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 eleptogenic 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 collegues 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 eloqent 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

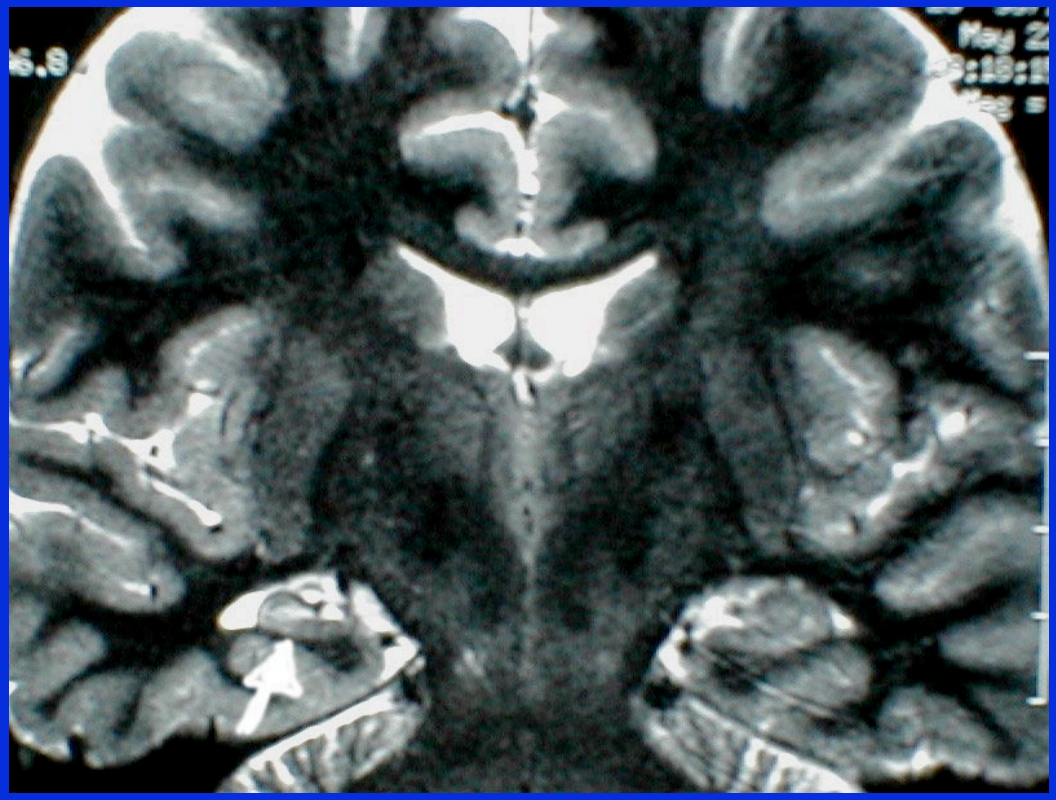
- = clinical manifestation of a seizure
- Localizing value

Preoperative Evaluation: Imaging

- MRI
- PET
- SPECT
- MEG – Magnetoencephalography
- fMRI

Preoperative Evaluation: MR Imaging

Mesial Temporal (hippocampal) Sclerosis (MTS)



Mesial Temporal Sclerosis (MTS)

Tumor

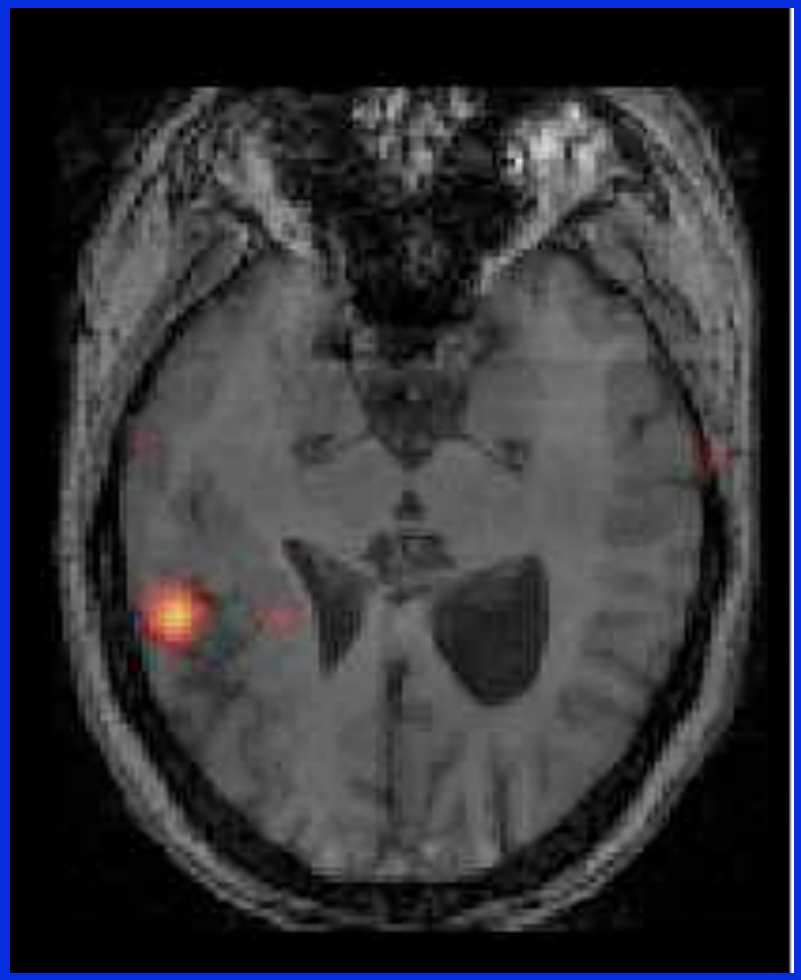
Vascular malformation

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
    - lateralization
  - Memory
    - prediction of postoperative decline

Preoperative Evaluation

- Intracranial EEG when needed
  - Grids and strips – subdural
  - Parenchymal “depth” electrodes -especially for recording from hipppocampus
  - 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 ⟷ *Palliative*

Pathologies

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

Procedures

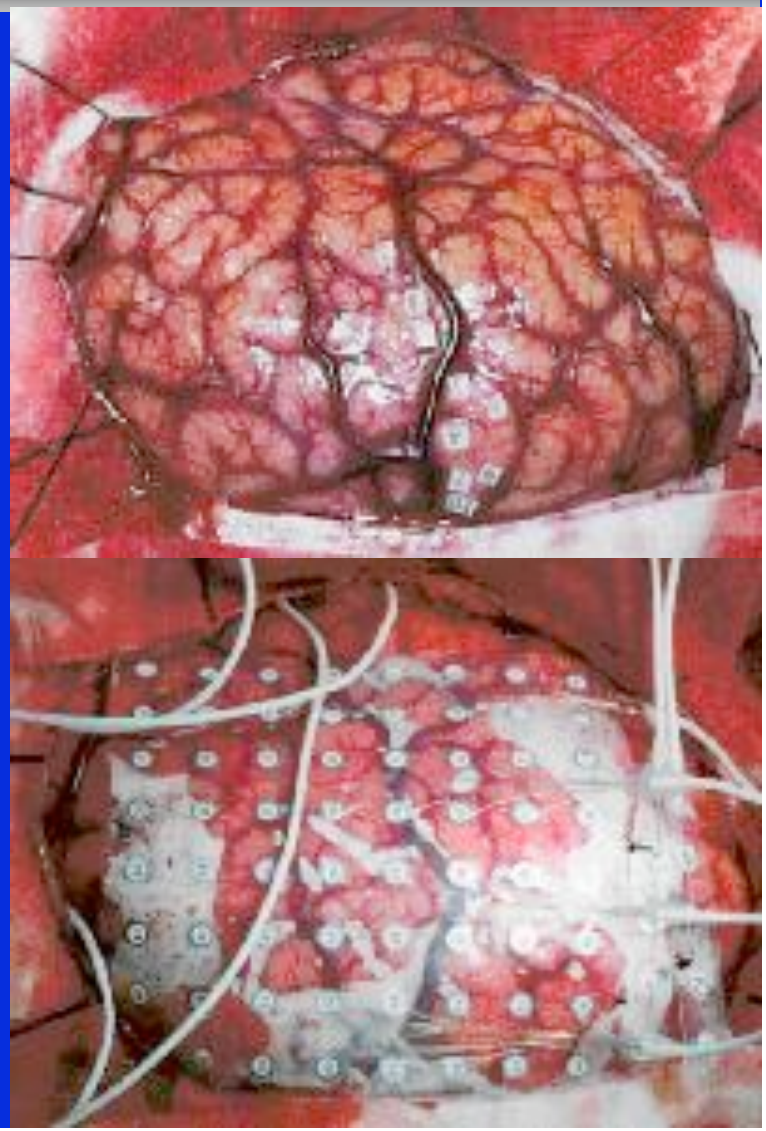
Lesionectomy	Hemispherectomy	Disconnection
Lobectomy	Topectomy	(Callosotomy)
	MST's	

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

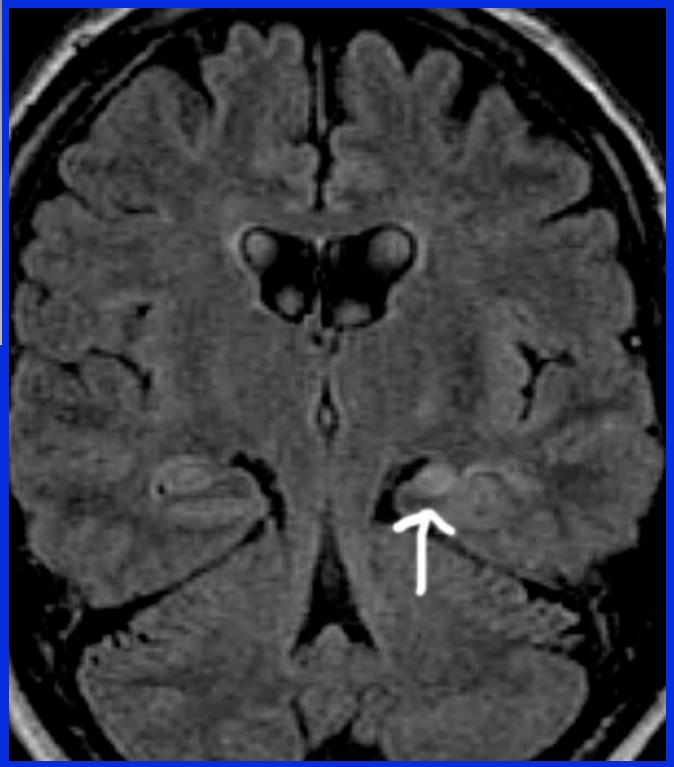
Mesial Temporal Lobe Epilepsy

- most common form of medically intractable epilepsy in adolescents/adults
- Seizures arise from:
  - Hippocampus
  - Amygdala
  - parahippocampal gyrus

Mesial Temporal Sclerosis (MTS)

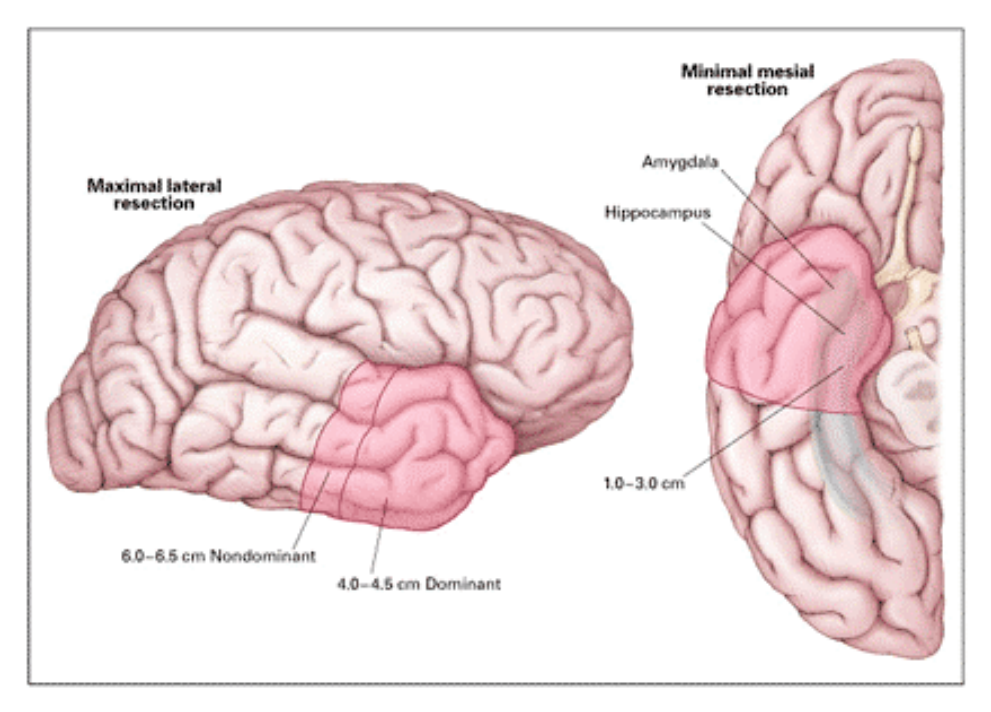
- pathological hallmark of medial temporal lobe epilepsy
- characterized by:
  - loss of hippocampal neurons (particular pattern - area CA1 is most severely involved)
  - Gliosis
  - synaptic reorganization - inner molecular layer of dentate gyrus (mossy fiber sprouting)

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

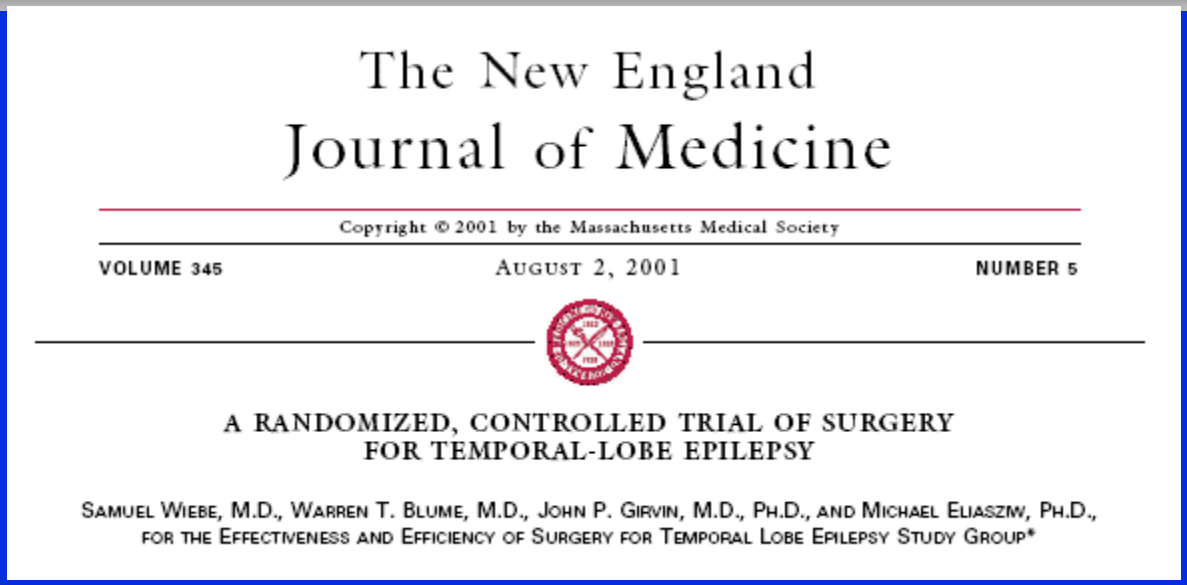
Anterior Temporal Lobectomy (ATL)

- 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 determinedby 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 ATLshow little or no significant deterioration of memory

Anterior Temporal Lobectomy (ATL)



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A RANDOMIZED, CONTROLLED TRIAL OF SURGERY FOR TEMPORAL-LOBE EPILEPSY

SAMUEL WIEBE, M.D., WARREN T. BLUME, M.D., JOHN P. GIRVIN, M.D., PH.D., AND MICHAEL ELIASZIW, PH.D., FOR THE EFFECTIVENESS AND EFFICIENCY OF SURGERY FOR TEMPORAL LOBE EPILEPSY STUDY GROUP*

- 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

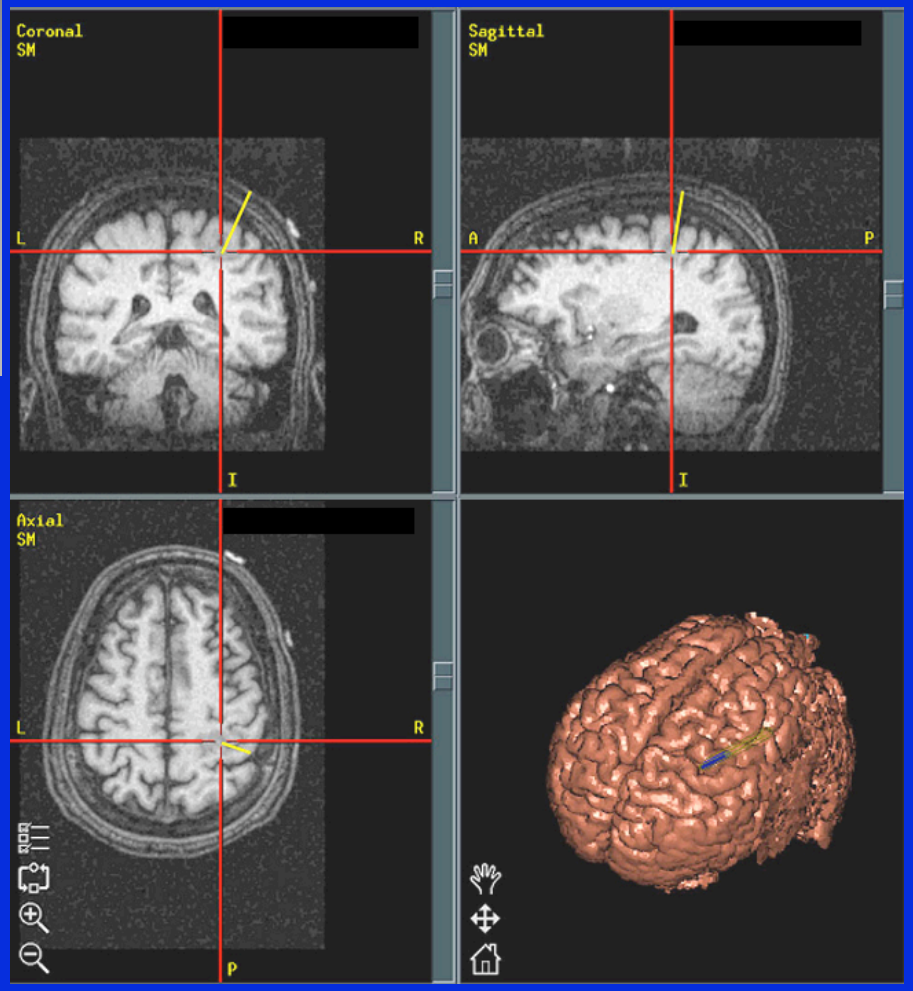
Selective Amygdalohippocampectomy

- **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 strucural 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

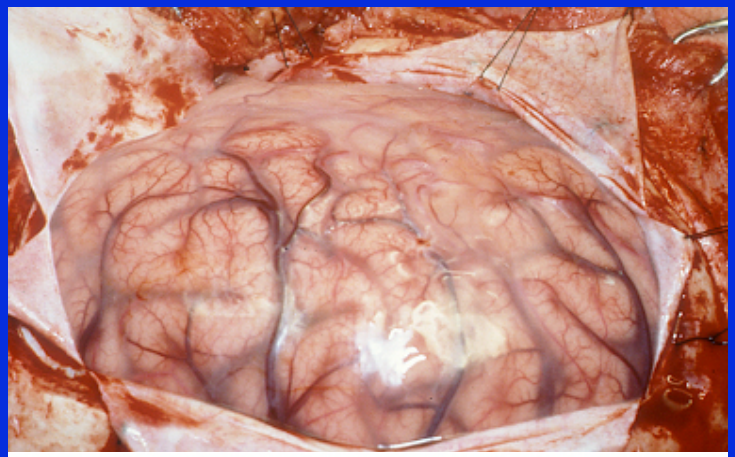
Surgical Treatment of Epilepsy: Hemispherectomy

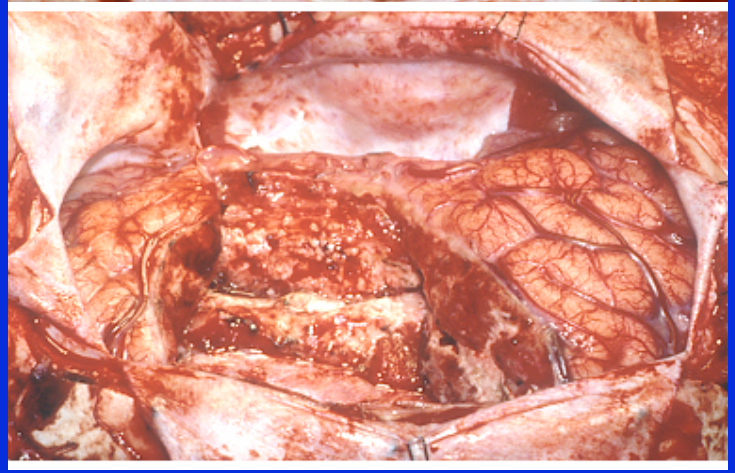
- Indication: seizures arising over most of one hemisphere
- Severe hemisphereric damage during development
- Processes:
  - Sturge-Weber
  - Perinatal Infarcts
  - Hemimeganencephaly
  - Rasmussen's Encephalitis
- Goal:
  - remove or disconnect all of cortex of one hemisphere from the rest of the brain

Surgical Treatment of Epilepsy: Hemispherectomy

- **Anatomic Hemispherectomy**
  - Resect hemisphric 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 horizintal 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

- device = generator + lead wire

- 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

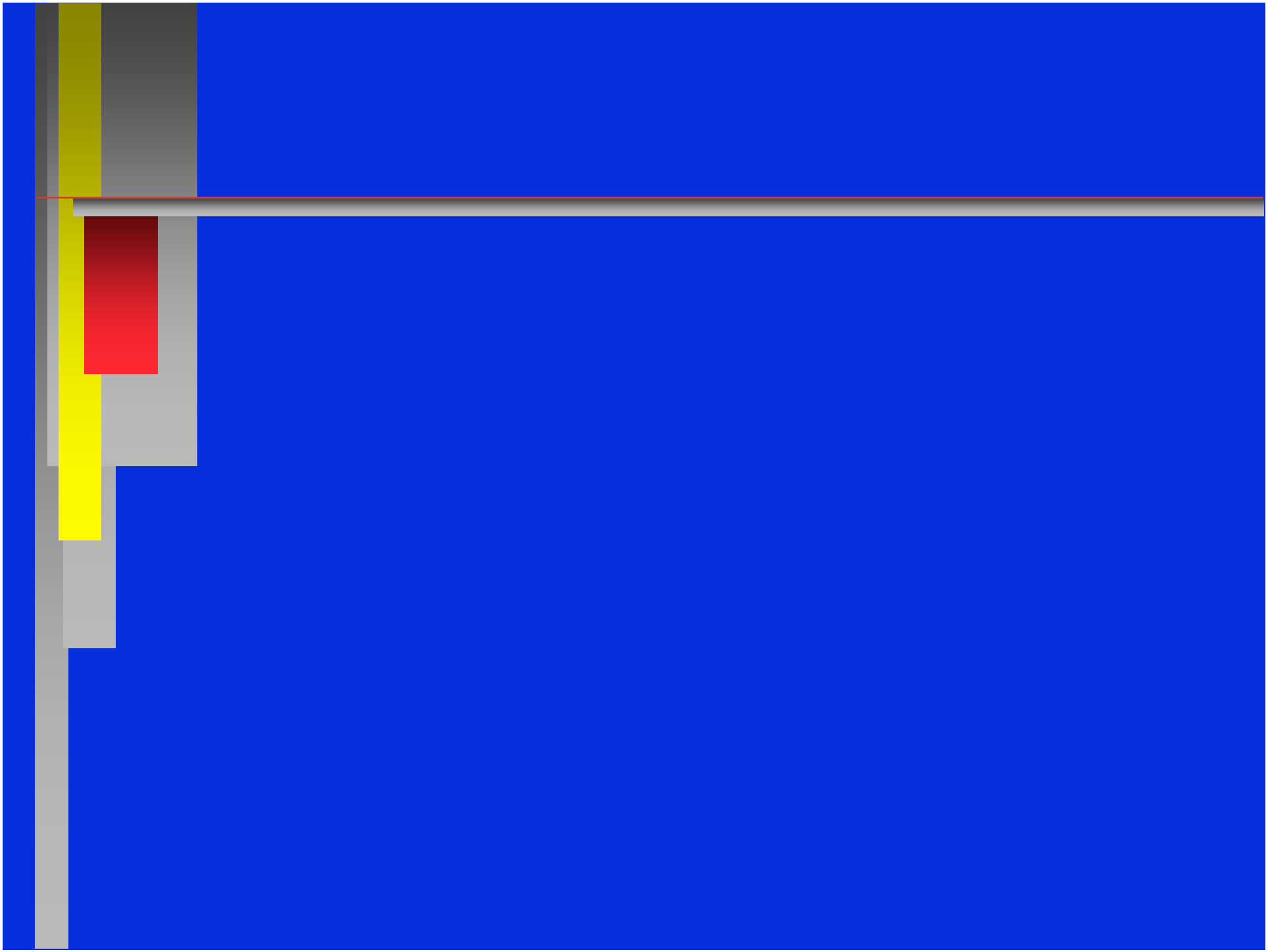
- developed as a treatment for medically refractory epileptic seizures
- FDA approval of VNS in 1997 as adjunctive therapy for treatment of partial seizures in patients 12 years of age and older
- considered a palliative therapy and is not curative
- an alternative for patients whose seizures have failed 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 wrt 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**



Epilepsy and Head Injury

- 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

Epilepsy and Head Injury

- 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.

Yablon, Arch Phys Med Rehab 1993.
Willmore, Epilepsy: A Comprehensive Text 1997.

Epilepsy and Head Injury

- 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%

Annegers., Neurology, 1980.

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.