IMAGING IN EPILEPSY

Thanwa Sudsang MD.

Department of Radiology,
Advanced Imaging Center (AIMC)
Ramathibodi Hospital
OUTLINE

- Role of Imaging in Epilepsy
- Indication of Imaging
- Imaging Modalities and Updates
- Variety of epileptogenic substrates commonly identifiable with MRI
Clinical & Electrophysiologic diagnosis

Identify and Locate Structural Abnormality
Role of Imaging

**Pre-surgery**
- Identify structural abnormality
- Localize

**Plan for surgery**
- Help confirm epileptogenicity
- Relationship with eloquent areas
- Predict resectivity and Prognostication

**Post-surgery**
- Evaluate residual lesion
- Surveillance
Localization-related Epilepsy

Find them

Visible abnormalities

Invisible abnormalities

MRI
Negative

SURGERY

Seizure free
Better quality of life
IMAGING IN EPILEPSY

- CT
- SPECT
- PET
- MRS
- Conventional MRI
- MEG
- fMRI
- DTI

Anatomy/Structural vs Functional Imaging
Ideal Imaging

• Distinguish abnormal from normal -> **High resolution**

• Tell etiology/nature of abnormality -> **Good Characterization**

• Allow assessment of relationship with eloquent structures
  -> **Functional/Microstructural derangement**

• Evaluate epileptogenicity -> **Physiologic data**
IMAGING CHOICES

Anatomy/Structural: CT, MRI

Physiology and Function: SPECT, PET, MEG, MRS, DTI, fMRI, Perfusion CT/MRI
Structural Imaging
MRI vs CT
<table>
<thead>
<tr>
<th>Pathology</th>
<th>CT Only</th>
<th>Standard MRI</th>
<th>High-Resolution MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hippocampal sclerosis</td>
<td>0</td>
<td>20</td>
<td>108</td>
</tr>
<tr>
<td>Vascular abnormalities</td>
<td>13</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Tumor</td>
<td>4</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>Brain damage</td>
<td>18</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Malformations of cortical development</td>
<td>0</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Nonspecific white matter lesions</td>
<td>17</td>
<td>18</td>
<td>0</td>
</tr>
</tbody>
</table>

IMAGING CHOICES

Emergent -> CT results change management in patients with acute seizure.

Non-emergent: MRI sensitivity 95% CT sensitivity 32%
**CT: Indication**

Emergency or First unprovoked seizure with neurologic abnormality
MRI
MRI
EPILEPSY 15%
Localisation-related 85%
Conventional MRI: Pros

- Good spatial resolution
- Soft tissue contrast
- Multiplanar
- No ionizing radiation
- Continuous development of techniques and softwares
Conventional MRI: Cons

• Long Imaging time
• Contraindications:
  • Cardiac pacemaker, intracranial aneurysm clip, cochlear implant
  • Poor renal function......Gd
  • Attention deficit, mental disability
  • Claustrophobia
• Cannot assess epileptogenicity or functionality
PITFALLS OF MRI

- Widespread abnormality
- Multiple lesions
- Dual pathologies
MRI Negative

Too Subtle To Identify

Combining physiologic data: EEG, SPECT, PET, Invasive methods

Microdysgenesis
Molecular/chemical abnormalities
Solution for MRI Negative

Combine data from multiple sources

Multimodal imaging co-registration
Physiologic Imaging

- SPECT
  - Ictal SPECT
  - Post-ictal SPECT
  - Interictal SPECT

- PET
  - FDG PET
TO Maximize MRI sensitivity

- Appropriate MRI Protocol
- High performance MRI equipment
- Updated software
- Experienced (Neuro)radiologist

Clinical History, EEG finding
MRI PROTOCOLS

- Coronal oblique
- Volume (3D) SPGR T1W -> reformat & post-processing, IR T1W
- FLAIR, T2W
- Volume T2W
- Contrast not routinely used
- Phase-array coil -> high resolution
- Optional: volumetric analysis, T2 relaxometry, MRS
T2W versus T1W
# Etiologies/Epileptogenic Substrates Identifiable with MRI

## Pediatric
- Birth-related
- Congenital Malformation
- Inborn-error of metabolism
- Neoplasm
- Infection
- Post trauma
- Vascular (malformation)
- MTS

## Adult
- Vascular (Stroke, AVM, cavernoma)
- Tumor (primary and mets)
- MTS
- Prior brain injury
EPILEPSY MRI MNEMONIC

• H ippocampal size and signal
• I AC & atrium (check correct plane and positioning)
• P eriventricular heterotopia
• P eripheral
  • Sulcal morphology abnormality
  • Atrophy
  • Gray matter thickening
  • Encephalocele
• O bvious lesion

HIPPO SAGE
Common Epileptogenic Substrates

• MTS
• MCD
• Vascular Malformation
• Gliosis/scar
• Neurocutaneous syndrome
• Miscellaneous
Seizure control in patients with partial epilepsy: the role of brain abnormalities detected by brain MRI.

HS = hippocampal sclerosis.

Hippocampal Sclerosis
Atrophy & T2 hyperintensity

Indirect MRI abnormalities: Atrophy of ipsilateral temporal lobe, fornix, mamillary body, collateral WM
Hippocampal Volumetry
## Neoplasm

<table>
<thead>
<tr>
<th>Neoplasm</th>
<th>Seizure frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysembryoblastic neuroepithelial tumour⁵,¹¹</td>
<td>100%</td>
</tr>
<tr>
<td>Ganglioglioma⁵,¹²</td>
<td>80–90%</td>
</tr>
<tr>
<td>Low-grade astrocytoma¹²,¹³</td>
<td>75%</td>
</tr>
<tr>
<td>Meningioma⁵,¹²</td>
<td>29–60%</td>
</tr>
<tr>
<td>Glioblastoma multiforme⁵,¹³</td>
<td>29–49%</td>
</tr>
<tr>
<td>Metastasis⁵,¹²</td>
<td>20–35%</td>
</tr>
<tr>
<td>Leptomeningeal tumour¹⁴,¹⁵</td>
<td>10–15%</td>
</tr>
<tr>
<td>Primary CNS lymphoma¹⁴</td>
<td>10%</td>
</tr>
</tbody>
</table>

*Table 1: Association between tumour type and seizure frequency*
Dysembryoplastic Neuroepithelial Tumor (DNET)

- Uncommon tumor with high epileptogenicity
- Most common and temporal lobe
- Associated with cortical dysplasia

Imaging: Heterogeneous mass with no enhancement or calcification, benign-appearing, characteristic bubbly appearance on FLAIR
Dysembryoplastic Neuroepithelial Tumor DNET
Ganglioglioma

- Rare tumor but highly epileptogenic
- Most common in frontal and temporal lobes
- Associated with cortical dysplasia
- Imaging: Solid or cystic mass with variable enhancement, approx. 30% with calcification, benign-appearing
Ganglioglioma
Pleomorphic xanthoastrocytoma
Desmoplastic infantile ganglioglioma
Oligodendroglioma
BRAIN METASTASIS
Schizencephaly
Subependymal/Periventricular heterotopia
Polymicrogyria
Focal cortical dysplasia with balloon cells
Cortical Dysplasia without Balloon cells
MCD: cortical dysplasia
Cavernomas
Encephalomalacia/scar
Tuberous sclerosis
Sturge Weber syndrome
Rasmussen encephalitis
PITFALLS
Dual pathology
3 day old, full term male, with status epilepticus
Hypoxic-Ischemic encephalopathy

- Lactate: within hours after injury before abnormal signal intensity seen on convention MRI -> early detection
- Glutamine/glutamate
- Decreased NAA: later
- Persistence of lactate after 24 hours may indicate permanent injury

Courtesy of Dr. Robert A. Zimmerman MD. The Children’s hospital of Philadelphia
Bilateral MTS/Equivocal MTS

T2 Relaxometry: Objective Measurement of T2 relaxation
1-H MRS

NAA (2.0 ppm): Neuronal marker

Creatine (3.0 ppm): Cellular energy

Choline (3.2 ppm): Cell membrane

mI (3.5 ppm): Astrocyte/glial cell marker

Lactate (1.3 ppm): Anaerobic metabolism
Emerging Imaging Techniques

1-H MR Spectroscopy (MRS) in Epilepsy Imaging

- Lateralization in TLE

  *Decreased absolute NAA, Decreased NAA/Choline, NAA/Creatine, NAA/Choline+Creatine ratios*

  Ipsilateral to lesion
Emerging Imaging Techniques

- MEG
- DTI
- fMRI
- MRS
- MR/CT Perfusion Imaging
Median Nerve Stimulation
Index Finger Movement
Tibial Nerve Stimulation
Emerging Imaging Techniques

**MEG (MagnetoEncephaloGraphy) & MSI (Magnetic Source Imaging)**

- Localize epileptogenic substrate
- Evaluate functioning cortex
Emerging Imaging Techniques

- MEG
- DTI: Diffusion Tensor Imaging
- fMRI
- MRS
- MR/CT Perfusion Imaging
DTI & TRACTOGRAPHY

U of Minn

H. Liu, CMRGT
Emerging Imaging Techniques

DTI in Epilepsy Imaging

- Plan for surgery evaluation

Research

- Assess epileptogenic zone in LRE
- DTI abnormality (Decreased FA) in TLE in ipsilateral brain
Sensorimotor task: Finger tapping
Emerging Imaging Techniques

fMRI in Epilepsy Imaging

- Evaluate functioning cortex/eloquent area: Motor cortex, Language lateralization, Memory
Summary: Role of Imaging

**Pre-surgery**
- Identify structural abnormality
- Localize

**Plan for surgery**
- Help confirm epileptogenicity
- Relationship with eloquent areas
- Predict resectivity and Prognostication

**Post-surgery**
- Evaluate residual lesion
- Surveillance
<table>
<thead>
<tr>
<th>Summary: Imaging of choice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emergency CT</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General</th>
<th>Conventional MRI (Standard protocol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Identify obvious epileptogenic substrates</td>
<td></td>
</tr>
<tr>
<td>- Follow up</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Special Attention</th>
<th>Conventional MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Identify subtle epileptogenic substrates</td>
<td></td>
</tr>
<tr>
<td>- Lateralization</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific Attention</th>
<th>fMRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Pre-surgical evaluation of risk, potential complication</td>
<td></td>
</tr>
<tr>
<td>- Research</td>
<td></td>
</tr>
</tbody>
</table>

- MRS
- DWI
- SPECT
- PET
- MEG + MSI
- 3T > 1.5T
- Special coil
- Special Protocol
- Experienced radiologist
- fMRI
- DTI
- DWI
- MRS
THANK YOU