ABSTRACT

Temporal lobectomy remains an underutilized procedure for intractable epilepsy, despite high success rates, low complication rates, and the development of several noninvasive localization techniques to evaluate potential surgery candidates. This paper briefly reviews some of the reasons behind the low utilization of epilepsy surgery, the different types of procedures, outcomes and complications of epilepsy surgery, and most importantly, the tools used to evaluate surgery candidates. Advances in neuroimaging can provide insights into the location of the epileptic focus. Epilepsy surgery is effective in about 75% of properly selected candidates, and serious complications occur in only 2% to 5% of patients, as discussed below. This article will review the appropriate selection criteria for epilepsy surgery, and the types of procedures, their indications, and their outcomes.

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emporal lobectomy is an underutilized procedure for the successful treatment of refractory epilepsy. For example, of the estimated 20,000 to 40,000 intractable epilepsy patients in the United States, only a few thousand of them are receiving lobectomies annually. Of note, there is a tendency among physicians, often among primary care physicians, to avoid the cost and risk of surgery if a patient is having, eg, 2 or 3 seizures a month.

CRITERIA FOR PATIENT SELECTION FOR SURGERY

Several important criteria determine the suitability of a patient for surgery. They include: seizures that interfere with quality of life, failure of adequate antiepileptic drug trials, a good social support system, and no current or recent psychological or psychiatric problems. In fact, there is a high prevalence of psychiatric problems, both acute and chronic, in people with epilepsy, and surgery may be the best way to stop their seizures and improve their psychiatric profile. So, psychiatric problems are not a contraindication, although surgery should clearly not be performed in the midst of an acute psychosis.

EPILEPSY OR IMITATOR?

Some patients with intractable seizures who are referred for consideration of surgery do not have epileptic seizures at all. Imitators of epilepsy can be divided into medical, neurological, and psychological categories, as outlined in Table 1. Some of the most common imitators are psychological: panic attacks, hyperventilation spells, night terrors (more common in children but occurring occasionally in adults), and nonepileptic seizures, ie, psychogenic seizures or pseu-
doseizures. The most important information source for this process is the seizure history, mostly to rule out imitators of epilepsy (Table 1). It is a somewhat common occurrence to refer patients for epilepsy surgery when they do not have epilepsy, mostly because the neurologist is not able to observe the seizure. Histories also inform of episodes with alteration of sensory function, motor function, and behavioral consciousness.

**Localized Seizure Focus**

Localizing the seizure focus is one of the primary presurgical goals. The seizure history may give symptoms at the start of a seizure, pointing to a partial onset. The neurological exam is another potential source for identifying fociality. The most important laboratory test is the electroencephalogram (EEG), but EEGs can be misleading. For example, frank interictal spikes in the EEG can occur but do not always originate from the same location as the ictal generator. Conversely, about half of patients with partial epilepsy will have a normal EEG when performed at a random point in time, almost always interictally. As the number of EEGs performed increases, so do the chances of detecting the seizure abnormality, reaching approximately 80% with the third EEG.3 EEG readings may be attenuated by effects of the skull and intervening tissue, distance of the recording electrodes from the generator of ictal activity, and variable orientation of the generator. Detection yield can be increased by recording the patient asleep and with deep deprivation, with hyperventilation, and with photic stimulation. Nasopharyngeal or sphenoidal leads are not used very often.

An EEG-clinical correlate is useful not only for localizing seizures, but also to rule out the occasional patient with mixed epileptic seizures and pseudo-seizures. It is preferred to observe 4 to 6 seizures all originating from the same location.

Magnetic resonance imaging (MRI) is the imaging method of choice for evaluating seizure patients. In particular, there are several types of abnormalities that would not be visible on a computed tomography (CT) scan that are detected with MRI, such as a cavernous angioma and cortical dysplasia.

Mesial temporal sclerosis is a common abnormality in temporal lobe epilepsy, but there is a problem: It is not clear whether seizures cause mesial temporal sclerosis, vice versa, or both. In evaluating epilepsy patients for surgery, it is preferable to observe mesial temporal sclerosis on an MRI, particularly if it is on the same side as numerous rhythmic seizures. This signals high likelihood of success in treating seizures. Other useful neuroimaging procedures include position emission tomography (PET) scanning, in particular to evaluate patients who do not have a clear MRI and do not have clear scalp localization. The PET scan helps in the decision to proceed further with invasive wires (discussed below). Single photon emission computed tomography and PET measure the functional changes produced by seizures.4 Other localization tests include neuropsychological tests; they are used not only to judge the level of function of the patient but also to localize and distinguish between visual, verbal, memory, and executive function.

Depth electrodes are used to identify the epileptogenic zone in patients with temporal lobe epilepsy and hibernal abnormalities seen on an scalp EEG.5 The multiple contact wires are arranged in strips or grids and are placed stereotactically into the brain through burr holes or craniotomy. This allows for recording multiple regions over one or both hemispheres.6

Magnetic resonance spectroscopy is a new and somewhat experimental but promising technique for looking at the metabolic alterations in epileptogenic tissue.7 The Wada amobarbital test inactivates 1 side of the brain for roughly 10 minutes; it is a reversible deficit. It is used to predict speech and memory functioning after epilepsy surgery, and it assists with localization of the epileptic focus by looking for asymmetry in memory and speech scores.8

Magnetoelectroencephalography is another window on the EEG, because every electrical current induces a corresponding magnetic field.9 Functional MRI is probably the fastest-growing new technique for localizing function in the brain at the region of the seizures.10

### Table 1. Imitators of Epilepsy

<table>
<thead>
<tr>
<th>Medical</th>
<th>Neurological</th>
<th>Psychological</th>
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<tbody>
<tr>
<td>Syncope</td>
<td>Transient ischemic attacks</td>
<td>Panic attacks</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>Confusional migraine</td>
<td>Hyperventilation spells</td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>Sleep disorders (e.g. narcolepsy)</td>
<td>Night terrors</td>
</tr>
<tr>
<td>Hypoxia</td>
<td>Vertigo</td>
<td>Night seizures (e.g. psychogenic, pseudoseizures)</td>
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Table 2. Reasons for Surgical Failure

<table>
<thead>
<tr>
<th>Incorrect diagnosis of epilepsy</th>
<th>Insufficient hippocampal resection</th>
<th>Neocortical temporal seizure origin</th>
<th>Extratemporal seizures</th>
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<tbody>
<tr>
<td>Frontal</td>
<td>Insular</td>
<td>Panseptal-occipital</td>
<td>Emergence of new seizure types</td>
</tr>
<tr>
<td>Parietal</td>
<td>Natural history</td>
<td>Consequence of surgery</td>
<td>Postoperative pseudoseizures</td>
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At 1 year after randomization, 58% of the surgical group (although a higher percentage among those who actually received surgery) and 8% of the medical group were free from seizures impairing consciousness (P < 0.001). Patients in the surgical group had a higher measured quality of life. The only death was in the medical group. This study reinforces the previously anecdotal experience that surgery is more effective than medication for complex partial and secondarily generalized seizures that do not respond to AEDs. Failure of a first AED due to lack of efficacy predicts subsequent intractability.11 Therefore, a study showing superiority of surgery suggests that clinicians should be considering surgery at an early stage of medication treatment failure.

### Epilepsy Surgery: Reasons for Failure

**Why does seizure surgery sometimes fail?** The most common reasons are shown in Table 2. Seizures can occur in a different region of the brain from that of the surgery—either the neocortical area on the temporal side or extratemporal seizures. Mesial temporal sclerosis can be bilateral, and if the 2 sides mature at different rates, the second locus may appear after an operation has been successful. Hennessy et al studied 282 patients after temporal resection; 44 were available for follow-up and having at least monthly seizures.

For further reading, please refer to the original article.
Twenty of those 44 had preoperative mesial temporal sclerosis, compared with 14 with nonspecific pathology and 9 with other pathology. Of the 20 with preoperative mesial temporal sclerosis, 5 were contralateral and 12 were ipsilateral. New seizure types may also emerge from natural history, or surgery can occasionally cause injuries that lead to seizures. Occasionally, patients can have postoperative pseudoseizures, reflecting adjustment difficulties to a seizure-free life.

**Epilepsy Surgery: Complications**

Mortality from epilepsy surgery has been reported at up to 0.5% in some series. Behrens et al followed 429 consecutive patients over 7 years, most of whom had temporal lobectomies. Of this cohort, 3% had transient problems. 2.4% had permanent neurological problems, including memory decline, aphasia, alexia, quadrantanopia, hemianopsia, hemiparesis, hemisensory loss, depression, mania, psychosis, personality change, infection, cerebrospinal fluid leak, hydrocephalus, or headaches. Although this series had no deaths, some patients were disappointed by worse seizures or emergence of new seizure types. A study by Henry et al of 60 consecutive anterior temporal lobectomy patients showed a cure rate for complex partial seizures of 77%, but 13% had more, or emergence of new, postoperative generalized tonic-clonic seizures. The tonic-clonic seizures often emerged during sleep, and were not just due to drug withdrawal.

Other types of operations include anterior corpus callosum resection, extratemporal lesion resection, and hemispherectomy. Corpus callosumotomy is used to disrupt the major central pathways involved in seizure propagation. Callosotomy is usually considered for patients with frequent secondary generalized, tonic-clonic, tonic, or atonic seizures that lead to falls or injuries. Extratemporal lesion resection is used for patients with extratemporal epilepsy with a structural brain lesion. The lesion and surrounding epileptogenic cortex is removed. Patients with intratemporal partial and secondarily generalized seizures in whom the entire hemisphere is considered epileptogenic with little or no remaining functional cortex (i.e., Rasmussen's encephalitis, Sturge-Weber syndrome, hemimegacephaly, or certain other large hemispheric lesions), hemispherectomy is a viable option. During a modified hemispherectomy, the frontal and temporal lobes usually are removed, and the remaining cortex and corpus callosum are isolated. Deep gray matter and frontal and occipital buttresses are left in place.

The Figure shows the outcomes for the different types of surgery.

**Vagus Nerve Stimulation**

Vagus nerve stimulation is an approved procedure, but the efficacy of vagus nerve stimulation in controlled clinical trials, while statistically significant, is not yet optimized. As reviewed by Binnie, there was a 23% reduction in the group that had the high stimulation levels. If the stimulator remains in place, 50% reduction has been observed, but the results are variable. Not all patients respond, but a few become seizure free.

Complications are rare but may include hoarseness, cough, throat tics, electrode fracture, rare vocal cord paralyses, and possible worsening of sleep apnoea (although not confirmed).

Many other sites are now being evaluated for possible stimulation, because they may be ‘pacemaker’ areas in brain. They include the cerebellum, the hypothalamus (although it is a difficult surgical target), subthalamus, the thalamic region (the centromedian nucleus and the anterior nucleus), and the caudate.

**Conclusion**

Epilepsy surgery is a generally safe, effective, and underutilized procedure for properly selected candidates. The best candidates are those with medically intractable partial epilepsies deriving from a mesial temporal or perilesional seizure focus. A combination of history, neurological exam, interictal EEG, ictal video, ERG, neuropsychological testing, and ever-improving neuroimaging studies can help epilepsy centers identify surgical candidates and operative targets. In experienced programs, rates of cure or major improvement approach 75% and complication rates are approximately 5% for mesial temporal lobectomy. Quality of life usually increases after seizure surgery.

Other types of surgery, such as vagus nerve stimulation, corpus callosum resection, and hemispherectomy, are useful for specific indications. Epilepsy surgery properly applied, can further the goal of rendering people free of side effects and of seizures.

**REFERENCES**