

## EPILEPSY SURGERY IN CHILDREN

**Faraji M. MD<sup>1</sup>,**  
**Ashrafzadeh F. MD<sup>2</sup>,**  
**Farajirad S. MD<sup>3</sup>**

1. Professor of Neurosurgery,  
Mashhad University of Medical  
Sciences  
2. Professor of Pediatric  
Neurology, Mashhad University  
of Medical Sciences  
3. Resident of Psychiatry,  
Mashhad University of Medical  
Sciences

Corresponding Author:  
Faraji M. MD  
Mashhad University of Medical  
Sciences  
Tel: +98 511 8424834  
Fax: +98 511 8425878  
E- mail:Farajirad@yahoo.com

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### Abstract

#### Objective

In the majority of patients with intractable epilepsy, seizures can be well controlled with appropriate medication. However, current estimates indicate that some of patients with epilepsy are refractory to all forms of medical therapy. The surgical treatment of intractable epilepsy in children has evolved with advances in technical innovations. These medically intractable patients are candidates for surgical treatment in an attempt to achieve better seizure control. The definitive successful outcome of epilepsy surgery is a seizure-free state without significant neurological impairments.

In this article, we will outline the essential elements of presurgical evaluation and describe a variety of therapeutic surgical options, and the related indications, techniques, results and complications of each procedure.

**Key words:** Intractable Epilepsy, Surgery, Children.

### Introduction

There are many types of seizures and different forms of epilepsy. A seizure is defined as a paroxysmal, self-limited change in behaviour associated with excessive electrical discharge from the central nervous system. Refractory epilepsy is defined as a condition of recurrent medically intractable seizures despite optimal treatment under direction of an experienced neurologist, over a two to three year period.

In the majority of patients with epilepsy, seizures can be well controlled with appropriate medication. However, current estimates indicate that 20-30% of patients with epilepsy are refractory to all forms of medical therapy (1, 2, 3). These medically intractable patients are candidates for surgical treatment to achieve better seizure control. Another group of patients, who might also benefit, are those, who despite relatively well controlled seizures may have certain characteristic presentations of lesions that strongly indicate surgical intervention might be curative. Overall, the single most important determinant of a successful surgical outcome is patient selection (4, 5).

While many treatment options exist for adult patients with epilepsy, relatively fewer are available for pediatric patients. In most cases, physicians prescribe pharmaceutical therapy to alleviate or control seizures before embarking on the course of surgery as a treatment, and surgery is performed only after patients have failed multiple trials of antiepileptic drugs (AEDs) (2,6).

Some authors review cell transplantation as an alternative approach to the treatment

of epilepsy. Recent work in animal models shows grafted neuronal precursors that differentiate into inhibitory interneuron can increase the level of local inhibition. Grafts of these inhibitory neurons could help restore equilibrium in temporal lobe epilepsy (7).

In this article, we will outline the essential elements of the presurgical evaluation as well as the diagnostic surgical procedures required for invasive EEG monitoring and then describe the variety of therapeutic surgical options and the related indications, techniques, results and complications of each procedure.

### Presurgical Evaluation

The goal of epilepsy surgery is to identify an abnormal area of cortex from which the seizures originate and remove it without causing any significant functional impairment. Prior to surgery, the presurgical evaluation, which involves the collaboration of neurologists, electrophysiologists, neuropsychiatrists, neurosurgeons, and nurses, is used to determine if a patient has seizures that are appropriate for surgical management and, if so, the type of surgery most likely to succeed (8,9).

The primary components of the presurgical evaluation include a detailed clinical history and physical examination, advanced neuro-imaging, video-EEG monitoring, neuropsychological testing and assessment of psychosocial functioning.

Major questions to be answered with this evaluation are:

- 1) Are the seizures focal or generalized?
- 2) If focal, are they temporal or extratemporal in origin?
- 3) Is there a lesion associated with the seizures?
- 4) If surgery is undertaken what functional deficits, if any, might be anticipated?

It is also important to determine the age of onset, response to medical treatment and family history of seizures. The pregnancy and delivery history is helpful in assessing congenital or earlier acquired abnormalities. Other past medical history of significance would include a history of febrile seizures, head injury or intracranial infection. An assessment of the adequacy of medication trials must also be made to ensure whether or not the patient is truly refractory to medical therapy (10).

### Neuro-imaging

Magnetic resonance imaging (MRI) has replaced CT scanning as the imaging study of choice to evaluate patients with epilepsy; MRI, an extremely sensitive tool, can detect abnormalities of the brain with exceptional anatomical detail (11, 12, 13).

This has been especially true for detecting focal atrophy (e.g. hippocampal atrophy), indolent gliomas, cortical dysplasias, cerebral gliosis and small structural lesions of the neo cortex (14). Although lacking the spatial resolution of MRI, PET and SPECT can play an important role in the localization of abnormal cortex (Fig.1). Some epilepsy centers use SPECT, interictal and ictal, to localize seizure foci. PET is an interictal study that can be very useful in localizing foci as well (Fig.2). Magnetoencephalography (MEG), although not available in all institutions, can be used to evaluate the patient with seizures. The goal of evaluation is to pinpoint the source of the seizures to make the most informed decision regarding treatment; each of these evaluation tools, individually and collectively, contributes to these critical decisions (15, 16).

In the Faraji et al study of clinically suspected temporal lobe epilepsy, MR imaging alone was not able to localize temporal lobe foci correctly, whereas SPECT was very helpful in localizing the lesions (under publication).

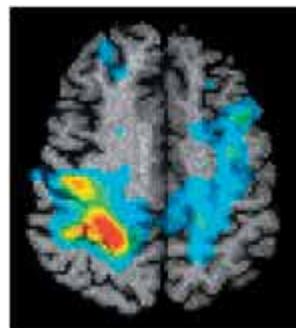


Fig.1: Seizure foci in SPECT

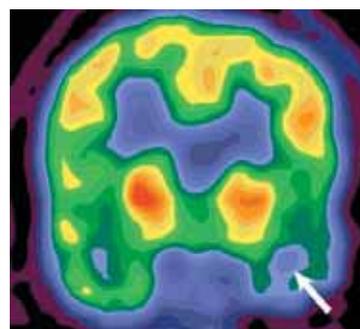


Fig.2: Seizure foci (white arrow) in PET

### Electroencephalographic (EEG) Investigation

EEG investigation remains the most important component of the presurgical evaluation. Analysis of unselected EEG activity between events (interictal) or of specific activity during events (ictal) can provide evidence of focal electrical dysfunction. While certain interictal EEG abnormalities (spike and slow wave complexes) can be of localizing value, it is extremely important to record the EEG with concomitant videotape during the spontaneous occurrence of the patient's events. Video/EEG monitoring can continuously record the EEG over a 24 hour period which allows for careful inspection of the record during any symptomatic event. Sophisticated computer hardware and software also allows for automatic detection of spontaneous interictal epileptiform transients and electrographic seizures that otherwise might have gone unrecognized (17). It is the early/primary EEG activity, at the very beginning of the seizure prior to its spreading to adjacent areas, which is most important in terms of localization; if a specific cortical area is involved consistently at the onset, then that area is likely to be the site of seizure origin. Patients are often hospitalized with reduction in anti-seizure medications and may be recorded for up to 7-14 days in order to capture 3-5 of their habitual seizures

### Psychosocial Assessment

Psychosocial evaluation is also extremely important to assess current level of functioning and to ensure realistic goals and attitudes in both the patient and their family before surgery (18, 19).

### Therapeutic Surgical Options

The primary objective of most epilepsy surgical procedures is to accurately localize and then completely excise the epileptogenic region without causing cognitive or neurologic deficit. An important determinant of the risk of surgery is the relationship of the lesion to functionally important or "eloquent" brain regions, because injury to these areas can cause irreversible neurologic impairment. The location of many functionally important areas can be approximated using anatomic landmarks; however individual variations occur and the presence of local

pathology can distort landmarks making localization imprecise (11, 14).

Regions responsible for seizure onset must be distinguished from regions of critical cortical function and a variety of strategies have therefore been employed both pre- and intra-operatively to optimize surgical resection while minimizing risk of injury to the functional cortex. After the resection strategy has been decided upon, tissue removal is carried out using subpial resection techniques. Cortical gray and white matter is carefully removed by suction or cavitron so that the pia remains intact over the adjacent gyri; this tends to form a nonscarring barrier and preserves blood supply to the remaining cortex as well. Following removal, some centers carry out post-resection cortical EEG recordings and may carry out further removal if considerable epileptic activity remains at the resection margins (20).

### Types of Surgical Approaches

1. **Resective Surgery:** Lesionectomy, Temporal lobe resections, Extra-temporal resections, Hemispherectomy.
2. **Radiosurgery:** Mesial Temporal lobe Epilepsy.
3. **Disconnection Surgery:** Corpus Callosotomy, Multiple Subpial Transections, Stereotactic ablations.
4. **Neuroaugmentative Surgery:** Vagus nerve stimulation, Deep brain Stimulation, Cerebellar stimulation.
5. **Diagnostic Surgery:** Depth Electrodes, Subdural Strip Electrodes.

### Lesionectomy

Lesions such as cavernous angiomas, low grade astrocytomas, cortical dysplasias and areas of focal atrophy, identified clearly as the cause of seizures can be removed by lesionectomy. In general, if these are located in extratemporal sites, removal of the lesion and a small rim of surrounding cortex is often successful in controlling seizures (21,22).

### Temporal Resections

The majority of temporal lobectomies, whether in the dominant or nondominant hemisphere, can now be safely performed under general anesthesia with or without electrocorticography (Fig3). In the dominant hemisphere, temporal lobe removals usually extend

back 4.5-5 cm behind the temporal tip or to the level of the central sulcus. In the non-dominant hemisphere, temporal lobectomies can extend beyond 7 or 8 cm but will result in a contralateral superior quadrantanopsia because of encroachment upon the optic radiation. It is important that the mesial temporal structures are included in the removal because most neurosurgeons believe that the hippocampus is intimately involved in seizure propagation or amplification (15).

Since almost 80% of temporal lobe seizures originate in the mesial structures, several operative approaches have been designed to reduce the amount of temporal neocortex removal while still resecting the amygdala and hippocampus. The so-called antero-medial temporal lobectomy with amygdalo-hippocampectomy is a modification of the classical temporal lobectomy by reducing the amount of cortical removal and extending the hippocampal resection (23). Memory impairment, which sometimes occurs with unilateral temporal removals in rare cases, is a complication that can be avoided by preoperative testing of speech and memory function during the intracarotid amytal test. If memory is affected by amytal injection ipsilaterally to the proposed side of the temporal removal, the temporal excision may be designed so as to spare the hippocampus and medial structures; however this approach may reduce operative success rates.



Fig.3: MRI after Temporal lobectomy

### Extra-temporal Resections

Locating a seizure focus in non-temporal lobe structures, one of the more challenging tasks for the clinical neurophysiologist is particularly difficult when the seizures are suspected to arise from the frontal lobe. Extra-temporal resections including the frontoparietal and occipital regions can give excellent results. Patients with epileptic discharge limited to the lobe of

resection, obviously tend to do better than those with more widespread discharges. In addition, some patients have more wide spread epileptogenic zones that require multilobar resections. In the largest cumulative series 64% of patients improved, with 36% being seizure free (24). With advances in neuro-imaging and other aspects of the presurgical evaluation, it is hoped that surgical success rates improve in the future.

### Hemispherectomy

The procedure is typically used in patients with severe unilateral motor seizures who already have a hemiparesis and a nonfunctional hand. Patients with Rasmussen's encephalitis and Sturge-Weber syndrome are frequently candidates for this type of surgery. In addition, patients with hemimegalencephaly and other disorders of cerebral dysgenesis, cerebral infarctions, and trauma may also benefit from hemispherectomy(Fig.4)(25).

Functional hemispherectomy or any of its variants, is one of the most successful surgical procedures for epilepsy with over 85% markedly improved and about 60% seizure free rates among patients (26,27). Many patients also demonstrate behavioral improvement probably on the basis of a better attention span and cognitive functioning (28,29).

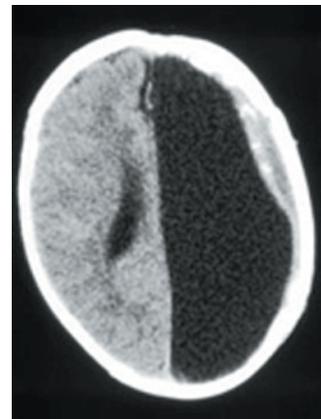


Fig.4: CT after hemispherectomy

### Corpus Callosotomy

In some patients, despite extensive evaluations, a focus cannot be identified, while in others, presurgical evaluation will detect more than one focus. These patients may benefit from a corpus callosotomy. In this procedure, epileptic tissue is not removed but the spread of the seizures is altered by cutting the nerve bridge, or

corpus callosum, that connects the right and left sides of the brain(Fig.5). The procedure is now primarily used for children who have” drop “attacks (30,31). The current practice is to section the anterior 2/3 of the corpus callosum in the first procedure; the posterior 1/3 may be sectioned during a second procedure, if the results of anterior section are not satisfactory. Transient abulia is common following anterior callosotomy but other disconnection effects are fortunately mild and uncommon. In patients with complete callosotomy, disconnection symptoms are more frequent. There is often some difficulty in bimanual tasks and apraxia for commands directed to the nondominant extremity. Visual presentation to the hemifield opposite to the dominant hemisphere cannot be comprehended or described by language modalities and there is often significant difficulty in writing with a nondominant hand. Fortunately, most of these functional deficits are not noticeable in normal daily life and are balanced by the improved seizure control (32,33).



Fig.5: MRI after Corpus Callosotomy

**Multiple Subpial Transections**

This technique leaves the vertical columnar arrangement of the cortex intact thereby preserving function but prevents spreading of the seizure discharge in the horizontal plane to reduce seizures. Some neurological deficits appear postoperatively but these generally resolve over several weeks with satisfactory improvement in seizure control in 70 % of patients (34,35,36).

**Stereotactic Ablations**

Stereotactic radiofrequency ablation of deep cerebral structures has been carried out for a variety of

generalized and focal forms of epilepsy in the past. Bilateral cingulotomies, amygdalotomies, lesions in the fields of Forel and thalamic lesions have all been tried (Fig.6)(37).



Fig.6: Frame of Stereotaxy

**Deep Brain Stimulation (DBS)**

In the past, brain stimulation in the anterior, centromedian, and ventralis intermedus thalamic nuclei and the caudate nucleus has been attempted for the modulation of cortical excitability(Fig.7)(38). Electrical stimulation of the hippocampus has also been tried in an attempt to block temporal lobe seizures (39). In an initial report of patients with DBS in the subthalamic nucleus, daytime seizures were reduced by more than 80% (40).

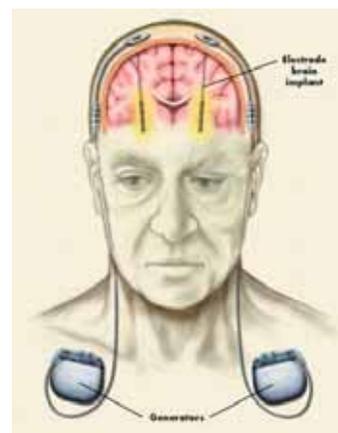


Fig.7:Bilateral Deep Brain Stimulation

**Cerebellar Stimulation**

Cerebellar stimulation has a theoretical basis from animal studies in which lesion induced cortical discharges were reduced or inhibited by cerebellar electrical

stimulation. Initial reports of clinical success could not be reproduced. Reports followed by tissue damage from the cerebellar stimulator and a large number of cases with late failures(41). Improvement in the technical quality of electrodes and stimulating devices, has led to some renewed interest in this technique but it is not currently a recommended treatment and no definitive evidence supporting its use in controlling epilepsy is available. Cerebellar electrical stimulation has been used to treat generalized focal and myoclonic seizures as well as for spasticity of cerebral palsy (42).

### Vagus nerve stimulation

Of a number of patients with both focal and generalized intractable seizures, that underwent implantation of a nerve stimulator around the left vagus nerve(Fig.8) less than half experienced a 50% reduction in seizure frequency and only the rare patient became seizure free (43).

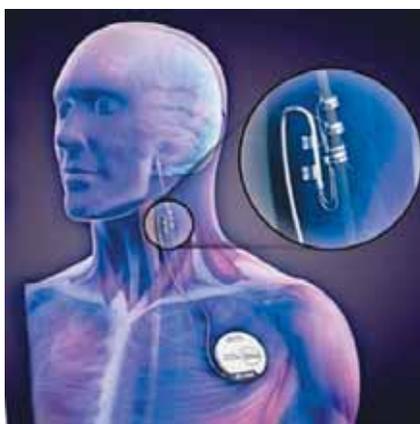


Fig.8:Vagus nerve stimulation Device

### Radiosurgery

There are a few reports of gamma knife radiosurgical treatment of patients with intractable mesial temporal lobe epilepsy. A dose of 20 to 25 Gy at 50% isodose line was employed with a target volume of 6500 to 7500 mm(Fig.9).The median interval to seizure cessation was 10.5 months and minimal side effects reported, included headache, nausea, and vomiting, which resolved with steroids (44).

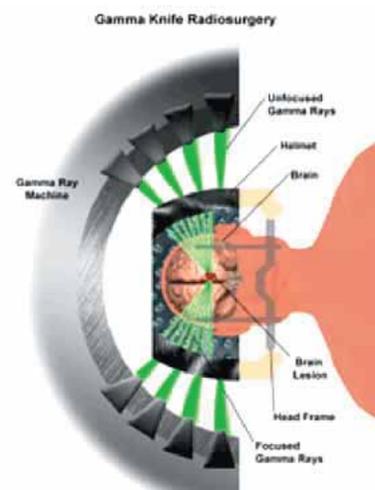


Fig.9:Gamma knife radiosurgery

In conclusion, the definitive successful outcome of epilepsy surgery is a seizure-free state without significant neurological impairments. Once a patient has failed to respond to two AEDs, evaluation for surgical intervention should be considered. The success or failure of the surgical treatment of epilepsy depends in large part on the proper selection and investigation of patients in the course of treatment. Recent advances in imaging and long term EEG monitoring have facilitated greater accuracy in the localization of the seizure focus, with overall better surgical results than before.

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