Epilepsy Surgery

Neurosurgery Teaching Seminar
Sept 22, 2005
Epilepsy

- Epilepsy - a heterogeneous group of syndromes with different etiologies, severities, clinical impact and treatment options
- Cardinal feature - a predisposition to recurrent unprovoked seizures (partial or generalized)
- Seizures occur when a population of hyperexcitable neurons discharge excessively
- current understanding of epileptogenesis, the cellular and molecular mechanisms by which epilepsy develops, remains incomplete
- surgical therapy is not a last resort but rather the treatment of choice for defined **surgically remediable syndromes**
Epilepsy Surgery: Outline

- History of Epilepsy Surgery
- Indications for Epilepsy Surgery
- Principles of Epilepsy Surgery
- Preoperative Evaluation
- Surgical Procedures
Epilepsy Surgery: History

- 1886 Horsley (Jackson & Ferrier)
  - surgical resection of post-traumatic scar and surrounding brain parenchyma successfully treating a patient with focal epilepsy

- 1929 Berger
  - human scalp EEG recordings

- 1934 Fischer & Lowenbach
  - first to demonstrate epileptiform spikes on EEG

- 1935 Intraoperative ECoG - Foerster & Altenburger
  - detection of the epileptogenic focus during surgery was reported by

- 1936 Jasper & Gibbs – Interictal Spike
  - Hallmark of epilepsy - the interictal spike described
Epilepsy Surgery: History

- 1934 Wilder Penfield and colleagues established the Montreal Neurologic Institute (MNI)
- 1939 MNI laboratory of EEG and neurophysiology
  - dedicated to selecting epilepsy patients for surgery and providing the technology for intraoperative recordings
  - Electroencephalography established as primary modality for seizure localization in the pre- and intraoperative evaluation of epilepsy surgery patients
- 1954 Penfield & Jasper
  - invasive EEG monitoring - chronically implanted epidural electrodes
- 1973 – CT (Hounsfield)
- 1981 MRI
Epilepsy Surgery

- Considerations for Surgical management of epilepsy:
  - type of epilepsy
  - localization of the epileptogenic focus
  - patient wishes
  - surgeon’s expertise
- Preoperative evidence for:
  - a structural abnormality of the brain, and/or
  - clinical and electrographic localization of the epileptogenic focus
- Immediate goal of epilepsy surgery:
  - maximal safe resection of epileptogenic tissue or
  - anatomical and functional disconnection to eliminate or reduce the number of clinically significant seizures without causing significant neurologic deficit
- Other goals
  - improving global brain function
  - decreasing medication dependence
  - improving patient quality of life.
Epilepsy Surgery: Indications

- Persistent seizures (focal origin) despite appropriate pharmacological treatment
  - 2 trials of monotherapy with 1st line AEDs (usually at least two drugs at limits of tolerability)
  - +/- one trial with combination therapy

- Quality of Life
  - Impaired due to ongoing seizures
Epilepsy Surgery: Principles

- Determination of medical Intractability
- Identify the region of seizure onset
- Evaluate the consequences of resecting this tissue
- Surgical Resection
- Medial Temporal Lobe = Most common location of seizure onset
Preoperative Evaluation

- Goals
- History + Physical exam
- EEG/Video Monitoring
- Imaging
- Neuropsychological Testing
- WADA Test
- Video/EEG monitoring with intracranial EEG
Preoperative Evaluation

- **Goals:**
  - Determine if a single epileptogenic focus exists
  - not in eloquent cortex
  - resectable without causing unacceptable neurologic deficit
Preoperative Evaluation: EEG

- Scalp EEG/Video monitoring
  - interictal epileptiform discharges
  - ictal
    - Seizure semiology
    - Ictal EEG discharge
  - Additional electrodes
Preoperative Evaluation: EEG

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Preoperative Evaluation: Seizure Semiology

- = clinical manifestation of a seizure
- Localizing value
Preoperative Evaluation: Imaging

- MRI
- PET
- SPECT
- MEG – Magnetoencephalography
- fMRI
Preoperative Evaluation: MR Imaging

Mesial Temporal (hippocampal) Sclerosis (MTS)

- Mesial Temporal Sclerosis (MTS)
- Tumor
- Vascular malformation
- Dysplasia
Preoperative Evaluation

- Functional Imaging
  - PET
    - hypometabolism interictally
  - SPECT
    - hypoperfusion interictally
    - hyperperfusion ictally
    - subtraction and co-registration with MRI
Preoperative Evaluation

SISCOM – coregistration of SPECT with MRI

Extratemporal epilepsy
Preoperative Evaluation

- Neuropsychological testing
  - Pre-operative baseline
  - Aid in localization
  - Predicting risk of cognitive decline with surgery

- Wada (intracarotid amobarbital) test
  - Language
    - Laterализация
  - Memory
    - Prediction of postoperative decline
Preoperative Evaluation

- Intracranial EEG when needed
  - Grids and strips – subdural
  - Parenchymal “depth” electrodes -especially for recording from hippocampus
  - Identification of ictal onset
  - Brain mapping
    - cortical stimulation
    - SSEPs
    - Functional MRI
Surgical Procedures

- Diagnostic: Invasive Diagnostic Procedures
- Curative/Resective Surgery
- Palliative Surgery
Types of Surgical Procedures

- **Resective Surgery:**
  - single seizure focus in non-eloquent region

- **Palliative Surgery:**
  - For drop attacks: corpus callosotomy
  - For Rasmussen’s encephalitis or hemimegalencephaly: hemispherectomy
Surgical Treatment of Epilepsy

Curative

Lesionectomy
Lesionectomy
Lobectomy
MST's

Palliative

Hemispherectomy
Topectomy
Disconnection
(Callosotomy)

Pathologies

MTS TLE
Non-MTS TLE
Lesional
Frontal Lobe epilepsy
- Low Grade Glioma
SMA/cingulate epilepsy
- Cav. Malformation
Malformations of cortical development

Procedures
Surgical Procedures: Diagnostic

Invasive Diagnostic Procedures

- Non-invasive presurgical evaluation inadequate to define epileptogenic zone

- Depth Electrodes
  - Suspect medial temporal lobe epilepsy

- Subdural Grid/Electrodes
  - Record from brain surface
Surgical Procedures: Resective

- Anterior Temporal Lobectomy (ATL)
- Selective Amygdalohippocampectomy (SelAH)
- Lesionectomy
- Neocortical Resection
- Hemispherectomy
Mesial Temporal Lobe Epilepsy

- most common form of medically intractable epilepsy in adolescents/adults

- Seizures arise from:
  - Hippocampus
  - Amygdala
  - parahippocampal gyrus
**Mesial Temporal Sclerosis (MTS)**

- pathological hallmark of medial temporal lobe epilepsy
- characterized by:
  - loss of hippocampal neurons (particular pattern - area CA1 is most severely involved)
  - Gliosis
  - synaptic reorganization - inner molecular layer of dentate gyrus (mossy fiber sprouting)
Mesial Temporal Sclerosis: MRI

- MTS frequently detected non-invasively by MRI
Anterior Temporal Lobectomy (ATL)

Standardized ATL (Spencer et al. 1984):
- Anterolateral temporal lobe
- Amygdala - majority of the amygdala
- Uncus
- Hippocampus
- Parahippocampal gyrus - to level of collicular plate
Anterior Temporal Lobectomy (ATL)

- Treatment of medial temporal lobe epilepsy
- Standardized ATL (Spencer et al. 1984):
- Alternate approach
  - define limits of resection using physiologic criteria for each patient
  - implantation of chronic subdural electrodes if ictal onset desired (most useful) or
  - intraoperative electrocorticography (ECOG) if interictal abnormalities are used (less reliable)
  - This approach is used if concerns that seizure focus may extend beyond medial temporal lobe
Anterior Temporal Lobectomy (ATL): Complications

1. Visual field defects
   - contralateral superior quadrant - Meyer’s loop fibers
   - Functionally significant visual field deficits uncommon using techniques that spare the posterolateral temporal lobe

2. Memory Deficits:
   - verbal memory impairment/worsening can result after language-dominant ATL
   - risk is determined by preoperative functioning
   - If verbal memory is intact preoperatively based on neuropsych and Wada testing, a more pronounced decrement can be expected after resection of the dominant medial temporal lobe
   - If preoperative verbal memory impaired, little or no decrement is seen
   - In most cases, because MTS is associated with preoperative verbal memory deficits, most patients who undergo ATL show little or no significant deterioration of memory
Anterior Temporal Lobectomy (ATL)

- Utility of temporal lobe surgery for intractable epilepsy vs. continued treatment with antiepileptic drugs
- Wiebe et al, NEJM 2001
  - prospective, randomized, controlled trial
  - Eighty patients randomized to surgery or medical treatment for one year
  - At one year, those undergoing surgery had a much higher rate of seizure freedom (58% versus 8%)
  - and a significantly better quality of life
Selective Amygdalohippocampectomy

- Treatment of MTE
- Tissue sparing operation with removal of mesial temporal structures
- Approach:
  - Transcortical (via middle temporal gyrus)
  - Transventricular
Lesionectomy

- Surgical resections aimed at curing epilepsy by removing structural brain lesions:
  - Malformations of cortical development, low-grade neoplasms, vascular malformations
- Surgical approach depends on lesion location
Intraoperative Frameless Stereotaxy:

- MRI frameless stereotactic localization of focal cortical dysplasia at the base of the central sulcus (center of cross hairs).

- Intraoperative localization of subtle cortical lesions

- Correlating the location of lesions with physiologic data acquired through subdural electrodes
Neocortical Resection

- Resection of cortex outside medial temporal lobe
- Boundaries of resections typically determined by recording area of seizure onset with chronically implanted subdural electrodes
- Surgical approach depends on the location of the focus
- Suspected regions of epileptogenesis may involve eloquent cortex
- Mapping of cortical function during diagnostic work-up
  - Extra-operative techniques: fMRI, MEG
  - Mapping through subdural electrodes as well as intra-operative cortical stimulation, ECoG and SSEPs
- In the absence of pathological abnormalities, extratemporal resections represent the poorest outcome group of the surgical resections
Surgical Treatment of Epilepsy: Hemispherectomy

- Indication: seizures arising over most of one hemisphere
- Severe hemisphereric damage during development

Processes:
- Sturge-Weber
- Perinatal Infarcts
- Hemimeganencephaly
- Rasmussen’s Encephalitis

Goal:
- remove or disconnect all of cortex of one hemisphere from the rest of the brain
Surgical Treatment of Epilepsy: Hemispherectomy

- **Anatomic Hemispherectomy**
  - Resect hemispheric cortex entirely

- **Functional hemispherectomy**
  - Remove temporal lobe and central cortex
  - Preserve some frontal and occipital cortex
Functional Hemispherectomy

- hemisphere severely injured by infection in early childhood

- extent of cortical resections in temporal and central cortex with disconnection of residual frontal and occipital cortex by transecting white matter fibers
Surgical Procedures: Disconnection Procedures

- Corpus Callosotomy
- Multiple Subpial transections
**Disconnection Procedures: Callosotomy**

- Transection of corpus callosum: anterior 66-75%
- Rationale: disruption of rapid spread of certain seizures from one hemisphere to the other
- Most common indication: Atonic drop attacks
  - Rapid onset, multiple injuries from unprotected falls
- Lennox-Gastaut Syndrome
- Complications:
  - Early/Transient
  - Permanent
Disconnection Procedures: Multiple Subpial Transections

- Developed to treat epilepsy arising from cortex that cannot be resected
- Extratemporal epilepsy
- Rationale:
  - disruption of horizontal connections within cortex that are vital for synchronizing neural activity, without affecting ascending and descending fibers
- Small hook cuts through gray mater leaving pia and surface vessels intact
- Transections at right angles to long axis of gyrus at 5mm intervals
Vagal Nerve Stimulation: Vagal Nerve Stimulator

- standard pacemaker generator
  - houses a lithium battery and electronics
  - implanted in a subclavicular pocket, and a

- lead wire
  - tunneled into left carotid sheath via a transverse or longitudinal neck incision
  - spiral endings of the leads attached to left vagus nerve

Left vagus is used due to a lower percentage of efferent fibers to the atrioventricular node
Surgical Procedures: Vagal Nerve Stimulation

- developed as a treatment for medically refractory epileptic seizures
- FDA approval of VNS in 1997 as adjunctive therapy for treatment of partial seizures in patients 12 years of age and older
- considered a palliative therapy and is not curative
- an alternative for patients whose seizures have failed to respond to AED therapy (or who are intolerant of AEDs) and who are not optimal candidates for curative epilepsy surgery
- juvenile myoclonic epilepsy, absence epilepsy, and Lennox-Gastaut Syndrome
Epilepsy Surgery: Efficacy

- Surgical treatment of focal epilepsy - success rate with respect to seizure control: 33 to 90%
- Surgical outcome improving in recent trials and case series
- Surgical success rate (Engel Class I or II): 80-90% when:
  - pre-operative electrophysiological work-up
  - clinical history
  - adjunctive test results
  - single abnormality is identified on MRI
- Factors predicting a desirable surgical outcome:
  - patient selection
  - single, unilateral pre-operative MR imaging abnormality
  - unilateral hippocampal sclerosis
  - ipsilateral ictal and interictal epileptiform activity exclusively on EEG
Epilepsy Surgery: Efficacy

- Factors associated with a poor outcome:
  - non-localizing electroencephalographical results
  - absence of an MR imaging abnormality
  - bilateral atrophy
  - suspected cortical dysplasia
  - multiple cortical MR abnormalities

- Surgical cure more likely with:
  - complete resection of the MR imaging abnormality
  - non-lesional cases (EEG localization only) - complete resection of the appropriate anatomic structures

- Subtle imaging abnormalities correlate with definite pathology which can act as persisting epileptic foci
5% of all epilepsy may be attributed to head injury.

Most patients with early seizures after head injury do not develop epilepsy.

With loss of consciousness: 2% develop epilepsy

With hospitalization: 7-15% develop epilepsy
Risks to developing epilepsy: penetrating injury (up to 50%), early seizures, hemorrhage, low score in G.C.S., cortical lesion, volume lost, depressed fx, metal fragments, loss of consciousness.

60% of epilepsy occurs in within 1 yr., 80% in 2 yrs, 88% by 10 yrs.

Mayo clinic study:

- Severe injury (contusion, hematoma, focal deficit, 24 hr. of amnesia or LOC): 11.5% epilepsy (in 5 yr.)
- Moderate injury (fracture, > 30 min LOC, amnesia): 1.6%
- Milder injury: no increased risk.
- Severe injury and early seizure: 36%

Head Injury and Prophylactic AEDs

- 404 pts, severe head injury with cortical damage randomized in ≤ 24 hr: DPH vs. placebo.
- Seizures in one week: placebo 14%, phenytoin 4%
- Once late seizure occurs, 86% recurrence.
- Recommend: Use prophylactic AED for 1-2 weeks after severe head trauma, then stop. If late seizures occur, treat with AED.

Temkin, NEJM 1990.