Review Article

Recent Advances in Epilepsy Surgery

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INTRODUCTION

Surgical treatment of epilepsy is indicated for patients who are either unable to control their epileptic seizures with maximum medication or who are so disabled by seizures that they cannot lead a decent life. In the last two decades the results of surgical treatment of epilepsy have improved, particularly after the introduction of advanced brain electrophysiology and the use of modern imaging studies.

PRESURGICAL EVALUATION OF PATIENTS WITH EPIEPSY

The presurgical evaluation involves a multidisciplinary approach involving epileptologists, neurophysiologists, neuroradiologists, neuropsychologists and neurosurgeons. This evaluation is carried out in two phases[1]. Phase I is based on non-invasive clinical investigations, neuropsychological assessment, interictal and ictal video-EEG recordings, functional and structural neuroimaging. Phase II is invasive and is aimed to precisely define the anatomical localization of the epileptogenic zones and their relationships with the structural lesions[2]. This phase comprises of electrocorticography, deep brain recordings, cortical and deep brain stimulation, and intraoperative electrostimulation.

During the presurgical evaluation the seizures must be classified according to their clinical phenomenology. Long-term video monitoring is the best method of detecting and reviewing a patient's seizures. The correct seizure diagnosis is necessary to ensure that appropriate medical treatment has been tried. The next steps are the detailed electroencephalographic investigations and imaging studies.

Electrophysiological studies

The use of interictal electroencephalography (EEG) has no role in making major surgical decisions. However, if for a period of years, interictal EEG spikes remain consistently restricted to a limited area of the cortex, this region likely harbors the epileptogenic focus. For example, if a patient is known to have complex partial seizures and if for several years the EEG spikes indicate a consistent unilateral right temporal lobe interictal focus, the patient's seizures probably originate from that particular focus.

Because interictal recordings have an error rate for localizing epileptogenic foci, long-term EEG monitoring has been used to provide ictal recordings to show the cortical region where the seizure arises. These recordings can be taken from the scalp or intracranially.

To improve the localizing potential of scalp recordings, some investigators have suggested special additional electrodes, such as sphenoidals, nasopharyngials, and ears electrodes[3]. The long-term scalp recordings also include video recordings of the patient. This combination can provide important evidence on the type of seizures that characterizes the patient's epilepsy[4]. When scalp recordings accurately show bilateral discharges, a significant number of patients have single or dominant unilateral seizure focus[5–8].

Magnetoencephalography (MEG): It is a useful noninvasive method for presurgical evaluation of intractable epilepsy[9–14]. In contrast to electroencephalography which measures extracellular volume currents, MEG detects the magnetic fields associated with intracellular current flow within neurons.

Magnetic source imaging (MS): It is a new non-invasive imaging system that attempts to combine functional data derived from magneto-encephalographic recordings with structural data obtained from magnetic resonance. MS, MEG, evoked and event-related potentials hold great promise as noninvasive methods of choice for precise location of lesions in the somatosensory, motor, language, visual or auditory cortices[5,16].

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Structural studies: Most partial epilepsy results from damage to, or abnormal development of, the brain. Therefore, a presurgical evaluation needs a search for a structural brain defect. This can be achieved by using Computerized Tomography (CT) or Magnetic Resonance Imaging (MRI). MRI is superior to CT for defining subtle structural lesions, especially those without calcifications[17–20]. Recently, special volumetric studies of the temporal lobes have been helpful in identifying medial temporal sclerosis preoperatively[21 –23].

Single photon emission computer tomography (SPECT): SPECT images regional cerebral blood flow and may help localize seizure foci in partial epilepsies. SPECT done in the interictal period is inaccurate[24–26]. Ictal scans may be accurate but often are unpractical for different reasons. For example, the isotope must be readily available for injection by a qualified person within 15 minutes of the onset of a seizure. Many seizures occur at night or at odd times and qualified personel to administer these injections may not be present. The results of Lee S, Lee, L, Kin K et al[27] indicate that repeated ictal SPECT is useful because it can yield new or additional information about the epileptogenic zones if the epilepsy is of multifocal origin.

Positron Emission Tomography (PET): Early studies with PET found that the epileptogenic focus is mainly hypometabolic rather than hypermetabolic. Surprisingly the hypometabolic area is larger than the extent of actual pathology found at surgery[28,29].

Neuropsychological studies: A detailed search for cortical function deficit could theoretically localize the damaged areas of the brain. Routine clinical neurological examination is too unsophisticated to pinpoint diseased foci, and a more precise examination is mandatory. This is the rationale for including a battery of neuropsychological tests as part of the preoperative evaluation. The examination should include tests of verbal and performance IQ, cognitive abilities, motor skill and memory.

Psychiatric evaluation: Psychiatric evaluation of candidates for surgery is important because some of them experience a variety of psychiatric sequelae resulting from the psychosocial situation, anticonvulsant medication and perhaps the epileptic focus itself[3,30,31]. One of the most common problems is unrecognized depression that may manifest as suicidal attempts. Some patients have postictal psychosis that starts 24 - 48 hours after a cluster of seizures and disappears within a week. In contrast, interictal psychosis usually improves transiently after seizures and carries the risk of worsening with successful epilepsy surgery. These patients should be evaluated preoperatively. If significant psychiatric problems exist, follow-up should be continued postoperatively[2,30].

Several methods for long-term intracranial recording are available. These include: intracerebral electrodes, strip electrodes, grid electrodes and foramen ovale electrodes. Intracerebral electrodes can be implanted by stereotactic surgery in different areas of the brain. These can record from deep areas such as the hippocampus and amygdala. Some researchers believe that intracerebral electrodes give better information than strip electrodes[32-35]. These strip electrodes are implanted subdurally through a burr hole and are inserted over a desired location of the cortex[33,36]. The infection rate for subdural strip electrodes is less than 1%[2]. In an attempt to limit the risk of intracranial infection, implanting strip electrodes in the epidural space has been advocated[37]. Many authors have found that by using both techniques simultaneously, additional data may be generated[35,38-40]. Grid electrodes are used primarily when lateralization of the focus is definite but localization within a hemisphere is difficult. By implanting grid electrodes the surgeon can record epileptogenic activity while using electrical stimulation to define regions with vital functions. With this strategy, an operation can be planned to remove as much of the offending tissue as possible while preserving maximum cortical function[41-44]. The grid electrodes must be implanted during craniotomy and left in place throughout the recording and testing period. A second craniotomy is required for the removal of the grid and the epileptogenic focus. Foramen ovale electrodes are an alternative to deep and strip electrodes[45-47]. They are inserted with the same technique as a percutaneous trigeminal ablation.

Amital test or Wada test: The Amital test or Wada test is used to identify the hemisphere dominant for speech. Many authors have attempted to expand this test to assess memory integrity within the temporal lobes[26,48,49]. Accurate memory assessment is difficult because of the variation in blood supply of the target areas[29]. This test can also be used to select which temporal lobe to remove in patients who have bilateral independent epileptogenic foci[50,51].

Electrocorticography (ECoG): ECoG is used during surgery to delimit the epileptogenic focus, and tailoring a resection to include as much spiking cortex as possible while excluding regions of vital function. It is of more value in extratemporal cortical resection than in temporal lobe surgery [52,53]. ECoG may be combined with electrical stimulation to map function. Functional mapping is accomplished by implanting an electrode grid over the cortex, and studying the patient in the epilepsy monitoring unit after closing the wound[25,41]. For tailoring resections near the eloquent cortex, this method produces the most reliable results. However, implanting a large electrode grid requires two craniotomies and carries an increased risk of infection. Recently frameless stereotactic systems to guide intracerebral electrode implantation for epilepsy surgery patient have been introduced [54].

Somatosensory cortex: This identification can be defined by somatosensory evoked potential recorded from the cortex while the patient is under general anesthesia. Motor cortex can be defined by direct cortical stimulation under local anesthesia[2].

SURGICAL PROCEDURES AND RESULTS

Anterior temporal lobectomy: Anterior temporal lobectomy is the most commonly performed epilepsy surgery. The extension of temporal lobe resection is different. Some of the surgeons perform limited resection of amigdala and hippocampus or lateral cortex[38,55-57]. Others prefer to resect the temporal lobe up to 4.5 cm from its pole with or without removing the amygdala and hippocampus. Schwart H, Marks D, Pak Yet al[58] use intraoperative MRI to control the extent of hippocampal resection. Some authors recommend the gamma knife radio surgery especially in temporal lobe epilepsy[59-61]. Little evidence exists to support any one approach to temporal lobectomy. Avariety of techniques appear to generate approximately similar results. 70 to 90% of the patients are either seizure free or are significantly improved after operation[2,8,31,50,62- 64].

The most common complication of temporal lobectomy is a contralateral superior quadrantanopsia due to interruption of Meyer's loop as it passes around the temporal horn of the lateral ventricle[65]. Occasionally, a homonymous hemianopsia may develop from vascular damage to the geniculate body[66,67]. Postoperative hemogenic meningitis usually is delayed 48 to 72 hours and may not become apparent until corticosteroids are withdrawn[68-70]. Lumbar puncture is required for CSF examination and culture. The meningitis is usually self-limiting and further treatment with corticosteroids may be required only for symptomatic relief.

Hemispherectomy: It is indicated for patients who have sustained major hemispherical damage that renders the hemisphere relatively nonfunctioning and epileptogenic. The most common cause of this damage is infantile hemiplegia, in which a cerebrovascular event damages most of the cortex supplied by the middle cerebral artery. The classical anatomic hemispherectomy consists of the entire hemisphere resection, except the basal ganglia and thalamus. This operation leaves a large empty space that fills with cerebrospinal fluid, and carries the serious complication of progressive hemosiderosis. This operation has been replaced by functional hemispherectomy that removes the central cortex and the top of the temporal lobe but leaves in place the frontal and occipital poles with some bridging parietal cortex[67]. These poles are disconnected from the remainder of the brain by sectioning all connections to the corpus callosum and basal ganglia. Seizures outcome from hemisphectomy is usually excellent. More than 90% of the patients become either seizure free or has a significant reduction in the number of seizures[71].

Callosotomy: The goal of callosotomy is to disrupt one of the major central nervous system pathways used in the generalization or spread of seizures. The rationale assumes that if the pathways for generalization can be disrupted, the frequency and severity of either primary or secondary generalized seizures will diminish. A variety of callosal sections are reported such as the frontal part callosal section, the compile callosotomy or the anterior comisssurotomy and the hippocampal commissurotomy. Callosotomy is indicated for any uncontrolled seizure disorder not proven to be focal in origin. Certain types of seizure appear to respond more favorably than others. If generalized seizures (i.e. tonic, clonic, tonic-clonic and atonic) are improved, the outcome in complex partial seizures is unpredictable. Despite renewed interest in callosotomy, much variation in outcome has been reported. In a review of the literature, 5 to 10% of the patients appear to be rendered seizure free, 10 to 20% are not helped significantly, and the remainder shows some decrease in seizures [72-75]. A 50% incidence of hydrocephalus and chemogenic or bacterial meningitis was reported in earlier series probably due to exposure of the ventricular cavities. Increases in focal seizures following callosotomy, especially in patients with asymmetrical bilateral epileptogenic foci, have been reported[2,34]. Language impairments in patients with crossed cerebral dominance have also been reported[76].

Multiple subpial transections: Morrell F, Whisler WW, Bleck TP[77] described a procedure termed multiple subpial transections in cases of epileptogenic focus involving functional cortex such as Broca's or sensomotor cortex. During surgery, local neuronal connections are cut, which theoretically prevent recruitment of a critical mass of synchronous activity required to provoke a seizure. Incisions through the gray matter of a gyrus are made to preserve corticothalamic and corticobasal ganglia connections to preserve cortical functions.

Vagus nerve electric stimulation: It is a new method for the treatment of drug resistant epilepsies. In 1997 the method was approved in United States by the FDA to be used in adults with refractory focal epilepsies not candidates for epilepsy surgery. Its mechanism is not known. The implantation of stimulator is carried out under general or local anesthesia. The result in controlled studies indicates a decrease of 30-50% in the seizure frequency in about 50% of the patients[78-80].

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