



# Avoidance of Pitfalls and Complications During Surgery for Temporal Lobe Epilepsy

Arimappamagan Arivazhagan, Sanjib Sinha, and Malla Bhaskara Rao

## Abstract

Anterior temporal lobectomy with amygdalohippocampectomy is the most common epilepsy surgery, which, in cases of mesial temporal lobe epilepsy caused by mesial temporal sclerosis, usually leads to improvements in seizure control, cognitive function, and quality of life. Nevertheless, while the primary goal of intervention is achieved in a large majority of patients, a small number of them, unfortunately, encounter complications. Some morbidity is nonspecific and may be noted after any craniotomy (e.g., surgical site infections, meningitis, bone flap osteomyelitis, and operative site or craniotomy-related hematomas). On the other hand, certain complications are specifically associated with surgery for temporal lobe epilepsy and can be discussed from the etiological standpoint: mechanical injuries of the brain; injury of eloquent neuronal structures; arterial and venous injuries; cerebral venous thrombosis; remote cerebellar hemorrhage; and postoperative hydrocephalus, seizures, and psychiatric disorders. In many cases, these complications are manifested in the early postoperative period by alterations of consciousness and a focal neurological deficit, and it may require immediate decisions on their appropriate management.

## Keywords

Amygdalohippocampectomy · Anterior temporal lobectomy · Complication · Epilepsy surgery · Mesial temporal sclerosis · Temporal lobe epilepsy · Vascular injury

A. Arivazhagan · M. B. Rao (✉)  
Department of Neurosurgery, National Institute of Mental Health and NeuroSciences (NIMHANS), Bangalore, India  
e-mail: [brmall@gmail.com](mailto:brmall@gmail.com)

S. Sinha  
Department of Neurology, National Institute of Mental Health and NeuroSciences (NIMHANS), Bangalore, India

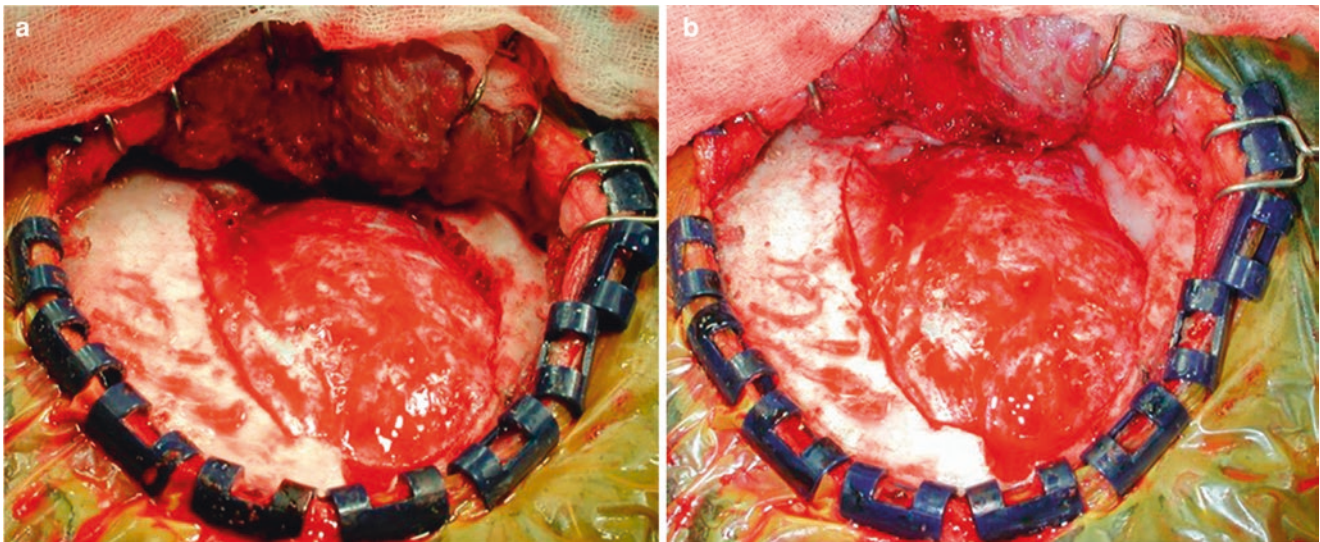
## Introduction

Mesial temporal lobe epilepsy (MTLE) caused by mesial temporal sclerosis (MTS) is the most common cause of surgically remediable chronic drug-resistant seizures. Anterior temporal lobectomy (ATL) with amygdalohippocampectomy is the most common surgical procedure for epilepsy, which, in cases of MTLE with MTS, usually leads to definite improvements in seizure control, cognitive function, and quality of life. Suitable candidates for ATL can be identified with standardized noninvasive investigational protocols, which typically include video electroencephalography (EEG), computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and, occasionally, magnetoencephalography (MEG). The clinical outcomes after such diagnostic examinations and subsequent surgical treatment are clearly cost effective.

Nevertheless, while the goal of surgery—that is, cure or control of chronic drug-resistant epilepsy—is achieved in a large majority of patients, a small number of them, unfortunately, encounter complications. Strategies for recognition of the possible pitfalls during surgery for MTLE, prevention of various morbidities, and accomplishment of their appropriate management are discussed herein, using descriptions of clinical cases from the experience of the senior author.

## Spectrum of Complications

The entire spectrum of epilepsy surgery complications has been generally classified into two main categories: (1) neurological and (2) nonneurological/surgical. The former mostly depend on the pre-existing functional deficit and the extent and location of the resection area, and they are governed largely by the hemispheric dominance, the proximity of the operative field to the eloquent cortex and critical white matter tracts, and variations in the vascular anatomy. On the



**Fig. 1** Intraoperative photography shows mastoid air cells that have been opened following right-side temporal craniotomy (a) and properly sealed (b) using bone wax to prevent cerebrospinal fluid leakage

other hand, there is always a possibility of nonspecific surgical morbidity.

Correspondingly, ATL with amygdalohippocampectomy may result in complications associated with craniotomy in general (e.g., surgical site infections, meningitis, bone flap osteomyelitis, and operative site or craniotomy-related hematomas). In addition, there are certain challenges and morbidities specifically associated with this surgical procedure, which can be discussed from the etiological standpoint: mechanical injuries of the brain; injury of eloquent neuronal structures; arterial and venous injuries; cerebral venous thrombosis; remote cerebellar hemorrhage; and postoperative hydrocephalus, seizures, and psychiatric disorders. In many cases, these complications are manifested in the early postoperative period by alterations of consciousness and a focal neurological deficit. Finally, surgical treatment failures may be related to false localization or incomplete resection of the epileptogenic focus or lesion, which may happen, in particular, during the learning curve of a comprehensive epilepsy management team.

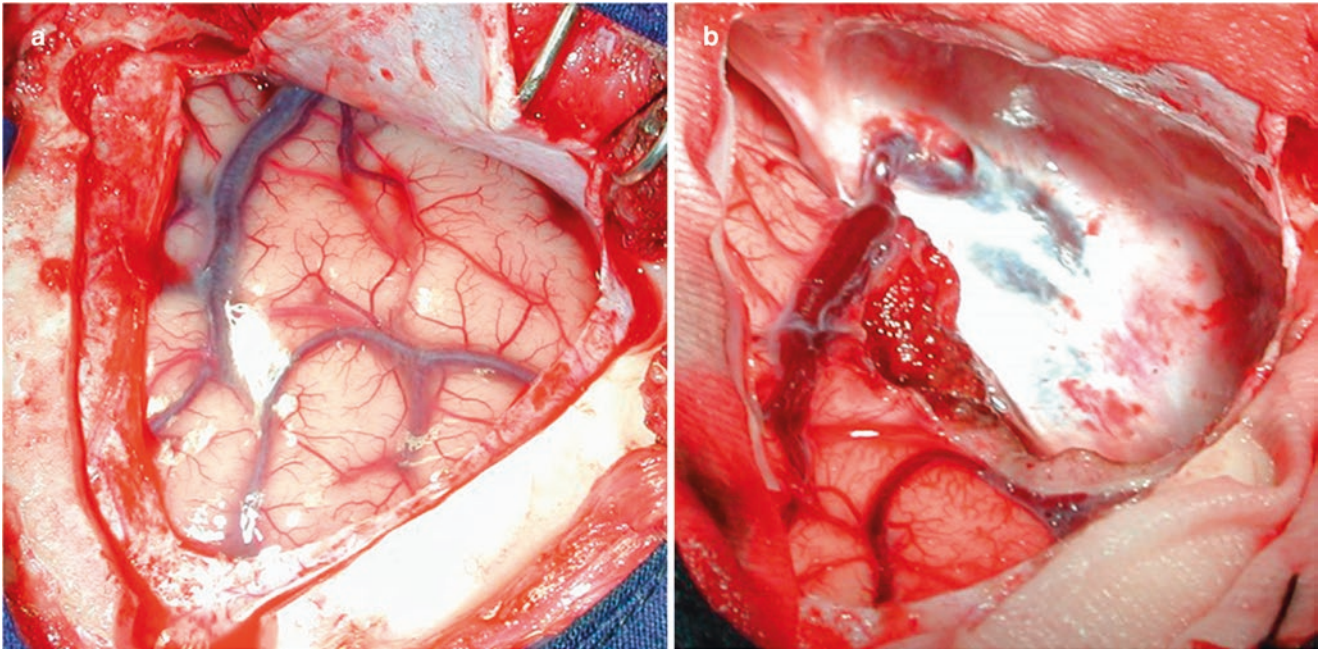
## General Technical Issues

It should be noted that in patients suffering from MTLE with MTS, hippocampal atrophy may be associated with atrophy of the entire temporal lobe. As a result of such chronic changes, bone and mastoid air cells, in particular, can be

hypertrophied. Occasional opening of these hypertrophied mastoid air cells during craniotomy is not a problem as long as it is recognized and they are properly sealed at the end of the procedure (Fig. 1) to avoid cerebrospinal fluid (CSF) leakage and meningitis, which can complicate an otherwise good surgical outcome.

ATL includes resection of the neocortex, extending for up to 3.5–4.0 cm on the dominant side and 4.0–4.5 cm on the nondominant side along the Sylvian fissure. Lateral neocortical resection, especially of the superior temporal gyrus (STG), may have to be limited in certain cases, depending on the hemispheric dominance and cortical eloquence, the location of the middle cerebral artery (MCA) branches, and the pattern of venous drainage (Fig. 2). Of note, the vein of Labbé is an inconstant structure and, when it is present, it indicates nothing more than posterior drainage of the Sylvian venous system.

The amygdala and the hippocampus are always removed via the transventricular approach. At this stage, use of an operating microscope is mandatory. Opening of the temporal horn of the lateral ventricle exposes the *pes hippocampi*. *En bloc* resection is limited to the anterior two-thirds of the hippocampus and the lateral two-thirds of the amygdala, along with the uncus and the parahippocampal gyrus, utilizing subpial dissection. The medial part of the amygdala is not removed, as it abuts the striatum, the anterior commissure, and the tail of the caudate nucleus. The hippocampal sulcus contains the Ammon's horn artery (the fundamental landmark for a subependymal, subpial resec-



**Fig. 2** Intraoperative photography shows a large vein traversing the temporal lobe (a), which was preserved during temporal lobectomy (b)

tion of the hippocampus). Of note, subpial resection minimizes manipulations of the anterior choroidal artery (AChA) and branches arising from the posterior cerebral artery (PCA), which reduces the risks of vascular injury resulting from occasional division and coagulation of these vessels.

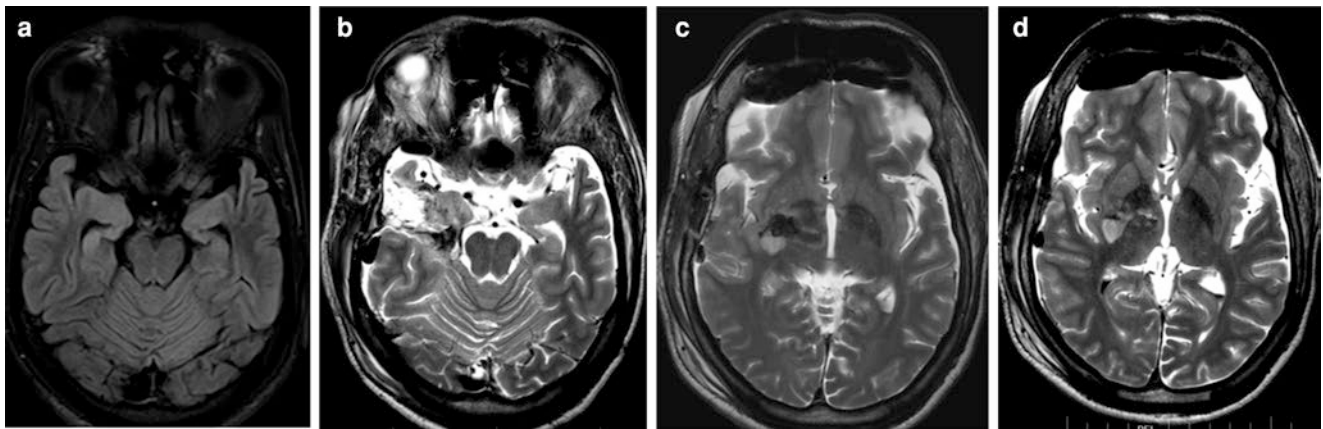
### Mechanical Injuries of the Brain

Mechanical injury of the brain during ATL is uncommon. The temporal craniotomy must be located anteriorly to avoid excessive retraction of the temporal lobe, which may lead to a neurological deficit. Retraction of the posterior temporal lobe must be done gently and, preferably, along the long axis of the hippocampus; undue retraction can cause brain edema and/or venous injury, and it may result in a postoperative language deficit if the surgery is performed on the dominant side. Similarly, during hippocampectomy, retraction of the roof of the temporal horn needs to be done carefully, because excessive pressure can cause postoperative hemiparesis. Preferably, the choroid plexus should not be taken under a spatula, since inappropriate traction of it can cause avulsion of arteries in the choroidal fissure. The entire dissection in the medial temporal lobe should be confined to structures below the choroidal fissure. Accidental dissection above the

choroidal fissure through the roof of the ventricle can extend to the internal capsule, resulting in permanent hemiparesis or hemiplegia.

### Illustrative Case 1: Postoperative Hemiplegia

A 31-year-old man presented with a history of focal seizures, which had started when he was 15 years of age. The clinical semiology consisted of perioral automatism, an aura of seeing stars, and tonic posturing of the left hand, followed by right-side hemifacial twitching with deviation of the angle of the mouth toward the right side, and with subsequent tonic posturing of the right upper limb and then of the right lower limb, and, finally, loss of consciousness. The frequency of the seizures was one per month. He received valproate (valproic acid; 1500 mg per day), levetiracetam (1000 mg per day), and carbamazepine (800 mg per day). Video-EEG revealed that the seizures originated from the right temporal region. The results of brain MRI were suggestive of right-side MTS (Fig. 3a), and PET-MRI showed hypometabolism in the right temporal area. The results of MEG were inconclusive. The patient underwent right-side temporal craniotomy and ATL with amygdalohippocampectomy. During the surgery, inadvertent injury of the right basal ganglia and thalamus occurred (probably because of excessive retraction), which resulted in left-side hemiplegia. Postoperative



**Fig. 3** In a 31-year-old man with a long history of focal seizures, pre-operative magnetic resonance imaging (MRI) showed atrophy of the right hippocampus with signal changes suggestive of mesial temporal sclerosis (a). Anterior temporal lobectomy with amygdalohippocampectomy was done, but left-side hemiplegia was noted immediately

after the surgery. Postoperative MRI (b–d) demonstrated the results of the temporal lobectomy, along with signal changes in the right basal ganglia, extending into the posterior limb of the internal capsule, suggestive of a hematoma

CT and MRI demonstrated a hematoma in the region of the right internal capsule (Fig. 3b–d). After >3 months of subsequent rehabilitation, his motor function had improved, with the power in the left upper and lower limbs being 2/5 and 4/5, respectively.

### Injury of Eloquent Neuronal Structures

When surgery in an eloquent brain region is planned, utilization of specific pre- and intraoperative brain mapping techniques is required for avoidance of injury of the functionally important cortex and white matter tracts.

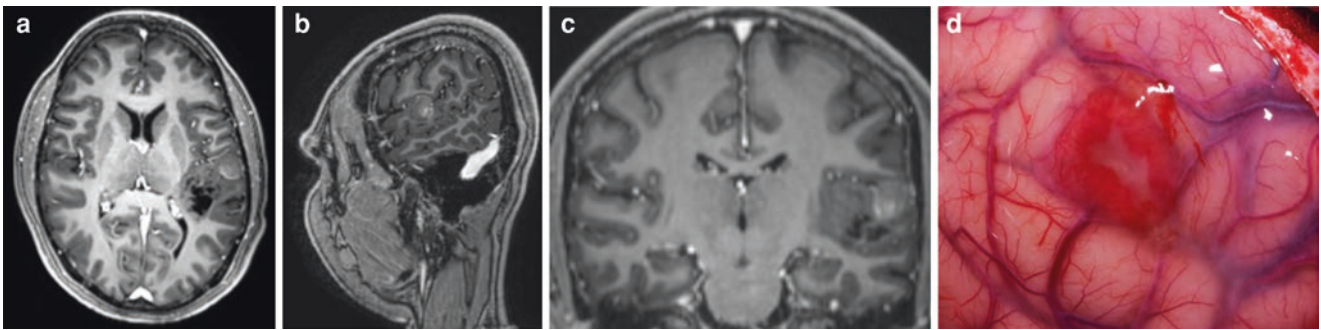
### Illustrative Case 2: Postoperative Naming Difficulty

A 37-year-old man presented with a history of drug-resistant seizures, which had started when he was 14 years of age. The clinical semiology consisted of bilateral ear fullness, *déjà vu* phenomena, motor freezing, and loss of awareness, followed by loss of tone in antigravity muscles and falls. Brain MRI demonstrated a well-defined heterogeneous lesion with perifocal edema, located in the left STG with extension into the posterior part of Sylvian fissure (Fig. 4a–c); the solid component of the lesion demonstrated restricted diffusion. Since the lesion was located in proximity to the temporal language area, the patient underwent functional MRI and received extensive counseling regarding the possibility of a postoperative neurological deficit.

Awake surgery was done, involving left-side temporal craniotomy and extended lesionectomy (Fig. 4d) under the control of electrocorticography (ECoG) and direct cortical mapping with electrical stimulation. Nevertheless, postoperatively, he developed a naming difficulty, which partially resolved with speech therapy.

### Visual Field Defects

A visual field defect is one of the most common deficits that can appear following ATL. Sometimes, the occurrence of superior quadrantanopia is even considered not as a complication but as an expected consequence of the procedure. Rather often, this side effect is not consistently evaluated during postoperative follow-up; thus, its reported incidence in different series has been rather variable. Superior quadrantanopia has been noted in 4.3–25% of patients but mostly has not led to subjective complaints [1–5]. In contrast, symptomatic hemianopia has been revealed less frequently (occurring in 1.2–1.3% of cases [5, 6]); in particular, in a prospective population-based study performed by Bjellvi et al. [6] the incidence of this complication after ATL with hippocampectomy was 1.2%. For avoidance of injury to Meyer's loop, use of basal approaches has been suggested, but their application requires sufficient expertise and experience. Tractography based on diffusion tensor imaging may depict Meyer's loop and facilitate preoperative planning of the surgical approach. Thudium et al. [3] applied such a technique in their series but still encountered incomplete superior quadrantanopia after surgery in 25% of patients.



**Fig. 4** In a 37-year-old man with a long history of drug-resistant seizures, preoperative postcontrast axial (a), sagittal (b), and coronal (c) magnetic resonance imaging demonstrated a mildly enhanced lesion of

heterogeneous intensity, located in the left posterior perisylvian region. Intraoperative photography (d) showed a hyperemic lesion on the cortical surface

### Arterial Injuries

Vascular injuries (either arterial or venous ones) during ATL with amygdalohippocampectomy are relatively uncommon if the procedure is performed carefully. Nevertheless, because of the close anatomical relationship of the mesial temporal lobe structures with the midbrain and choroidal fissure, the incidence of severe vascular complications, such as postoperative stroke, may be as high as 2.5%. They usually manifest with a motor deficit. Behrens et al. [7] noted transient and permanent hemiparesis in 3.03% and 2.3% of patients, respectively. Upon subgroup analysis of their series, Hader et al. [8] noted occurrence of hemiparesis in 1.8% of cases following temporal lobe resection (in comparison, the incidence of minor hemiparesis after extratemporal resection was 7.9%).

There are two main stages in temporal lobe surgery during which special care should be taken to avoid arterial injury. The first is during subpial dissection of the STG, since the MCA and its branches are located very close to the area of surgical manipulations, requiring a proper dissection technique with preservation of the pia mater and the arachnoid of the Sylvian fissure for avoidance of vascular damage. The second (and most important) stage is during dissection of the hippocampal complex from the choroidal fissure, since the AChA can be injured during removal of the head of the hippocampus, which can cause hemiparesis.

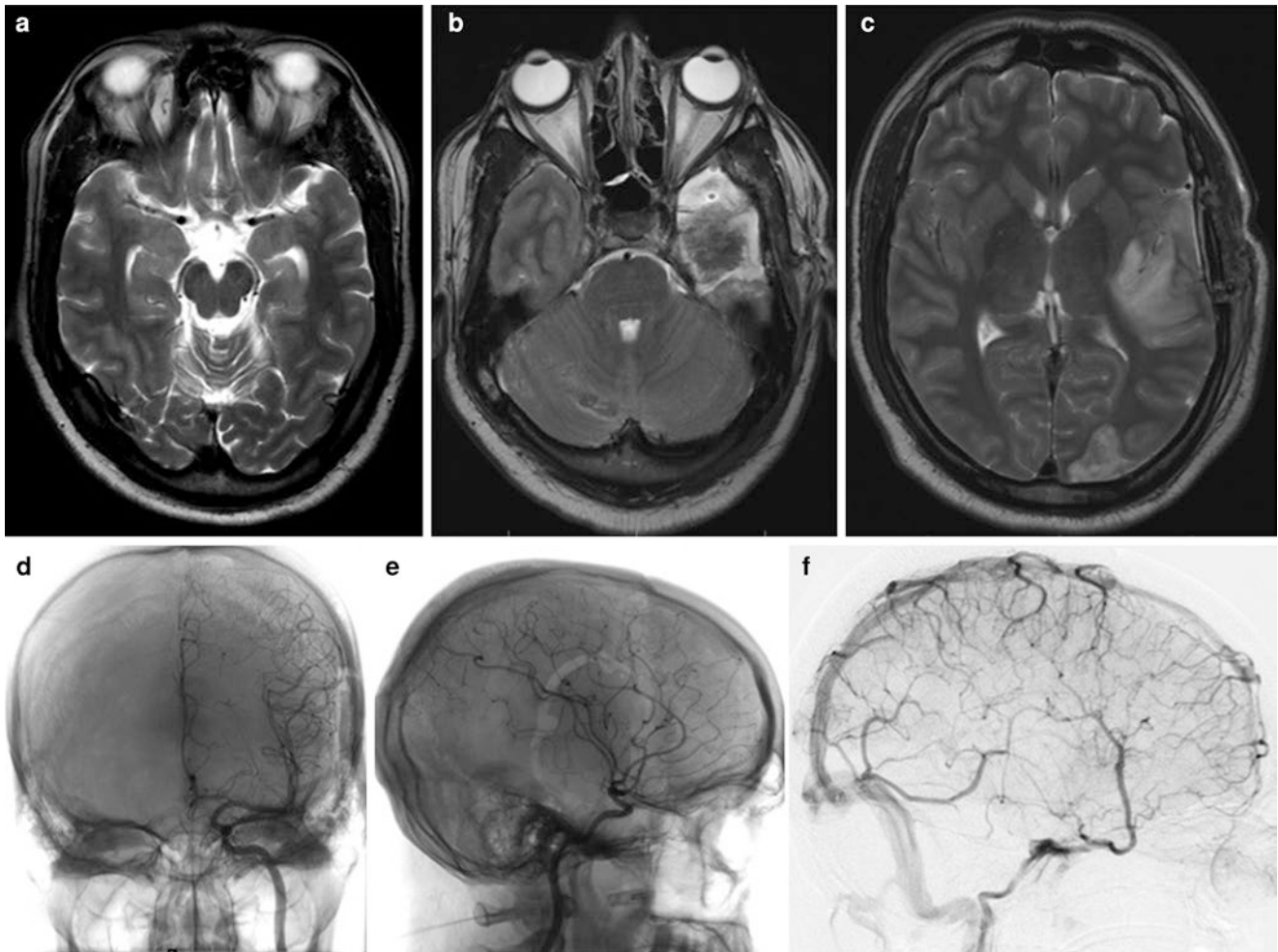
Hippocampal arteries arise from the PCA and should be carefully dissected or coagulated at the hippocampal sulcus to facilitate further subpial dissection of the hippocampal complex. Traction on these vessels should be avoided, since it can lead to their avulsion from the PCA and hemorrhage. Sometimes, an accessory artery from the AChA can be revealed in the most anterior part of the hippocampal sulcus, and this should be preserved. Slight oozing can usually be controlled with local hemo-

static agents (e.g., oxidized cellulose), and coagulation should be avoided as much as possible.

Traction injury of perforators can happen during dissection of medial structures, more often if *en bloc* resection of the temporal lobe is attempted. Therefore, it is advisable to separate the procedure into two parts and to perform lateral temporal lobectomy followed by resection of the mesial structures.

### Illustrative Case 3: Multiple Postoperative Cerebral Infarcts

A 41-year-old man presented with a history of complex partial seizures, which had started when he was 33 years of age and occurred 5–6 times per month. Video-EEG revealed ictal onset in the left anterior and midtemporal regions. Brain MRI demonstrated volume reduction of the left temporal lobe with hippocampal atrophy (Fig. 5a). MEG did not show definite localization of the epileptic focus. Neuropsychological assessment indicated left frontotemporal impairment. The patient underwent left-side ATL with amygdalohippocampectomy. During subpial dissection of the STG, the pia mater over the Sylvian vessels was breached, but otherwise the surgery was uneventful. Postoperatively, the patient demonstrated a gradual decline of his consciousness level, and within 5 h, his condition corresponded to a Glasgow Coma Scale score of 7 (eye opening: 2; verbal response: 1; motor response: 4) with right-side hemiparesis. Ventilatory support was required. Plain brain CT showed a hypodensity in the left temporal area and specks of hemorrhage in the right cerebellar hemisphere and in the left temporal, left occipital, and right temporal lobes. Brain MRI disclosed infarction in the territory of the inferior branch of the left MCA (Fig. 5b, c). Digital subtraction



**Fig. 5** In a 41-year-old man with complex partial seizures, preoperative magnetic resonance imaging (MRI) showed volume reduction of the left temporal lobe with hippocampal atrophy suggestive of mesial temporal sclerosis (a). Anterior temporal lobectomy with amygdalohippocampectomy was done, but, during the early postoperative period, the patient demonstrated a gradual decline of his consciousness level and development of right-side hemiparesis. Postoperative MRI (b, c)

showed the results of the temporal lobectomy, along with signal changes suggestive of infarction in the territory of the inferior branch of the left middle cerebral artery, and specks of hemorrhage in the right cerebellar hemisphere and in the left temporal, left occipital, and right temporal lobes. Digital subtraction angiography (d–f) did not demonstrate any abnormalities

angiography did not demonstrate significant abnormalities (Fig. 5d–f). With conservative treatment, the condition of the patient gradually improved and he was therefore weaned off ventilatory support and extubated. Thyroid function tests revealed decreased T3 levels; thus, low-dose thyroxine replacement was started. He received speech therapy for dysphasia. Symptomatic treatment during the subsequent 3 months resulted in further improvement of his condition. Although the exact cause of the complication in this case remained unclear, a possibility of vasospasm causing infarction involving multiple cerebral lobes and the right cerebellar hemisphere was considered.

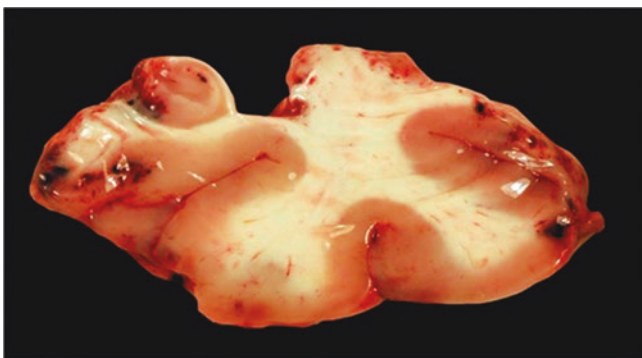
#### **Illustrative Case 4: Postoperative Hemiparesis Caused by Perforator Injury**

A 19-year-old woman presented with drug-resistant epilepsy of 10 years' duration. Clinical, EEG, and MRI data were concordant with a diagnosis of right-side MTS; thus, ATL with amygdalohippocampectomy was performed. The temporal lobe and medial temporal structures were resected *in toto* (Fig. 6). Immediately after the surgery, left-side hemiparesis was noted, and brain MRI revealed an internal capsule infarct, most probably due to a perforator injury caused by traction. The patient also demon-

strated adjustment disorder and depression, which improved with psychiatric counseling, antidepressant therapy, and rehabilitation.

## Venous Injuries

Venous injuries during temporal lobectomy primarily affect superficial veins of the temporal lobe. However, since the posterior limit of brain resection on the nondominant side is located within 4–5 cm of the temporal pole, it often reaches the proximity of the vein of Labbé. The latter may also be occasionally damaged during retraction of the temporal lobe, if appropriate care is not taken. In addition, a dominant vein draining the Sylvian veins into the transverse sinus may

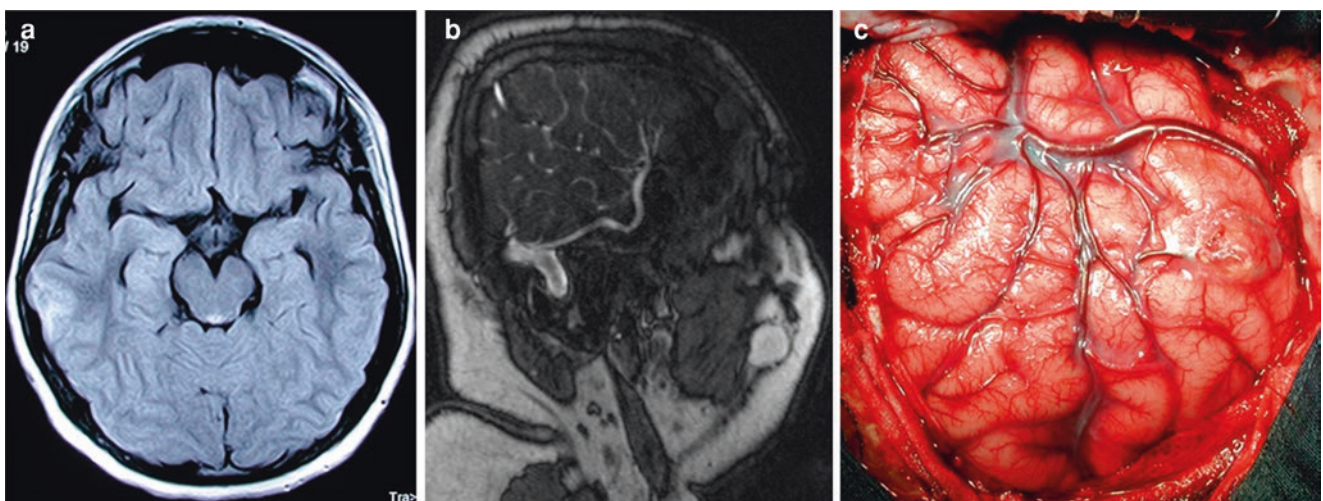


**Fig. 6** A surgical specimen from the right lateral temporal lobe and mesial structures resected *in toto* in a 19-year-old woman who presented with a long history of drug-resistant epilepsy. The postoperative period was complicated by left-side hemiparesis, most probably due to a perforator injury caused by traction

sometimes be found in the anterior temporal lobe. If such a posteriorly directed vessel is present, it should be preserved and the temporal lobe resection should be done anteriorly to it. At the time of hippocampectomy, the basal vein of Rosenthal and its tributaries are encountered in the ambient cistern; thus, a diligent surgical technique is required for avoidance of their injury, which is attained by preservation of the arachnoid of the ambient cistern.

## Illustrative Case 5: Surgical Limitations Attributable to Vascular Anatomy

A 22-year-old man presented with a long history of stress-induced complex partial seizures, which occurred 6–7 times per month and were characterized by lip smacking and stiffness of the left limbs. Video-EEG revealed ictal onset in the right mesial temporal region, and brain MRI demonstrated a neocortical lesion in the right posterior temporal lobe (Fig. 7a); a large vein of Labbé draining into the transverse sinus was also noted (Fig. 7b). The patient underwent anterior temporal lobe resection with lesionectomy under the guidance of ECoG. The medial temporal lobe structures were preserved. During the surgery, a large vein of Labbé was noted quite anteriorly (Fig. 7c), which limited the volume of the resection. Temporal lobe tissue was removed on either side of the vein, preserving the vascular continuity. Postoperative MRI showed no residual lesion and demonstrated preservation of the mesial temporal lobe structures. The seizures, however, recurred when the patient abruptly stopped taking his antiepileptic drugs (AED) 9 months after the surgery.



**Fig. 7** In a 22-year-old man with a long history of stress-induced complex partial seizures, preoperative magnetic resonance imaging demonstrated a well-defined neocortical lesion in the right posterior temporal

lobe (a) and a large vein of Labbé draining into the transverse sinus (b). Intraoperative photography (c) showed a large vein of Labbé located quite anteriorly, which limited the volume of resection

## Cortical Venous Thrombosis

Overall, postoperative cortical venous thrombosis (CVT), as a consequence of intraoperative venous injury, is not an uncommon complication and is encountered in 7% of cases. However, spontaneous CVT is extremely rare, and such a diagnosis may be established only after definite exclusion of iatrogenic venous damage during surgery.

### Illustrative Case 6: Postoperative Remote Cortical Venous Thrombosis

We have experienced a case of contralateral (left-side) CVT after right-side ATL for MTS. This event has previously been reported elsewhere, with a discussion on various factors that could have resulted in such a unique and previously undescribed complication [9]. The patient developed right-side focal motor seizures and alterations of consciousness on the second postoperative day. Imaging revealed left parietal CVT accompanied by a significant mass effect, which necessitated left-side temporo-parieto-occipital decompressive craniectomy and lax duraplasty. Thereafter, the condition of the patient improved gradually, but mild residual right-side hemiparesis persisted. In this case, development of CVT unrelated to the contralateral temporal lobe surgery might have been linked to existent hyperhomocysteinemia and a probable subclinical hypercoagulable state aggravated by perioperative hemodynamic disturbances [9].

### Remote Cerebellar Hemorrhage

Remote cerebellar hemorrhage following supratentorial surgery has been well described in the neurosurgical literature. Its causes are considered to be multifactorial, and the most frequently mentioned risk factors include coagulation disorders, perioperative CSF drainage, arterial hypertension, and seizures. In a review of such cases, Sturiale et al. [10] noted that they were mainly encountered following surgery for intracranial aneurysms, tumor debulking, and lobectomies. Obviously, surgery for MTLE—which entails temporal lobectomy, opening of the cerebral ventricle, and a significant amount of CSF drainage—may occasionally predispose to this complication.

### Illustrative Case 7: Remote Cerebellar Hemorrhage

A 39-year-old right-handed man presented with a long history of seizures, which were characterized by vague discom-

fort and apprehension prior to their onset, followed by lip smacking and automatism in the form of folding of both hands together, with a subsequent staring look and a brief period of unresponsiveness lasting for about 3–5 min. Despite AED administration, the seizures occurred 25–30 times per month. Video-EEG revealed a seizure focus in the right temporal area, and brain MRI demonstrated atrophy of the right hippocampus, suggestive of MTS. The patient underwent right-side ATL with amygdalohippocampectomy. Postoperatively, however, he developed difficulty with breathing, became drowsy (although arousable), and did not obey commands. Neurological examination revealed left-side hemiparesis and poor cough and gag reflexes. He also had bilateral crepitations in the lungs, most probably caused by aspiration. Postoperative CT and MRI examinations, including diffusion-weighted and perfusion-weighted imaging, demonstrated infarction in the posterior limb of the right internal capsule, most likely resulting from a perforator injury. In addition, there were specks of hemorrhage in both cerebellar hemispheres. Antiedema therapy was initiated, but the next day, the patient's condition deteriorated, necessitating intubation and ventilation. Repeat CT showed an increase in the right cerebellar hemorrhage size and obliteration of the fourth ventricle. Urgent posterior fossa decompressive craniectomy with duraplasty was done. After the surgery, he electively remained on a ventilator but was then weaned off it, since his level of consciousness demonstrated gradual improvement. At the time of discharge, the patient was alert and obeyed commands, and the power in his left extremities had improved to 4/5. The reason for the remote cerebellar hemorrhage in this case remained unclear.

### Postoperative Hydrocephalus

Hydrocephalus is a very rare complication after epilepsy surgery and is mostly encountered following hemispherotomy or hemispherectomy. In their series of 523 temporal lobe resections, Bjellvi et al. [6] identified only one patient whose postoperative course was complicated by a hematoma and subsequent hydrocephalus. Correspondingly, among 279 patients who underwent temporal lobe surgery, Behrens et al. [7] noted postmeningitic hydrocephalus in only one patient, who underwent implantation of a CSF shunt. On very rare occasions, there may be symptomatic cyst formation at the lobectomy site, resulting in increased intracranial pressure and neurological deterioration; only a few such cases have been reported previously. We have previously described our own experience with such an unusual complication, which required repeat surgery for excision of the cyst, resulting in improvement of the patient's condition [11].



### Illustrative Case 8: Postmeningitic Hydrocephalus

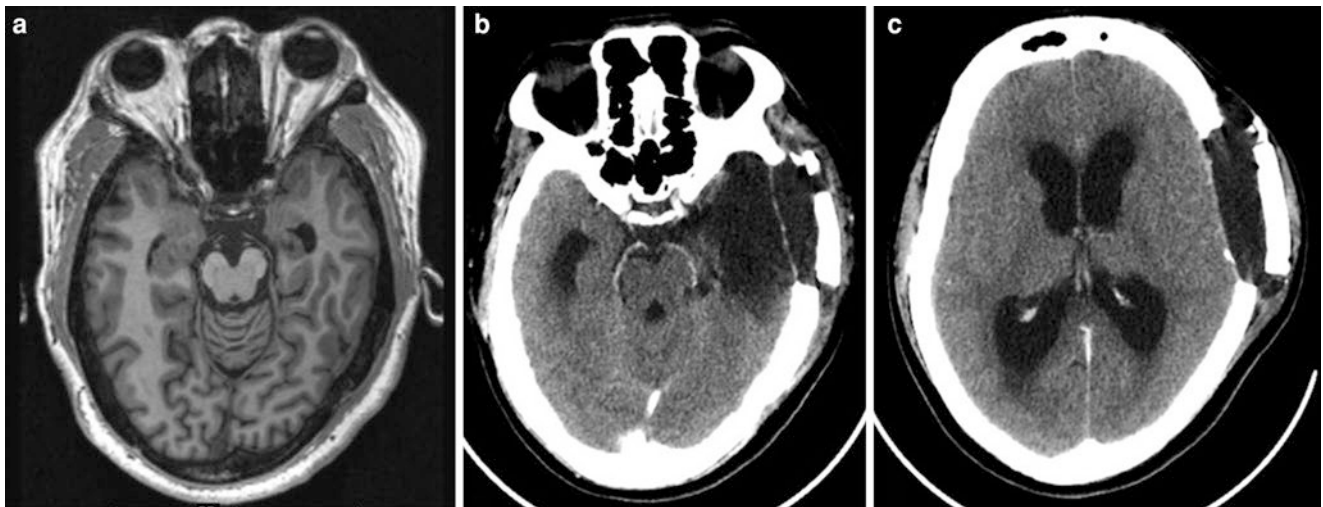
A 31-year-old man presented with a 17-year history of multiple episodes of seizures. The clinical semiology consisted of blurring of vision and palpitations, followed by loss of awareness, vocalization, a staring look, orofacial automatism, deviation of the face to the right side, and posturing of the right upper and lower limbs. Despite therapy with multiple AED, including oxcarbazepine and lacosamide, the seizures occurred with a frequency of 10–15 times per month. Video-EEG revealed ictal onset in the left anterior and midtemporal regions, and brain MRI demonstrated atrophy of the left hippocampus (Fig. 8a). Neuropsychological assessment indicated diffuse impairment. The patient underwent left-side ATL with amygdalohippocampectomy. The postoperative course was complicated by fever; thus, a lumbar puncture was done. CSF analysis showed an increased cell count with predominance of polymorphonuclear leukocytes, as well as elevated lactate and protein levels; however, there was no microbial growth from the CSF culture. Treatment with broad-spectrum antibiotics cured the meningitis. Nevertheless, the patient developed fluctuant protrusion of tissues in the area of the craniotomy, and CT demonstrated epidural fluid collection, elevation of the bone flap, and mild hydrocephalus (Fig. 8b, c). There were no contrast-enhanced lesions. In addition, clinical features of normal pressure hydrocephalus were noted (incontinence, ataxia, and disorientation in time and place). Therapy with acetazolamide (750 mg per day) was started, while lumboperitoneal shunting was considered as a reserve option. With medical treatment over the next

3 weeks, the condition of the patient gradually improved and the symptoms decreased; thus, he did not undergo a CSF diversion procedure and was discharged.

### Postoperative Seizures

Seizures in the immediate or early postoperative period are often noted following surgery for MTLE, and previous studies have suggested that their occurrence may predict poor seizure control thereafter [12, 13]. A meta-analysis of 17 published studies revealed a 22.58% prevalence of acute postoperative seizures and showed that in comparison with their counterparts, a significantly higher proportion of patients who did not experience seizures within 30 days after the surgery were seizure-free at  $\geq 1$  year of follow-up (73.49% versus 38.96%; odds ratio 4.20, 95% confidence interval 2.97–5.93;  $P < 0.0001$ ) [13]. However, patients who had seizures within 24 hours after their surgery (particularly seizures with different semiology from that of their habitual preoperative seizures) were more likely to achieve a seizure-free outcome, although the difference did not reach the level of statistical significance [13].

In fact, if the semiology of postoperative seizures differs from that of the patient's habitual seizures, then their etiology is most often related to perioperative causes. Among the latter, pneumocephalus is frequently noted, since its occurrence is facilitated by the large volume of the resection cavity following temporal lobectomy (this cavity should be filled fully with saline before completion of watertight dural closure). Other possible causes of postoperative seizures include



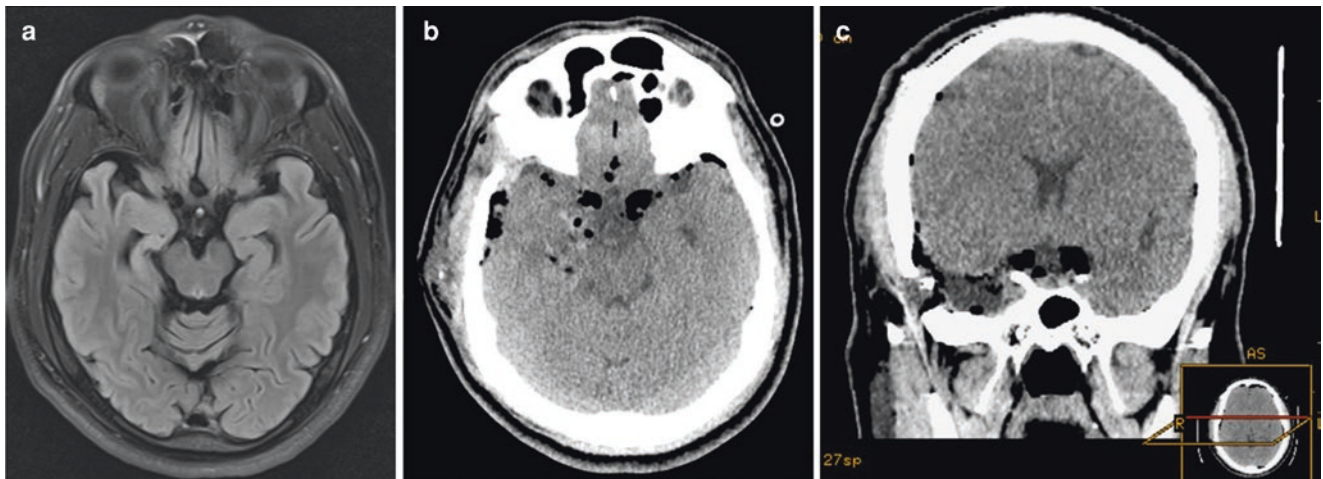
**Fig. 8** In a 31-year-old man with a long history of epilepsy, preoperative magnetic resonance imaging demonstrated atrophy of the left hippocampus, suggestive of mesial temporal sclerosis (a). Anterior temporal lobectomy with amygdalohippocampectomy was done, but

the postoperative course was complicated by meningitis. Subsequent computed tomography (b, c) demonstrated epidural fluid collection, elevation of the bone flap, and hydrocephalus

cerebral venous infarction, a subdural hematoma, electrolyte disturbances, and decreases in blood AED concentrations caused by perioperative changes in their administration.

### Illustrative Case 9: Postoperative Seizures with Different Semiology

A 36-year-old man presented with recurrent seizures, which had started when he was 10 years of age and occurred with a frequency of 2–3 times per month. The clinical semiology consisted of a sensation of fear, followed by rotatory movement of the right wrist, perioral automatism, and postictal confusion lasting approximately 5 min. He received levetiracetam (2000 mg per day), clobazam (20 mg per day), and carbamazepine (1600 mg per day). Ictal EEG revealed that the seizure origin was in the right anterior temporal region. Brain MRI demonstrated atrophy of the right hippocampus, suggestive of MTS (Fig. 9a). PET-MRI showed moderate-to-severe hypometabolism involving the right medial temporal lobe. The patient underwent right-side ATL with amygdalohippocampectomy. In the immediate postoperative period, he had alterations of consciousness. Within 24 h after the surgery, he experienced generalized tonic–clonic seizures (GTCS) twice and a left-side focal motor seizure once. CT demonstrated pneumocephalus (Fig. 9b, c). Therapy with valproate (1500 mg per day) was started. The patient required intubation and ventilatory support for 2 days but demonstrated gradual improvement and was therefore weaned off it. In this case, the occurrence of GTCS after ATL was most likely caused by diffuse pneumocephalus.



**Fig. 9** In a 36-year-old man with a long history of epilepsy, preoperative magnetic resonance imaging showed atrophy of the right hippocampus, suggestive of mesial temporal sclerosis (a). Anterior temporal lobectomy with amygdalohippocampectomy was done, but, in the immediate postoperative period, the patient experienced seizures with a

### Acute Postoperative Psychiatric Disorders

Patients with drug-resistant epilepsy usually have a variety of significant mental disturbances, which can be part of an associated personality disorder and/or the consequences of long-standing seizures. In addition, some AED may cause psychiatric side effects. Therefore, a detailed mental health assessment is essential in all such individuals to identify even subtle psychopathological abnormalities.

Surgery for MTL with removal of medial temporal lobe structures can have a bearing on pre-existing mental disturbances, which may be exacerbated during the perioperative period. In particular, depression after such interventions has been reported in 4.3–10% of patients [1, 14]. More rarely, new-onset psychopathological problems may appear. Macrodimitris et al. [15] performed a systematic review of studies reporting psychiatric outcomes following epilepsy surgery and noted that the rate of mental disorders occurring *de novo* ranged widely from 1.1% to 18.2%. In such clinical scenarios, collaborative care of the patient with a psychiatrist is mandatory.

### Illustrative Case 10: Postoperative Exacerbation of Behavioral Disturbances

A 17-year-old right-handed man presented with a 7-year history of seizures. The clinical semiology included a sudden speech arrest with a vague sensation in the abdomen and head turning to the right side. Behavioral changes with anger outbursts were also noted. Video-EEG revealed seizure onset

semiology different from that of his habitual seizures. They were most likely caused by diffuse pneumocephalus, as postoperative computed tomography (b, c) demonstrated air in the basal cisterns and along the cerebral convexity

in the left anterior and midtemporal regions. Brain MRI demonstrated loss of gray–white differentiation in the left temporal lobe, along with volume loss suggestive of left temporal lobe focal cortical dysplasia. PET-CT showed decreased metabolism in both hippocampi, more prominent on the left side. The patient underwent left ATL with amygdalohippocampectomy under ECoG monitoring. Postoperatively, he developed a rebound increase in his pre-existing psychiatric disturbance, manifested by frequent outbursts of intense anger, aggressive behavior, and assaults on his parents. Therapy with antipsychotics and AED resulted in gradual stabilization of these mental disorders.

### Alternative Surgical Techniques

There are a number of alternative surgical techniques besides standard ATL (e.g., tailored ATL and selective amygdalohippocampectomy), and their different variations have been well described in the literature. However, for a beginner in epilepsy surgery, it is preferable to perform a standard procedure (i.e., ATL with amygdalohippocampectomy), taking into consideration the neurological and neuropsychological status of the patient, the hemispheric dominance, the results of pre- and intraoperative brain mapping, and details of the vascular anatomy. Thereafter, when adequate experience has been obtained, it is possible to apply various types of selective amygdalohippocampectomy based on appropriate indications in each individual case. During such stepwise professional progress, appropriate measures must be taken for attainment of optimal postoperative seizure outcomes, as well as for avoidance of surgical, neurological, and neuropsychological morbidity.

### Conclusion

ATL with amygdalohippocampectomy for temporal lobe epilepsy is one of the few neurosurgical procedures that has demonstrated clear class 1 evidence of its superiority to medical treatment with regard to seizure control and improvements in cognitive function and quality of life. However, while the technique of surgical intervention for MTLE is well established and has been safely performed at many centers, one needs to be aware of the possible complications that can occur and must make the best efforts to avoid them for attainment of the best possible outcome with minimal morbidity. The ultimate goal of surgical treatment is restoration of the full functional capacity of patients, giving them freedom from seizures without any neurological deficit and allowing their complete integration into society.

**Conflict of Interest Statement** The authors have no conflict of interest concerning the reported materials or methods.

### References

1. Erba G, Winston KR, Adler JR, Welch K, Ziegler R, Hornig GW. Temporal lobectomy for complex partial seizures that began in childhood. *Surg Neurol.* 1992;38:424–32.
2. Kim SK, Wang KC, Hwang YS, Kim KJ, Chae JH, Kim IO, Cho BK. Epilepsy surgery in children: outcomes and complications. *J Neurosurg Pediatr.* 2008;1:277–83.
3. Thudium MO, Campos AR, Urbach H, Clusmann H. The basal temporal approach for mesial temporal surgery: sparing the Meyer loop with navigated diffusion tensor tractography. *Neurosurgery.* 2010;67(2 Suppl Operative):385–90.
4. Georgiadis I, Kapsalaki EZ, Fountas KN. Temporal lobe resective surgery for medically intractable epilepsy: a review of complications and side effects. *Epilepsy Res Treat.* 2013;2013:752195.
5. Mathon B, Navarro V, Bielle F, Nguyen-Michel VH, Carpentier A, Baulac M, Cornu P, Adam C, Dupont S, Clemenceau S. Complications after surgery for mesial temporal lobe epilepsy associated with hippocampal sclerosis. *World Neurosurg.* 2017;102:639–50.e1.–2.
6. Bjellvi J, Flink R, Rydenhag B, Malmgren K. Complications of epilepsy surgery in Sweden 1996–2010: a prospective, population-based study. *J Neurosurg.* 2015;122:519–25.
7. Behrens E, Schramm J, Zentner J, König R. Surgical and neurological complications in a series of 708 epilepsy surgery procedures. *Neurosurgery.* 1997;41:1–10.
8. Hader WJ, Tellez-Zenteno J, Metcalfe A, Hernandez-Ronquillo L, Wiebe S, Kwon CS, Jette N. Complications of epilepsy surgery: a systematic review of focal surgical resections and invasive EEG monitoring. *Epilepsia.* 2013;54:840–7.
9. Arivazhagan A, Mundlamuri RC, Shreedhara AS, Bharath RD, Mahadevan A, Sinha S, Rao MB, Satishchandra P. Remote contralateral side cerebral venous thrombosis following intracranial surgery: a rare complication in an unusual setting. *Neurol India.* 2018;66:520–2.
10. Sturiale CL, Rossetto M, Ermani M, Volpin F, Baro V, Milanese L, Denaro L, d'Avella D. Remote cerebellar hemorrhage after supratentorial procedures (part 1): a systematic review. *Neurosurg Rev.* 2016;39:565–73.
11. Rao MB, Radhakrishnan K, Radhakrishnan VV, Gupta AK. Expanding cyst following temporal lobectomy: an unusual complication of epilepsy surgery. *Clin Neurol Neurosurg.* 1999;101:141–4.
12. Rao MB, O'Brien TJ, Cascino GD, So EL, Radhakrishnan K, Silbert P, Marsh WR. Acute postoperative seizures following anterior temporal lobectomy for intractable partial epilepsy. *J Neurosurg.* 1998;89:177–82.
13. Giridharan N, Horn PS, Greiner HM, Holland KD, Mangano FT, Arya R. Acute postoperative seizures as predictors of seizure outcomes after epilepsy surgery. *Epilepsy Res.* 2016;127:119–25.
14. Lopez-Gonzalez MA, Gonzalez-Martinez JA, Jehi L, Kotagal P, Warbel A, Bingaman W. Epilepsy surgery of the temporal lobe in pediatric population: a retrospective analysis. *Neurosurgery.* 2012;70:684–92.
15. Macrodimitris S, Sherman EM, Forde S, Tellez-Zenteno JF, Metcalfe A, Hernandez-Ronquillo L, Wiebe S, Jetté N. Psychiatric outcomes of epilepsy surgery: a systematic review. *Epilepsia.* 2011;52:880–90.