Epilepsy Surgery, Imaging, and Intraoperative Neuromonitoring: Surgical Perspective

AC Duhaime, M.D.
Director, Pediatric Neurosurgery, Massachusetts General Hospital
Professor, Neurosurgery, Harvard Medical School
(No disclosures)
What this talk will cover

• Overview of pediatric epilepsy surgery
  – Epidemiology and burden

• Who are candidates for consideration

• General scheme of surgical decision-making
  – Role of imaging and physiologic modalities
    • Benefits
    • Risks

• Outcomes
Epilepsy surgery rationale:
Childhood – “designed to learn”
Childhood – “designed to learn”
Epilepsy: How Many Kids?

• 1/100 children have seizures
• 20% not controlled with medications

• For some kids, surgery is the best way to decrease or even stop seizures.
• For others, surgery may allow decrease of multiple medications.
• Surgery may also “stop the static”
Who is a candidate for surgery in 2017?

1. “Intractable” epilepsy
   - Still seizing despite adequate medication trials
   - Unacceptable side effects of medications
   - Seizures interfere with quality of life

2. Seizures associated with **focal, resectable** lesion
   - *Don’t have to wait until intractable!*
   - Tumors - but also **dysplasias, vascular malformations, other static lesions**
Focal lesions – don’t lose years waiting!
1 year old girl, clinical szs better on meds, but behavioral regression, background spikes
Surgery can help “fix the static”
Newborn with tuberous sclerosis, subclinical status

Development now on target
Evaluation for Epilepsy Surgery

- **Strategy: Benefit vs. Risk**
  - **Benefit:** How likely is it that seizures will diminish or stop?
  - **Risk:** What could happen from surgery that’s bad?
Improving risks and benefits: tools

To increase chance of resecting the area causing the seizures:

- Video EEG, HDEEG, PET, ictal SPECT, MEG
- High resolution structural imaging (3T, 7T)
- Invasive monitoring (subdural and depth electrodes)
- Intraop image guidance; intraop corticography

To decrease chance of causing new problems with language, memory, or motor function:

- Preop Wada, task-based or resting state fMRI, neuropsych testing, visual field mapping
  -- Intraop image guidance of eloquent cortex, tractography
- Intraop mapping for motor function, internal capsule
TEAM APPROACH

- Neurology/epileptology
  - Neuropsychology
  - Neuroradiology
  - Nuclear medicine
    - Nursing
    - Intensive Care
    - Anesthesia
- Intraoperative Monitoring
  - Neurosurgery
  - Rehabilitation
Pediatric Epilepsy Team

- Pediatric Neurology - Epilepsy Specialist Physicians
- Pediatric Neurosurgery
- Neuropsychology
- Nursing
- EEG Technicians
- Many others!

Imaging specialists
Imaging – can show amazing things

- Imaging experts help figure out brain structure, function, and seizure onset areas
Intraoperative Monitoring and Mapping

- Record cortical signals, response to stimulation
- Estimate location of eloquent areas of the brain in real time
  - Motor cortex - good for hand, less for leg, face, tongue
  - Internal capsule - “you’re getting close”
  - Sensory cortex – okay but not perfect
  - Language – awake crani; surrogate (e.g. tongue)
  - Still can’t map reliably: memory, vision, higher cortical function, affect, behavior

- Electrocorticography
  - Areas that show “spiky” corticography suggest seizure onset zones
Ways to remove tissue

• **Open surgery**
  – Most established
  – Can do intraop functional mapping and corticography
  – “Makes room”

• **Ablation techniques**: radiosurgery, focused ultrasound, laser fiber, others
  – Less “invasive” – less scalp/skull healing, scar
  – Lesion controlled by imaging
  – Can’t do mapping
  – **Conformational limitations**
  – May have swelling, no “extra space”
  – Long term outcomes not yet known
Case Examples
5 year old with intractable daily seizures since age 1, large left temporo-occipital lesion, behavioral side effects on meds

*Dysplasia vs. tumor*

Initial surgery (Stage 1)
Path ➔ cortical dysplasia
Stage 2
Laser interstitial thermal therapy (LITT)

Outcome: Sz free X 2 yrs
Cortical dysplasia – risks/benefits

• 4 year old boy, seizures since age 2
  – Multiple meds, ketogenic diet
  – Visible seizures controlled
  – Developmental slowdown, speech delay; subclinical seizures on EEG
  – Left handed

• Left frontal cortical dysplasia
  – Irregular shape extending deep in 3D
  – YOU CAN’T SEE THIS IN THE OPERATING ROOM
“He’s either seizing or sleeping”
“Doc, what are the chances of stopping the seizures?”

- Temporal lobe ~70%
- Other lobes ~50%  
  - With or without meds

*Cortical dysplasia looks just like normal brain in the OR*
Surgical decision-making: questions

• Where are seizures arising?
• Should you try to resect/ablate the entire (radiologically) visibly abnormal volume?
• How close is this volume to important cortex or connecting fibers?
  – Where is language?
  – How close are motor fibers?
  – Are things where they usually are, or elsewhere?
Phase I and Phase II evaluation

- Phase I evaluation
  - Video EEG, imaging, functional tests

- Phase II evaluation
  - Strips, grids, depth electrodes
    - When you can’t answer risks and benefits
      - Where do seizures start?
      - What else important is nearby?
Phase I Evaluation

- Video EEG monitoring
  - Want to capture 5-10 typical seizures
  - High density EEG

- High-resolution MRI (3T, 7T)
- Ictal and interictal SPECT
- PET (positron emission tomography)
- MEG (magnetoencephalography)
- Neuropsychological evaluation
- Functional mapping
  - Wada, task or RS fMRI, tractography, others
Ictal SPECT may help you **find** the dysplasia

8 yr old boy, 10 second injection

Hot spot linked to operative anatomy via MR image guidance

Courtesy of Drs. Ruth Lim and Paul Caruso, MGH
Magnetoencephalography (MEG)

Magnetic field analysis helps localize seizure onset zone, functional areas

4 yr old w TS, multiple daily szs → rare seizures
So, back to our 4-yr-old: Very frequent *subclinical* szs (so not a good candidate for ictal SPECT)

**“Ictal PET”**

**Good news for “benefit” side of scales**...

BUT - Left handed, left frontal lobe...
Where is language?

• Can do surgery awake
• Can implant electrodes and stimulate them when you’re awake
• “Functional” MRI or MEG – think of words in the scanner
  – *Only works in kids who can cooperate*
• IOM - Face/tongue motor as a surrogate for language motor, but not reception

Now what??
Resting State fMRI

Language probably on LEFT

Courtesy of Steven Stufflebeam, MD
How are things related in 3D space?

- Structural lesion
- Epileptogenic zone
- Motor tracts
- Language
“PET blobs”

Language networks
How does it all come together in the OR?

Erik Shank, MD, Anesthesiology

Jeffrey McHugh, Neurosurgery Tech Support

Mirela Simon, MD, Neurology – Intraoperative Corticography
"Numerous dysmorphic neurons, balloon cells, complete disruption of normal cortical lamination...Cortical dyplasia Type IIIB"
What still needs improvement

- Image guidance tells you where things WERE, not where they are NOW
- Where are the gray-white junction “finger” boundaries at the depth of the resection in 3D space?
- Capsule mapping still imperfect
Postop Day 1
7 months later – recurrent seizures

PET spots
“Chickened out zone”
Underwent 2 further resections – had weakness but recovered – currently sz free
Intraop MRI for resection guidance

- 12 year old girl with hx prolonged status → atrophy, focal cortical dysplasia, intractable seizures

Surface vessel anatomic mapping compensates for shift
Seizure free (on meds) x 5 years

There it is (but we can’t see it!)

Intraop MR image
8 yr old with Rasmussens vs. focal cortical dysplasia

→ Hemispheric disconnection
Combined modality approach

*High resolution imaging, functional mapping, EEG, HDEEG, MEG, SPECT, resection techniques*

- Decreased need for two-stage surgery
  - Strips, grids, depths
- More precise prediction
  - Benefits
  - Risks
- Better outcomes?
Conclusions

- Epilepsy surgery can be highly effective and may be *life-altering* for many children
- *Shouldn’t be considered a “last resort”*
- Takes a team
- Still potential for “network” localization, imaging and functional mapping advances

THANK YOU

On top of fire tower after successful hemispheric disconnection