The selective amygdalohippocampectomy for intractable temporal limbic seizures

Historical vignette

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Object. The proximal (anterior) transsylvian approach through a pterional craniotomy was developed by the senior author (M.G.Y.) in 1967 for the microsurgical treatment of saccular aneurysms of the circle of Willis, frontoorbital and temporobasal arteriovenous malformations, cavernomas, and extrinsic and intrinsic tumors. The acquired positive surgical experiences on this large series enabled the senior author, in 1973, to apply this approach for the selective amygdalohippocampectomy in patients with intractable mesial temporal lobe epilepsy.

Methods. The proximal (anterior) transsylvian-transamygdala approach to the mesial temporal structures permits the selective two-thirds resection of the amygdala and hippocampus-parahippocampus in an anteroinferior to posteroinferior exploration axis along the base of the semicircular temporal horn. This strategy ensures preservation of the overlying neopallial temporal convolutions such as the T1, T2, T3, and T4 gyri as well as the related subcortical connective fiber systems and other essential components of the temporal white matter.

The application of rigid brain self-retaining retractor systems was strictly avoided during the entire procedure. Computer-assisted navigation was never used. On routine postoperative CT scanning and MR imaging studies, infarction was not observed in any patient. The availability of tractography technology has proven that the connective fiber system around the resected mesial temporal area remains intact.

Results. The surgical outcome and results on neoplastic and vascular lesions of the mesiobasal temporal region have been presented in Volumes II, IIIB, and IVB of Microneurosurgery. The surgical outcomes and results in 102 patients with mesial temporal seizures who underwent surgery performed by the senior author in Zürich have been previously published.

In this paper, 73 patients who underwent surgery between 1994 and September 2006 in Little Rock, Arkansas, are presented, and 13 other patients are excluded who underwent surgery after September 2006. Altogether, among 188 patients who underwent surgery, there was no surgical mortality or morbidity, and no neurological deficits, new neurocognitive dysfunction, or impairments of the preoperative incapacities.

Conclusions. The surgical outcome in terms of seizures was rewarding in the majority of patients, particularly in those who exhibited the following irregularities on preoperative investigations: regular local dysfunctions on electroencephalography, dysmorphic changes in the mesiobasal temporal parenchyma on MR imaging studies, and hypometabolism in the anterior third of the temporal lobe on PET studies. (DOI: 10.3171/2008.12.JNS081112)

Key Words • mesial temporal epilepsy • diagnostic advances • proximal transsylvian-transamygdala approach • selective amygdalohippocampectomy

For the treatment of MTLE, a selective amygdalohippocampectomy through a proximal (anterior) transsylvian-transamygdala approach was introduced by the senior author (M.G.Y.) in 1973. The aim was to perform a “pure lesionectomy,” avoiding trauma to the adjacent, normal, and healthy temporal neopallial cortical-subcortical areas (T1–T4) and to the vasculature.

This approach comprises a pterional craniotomy and opening of the proximal (anterior) section of the sylvian fissure only 3.0–5.0 cm. A pial incision, 15–20 mm long, is made lateral to the M1 segment of the MCA between the origins of the temporal polar and anterior temporal arteries. This has been described and illustrated in detail in previous publications.55,59,60

On completion of this dissection of the fissure, the amygdala is gradually removed in its lateral and basal portions toward the crural and ambient cisterns. Once this is achieved, the temporal horn is explored in an anteroinferomedial axis. The hippocampus and parahippocampus are approached between the choroidal fissure, along the anterior sector of the transverse fissure, and the collateral sulcus, medial to the fusiform gyrus. The anterior two-thirds (2.5–3.0 cm long) of the hippocam-
Selective amygdalohippocampectomy

pul-para hippocampus is resected in an en bloc fashion, (required by the epileptologist in Zürich for subsequent biochemical studies). The surgical outcomes using this strategy in 102 patients at the University Hospital, Zürich, Switzerland, have been previously published. Since moving to the University of Arkansas for Medical Sciences in Little Rock in 1994, the surgical strategy for selective amygdalohippocampectomy has been partially modified because there is no longer a requirement for en bloc removal of the hippocampus for biochemical studies. Accessing through a pterional craniotomy and proximal transylvian-transamygdala approach, the lateral and basal portions of the amygdala and anterior third of the hippocampus-para hippocampus (1.0–1.5 cm long) are removed for histological studies using rongeurs, and the remaining middle portion of the hippocampus-para hippocampus (1.5–2.0 cm) is aspirated using an ultrasonography suction technique.

Methods

Between November 1994 and September 2006, 73 patients with drug-resistant nonlesional MTLE underwent surgery performed by the senior author (M.G.Y.); these cases have been retrospectively analyzed by 1 author (N.K.) regarding clinical and seizure outcome. Since this time, 8 patients have undergone surgery at the University of Arkansas for Medical Sciences, and 5 others have undergone surgery at other institutions. These cases are not included in this paper because of the limited follow-up period.

Presurgical Evaluation

Patients were evaluated and recommended for selective amygdalohippocampectomy by Victor B. Biton, M.D. (Arkansas Epilepsy Program at Baptist Medical Center), and Naim Haddad, M.D., and Bashir Shihabuddin, M.D., (Department of Neurology, University of Arkansas for Medical Sciences). The patients underwent follow-up performed by their referring doctors after surgery. The evaluation of patients with drug-resistant MTLE includes detailed patient history, physical examination, and video-EEG monitoring with ictal EEG to confirm the location of seizure onset. Thirty-six patients (49.3%) underwent a selective intracarotid amobarbital test (Wada). Neuropsychology and ophthalmology evaluations were routinely performed. Sixteen patients (21.9%) were evaluated with deep electrodes, 15 (20.5%) by FDG-PET,13,14,19 and 7 (9.6%) by interictal SPECT. All patients underwent preoperative MR imaging (after 2005, 3-T MR imaging). Intraoperative surface and deep electrodes were placed, and EEG recordings were obtained in all patients before amygdala and hippocampus removal to verify the source of seizure activity. They were placed again after resection, and EEG recording was repeated for comparison and control.

Pterional Craniotomy

The patient is positioned supine, and the head is fixed in the Mayfield-Kees system, elevated 30° above the chest, and turned 30° to the opposite side (Fig. 1). A semicircular frontoparietotemporal skin incision is made and the skin flap fixed laterally. After interfascial dissection, the muscle flap is turned and fixed posterolaterally.

A single bur hole is placed in the parietal bone, ~ 2.0 cm posterior to the pterion, below the temporal line in the shallow depression that runs obliquely over the lateral peritonal wing. A flexible dura mater dissector is used to dissect the dura free from the bone. Using a high-speed craniotome, a bone flap is created. It is important to extend the cut anteriorly as far as the origin of the frontozygomatic process. The margin of the bone flap along the greater sphenoid wing is drilled with a round, steel cutting bur, and the bone flap is elevated and removed. The lateral sphenoid wing and the bone projections on the superior orbital roof are flattened using the high-speed drill.

The dura is opened in a semicircular fashion around the middle sylvian fissure and arched toward the sphenoid ridge and orbit. The dura flap is snugly tented over the sphenoid ridge and orbit. The dura over the sylvian fissure is always cut in small portions, paying attention to the possibility of early entrance of the sylvian vein(s) into the dura (in ~ 1–2% of cases).

Surgical Anatomy of the Lateral Cerebral Cistern

The sylvian cistern comprises 3 distinct components, namely the fissure, the opercular sulci, and the fossa (Fig. 2).

The Sylvian Fissure. The sylvian fissure is a long (10–14 cm) division between the orbital, frontal, and parietal opercula on one side and the temporal operculum on the other side. The sylvian fissure is divided into 2 sections. The proximal section (also called the horizontal, anterior, medial, or sphenoidal limb) is located between the bifurcation of the ICA and the pars triangularis of the inferior frontal gyrus (F3), where the basal frontoorbital surface curves to the dorsal surface of the frontal brain (sylvian point). The configuration of the proximal section, which is 30–50 mm long, rarely follows a straight line. Often the lateral orbital gyrus makes a marked indentation laterally and compresses the medial surface of the superior temporal gyrus (polar planum), causing a C- or S-shaped course of the proximal fissure. The distal section of the sulcus (also called the lateral or posterior limb) extends from the sylvian point to the supramarginal gyrus, measures 6–9 cm long, and courses in a slightly or moderately undulating line because of indentations of the frontal, parietal, and temporal gyri into the sulcus.

The Interopercular Sulci. The sylvian fissure is intercepted by interopercular sulci, which are located between the opercular surfaces of the lateral orbital, inferior frontal, inferior parietal, and opercular surfaces of the superior temporal gyrus. These sulci are usually oblique and curved due to the indentations of the opposing gyri. Numerous short, thin, and fragile or even tough arachnoidal-pial fibers form a dense network within these very narrow (0.1–0.3 mm) sulci. In the proximal part of the fissure, the depth of the interopercular sulci is 10–30 mm. In the middle section of the sylvian fissure, between the subtriangular, subpercular, and subprecentral gyri
and the opposing parts of the superior temporal gyrus, the depth of the interopercular sulci increases to 25–40 mm. In the distal part of the sylvian fissure, between the subcentral, anterior, middle, and posterior transverse gyri of the inferior parietal lobe and the anterior and posterior transverse gyri (Heschl), the depth of the interopercular sulci increases even more (to 35–50 mm).

The Sylvian Fossa. The sylvian fossa is hidden beneath the opercula and consists of 3 sections: proximal, middle, and distal (Fig. 2 right).

The proximal section is located between the bifurcation of the ICA and the limen insula, where the MCA bifurcates into superior and inferior trunks. It is 30–50 mm long and 5–6 mm wide, and is called by anatomists the “vallecula” or preinsular sulcus (Fig. 2 right). Coursing within the vallecula are the M1 segment of the MCA, the lateral lenticulostriate arteries, deep sylvian vein, and, occasionally, M2 trunks that may originate in the proximal or middle part of the M1 segment. The lateral orbital gyrus often indents into the superior temporal gyrus at the level of the polar planum.

Along all these sections of the sylvian fossa, a dense network, occasionally even a membranous structure, of piaarachnoid fibers intertwine arteries, veins, and pial surfaces of the adjacent opercular and insular gyri.

The M1 Segment

The course of the M1 segment (3–5 cm long) does not always follow a straight, ascending diagonal line along the proximal sylvian fossa (in ~ 45% of cases) but may take an undulating C- or S-shaped route (Fig. 3). Furthermore, in ~ 10% of cases, the M1 segment makes a significant curve posteriorly and can be obscured by the arch of the limen insula (Fig. 4B). In ~ 40% of cases, the M1 segment makes a significant curve anteriorly (Fig. 4C), and in 1% of cases, double anterior curves (Fig. 4D). The proximal part of the M1 segment is rarely (~ 0.1–0.3%) fenestrated. In the literature, a duplication of the M1 segment is found in 0.3–3.0% of cases. At surgical exploration, 2, 3, or even 4 arteries, equal in size, coursing parallel to each other along the proximal sylvian fossa, may be identified. This perplexing configuration can be resolved by further exploring these arteries proximally as far as the ICA bifurcation, which reveals that this particular situation is related to the fact that the temporal arteries (polar, anterior, middle, and posterior temporal arteries) arise as a common trunk from the proximal or middle lateral wall of the M1 segment. This occurs in ~ 10% of cases (Fig. 5A). In another 8% of cases, the frontal arteries (temporal frontoorbital, prefrontal, and precentral arteries) arise as a common trunk from the medial wall of the M1 segment. This represents early bifurcation on the frontal side of the M1 segment (Fig. 5B). In ~ 2% of cases, both types of common trunks originated from the proximal sector of the M1 segment (Fig. 5C). Such unusual occurrences give the impression of a true duplication of the M1 segment. Another issue is the occasional (in ~ 0.5%) presence of an accessory MCA, which originates from a proximal or distal A1 segment (Fig. 5D), and which can also imitate a true duplication of the M1 segment. Four arteries are found in a combined variation such as that shown in Fig. 5E.

The M2 Segment

In 50% of cases, the M1 segment divides into superior (frontoparietal) and inferior (temporal) M2 trunks, usually at the level of the limen insula (Fig. 6B). In ~ 2% of cases, the M1 segment does not divide; it continues as a single trunk along the entire length of the sylvian fossa and consistently branches to the frontal, parietal, and temporal areas (Fig. 6A).

In ~ 15% of cases, the superior M2 trunk and, in another 10% of cases, the inferior M2 trunk divide again close to the M1 bifurcation, which is diagnosed on angiograms as a trifurcation (Fig. 6D and E). In ~ 8% of cases, the superior and inferior M2 trunks divide close to the M1 bifurcation, which gives the impression of a tetrafurcation (Fig. 6C). It is important to recognize that not just 2, but 3 M2 trunks may be present, namely superior, middle, and inferior trunks, which supply, with their branches, in a consistent and regular pattern the frontal, parietal, temporal, and lateral temporooroccipital areas.

The lateral frontoorbital and prefrontal branches may...
Selective amygdalohippocampectomy

arise from the M1 or superior M2 trunk. The precentral, central, anterior, and posterior parietal arteries may arise either from a superior (~60%), middle (~25%), or inferior (15%) trunk (Fig. 6D–F). The superior M2 trunk does not give any branches to the temporal lobe; rather, the middle and inferior trunks give branches to both the temporal and parietal areas (Fig. 6F).

The branches of the superior and middle trunks course over the insular gyri or along the insular sulci into the anterior and superior pouches (limbs) of the sylvian sulcus (Fig. 7). At the level of the anterior and superior periinsular sulci and within the retroinsular fossa, these branches angle 180° and follow a return course beneath the operculum as the M3 segment, pass through the narrow Sylvian fissure, and curve 180° around the operculum, reaching the lateral surface of the frontal and parietal lobes as M4 segments.

These arteries, as M1 branches, continue over the gyral surfaces or course through the depths of the sulci to areas of the middle frontal gyrus, pre- and postcentral gyri, and superior parietal lobe, where they may connect to the A5 branches of the ipsilateral anterior cerebral artery.

The inferior M2 trunk courses into the inferior pouch (limb) of the sylvian fossa beneath the temporal operculum, and gives anterior, middle, posterior, and temporocipital arteries, which pass the Sylvian fissure beneath the temporal operculum as M3 segments, reaching the surface of the temporal lobe as M4 segments. The M4 branches to the neopallial temporal lobe are connected to the temporal branches of the ipsilateral PCA.

In ~15% of cases, the inferior trunk gives branches to the pre- and postcentral and parietal areas. They course diagonally across the Sylvian fossa to reach the
superior and posterior pouches of the sylvian fossa, returning around the operculum to the lateral surface of the superior temporal gyrus. The variations and courses of the posterior communicating, anterior choroidal and posterior cerebral arteries and their branches are presented in Volumes I, II, and IVB of Microneurosurgery.10,58

Opening of the Proximal Sylvian Cistern, Fissure, Interopercular Suli, and Fossa

For the selective amygdalohippocampectomy, only the proximal sylvian cistern (3.0–5.0 cm long) is opened in the following stages. First, the lateral frontoorbital gyrus is displaced 2–3 mm with a small diameter suction tube in the left hand set with very low suction pressure. Bipolar forceps, 7.5 cm long, held in the right hand, explore the basal cisterns. The CSF is released between the optic nerve and the ICA or lateral to the ICA. The CSF release results in a relaxed brain prior to further exploration.

The sylvian fissure is covered with arachnoid membrane along its entire length. This membrane varies in each individual case, in its thickness, width, density, toughness, and fragility. The superficial sylvian vein(s) courses beneath this membrane, revealing great variations in number, length, and drainage routes, and usually with only scant adherence to the arachnoid membrane. The superficial sylvian vein(s) proves to be a valid and significant marker distinguishing the outline of the sylvian fissure. When absent, identification of the fissure can be quite difficult and perplexing. When confronted with this situation, a survey of the temporal and frontal arteries, in particular their divergent points of exit from the

Fig. 4. Illustrations showing the course variations of the left M₁ segment in the vertical plane: the straight diagonal (in 45% of cases [A]), posterior (in ~ 10% [B]), anterior (in ~ 40% [C]), and double anterior loupe (in ~ 5% [D]) courses.

Fig. 5. Illustrations of the branching variations of the left M₁ segment. A: The common trunk of the temporal arteries arising from the proximal or middle part of the M₁ segment (temporal early bifurcation; in ~ 10% of cases). B: The common trunk of the orbital and frontal arteries arising from the medial wall of the M₁ segment (frontal early bifurcation; ~ 18%). C: Both common trunks arising from the proximal or middle part of the M₁ segment (early pseudobifurcation; ~ 2%). D: The accessory MCA can imitate a double M₁ segment (~ 0.5%). E: The proximal origin of both trunks and accessory MCA imitating 4 M₁ segments (~ 0.1%).

M. G. Yaşargil et al.
Selective amygdalohippocampectomy

The sylvian fissure and their various courses, will promote recognition of the fissure. Familiar anatomical landmarks clearly identified on cadaver brains, such as the pars orbitalis, pars triangularis, and pars opercularis of the inferior frontal gyrus, as well as the horizontal, ascending, and diagonal rami of the sylvian fissure, are not always clearly distinguishable in the operating field during surgical exploration. A reliable assumption can be made that the pars triangularis of the inferior frontal gyrus is located in the same plane in which the anterior sylvian fissure curves from the basal orbital surface to the dorsal surface of the frontal brain. This discreet inflection is termed the “knee” of the sylvian fissure or the anterior sylvian point. The limen insula and bifurcation of the MCA are located beneath this area (1.0–2.0 cm deep). The tributaries of the temporal, frontal, and parietal veins drain into the sylvian vein(s), and this junction is termed the “sylvian venous confluence.” It is recommended to commence opening the fissure immediately anterior to the venous confluence, at a point where a temporal or frontal artery, or both arteries, appear at the surface of the fissure. In ~ 1% of cases, bulging parts of F3 and T1 hide the surfaces of the sylvian fissure.

Using a round arachnoid blade, a small (2–3-mm) incision is made on either side of the superficial sylvian vein(s), at a place where the superficial arachnoidal membrane is well demarcated. Incising the membrane at suitable points along a 3–4 mm length, the membrane can be gently split, from 1 incision to the next, by holding 1 edge of the incised membrane with short bipolar forceps and gently introducing very small, soft pledgets between the membrane and vein(s) without causing pressure. The entry through the initial incisions into the interopercular sulci is accomplished by holding the edges of the membrane with 2 short forceps (2.5 cm) and meticulously splitting the membrane, millimeter by millimeter, proximally then distally, to a length of 10–15 mm on the surface. The interopercular sulci (Fig. 2) between opposing opercular frontoorbital and temporal surfaces, ~ 0.1 mm wide, are tightly closed using numerous fibers, which can be tender or tough. Small, soft, flat pledgets (1.0 × 1.0 mm) are gently glided between the pial layers. Gradual and meticulous

Fig. 6. Illustrations showing variations of MCA divisions on the left side. A: No bifurcation (~ 2% of cases). B: Typical bifurcation with superior and inferior trunks (50%). C: Pseudo-tetrabifurcation; early divisions of superior and inferior trunks create 4 trunks (~ 8%). D: The middle trunk originates from the inferior (temporal) trunk (~ 10%). E: The middle trunk originates from the superior (frontal) trunk (~ 15%). F: The middle trunk arises from the distal inferior (temporal) trunk (~ 15%).
compression on the pledget by the forceps, aided by a fine suction tube (minimal suction pressure), achieves a gentle spreading action.

To protect the fragile pial layers and slender pial vessels, small, soft pledgets (of high-quality cotton) are applied to the exposed areas as dissection proceeds and, with minimal pressure of the forceps and suction tube, the adjacent lateral, orbital, and superior temporal gyri are meticulously and carefully separated. Exploring first in a direction toward the limen insulae establishes the location of the MCA bifurcation, which will prove to be an authentic reference point. The M1 segment is followed along its dorsal surface proximally, where no branches arise. The deep Sylvian vein lies hidden beneath the M1 segment.

As mentioned earlier, the proximal Sylvian fissure is seldom rectilinear, but frequently it forms a C or an S shape, due to indentation of the lateral orbital gyrus into the superior temporal gyrus (polar planum) or vice versa. This complex configuration imposes the need to continue with skill and precision to open the proximal Sylvian fissure, interpeduncular sulci, and Sylvian fossa along the dorsal surface of the M1 segment until the area of the ICA bifurcation is reached. The fissure is opened from inside to outside, that is, from the inside toward the surface. The superficial arachnoid membrane can then be opened using scissors or a round knife blade in between crossing frontoorbital veins and superficial Sylvian vein(s). The strong arachnoid fibers over the ICA bifurcation are severed using scissors.

Using gradually longer bipolar forceps (2.5, 3.5, 5.5, and 7.5 cm), small to larger soft cotton pledgets, and a low-pressure small suction tube, the proximal Sylvian fissure and fossa are opened along the entire length (3.0–5.0 cm). Dissection of the proximal Sylvian fissure is completed without application of a rigid self-retaining retractor system.

Opening the proximal Sylvian fissure can be accomplished in an atraumatic manner, but occasionally this procedure can be extremely difficult and time consuming (30–60 minutes). A profound knowledge of neuroanatomy and surgical skills, acquired through intense laboratory training, are essential to successfully accomplish these maneuvers for atraumatic opening of the often closely adherent interopercular sulci (Figs. 8 and 9).

Opening of the proximal Sylvian fissure, interopercular sulci, and fossa allows inspection of the M1 segment of the MCA with its branches and variations, the ICA, and the PCoA, as well as the AChA with its striocapsular branches, the ipsilateral A1 segment, the adjacent veins (the deep Sylvian, anterior cerebral, and basilar veins), and cranial nerve III. It is important to identify the exact anatomical location and course of these structures before proceeding with dissection and removal of the amygdala. The space between the tentorial edge and the ICA can occasionally be very narrow (1–2 mm). In this series, the uncus and mediobasal part of the parahippocampus were often found to be ≥ 3–5 mm below the tentorial edge.

Selective Removal of the Amygdala-Hippocampus-Parahippocampus

Two large but very soft cotton pledgets, saturated with saline, are positioned at the proximal and distal ends of the opened proximal Sylvian fissure and fossa (3.0–5.0 cm long, 0.5–1.0 cm wide). Exerting gentle pressure, these 2 pledgets maintain a cleft in the Sylvian fissure, giving adequate access to explore and to dissect the mesiobasal temporal structures without applying a rigid retractor system. A small pledget is left as a marker over the AChA. A pial incision into the piriform cortex, just over the amygdala is made 2–3 mm lateral to the M1 segment and lateral to the deep Sylvian vein, between the temporal polar and anterior temporal arteries or distal to the latter depending on the individual anatomy (Fig. 10).

In some cases the tip of the temporal horn can be easily located in an anteroinferomedial direction. However, as the CSF is routinely released at the first stage of surgery by opening the parachiasmal cisterns, the ventricle may collapse, consequently rendering it more difficult to locate the tip of the temporal horn. Therefore only the lateral parts of the amygdala should be removed initially until the tip of the temporal horn can be identified (Fig. 11) (see also Yaşargil et al., 60 p. 110, Figs. 8 and 9).

The superior part of the amygdala (piriform cortex) can be recognized by its beige color. A 10–15-mm-long incision is made and samples of amygdala are removed,
Selective amygdalohippocampectomy

using a biopsy rongeur, for histological examination. The lateral, anterior, basal, and cortical nuclei of the amygdala are then aspirated using the ultrasound suction system, until the transparent curtain of pial and arachnoid membranes, adjacent to the crural and ambient cisterns, is reached. Through these membranes can be seen the optic tract and oculomotor nerve, as well as the PCoA and AChA and their branches, the P1 and P2 segments of the PCA and their branches, and the basilar vein, as well as their individual anatomical variations and pathways. Along the semicircular axis of the temporal horn, the choroidal fissure, choroidal plexus, taenia fimbria, pes and body of the hippocampus, and eminentia collateralis are all inspected (Fig. 11).

The choroidal plexus is then displaced medially, and the transparent membrane of the choroidal fissure opened between the plexus and taenia fimbria; thus the course of the AChA, basilar vein, and optic tract can be explored (Fig. 12).

A small but regular lateral branch of the AChA, which supplies the anterior part of the parahippocampus and uncus, is dissected, coagulated, and severed (Fig. 13). The medial branches of the AChA, which supply the optic tract, lateral geniculate body, and posterior limb of the internal capsule, should always be preserved. The anterior portions of the hippocampus and parahippocampus (10–15 mm long) are removed with rongeurs and preserved for histological studies. The posterior parts of the hippocampus-parahippocampus (10–15 mm long) are gradually aspirated using CUSA and regular suction, as far as the posterior rim of the cerebral peduncle where the P2 segment bifurcates. The collateral eminentia is a reliable and consistent landmark, indicating entrance into the collateral sulcus and helping to identify the fusiform gyrus lateral to it.

The arterial supply to the posterior two-thirds of the hippocampus-parahippocampus arises either from the distal sector of the P2 segment as a separate single artery, or from the inferior temporal or tempororooccipital branches.10,21 They are identified at the entrance to the hippocampal sulcus, coagulated, and severed (see Fig. 13 in Yaşargil et al.60). The hippocampal vein draining into the basilar vein is saved until the final phase of resection, and then it is coagulated (Figs. 14 and 15).

Intraoperative preresection recording of electrical activities with surface electrodes (temporal pole, T1–T3, and frontoorbital) and deep electrodes (amygdala, hip-
pocampus-parahippocampus) is essential to confirm the source of seizure activity, and is repeated after resection for comparison and control. In 5 patients, postresection recording indicated the necessity to further remove ~1.5–2 cm subpially toward the medial sector of the temporal pole. An epileptologist was always present in the operating room to evaluate the recordings and relay the results and opinions to the surgeon.

Specific Surgical Problems

The proximal transsylvian-transamygdala approach for selective amygdalohippocampectomy is a challenging procedure even for an experienced microneurosurgeon. This is because many vital structures are encountered during exploration along the narrow sylvian fissure and through the transamygdala entrance, which is only 10–15 mm in diameter, that need to be identified, dissected, and then preserved: the interopercular sulci and the sylvian fossa, crural and ambient cisterns, choroidal fissure with choroidal plexus, optic radiation, oculomotor nerve, the AChA and PCA and their branches to the hippocampus-parahippocampus, and the basilar vein with its tributaries. The rigid self-retaining retractor system would traumatize the parenchymal structures and would stretch the arachnoid and pial fibers, consequently resulting in spasm of the arteries. A thorough training in the laboratory will enable the microneurosurgeon to dissect and explore along the described proximal sylvian fissure and transamygdala without use of the rigid retractor system.

Extraordinary diverse individual variations were observed in the length, thickness, and tensile strength of both the sphenoid wing and anterior clinoid process, and in the width of the middle fossa. This may create a more complex surgical exploration, as previously described by Penfield.

The superficial and deep sylvian vein(s) and their tributaries from the orbital and temporal gyri can be well dissected and saved. Variations are frequently encountered in the pattern and distribution of the temporal branches of the M1 segment. It is important to create sufficient space for a 10–15-mm incision between the temporal polar and anterior temporal arteries, which can be achieved by mobilizing a few millimeters of these branches of the M1 segment. Specific care and attention are directed to the short, straight course of the temporal polar artery to avoid stretching or damage.

Resection of the amygdala using biopsy rongeurs, tumor ring forceps, and suction (regular and/or CUSA) is usually nonhemorrhagic. On approaching the ventricle wall, however, one must be aware of veins coursing from the amygdala within the subependymal layer, which continue subependymally to the choroidal fissure and thence to the basilar vein. Any injury to these veins or to the basilar vein could result in severe venous hemorrhage retrograde from the vein of Galen, which the senior author experienced in 1 case. In these instances, application of a
small sponge and gentle compression to the bleeding vein reveals the bleeding corner of the vein, which is then controlled using bipolar coagulation at a lower setting.

Volumetrically, ~70% of the amygdala is resected. From a surgical perspective, the lateral, anterior, basal, and cortical nuclei of the amygdala are removed, whereas the areas medial to the optic tract, such as the neighborhood of the amygdalostriatal zone, are intentionally not explored and removed.

The size and configuration of the hippocampus-parahippocampus varies considerably. In some cases it curves only gently around the peduncle, while in others it resembles the form of a coiled worm. A possible explanation for differences in the shape of this structure could be attributed, partially, to the size and formation of the skull, in particular the pterional wing and middle fossa. These variations require further study by neuroanatomists.

Individual anatomical variations pertaining to the connections between the parahippocampus and fusiform gyrus (lateral temporoccipital) have been observed. For example, 1 or 2 parenchymal bridges have been seen to intercept the collateral sulcus, and in some patients the rhinal sulcus was not present. Possible surgical consequences of these anatomical deviations emerge. The lateral parts of the parahippocampal gyrus may not be readily identified and remain unresected, or the medial part of the fusiform gyrus may be inadvertently removed, which can occur if the collateral sulcus is very tightly closed. The MR imaging technology demonstrates these variations, but only to a certain degree. Adequate detail is lacking.

Following the advice of Glenda Miller, pioneer in the field of neuropsychology at Montreal Neurological Institute, the posterior third of the hippocampus-parahippocampus is not resected, to prevent possible short-term memory deficits.

Another reason for this restricted resection is to avoid injury to the vasculature of the lateral geniculate body. Pertuiset et al. described ophthalmological symptoms that are caused by occlusion of the AChA and found that these symptoms occur depending on the site of the occlusion and its relation to the lateral geniculate body. In pregeniculate lesions, a noncongruent hemianopia and macular sparing, ipsilateral pupillary dilation, and no reaction to light in the blind half of the retina are resulting deficits. If the geniculate branches of the AChAs are damaged, an upper quadrantanopia is produced. Damage to the branches supplying the optic radiation and continuing through the retrolenticular and sublenticular segments of the internal capsule produce a congruent hemianopia with macula sparing. Therefore preservation of any medial branches, particularly of the striocapular branches of the AChA, is of extreme importance.
Postoperative Evaluation

Postoperative seizure control was classified according to the Engel classification. Subgroups were further analyzed according to preoperative evaluation and postoperative histological result. Patients were divided into 6 groups depending on whether they had an ictal EEG with seizure origin within the mesial temporal lobe, an MR image with signs of mesial temporal sclerosis, hypometabolism of the temporal lobe on PET studies, and a positive pathological result with signs of sclerosis, gliosis, or satellitosis (Table 1).

Patients were observed by their referring neurological center at 3, 6, and 12 months after surgery and yearly thereafter, depending on their seizure status. Antiepileptic medications were gradually decreased based on postoperative seizure control and desires of the patient and his or her family. The number and dosage of seizure medications were noted at each follow-up. All patients were evaluated for visual field defects by a neuroophthalmologist.

Results

General Features

Between 1994 and 2006, 73 patients (female/male ratio 36:37) with a mean age at exploration of 39.7 years underwent surgery. The mean age at seizure onset was 16.4 years, and the mean duration of seizure activity was 21.9 years. In 44 patients (60.3%) seizure onset was on the left, and in 29 patients (39.7%) it was on the right. Complex partial seizures were present in 89.0%, simple partial seizures in 32.9%, secondary generalization in 64.4%, and a combination of the different seizure types was pres-
Selective amygdalohippocampectomy

ent in 68.5%. A history of febrile seizures was present in 11%, a history of meningitis or encephalitis in 15.1%, and a history of cerebral trauma in 19.2%. There was a family history of seizures in 28.8%. Presurgical evaluation with MR imaging showed signs of mesial temporal sclerosis in 45.2%. Histopathology revealed sclerosis in 48% of patients and gliosis in 41%. Tissue was found to be normal in 11% of cases. Details describing clinical features are found in Table 1.

Prior to amygdalohippocampectomy, 2 patients had previously undergone surgery for seizures: 1 patient had partial temporal lobectomy and the other had a vagal nerve stimulator implanted, both at other institutions.

Fourteen patients (19.2%) had been prescribed 1 seizure medication before surgery, 48 patients (65.8%) 2 medications, 10 patients (13.7%) 3 medications, and 1 patient (1.4%) 4 medications.

Surgical Outcome

The mean (± SD) follow-up of the 73 surgically treated patients was 4.3 ± 3.2 years. Regarding seizure outcome as classified by the Engel classification, 75.3% of patients were classified as Class I, 17.8% as Class II, and 6.8% as Class III. The statistics pertaining to each Engel class are summarized in Table 2.

Analyzing the various pathological conditions, in those patients with sclerosis, a Class I outcome was achieved in 88.6% and Classes II and III in 5.7%. One of these patients needed further resection and vagal nerve stimulator implantation during follow-up. In those patients with gliosis, a Class I outcome was achieved in 66.7%, Class II in 30%, and Class III in 3.3%.

In patients with normal findings on histopathological examination, outcome was Class I in 50%, and Classes II and III in 25% of cases. One of these patients had previously undergone surgery with partial temporal lobectomy at another institution. Details of pathology in relation to Engel class are given in Table 2.

When seizure outcome of the various subgroups is analyzed according to preoperative evaluation and histological findings (Tables 3 and 4), the best outcomes were seen in the 30 patients in Group 1 (90% Class I) in whom EEG, MR imaging, and pathological results were abnormal. In the 31 patients in Group 4 (74.2% Class I), the EEG and histopathological findings were abnormal, but the MR images did not reveal any changes. The question remains whether higher-tesla MR imaging technology will visualize some convincing changes. In Groups 2, 3, and 5 the number of cases is too few to evaluate. In Group 6, the 7 patients had normal MR imaging and histopathological findings, but because of focal seizure activities in the temporal lobe only 42.9% attained good surgical results.

Postoperatively, 31 patients (42.5%) had discontinued their seizure medication, 22 patients (30.1%) took only 1 medication, 12 patients (16.4%) took 2 medications, 6 patients (8.2%) took 3 medications, and 2 patients (2.7%) took 4 medications (Table 5).

Discussion

Analysis of the collected pre- and postoperative data for 73 patients who underwent selective amygdalohippocampectomy revealed 2 specific conclusions: the procedure is demanding, but it is effective.

Surgical Challenges

The proximal (anterior) transsylvian-transamygdaloid approach for selective amygdalohippocampectomy with subtotal removal of the amygdala and removal of the anterior two-thirds of the hippocampus-parahippocampus is a demanding surgical procedure. A comprehensive knowledge of the detailed anatomy pertaining to this region, which is fraught with numerous intricate variations, is an essential component in achieving successful surgical dissection and resection.8,11

Learning and improving microsurgical skills and techniques in the cadaver-laboratory complements knowledge of anatomy and contributes to accomplishing selective amygdalohippocampectomy through the natural anatomical opening along the proximal sylvian fissure.8,10,46,47

The anterior third of the hippocampus-parahippocampus (~ 1.0–1.5 cm long) is resected for histological
examination, and the posterior two-thirds of the hippocampus-parahippocampus (~2.0–2.5 cm long) is aspirated between the taenia fimbria and collateral sulcus. Applying microsurgical techniques to approach along the anteroinferomedial to posteromedial curvature axis of the temporal horn and hippocampus permits the selective removal of archi- and paleopallial areas of the mesiobasal temporal lobe, leaving intact and untouched the lateral and dorsolateral walls of the temporal horn, the neopallial temporal gyri such as T1, T2, T3, and T4, and their white matter.

Accurate resection of selective amygdalohippocampectomy was demonstrated using CT scanning technology in Zurich in 1973. The MR imaging technology (acquired in Zurich in 1986) visualizes the individual structures at a higher resolution. Diffusion tensor MR imaging technology reveals the preservation of important fiber tracts following the surgical procedure of selective amygdalohippocampectomy, for instance the temporal loop of the optic radiation, the anterior commissure, inferior fronto-orbital fasciculus, temporopontine fibers, inferior thalamic peduncle, and the neopallial connection of the uncinate fasciculus (Fig. 16).

The white matter has a seemingly amorphous, homogenous appearance, but presents the most ingenious architecture of evolution in its anatomical, embryological, biophysical, biochemical, genetic, and immunological aspects. The known components of white matter are the 3D myriad networks of perfectly organized myelinated and unmyelinated fiber systems, a network of intraparenchymal vascular and CSF pathways, cellular and fluid components of the endocrine and immune systems, stem cells, and newly generated glial and neuronal cells migrating between fibers and other pathways. The detailed architecture of the fiber systems remains unknown, with their lamellae, similar to curling leaves of a cabbage, stratified in 3D layers as described by Malpighi, who used for his studies a monocular microscope. In 1963, Krieg proposed that there might be bifurcations of these 3D layers.

The perpetual and generally perfect regulation governing the transmission activities of fiber systems and the intricate microarchitecture of the fiber systems, as well as the physiochemical tandem functions of neurons and TABLE 1: Clinical characteristics of 73 patients who underwent selective transsylvian-transamygdala hippocampectomy for MTLE

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Female (%)</th>
<th>Male (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex (%)</td>
<td>36 (49)</td>
<td>37 (51)</td>
<td>73 (100)</td>
</tr>
<tr>
<td>mean age at seizure onset (yrs)</td>
<td>16.0 ± 12.5</td>
<td>15.8 ± 11.3</td>
<td>16.4 ± 11.9</td>
</tr>
<tr>
<td>mean age at op (yrs)</td>
<td>37.5 ± 9.4</td>
<td>38.3 ± 13.0</td>
<td>37.9 ± 11.3</td>
</tr>
<tr>
<td>mean duration of epilepsy (yrs)</td>
<td>21.2 ± 1.1</td>
<td>22.8 ± 14.9</td>
<td>21.9 ± 13.1</td>
</tr>
<tr>
<td>side of op l/r</td>
<td>24/12 (66.7/33.3)</td>
<td>20/17 (54.1/45.9)</td>
<td>44/29 (60.3/39.7)</td>
</tr>
</tbody>
</table>

* Unless otherwise indicated. Mean values are presented as ± SDs.

<table>
<thead>
<tr>
<th>Pathology</th>
<th>Female (%)</th>
<th>Male (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTLE on MRI</td>
<td>14 (38.9)</td>
<td>19 (51.4)</td>
<td>33 (45.2)</td>
</tr>
<tr>
<td>gliosis</td>
<td>19 (52.8)</td>
<td>11 (29.7)</td>
<td>30 (41)</td>
</tr>
<tr>
<td>sclerosis</td>
<td>13 (36)</td>
<td>22 (59.5)</td>
<td>35 (48)</td>
</tr>
<tr>
<td>normal findings</td>
<td>4 (11)</td>
<td>4 (10.8)</td>
<td>8 (11)</td>
</tr>
<tr>
<td>mean follow-up (yrs)</td>
<td>5.0 ± 3.7</td>
<td>3.5 ± 2.5</td>
<td>4.3 ± 3.2</td>
</tr>
</tbody>
</table>

* Additional surgeries noted here were performed at other institutions.

TABLE 2: Outcome according to the Engel classification of 73 patients who underwent an anterior transsylvian-transamygdala hippocampectomy

<table>
<thead>
<tr>
<th>Engel Class</th>
<th>Sex (%)</th>
<th>Pathology (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>I</td>
<td>27 (75)</td>
<td>28 (75.7)</td>
</tr>
<tr>
<td>II</td>
<td>7 (19.4)</td>
<td>6 (16.2)</td>
</tr>
<tr>
<td>III</td>
<td>2 (5.6)</td>
<td>3 (8.1)</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>total</td>
<td>36</td>
<td>37</td>
</tr>
</tbody>
</table>
Selective amygdalohippocampectomy

TABLE 3: Subgroups related to the analysis of preoperative interventions in patients with MTLE

<table>
<thead>
<tr>
<th>Group No.</th>
<th>No. of Patients</th>
<th>EEG*</th>
<th>MRI†</th>
<th>Histology‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>(+)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>total</td>
<td>73</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* + = confirmation of seizure origin within the mesial temporal lobe by ictal EEG; (+) = limbic and extralimbic seizure activities are seen on EEG.
† + = confirmation of mesial temporal sclerosis on MR imaging; − = not confirmed.
‡ + = histological confirmation of hippocampal sclerosis or gliosis; − = not confirmed.

The dorsal and basal temporal transcortical and transsulcal approaches to the mesial temporal region are rejected by the senior author (M.G.Y.) because it is not possible to preserve the neopallial temporal gyri and the delicate architecture and functions of the white matter during these explorations (Fig. 17).1,3,5,6,9,12,15–18,22,24,26–28,31,32,34,35,38,40–45,48,49,50,56,65 However, the supracerebellar-transsylvian approach can be considered in patients with intractable seizures and no involvement of the temporal pole region.

**Effectiveness of Selective Amygdalohippocampectomy**

The total operating time for the proximal transsylvian selective amygdalohippocampectomy procedure averages 3–4 hours. All patients awoke immediately from general anesthesia. There were no deaths due to surgery. No immediate or delayed neurological deficits were observed with the exception of 1 patient who developed, 24 hours postsurgery, progressive hemisyndrome due to hematoma in the subdural space and in the resection area.

TABLE 4: Seizure outcome in 73 patients according to the Engel classification in relation to preoperative evaluation and postoperative histological result

<table>
<thead>
<tr>
<th>Engel Class</th>
<th>Group No.</th>
<th>I (%)</th>
<th>II (%)</th>
<th>III (%)</th>
<th>IV (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27 (90)</td>
<td>2 (6.7)</td>
<td>1 (3.3)</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 (50)</td>
<td>1 (50)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>2 (100)</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>23 (74.2)</td>
<td>6 (19.4)</td>
<td>2 (6.5)</td>
<td>0</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 (100)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3 (42.9)</td>
<td>2 (28.6)</td>
<td>2 (28.6)</td>
<td>0</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>55 (75.34)</td>
<td>13 (17.8)</td>
<td>5 (6.8)</td>
<td>0</td>
<td>73 (100)</td>
<td></td>
</tr>
</tbody>
</table>

The hemisyndrome resolved completely after removal of the hematomas. In this patient only, a permanent superior quadrantanopia was observed (Tables 6 and 7).

Postoperative MR imaging studies, obtained 1 day and 3 months after surgery, showed a selectively resected amygdala-hippocampus-parahippocampus in all patients. No other parenchymal injury was observed. Postoperative PET studies showed diminished hypometabolism of the ipsilateral temporal lobe.14,19 A similar improvement was observed on MR imaging spectroscopy studies.

The preoperative neuropsychology evaluation, including verbal and figural memory, association, learning and planning, spoken and written language, and mathematics tests revealed normal findings in 12 patients (16.4%), and mild, moderate, and severe changes in 24 (32.9%), 32 (43.8%), and 5 (6.8%) patients, respectively (Table 8).

During the postoperative course a deterioration of mental functions was not observed in any patient. Temporary short-term memory weakness was noticed in 26 patients (35.6%); in 14 cases surgery was on the left and in 12 cases on the right. However, in 44 patients (60.3%) the neuropsychology evaluation revealed remarkable improvement in mental function, which is the consequence of freedom from seizures and cessation of seizure medication (Table 8). All patients were seen at routine clinic visits, but in 29 patients (39.7%) neuropsychology evaluation is pending.

Selective amygdalohippocampectomy, avoiding involvement of the neopallial temporal area during dissection, is advocated as an effective therapeutic procedure for patients with mesial temporal lobe seizures. Approximately 70% of patients became seizure free. In 20% of patients, seizures reduced in frequency and intensity, and could be better controlled. In 10% of patients, seizure activity remained unchanged. We hope that further advances in clinical studies of patients with so-called temporal lobe epilepsy and advances in EEG monitoring, PET scanning, and 7-T MR imaging will lead to a better understanding and differentiation in these 30% of patients.

Freedom from seizures has positive consequences for the patients’ overall quality of life, regardless of whether they remain medication free or medication dependent. Verbal and figural memory improves, mood swings and depression recede, self-confidence and independence are gained, and sexual life improves.

Long-term results of seizure outcome following selective amygdalohippocampectomy in 102 patients who

TABLE 5: Number of seizure medications taken by the patients*

<table>
<thead>
<tr>
<th>No. of Drugs</th>
<th>Preop</th>
<th>Postop</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>0</td>
<td>31 (42.5)</td>
</tr>
<tr>
<td>1 AED</td>
<td>14 (19.2)</td>
<td>22 (30.1)</td>
</tr>
<tr>
<td>2 AEDs</td>
<td>48 (65.8)</td>
<td>12 (16.4)</td>
</tr>
<tr>
<td>3 AEDs</td>
<td>10 (13.7)</td>
<td>6 (8.2)</td>
</tr>
<tr>
<td>4 AEDs</td>
<td>1 (1.4)</td>
<td>2 (2.7)</td>
</tr>
<tr>
<td>total</td>
<td>73</td>
<td>73</td>
</tr>
</tbody>
</table>

* AED = antiepileptic drug.
underwent surgery at the University Hospital in Zurich and 73 patients who underwent surgery at the University of Arkansas for Medical Sciences in Little Rock, who suffered nonlesional MTLE, are very similar. Recent advances in the neurosciences and in scientific technology, for instance, higher-quality EEG monitoring, video-EEG, intraoperative surface and deep electrode EEG, 3- or 7-T MR imaging, MR imaging spectroscopy, diffusion tensor imaging, and improved histopathological studies offer rewarding prospects for our patients suffering drug-resistant epileptic seizures.

These greatly appreciated diagnostic innovations enable differentiation between the following 4 varieties of MTLE:

1) Macrolesions surgically treated by the senior author between 1967 and 2006: extrinsic tumors of the middle fossa [meningiomas, chordomas, epidermoids]; optic tract glioma [186 cases] and intrinsic tumors [330 cases]; cavernomas [16]; AVMs [15] in the mesial temporal lobe; and large saccular aneurysms [6] in the PCoA and the P2 segment, which affect the mesial temporal structures directly or indirectly.

2) Microlesions (dysgenesis) such as sclerosis, gliosis, volume reduction, hypometabolism, all of which can be well visualized on MR imaging, PET, and histopathological studies (see Table 2). 

3) Seizures identified only on EEG studies in the mesial temporal lobe, but not seen on MR images, PET, or histopathological studies.

4) Infectious diseases localized in the mesial temporal lobe; for example, herpes virus encephalitis.

The complete elimination of macrolesions, particularly of AVMs, cavernomas, and gliomas of the mesial basal temporal lobe through an anterior transsylvian approach, resulted in cessation of seizures in 96% of patients. These patients regained full activities in their private and professional lives. Of patients with microlesions of the amygdala-hippocampus, 90% became seizure free and enjoyed good quality of life. Of patients with focal findings on EEG and normal MR imaging, PET, and histopathological findings of the amygdala and hippocampus, only 42.8% became seizure free.

We are aware that evaluating these statistical results is more complex. Many other factors influence the surgical outcome, including seizure type, history of seizure onset (for example trauma, infection, and heredity), and time span between seizure onset and surgical intervention, among others.

The goal of neurosurgical treatment is always to perform a “pure lesionectionomy” and to avoid harm to the adjacent normal tissues and prevent disturbance of their functions. If it would be possible for the epileptologist to define precisely the parts of the amygdala, hippocampus, parahippocampus, or mesial temporal pole to be removed, this would prove to be an important advance. The cooperation and resolve of our partner disciplines in neuroscience are welcomed, and we support their sustained efforts to comprehend and formulate objectively the extent of resection.

![Fig. 16. A: Coronal MR image obtained after a left-sided selective amygdalohippocampectomy was performed in a 23-year-old man with mesial temporal epilepsy since his childhood. Arrows indicate the anterior commissure. B: Diffusion tensor tractography in the same patient. The yellow area denotes the anterior commissure; green, the uncinate fascicle; and pink, the inferior frontooccipital fascicle. C: Axial postoperative diffusion tensor MR image obtained in the same patient. Blue area denotes posterior thalamic peduncle together with optic radiation. Since surgery 2 years ago, no seizure has occurred.](image)

![Fig. 17. Photograph of a cadaver brain showing the different approaches for selective amygdalohippocampectomy. The proximal transsylvian-transamygdala (1), transgyral (2), transsulcal (3), subtemporal (4), and supracerebellar-transtentorial (5) approaches. Reprinted from Yaşargil et al: J Neurosurg 101:725–738, 2004.](image)
Selective amygdalohippocampectomy

TABLE 6: Neurological deficits

<table>
<thead>
<tr>
<th>Deficit</th>
<th>Preop</th>
<th>Temporary</th>
<th>Permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensorimotor</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>cranial nerve</td>
<td>0</td>
<td>3 (oculomotor)</td>
<td>0</td>
</tr>
<tr>
<td>visual field</td>
<td>0</td>
<td>0</td>
<td>1 (superior quadrantanopia)</td>
</tr>
</tbody>
</table>

TABLE 7: Speech difficulties in 73 patients

<table>
<thead>
<tr>
<th>Difficulty</th>
<th>Preop</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>53</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>mild</td>
<td>12</td>
<td>0</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>moderate</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>total</td>
<td>73</td>
<td>45</td>
<td>20</td>
<td>8</td>
</tr>
</tbody>
</table>

* These difficulties were temporary (surgery was on the right side in 3 patients and on the left in 5).

TABLE 8: Mental condition determined by neuropsychology evaluation*

<table>
<thead>
<tr>
<th>Mental Deterioration</th>
<th>Preop</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>none</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>mild</td>
<td>24</td>
<td>6</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>moderate</td>
<td>32</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>severe</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>total</td>
<td>73</td>
<td>10</td>
<td>22</td>
<td>19</td>
<td>6</td>
</tr>
</tbody>
</table>

* Evaluated by verbal, figurative memory, associations, learning, planning, decision, language, affects, and behavior testing. There was short-term (3–6 months) memory deficit in 26 patients (35.6%). Of these, 14 had undergone surgery on the left side and 12 on the right.

† Findings from the postoperative neuropsychology evaluation were available in 44 patients (60.3%). In the remaining 29 patients, the results are pending.

necessary in the mesiobasal temporal limbic structures. There is justifiable reason to believe that further advances in molecular biology research will lead to accurate definition of therapeutic options for the treatment of patients with temporal limbic seizures.

Conclusions

Patients with MTLE presenting with definitive abnormalities on EEG, MR imaging, MR imaging spectroscopy, and PET studies should not be subjected to lengthy experimental drug therapies, but be offered the treatment of selective amygdalohippocampectomy, a pure lesionectomy, avoiding injury to the intact and unaffected neopallial temporal lobe.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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M. G. Yaşargil et al.

20. Krieg WJS:

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