Epilepsy Surgery

Ersin Erdoğan, Zeki Gökçil

History

Cemil Pasha (Dr. Cemil Topuzlu), who performed the first recorded brain surgery in Turkey, described the trepanation surgery in a patient with Jacksonian epilepsy in detail in his book “Memories at Observations Medicales” published in 1905. (6). (Figure 1) It is known that William MacEven and Victor Horsley first localized and removed the epileptic area in London. This knowledge was first reported by Wilder Penfield in 1936

Figure 1: Cemil Pasha (Dr. Cemil Topuzlu) (1866-1958): Cemil Pasha, the pioneer of modern surgery in Turkey, made many surgical innovations as well as many neurosurgical firsts. Laminectomies performed to relieve spinal cord compression in Pott's disease, laminectomies performed in spinal cord injuries, and trepanation operations performed in brain abscesses are some of these.

The first temporal lobectomy with EEG guidance was performed in Boston in 1947 by Percival Bailey and neurologist Frederick Gibbs. The discovery of PET in the late 1970s and MRI in the 1980s increased the interest in epilepsy surgery in patients with potentially drug-resistant epileptic lesions worldwide (24). The increase in these examinations reduces the number of unknowns in patients before surgery. With more lesion-specific approaches, MRI and functional imaging examinations (PET and SPECT), it is easier to reveal the epileptic lesion and functional deficit zone. Developments have been further supported by the digital storage of EEG and videos..

In the last thirty years, very important developments have increased the feasibility of epilepsy surgery; These are; microsurgery, improvement in surgical results, acceptance that brain surgery can also be elective surgery, development of new views and fields regarding epileptogenesis, and simultaneous stereo-EEG with superficial and deep electrodes, and the spread of epileptic activity is more clearly revealed (24).

The epileptogenic zone is the area in the cortex that must be present for an epileptic patient to have a seizure. This view can only be proven by the cessation of seizures after surgical removal. In clinical practice, the existence of the epileptic zone in many centers can be said for cases where the epileptic zone cannot be clearly demonstrated despite using all available examination methods (15). What is drug-resistant epilepsy?Epilepsy is a disease that can limit the quality of life and cause patients to become dependent on behavioral, psychological, social, economic and legal issues.

Approximately 40% of patients with epilepsy have seizures that are resistant to drug treatment. In order to perform epilepsy surgery, the patient must first be resistant to the drug, so it is very important to know the concept of drug resistance. In general, the patient should use medication for at least 1-2 years before deciding on surgery. If seizures are frequent and affect the patient's quality of life, surgical treatment can be considered within 1 year of the onset of the disease. At least two appropriate AED (Anti-Epileptic Drug) monotherapy and at least one polytherapy should be applied. If seizures continue despite these medical treatment attempts and affect the patient's quality of life, then drug resistance can be mentioned..

Preoperative Evaluation

Hasta Seçimi: Patient selection is the most fundamental point of epilepsy surgery. In order for a patient with drug-resistant partial epilepsy to be a candidate for epilepsy surgery, the epileptogenic zone must first be shaped. General criteria for candidates are as follows:

1) Drug resistance,

2) Clinical diagnosis of focal seizure,

3) Preoperative evaluation and absence of contraindications for epilepsy surgery

4) The patient is willing to undergo pre-surgical evaluation after being informed.

The presence of psychogenic nonepileptic seizures together with epileptic seizures or the patient's low intelligence is not a condition that prevents preoperative examination (11).

Preoperative Clinical Evaluation:

In our Epilepsy Surgery Group, preoperative evaluation is performed using a phase system (Table I):**P I:** n order to evaluate the semiology of the seizure, information about the behavior of the seizure should be obtained from the patient and their relatives. During and after the seizure, the patient should be tested to determine the patient's level of consciousness and to review whether there are postictal effects such as aphasia and paresis..

EEG: Electroencephalography (EEG) is cerebral bioelectrical activity recorded through electrodes placed on the scalp. Since the first electrical activity recording from the human brain by Hans Berger in 1929, positron emission tomography (PET) has maintained its validity in the examination of cerebral bioelectrical activity despite functional MRI and magnetoencephalography (MEG) (13).

Tablo I: Phase Evaluation

	PHASE EVALUATION
Phase I:	Anamnez, nörolojik muayene ve Non invaziv testler (EEG, Video-EEG, MRG, iktal ve interiktal SPECT, PET ve nöropsikolojik testler)
Phase II:	WADA testi (son dönemlerde kullanılırlığı gittikçe azalmıştır)
Phase III:	İnvaziv testler. Grid, strip ve derin elektrotlar kullanılarak invaziv EEG uygulamaları
Phase IV:	Cerrahi

Detection of “epileptiform activity” in the EEG of a patient with a history of seizures does not leave the diagnosis beyond suspicion, as similar activity can be seen in many individuals who have never had a seizure, and a normal EEG does not exclude the diagnosis of epilepsy. In patients with a definite diagnosis of epilepsy, EEG findings are used to classify the disease, identify a focal or lateralized epileptic focus, select the appropriate treatment, guide prognosis, and monitor the course of the disease (13).

Non-invasive Video-EEG Monitoring (VEM): During surface EEG recording, interictal epileptiform discharges can be recorded in 50% of patients. This can increase to 90% when performed after the patient is sleep deprived or when combined with video. In patients with complex partial epilepsy originating from the temporal lobe, focal activities can be detected in recordings made using additional surface electrodes that can receive data from the sphenoidal, mesial frontal lobe and extratemporal regions. Activities in these regions cannot be shown with scalp EEG recording. In cases where interictal epileptiform activity cannot be detected in a standard EEG using activation methods, long-term video-EEG recording increases the probability of capturing interictal and ictal events (13).

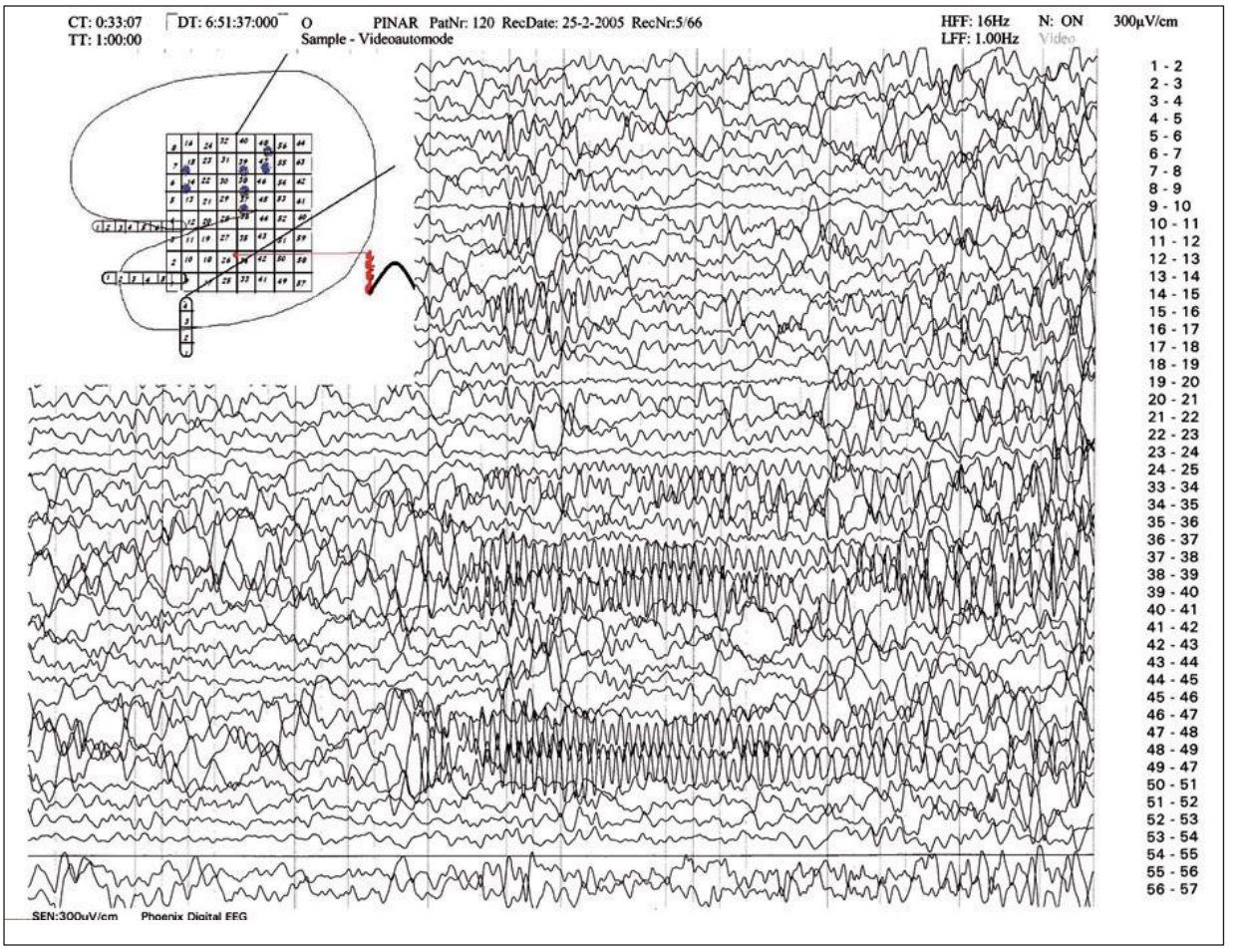
Video-EEG monitoring helps to classify the type of seizure by determining whether the seizure activity is epileptic and to determine the appropriate treatment protocol to control the seizure activity. The sensitivity and specificity of ictal EEG recording make it a superior diagnostic tool to interictal EEG. VEM allows the ictal semiology of seizures to be observed as clearly as the EEG itself (Figure 2a). The duration of such a recording can be extended from several hours to several days, depending on the clinical information. It is recommended to use a modified version of the standard 10-20 system for these recordings (13).

Long-term VEM may be the only way to distinguish between epileptic and non-epileptic seizures and may be a necessary part of the preoperative evaluation. Today, approximately 20% of patients who are followed up with a diagnosis of refractory epilepsy and referred to epilepsy centers because they do not respond to treatment are also diagnosed with nonepileptic seizures thanks to video-EEG monitoring.

It is of great importance for interpretation that a trained technician or nurse be present at all times during the video-EEG recording to test the patient's reflexes, muscle tone, etc., should any suspected ictal event occur. Various testing methods, including speech tests, should be available for the examining staff to perform during the suspected ictal event (Figure 2a).

During long-term VEM, in most cases, AEDs are significantly reduced or discontinued. The number of seizures recorded depends on the patient's seizure type, the presence of pathology on MRI and its compatibility with other tests, and whether invasive VEM (Figure 2b) is considered. Interictal recordings should be analyzed according to their presence, location, and distribution, and epileptogenic focus should be revealed. Meanwhile, EEG recording programs automatically detect spike waves in the EEG and record the entire recording.

Figure 2A: *Non-invasive ictal EEG: An ictal pattern of rhythmic sharp wave activity is observed in the right temporal region.*



Şekil 2B: *İnvaziv iktal EEG. Sol frontotemporoparyetal grid strip ve derin elektrotlar kullanılarak yapılan invaziv EEG'de 38-39 ve 47-48 nolu elektrotlarda iktal patern izlenmektedir*

Documentation with continuous video recording is still the most important part of VEM. There are currently 3 adult and 1 pediatric VEM recording patient rooms in GATA Epilepsy Surgery Group (Figure 3).

Neuropsychiatry: The evaluation of higher verbal and visual functions, speech, visual and verbal memory, attention and intelligence with neuropsychological tests plays an important role especially in the examination of TLE. In GATA Epilepsy Surgery Group, patients are evaluated with visual and verbal memory functions before surgery, 3 months after surgery and 12 months after surgery.

Figural memory demonstrates right temporal lobe functions. At least one standard deviation in preoperative verbal and visual memory is a sign of "lateralization" for the weaker side.

Attention can be measured as speed and quantity. Attention is generally not a side-specific feature. Details regarding its measurement are explained in the literature (17).

Figure 3: *In the EEG-video monitoring used for adult patients, the patient is seen during the recording.*

MRI: Whether or not a lesion is detected in MRI depends on the image quality and the experience of the reader. In order to reveal the lesions, many epilepsy surgery centers use high-resolution 1.5T systems and the images are taken according to the seizure semiology. In order to visualize TLE well, appropriate slices parallel to the long axis of the hippocampus and the middle fossa should be made. The use of special techniques, imaging algorithms and the experience of the technicians have increased the sensitivity in Mesial Temporal Sclerosis (MTS) to 98% (Figure 4). New algorithms (diffusion tensor imaging) can identify white matter fibers (optic radiation, pyramidal tract can be visualized and navigated) as a result of anisotropy and these functionally important structures can be preserved during surgery.

In our center, 1.5T MRI is routinely applied, and recently, we have been able to use 3T MRI in some cases. First, a three-dimensional T1-weighted gradient echo sequence is taken in the sagittal plane. Images are obtained with a 1.1 mm slice thickness, a 250 mm field of view, and a 256X256 matrix, using slightly isotropic voxels (1.17X1.17X1.1 mm). Axial FLAIR (Fluid-Attenuated Inversion Recovery) and axial T2-weighted fast-spin echo sequences are performed with a slice thickness of 5 mm and a 1 mm gap between them, and in patients suspected of having TLE, the angle is parallel to the long axis of the hippocampus. Another issue worth noting is that in patients with extratemporal epilepsy, images are taken at an angle according to the line between the anterior and posterior commissures. Then, MRI is continued with coronal FLAIR fast-spin echo (slice thickness 3 mm), coronal T2-weighted fast-spin echo (slice thickness 2 mm) and coronal T1 inversion recovery sequence (slice thickness 5 mm and interslice spacing 0.5 mm). If axial slices are made parallel to the length of the hippocampus, coronal slices are taken perpendicular to it. If there is a lesion other than hippocampal sclerosis, axial and coronal T1-weighted spin-echo sequences (slice thickness 5 mm; interslice spacing 1 mm) are performed before and after gadopentetate-dimeglumine injection.

SPECT: SPECT can be used to measure cerebral perfusion both interictally and ictally, when radioactive material is administered immediately following a seizure. It has been widely accepted that ictal SPECT provides better information than interictal (24). SPECT can show the area thought to be the epileptogenic zone, for example, as ictal temporal hyperperfusion. This method is important in that it shows where the seizure spreads rather than where it originates. Although successful results are obtained by subtracting the area it shows, when looking at unsuccessful results, the low resolution of localization should be taken into account. In interictal SPECT images, the epileptogenic zone is seen as hypoperfusion (Figure 5).

Combining ictal SPECT and MRI images: The problem of SPECT having low resonance and providing limited information about anatomical details has been overcome by combining SPECT with MR images with computer assistance (SISCOM). The SISCOM technique has been proven to be superior to SPECT evaluated only as a film, also with surgical results (24).

PET: The typical finding of PET is the epileptogenic zone with focal or regional hypometabolism with the application of [18F] fluorodeoxyglucose (Figure 6). The underlying pathophysiological mechanism has not yet been resolved. There are different theories; one of them is that in cases with sclerosis and a history of febrile convulsions in the Ammon horn, the effect in the lateral temporal lobe is more focal rather than widespread (36). There are series with good surgical results despite being MRI-negative (4). PET imaging helps to reveal which of the multiple tubers are active and which are passive for epilepsy in cases with multiple MRI detected in children. More detailed studies can be performed with different more specific agents (e.g., flumecinol-PET, alpha-methyl-tryptophane-PET). Furthermore, PET plays an important role in children with catastrophic epilepsy and no apparent MRI changes.

Magnetencephalography (MEG): MEG is not yet available in any center in Turkey, but it is becoming widespread in the world. It is based on the principle of localizing large amounts of cells by means of magnetic dipoles, which are indicators of their synchronous electrical activity.

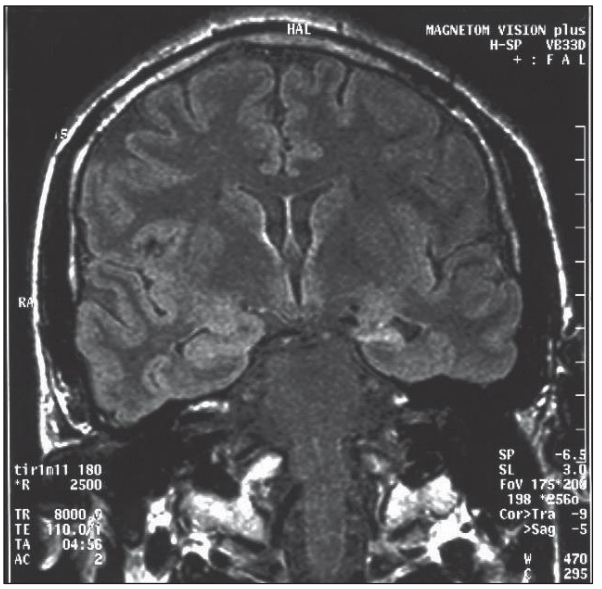


Figure 4: *Coronal FLAIR MRI shows left hippocampal sclerosis as hyperintense. Atrophy in the hippocampus and secondarily enlarged temporal horn are evident.*

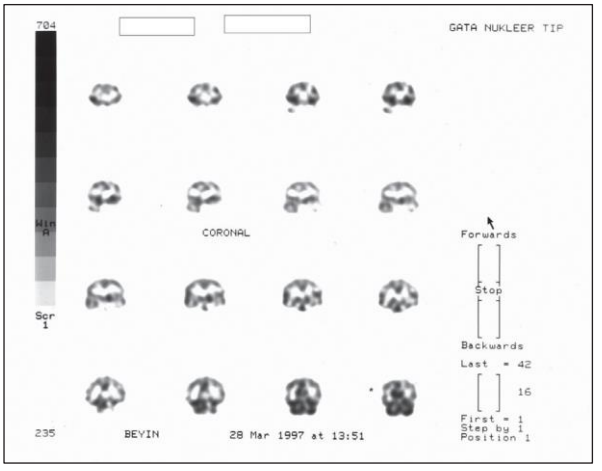


Figure 5: *Interictal coronal SPECT image shows left temporal hypoperfusion.*

MEG can also be performed both ictally and interictally and is a potential replacement for invasive EEG (22).

Functional MRI: The use of functional MRI in epilepsy is new. Motor function areas can be detected quite well. Detection of speech activation with functional MRI is important in revealing hemisphere dominance and in predicting cognitive deficits that may occur with surgery preoperatively. However, there is a 25% false lateralization in patients with left extratemporal epilepsy (ETLE) (24).

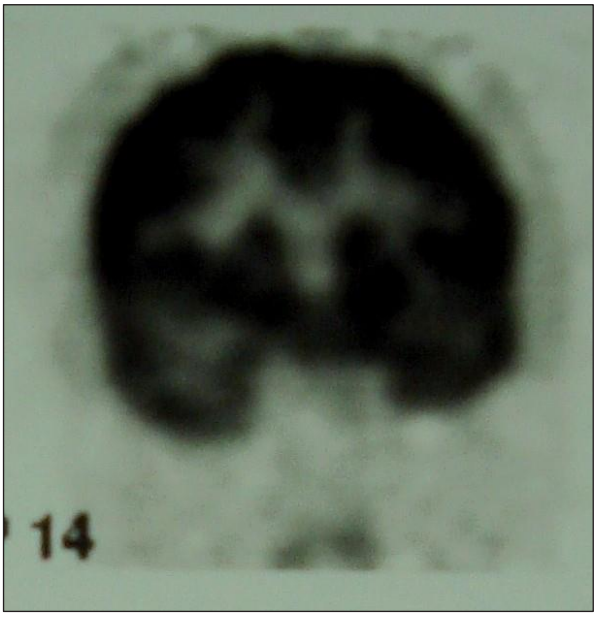


Figure 6: *In PET, right temporal focal hypometabolism compatible with the epileptogenic zone is observed with the application of [18F] fluorodeoxyglucose.*

Studies are ongoing to use functional MRI and EEG together to non-invasively reveal interictal and ictal spike waves and their location.

PHASE II

Intracarotid Amobarbital Test: Thanks to noninvasive advanced neuropsychological tests, the need for intracarotid amobarbital testing has decreased. Intracarotid amobarbital testing has become available only in cases undergoing hemispherectomy, callosotomy, and in cases where the epileptic focus is above the speech center. Memory testing with intracarotid amobarbital testing has been abandoned because it does not provide any benefit in determining the memory performance that will occur after surgery in TLE cases (24).

PHASE III

Invasive EEG Monitoring: Many different electrode types and procedures are used. Deep electrodes, multiple deep electrodes, subdural electrodes, epidural electrodes, PEG electrodes applied to the bone, sphenoidal and foramen ovale electrodes are some of the electrodes that can be considered (Figure 7).

Chronically implanted invasive recording is currently in use. Its indications can be briefly summarized in three items:

1) If no conclusion can be reached with the data obtained from ictal and interictal recordings and there is incompatibility between them;

2) In cases with high-resolution non-lesional MRI or multiple lesions;

3) The presumed epileptogenic lesion overlaps with important brain areas, prompting the need for cortical mapping (an alternative to awake brain surgery).

Deep Electrodes: In difficult cases with mesial temporal seizures (for example; bilateral hippocampal sclerosis or unilateral hippocampal sclerosis with contralateral onset of seizures on EEG), temporobasal subdural electrodes can be used to localize false seizures. Stereotaxic placement of brain electrodes was performed by Spencer et al. by placing many intrahippocampal electrodes first with the help of angiography and brain atlases and then with CT and MRI. With temporomesial electrodes, stereotaxic recording can be made by passing through the occipito-parietal region and parallel to the hippocampus, reaching the amygdala through the hippocampus (Figures 8, 9). Electrodes can be placed anywhere in the brain, they do not always have to be placed stereotaxically, they can also be placed manually. The important thing is to place them in the desired and problematic areas, and the placement is checked with CT or MRI taken after surgery (Figure 10).

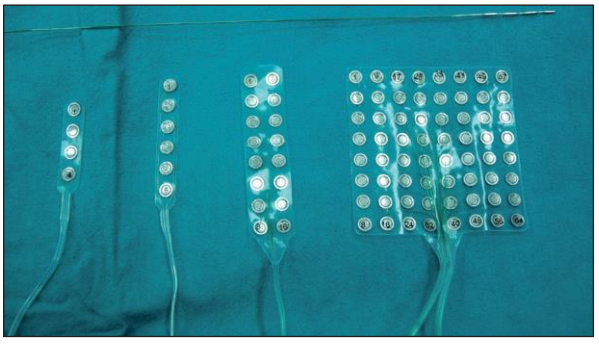


Figure 7: *The electrodes primarily used for invasive monitoring are shown. At the top is the 1X4 deep electrode, from left to right, the 1X4, 1X6 and 2X8 strip electrodes, and the 8X8 grid electrode.*

Figure 8: *After the patient is fixed to the spiked head in the prone position, the placement of two hippocampal and two neocortical electrodes with the help of two small burrholes from the occipital bone is shown stereotaxically.*

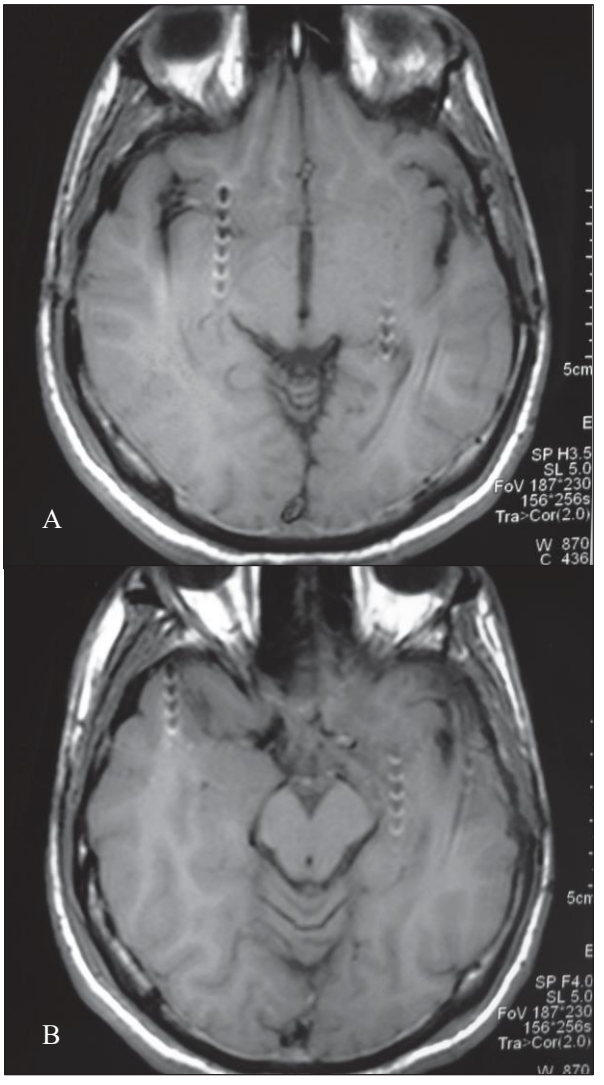


Figure 9A-B: *The location of the deep electrodes placed stereotaxically postoperatively is visualized with axial MRI..*

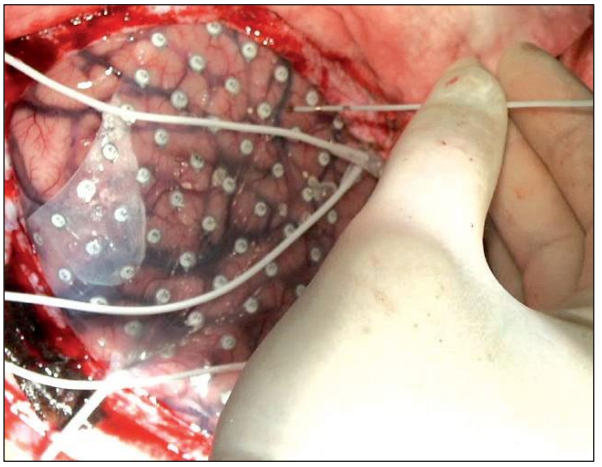
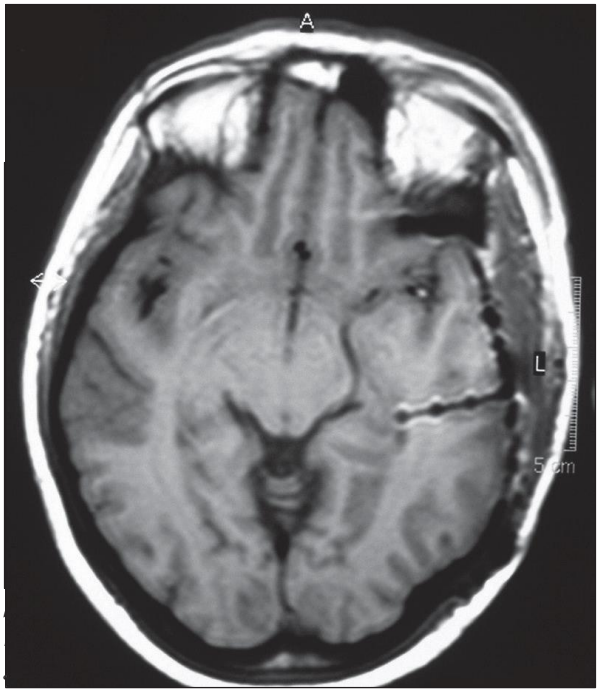


Figure 10A: *Manual deep electrode placement during a phase III study of a patient with left temporal lobe epilepsy is shown.*

Subdural Strip and Grid Electrodes: The strips have 4 to 16 contacts and can be placed directly on the cortex through a small opening in the dura. It is frequently used in patients with TLE, typically two electrodes are directed inferiorly and mesially while the third is directed laterally to the cortex. In many cases, these strip electrodes are combined with deep electrodes (Figure 11). In some cases, a neuronavigation system is used for proper placement. However, it is open to risks such as subdural hematoma formation in some complex areas. Although CT allows the localization of grid electrodes, MRI is better correlated with brain anatomy, but it may be difficult to obtain proper images due to excessive artifact. For this reason, postoperative CT can be combined digitally with preoperative MRI. In order to make the anatomical localization exactly, images should be taken with a digital camera after the grid electrodes are placed (Figure 11). With postoperative CT, especially the localization of electrodes placed manually, good three-dimensional images can be obtained using the navigation system computer (Figure 12). According to the cortex anatomy, electrode contacts can be placed on the patient's brain images with the three-dimensional MRI surface rendering technique (24). The information obtained from ictal activity and mapping is planned according to the digital photo taken during surgery and the surgery is planned (Figure 13).

Extraoperative brain stimulation is required if the epileptogenic area is located over functionally



important areas of the brain or if there is suspicion of this (Figure 14).

In the GATA epilepsy surgery program, extraoperative brain stimulation is performed in the video-EEG room for recording purposes and the patient is not sedated. Stimulation is performed with the cortical stimulator produced by GATA Biophysical Department and stimulation is performed bipolarly by stimulating step by step and passing to neighboring electrodes. Motor and sensory functions are performed in the form of single stimulation and multiple stimulation series. (Figure 14)

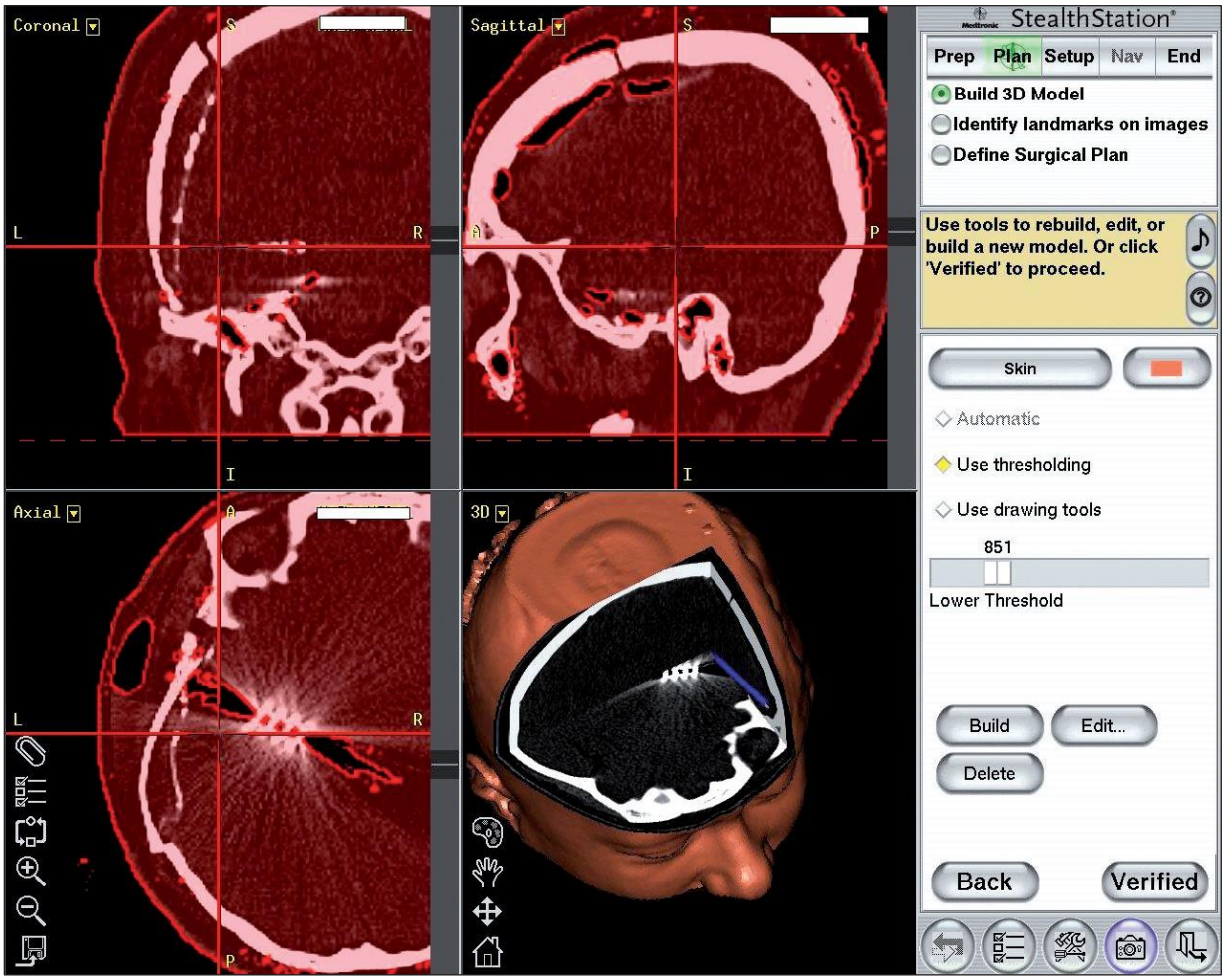


Figure 12: *The localization of the manually placed electrodes was determined three-dimensionally using the computer of the navigation system, especially with the postoperative CT.*

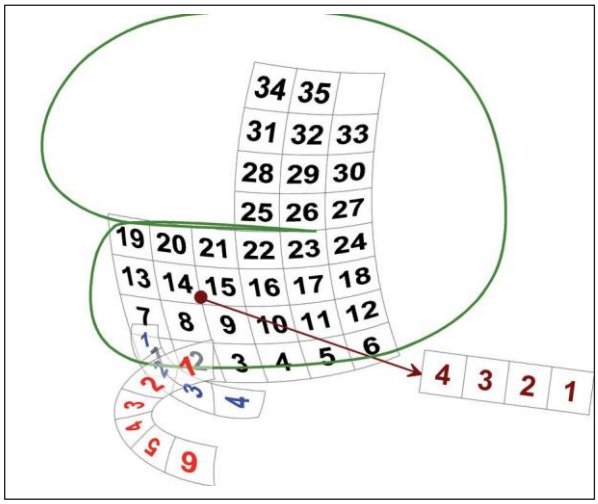


Figure 13: *The surgery is planned by drawing on photographs taken with a digital camera and MRI and CT images. This picture shows a drawing prepared according to information obtained from a phase III study of a patient with left temporal lobe epilepsy.*

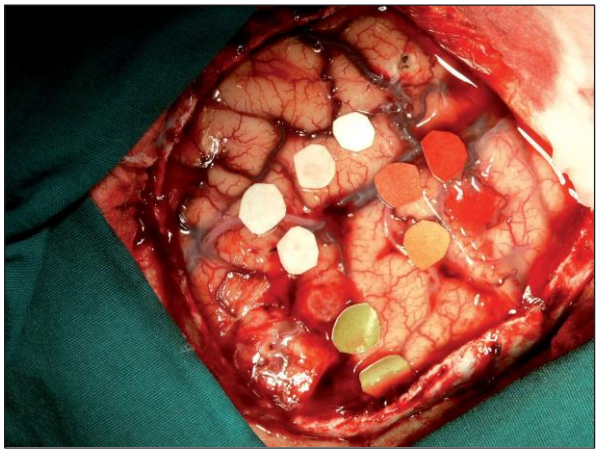


Figure 14: *A case in which the functional areas were marked according to the location of the electrodes after extra-operative brain mapping was applied to a patient who had previously been operated on for epilepsy in another center because the epileptic focus was close to the sensitive area. White scales: Wernicke's area, Red scales: Broca's area and green scales: the lip region of the motor strip are shown. The malacia area posterior to the green scales is due to the previous lesionectomy surgery.*

Intraoperative EcoG: The indications and use of ECog vary from center to center. Its disadvantages are; it is affected by anesthetics, the recording time is short, and seizure recording is not possible. Basically, ECoG recording is interictal. Therefore, the location shown in the recording reveals the irritative zone and prevents the epileptic region and important brain regions from being fully identified. In our center, it is performed to collect information in temporal lobectomies and is never used to determine the resection margin (Figure 15). However, in ETLEs, it is used non-invasively to determine the cortical resection margin, especially in cases far from sensitive areas of the brain. Electrodes (32-20 grid or 4-6 contact strip electrodes) are placed directly on the brain under general anesthesia.

PHASE IV

Surgery

Temporal Lobectomy and Amygdalo hippocampectomy technique: The standard subpial anterior temporal lobectomy is divided into 3 parts:

a) Neocortical resection,

b) Hippocampectomy

c) Amygdalectomy

a) Neocortical resection After exposing the temporal lobe, cortical resection can be performed with or without the inclusion of the superior temporal gyrus. In our practice, a portion of the superior temporal gyrus is included. Dissection towards the temporal horn is not as easy as in anatomical drawings. Here, useful landmarks, the edge of the tentorium, and the angle in the preoperative coronal images of patients are important..

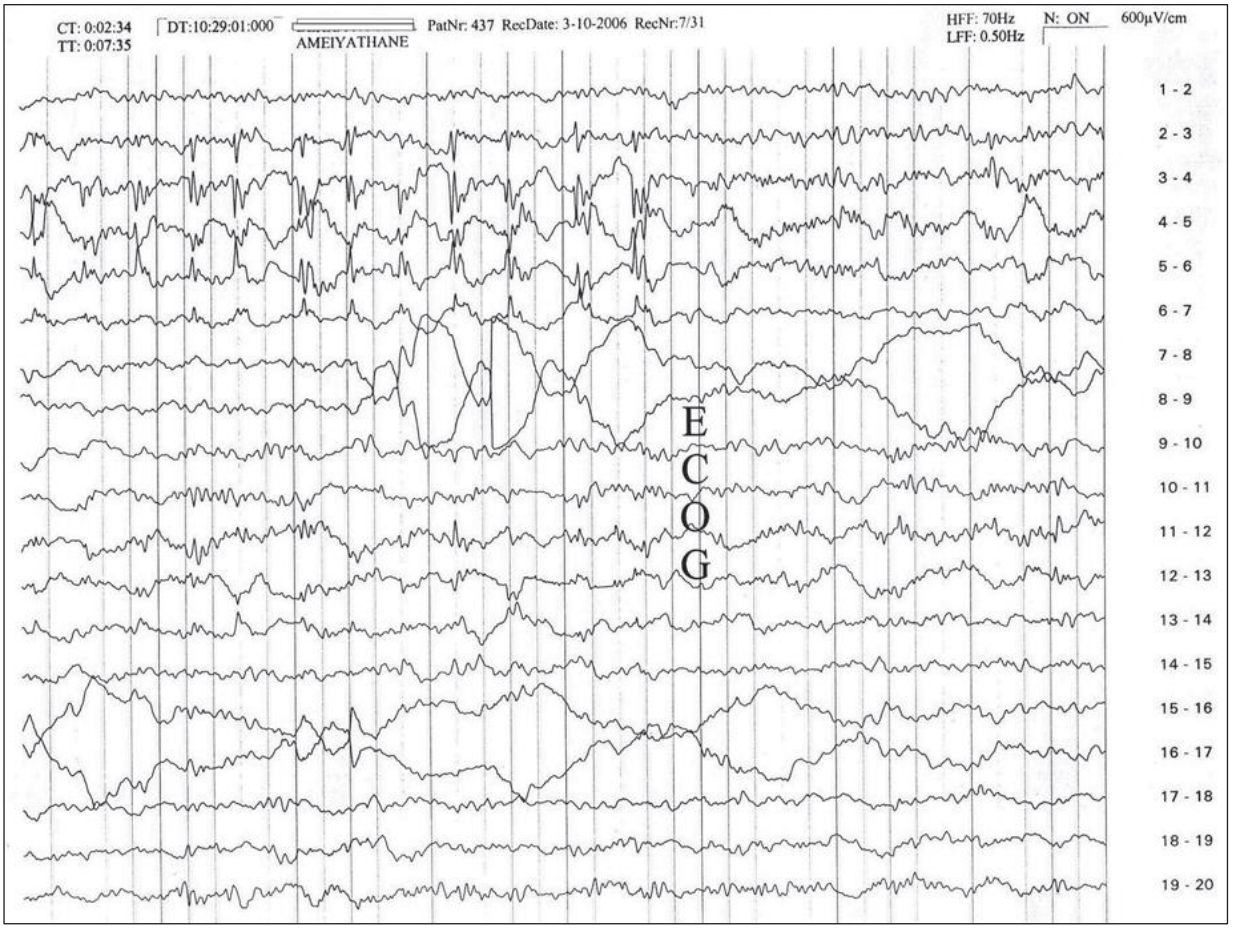


Figure 15: *ECoG recording: Interictal spike wave discharges are visible in electrodes 4 and 5.*

After entering the temporal horn from its roof, the collateral eminence and hippocampus are seen and the neocortical resection is advanced to the medial aspect of the collateral eminence (Figure 16). This shows that the basal part up to the collateral sulcus has been resected.

b) **Hippocampectomy:** En bloc hippocampectomy is based on 4-step anatomical landmarks:

(1) opening of the choroidal fissure,

(2) anterior dissection (detechment of the head of the hippocampus),

(3) medial disconnection,

(4) posterior disconnection, lateral disconnection were performed during neocortical resection.

Within the temporal horn, the choroid plexus can be found at the medial edge of the temporal horn. Such structures located lateral to the choroidal fissure can be removed, while the medial structures should be preserved. The discovery of the choroidal fissure allows the body, tail, and head of the hippocampus to be exposed (Figure 17). The choroid fissure is opened by separating the taenia fimbria (Figure 18). The taenia fimbria is the ependymal fold that connects the choroid plexus to the fimbria. During this separation, the choroid plexus is left attached to the thalamus.

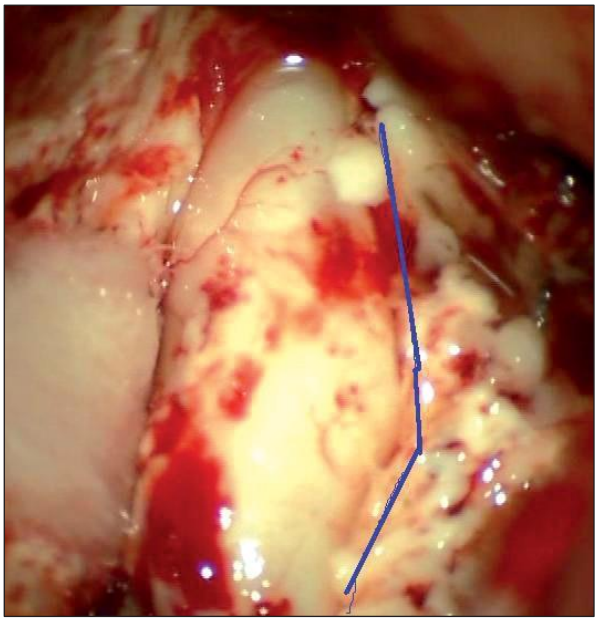


Figure 16: *Hippocampus is seen after neocortical resection up to the collateral eminence. The collateral eminence is indicated by the blue line.*

When the anterior part of the choroidal fissure is opened, the arachnoid of the ambient cistern is seen. The branches of the posterior cerebral artery and sometimes the basal vein can be seen inside. When the posterior part of the choroidal fissure is opened, the structure that comes to view on the medial side of the hippocampus corpus is the parahippocampal gyrus. Meanwhile, the protrusion on the thalamic side of the choroidal fissure is the pulvinar.

After the choroidal fissure is opened and exposed, the next stage is anterior dissection. The uncal recesses and the head of the hippocampus are followed to the inferior choroidal point on the medial wall of the temporal horn.

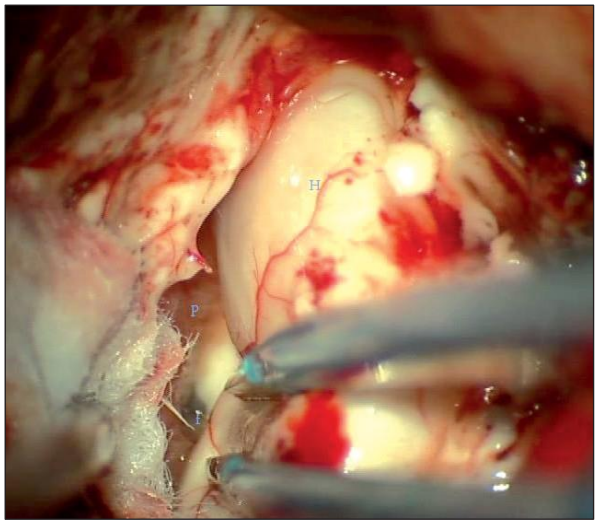


Figure 17: *Hippocampus (H), choroidal fissure (F) and choroid plexus (P)*

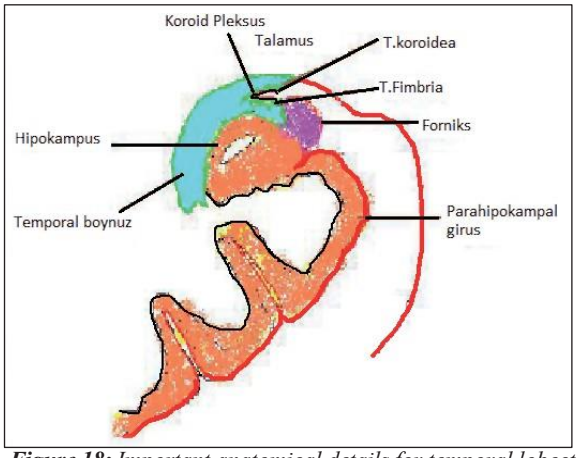


Figure 18: *Important anatomical details for temporal lobectomy are marked in the coronal section of the anatomical drawing.*

The uncal recess and the head of the hippocampus lead us to the apex and the posterior segment of the uncus, respectively. Removal of this allows exposure of the arachnoid medial to the apex and posteromedial surface; the P2A segment of the PSA, which surrounds the brainstem, and the third nerve are seen under the arachnoid membrane. The presence of these two structures is evidence that the apex and posteromedial portion of the uncus have been removed; however, it does not mean that the superior portion of this portion has been removed, so there is still a superior portion to be removed.

After the anterior part of the temporal horn is released, the anterior disconnection continues laterally with the collateral eminence. The anterior disconnection continues medially and posteriorly to the choroid plexus; from this point on, the third part of the hippocampectomy, the medial dissection, begins. The medial dissection is performed by cutting the relationship between the medial temporal structures and the structures within the crural and ambient cisterns using the previously opened choroidal fissure, and the separation is performed by cutting the hippocampal arteries.

After the choroidal fissure is opened by the taenia fimbria, there is an additional arachnoid membrane with vessels and it enters the temporal lobe perpendicularly to the ambient cistern under the head of the hippocampus. This arachnoid membrane carries the hippocampal artery and vein to the hippocampal notch. These vessels are cut to free the head of the hippocampus. This arachnoid membrane separates the inferior surface of the uncus above from the parahippocampal gyrus.

At this stage, the remaining part of the hippocampus can be separated from the choroidal fissure medially and can be freed like the head of the hippocampus. However, after separating the taenia fimbriae (lateral posterior choroidal artery and anterior choroidal artery, inferior ventricular vein should remain intact on the thalamic side. Because the part where it attaches to the choroid plexus and thalamus remains intact). The arachnoid membrane of the ambient cistern comes into view, there is another arachnoid membrane running perpendicular to the ambient cistern. The final dissection is the posterior disconnection in this hippocampal section. It is the part of the choroidal fissure that is connected to the hippocampus to be removed at the floor of the middle fossa laterally.

If the entire hippocampus is to be removed, the finding that indicates the end of the tail is the inferior prominence on the medial wall of the atrium of the lateral ventricle, where the tail of the hippocampus joins the calcar avis.

When the medial temporal cortex and mesial temporal structures (hippocampus, fornix, and parahippocampal gyrus) are removed laterally, the structures seen are the crus cerebri, tegmentum, PSA, Rosenthal's basal vein, 4th nerve, and superior cerebral artery (32)

Amygdalectomy: The entire temporal amygdala is localized within the borders of the uncus. In subpial anterior temporal lobectomy, the uncus is approached subpially from the lateral side, and the arteries are very important landmarks here. The anteromedial uncus surface is adjacent to the proximal half of the ICA and M1 segment; the inferior part of the vertex of the uncus is adjacent to the ocular motor nerve; the inferior and superior parts of the posteromedial surface of the uncus are adjacent to the P2A segment of the PSA and the cisternal part of the anterior choroidal artery just before entering the temporal horn, respectively. There is no sharp boundary between the amygdala and the globus pallidus above.

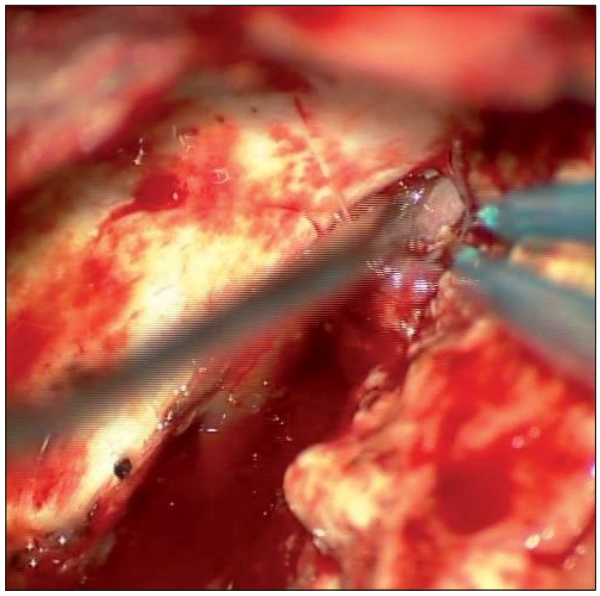
The subpial resection of the uncus can be limited according to the vascular structures seen under the arachnoid membrane; so how far should we continue? The proximal segment of the ICA and ASM seen anteriorly indicates that the anteromedial surface of the uncus has been removed (Figure 19), while the inferior part of the posteromedial surface is removed, revealing the PSA P2A segment (Figure 20); the real question is the superior limit of removal. Because there is no border between the amygdala and the globus pallidus.

The most striking indication that the superior limit of the uncus has been removed is the optic tract; however, the optic tract is not seen during subpial removal. Another indication is the cisternal segment of the anterior choroidal artery; this segment lies immediately below the optic tract.

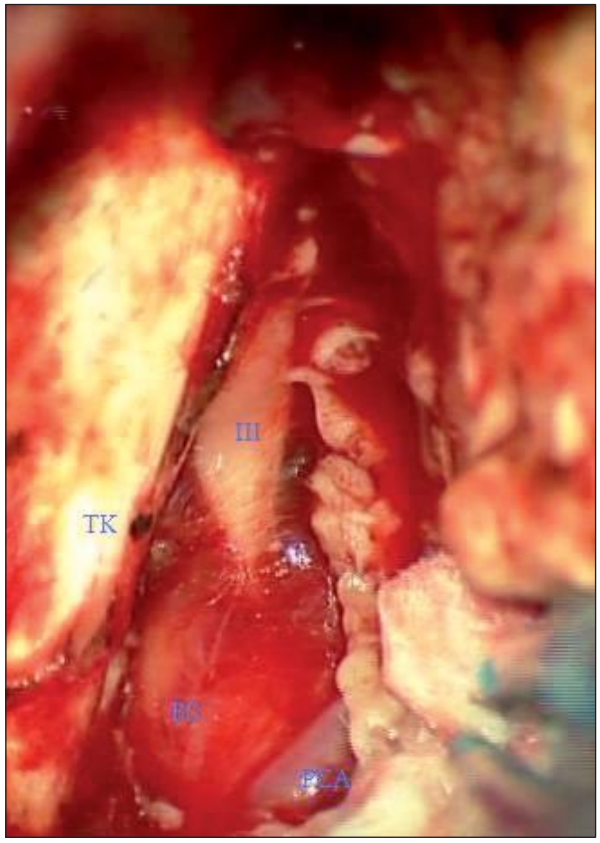
If a line can be drawn between the ICA bifurcation or the proximal M1 segment and the inferior choroidal point (carotichoroidal line), the entire uncus is located below this line. Intraventricularly, the posterior part of the amygdala is the protrusion on the roof of the ventricle just anterior to the inferior choroidal point, the part below the line passing through here can be removed. It is not desired to go superior to this line because it is thought to damage the globus pallidus, and it is not removed because it can damage the anterior perforating substance in the white matter deep in the biforation of the internal carotid artery. The carotid-choroidal line is an important operative location. As a result, for MTSs, after the temporal lobe hippocampus and amygdala are completely removed, the surgeon performs the following procedures: ICA (Internal Carotid Artery), ASM (Middle Cerebral Artery), PcoA (Posterior Communicating Artery), AchA (Anterior Choroidal Artery), PSA (Posterior Cerebral Artery), III. The nerve, basal vein, crus cerebri, lateral massocephalic sulcus and vein, tegmentum of the mesencephalon, sometimes the 4th nerve and superior cerebellar artery should be seen.

Limited and Lobar Resections in TLE: After the limited resection view became popular, limited amygdalohippocampectomies (AH) increased and anterior temporal lobectomies (ATL) began to decrease. Although limited resections were said to show less deterioration in postoperative neuropsychological tests and similar success results in patients, their number is still small. Arruda et al. performed a series of 74 patients with TLE and achieved similar good results in both ATL and AH (1). Wieser et al. published the long-term retrospective results of 369 patients who underwent selective AH at the University of Zurich between 1975 and 1999 (35). The cure rate of distressing seizures (Engel Class I and ILEA Class I-II) was 67%. Thus, promising results were documented after AH.

AH can be performed with different approaches. Originally presented by Neimeyer (20) and later by Olivier in Montreal: the hippocampus is reached by navigating through the middle temporal gyrus, from where the hippocampus, uncus, amygdala and parahippocampal gyrus are removed. Small craniotomy and limited mesial temporal damage are advantages. Yaşargil et al. (37) performed a Sylvian dissection, followed the inferior circular sulcus, and resected the mesial temporal structures,



Şekil 19: *Sol temporal lobektomi amigdalohipokampektomi olgusu. Anteriorda İKA'in proksimal segmenti bipoların altında gösterilmektedir. Bu şekilde unkusun anteromedial yüzeyinin çıkarıldığı anlaşılır.*



Şekil 20: *Sol temporal lobektomi amigdalohipokampektomi olgusu. PCA: Posterior Serebral Arter, III: Üçüncü Sinir, BS: Beyin Sapı ve TK: Tentorium Kenarı*

entered the temporal horn from the temporal stem, and resected the mesial temporal structures.

Sylvian dissection can be difficult, but a good exposure of the dorsal aspect of the hippocampus can be achieved. Spencer et al. used a combined temporal pole and mesial resection method to easily reach and resect the posterior mesial structures (26). Other approaches include subtemporal, zygomatic, subtemporal-transparahippocampal, transsylvian-transcisternal, and others; all of these methods are not used as frequently as the transsylvian and transcortical methods. We see that stereotaxic ablation treatment is less successful, because it is due to the effect of the entorhinal cortex in the formation of TLE. There is no consensus on which approach is better, especially when neurological side effects such as memory impairment and visual field defects are considered. A randomized prospective study compared the transsylvian and transcortical approaches, but no difference was found (17).

It has been suggested that the success of mesiotemporal surgery is directly proportional to the amount of tissue removed (3). It was thought that the remaining tissue was important in seizure recurrence and this was thought to be more common in AH than in ATLs. Reoperation to remove the remaining tissue should be considered for these cases, and seizure cessation with reoperation is seen in 50% of patients (24).

There are significant differences between patients with mesial TLE and dominant lesions and non-lesional groups, the latter being a distinct clinical entity compared to MTS. In cases of lesional (nonsclerotic) mesial TLE with only limited resection, satisfactory results were obtained in 86% of patients (24).

Similar results have been obtained in surgery for patients with neocortical temporal lesions, in which lesionectomy and corticectomy have a higher success rate (95% satisfactory seizure control), especially in the presence of tumors (24).

Treatment of Extratemporal Epilepsies: Several types of surgery are used: lobectomy, lesionectomy (simple or with surrounding cortex), corticectomy, and Multiple Subpial Transresection (MST).

The success of surgery for extratemporal epilepsies is more limited compared to TLE surgery and hemispherectomies. In some cases, the epileptogenic zone may be located over sensitive areas of the brain (such as movement, speech, vision, etc.) and cannot be removed. The precise location of sensitive brain areas can be determined by stimulation of chronically implanted electrodes or by brain mapping via “awake craniotomy.” The aim of these measurements is to remove enough brain tissue to treat the epilepsy without causing any deficits to the patient. The depth of the resection should be sufficient to include deep cortical structures. A resection depth of 2.5–3 cm is usually sufficient (Figure 21). It is important to preserve vascular structures during this procedure. Therefore, the use of CUSA is recommended. The most difficult part is estimating the width of the resection. Pathology usually determines our limits. Usually, the lesion is removed along with 0.5–1 cm of surrounding normal cortex. In all these lesions, a small cortical frame and the hippocampus, if associated, are usually removed. In many cases, the surgeon's own experience is important, as the surgeon will eventually come face to face with the neurological side effects that will develop in the patient. As we have said before, intraoperative ECoG provides additional information, but it is not definitive. If complete resection is not performed, MST can be performed in sensitive brain areas. The aim of multiple subpial transresection is to prevent the spread of seizures in sensitive brain areas by cutting the horizontal cortical fibers that are effective in the spread of seizures perpendicularly to the length of the gyrus with the help of a knife. The resulting neurological deficits will recover well in all patients within a few weeks. In addition, when complete seizure control is considered, success is low in these patients.

When considering ETLE, most of the publications are related to the treatment of Frontal Lobe Epilepsy (FLE), but there are also patients with parietal, occipital or multilobar epilepsy (14). Detection of focal epileptogenic lesion is very important because if there is a lesion on MRI, it is the most important factor for good prognosis. Similar successful results are obtained in patients with focal FLE as in cases with TLE. Limited resection can yield successful results in cases with FLE; frontal lobectomies can be applied in cases

where limited resection does not yield successful results or in cases with large frontal epileptic foci. When treating parietal and occipital lobe epilepsies, cognitive functions and visual field effects should be kept in mind. In order to obtain good information about cortical areas, invasive VEM should be performed and sensitive areas should be revealed (Figure 14). However, occipital and parietal lobe epilepsies can be treated with high success rates.

Hemispherectomy and Hemispherotomy: The treatment of children with catastrophic epilepsy is an important issue, especially in children with drug-resistant epilepsy where one half of the brain is globally damaged. Recent developments in hemispherectomy techniques have allowed for greater disconnection by removing less brain tissue. Rasmussen was the first to use this functional hemispherectomy technique, in which the temporal lobe and extensive frontoparietal central cortex were removed, while the frontal lobe and occipitotemporal lobe were left disconnected and in situ. Recently developed functional hemispherectomy techniques include the perisylvian window technique, the transcortical subinsular central hemispherotomy, the transsylvian transcortical transventricular keyhole approach, and related techniques (7). Surgeons in some centers still prefer anatomic hemispherectomy, in which all brain tissue except the basal ganglia is removed (21).

The basic principle of the modern hemispherotomy technique is to perform a callosotomy from inside the ventricle. To enter the ventricular system, it is possible to enter via the Sylvian fissure or by opening a window from the frontoparietal operculum or by opening a window to the structures below the operculum (7). Using these techniques has significantly shortened the duration of surgery and has also significantly reduced the patient's need for transfusion. Modern techniques are more suitable for infants and young children. In previous series, the mortality rate was between 2-5%, while in modern techniques this rate is 0% or less than 1% (7). Modern hemispherotomy techniques have shortened the duration of surgery, smaller surgical incisions are made. It has also reduced the need for blood transfusion and reduced the possibility of hemodynamic instability. Resection of small parts of the hemisphere can be added to modern hemispherotomy techniques (anterior hippocampus, insular cortex or frontal operculum).

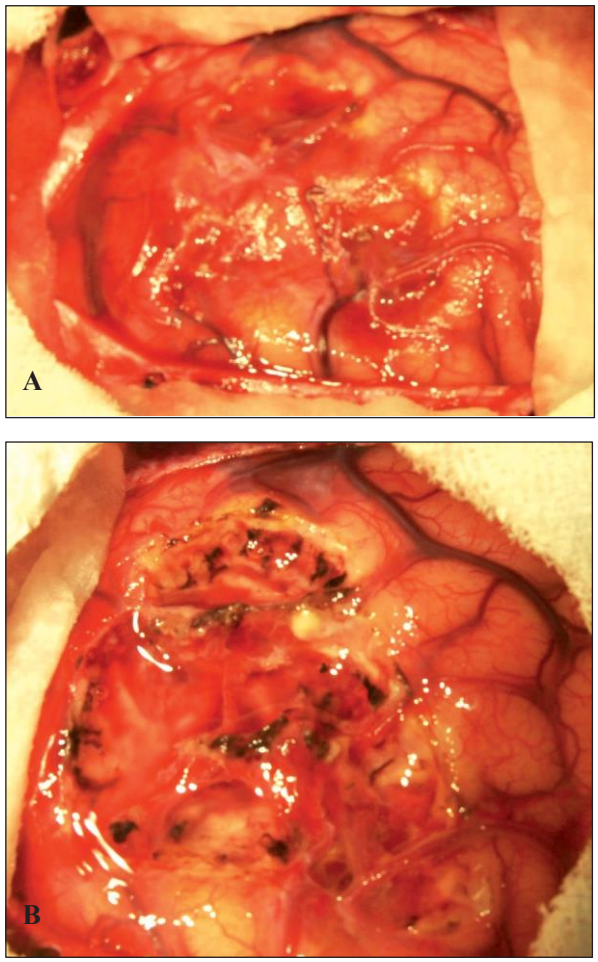


Figure 21: *The encephalomalacia area, thought to be the epileptogenic focus, is seen (A). This area is seen after being removed with the help of CUSA (the point to be emphasized in this image is the preservation of vascular structures) (B).*

Seizure freedom success generally depends on etiology, with the best results being obtained in Sturge-Weber disease, while poorer results are often obtained in hemimegalencephaly. Surgical and anatomical details of the techniques are available in publications, with possible disadvantages of new techniques being incomplete disconnections (12,19).

Palliative Treatments: Initially, some information was given about Multiple Subpial Transresection (MST). MST is often performed in addition to lesionectomy or corticectomy to increase the margins of disconnection. MST is usually used in addition to resective intervention. In pure MST cases, Engel class I and II results were obtained in 10% of patients, and Engel class III results were obtained in 35% of patients.

In other words, 45% of patients benefited from other palliative or drug treatments. The success rate of palliative methods in different classifications is 71% in generalized seizures and 62% in focal seizures (24). Corpus callosotomy is indicated in GTC seizures, atonic seizures, Lennaux-Gastaut syndrome or drop attacks. The aim here is to prevent the spread of seizures rather than to eliminate their cause. Typically, callosotomies are frequently used in patients with drop attacks and related injuries. However, the method and indications for its use vary from center to center. Depending on the tests performed before the surgery, full or partial callosotomy can be performed. Studies have shown that the rate of conversion to full callosotomy after partial callosotomy is high (28). The importance of callosotomy has decreased in the last decade due to Vagus nerve stimulation (VNS).

VNS has been accepted as a palliative treatment method in the last decade and its effectiveness has been proven (8). Although there are difficulties in understanding its mechanism of action, a 50% decrease in the number of catastrophic seizures is detected in approximately half of the patients. Recent information has shown that the positive effect of VNS on seizure frequency increases over time. Furthermore, positive changes in the psychology of the patients have been detected and therefore studies on the use of VNS in depression have begun.

VNS surgery is performed under general anesthesia in the supine position (Figure 22) with two incisions made in the left neck region and under the clavicle. The electrodes are passed under the skin with the help of a passer and passed under the two incisions. After the left vagus nerve is exposed, the electrodes are attached to the left Wagus nerve with the help of helical tips (29). The electrode tip inferior to the clavicle is attached to the battery and controls and recordings are made with the help of a wand, then the battery is placed in the bag (in the chest skin insicion) and the surgery is terminated.

New Surgical Techniques: Over the last three decades, surgical technique has been characterized by smaller and less invasive resections. Although it was initiated by Niemeyer (20), the first transsylvian selective amygdalohippocampectomy was performed by Yaşargil in 1975 (37). Later, developments in microsurgery enabled this technique to shed light on epilepsy surgery. Smaller resections were limited to cases with mesial TLE and were no longer applied to all TLE cases (9). Limited neocortical resections were shown to be more successful in cases with TLE and neocortical involvement. A similar view was also put forward in frontal lobe epilepsy (FLE) and limited resections were used instead of frontal lobectomy. Reducing the size of the resections did not reduce the success of the surgery and it was ultimately shown that surgical success depended on the type of lesion and

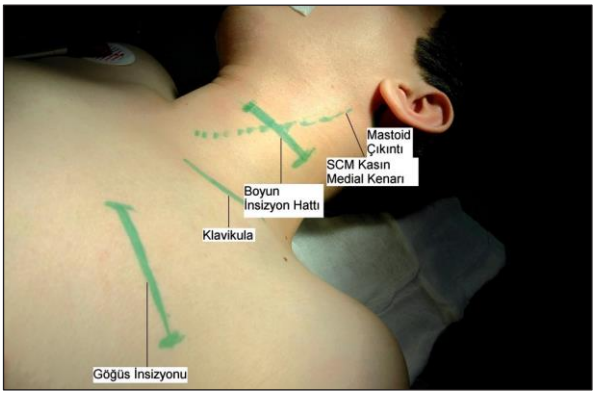


Figure 22: *Vagal nerve stimulator insertion. When calculating the incision, a 2-3 cm incision is made parallel to the neck pleats in the middle of the line drawn between the mastoid process and the clavicle and parallel to the medial side of the sternocleidomastoid (SCM) muscle. The chest incision can be made as in the figure or it can be made towards the armpit to obtain more cosmetic results..*

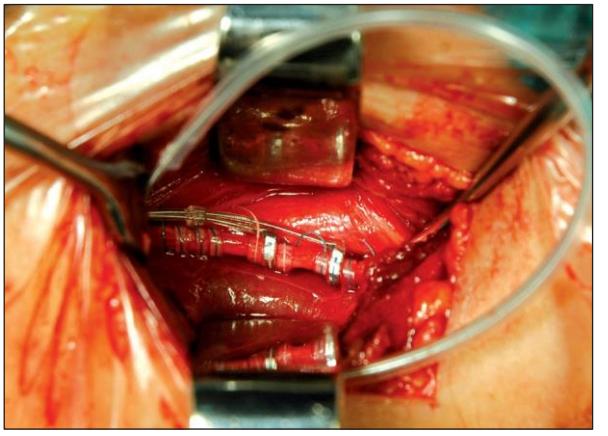


Figure 23: *The surgical photograph shows the helical electrodes placed on the left vagus nerve (from left to right; Anchor, negative and positive electrodes).*

not on the size of the resection (24).

The second trend in surgery for epilepsy is the application of new surgical techniques such as modern hemispherotomy or hamartoma resection. The application of microsurgical principles and better diagnosis are trying to reduce the complications of 2/3 temporal lobectomy by applying different surgical techniques to mesial TLE. Transsylvian, transcortical, transsulcal, transcisternal and subtemporal or transtentorial techniques have been developed (34). The use of microsurgery and other modern tools (CUSA) has decreased postoperative morbidity and increased the rate of Class I (9, 10) seizure control.

Tools such as neuronavigation or intraoperative MRI (iMRI) that assist the neurosurgeon have further increased success (Figure 24). By adding this information to the microscope, not only can the structure be visualized, but more functional surgery can be performed with information gathered from electrophysiological recordings, functional MRI, or DTI MRI.

Side Effects: The risks associated with elective surgery are an important issue. Patients considered for epilepsy surgery are generally young and have no other health problems. The future success rate is higher than the potential risks. A common side effect of temporal lobe surgery is a visual field defect (upper partial quadronopsia) and is not considered important by the affected patients. Cognitive impairment is frequently seen in patients undergoing left temporal lobe surgery.

With the use of microsurgery, brain surgery has definitely become safer. However, there are some risks, such as bleeding and infection, which are encountered in all surgeries, although small. In addition to the general risks of intracranial surgery, diseases caused by bleeding dyscrasias carry additional risks during surgery (such as von Willebrand disease).

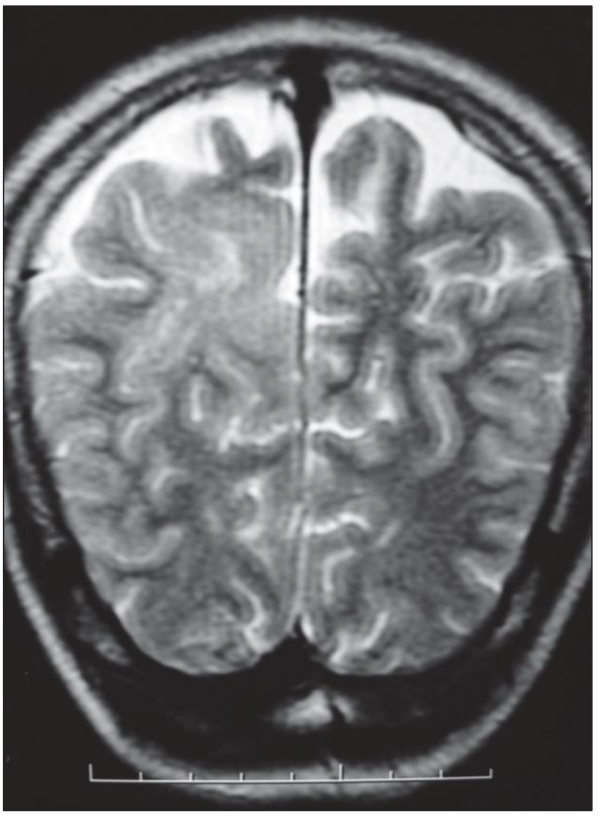
Generally, the complication rate of epilepsy surgery is low and acceptable, with a permanent morbidity of 1-2%. The mortality rate is 1% in large series. In our series of 155 cases, the mortality rate was 0% due to surgery. It has been reported in publications that the complication rate is higher in patients over 50 years of age. Studies have shown that the rate of sudden unpredictable death (SUDEP) in patients with drug-resistant epilepsy is 1:1000 to 1:500 per year and these rates statistically decrease after epilepsy surgery performed on the patients (31). In the 478-case Zürich AH series, the minor complication rate is 3.6% and the major complication rate is 1.26%. The rate of permanent hemiplegia due to choroidal infarction is 0.84% (35). After surgeries performed for TLE, side effects such as temporary speech impairment and hemiparesis can sometimes be seen. Classical surgical problems such as infection and thrombosis do not cause permanent damage and are seen in 2-4%.

The presumed benefit of epilepsy surgery in TLE was studied in a prospective randomized trial with drug therapy by Wiebe and colleagues (33). In 2003, the American Academy of Neurology accepted surgery as the treatment of choice for drug-resistant temporal lobe epilepsy (10). In recent years, the risk-benefit ratio has increased in a positive way.

Figure 24: *N20 Intraoperative MR and connected navigation system in our operating room are seen. Since the operating room is built according to iMRI, there is no need for a cage during the shooting.*

Preoperative research from many perspectives has enabled discussions on whether or not surgery should be personalized. The success rate of seizure control has increased significantly over the past 30 years. On the other hand, the risks associated with surgery have been reduced, if not eliminated. The patient must distinguish between the risks associated with specific surgery (e.g., minimal visual field impairment after temporal lobectomy or partial loss of verbal memory after dominant hemisphere surgery (mostly left)) and the common risks of brain surgery.

The accumulation of knowledge about new entities plays an important role in this regard; surgery is increasingly being performed on patients with hippocampal sclerosis without invasive monitoring (31). A study by Castro et al. also yielded really interesting results; patients with radiologically unilateral mesial temporal sclerosis were divided into two groups, the first group (appropriate group) included patients with EEG, Video-EEG and ictal and interictal SPECT on the same side. The second group was called the inappropriate group, where at least one seizure started on the opposite side. Both groups underwent anterior temporal lobectomy and amygdalohippocampectomy for MTS seen on MRI. The results were found to be similar. This result does not mean that EEG-video monitoring should not be performed. Psychological or frontal seizures can be revealed with VEM. However, invasive VEM may not be necessary for these cases (5). Similar reasons also apply to focal cortical dysplasia; new MRI techniques can clearly show structural abnormalities (Figure 25). The success of epilepsy surgery is determined by the extent of the lesion and its histological subtype (18).



Şekil 25: *T2 ağırlıklı koronal MRG'de sağ posterior paryetalde belirgin kortikal displazi izlenmektedir.*

Limits of Epilepsy Surgery: The increasing awareness of the risks has made it clear that the limits of epilepsy surgery must be known. First, it is not possible to remove areas of the brain that have important functions, with a few exceptions. The method that can be done for these cortical areas is multiple subpial transection (MST). However, this technique is limited because it is palliative. Another important problem is the creation of neuropsychiatric deficits in the patient. This is a burden that outweighs the benefit of the patient being free of seizures. Furthermore, increasing psychiatric impairment may be a problem, such as the development of psychosis after TLE surgery. Another problem that has not been completely resolved is the lack of social reintegration in some patients, even with full seizure control (27).

Limited resection will contribute to the reduction of neurological and cognitive morbidity. After extensive preoperative investigations, it is controversial how effective super selective surgery is on surgical success, and as is generally known, a certain amount of brain tissue needs to be removed to remove the epileptogenic area. Neuronavigation systems during surgery and calculation of brain shift by verifying it or using intraoperative MRI can increase surgical success. Recently, a surgical technique called hippocampal transection without hippocampectomy has been published (24). Although the technique is easier, it has not yet been compared with hippocampal resection in terms of seizure control and cognitive damage.

Studies on the risks of radiosurgery treatment of TLE are ongoing (23). Although there are publications expressing successful results of radiosurgery treatment of mesial TLE, there are also publications with quite unsuccessful results (23,29). The general view is that this treatment will first increase seizures and there may be risks including death. We have no information on the late results of radiotherapy applied to young patients who are healthy except for epilepsy (development of secondary neoplasia) (25). In a recent publication, Sheehan et al. (25) detected meningioma in two cases in 288 cases who underwent radiosurgery due to arteriovenous malformation, with a rate of 0.69%. Their effects on cognition are not equal and even mortality has been reported. Therefore, its safety and usability are controversial (23,29).

The discovery of complex stimulation devices and their use in Parkinson's as deep brain stimulation has begun to be used in drug-resistant TLE and its systematic evaluation will be done soon. Furthermore, stimulation devices triggered by epileptiform activity are also beginning to be used (stimulation on demand).

Another problem of the treatment is the blood-brain barrier; in order for the drug level to be sufficient intracerebrally, a toxic dose of blood is required in patients. With the help of implanted pumps, the drug can be administered directly to the brain, allowing the blood-brain barrier to be overcome, and even interactive drug delivery can be achieved with electrochemical adjustment.

Evaluation of Results: Postoperative documentation and knowledge about seizures have been shown to be a prerequisite for the success of the surgery. The definition of the seizure outcome is not that simple. If there are no seizures, it is possible to speak of complete seizure freedom. The gradual decrease in seizure frequency also creates difficulty in classification, and although measuring the severity of the patient's seizures is more difficult than measuring their frequency, the type and severity of the seizures play an important role in the evaluation of seizures. Furthermore, quality of life and socioeconomic status should be taken into consideration.

In the early years of epilepsy surgery, the outcome was seen as “success” or “failure” depending on whether seizures occurred or not. It was thought that seizures would stabilize after two years and late recurrences were discussed. This issue was focused on at the Palm Desert conferences in 1987 and 1992, and many epilepsy centers participated in these meetings. Engel et al. (10) presented four main outcome classification items, which were divided into 13 subgroups. This classification consisting of four main items is frequently used in the postoperative evaluation of seizures.

Tablo II: Engel Classification

Ia: Complete seizure freedom (except early seizures)
Ib: Only simple partial seizures
Ic: Postoperative seizures, but seizure-free for the last 2 years
Id: Generalized seizure only after AED discontinuation
IIa: Initially seizure-free, now rare seizures
IIb: Infrequent seizures
IIc: More frequent seizures, but infrequent seizures for the last 2 years
IId: Only nocturnal seizure
IIIa: Significant seizure reduction
IIIb: No seizures for more than half of the follow-up period (more than 2 years)
IVa: Decrease in seizures
IVb: No difference in seizures
IVc: Increased seizures

The ILAE classification committee recommended the use of the six-item classification system in postoperative evaluation..

The “real” goal of epilepsy surgery is not only to reduce seizures but also to facilitate social reintegration and to remove disabilities (2). In measuring the benefits of a person, “being well” and “being functional” have been frequently reported in recent publications (24). Despite this, measuring quality of life is still of interest. It can be said that neuropsychological issues and depression play an

Tablo III: ILAE sınıflaması

ILAE Sınıflaması
I : Tam nöbetsizlik, aura yok
II: Tam nöbetsizlik, sadece aura var
III: Yılda 1-3 nöbet günü, aura var yada yok
IV: Yılda 4 nöbet günü ile nöbetlerinde %50'den fazla azalma, aura var yada yok
V: Nöbet günü sayısında %50'den daha az azalma ile %100'e kadar artma olması
VI: Nöbet günü sayısının %100'den fazla olması

important role (16). Surgery is superior to medical treatment not only in prospective randomized controlled trials but also in quality-of-life measurements. Recent studies have shown that cognitive impairment plays an important role in health-related quality-of-life measurements, and therefore resection without causing cognitive impairment has become more important. Despite this, there is still no consensus that can fully evaluate the results of epilepsy surgery.

The Importance of Establishing an Epilepsy Surgery Group: The creation of an epilepsy surgery program is achieved through the teamwork of two important partners: the epileptologist (neurologist who deals with epilepsy) and the brain surgeon. It is essential that the neurologist is experienced in neurophysiology. In addition to the imaging facilities mentioned above (high-resolution MRI and an experienced neuroradiologist), there must be continuous EEG-video monitoring. PET and SPECT should also be available. In addition, neuropsychology and neuropathology staff should also be on the team. It seems difficult for a brain surgeon who is far from these facilities to make preoperative preparations and evaluations without assistance. The third and important step is to collect the files from three different clinics (brain surgery, neurology and pathology) in one center.

Conclusion

Dramatic advances in imaging and diagnosis over the past three decades have contributed to the advancement of epilepsy surgery. New, less invasive, and safer resection techniques have been developed and new palliative and supportive treatment methods have begun to be used. Epilepsy surgery is a more effective treatment method for controlling seizures today, it is safer, less invasive and creates less morbidity and mortality..

References

1. Arruda F, Cendes F, Andermann F, Dubeau F, Villemure JG, Jones-Gotman M, Poulin N, Arnold DL, Olivier A: Mesial atrophy and outcome after amygdalohippocampectomy or temporal lobe removal. Ann Neurol 40:446–450,1996.
2. Bien CG, Schulze-Bonhage A, Soeder BM, Schramm J, Elger CE, Tiemeier H: Assessment of the long-term effects of epilepsy surgery with three different reference groups. Epilepsia 47:1865–1869, 2006.
3. Bonilha L, Kobayashi E, Mattos JP, Honorato DC, Li LM, Cendes F: Value of extent of hippocampal resection in the surgical treatment of temporal lobe epilepsy. Arq Neuropsiquiatr 62:15–20, 2004.
4. Carne RP, O'Brien TJ, Kilpatrick CJ, MacGregor LR, Hicks RJ, Murphy MA, Bowden SC, Kaye AH, Cook MJ: MRI-negative PET-positive temporal lobe epilepsy: A distinct surgically remediable syndrome. Brain 127:2276–2285, 2004.
5. Castro LH, Serpa MH, Valério RM, Jorge CL, Ono CR, Arantes PR, Rosemberg S, Wen HT. Good surgical outcome in discordant ictal EEG-MRI unilateral mesial temporal sclerosis patients. Epilepsia 49(8):1324-32, 2008
6. Cemil topuzlu Mut M, Dinç G, Naderi S: On the report of the first successful surgical treatment of brain abscess in the Ottoman Empire by Dr. Cemil Topuzlu in 1891: Neurosurgery 61(4):869-72, 2007.
7. Cook SW, Nguyen ST, Hu B, Yudovin S, Shields WD, Vinters HV, Van de Wiele BM, Harrison RE, Mathern GW: Cerebral hemispherectomy in pediatric patients with epilepsy: Comparison of three techniques by pathological substrate in 115 patients. J Neurosurg 100 [Suppl]:125–141, 2004.
8. De Herdt V, Boon P, Ceulemans B, Hauman H, Lagae L, Legros B, Sadzot B, Van Bogaert P, van Rijckevorsel K, Verhelst H, Vonck K: Vagus nerve stimulation for refractory epilepsy: A Belgian multicenter study. Eur J Paediatr Neurol 11:261–269, 2007.
9. Engel J Jr, International League Against Epilepsy (ILAE): A proposed diagnostic scheme for people with epileptic seizures and with epilepsy: Report of the ILAE Task Force on Classification and Terminology. Epilepsia 42:796–803, 2001.

10. Engel J, Wiebe S, French J, Sperling M, Williamson P, Spencer D, Gumnit R, Zahn C, Westbrook E, Enos B, Quality Standards Subcommittee of the American Academy of Neurology, American Epilepsy Society, American Association of Neurological Surgeons: Practice parameter: Temporal lobe and localized neocortical resections for epilepsy: Report of the Quality Standards Subcommittee of the American Academy of Neurology, in association with the American Epilepsy Society and the American Association of Neurological Surgeons. Neurology 60:538–547, 2003.
11. Gleissner U, Clusmann H, Sassen R, Elger CE, Helmstaedter C: Postsurgical outcome in pediatric patients with epilepsy: a comparison of patients with intellectual disabilities, subaverage intelligence, and average-range intelligence. Epilepsia 47:406–414, 2006.
12. González-Martinez JA, Gupta A, Kotagal P, Lachhwani D, Wyllie E, Lüders HO, Bingaman WE: Hemispherectomy for catastrophic epilepsy in infants. Epilepsia 46:1518–1525, 2005.
13. Gökçil Z. Epilepside elektroensefalografi. Ks 12, Bl 38. Bora İ, Yeni SN, Gürses C. (editörler). Epilepsi, Nobel Tıp Kitabevleri, İstanbul, s.475-499, 2008.
14. Kun Lee S, Young Lee S, Kim DW, Soo Lee D, Chung CK: Occipital lobe epilepsy: Clinical characteristics, surgical outcome, and role of diagnostic modalities. Epilepsia 46:688–695, 2005.
15. Loddenkemper T, Kellinghaus C, Wyllie E, Najm IM, Gupta A, Rosenow F, Lüders HO: A proposal for a five-dimensional patient-oriented epilepsy classification. Epileptic Disord 7:308–316, 2005.
16. Loring DW, Meador KJ, Lee GP: Determinants of quality of life in epilepsy. Epilepsy Behav 5:976–980, 2004.
17. Lutz MT, Clusmann H, Elger CE, Schramm J, Helmstaedter C: Neuropsychological outcome after selective amygdalohippocampectomy with transsylvian versus transcortical approach: A randomized prospective clinical trial of surgery for temporal lobe epilepsy. Epilepsia 45:809–816, 2004.
18. Lüders H, Schuele SU: Epilepsy surgery in patients with malformations of cortical development. Curr Opin Neurol 19:169–174, 2006.
19. Mani J, Gupta A, Mascha E, Lachhwani D, Prakash K, Bingaman W, Wyllie E: Postoperative seizures after extratemporal resections and hemispherectomy in pediatric epilepsy. Neurology 66:1038–1043, 2006.
20. Niemeyer P: The transventricular amygdala-hippocampectomy in temporal lobe epilepsy, in Baldwin M, Bailey P, Ajmone-Marsan C, Klatzo I, Tower D (eds): Temporal Lobe Epilepsy. Springfield, Charles C. Thomas, pp 461–482, 1958.
21. O'Brien DF, Basu S, Williams DH, May PL: Anatomical hemispherectomy for intractable seizures: Excellent seizure control, low morbidity and no superficial cerebral haemosiderosis. Childs Nerv Syst 22:489–499, 2006.
22. Papanicolaou AC, Pataraia E, Billingsley-Marshall R, Castillo EM, Wheless JW, Swank P, Breier JI, Sarkari S, Simos PG: Toward the substitution of invasive electroencephalography in epilepsy surgery. J Clin Neurophysiol 22:231–237, 2005.
23. Régis J, Rey M, Bartolomei F, Vladyka V, Liscak R, Schrottner O, Pendl G: Gamma knife surgery in mesial temporal lobe epilepsy: A prospective multicenter study. Epilepsia 45:504–515, 2004.
24. Schramm J, Clusmann H. The surgery of epilepsy. Neurosurgery 62 [suppl 2]: 463-481, 2008.
25. Sheehan J, Yen CP, Steiner L: Gamma knife surgery-induced meningioma. Report of two cases and review of the literature. J Neurosurg 105:325–329, 2006.
26. Spencer DD, Spencer SS, Mattson RH, Williamson PD, Novelly RA: Access to the posterior medial temporal lobe structures in the surgical treatment of temporal lobe epilepsy. Neurosurgery 15:667–671, 1984.
27. Spencer SS, Berg AT, Vickrey BG, Sperling MR, Bazil CW, Shinnar S, Langfitt JT, Walczak TS, Pacia SV, Ebrahimi N, Frobish D, Multicenter Study of Epilepsy Surgery: Initial outcomes in the Multicenter Study of Epilepsy Surgery. Neurology 61:1680–1685, 2003.
28. Spencer SS, Spencer DD, Williamson PD, Sass K, Novelly RA, Mattson RH: Corpus callosotomy for epilepsy. I. Seizure effects. Neurology 38:19–24, 1988.
29. Srikijvilaikul T, Najm I, Foldvary-Schaefer N, Lineweaver T, Suh JH, Bingaman WE: Failure of gamma knife radiosurgery for mesial temporal lobe epilepsy: Report of five cases. Neurosurgery 54:1395–1404, 2004.
30. Terra VC, Machado HR, Sakamoto AC, Arida RM, Cavalheiro EA, Scorza FA.: Epilepsy surgery could be considered a line of defense against sudden unexpected death in epilepsy. Childs Nerv Syst. Mar 24. [Epub ahead of print], 2009.
31. Tonini C, Beghi E, Berg AT, Bogliun G, Giordano L, Newton RW, Tetto A, Vitelli E, Vitezic D, Wiebe S: Predictors of epilepsy surgery outcome: Ametaanalysis Epilepsy Res 62:75–87, 2004.
32. Wen HT, Rhoton AL Jr, de Oliveira E, Cardoso AC, Tedeschi H, Baccanelli M, Marino R Jr.: Microsurgical anatomy of the temporal lobe: part 1: mesial temporal lobe anatomy and its vascular relationships as applied to amygdalohippocampectomy. Neurosurgery 45(3):549-91 1999.
33. Wiebe S, Rose K, Derry P, McLachlan R: Outcome assessment in epilepsy: Comparative responsiveness

of quality of life and psychosocial instruments. Epilepsia 38:430–438, 1997.

34. Wieser HG, Yaşargil MG: Selective amygdalohippocampectomy as a surgical treatment of mesiobasal limbic epilepsy. Surg Neurol 17:445–457, 1982.
35. Wieser HG: Selective amygdalohippocampectomy has major advantages, in Miller JW, Silbergeld DL (eds): Epilepsy Surgery: Principles and Controversies. New York, Taylor & Francis, pp 465–478, 2006.
36. Willmann O, Wennberg R, May T, Woermann FG, Pohlmann-Eden B: The contribution of 18F-FDG PET in preoperative epilepsy surgery evaluation for patients with temporal lobe epilepsy. A meta-analysis. Seizure 16:509–520, 2007.
37. Yaşargil MG, Teddy PJ, Roth P: Selective amygdalo-hippocampectomy. Operative anatomy and surgical technique. Adv Tech Stand Neurosurg 12:93–123, 1985.