Pre-operative imaging in Epilepsy

Financial disclosures

• I have no conflicts of interest or financial disclosures

Objectives

• Need for treatment of intractable epilepsy
• Diagnostic algorithm
• Aims of imaging study
• Techniques, strategies, tips and traps
• Examples

Intractable epilepsy

• Adverse effect on development
• Repeated seizures \rightarrow brain injury
• Drug resistance in 25-30% with partial seizures

Intractable epilepsy

Only hope in many cases

SURGICAL RESECTION OF EPILEPTOGENIC FOCUS

Pre-surgical work-up of intractable epilepsy

Phase 1 (non-invasive)

• History, EEG and clinical exam
• 24 hour audiovisual EEG
• High quality structural MR
• PET, ictal and interictal SPECT

Localized focus
Concordant findings

Indeterminate/discordant
Findings
Dual pathology
Cortical malformation
Aims of structural imaging

• Locate epileptogenic focus/foci
• Provide surgical planning map
• Eloquent brain areas
• Support functional studies- PET, SPECT, MEG and fMRI

Checklist prior to scan

• Confirm seizure semiology
• Review EEG reports and functional data if available
• Use of best available scanner
• Optimize technique

3T versus 1.5T?


• Experienced, unblinded review yielded additional info in 48% compared to routine clinical reads at 1.5T
• Subgroup with prior "normal" 1.5T MRIs, 3T MRI detected new lesion in 65%
1.5T Iceland- Lt frontal/insular seizures- "normal"

Practical view
• 3 Tesla imaging at least in patients undergoing Phase 1 presurgical evaluation and patients with focal epilepsy

Sequences
• Sagittal T1 spoiled gradient echo 3D (MPRAGE or SPGR)*
• Sagittal 3D FLAIR with multiplanar reformats
• Axial T2 (2.5 mm no skip)
• Thin section coronal T2
• Susceptibility-weighted imaging (SWI)
• DTI > 30 direction
• MRS and perfusion imaging (ASL)
• Gadolinium not routinely used

What does one look for?
Substrates of focal epilepsy
• Hippocampal sclerosis
• Malformations of cortical development
• Neoplastic lesions
• Vascular lesions
• Gliosis, inflammatory and other miscellaneous lesions
**MR findings in hippocampal sclerosis**

- Atrophy & T2 prolongation
- Loss of internal architecture
- Loss of hippocampal head interdigitations
- Loss of hippocampal striations
- Temporal horn dilatation
- Mammillary body & fornix atrophy
- Volume loss in temporal lobe
- Collateral white matter atrophy between hippocampus and collateral sulcus

**Hippocampal sclerosis - Pitfalls**

- Dual pathology (8-22%)
- Subtle contralateral changes
- Asymmetry due to head rotation
- Normal variants of gyral/sulcal configuration
- FLAIR signal slightly higher than cortex even in healthy subjects

**Malformations of cortical development**

- Focal cortical dysplasias - most common MCD in pts with intractable focal epilepsy

  - 80% of surgically treated patients under age of 3 years

**Latest classification**


**Axial T2**

- 7y male with 2 year history of right frontal-onset tonic-clonic seizures

**Axial FLAIR**

- 6 years later - right frontal FCD better seen (1.5T, 4 NEX, 2 mm sections, no skip) - FCD TYPE IIB
Right frontal lobe seizures
MRI diagnosis: Transmantle FCD Type IIb

PET showed right frontal hypometabolism

Pathology: Gliosis
• BUT- seizures ceased after surgery and has been seizure-free for 2.5 years

Ax T2
Coronal MPRAGE
3 year old with left frontal lobe onset seizures

Summary of MRI features of FCDs
• Cortical thickening (multiple planes)
• Increased cortical signal on T2 and T1
• Blurring of gray-white junction on T1 and T2- (FLAIR not optimal)
• Gyral and sulcal morphology
• T2/FLAIR signal from cortex with/without extension toward ventricle
• Gray matter heterotopia
• Sulcal cleft and cortical dimple
• Atrophy

Importance of MRI technique
• “Catch-rate” of epilepsy protocol versus conventional brain screen:
  • 72% vs 49%, 91% vs 50%

Weishmann UC. Clinical application of neuroimaging in epilepsy. J Neurol Neurosurg Psychiatry. Apr 2003;74(4):466-70
Tips for improving 1.5T yield

- Thin section, no gap axial T2 3-4 mm
- Higher number of echoes 2 or 3
- Focus on area of concern based on EEG
- Optimize the MPRAGE or SPGR sequence
- Scan coronals all the way through

Systematic approach

- Axial and coronal thin section T2 and FLAIR
  - Cerebral hemisphere symmetry
  - Gyral folding pattern
  - Gray-white junction: smooth, irregular or blurred
  - Symmetry of white matter signal
- Volumetric T1/MPRAGE/SPGR
  - Gyral folding pattern: normal, simplified or increased
  - Gray-white junction: smooth, irregular or blurred
  - Uniformity of cortical signal
  - Subcortical or periventricular gray matter lesions

Newborn with seizures

Incomplete myelination

5 day old infant with seizures

3 month follow-up MRI

Outside study
12 months of age- rescanned

Neoplastic lesions versus dysplasia

Ax T2  Ax MPRAGE  Ax T1+C

Be aware of presence of Dual pathology (FCD III)

20 mo boy, AEDR seizures from DOL #1

II-SPECT
FCD IIb and low-grade glioma

Intraop MR 6 mo follow-up

Neoplasms can resemble dysplasia

Neoplasms can resemble dysplasia

Ganglioglioma

Cigarette olfaction aura, generalized tonic-clonic seizures

Pathology: Hippocampal sclerosis with cortical dysplasia FCD IIIa

Pitfalls in MCD Dx- summary
- Beware of appearing/disappearing lesions with myelination
- Foci of “accelerated myelination” indicating cortical dysplasia
- Rescan when myelination complete
- True extent of dysplasia may not be identified
- Distractors on the scan or order form
- Beware the “neoplasm in disguise”

ROLE OF NUCLEAR MEDICINE STUDIES
Right occipital lobe seizures

Role of DWI and DTI

- Seizure edema
- Disorganization of white matter may be associated with cortical dysplasias
- Extent of white matter beyond visually detectable signal change
- Surgical planning

18 month-old infant with seizures

Presentation 9 week F/U 3 years of age (18 mth F/U)
Role of DWI and DTI
- Seizure edema
- Disorganization of white matter may be associated with cortical dysplasias
- WM abn beyond visually detectable signal change
- Surgical planning

Radionuclide studies
- PET- FDG, $^{11}$C flumazenil, $^{11}$C-alpha-methyl-L-tryptophan ($^{11}$C-AMT)
- PET/MR
- HMPAO SPECT
- Multimodality co-registration

Role of MRS
- Characterize focal lesions
- Determine functionally abnormal zone
- Temporal lobe epilepsy

Arterial spin labeling (ASL)
Left frontal cortical dysplasia-interictal hypoperfusion

Role of ASL- case 2
- Child with Na+ channel abnormality-MRI for refractory myoclonic seizures
Functional MRI in presurgical epilepsy
- Eloquent cortex
- Motor and sensory mapping
- Language mapping (may help replace WADA test)
- Language lateralization

Magnetoencephalography (MEG) and MSI (magnetic source imaging)
- Records magnetic fields generated by spontaneous or evoked brain activity
- Localize focal epileptic activity to guide invasive procedures
- Delineate functionally significant areas
- Plan neurosurgical procedures
- Aberrant connectivity data

Phase 2 evaluation- invasive
- Subdural electrode placement
- Medication reduced or stopped
- Monitoring of EEG
- Imaging- look for complications
Surgical mapping

- Extent and nature of lesion
- Functionally abnormal region
- Connections
- Vascular landmarks
- Brain lab
- Intraoperative MRI
- Post-operative surveillance

Surgical Techniques

- Anterior temporal lobe resection
- Amygdalohippocampectomy
- Neocortical resection
- Lesionectomy
- Hemispherectomy or hemispherotomy
- Multilobar resection
- Corpus Callosotomy
- Multiple subpial transection
- Stereotactic ablation
- MRI guided laser ablation

Role of DTI in post-operative patients
Summary
• Diagnostic workup
• Aims of imaging study
• MR features of FCDs
• Techniques, strategies, tips and traps
• Role of DTI, MEG, fMRI

TAKE HOME MESSAGES
• TEAM APPROACH WORKS BEST
• Seizure freedom more likely with resection of lesion on MRI
• Even seizure reduction can improve quality of life of the child and the family