Current Surgical Treatment Strategies for the Management of Pediatric Epilepsy

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May 22, 2009

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Surgery for Pediatric Epilepsy: The Arsenal

- Temporal Lobectomy
- “Lesional” epilepsy surgery
- “Non-lesional” epilepsy surgery
- Multiple Subpial Transections (MST)
- Corpus Callosotomy
- Hemispherectomy
- Vagus Nerve Stimulation (VNS)

The Epilepsy Team

- Pediatric Neurosurgery
- Pediatric Neurology
- Neuroradiology
- Neurophysiology
- Neuropathology
- Neuropsychology

Pre-Surgical Work-up: ‘Noninvasive’ Monitoring/Imaging

- CT
- *MRI/MRI
- EEG
- Video EEG
- PET: interictal 18FDG hypometabolism
- SPECT: ictal hyperperfusion
- *MEG: sz → magnetic dipoles
- WADA: language dominance testing via intraarterial amytal
Pre-Surgical Work-up: ‘Noninvasive’ Monitoring/Imaging

- CT
- *MRI/fMRI
- EEG
- Video EEG
- PET
- SPECT: ictal hyperperfusion
- *MEG
- (WADA: language dominance)

Functional MRI

Intraoperative Neuronavigation

Utility of Neuronavigation to Treat Epilepsy Caused by Tumors
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Temporal Lobe Epilepsy

- Temporal lobe, amygdalohippocampal complex highly sensitive to injury, susceptible to seizure
- ~30% of pediatric complex partial seizures
- ~30% of TL seizures controlled with meds
- Only half of remaining pts lived independently
- Risks to psychosocial development, isolation
- Depressed IQ scoring over time
- Cumulative toxicity of anticonvulsants

Temporal Lobectomy: Outcomes

- >75%: ↓or no sz
- <5-10%: no improvement
- Behavior, function, neuropsych testing improved
- Best outcomes with surgery before adolescence, shorter interval from onset to surgery
- Histopathology:
  1. Cortical dysplasia: structural anomaly
  2. Lesional epilepsy: neoplasm
  3. Mesial temporal sclerosis: neuronal loss & gliosis
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Lesional Epilepsy

- Complete resection of lesion AND electrographically abnormal region
- 92% have ‘good’ outcome (sz free or >90% reduction)
- Electrographically abnormal region
  - Electrocorticography (intraoperative)
  - Chronic subdural grid recordings (extraoperative)

Electrocorticography
Invasive Subdural Grid, Strip and Depth Electrode Monitoring

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Subdural Grids for Extraoperative Mapping

Functional mapping
- Goal: localize eloquent cortex
- Motor and language function
- Deliver escalating currents to subdural grid
  - After-discharges on EEG
  - Interruption of function
Seizure Mapping

- Goal: 1-2 “typical” seizures/day
- AED wean: depending on sz freq
- Site of sz onset is most important

Non-lesional epilepsy

- Subdural grid/strips mandatory
- At 2 year follow-up
  - 44% seizure free
  - 15% >90% reduction
  - 17% >50% reduction
- 10 year follow-up
  - 33% seizure free

Complications

- 112 children
- mean monitoring time 7.1 days (2-21)
- Add'l electrode placement 5.7%
- Wound infection 2.4%
- CSF leak 1.6%
- 1 case each
  - SDH, symptomatic pneumocephalus, bone flap osteo, strip fracture requiring retrieval.
- No permanent deficit or death

(Jayakar, P et.al., Epilepsia 2008 49(5) 758-64)

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Multiple Subpial Transections (MSTs)

- 30 patients (1996-2000)
- 18 females; 12 males
- Minimum 2 year follow up
- Average age: 11.7 years (std dev 4.5 years)
- 46% Engel class I
- All patients experienced transient hemiparesis
- Resolved within 6 weeks

MST Outcomes

- Long term control?
- Relapses reported
- May create longterm, permanent deficits
- ICH
- Stroke
- Hemosiderin scarring

Limitations of MSTs
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Corpus Callosotomy: Outcomes

- Literature overall: 10-100% improvement in freq.
- 10-50%: partial seizures (Black, 1992; Spencer, 1993)
- 80-100%: drop attacks (Black, 1992; Spencer, 1993)
- Sz control: complete > anterior 2/3 callosotomy
- *pre-op, baseline EEG not predictive of success
- Callosotomy can ‘uncover’ foci (Clarke, 2007)
- 88% of families would recommend (Gilliam, 1996)
  - Seizure control
  - Alertnaess
  - Responsiveness

Corpus Callosotomy: Complications

- “Split-brain Syndrome”: L/R dyscoordination
- “Disconnection Syndrome”
  - Mutism
  - Left arm/leg apraxia
  - Inattention
  - Incontinence
- Postcallosotomy Dysphasia
- Memory deficits
- Increase in seizures: generalized → partial
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Hemispherectomy

**Indications**

Large hemispheric processes:
- Developmental abnormality
  - Hemimegalencephaly
  - Sturge-Weber Syndrome
- Acquired abnormality
  - Neonatal/perinatal stroke
  - Post-traumatic injury
- Progressive abnormality
  - Chronic (Rasmussen’s) encephalitis

*Medically-refractory
*Hemisphere effectively ‘removed’ by pathology

Hemispherectomy: Outcomes

Overall: >80% pts have >75% reduction in seizure frequency

(Devlin, 2003)
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**Vagus Nerve Stimulation**

- For medically-refractory epilepsy patients
- Exact mechanism unknown
- Disruption of hypersynchronous brain activity (Henry, 2002)
- Vagus $\leftarrow$ brainstem (medulla, N.tractus solitarius) $\leftarrow$ bilateral cerebral cortex, limbic system
- *action typically *interictal*, not during seizure activity
- Percutaneous programming
- Battery life: ~10 years

**Vagus Nerve Stimulation: Side Effects**

- Headache
- Cough
- Hoarseness
- Bradycardia
- Shortness of breath
- Vocal cord paralysis
- Horner’s Syndrome
- Lower facial muscle paresis/paresthesias
- Cardiac arrest

**Vagus Nerve Stimulation: Outcomes**

(Benifla, 2006): 41 children, mean F/U 31 months
- 38% with $\geq 90\%$ reduction in seizures
- 24% with 50-90% reduction in seizures
- 38% with $<50\%$ reduction in seizures

(Rossignol, 2008): 28 children followed 2 years
- 68% seizure decrease $\geq 50\%$
- 14% seizure-free
- 68% transient adverse events

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The Horizon: Advanced Imaging

- Cluster
  - ≥20 spike sources within a 1 cm
- Small Cluster
- Scatter
  - spike source distance >1 cm
  - <6 spikes
  - No spike source

Characterizing Magnetic Spike Source with MEG-guided Neuronavigation in Pediatric Epilepsy Surgery

- Resection of MEG spike clusters may correlate with seizure outcome
The Horizon: Cerebral Cooling

- Rationale: Focal cooling suppresses seizure activity
- Peltier thermoelectric device: semiconductors, ceramic plates
- Heat transfer with passage of current
- Seizure suppression in epileptic rats

(Yang et al. Epilepsia 2002 & Ann Neurol 2001)

The Horizon: Neuropace

- Neuropace Inc.: Design of implantable brain stimulators
- eRNS: external Responsive Neurostimulator System

(Bergey et al. Epilepsia 2003)

Thank you.