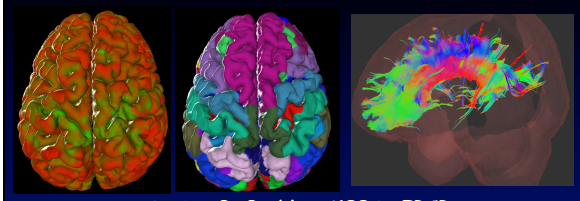
Pre-operative imaging in Epilepsy



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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 → brain injury
- Drug resistance in 25-30% with partial seizures

Intractable epilepsy

Only hope in many cases

↓

SURGICAL RESECTION OF EPILEPTOGENIC FOCUS

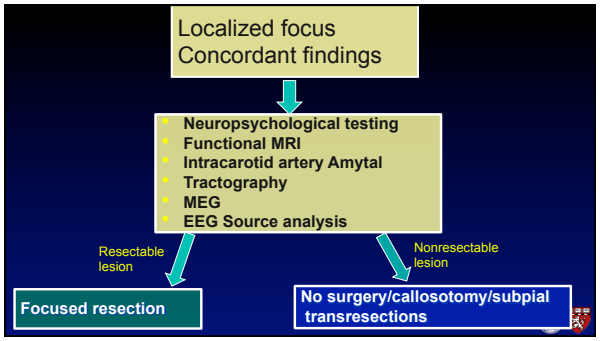
Pre-surgical work-up of intractable epilepsy

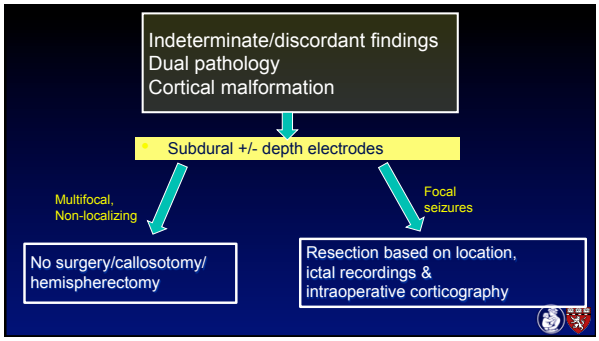
Phase 1 (non-invasive)

- 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

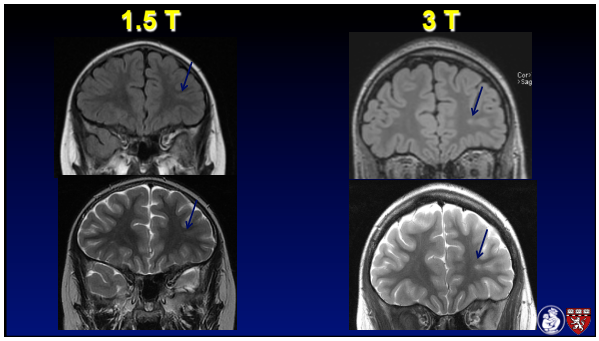
Checklist prior to scan

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

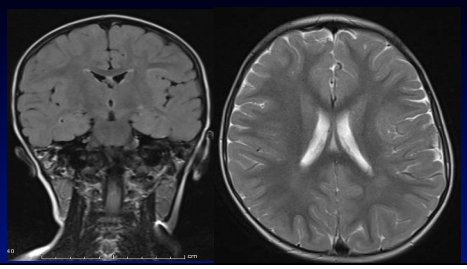
3T versus 1.5T?

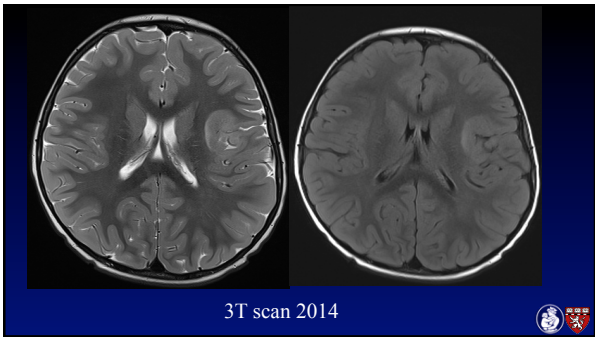
3T phased array MRI improves the pre-surgical evaluation in focal epilepsies: a prospective study- Knake et al. Neurology. 2005 Oct 11;65(7):1026-31.

- 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"





3T scan 2014

Practical view

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

Children's Hospital Boston

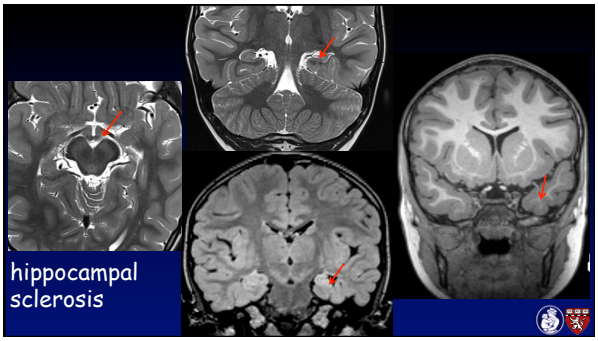
32 or 64 channel coil on a 3 Tesla magnet

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

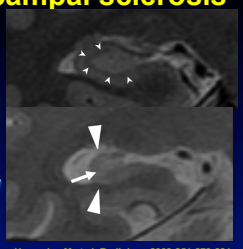
- Hippocampal sclerosis
- Malformations of cortical development
- Neoplastic lesions
- Vascular lesions
- Gliosis, inflammatory and other miscellaneous lesions



hippocampal sclerosis

MR findings in hippocampal sclerosis

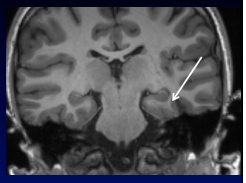
- Atrophy & T2 prolongation
- Loss of internal architecture
- Loss of hippocampal head interdigitations
- Loss of hippocampal striations
- Temporal horn dilatation
- Mammillary body & fornix atrophy
- Volume loss in temporal lobe
- Collateral white matter atrophy between hippocampus and collateral sulcus



Hanamiya M et al. Radiology 2009;251:873-881

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



Parahippocampal gyral abnormality

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

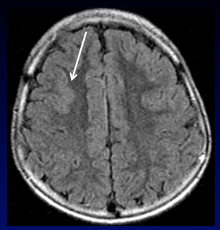
Latest classification

FCD Type I (isolated)	Focal Cortical Dysplasia with abnormal radial cortical lamination (FCD Ia)	Focal Cortical Dysplasia with abnormal tangential cortical lamination (FCD Ib)		Focal Cortical Dysplasia with abnormal radial and tangential cortical lamination (FCD Ic)
FCD Type II (isolated)	Focal Cortical Dysplasia with dysmorphic neurons (FCD IIa)		Focal Cortical Dysplasia with dysmorphic neurons and balloon cells (FCD IIb)	
FCD Type III (associated with principal lesion)	Cortical lamination abnormalities in the temporal lobe associated with hippocampal sclerosis (FCD IIIa)	Cortical lamination abnormalities adjacent to a glial or glio-neuronal tumor (FCD IIIb)	Cortical lamination abnormalities adjacent to vascular malformation (FCD IIIc)	Cortical lamination abnormalities adjacent to any other lesion acquired during early life, e.g., trauma, ischemic injury, encephalitis (FCD IIId)

Blumcke, et al. Epilepsia. 2011

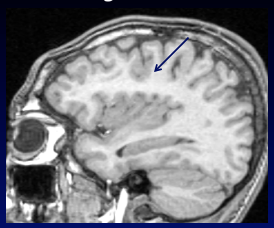
Axial T2

Axial FLAIR

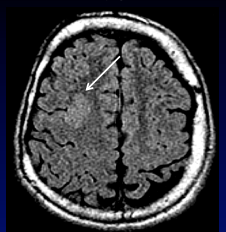


7y male with 2 year history of right frontal-onset tonic-clonic seizures

Sag SPGR

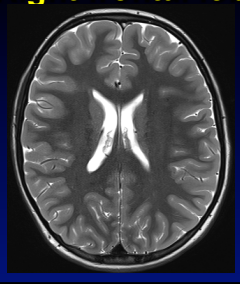


Axial FLAIR



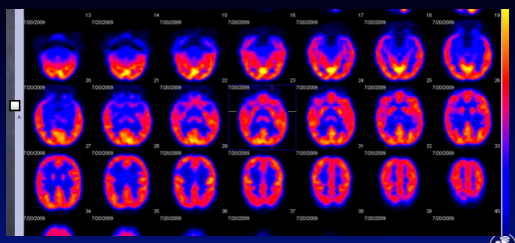
6 years later- right frontal FCD better seen (1.5T, 4 NEX, 2 mm sections, no skip)- FCD TYPE IIB

Right frontal lobe seizures



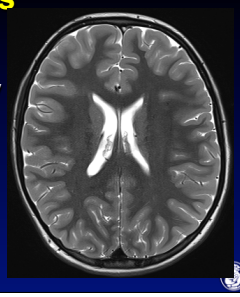
MRI diagnosis:
Transmantle FCD Type IIb

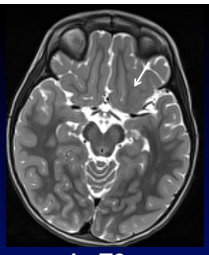
PET showed right frontal hypometabolism



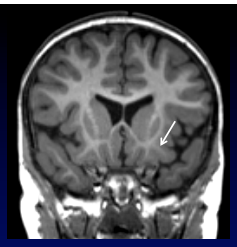
Pathology: Gliosis

- **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%**

Wieshmann UC. Clinical application of neuroimaging in epilepsy. J Neurol Neurosurg Psychiatry. Apr 2003;74(4):466-70
Von Oertzen J et al. Standard magnetic resonance imaging is inadequate for patients with refractory focal epilepsy. J Neurol Neurosurg Psychiatry. Dec 2002;73(6):643-7

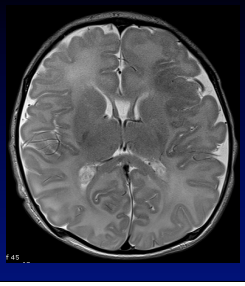
Tips for improving 1.5T yield

- 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

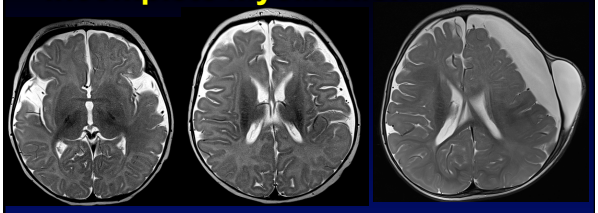
Systematic approach

- **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

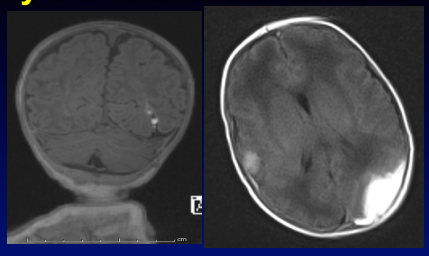
Newborn with seizures



Incomplete myelination

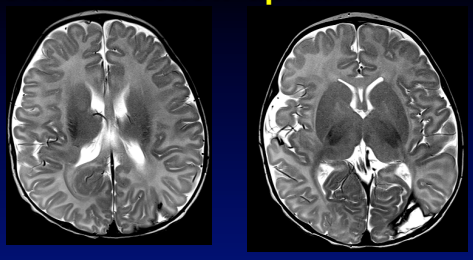


5 day old infant with seizures

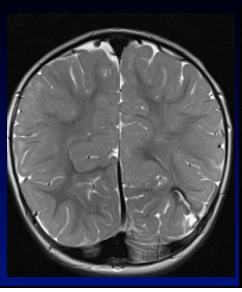


Outside study

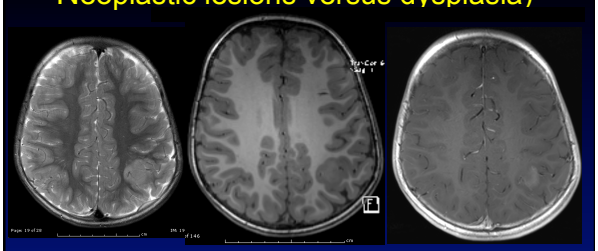
3 month follow-up MRI



12 months of age- rescanned



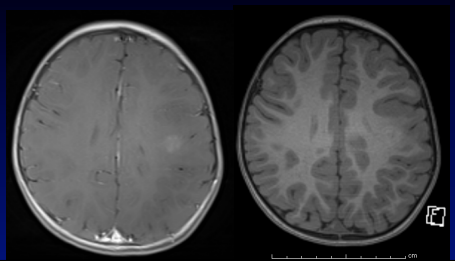
Neoplastic lesions versus dysplasia)

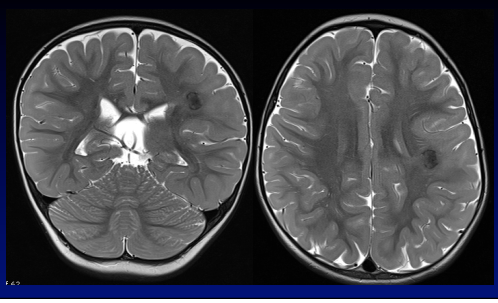


Ax T2 Ax MPRAGE Ax T1 +C

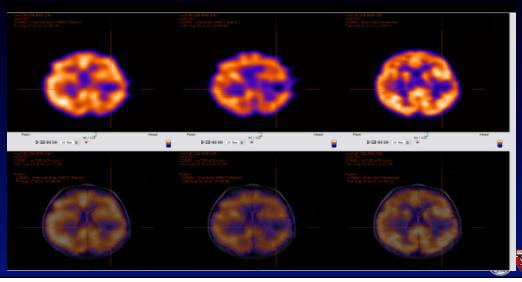
Be aware of presence of Dual pathology (FCD III)

20 mo boy, AEDR seizures from DOL #1

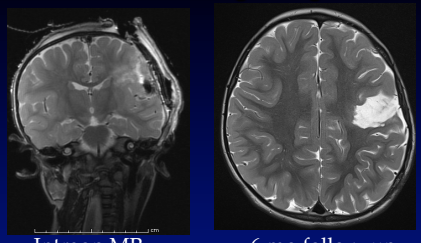




II-SPECT

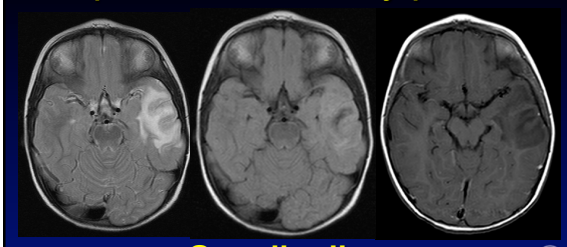


FCD IIb and low-grade glioma



Intraop MR 6 mo follow-up

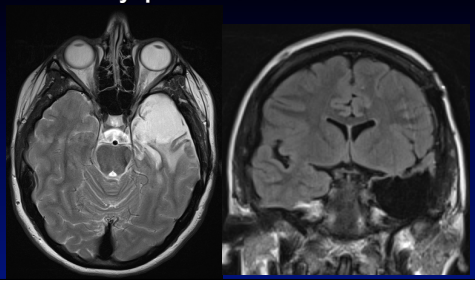
Neoplasms can resemble dysplasia



Ganglioglioma

Cigarette olfaction aura, generalized tonic-clonic seizures

Pathology: Hippocampal sclerosis with cortical dysplasia FCD IIIa

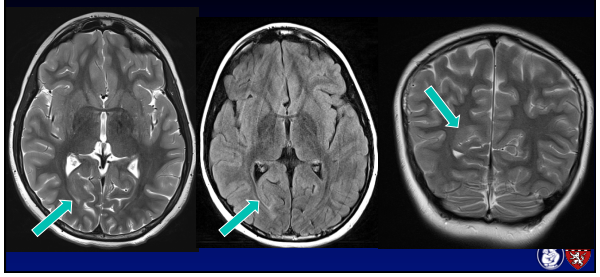


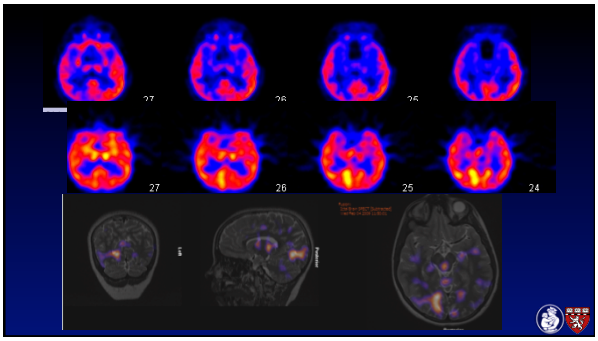
Pitfalls in MCD Dx- summary

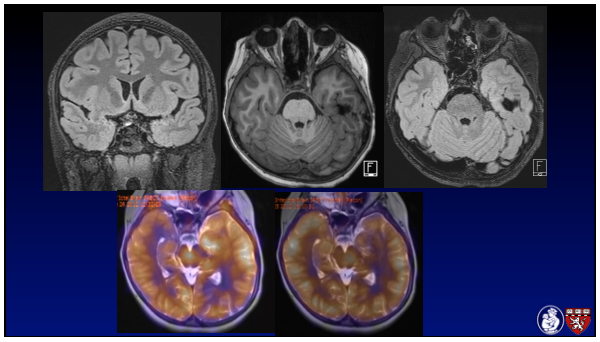
- Beware of appearing/disappearing lesions with myelination
- Foci of “accelerated myelination” indicating cortical dysplasia
- Rescan when myelination complete
- True extent of dysplasia may not be identified
- Distractors on the scan or order form
- Beware the "neoplasm in disguise”

ROLE OF NUCLEAR MEDICINE STUDIES

Right occipital lobe seizures

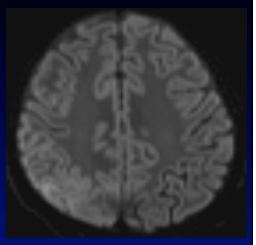




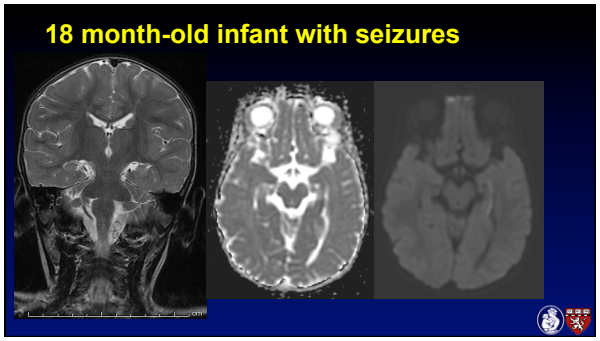


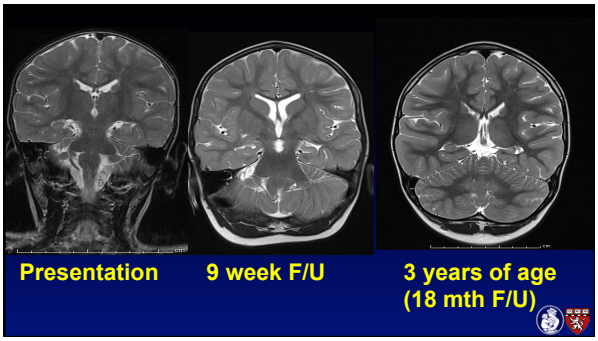
Role of DWI and DTI

- **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

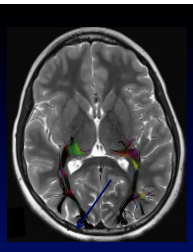




Presentation | 9 week F/U | 3 years of age (18 mth F/U)

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

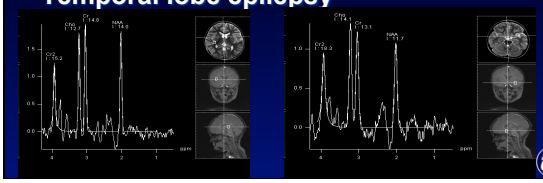


Radionuclide studies

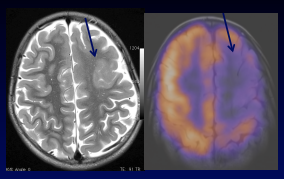
- PET- FDG, (^{11}C) flumazenil, $_{11}$C-alpha-methyl-L-tryptophan ($_{11}$C-AMT)
- PET/MR
- HMPAO SPECT
- Multimodality co-registration

Role of MRS

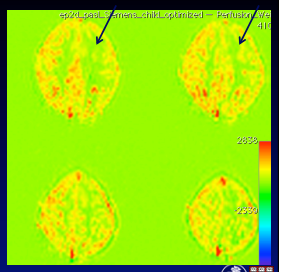
- Characterize focal lesions
- Determine functionally abnormal zone
- Temporal lobe epilepsy



Arterial spin labeling (ASL)

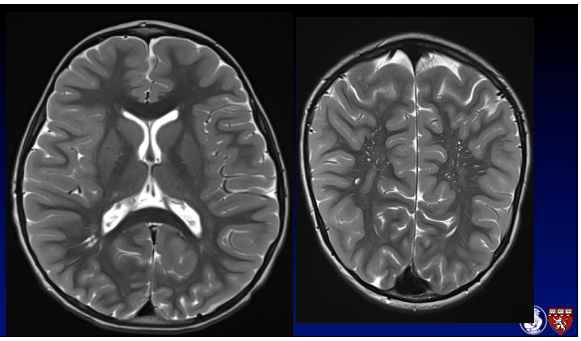


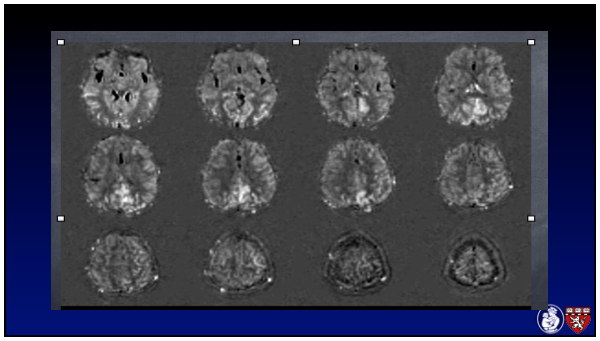
Left frontal cortical dysplasia- interictal hypoperfusion



Role of ASL- case 2

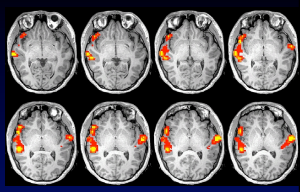
- Child with Na+ channel abnormality- MRI for refractory myoclonic seizures





Functional MRI in presurgical epilepsy

- Eloquent cortex
- Motor and sensory mapping
- Language mapping (may help replace WADA test)
- Language lateralization

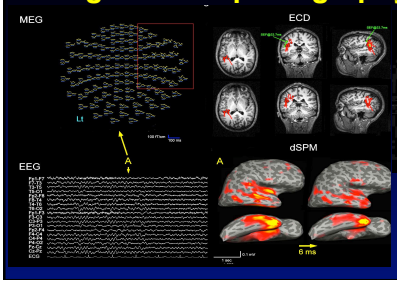


PT WITH LEFT MTS- Auditory antonym generation task- right sided preference

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

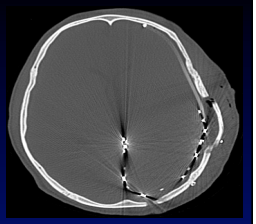
Magnetoencephalography (MEG)

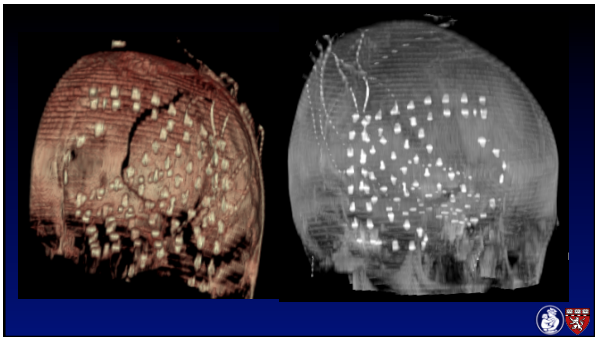


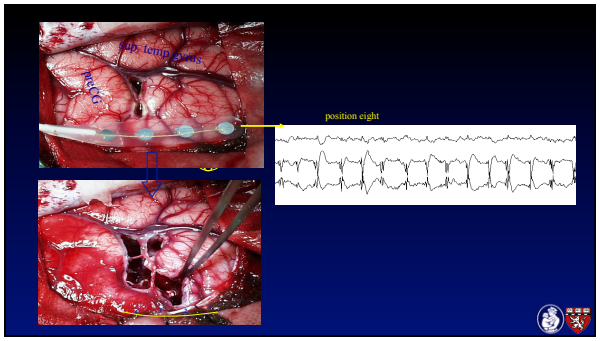
Clustered activity ➡ FCD

Phase 2 evaluation- invasive

- Subdural electrode placement
- Medication reduced or stopped
- Monitoring of EEG
- Imaging- look for complications







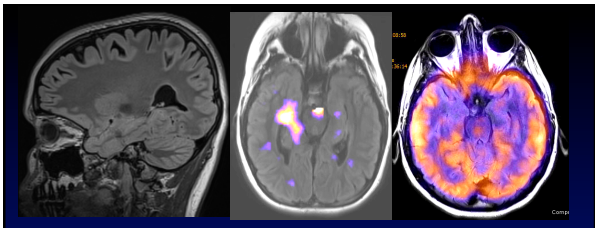
Surgical mapping

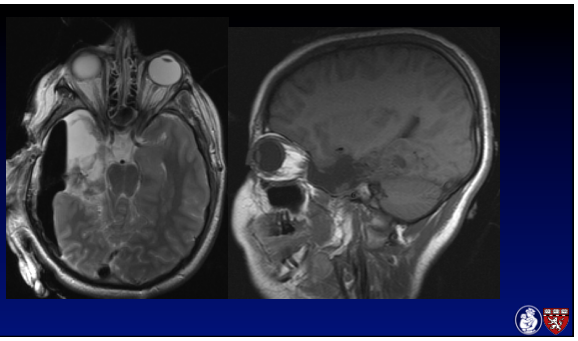
- Extent and nature of lesion
- Functionally abnormal region
- Connections
- Vascular landmarks
- Brain lab
- Intraoperative MRI
- Post-operative surveillance

Surgical Techniques

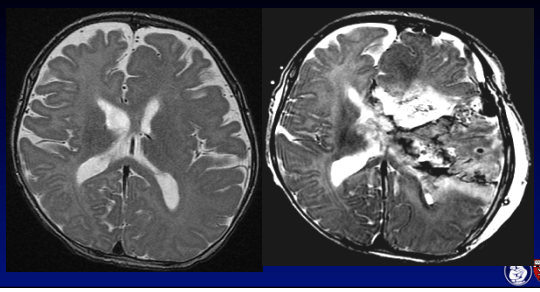
- **Anterior temporal lobe resection**
- **Amygdalohippocampectomy**
- **Neocortical resection**
- **Lesionectomy**

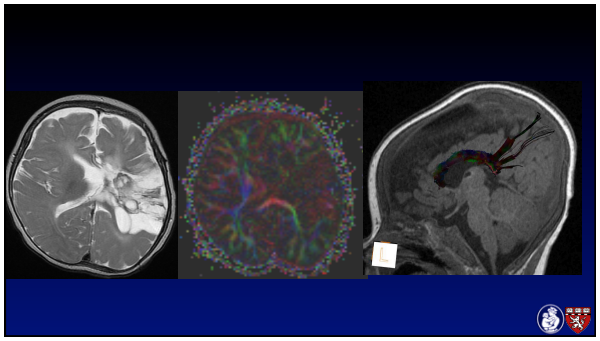
- Hemipsherectomy or hemispherotomy
- Multilobaar resection
- Corpus Callosotomy
- Multiple subpial transection
- Stereotactic ablation
- MRI guided laser ablation



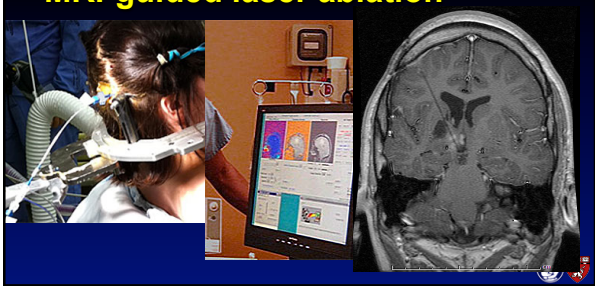


Role of DTI in post-operative patients





MRI-guided laser ablation



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