



2023 GW

**Epilepsy Board Review**  
& *Best Practices*

# Structural Imaging

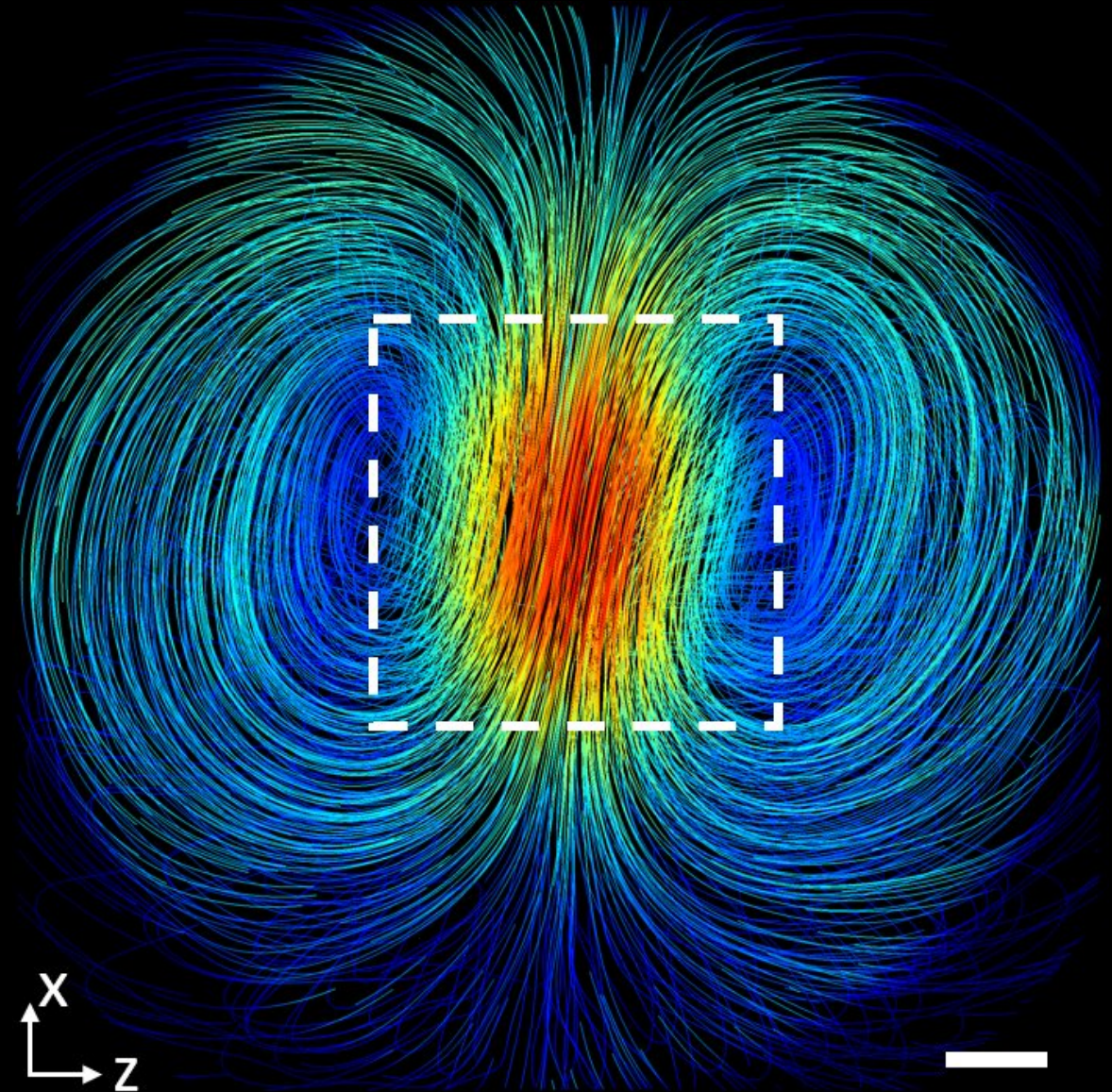
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Nathan T. Cohen, MD

Assistant Professor

Neurology & Pediatrics

GWU School of Medicine



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- Many slides based on prior lectures of Taha Gholipour, MD.

# Outline

- Patient and Protocol Selection
- Common Epilepsy Imaging Findings

# Clinical Uses of Neuroimaging in Epilepsy

- Acute/emergent eval (CT most helpful)
- Determine risk recurrence after single unprovoked sz
- Assist with classification (focal/multifocal/diffuse)
- Evaluate/select candidates with pharmacoresistant epilepsy (PRE) for surgery



# Clinical Uses of Neuroimaging in Epilepsy

- In PRE pts who are “MRI-negative,” multimodal imaging with FDG-PET, SISCOM, voxel-based morphometry, automated detection algorithms, MSI
- fMRI/MEG for language lateralization, motor localization

# ILAE 2019

**Recommendations for the use of structural magnetic resonance imaging in the care of patients with epilepsy: A consensus report from the International League Against Epilepsy Neuroimaging Task Force**

# ILAE 2019

- Who should have MRI?
  - Rate sz recurrence doubles with lesional MRI
    - From 10 to 26% at 1y; 29 to 48% at 5y
- First seizure
  - Acute setting: CT recommend in acute setting, with HARNESS MRI soon after
  - Note: early MRI recommended in young children as progression of myelination may mask FCD

# ILAE 2019

- **Newly diagnosed epilepsy**

- MRI lesion strongly associated with PRE
- lesional MRI is *2.5x more likely sz-free* with surgery

- **Generalized epilepsy**

- Insufficient evidence
- Is recommended if atypical features: focal neurological deficit, cognitive decline, refractory seizures, or focal interictal discharges

# ILAE 2019

- **Repeating MRI**

- Repeat if prior images not available or suboptimal
- For PRE with prior “normal” MRI, repeat MRI may reveal lesion in 30-65% of cases, up to 70% with postprocessing



# Protocol

- *Harmonized Neuroimaging of Epilepsy Structural Sequences (HARNES)*
  - isotropic, millimetric 3D T1 and FLAIR images
  - high-res 2D submillimetric T2 images
- 3T MRI preferred
  - If 1.5T, preferred minimum 8-channel phased array coil to boost signal to noise ratio

# HARNES Protocol Specific Details

Name	Primary MR image weighting	MR image acquisition	Advantages
<b>Mandatory sequences</b>			
Magnetization-prepared rapid gradient echo (MPRAGE), spoiled gradient echo (SPGR), or turbo field echo (TFE)	T1-weighted	3D	High-resolution images that can be reformatted to be viewed on coronal, axial, and sagittal planes; optimal visualization of brain anatomy and morphology
3D fluid attenuation inversion recovery (FLAIR)	T2-weighted	3D	3D high-resolution images that can be reformatted to any plane; CSF nulling enhances visibility of epileptic pathologies such as focal cortical dysplasia, hippocampal sclerosis, tubers, hamartomas, and glial scars
Coronal spin echo (acquisition plane perpendicular to the long axis of the hippocampus)	T2-weighted	2D	High in-plane resolution; optimal visualization of hippocampal internal structure on coronal cuts
<b>Optional sequences</b>			
Gadolinium-enhanced MRI	T1-weighted	3D	Best for assessing tumor-like lesions, vascular malformations, or infectious processes
Susceptibility-weighted imaging (SWI)	T2*-weighted	3D	Sensitive to iron deposits, blood products, and calcifications

## EPILEPSY PROTOCOL – 3D MRI

### T1-weighted

*Sequence type:* gradient echo

*Voxel size (mm):* 1 x 1 x 1

*Best to evaluate:* anatomy and morphology  
(volume, thickness, sulco-gyral shape, grey-white matter interface integrity)



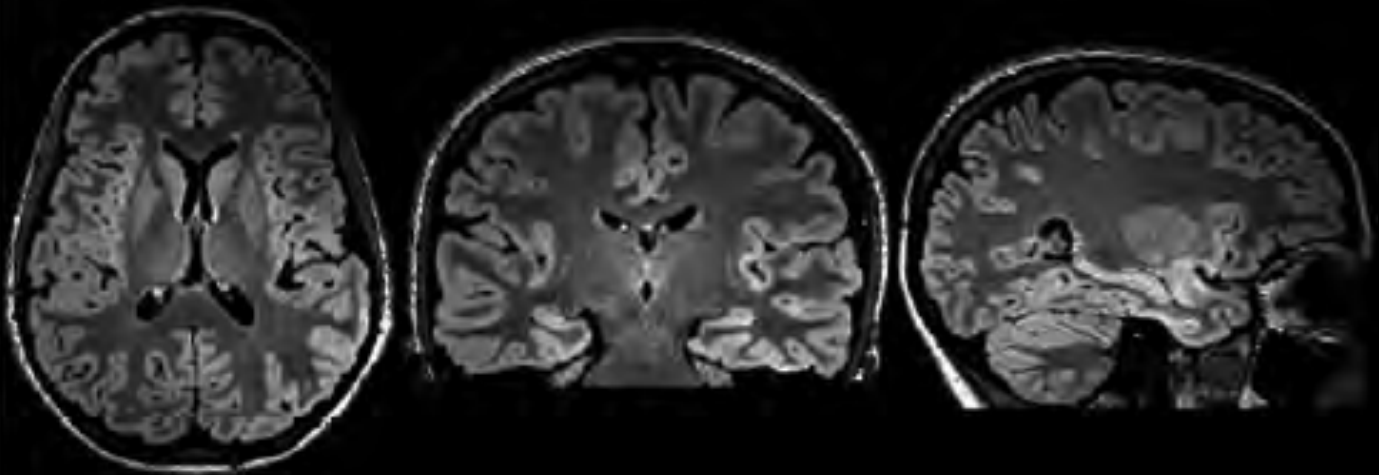
### FLAIR

*Sequence type:* turbo spin echo

*Voxel size (mm):* 1 x 1 x 1

*Best to evaluate:* signal intensity

*Caveat - Not sensitive in neonates and children <24 months of age due to incomplete myelination*

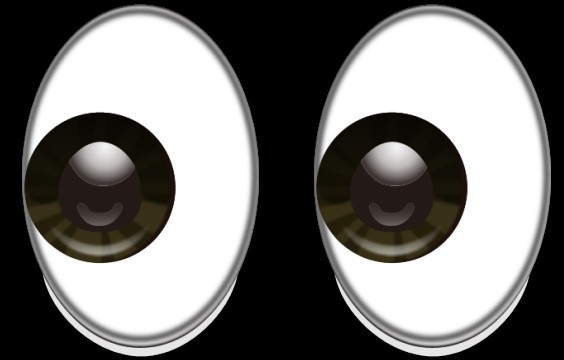


# MRI Yield

- Prospective study adults NOS, epilepsy protocol MRI ID lesion in 28% all pts, 58% if focal sz
- Cross sectional study 495 focal epilepsy pts
  - Standard MRI lesion 49%, epilepsy protocol MRI 72%

# MRI Yield

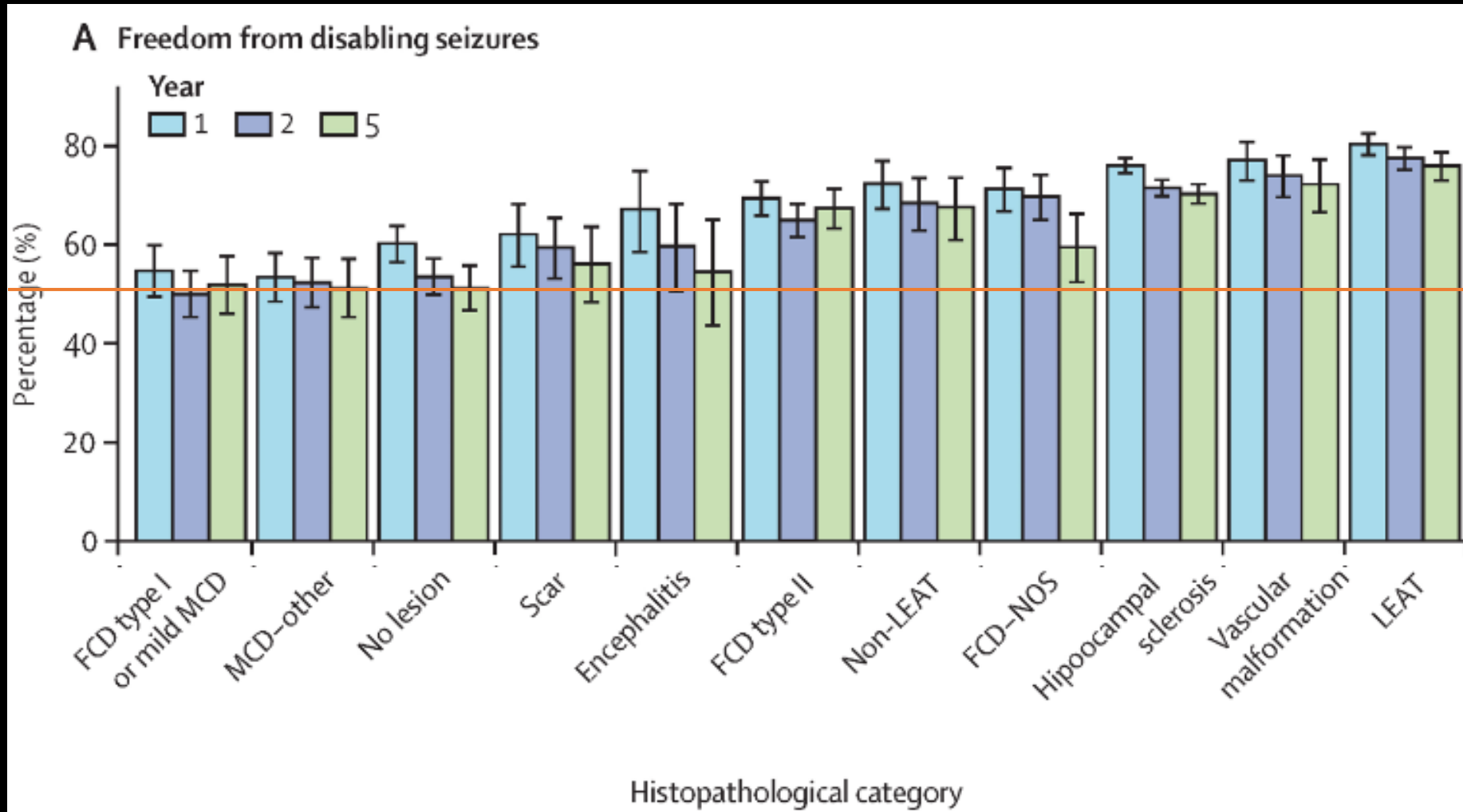
- Importance of experienced neuroradiologist:
  - Epilepsy protocol MRI + experienced radiologist boosts detection from 39% to 85%





# Lesional MRI = Better Surgical Outcome

- European Epilepsy Brain Bank Study, n=9147



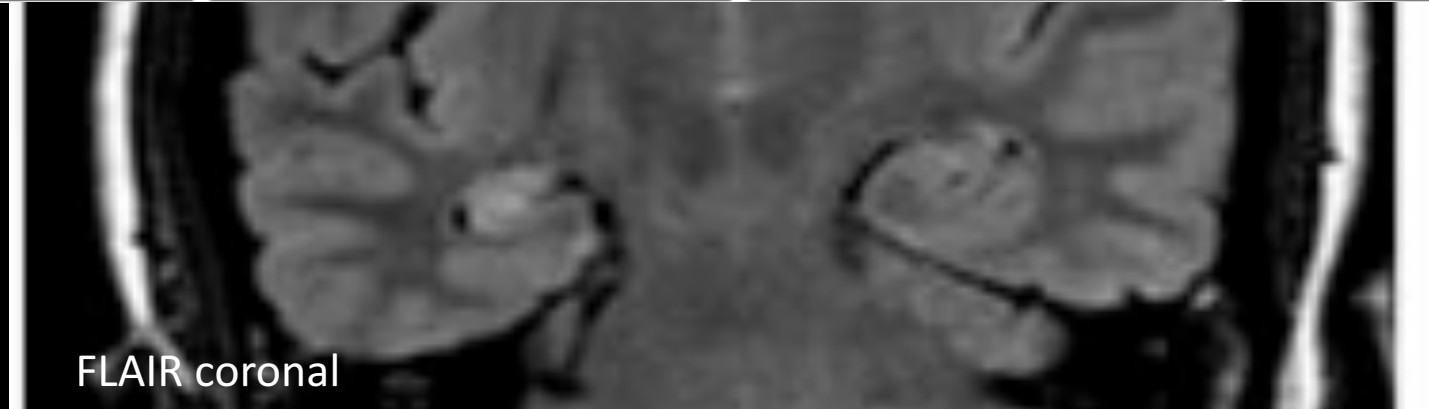
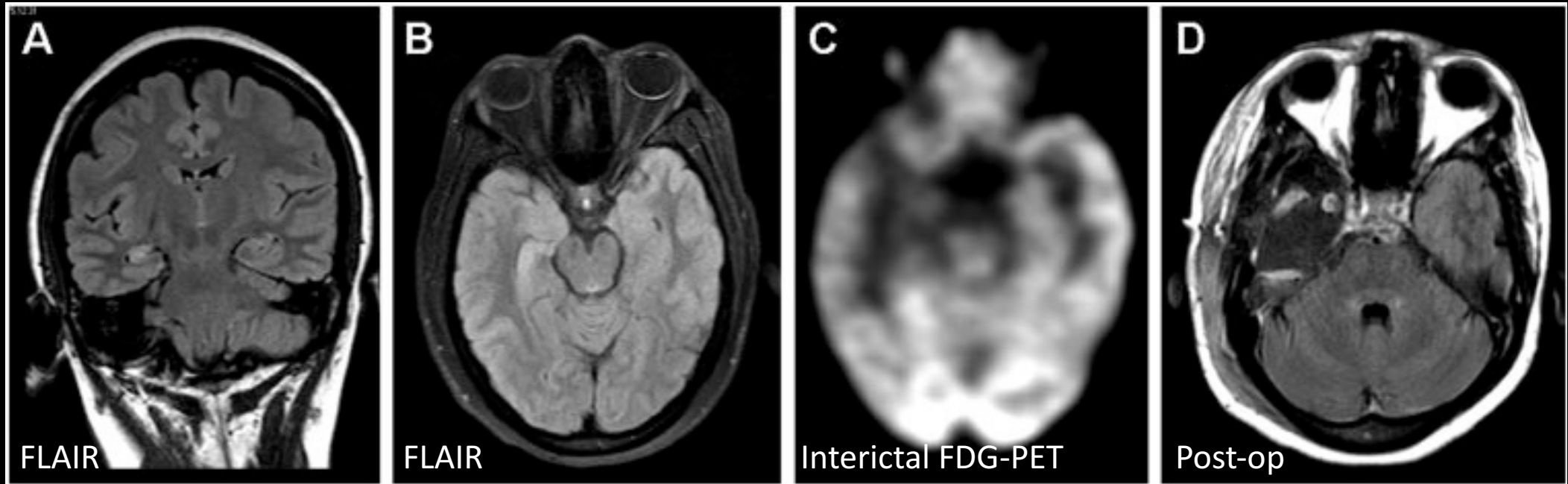
# High Yield Epilepsy Imaging Findings



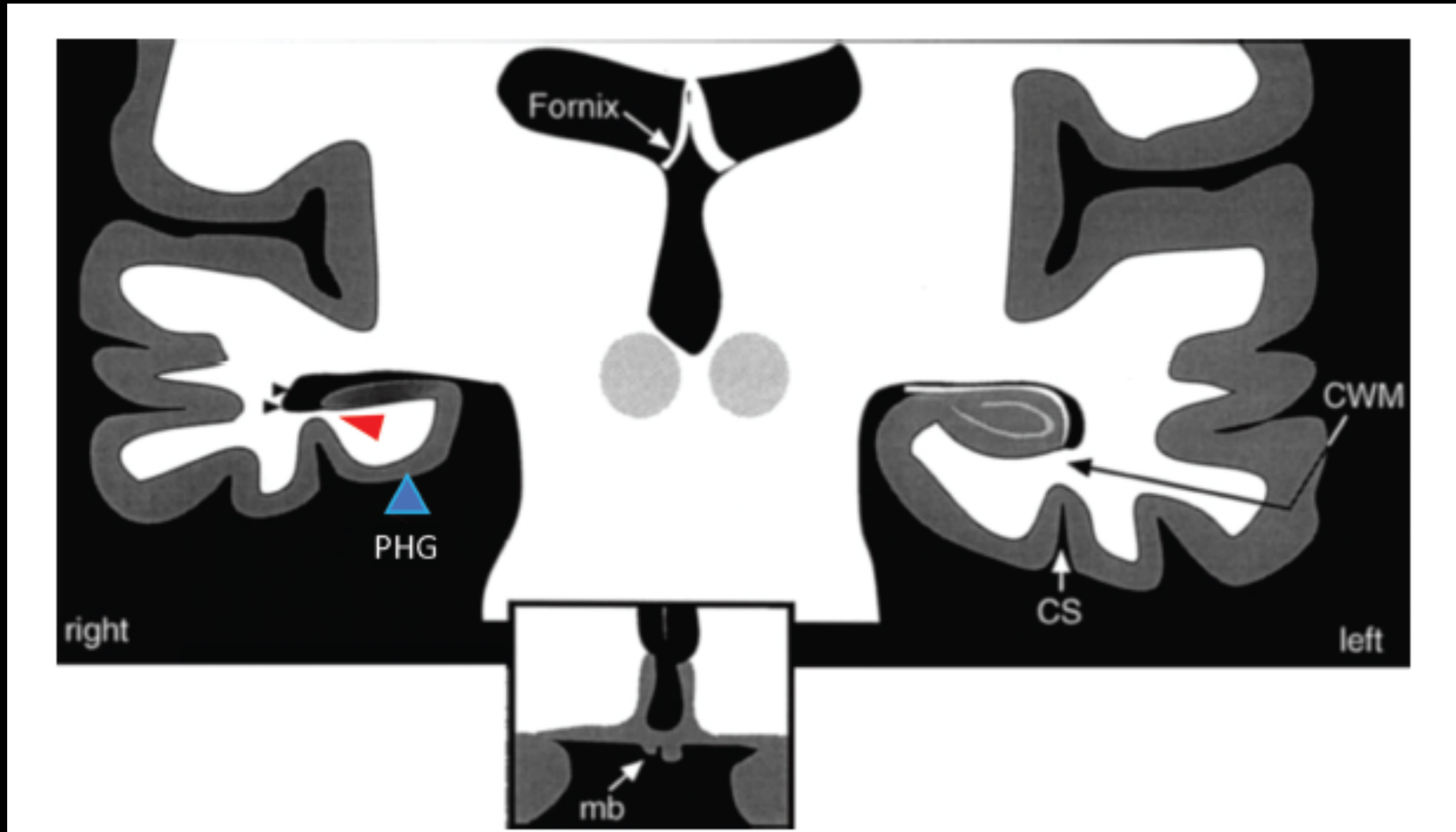
# Hippocampal sclerosis (MTS)

- Neuronal loss/gliosis
- 15% pediatric/44.5% adult surgical specimens
- Diagnostic Triad (needs 2 of 3):
  - Hippocampal atrophy (coronal T2)
  - High T2/FLAIR signal of hippocampus (coronal FLAIR)
  - Loss of internal architecture (interdigitations) of hippocampus (coronal T2)

# Hippocampal sclerosis (MTS)



# Hippocampal Sclerosis Secondary Findings





# Hippocampal Sclerosis Dual Pathology

- HC atrophy + coexisting extrahippocampal macroscopic lesion not encroaching on HC structure
- Only ~5% of cases (if use FCD classification)
- Vascular malformations, MCD, glioneuronal tumor, perinatal ischemic lesion etc.
- Note FCD Type IIIA (FCD + HS) is not dual pathology

# Malformations of Cortical Development (MCD)

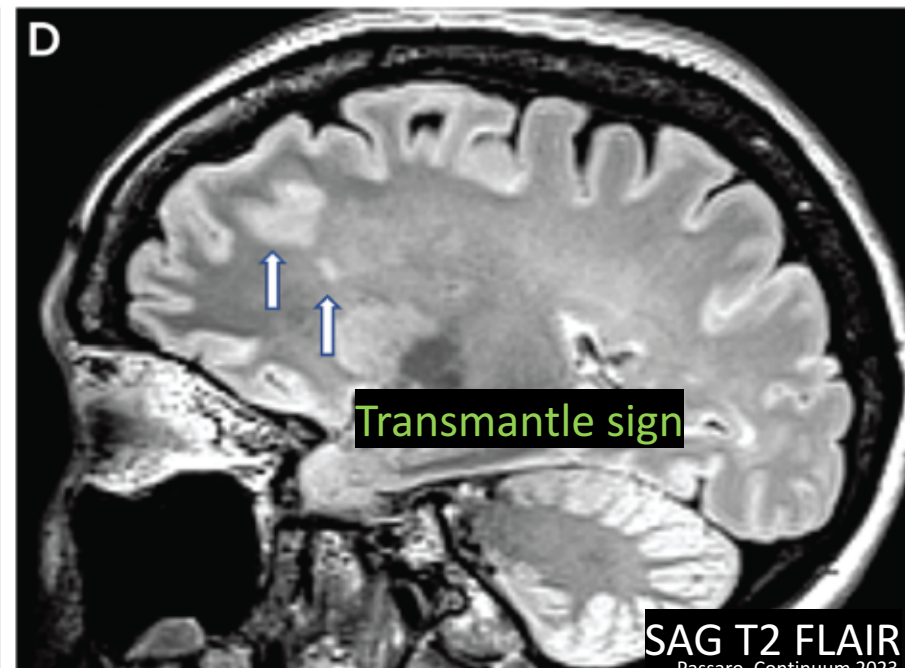
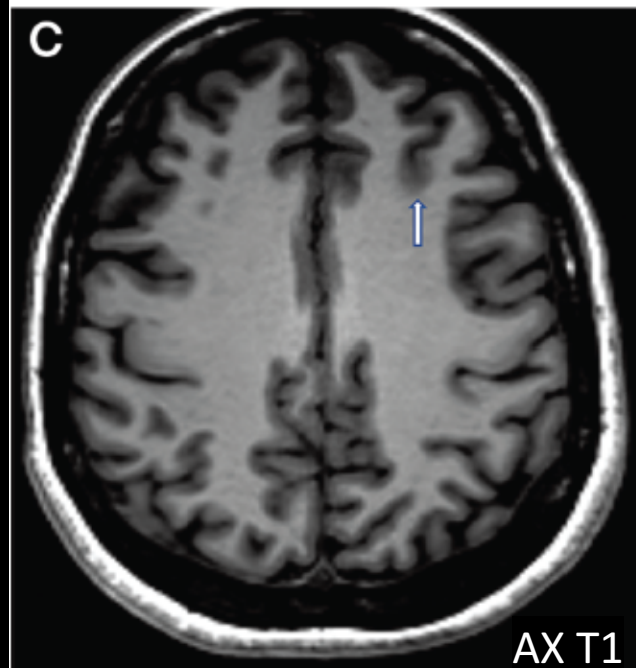
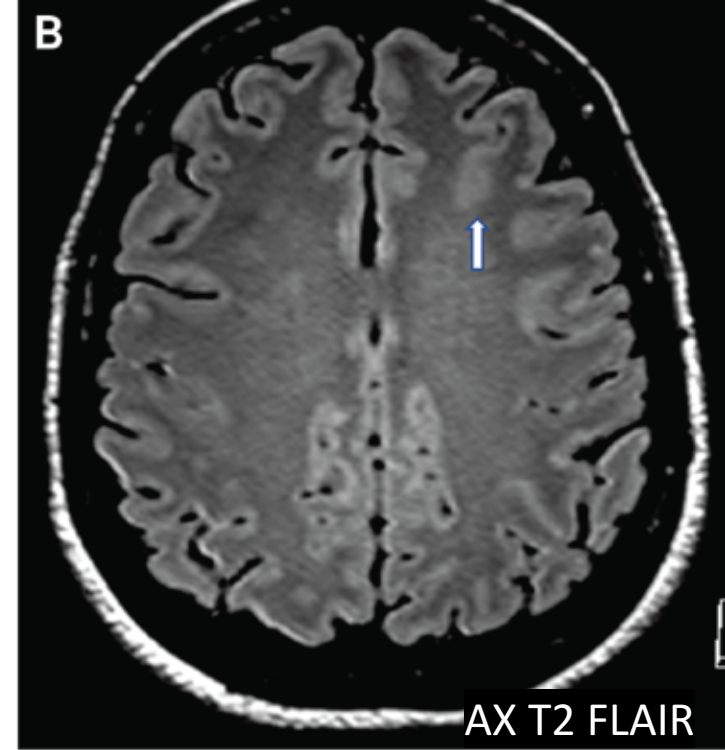
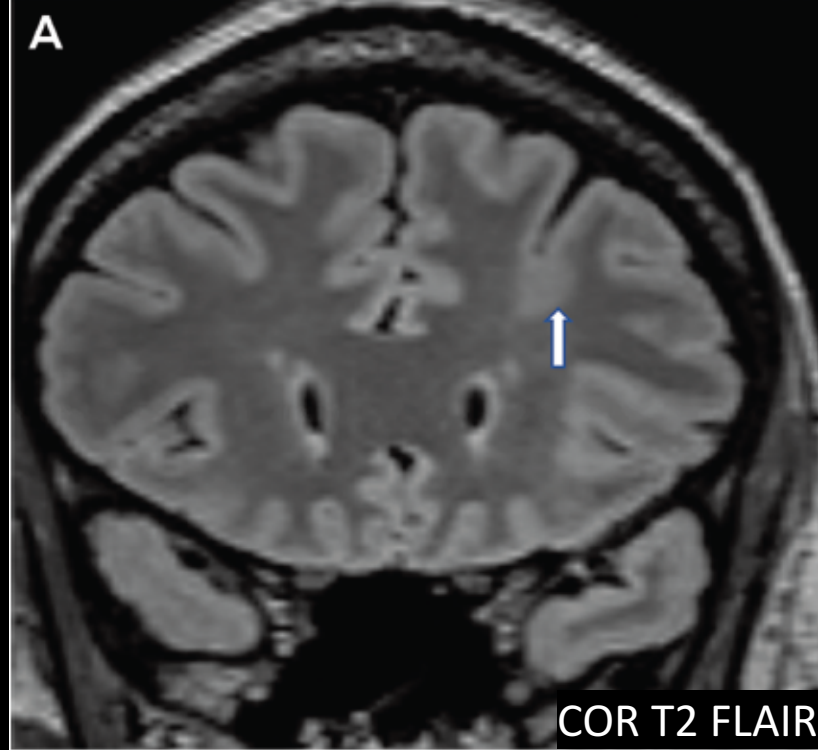
- Abnormal Proliferation or Apoptosis
  - Microcephaly, Megalencephaly, Dysplasia (FCD Type II or ganglioglioma)
- Abnormal Migration
  - Band & Nodular Heterotopia, Cobblestone malformation, Lissencephaly, PMG
- Abnormal Post-Migrational Development
  - FCD Type I

# Focal Cortical Dysplasia

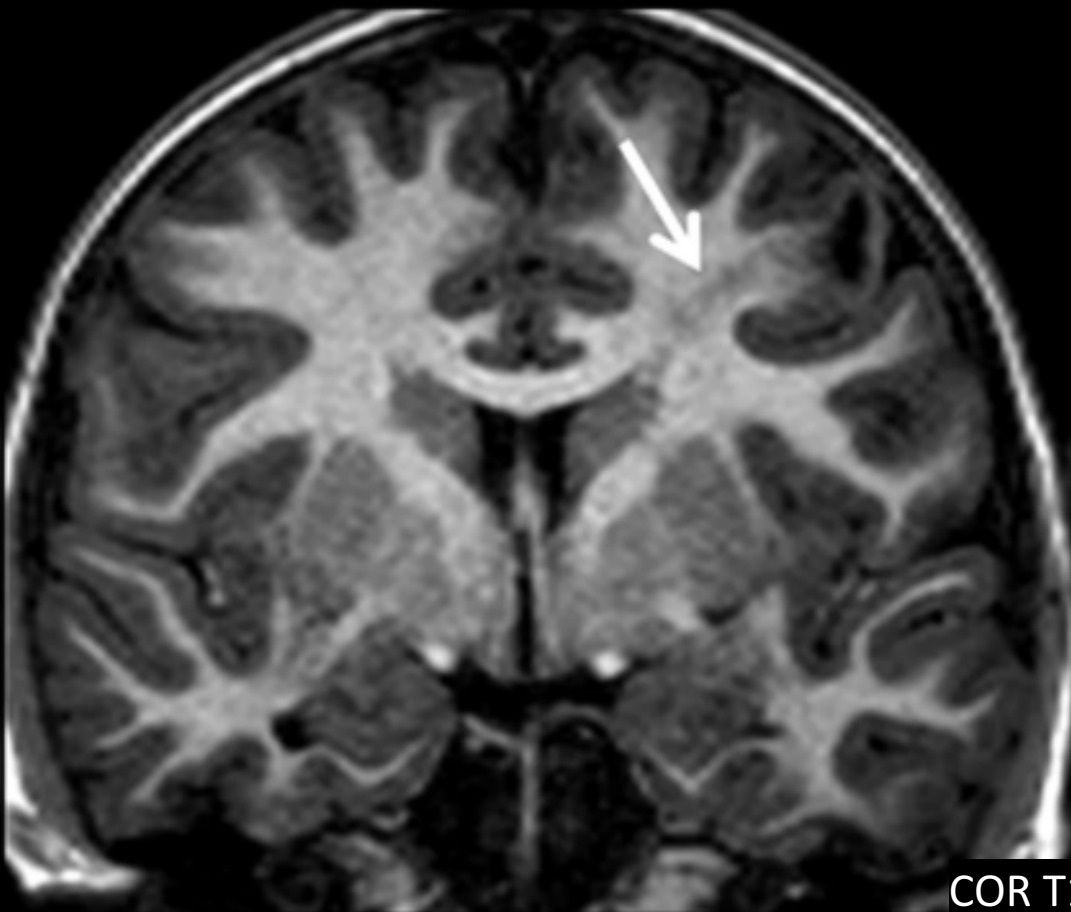
FCDI <sup>a</sup>	FCDIa abundant microcolumns	FCDIb abnormal layering	FCDIc vertical and horizontal abnormalities	
FCDII <sup>a</sup>	FCDIIa dysmorphic neurons		FCDIIb dysmorphic neurons and balloon cells	
FCDIII <sup>a</sup>	FCDIIIa cortical dyslamination associated with hippocampal sclerosis	FCDIIIb cortical dyslamination adjacent to brain tumor	FCDIIIc cortical dyslamination adjacent to vascular malformation	FCDIIIId cortical dyslamination adjacent to lesion acquired during early life, e.g. stroke
White Matter <sup>a</sup>	mMCD <sup>b</sup> with excessive heterotopic neurons <sup>a</sup>		mMCD with oligodendroglial hyperplasia in epilepsy (MOGHE) <sup>c</sup>	
No definite FCD on histopathology <sup>a</sup>	Abnormality of cortical organization remains ambiguous and histopathological findings not compatible with FCDI, II or III <sup>d</sup>			

# FCD IIB

- Bottom-of-sulcus
- Balloon cells
- mTOR pathway  
*DEPDC5, NPRL2, NPRL3*



# Other FCDIIB



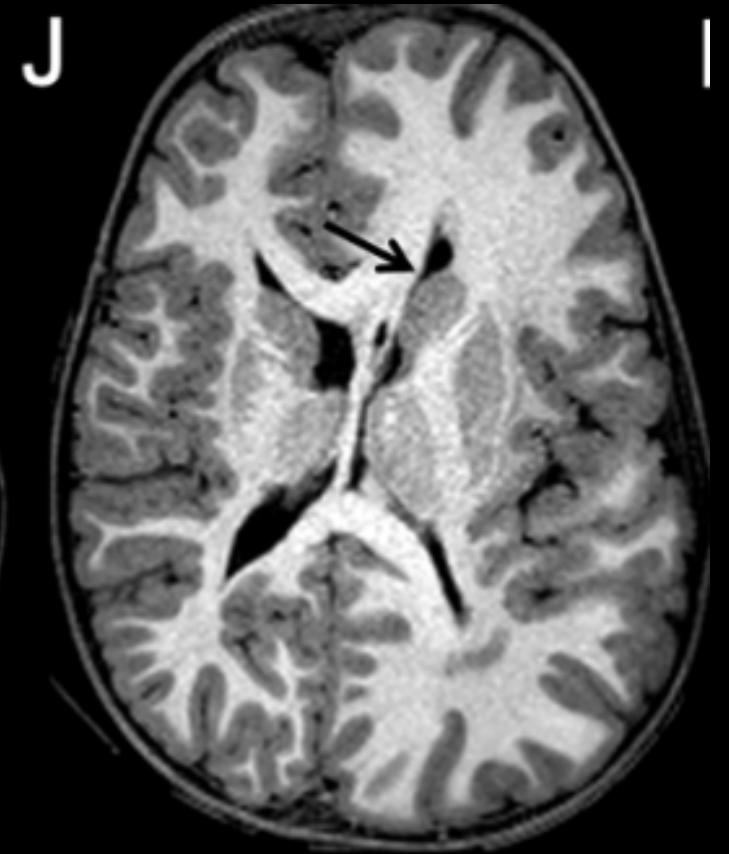
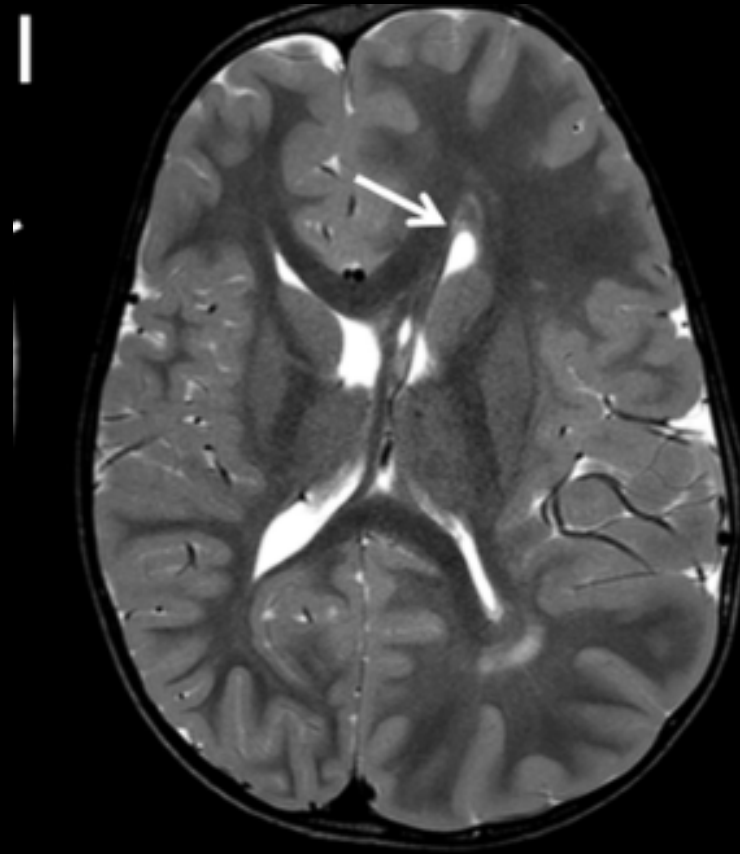


# 7T

- ILAE 2022 Consensus FCD classification recommend 7T if 3T remains negative
- “Ultra-high-field MRI could further advance the diagnostic yield in FCDI and FCDII and should be used in “MRI-negative” cases whenever possible”
- 7T yields 1/3 detection subtle FCD in 3T-negative studies

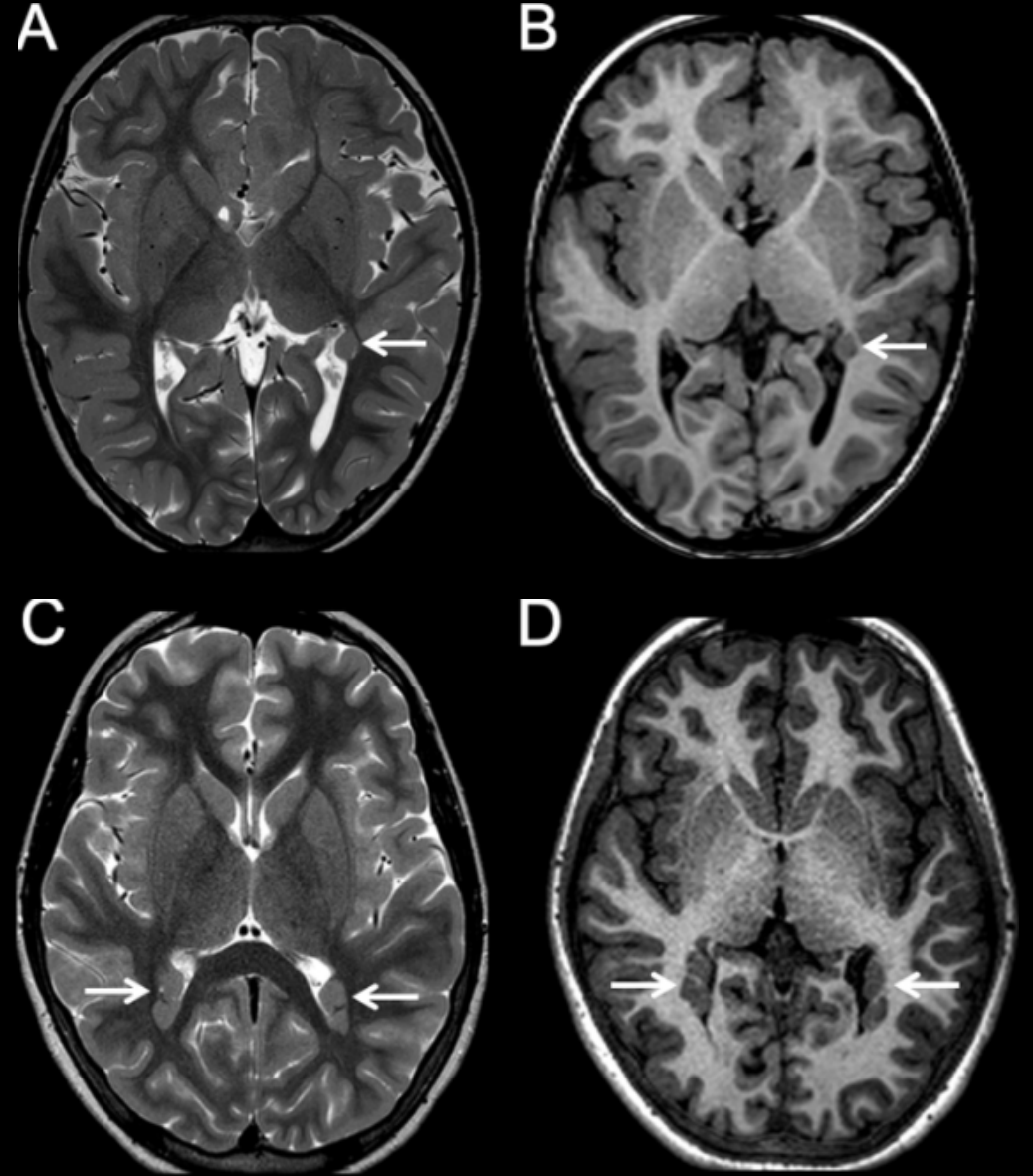
# Hemimegalencephaly

- Unilateral overgrowth
- Pachygyria (thick)
- Tx: hemispherectomy



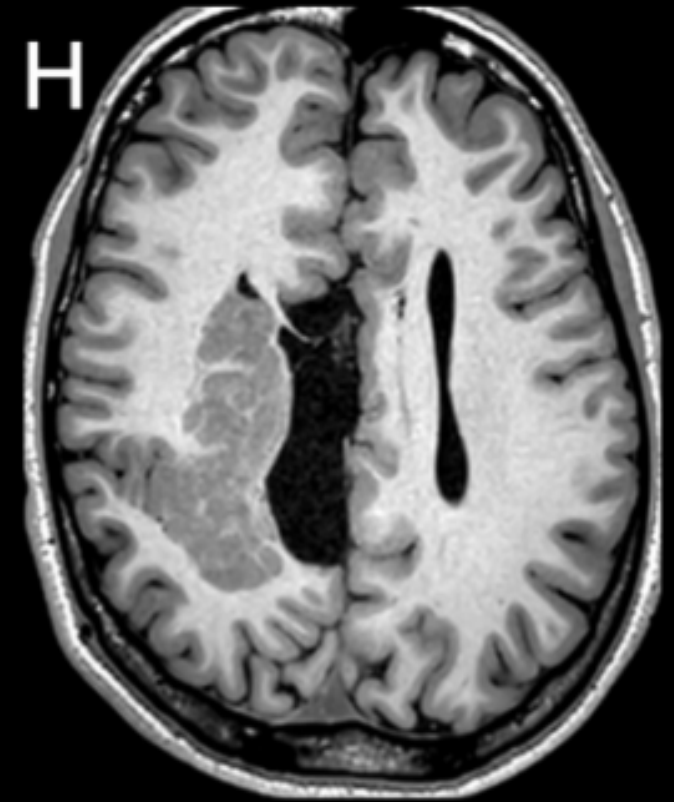
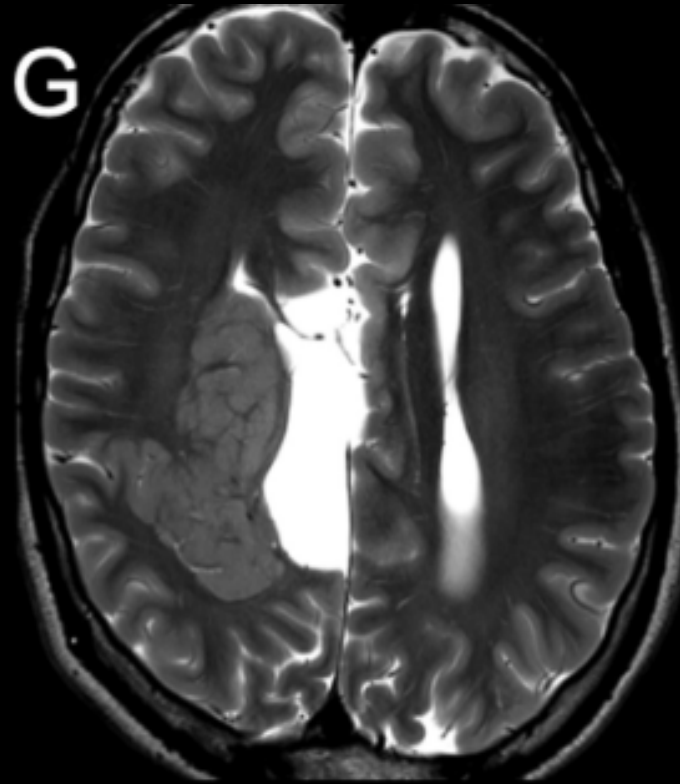
# Gray matter heterotopia

- Periventricular nodular
  - Unilateral (A+B)
  - Bilateral (C+D)



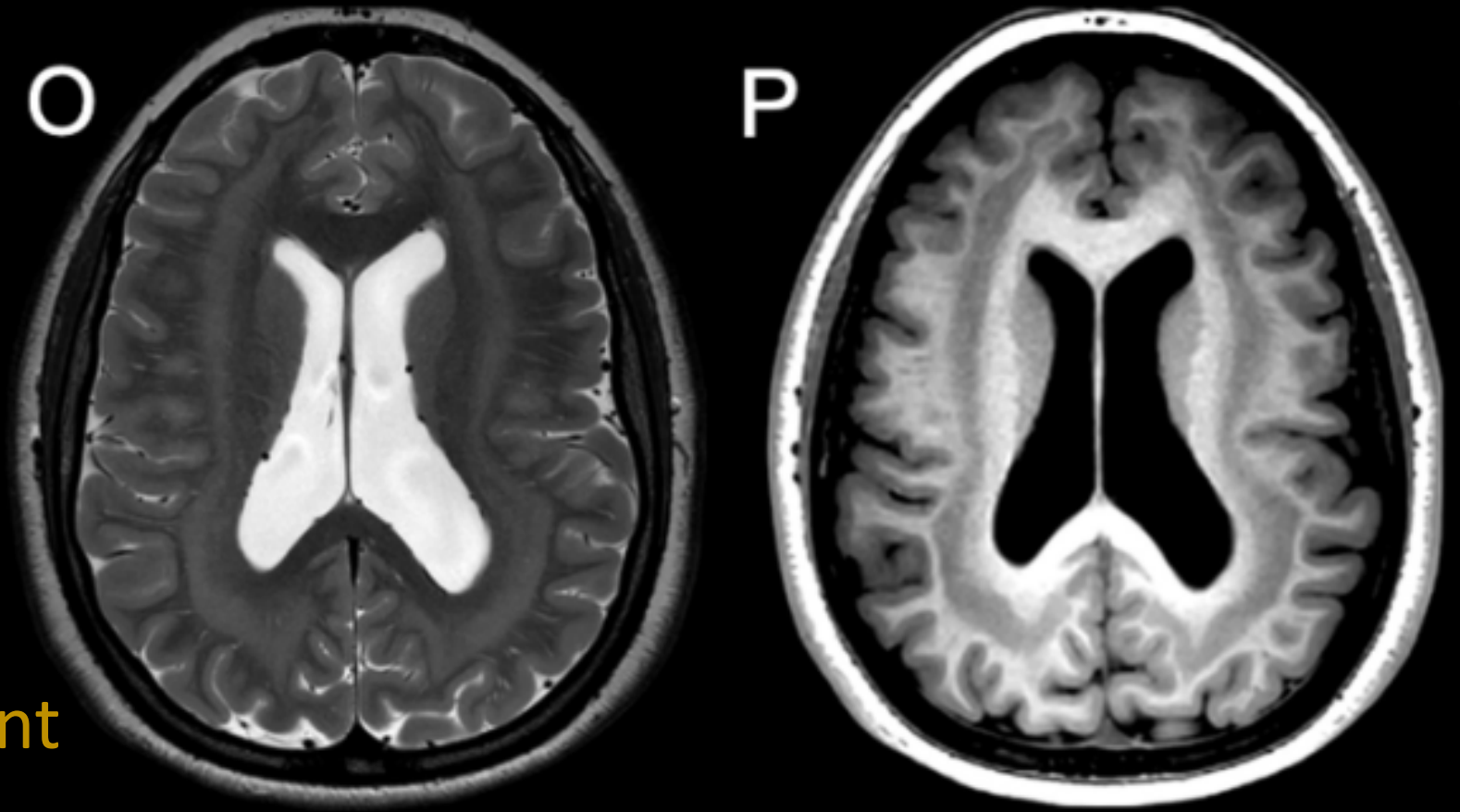
# Gray matter heterotopia

- Subcortical transmantle
  - Ventricular wall to cortex
- 22q11.2 and *FLNA*



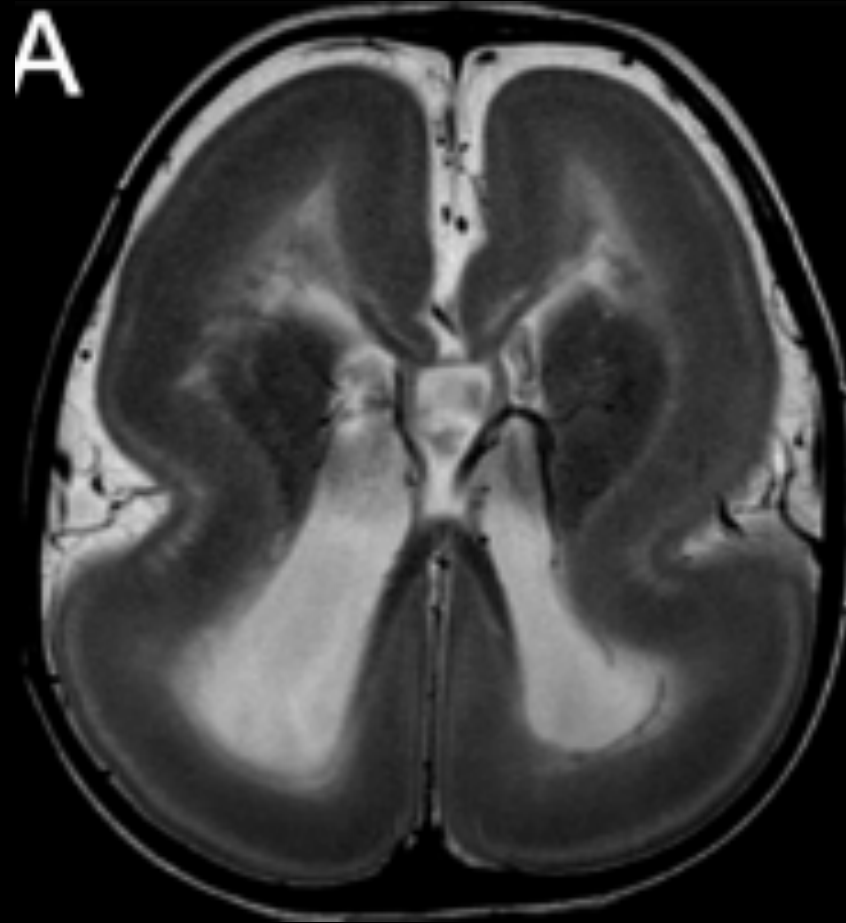
# Gray matter heterotopia

- Subcortical band
- Doublecortin *DCX*
  - More common
  - Female/anterior
- *LIS1*
  - Posterior predominant



# Lissencephaly

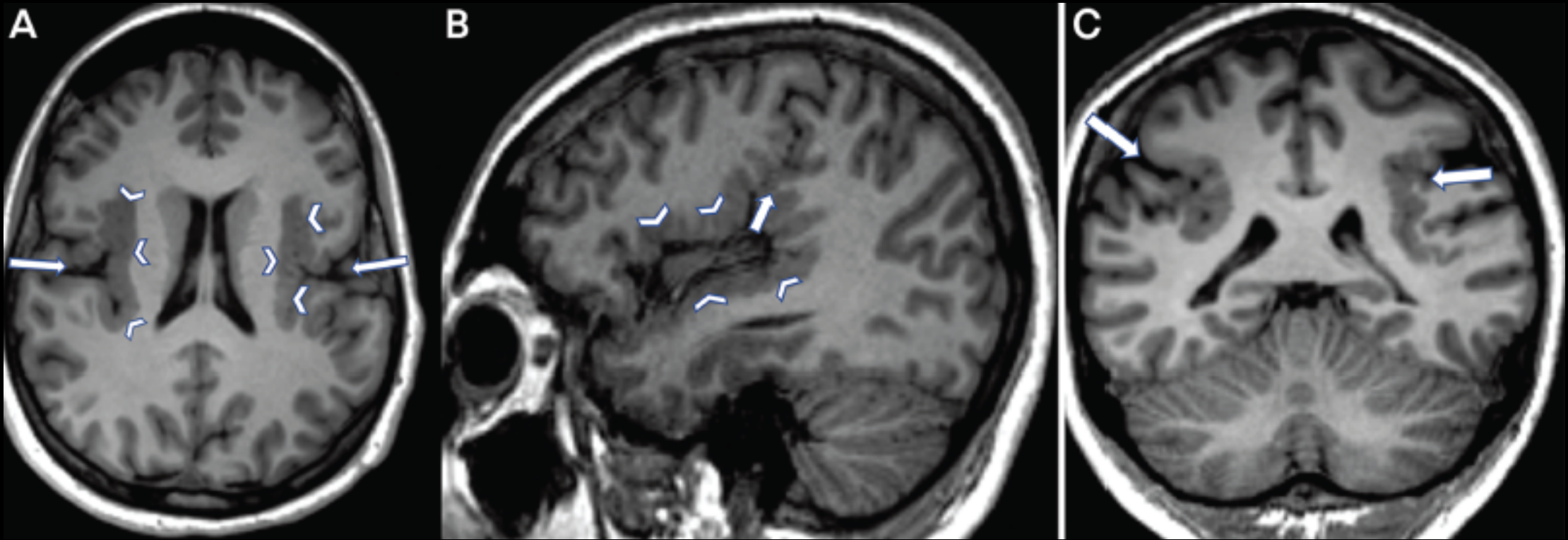
- “smooth brain”
- Agyria or pachygyria





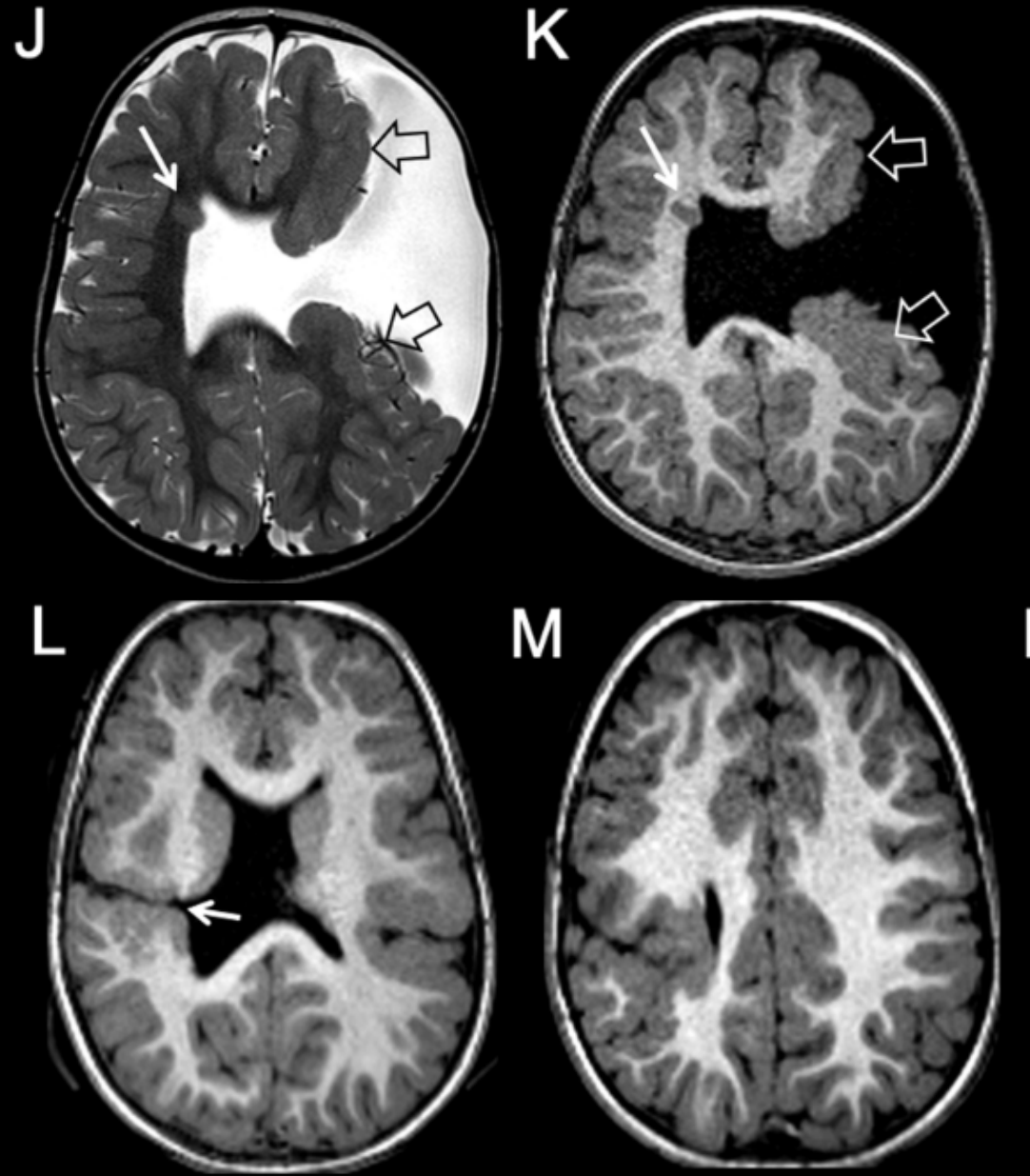
# Polymicrogyria

- Bilateral perisylvian PMG



# Polymicrogyria

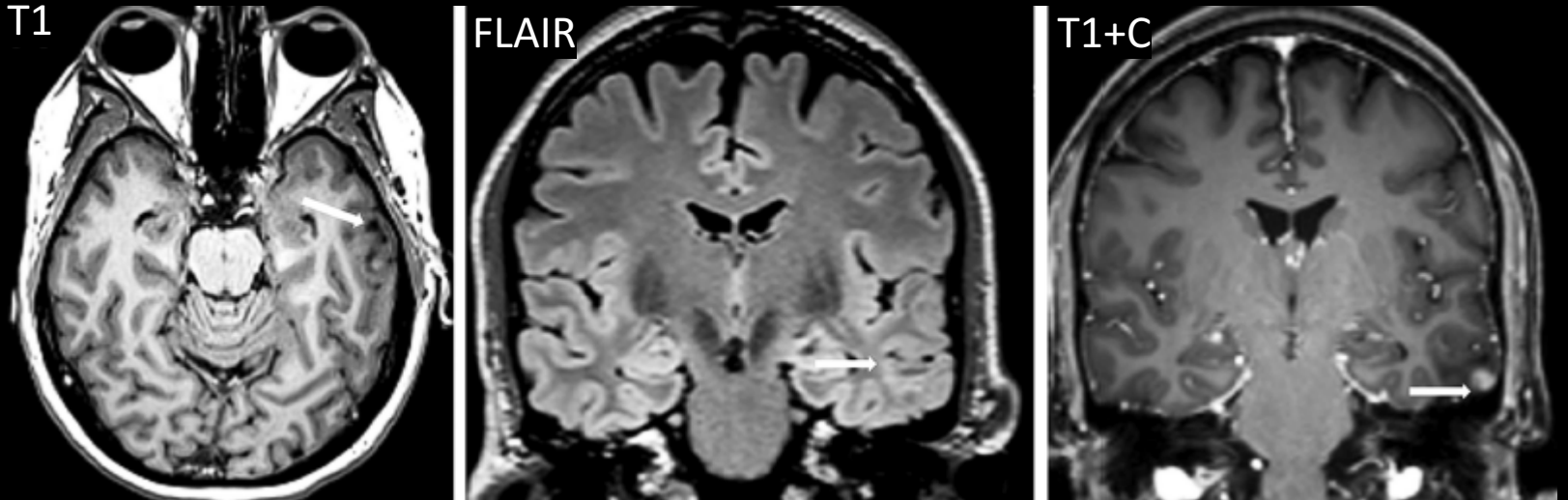
- Focal unilateral
  - Can be acquired
  - E.g. CMV or perinatal stroke
- Schizencephaly
  - PMG often lines cleft
  - Open lip (J+K)
  - Closed lip (L+M)





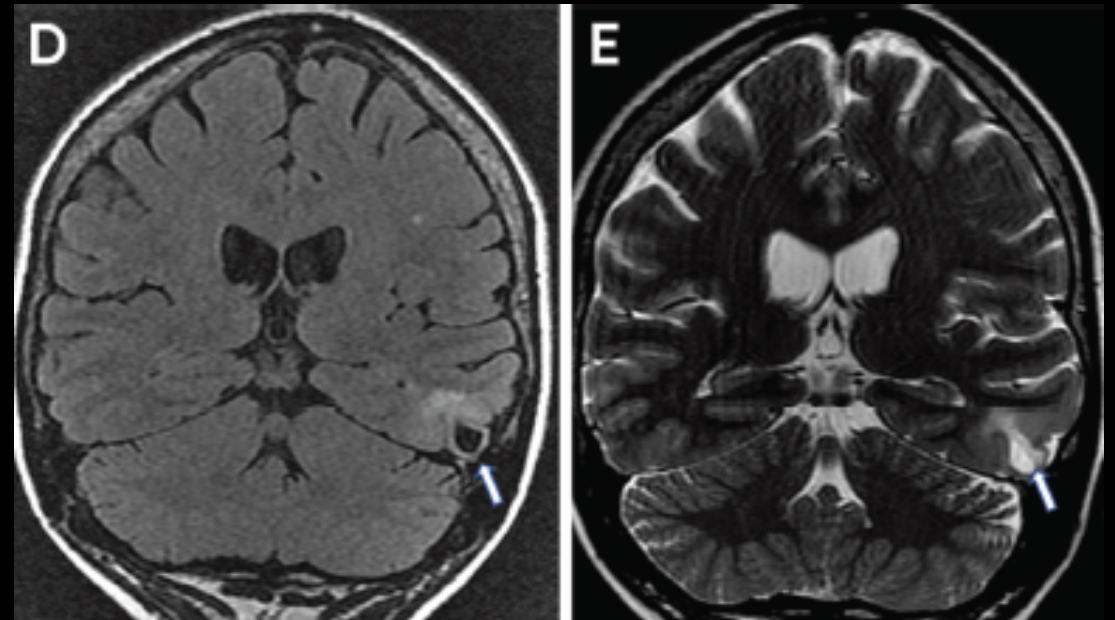
# Long-term-Epilepsy-Associated Tumors

- 22% of cases
- Ganglioglioma most common
  - Peripherally cystic w/enhancing mural nodule
  - T1 hypo to isointense
  - FLAIR hyperintense



# Long-term-Epilepsy-Associated Tumors

- Dysembryoplastic neuroepithelial tumor (DNET)
- Bubbly appearance
- Nodule without enhancement



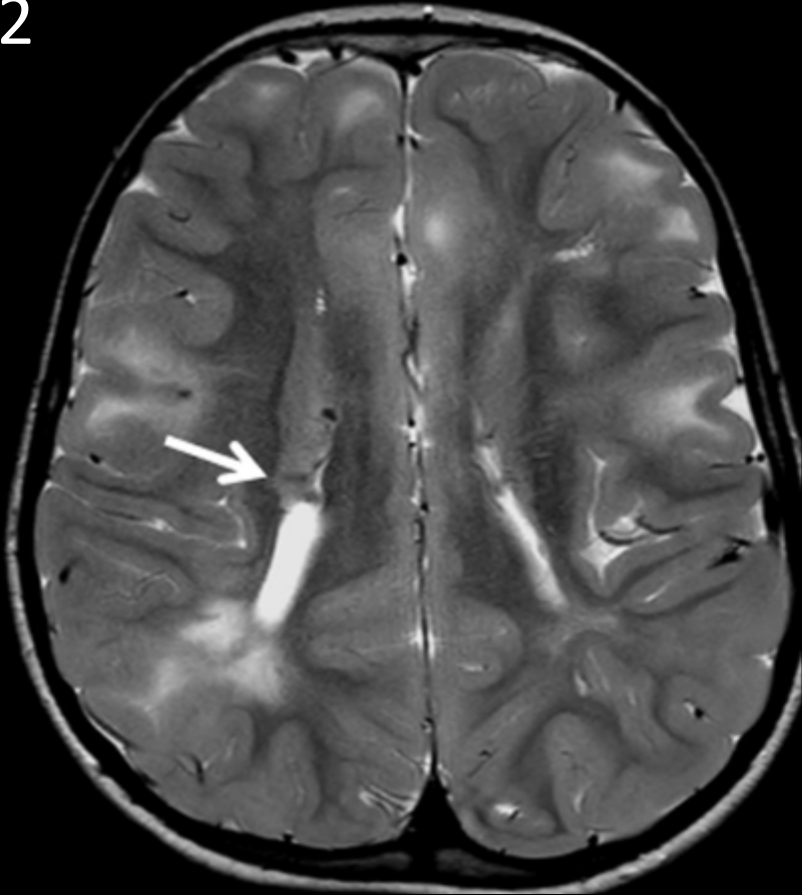
# Tuberous Sclerosis Complex

- TSC1 (hamartin Chr9) or TSC2 (tuberin Chr16)
- Neurocutaneous disorder (skin/eye/brain)
- Cardiac (rhabdomyoma)
- Renal (angiomyolipoma)
- Lung (lymphangio-leiomyomatosis)

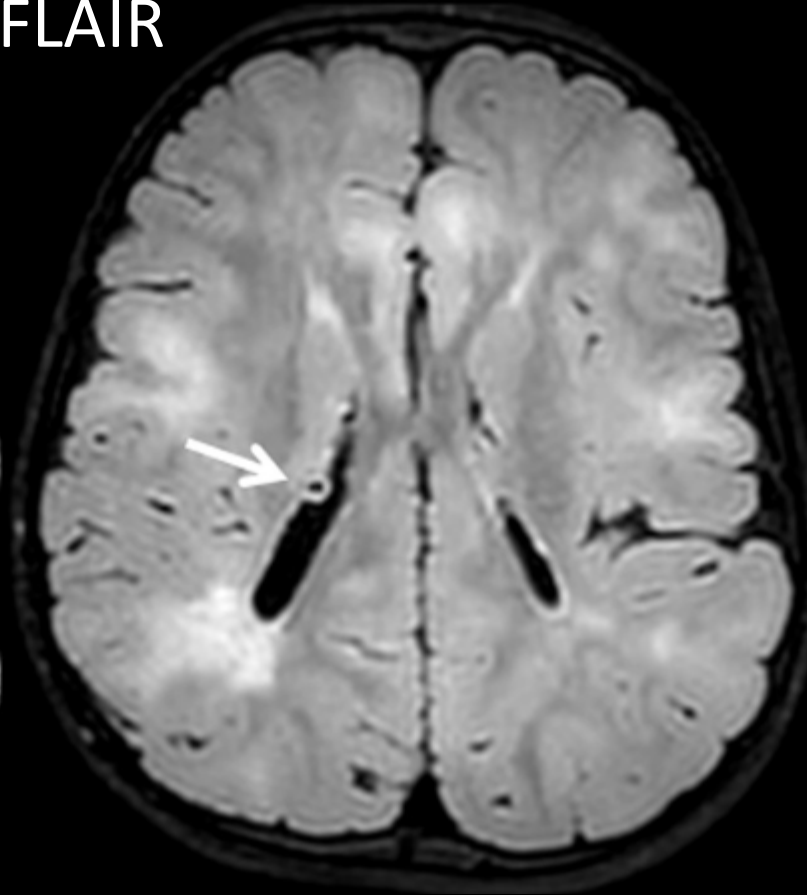


# Tuberous Sclerosis Complex

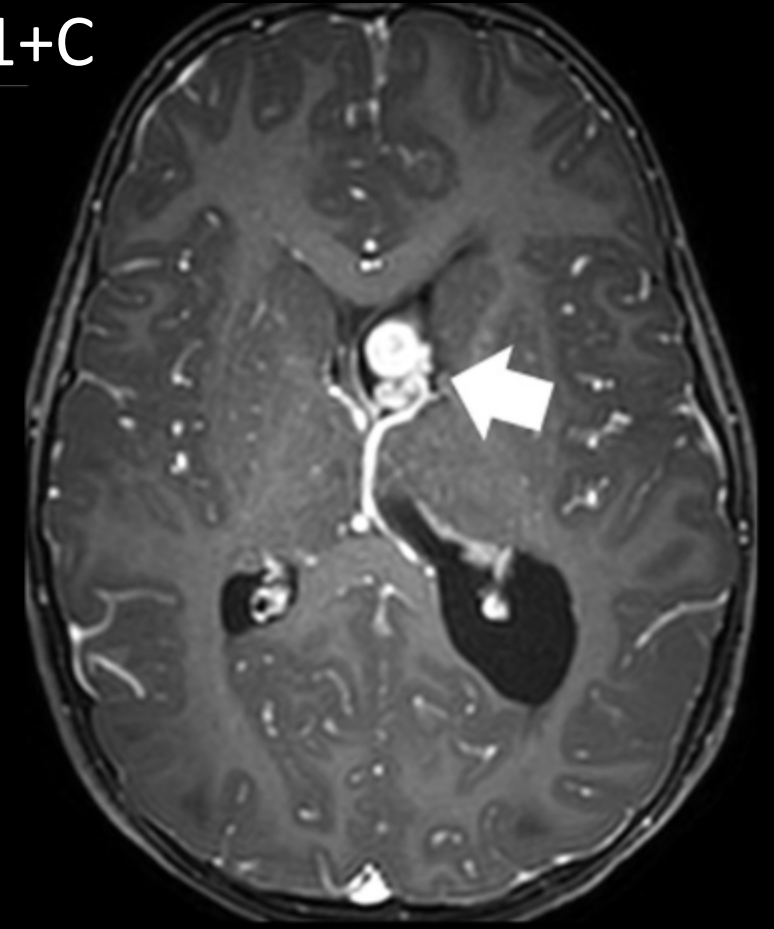
T2



FLAIR



T1+C



Numerous cortical tubers (High T2, low T1)  
Subependymal nodules (arrow, often calcified)

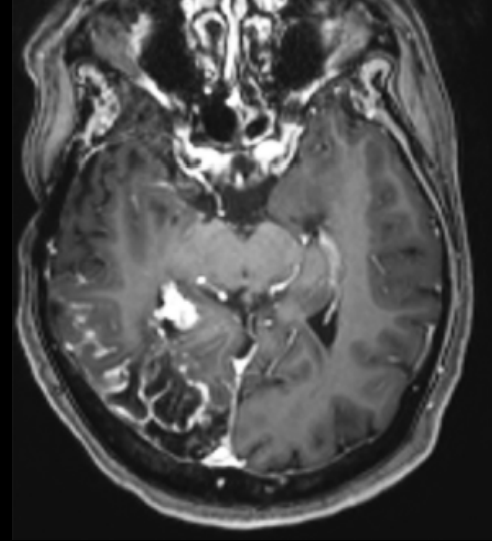
Subependymal giant cell  
astrocytoma (SEGA)  
(enhancing)



# Sturge Weber Syndrome

- Facial nevus flammeus (port wine stain) V2
- Leptomeningeal angiomas
- Glaucoma
- Scleral or choroidal angioma
  
- *GNAQ*

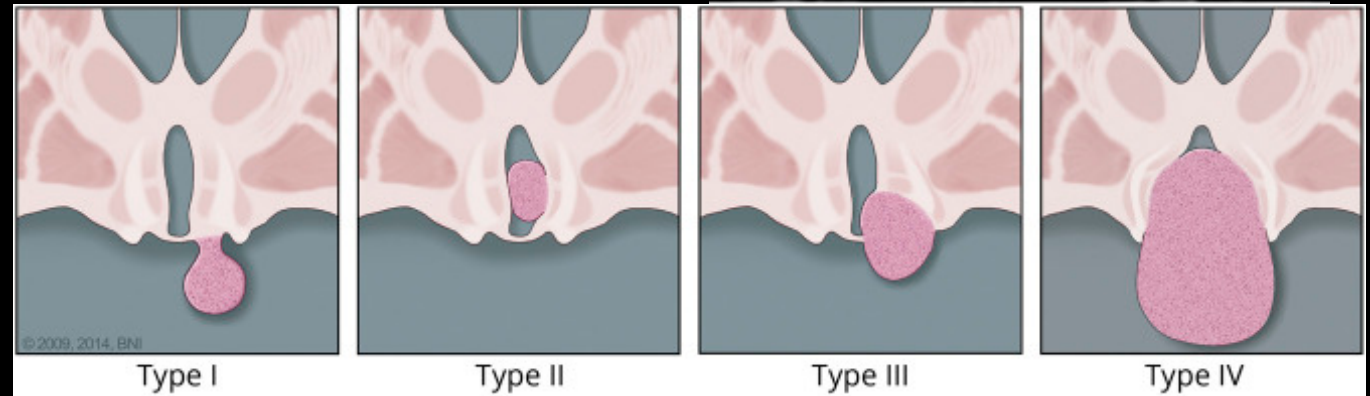
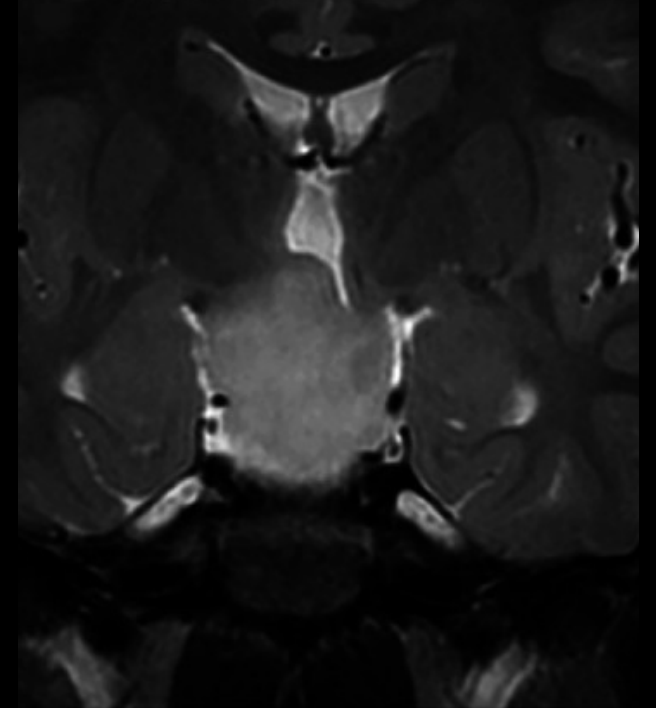
Leptomeningeal enhancement



Tram track calcification

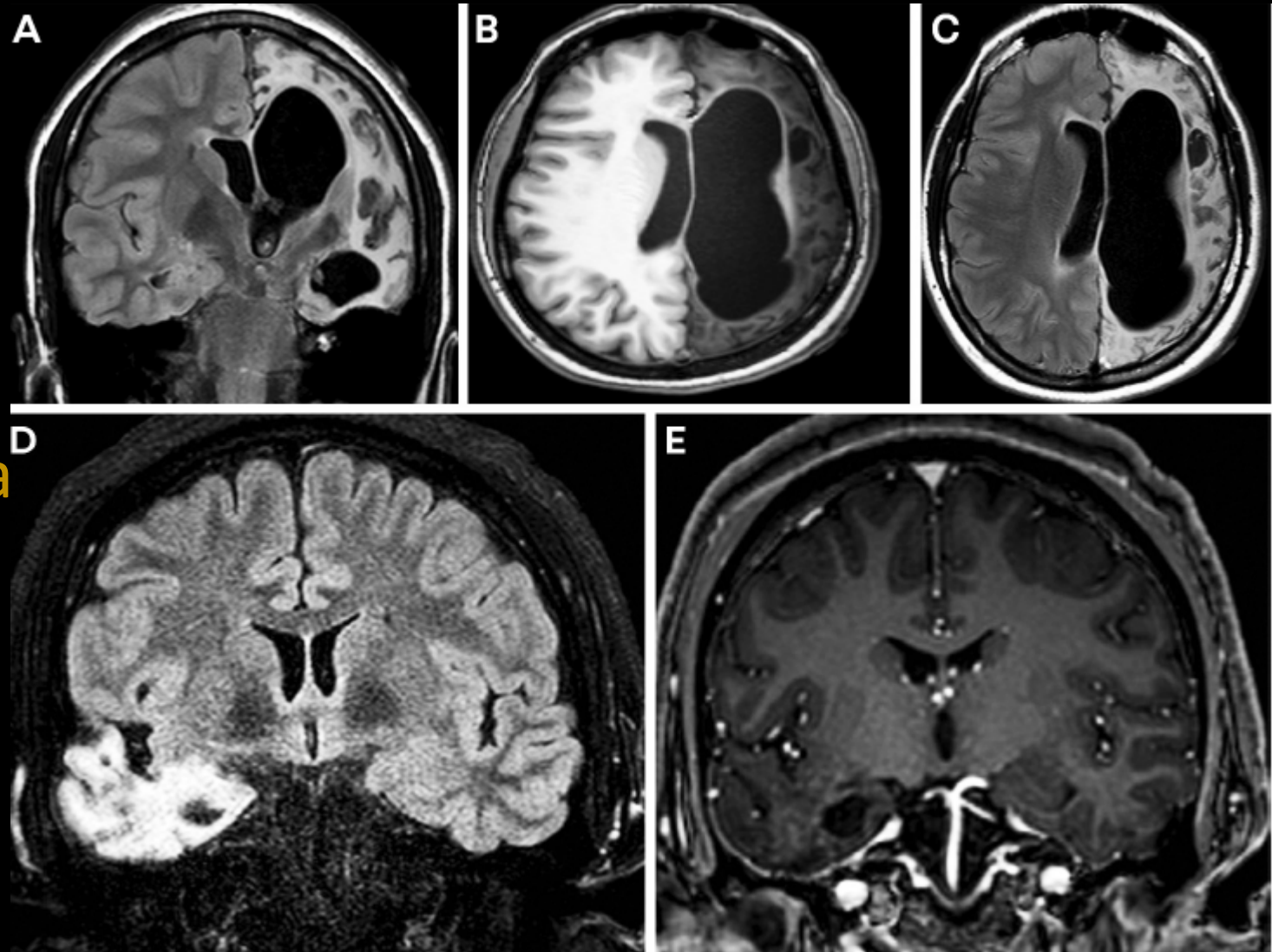
# Hypothalamic Hamartoma

- Refractory epilepsy/encephalopathy
  - Gelastic seizures
- Endocrinopathy
- Isointense to gray matter
- Nonenhancing



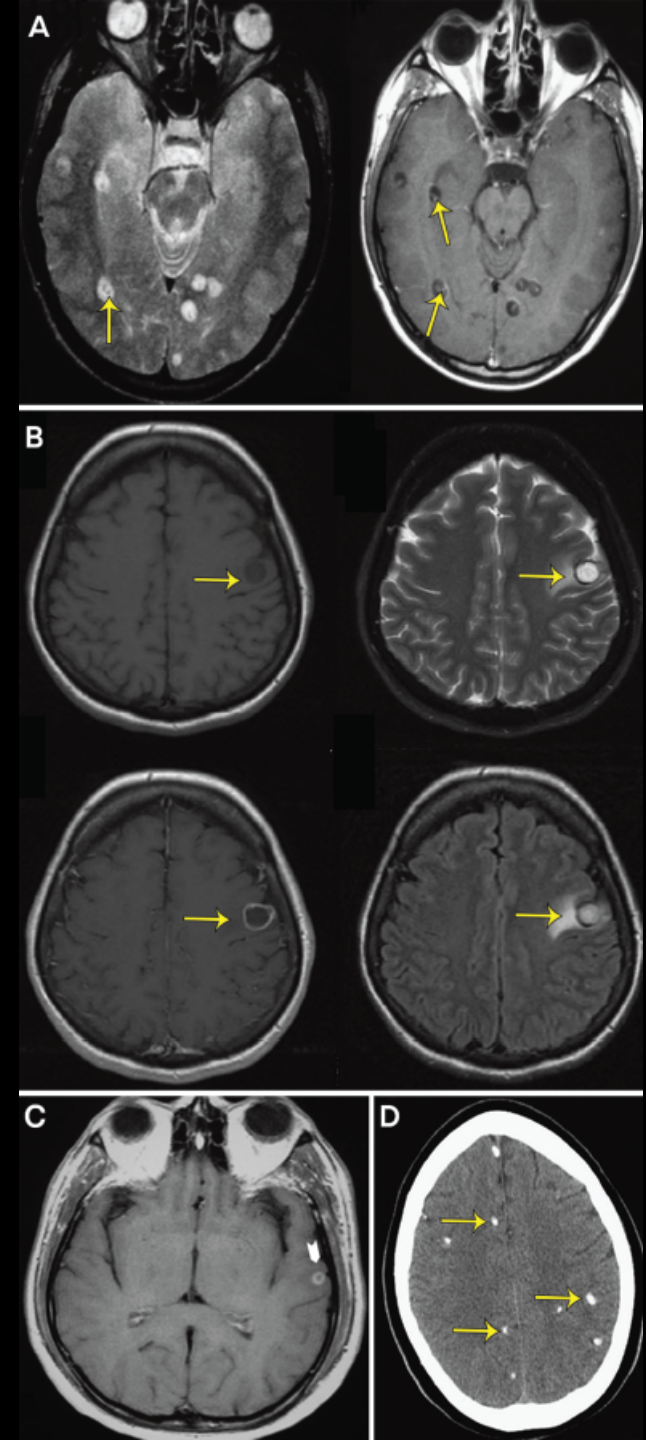
# Rasmussen encephalitis

- Progressive encephalitis
- Hemiparesis
- PRE  
Epilepsia partialis continua



# Neurocysticercosis

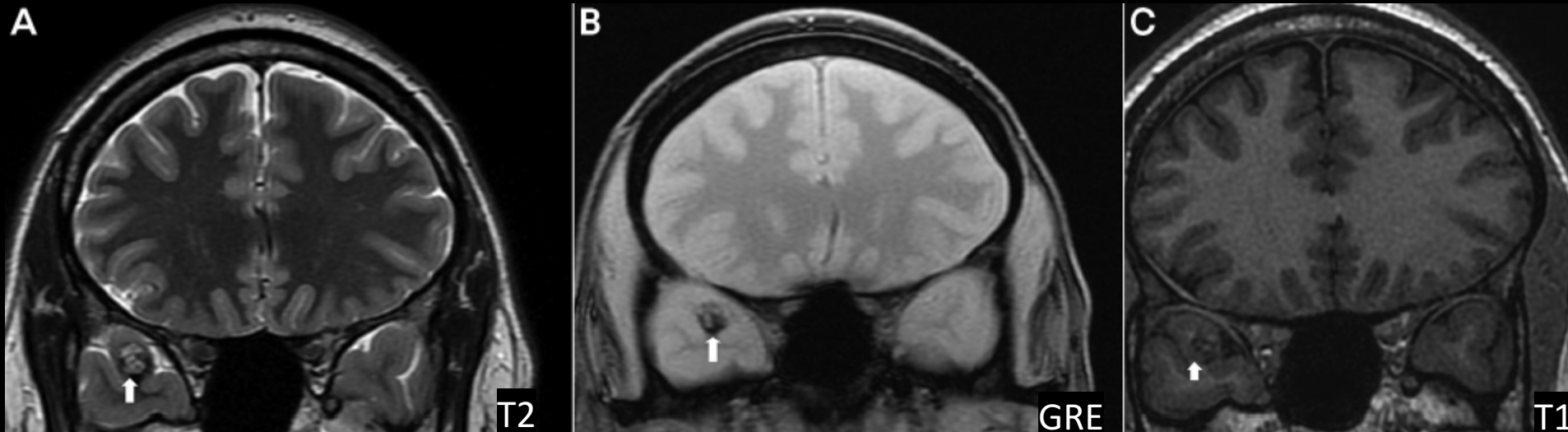
- *Taenia solium*
- MRI stages:
- Scolex (A) T2+, T1-, enhancing
- Colloidal (B) cyst T2+, T1-, FLAIR+
- Granular nodular (C) small enhancing
- Late granular (D) T2-, T1-, CT calcified





# Cavernous Malformations

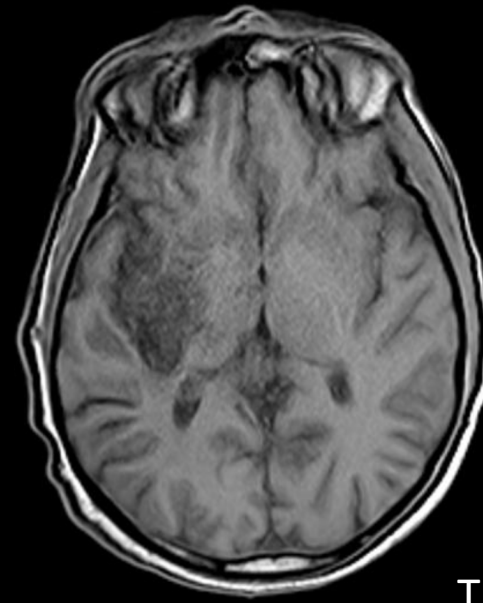
- T2 Central hyperintensity (subacute hemorrhage-methemoglobin)
  - “black halo” sign (chronic hemorrhage-hemosiderin)
- GRE dark (hemosiderin)
- T1 central hyperintense, circumferential hypointensity



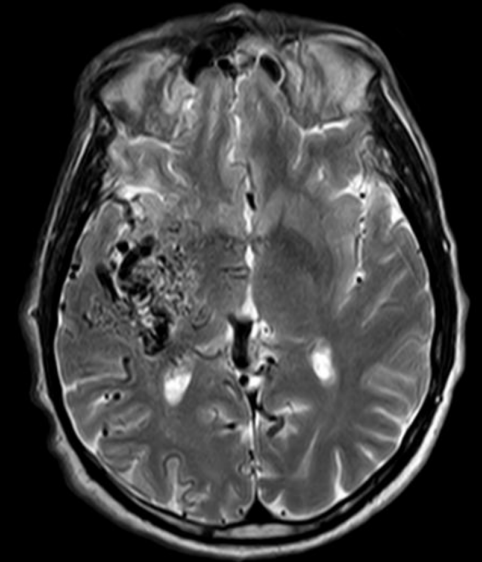
# Vascular Malformations

- AVM

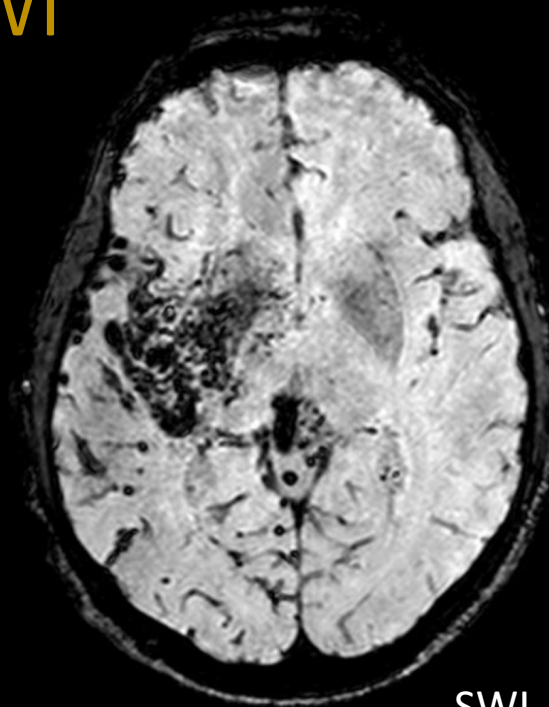
- Tangle blood vessels
- T1 and T2 serpiginous flow voids
- Nidus (feeding vessel) seen on T2/SWI



T1



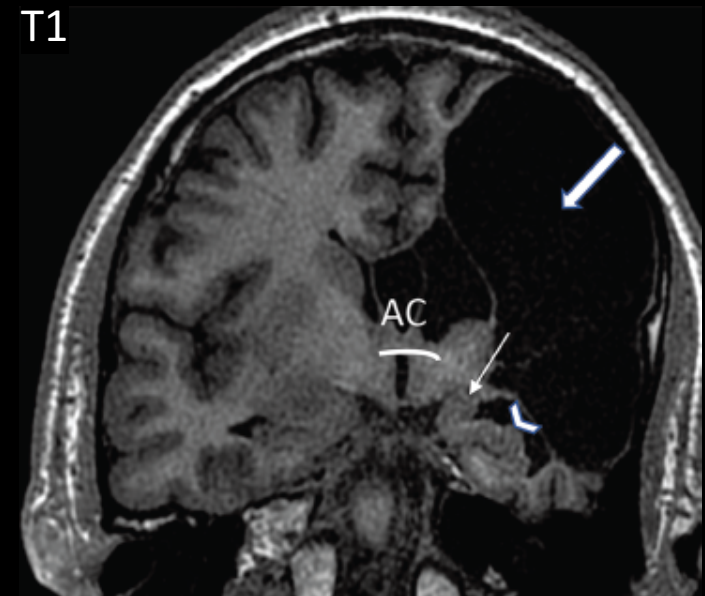
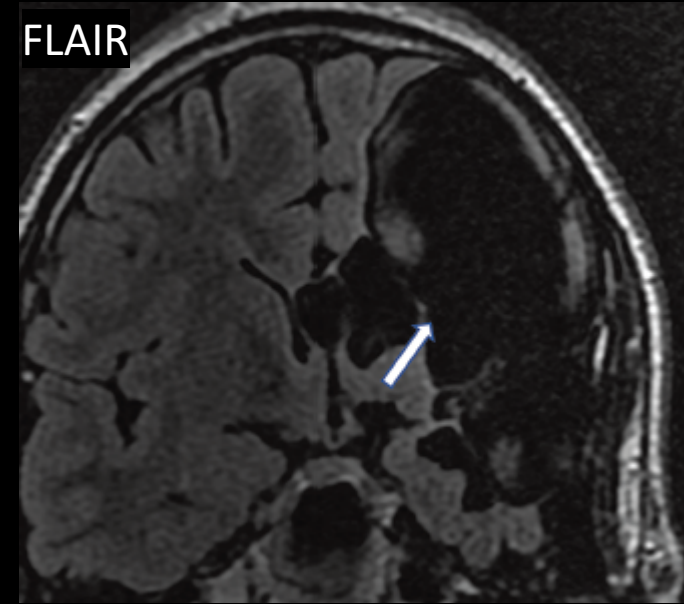
T2



SWI

# Porencephaly

- Trauma/infection/stroke
  - Encephalomalacia
  - Laminar necrosis
  - Gliosis with cortical/subcortical T2+
  - If communicate w/ventricle
    - **Porencephalic cyst**



# Summary

- High-resolution epilepsy protocol MRI done at highest resolution available is recommended
- Lesional MRI affects
  - seizure risk prognostication
  - epilepsy diagnosis
  - surgical outcomes
- Always review your studies!



Thank you!

