Selective amygdalohippocampectomy via the transsylvian approach

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Surgery is an established treatment for temporal lobe epilepsy refractory to medication. Several surgical approaches have been used to treat this condition including temporal lobectomy, transcortical selective amygdalohippocampectomy, subtemporal amygdalohippocampectomy, and transsylvian amygdalohippocampectomy. In this article the author reviews the transsylvian amygdalohippocampectomy and pertinent anatomy. He also discusses the procedure’s results with regard to seizure control, neuropsychological outcome, and visual field preservation.

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COMPLEX partial or psychomotor seizures are the most common types of focal seizures. Their association with hippocampal sclerosis is now established and well known. The first account of hippocampal sclerosis in a patient with epilepsy appeared in 1825 and is credited to Bouchet and Cazauvieilh.1 Hippocampal sclerosis, at that time, was thought to be a consequence of repeated seizures, not part of a circuitry able to trigger electrical discharges. With the advent of electroencephalography, it became clear in the 1930s that complex partial seizures were originating from the temporal lobe. By 1941 Jasper and Kershman14 had associated the psychomotor phenomenon with abnormal electrical discharges from that area, which led several surgeons to perform anterolateral temporal corticectomies. Penfield and Flanigin’s29 series showed limited success (< 50%) with this procedure, however.

Animal and experimental studies performed later in the 1950s began to implicate the mesial temporal structures in these seizures. Kaada17 induced the arrest of movement, licking, chewing, and swallowing by stimulating the amygdala, the head of the hippocampus, and the pyriform region in animals. Convincing physiological evidence that the mesial temporal region is a crucial zone for the generation of temporal lobe seizures has come from surgical studies. The systematic reproduction of habitual auras and other features typical of these attacks by applying depth stimulation in patients during surgery within and around the amygdala offered convincing evidence of the mesial temporal region’s role as a generator of seizures. Given that the role of the mesial temporal structures in TLE was becoming clearer, Penfield modified his temporal lobe resection to include the amygdala and hippocampus. Penfield and Baldwin28 published a series in 1952. Soon thereafter Niemeyer26 presented a transcortical approach for selectively resecting the amygdala and hippocampus with good control of seizures.

With the introduction of microsurgery and microtechniques by Yaşargil, the proximal transsylvian approach to the mesial temporal lobe grew in familiarity as he routinely tackled vascular and neoplastic lesions in this region. Invasive electroencephalographic evaluation of patients with TLE gave more evidence of the involvement of the mesial temporal structures in generating seizures and exonerated the neocortical areas in a significant number of patients. Combining this knowledge, Weiser and Yaşargil40 developed the proximal transsylvian selective transamygdalohippocampectomy.

Anatomy of the Mesial Temporal Structures

Topographic Details

Understanding the topography of the mesial temporal structures is paramount in successfully performing selective resection of the amygdala, hippocampus, and parahippocampal gyrus. The parahippocampal gyrus has a curved anteroposterior course encircling the brainstem as well as the crural and ambient cistern. Superiorly it is separated from the hippocampal formation by the hippocampal sulcus. Laterally it has the collateral sulcus as its limit. The

Abbreviations used in this paper: AChA = anterior choroidal artery; PCA = posterior cerebral artery; PCoA = posterior communicating artery; TLE = temporal lobe epilepsy.
collateral sulcus projects in the temporal horn as the collateral eminence.\(^4\)

On the mesial-most surface of the temporal lobe is the uncus, measuring 10–12 mm in length. It extends anteriorly to the parahippocampal gyrus. Laterally it is limited by the rhinal sulcus. The anteromedial surface of the uncus has 2 gyri: the semilunar gyrus anteriorly and the ambient gyrus posteriorly.\(^3\) The posteromedial surface of the uncus is divided horizontally by the uncal sulcus, above which are 3 gyri—the uncinate gyrus, the band of Giacomini, and the intralimbic gyrus—and below which is the entorhinal area.\(^3\) Very often the uncus is herniated through the tentorial incisura, which leaves a tentorial groove on it.

The amygdala is intimately related to the uncus; the semilunar gyrus is the cortical projection of the amygdala on the anteromedial surface of that structure. Superiorly the amygdala is bordered by the globus pallidus, and inferomedially it comes into contact with the head of the hippocampus.\(^4\) The hippocampus in turn has 3 parts: a head, a body, and a tail. The head has a transverse course and no choroid plexus covering it, and medially it projects to the posteromedial surface of the uncus. The body has an anteroposterior course, and choroid plexus covers it superiorly and medially; its dorsal part is also covered by the alveus, the origin of the fimbria. Medially it is separated from the dentate gyrus by the limen insulae. Laterally it is limited by the collateral eminence. The tail of the hippocampus curves back medially and forms the medial floor of the atrium.

The choroid fissure starts posterosuperiorly to the uncus. Medial to it is the ambient cistern. Superiorly and medially are the thalamus and its lateral geniculate body.\(^25\)

**Fiber Anatomy**

The fiber systems in the vicinity of the mesial temporal structures are complex (Fig. 1). A review of their anatomy is beyond the scope of this paper. Several anatomical and radiological studies with diffusion tensor imaging offer a good presentation of these fiber systems.\(^15,20,31,32,35,36,43\) The connections of the amygdala and hippocampus as well as the association fibers such as the uncinate fasciculus, the occipitofrontal fasciculus, the optic radiations, the fibers of the anterior commissure, and projection fibers of the inferior thalamic peduncle must be understood before performing surgery in this area.

The occipitofrontal fasciculus has a fanlike configuration with its isthmus at the level of the limen insulae. Its fibers pass through the deeper area of the extreme and external capsules before reaching the occipital lobe. The uncinate fasciculus originates in the frontoorbital and frontomedial regions, connecting them to the superior, middle, and inferior temporal gyri in the temporal pole, passing through the limen insulae. The fibers of the anterior commissure pass through the globus pallidus pars interna through the Gratiolet canal. Their course is parallel to the optic tract, after which they pass posteriorly, partially merging with the occipitofrontal fasciculus.

The optic radiations, originating from the lateral geniculate body, are located in the roof of the temporal horn. Some of their fibers will travel anteriorly for a distance of ~2 cm before looping back posteriorly, which has come to be known as the Meyer loop and is located 0.5–1 cm lateral to the temporal horn. Posteriorly the optic radiations merge with the occipitofrontal fasciculus and the fibers of the anterior commissure, forming the sagittal stratum.\(^25,43\)
Vascular Anatomy

The vascular anatomy of the mesial temporal area is complex. On the arterial side several structures are in the vicinity and intimately related to the medial temporal lobe, including the supraclinoid carotid artery, the PCoA and its branches, the AChA, the M1 segment, and the PCA with its branches. A thorough knowledge of this vascular anatomy is necessary to safely approach this area. Consider the vasculature of the hippocampus. Its arterial supply is multiple and most often is a mix originating from the AChA (giving aregular lateral branch to the head of the hippocampus and parahippocampal area), the PCA, and branches of the PCA such as the inferior (anterior, middle, and posterior) temporal branches, the lateral posterior choroidal artery, and the splenial artery. The variations in this supply have been well described by Erdem et al.7 and in order of frequency would include an exclusive supply to the hippocampus from the inferior temporal trunk or the inferior temporal branches such as the anterior, middle, or posterior inferior temporal branches of the PCA. Next in frequency would be an exclusive supply from the anteroinferior temporal artery. Least common is a solitary supply directly originating from the PCA (Uchimura artery) or the AChA.

Unlike the hippocampal arteries, which penetrate the hippocampal formation via the dentate gyrus, fimbredentate sulcus, and hippocampal sulcus, the lateral posterior choroidal arteries enter the temporal horn via the choroidal fissure, which is also an important intraoperative landmark.21,22 On the venous side (Fig. 2), the mesial temporal structures drain into the basal vein of Rosenthal through the inferior ventricular vein, which exits the temporal horn through the inferior choroidal point of the choroid fissure. Several intraventricular veins from the temporal horn will coalesce to merge into the inferior ventricular vein. These veins include the vein of the amygdala, running on the anterior wall of the temporal horn in a medial direction, the anterior longitudinal hippocampal vein on the ventral surface of the hippocampus, and the inferior choroidal vein adjacent to the choroid plexus. The hippocampus also has small veins on its dorsal surface running in a transverse direction and exiting the temporal horn through the fimbredentate sulcus.13

Surgical Technique

A significant misconception about the transsylvian selective amygdalohippocampectomy is its description as transinsular (Fig. 3). In reality the resection of the mesial temporal structures is transamygdala and proceeds through an anteroposterior axis.42 Classically, a pterial craniotomy is fashioned. Care should be taken to elevate the temporals muscle in a way that allows exposure of the temporal pole. Once a craniotomy is performed, the orbital roof is flattened, and both the lesser and greater wings of the sphenoid are drilled down to the superior orbital fissure. After dural opening, the arachnoid over the sylvian fissure is incised anterior to the venous sylvian confluence. The interopercular sulci between the lateral frontoorbital gyrus and superior temporal gyrus are opened using sharp dissection. The use of a rigid self-retaining retractor is strictly avoided. The entrance into the surgical field is maintained using cottonoids wedged at each end of the sylvian fissure opening. Once the interopercular sulcus is opened down to the sylvian fossa and the middle cerebral artery bifurcation is seen, the M1 segment is followed proximally to the carotid artery bifurcation and the proximal sylvian fossa is opened from inside to outside. At this point several structures must be inspected. The lateral aspect of the supraclinoi
d internal carotid artery is visualized and its branches, including the PCoA and the AChA complex, are identified. Special attention is given to the lateral branches of the M1 segment, specifically the temporopolar and anterior tempo-
ral arteries. Sometimes the temporopolar or anterior temporal arteries will need to be mobilized to allow enough working room to start the exploration of the amygdala. The position of the uncus is noted, as it is very common for it to be herniated through the tentorial incisura. Resection of the amygdala proceeds first in an anterobasal direction down to the crural and ambient cisterns. An inferior resection of the amygdala follows; however, this structure’s relation to the optic tract must be well visualized and understood before excision. The medial part of the amygdaloid nucleus, under the M1 segment and in continuity with the basal forebrain, is left unresected. As resection of the amygdala is completed, the temporal horn is entered and the pes hippocampus is identified; anteriorly the crural cistern is now well exposed, and the AChA with its branches, the PCoA, the PCA, and the cranial nerve III are all within sight. Resection of the hippocampus and parahippocampal gyrus proceeds posteriorly in the direction of the atrium. The choroid plexus covering its body is reflected medially, and the tenia fimbriae is exposed gradually and opened anteriorly and posteriorly with the help of bipolar forceps. During this opening the crural cistern is further exposed. The AChA, basilar vein, and optic tract are now well visualized. The lateral branch of the AChA as well as the branches of the PCA coursing to the hippocampus are coagulated and divided. The extent of the hippocampal resection is continued posteriorly to the bifurcation of P2 as it divides into the superomedial and inferolateral trunks, at the level of the lateral geniculate body, for a total resection of 25–30 mm (Fig. 4). At this level the optic tract is merging into the lateral geniculate body, and the lateral posterior choroidal artery can be seen originating either proximal or distal to the P2 bifurcation. The resection is now continued laterally with its limit at the level of the collateral eminence. Care should be taken not to injure the inferior temporal trunk and its branches; only those vessels going from it to the parahippocampal gyrus are sacrificed. The inferior ventricular vein that collects the hippocampal veins and drains into the basilar vein is identified, coagulated, and divided to complete the resection.

**Surgical Outcome**

**Epilepsy Control**

Surgery for pharmacologically resistant TLE clearly has been shown to be superior to medical treatment. In a prospective randomized controlled trial in which anterior temporal lobectomy was compared with the best medical treatment, 64% of patients who did undergo surgery were free of disabling seizures, whereas this number was only 8% in the medical group.\(^\text{38}\) In that same study patients who underwent surgery had a better quality of life when compared with patients treated medically. A significant number of case series of patients treated with a temporal lobectomy for epilepsy have confirmed these results. Most of these studies demonstrated a two-thirds rate of freedom from disabling seizures.\(^\text{8,16,33}\)

The presence of unilateral hippocampal sclerosis on the side responsible for seizures and the absence of tonic-clonic seizures preoperatively were predictive of seizure remission postoperatively. A remission of seizures is usually defined as the complete absence of seizures for 2 years. The rate of seizure relapse after remission in patients who underwent a temporal lobectomy varied from 20 to 40%. Predictors of relapse included a delay in achieving remission, a normal hippocampus on pathological examination,
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and a high number of monthly seizures preoperatively. In 1992 the Second Palm Desert Survey documented the outcomes of several centers with regard to seizure control following surgery for TLE. It showed that selective limbic resections led to a seizure-free rate of 68.8%, comparable to the 67.9% rate reported for temporal lobectomies. Since that survey several centers have published the results of their selective resections of the amygdala and hippocampus. Different approaches were used at different centers, including transcortical, subtemporal, and transsylvian amygdalohippocampectomies. In all of these series, ~70% of patients were free of disabling seizures (Engel Class I) postoperatively. These results refute the argument that a more extensive neocortical resection might be necessary to obtain good seizure control.

Another concern brought against selective resections of the mesial temporal structures is long-term seizure control. When Wieser et al. looked into that issue in a series of subarachnoid hemorrhages, 88% of patients with an Engel Class I outcome the 1st year after surgery remained stable over the next 5 years, which is comparable or even superior to results reported following temporal lobectomies.

In the same series of transsylvian amygdalohippocampectomies, 70% of patients had reduced their antiepilepsy medication postoperatively. At the time of the last available outcome 49.4% of patients had reduced their antiepilepsy medication compared with preoperative levels, and 27% were without any antiepilepsy medicine.

When the nature of the pathology underlying an epileptic disorder was considered, the seizure outcome after transsylvian selective amygdalohippocampectomy varied. Patients with classic hippocampal sclerosis fared well, and 73% of them had an Engel Class I outcome after transsylvian amygdalohippocampectomy. If patients with mesial TLE had more extensive disease affecting the temporal neocortex or when the seizure-generating structures exceeded the area of resection performed via a transsylvian approach, only 12% of patients had an Engel Class I outcome. As in patients with lesional mesial TLE, the results following transsylvian selective resections were good. Seventy percent of patients with vascular malformations or benign tumors had an Engel Class I outcome. Patients with World Health Organization Grade III or IV tumors had an Engel Class I outcome in 60% of cases. Wieser and associates reported on 34 patients (11 vascular malformations and 23 tumors or hamartomas) with dual pathology who underwent surgery via the transsylvian approach. This group had a seizure outcome similar to that in patients with hippocampal sclerosis.

Cognitive Outcome

Given that seizure control has been found to be similar among the different surgical procedures offered, other factors must be considered when deciding on the best approach to be utilized. The cognitive outcome following temporal lobe surgery for epilepsy has been a significant concern. Before discussing the neuropsychological results of the different surgical techniques, several issues that have a direct impact on outcome must be addressed.

First is the issue of “silent cortex.” The myth that the normal brain contains functionless, silent areas arose from the leading theory of brain function and some data on resec-

tion, disconnection, and electrical stimulation that were misinterpreted to fit that model. The concept of silent cortex—truly nonfunctional areas that, when removed, could be fully compensated for by other areas—was consistent with the tenets of gestalt, holistic psychology, and neurology, in which the greater part of the brain was considered to support general intellectual functions. This view was concordant with the prevailing notion of a general intelligence factor underlying the IQ. However, animal and human studies are showing involvement of those silent areas, such as the temporal pole, in several functions. Temporal pole lesions in monkeys disrupt social behavior, reducing affiliative behavior and leading to social isolation. In humans the temporal pole has naming, sensory, and emotional functions. In functional studies the structure is activated while recalling proper names, detecting a familiar stimulus, analyzing auditory stimuli, and learning new visual patterns. Most patients undergoing temporal lobe resections are well evaluated for memory and speech; however, emotion, visual recognition and learning, topographic memory and orientation, and musical, sexual, and other functions are rarely considered. Similarly, studies on emotional function are often limited to assessments of mood and anxiety, and social function is rarely addressed. In many cases, patients may not report emotional and social issues, which are more apparent to family members, friends, coworkers, and teachers.

The second issue to be addressed is the dissociation between blood flow and metabolism in cortex adjacent to the epileptic focus. It is now well recognized that normal cortex adjacent to the seizure-generating area has a hypometabolic activity as demonstrated on preoperative fluorine-18-fluorodeoxyglucose positron emission tomography scans. This hypometabolic activity has been shown to recover after resection of the epileptic focus and once the seizures are well controlled. This phenomenon should be considered when preoperatively assessing cognition, as it accounts for the improvement seen in cognitive function postoperatively once the seizures stop. Hence every effort must be made to preserve that cortex with its potential for recovery.

The third issue is the white matter fiber anatomy that might be disrupted while performing the lateral transcortical approaches. Transcortical or transinsular approaches might cause injury to the different long associational fibers, and that in itself might result in a disconnection syndrome. Thus the choice of surgical approach should take into consideration all of these issues.

Several retrospective reviews in which transsylvian amygdalohippocampectomy were compared with temporal lobectomies have shown a better outcome with regard to total IQ as well as verbal and performance IQs when using the former procedure. The risk of developing severe global memory deficits or persistent dysphasia was absent in a series of nonlesional selective amygdalohippocampectomies; however, this risk was reported in 1–5% of temporal lobectomy cases. A slight decline in verbal memory was noted following left-sided transsylvian amygdalohippocampectomies, especially in patients who had good preoperative verbal memory function.

The superiority of the cognitive outcome after selective resections compared with that following anterior temporal
lobectomy was not as apparent when the resection was conducted via a transcortical approach or when the association fibers (uncinate fasciculus, anterior commissure, or occipitofrontal fasciculus) were disrupted at the limen insulae as a corticectomy is performed through the inferior insular sulcus as described in the study by Helmstaedter et al. 11

Visual Field Outcome

Superior quadrantanopia is a common complication of anterior temporal lobectomy. Several authors have reported rates as high as 78%. In a prospective randomized trial in which temporal lobectomy was compared with medical treatment, the rate of superior subquadrantic visual field defect was 55%. This rate has also been high with the transcortical amygdalohippocampectomy. The rate of visual field deficit in a study comparing transcortical amygdalohippocampectomies and temporal lobectomies was found to be identical at ~ 70%.

The transsylvian approach offers the advantage of staying medial to the Meyer loop and sparing the optic fibers. However, when using the transsylvian approach, care should be taken not to extend the hippocampal resection beyond the bifurcation of P2, as the lateral geniculate body could be injured, causing a visual field defect. In a series of 32 patients who underwent transsylvian amygdalohippocampectomy, Vajkoczy et al. 32 described 1 patient who had a superior quadrantanopia. After surgical treatment in 102 patients in Zurich and 73 in Little Rock, Yasargil and colleagues 33 reported superior quadrantanopia in just 2 cases, and both instances happened after a hematoma developed in the surgical field.

Conclusions

Amygdalohippocampectomy via the transsylvian approach is a challenging procedure that requires precise anatomical knowledge and thorough experience in microsurgical techniques. It offers a good rate of sustained seizure control. It decreases the risk of cognitive decline and visual field deficits when compared with the anterior temporal lobectomy and the transcortical amygdalohippocampectomy. In comparison with the subtemporal amygdalohippocampectomy, it decreases the risk of retraction injury to the temporal lobe and avoids the venous structures at its base. It also allows direct access to the mesial temporal structures that are often herniated through the tentorial incisura.

Disclaimer

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