. Head of caudate nucleus is in contact with the medial surface of the anterior limb of internal capsule. Body of the caudate nucleus is in contact with the upper part of the medial surface of posterior internal capsule, whereas thalamus is in contact with the lower part. A portion of the medial surface of the genu between the interval of thalamus and caudate nucleus, which is subependymal and is just lateral to the foramen of the Monro, is separated only by the ependymal layer and the ventricle. The internal capsule has 5 parts: the anterior limb, posterior limb, genu, retrolenticular, and the sublenticular parts. The anterior and posterior limbs of the internal capsule join at right angle around the medial margin of the apex of the pallidal part of the lentiform nucleus to form the genu. The anterior limb is located between the caudate nucleus medially and the lentiform nucleus laterally, and a posterior limb is interposed between the thalamus medially and the lentiform nucleus laterally. The anterior limb is composed predominantly of

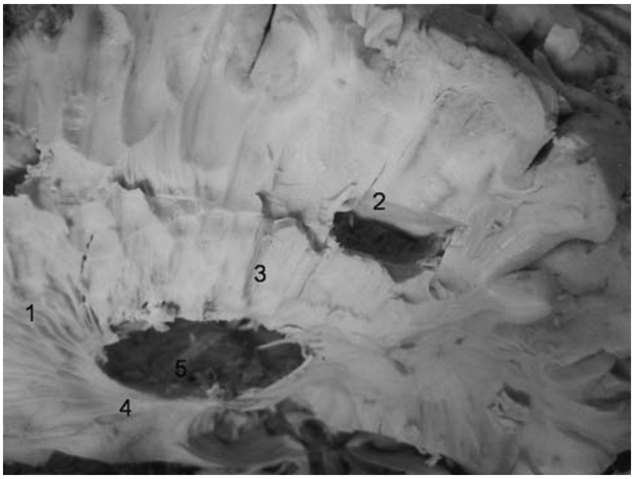

FIGURE 13. White fibers dissection of the brain; white fibers relation with transcortical incision made to the ventricle. 1 indicates superior bundle of optic radiation; 2, transfrontal incision; 3, corona radiate; 4, anterior Meyer's loop of optic radiation; 5, area for lentiform nucleus.

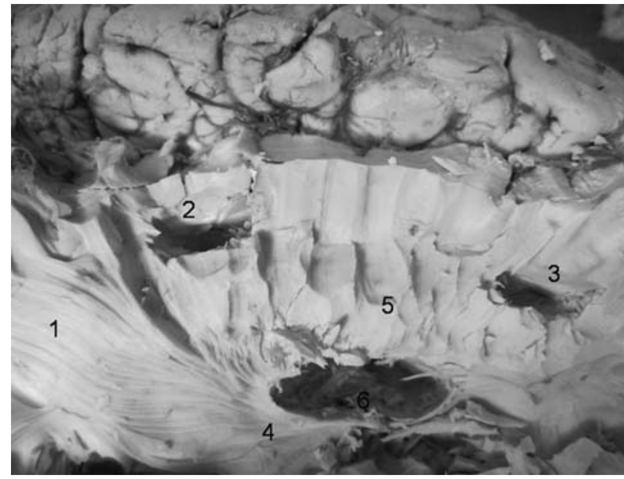

FIGURE 15. White fibers dissection of the brain; white fibers relation with transcortical incision made to the ventricle. 1 indicates superior and middle bundle of optic radiation; 2, transparietal incision; 3, transfrontal incision; 4, anterior Meyer's loop of optic radiation; 5, corona radiate; 6, area for lentiform nucleus.

fibers that connect the anterior and medial thalamus (anterior thalamic radiation) to the frontal lobe (Fig. 7). The genu of the internal capsule contains important corticobulbar fibers that originate from the inferior part of the primary motor area to the motor nuclei of the cranial nerves. In addition to the posterior thalamic radiation to the cortex, the posterior limb contains the corticospinal fibers to the motor nuclei of the upper and lower extremities and trunks. The fibers of the internal capsule that curve around the posterior edge of the lentiform nucleus are called the retrolenticular fibers. The fibers that pass below the lentiform nucleus are referred as sublenticular fibers. The sublenticular part contains the auditory radiation fibers directed from the medial geniculate body to the auditory area. The retrolenticular and the rest of the sublentiform parts form the optic radiation that course from the lateral geniculate to the walls of the calcarine sulcus. Some optic radiation fibers also pass in the retrolenticular part of the internal capsule but most pass through the sublenticular part. The optic radiations are separated from the roof and the lateral wall of the temporal horn and the lateral atrial wall by only a thin layer of the tapetal fibers (Fig. 6). The fibers passing to the superior lip of the calcarine fissure leave the upper

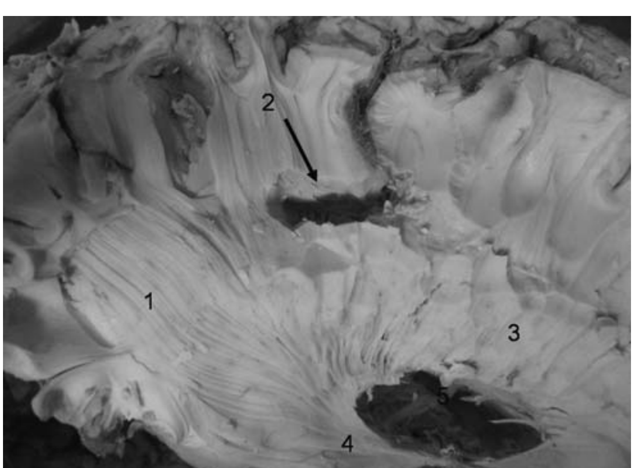

FIGURE 14. White fibers dissection of brain; white fibers relation with transcortical incision made to ventricle. 1 indicates superior and middle bundle of optic radiation; 2, transparietal incision to trigone of the lateral ventricle; 3, corona radiate; 4, the Meyer loop of optic radiation.

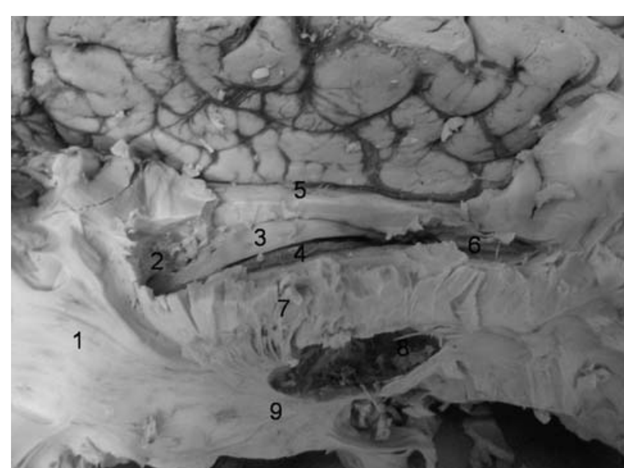

FIGURE 16. White fibers dissection of the brain; white fibers relation with transcortical incision made to the ventricle. 1 indicates superior and middle bundle of optic radiation; 2, transparietal incision; 3, fornix; 4, choroid plexus of lateral ventricle; 5, corpus callosum; 6, transfrontal incision; 7, corona radiate; 8, area for lentiform nucleus; 9, the Meyer loop of optic radiation.

part of the lateral geniculate body and course almost directly posterior around the lateral aspect of the atrium to reach the striate visual cortex. Fibers from the lower part of the geniculate body destined for the inferior lip of the calcarine fissure initially loop forward and downward in the temporal lobe forming the Meyer loop before turning back to join the other fibers in the optic radiations.

Transcortical Middle Temporal Gyrus Approach to the Temporal Horn

The sublentiform and retrolentiform part of the internal capsule is the optic radiation (Fig. 5). These white fibers start from the lateral geniculate body and ends in the visual area situated on the upper and lower lip of the calcarine sulcus. The anterior bundles of the optic radiation (Meyer loop) initially pass anteriorly to the roof of the temporal horn then turning backward pass along the roof and lateral surface of the temporal horn. Middle fibers (Macular fibers) from the lateral geniculate body pass to the roof of inferior horn and turn posteriorly to pass along the lateral wall of the atrium and occipital horn of the lateral ventricle and reach the visual cortex. The upper fibers pass directly posteriorly around the atrium and occipital horn to reach upper lip of the calcarine sulcus. Anterior end of the optic radiation extended in an 1 to 3.5 mm (range) (average, 2 mm) length beyond the tip of the temporal horn. The distance of optic radiation from the temporal pole was 23 to 31 mm (average, 25.6 mm). Anterior 8 to 10 mm optic radiation does not extend over lateral wall of the temporal horn. Most anterior 8 to 10 mm of the Meyer loop is completely on the roof and does not extend over the lateral wall of the temporal horn. Further, it extends 16 to 20 mm over the lateral wall of the temporal horn with gradual progression. The incision that was made over the middle temporal gyrus entered 2 mm below into the temporal horn and lateral to the optic radiation at its anterior part and 0.75 to 1 mm below the optic radiation at its posterior end. Posterior end of the incision is 1 to 2.5 mm anterior to the optic radiation margin. No damage was caused to the optic radiation by any of the incision made to the cerebral hemispheres.

Middle Frontal Gyrus and Superior Parietal Lobule Transcortical Approaches to the Lateral Ventricle

In the middle frontal gyrus approach to the lateral ventricle, the incision was 1 to 2 mm (average, 1.5 mm) superio-medial from the upper margin of the superior longitudinal fibers in 4 cerebral hemispheres (Fig. 12) and upper 1 mm of the superior longitudinal fascicle was cut by the incision made in 2 hemispheres. The incision also cut some frontopontine fibers that join the anterior corona radiate and anterior limb of the internal capsule (Figs. 13, 15). The incision also cut corpus callosal fibers and some fibers of the anterior thalamic radiation that end to the cingulate gyrus piercing through the callosal fibers in the formation of the Papez circuit (Fig. 16). Caudate nucleus was not damaged by the incision made in any of the hemispheres. Cortico-nuclear and cortico-spinal fibers originating from the precentral gyrus were not damaged by the incision and these fibers were in safe distance from the incision made.

In the superior parietal transcortical approach to the lateral ventricle, the incision was made 3 to 5 mm (average, 3.5 mm) superio-medial from the upper margin of the superior longitudinal bundle (Fig. 12). Some parieto-pontine fibers were cut by the incision infero-medial to superior longitudinal fascicle. Two-cm-long corpus callosal fibers lying superio-medial to the body of the caudate nucleus were damaged (Fig. 16). Superior bundle of the optic radiation was found 12 to 15 mm (average, 13 mm) posteriolateral to the posterior end of the incision (Figs. 14–16). Cortico-nuclear and cortico-spinal fibers originating from the precentral gyrus were not damaged by the incision made, and these fibers were also in safe distance from the incision made.

DISCUSSION

Many early neuroanatomists demonstrated tracts and fascicle of the brain by white fiber dissection, although the modern technique of fiber dissection was not used.[14–18] In fact, the fiber dissection technique was one of the first methods used to demonstrate the internal structures of the brain.[14] In 1927, English anatomist Herbert Mayo demonstrated corona radiate, internal capsule, superior and inferior cerebeller peduncles, fasciculus uncinatus, fasciculus longitudinalis superior, outer surface of the lentiform nucleus, tapetum, mamillothalamic tractus, and the anterior commissure.[14] Because the fiber dissection technique is a complicated and a time-consuming process, it has been almost inevitably neglected after the development of the microtome and the histologic techniques.[14] During the early part of the 20th century, a few anatomists preferred this technique to study the anatomic features of the brain.[14] An extensive historical review was made in an outstanding manner by Ture et al.[14] Joseph Klingler (1888 to 1963) was an anatomist in Basel who made the greatest contribution to the fiber dissection technique. In 1935, he developed an improved method of brain fixation and this technique now bears his name[19,20] (the Klingler technique). However, he froze and thawed the brains before dissection. Freezing helps to separate the fibers. His superb atlas containing detailed anatomic studies of the brain was published in 1956. Although his studies were impressive, this technique was never widely used.[14,19,20]

Illustrations of the internal structures of the brain in current textbooks are usually pictures of the sections or schematic drawings. Only few fiber dissection techniques from earlier textbooks are still reproduced.[14] In Rhoton's masterpiece published in 2002, we can appreciate some superb pictures of white matter anatomy exposed. In his publication, he described the white matter anatomy in detail.

Without knowing the 3-dimensional internal anatomy of the brain, one cannot interpret precisely the new neuroimaging studies such as "tractography," diffusion tensor imaging. Diffusion-tensor magnetic resonance imaging is a promising and rapidly evolving tool to evaluate white matter anatomy. The first attempt to visualize the white matter tract was made by Kinosada et al[21] in 1993. In the literature, one can find reports about the correlation of anterio-venous malformations[22] or tumors[2] with the white matter tracts. According to Ture et al,[14] the fiber dissection technique is a demanding and a time-consuming technique. The technique was somehow abandoned after the introduction of the microtome and histologic preparations. The histologic sections are very important for the interpretation of biplanar magnetic resonance imaging films, but, to build our ability to think in 3 dimensions, the knowledge of intrinsic white matter anatomy is of great importance. The first surgeon that gave attention to this technique was Yasargil.[23] After he gained knowledge of this technique, he applied it to all of his routine microsurgical procedures.[23–25]

The white fibers and ventricular system may be affected by various pathologies, such as congenital, developmental, degenerative, demyelinating, deficiency condition (vitamin deficiency), vascular (infarction, hemorrhage, anterio-venous malformation, angioma), hypoxia, intrinsic neoplastic (glioma, oligodendroglioma, ganglioglioma, primitive neuroectodermal tumor, metastatic lesion), infection (tuberculosis, pyogenic abscess), parasitic involvement (neurocystocercosis, hydatid cyst), trauma, iatrogenic (postsurgical), epilepsy, psychiatric illness, etc. Sometime intraventricular lesions such as ependymoma, glioma, meningioma, colloid cyst, craniopharyngioma, choroids plexus papilloma, metastatic, etc, can extend into the internal capsule and other white fiber tracts. Proper microneurosurgical 3-dimensional anatomic knowledge and orientation are essential along with physiological, pathologic, and microneurosurgical skills for dealing the abovementioned pathologies.

During dissection of optic radiation, we found that fibers originating from the lateral geniculate body were traced to visual area as 3 bundles (anterior, middle, and posterior), as described in other articles.[5,26,27] We found that anterior bundles (Meyer loop) passes through the roof of the temporal horn to a point 23 to 31 mm (average, 25.6 mm) behind the temporal pole. In the published articles this measurement is 21 to 30 mm (average, 25 mm).[3,5,8,28] We also found that it is 2 mm long from the tip of the temporal horn similar to that reported by Rubino et al[8] and Pujari et al.[28] These fibers loop back over the roof of the temporal horn. Most anterior 8 to 10 mm of the Meyer loop is completely on the roof and does not extend over the lateral wall of the temporal horn. Further, it extends 16 to 20 mm over the lateral wall of the temporal horn with smooth progression. Rhoton and colleagues described that the Meyer loop extends from the roof to the lateral wall of the temporal horn during its way to visual area. The 2 cm anterior-posterior incision made over the middle of the middle temporal gyrus 3 cm behind the temporal pole perpendicular to the surface does not cause any damage to optic radiation. The incision enters into the ventricles about 2 mm below the optic radiation at its anterior part and 0.075 to 1 mm below the optic radiation at its posterior end. Posterior end of the incision is 1 to 2.5 mm anterior to the optic radiation margin. Thus, resection of the temporal horn lesions and an amygdalohippocampectomy performed through the middle temporal gyrus approach with 2 cm incision 3 cm behind the temporal pole is relatively safer with respect to causing damage to the optic radiation. But change of direction to upward or posterior extension of incision or dissection is prone to cause damage to the optic radiation. One thing to note that any surgical resection of temporal lobe including superior temporal gyrus > 25.6 mm is prone to cause damage to the Meyer loop of optic radiation. In the published journal's articles, the safe anterior resection of the temporal lobe is 25 to 30 mm.[3,8,28]

The frontal and parietal transcortical approaches to the lateral ventricles do not cause any damage to the eloquent white fibers of the internal capsule or corona radiate. Chance of causing damage to the optic radiation is only in the superior parietal lobule approach to trigone of the lateral ventricle when appropriately placed and performed, but there may be a chance of transient or permanent damage caused by indirect vascular insult from retraction. Transcortical approaches to the lateral ventricle often broach the tracts of the visual pathways, resulting in varying degrees of temporary and permanent deficits.[29–32] In our study, we found that, when performed properly, the transcortical approach to the lateral ventricle does not damage the optic radiation directly. Cortical incisions and trajectories performed in the superior parietal lobe approach may be placed high and lateral enough to avoid optic radiations completely. Retraction in these regions, even when performed gently, may cause temporary and permanent visual-field deficits, especially when removing a large or invasive tumor.[33] Similar to the transfrontal approach convulsion, transient mutism[33] and disconnection syndrome from damage caused to the parieto-pontine fibers may take place after surgery through this approach.

Some short-association fibers, small part of superior longitudinal bundle, and some frontopontine fibers may be damaged in the middle frontal transcortical approach. Small part of the anterior corpus callosal fibers along with some fibers of the anterior thalamic radiation to cingulated gyrus are damaged in the middle frontal gyrus approach to the lateral ventricle that may cause transient mutism, convulsion, and memory disturbances.[33] There may be also disconnection syndrome due to damage of the frontopontine fiber that needs to be defined by proper preoperative and postoperative monitoring of the patients who underwent such surgery.

CONCLUSIONS

The white fiber dissection is the best method to learn the 3-dimensional internal anatomy of the brain. Knowledge of the microsurgical anatomy of the internal capsule and other white fiber tracts is not only important for understanding the 3-dimensional intrinsic brain anatomy but also important in the management of intrinsic brain lesion such as glioma, vascular malformation, etc., intractable epilepsy, and intraventricular pathologies. It is very important especially for the younger generation of neurosurgeons to become experts and experienced in microsurgical 3-dimensional neuroanatomic features for application in microsurgical practice. In dealing of intraventricular pathologies, commonly used transcortical approaches to lateral ventricles are relatively safe with respect to damage caused to the important white fiber bundle and the internal capsule including optic radiation.

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