Optic radiations: a microsurgical anatomical study

JOHANN PELTIER, M.D., NADINE TRAVERS, M.D., CHRISTOPHE DESTRIEUX, M.D., AND STÉPHANE VELUT, M.D.

Department of Anatomy and Organogenesis, University of Amiens; and Department of Anatomy, University of Tours, France

Object. In this study, the authors used a fiber-dissection technique to describe the optic radiation. They focused on the morphological characteristics (length and breadth) of this structure, its course, and its relationships with neighboring fasciculi and the lateral ventricle.

Methods. The authors dissected 10 previously frozen, formalin-fixed human brains with the aid of an operating microscope by following the fiber dissection technique described by Klingler in 1960. Lateral, inferior, and medial approaches were made. The optic radiation, also known as the Gratiolet radiation, extended from the lateral geniculate body to the calcarine fissure. The average distance from the tip of the anterior Meyer loop to the calcarine sulcus was 105 mm (range 95–114 mm). The breadth of the optic radiations, one on each side of the brain, averaged 17 mm at the level of the inferior or horn (range 15–18 mm). This tract could be divided into three main segments: the anterior or Meyer loop, the body, and the end of the optic radiation. Adjacent anatomical structures included: laterally, the inferior longitudinal fasciculi; medially, the tapetum of the corpus callosum; and the ependyma of the inferior horn of the lateral ventricle.

Conclusions. Various practical surgical approaches are discussed. The knowledge gained by studying this particular anatomy will help prevent injury to the optic radiations during neurosurgery.

KEY WORDS • lateral ventricle • white matter • optic radiation • fiber-dissection technique

Described and identified in 1857 by Louis Pierre Gratiolet, the optic radiation extends from the lateral geniculate body to the occipital cortex and belongs to the visual pathways.21 By relying on a dissection technique used in the past, we performed this study to improve our understanding of the morphological characteristics of the optic radiation to prevent a misinterpretation of the complex relationships of the myelinated fasciciles.

Materials and Methods

Twenty hemispheres from 10 formalin-fixed normal adult human brains of both sexes were examined. The fiber-dissection method described by Klingler21 was applied with the aid of a Zeiss operating microscope (magnification 6–40; Carl Zeiss, Oberkochen, Germany). Each brain had been removed from the cranium no later than 12 hours postmortem and was fixed in 10% formalin solution for at least 3 months, while suspended by the basilar artery to avoid deformation. The specimens were washed under running water for several hours. The arachnoid and vessels were completely removed. They were then refrigerated at temperatures ranging from −10°C to −15°C for 15 days. Because water increases 10% in volume with the formation of ice, the fibers were somewhat spread apart. The primary dissection tools that we used in this study were handmade, thin wooden as well as inwardly curved metallic spatulas with various tip sizes.

Results

The optic radiation arises from the deep face of the lateral geniculate body. We can compare the lateral geniculate body with an equestrian hat. The superficial face forms the hilus of the lateral geniculate body. This area was very difficult to dissect because of its hard consistency.

In each hemisphere the optic radiation extended laterally between the cells of the lateral geniculate body and the occipital pole. The average distance from the tip of the anterior Meyer loop to the calcarine sulcus was 105 mm (range 95–114 mm). The breadth of the optic radiation averaged 17 mm at the level of the inferior horn (range 15–18 mm). The optic radiation slightly increased in thickness along its course from the temporal lobe to the occipital pole, where its breadth approximated 23 mm (range 20–26 mm). We divided the course of the optic radiation into three main parts: ventral, central, and dorsal.

First Ventral Segment: the Meyer Loop

The first portion, the Meyer loop, is not only the most ventral but also the most cranial (Figs. 1 and 2). It was discovered in the depth of the middle temporal gyrus. This loop, along with an anterior concavity, draped behind the distal portion of the anterior commissure, whose lateral expansion appeared to follow a counterclockwise rotation similar to the pattern of a hemp rope. The temporal tip of the uncinate fascicle is also an adjacent ventral fiber tract of the anterior loop. In addition, several other fiber tracts, such as the inferior occipitofrontal fasciculus, were found in the temporal stem, in the vicinity of the Meyer loop.

Second Segment: the Body of the Optic Radiation

The central segment, the body of the optic radiation, passed below the inferior longitudinal fasciculus and fol-
followed a rectilinear course along a sagittal plane, although it curved laterally in a horizontal plane (Fig. 3). The anterior third of the body of the optic radiation draped over the auditory radiations at a right angle. This constitutes the sensory cross-road. The medial relationships of the body of the optic radiation were successively the tapetum of the corpus callosum, whose fibers were turned to face the floor, the ependyma of the temporal horn of the lateral ventricle, and the atrium. The dorsal two thirds of the body of the optic radiation rotated 90° on their axis in the same way that the latissimus dorsi muscle does when joining the crest of the humeral lesser tubercle. Vessels were found perforating the body of the optic radiation at 8-mm intervals all along its course.

Third Dorsal Segment of the Optic Radiation

The last segment of the optic radiation joined the upper and lower lips of the retrocalcarine sulcus of the calcarine fissure at the level of the V1 striate area (Brodmann area 17, or the primary visual cortex; Figs. 4–6). The trunk of the corpus callosum provided an origin for the splenium, which spread out and covered the superomedial portion of the atrium to constitute the forceps major of the corpus callosum. The bulb of the corpus callosum swept aside the medial wall of the occipital (posterior) horn of the lateral ventricle. A second lower prominence could be detected on the medial wall: this was the calcar avis, which results from the indentation of the anterior calcarine sulcus.

Discussion

The white matter of the cerebral hemispheres can be di-

Fig. 1. Photograph of the right hemisphere (lateral view). 1 = Meyer loop; 2 = uncinate fasciculus; 3 = ventral amygdalofugal tractus; 4 = anterior commissure; 5 = optic tract; 6 = internal capsule; 7 = external capsule; 8 = temporal branch of the superior longitudinal fasciculus; 9 = inferior longitudinal fasciculus; 10 = body of the optic radiation; 11 = frontal branch of the superior longitudinal fasciculus; 12 = arcuate fibers; 13 = ependyma; 14 = inferior horn of the lateral ventricle.

Fig. 2. Photograph of the right hemisphere (inferior view). 1 = Meyer loop; 5 = optic tract; 10 = body of the optic radiation; 13 = ependyma; 15 = atrium; 16 = calcar avis; 17 = splenium; 18 = posterior horn of the lateral ventricle; 19 = tapetum; 20 = amygdaloid nucleus; 21 = acoustic radiations; 22 = pes pedunculi; 23 = substantia nigra; 24 = medial geniculate body; 25 = superior colliculus.
vided into association fasciculi, commissural fasciculi, and projection fasciculi.

**Morphological Characteristics of the Optic Radiation**

The optic radiation contains all the visual fibers related to the contralateral visual field. Their average length is 98 mm. The optic radiations constitute part of the posterior thalamic peduncle and pass under the lentiform nucleus in the infralenticular portion of the internal capsule, above the tail of the caudate nucleus, to join the stratum sagittale in the lateral wall of the ventricle. The optic radiation arises from a site deep with respect to the middle and superior temporal gyri; the inferior end is never observed to be lower than the inferior temporal sulcus. The medial wall of the inferior horn is free from optic radiation fibers, except at the level of the lateral geniculate body. The optic radiation covers the entire superior wall of the inferior horn, whereas its entire inferior wall is free from optic fibers lying anterior to the level of the lateral geniculate body. After it leaves the lateral geniculate body, the optic radiation is divided into three main bundles.

The anterior bundle initially passes anteriorly over the
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The central bundle crosses the roof of the inferior horn and then runs posteriorly along the lateral wall and roof of the trigone and the occipital horn of the ventricle to the occipital pole. This bundle contains the macular fibers (central areas of the retina) and is larger than the anterior or posterior bundle, which represents fibers of the upper and lower quadrants of the retina, respectively. At the level of the occipital horn, these three fascicular bundles meet to form a horseshoe-shaped structure, which runs along the lateral wall of the lateral ventricle.

The posterior or upper bundle courses straight posteriorly to the roof of the atrium and the posterior horn, and radiates into the upper lip of the calcareous fissure. At the level of the occipital horn, one can find two characteristic elevations in the medial wall of the lateral ventricle: the bulb of the corpus callosum and the lower calcar avis. A third elevation can sometimes be present.

The origin of the optic radiation is supplied by the superior branches of the cisternal segment of the anterior choroidal artery. These distal arteries arise at the level of the lateral geniculate body or beyond and pass through the brain to send branches to the inferior half of the posterior limb of the internal capsule and the retrolenticular fibers of the internal capsule. The body of the optic radiation is supplied by branches of the lenticulostriate arteries, which originate from the middle cerebral artery. This can explain both the effects of occlusion of the anterior choroidal artery and the effects of a deep sylvian infarction, which cause hemianopia and associated hemiplegia on the contralateral side.

Relationship Between Other Fascicles and the Optic Radiation

Uncinate Fascicle. The shape of the uncinate fascicle appears hooklike and this structure interconnects the tip of the temporal lobe with the orbital gyri. The uncinate fascicle is approximately 2 mm thick and lies in the limen insulae, underneath the putamen and claustrum. The limen insulae is located deep within the sylvian fissure and constitutes the anterobasal portion of the insula. The uncinate fascicle joins intermingling fibers of the temporal stem, such as the Meyer loop, anterior commissure, inferior occipitofrontal fasciculus, and inferior thalamic peduncle. The uncinate fascicle interconnects the cortical nuclei of the amygdala, hippocampal formation, temporal pole, first temporal convolution (superior temporal gyrus), and second temporal convolution (superior temporal gyrus), and second (middle) temporal gyrus with the orbital frontal lobe.

Inferior Occipitofrontal Fasciculus. The inferior occipitofrontal bundle courses in parallel and superior to the optic radiations and belongs to the infralenticular portion of the external and internal capsules.

Auditory Radiations. These fibers course toward the transverse temporal gyrus and constitute a lateral relationship.
with the inferior horn, atrium, optic radiations, and a portion of the anterior commissure. They belong to the retrolenticular area.

Superior Longitudinal Fasciculus and Arcuate Fasciculus. Universally considered to be an integral portion of the superior longitudinal fasciculus, the arcuate fasciculus can be followed to the wall of the lateral ventricle, where it connects the superior and posterior portions of the frontal lobe (precentral gyrus) to the parietal, middle temporal, and occipital lobes. The arcuate fasciculus passes over the superolateral aspect of the caudate nucleus and surrounds the insula with a C-shaped arch.

The Anterior Commissure. The anterior commissure expands laterally to a point at which it crosses the basal portion of the globus pallidus toward the temporal pole.

Surgical Applications

To reach tumors of the inferior horn or those of the atrium of the lateral ventricle, or to perform an amygdalohippocampectomy, surgeons must use strategies to avoid creating a neurological deficit. The temporal cortex, which surrounds the inferior horn and trigone of the lateral ventricle, has many high-level, organized functions, including language, vision, memory, and music processing. Various transcortical approaches can threaten the optic radiations.

The middle temporal approach causes contralateral visual quadrantanopia, which can be limited provided resection of the temporal lobe is performed along the lower portion of the lateral wall of the inferior horn or the trigone region. At the level of the middle temporal gyrus, the low-lateral wall of the inferior horn or trigone is reached at a depth of 22 to 26 mm, although this distance is only approximately 10 to 14 mm from the floor of the middle fossa. Seven percent of patients who undergo surgery performed using this corridor develop this visual deficit. The incision must be parallel and longitudinal to respect the optic radiations. In addition, this middle temporal approach entails a certain risk for the development of Wernicke aphasia in the dominant hemisphere, which is the location of the sensory speech area in the superior and middle temporal gyri, beginning approximately 5 to 6 cm behind the temporal pole. The middle temporal gyrus, which continues posteriorly with the angular gyrus, has important functional connections with the parietal and occipital lobes.

The parietal transcortical approach, also known as the atrial approach through the superior parietal gyrus, causes a homonymous visual field deficit due to an interruption of the optic radiation, even if this access is associated with a reduced incidence of visual deficits. In the same way, a trajectory through the temporoparietal junction to reach the atrium may cause a lateral homonymous hemianopia.

Another primary surgical route is the transsylvian–transventricular approach described by Yasargil, et al. This popular route is used for amygdalohippocampectomy. It opens the insular cistern along the Heschl (transverse temporal) gyrus and provides an “inside-out” orientation with circumferential handling of the anatomy of the mesial temporal lobe. Exposure of the inferior horn is performed through a corticectomy in the superior temporal gyrus, at the level of the limen insulae. Advantages of this approach include preservation of the language area and the visual pathways, and sparing of normal cortical tissue.

More recently, a transsylvian–transcisternal mesial en bloc resection has been proposed to treat hippocampal sclerosis. A semicircular opening in the dura mater is created above the sylvian fissure, and the arachnoid of the interpeduncular cistern is opened, allowing the surgeon to see the basal arteries. The medial face of the parahippocampal gyrus rhinal sulcus is exposed. Resection of the anterior hippocampus and amygdala is made en bloc up to the midmesial.
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encephalic level; this is facilitated by following the medial wall of the opened inferior horn of the lateral ventricle. This approach preserves the lateral as well as the laterobasal temporal lobes; nevertheless, this route can produce a temporary mechanical irritation of the oculomotor nerve in 9% of patients, explained by an arachnoid tunnel, which represents the lateral duplicate extension of the Liliequist membrane. Three percent of patients in whom this approach is followed present with a contralateral superior quadrantopia.\(^{50}\)

A subtemporal transfusiform gyrus approach to the parahippocampal gyrus spares the lateral temporal neocortex with its higher cortical functions; however, it can cause injury to the vein of Labbé or a well-developed basal temporal bridging vein, and it can produce a direct or retraction-related injury to the inferior temporal gyrus, as demonstrated on postoperative magnetic resonance imaging.\(^{18,29,46}\)

Other innovative, less destructive, minimally invasive procedures, especially with regard to the fibers of visual pathways, temporal stem, and lateral temporal neocortex, can be proposed.

The transsylvian keyhole technique is an original method of minimally invasive mesial temporal lobectomy. A small \((4 \times 4\text{–}4\text{–}4\text{–}4\text{–}cm)\) trephination is created under neuronavigation control, permitting exposure of the sylvian fissure, frontal and temporal opercula, limen insulae, and circular sulcus. Through the inferior limb of the insular sulcus, the inferior horn is opened transcrortically. Removal of the hippocampus and amygdaloid body and removal of the uncus are then performed. This less invasive procedure reduces operating time by approximately 25%; it also decreases the morbidity rate and the amount of blood required. Moreover, this route spares the optic radiation.\(^{41}\)

A lateral transtemporal approach through the superior temporal sulcus can be adopted for lesions in the dominant hemisphere. This route allows the surgeon to reach the trigone of the lateral ventricle with a short white-matter incision. The medial end of the Heschl gyrus is an appropriate anatomical landmark for this route. The length of this approach from the surface of the insular cortex to the atrium is approximately 10 mm. This horizontal insular aperture may damage the superior bundle of the optic radiation and transsect the auditory radiations.\(^{27}\)

The anterolateral floor of the inferior horn of the lateral ventricle can also be approached via an inferior temporal sulcus route. This approach can be performed using a stereotactic navigational system. A 35-mm-diameter free bone flap is made as low as possible to reach the inferior temporal sulcus. Using an operating microscope, the surgeon inserts a brain speculum into the bottom of the inferior temporal sulcus. Using an operating microscope, the surgeon inserts a brain speculum into the bottom of the inferior temporal sulcus. A helium-neon guiding laser allows the surgeon to localize the direction of the anterolateral floor of the temporal horn. The anterior hippocampus and parahippocampal gyrus are removed subpially en bloc by using suction. The anterior temporal sulcus will transect the optic radiation. The transsylvian approach preserves the lateral as well as the laterobasal temporal sulcus route. This approach can be performed using a ste-


