Pediatric Epilepsy Surgery

**Goals of epilepsy surgery**

- **Curative** – Resection /ablation of epileptogenic zone [EZ] to achieve seizure freedom

- **Palliative** – Disconnection or neuromodulation to reduce seizure burden

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Prasanna Jayakar, MD, PhD

Minimally invasive strategies for epilepsy surgery in children
Curative Resection strategies

Larger complete Resection of EZ
>> Enhance chances of seizure freedom
>> increased risk of neurological deficit

Smaller incomplete Resections of EZ
>> lesser chances of seizure freedom
>> better preservation of function

"LESS IS MORE"

Less is more strategy

Defining the Epicenter - I

- Discrete epileptogenic MRI lesion
Defining the Epicenter - II

- Multimodal Convergence of functional abnormalities
  - EEG
  - 3D EEG source/MEG
  - EEG-MRI
  - PET: Hypo or Hyper
  - SPECT/SISCOM
  - Others


Defining the Epicenter - III

- Specific patterns on Invasive EEG:
  - Ictal onsets
  - Discrete burst suppression or attenuation
  - Continuous epileptic discharges [CEDs]

Kalamangalam et al. (2013)  
Lee et al. 2005; Seo et al., 2011

IEEG post-processing to define the Epicenter


- Weiss et al. A practical, efficient method to identify the small ictal core regions. Brain.2013 Dec;136(Pt 12):3796
Brain Mapping of Critical Function

Why?

How?

Lesions may retain or reorganize function

- **RETAIN**: Disturbances of cortical organization
  (polymicrogyria, schizencephaly, and mild-type FCD)
- **REORGANIZE**:
  - Disturbances of abnormal neuronal or glial proliferation
    (hemimegalencephaly, Taylor-type FCD, and heterotopia)
  - Destructive or sclerotic lesions


Brain Mapping Tests

Critical Cortex:
- MRI
- MEG
- TMS
- ECS mapping

Critical Pathways
- DTI Tractography

No Silver Bullet test
Example- False negative lateralization of language (Jayakar et al., 2001)

- Rt handed
- Lt TLE
- 12 hrs post-ictal
- 2 wks post-ictal

- fMRI showed preserved motor on the left in ¾ subjects
- TMS- no response from left & bilateral response from right
- No deficit following hemispherectomy


Example- fMRI false positive

- fMRI showed preserved motor on the left in ¾ subjects
- TMS- no response from left & bilateral response from right
- No deficit following hemispherectomy

Pediatric Epilepsy Surgery

Goal

“Less is More”
Strategy

Tests

Techniques

Epileptogenic region

Critical Cortex

Conventional Surgery

Minimally / Non Invasive

MCH series of Epicenter resection – conventional surgery
Hyslop et al., 2014 - submitted

- 25 pts aged 0.5-19.9 yrs [mean 11.8] who underwent focal corticectomy involving one aspect of a single lobe preserving all function

<table>
<thead>
<tr>
<th>Engel</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
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<tbody>
<tr>
<td>N=25</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>5</td>
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<table>
<thead>
<tr>
<th></th>
<th>60%</th>
<th>12%</th>
</tr>
</thead>
</table>

Case example- Rt parietal ictal onset
ECoG using multiple SD+depths – discrete CEDs

Engel I outcome

Minimal/ Non invasive surgical techniques

<table>
<thead>
<tr>
<th>Epicenter</th>
<th>Minimally Invasive</th>
<th>Non Invasive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unclear</td>
<td>Stereo-EEG guided Radiofrequency Ablation</td>
<td>MR Guided laser interstitial thermal therapy (MRgLITT)</td>
</tr>
<tr>
<td>Clear</td>
<td>MR guided Thermal Laser Ablation</td>
<td>MR guided Focused Ultrasound</td>
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</tbody>
</table>
Stereo-EEG guided radio frequency thermocoagulation


Outcome of RF thermocoagulation of nodules


<table>
<thead>
<tr>
<th>Case</th>
<th>N of THC lesions in the nodule</th>
<th>Extent of nodule THC (postop MRI)</th>
<th>Subsequent resective surgery</th>
<th>Follow-up (months)</th>
<th>Outcome (Engel's class)</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Incomplete</td>
<td>No</td>
<td>60</td>
<td>6b</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>Complete</td>
<td>No</td>
<td>41</td>
<td>6b</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Incomplete</td>
<td>No</td>
<td>21</td>
<td>6b</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Complete</td>
<td>Yes</td>
<td>4</td>
<td>6b*</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Incomplete</td>
<td>No</td>
<td>12</td>
<td>6c</td>
</tr>
</tbody>
</table>

THC, thermocoagulation; "*", patient is seizure-free 24 months after resection of left frontal lobe.
13 adults. A mean 60% volume of the amygdalohippocampal complex was ablated. Visual field deficit from deviated insertion. Variances in ablation volume and length did not correlate with outcomes. At follow-up from 5 to 26 months (median, 14 months):

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<th>III-IV</th>
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<tr>
<td>N=13</td>
<td>7 [54%]</td>
<td>3 [23%]</td>
<td>3 [23%]</td>
</tr>
</tbody>
</table>

Hypothalamic Hamartoma - Thermal Laser series

- Willson & Curry. Epilepsia. 54(Suppl.):10  9–11, 2013
- SF 12 (80%) of 14 cases

<table>
<thead>
<tr>
<th>Age</th>
<th>1 year</th>
<th>2 years</th>
<th>3 years</th>
<th>4 years</th>
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<tbody>
<tr>
<td>1 year</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2 years</td>
<td>10</td>
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<td>3 years</td>
<td>10</td>
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<tr>
<td>4 years</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

- MCH - Thermal laser series
  - Miller et al., 2014 AES
  - 17 patients mean age 15.3 years (range: 5.9 - 20.6 years).
  - Varied substrates including FCD, Tuberous Sclerosis, Hypothalamic Hamartoma, HS
  - No major or permanent complications
  - At 2 yr follow up

<table>
<thead>
<tr>
<th>Group</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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<tr>
<td>N=17</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

- Example Thermal laser – Mesial occipital
  - Miller et al., 2014

Seizure free after two treatments
No Visual field deficit
Example Thermal laser – Left Insula

- Preoperative FLAIR and T2-weighted MRI
- Ictal SPECT
- T1 with gadolinium and T2-MRI postoperative day 1
- 5 months postoperatively

Thermal Laser – Low neuropsychologic deficits and complications

- Willie et al., Neurosurgery. 2014 Jun;74(6):569-84

MR-guided Laser Interstitial Thermal Therapy (MRgLITT)

- Wagner et al., Epilepsy Behav. 2014 Jul 22;37C:204-209.
- Problem in children—Radiation/radiation/radiation !!
MR guided Focused Ultrasound System

**FUS Device**
1024 phased array transducers

Benefits compared to MRgLITT:
- No radiation
- Immediate result that can be controlled and monitored by thermal MR imaging.

Limitations:
- Mainly effective towards the center of the skull
- Not FDA approved

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MRgFUS – Scope of clinical applications

- **Clinical Trials in adults**
  - Movement disorders: 175 patients with essential tremor > no safety concerns > being submitted to FDA
  - Tumor ablations [3 patients]

- **Experimental data**
  - Epilepsy targets [starting 2015]
  - Anterior Cingulotomy, Septum Pellucidotomy, Third ventriculostomy for hydrocephalus, Cyst Fenestration, Trigeminal Neuralgia, Thrombolysis

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Example of Pallidotomy for essential tremors

- Highly precise ablations
MRgFUS Cadaveric Ablation

Summary of techniques

<table>
<thead>
<tr>
<th>Feature</th>
<th>Radio Frequency</th>
<th>Thermal Laser</th>
<th>MRgLITT</th>
<th>MRgFUS</th>
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<tbody>
<tr>
<td>Invasive</td>
<td>Min</td>
<td>Min</td>
<td>Non</td>
<td>Non</td>
</tr>
<tr>
<td>Radiation</td>
<td>++</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALOS</td>
<td>7-10 d</td>
<td>2</td>
<td>OP</td>
<td>OP</td>
</tr>
<tr>
<td>EEG</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td># of Surgeries</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Effect</td>
<td>Immediate</td>
<td>Immediate</td>
<td>Delayed</td>
<td>Immediate</td>
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<tr>
<td>Monitored</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Advantages compared to conventional surgery

- Access to deep seated lesions, prior operated cases or surgically inoperable regions.
- Safety - Low risk to surround grey and white matter > better functional outcome
- Recovery times and hospital stays reduced - usually OP or 1 day stay
- Procedure can be repeated multiple times
- Family Preference
Limitations compared to conventional surgery

- Concern for swelling limit the size of ablation in one session.
- Large lesions are not suited.
- Ablation of irregular lesions or functional abnormal zones is difficult especially near critical cortex.
- Intracranial EEG tailored resection is not feasible.

Conclusions

- “Less is More” – ablation of the Epicenter is an effective treatment strategy in select epilepsy cases.
- Minimally or Non Invasive techniques offer an attractive alternative to conventional surgery and enhance safety and comfort.
  - Comparable efficacy for discrete deep seated targets - HS, HH, TS, or periventricular nodule.
  - Less efficacious for irregular or ill-defined targets - Complex FCD or TS.

Epilepsy Program Team

- Epileptology/Neurophysiology:
  - Ian Miller MD
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  - Sanjiv Bhatia MD
  - Toba Niazi MD

- Neuroradiology:
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  - Santiago Medina MD

- Neurology:
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- Neuropsychology:
  - Pia Dioue

- Nursing specialist:
  - Aileen Rodriguez

- Neurointensivist

- Neuroanesthesiologist

- Neuropathologist

Thank You