

Advanced Imaging in Epilepsy

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ESPR
European Society of
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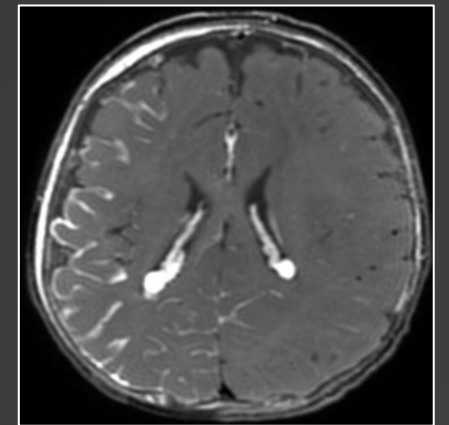
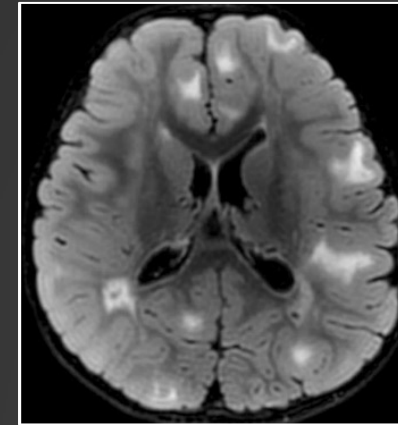
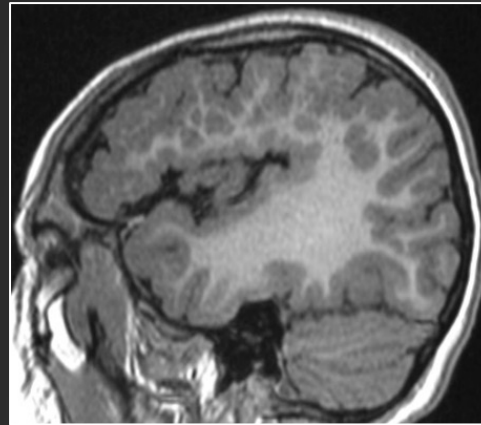
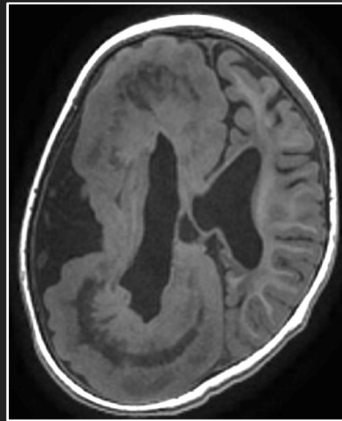
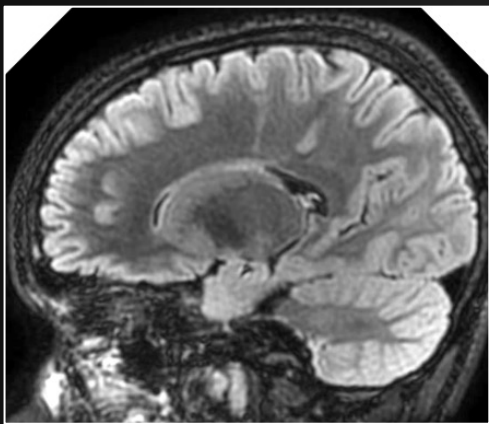
*Service de Radiopédiatrie
du Pr Boddaert
Hôpital Necker, Paris, France*



- GE Healthcare: research funding 2019-2020

- Epilepsy :
 - Repetition of seizures
 - Focal epilepsy:
 - Partial seizures
 - Frequently drug-resistant

- Etiology:
 - Low-grade epilepsy-associated tumors
 - Malformations of cortical development
 - Vascular anomalies, sequelae, hippocampal sclerosis



Low-grade epilepsy-associated tumors

Classics: ganglioglioma, DNT

“New” entities: PGNT, MVNT, PLNTY, IDG, AG



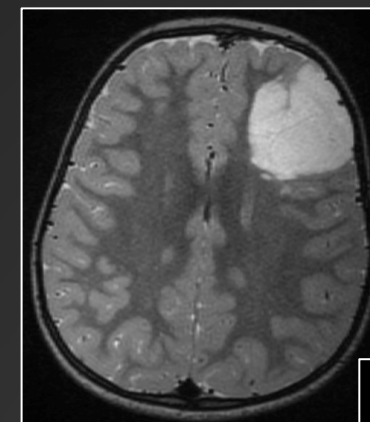
Focal cortical dysplasias

Imaging features

Dealing with “MR-negative” FCDs

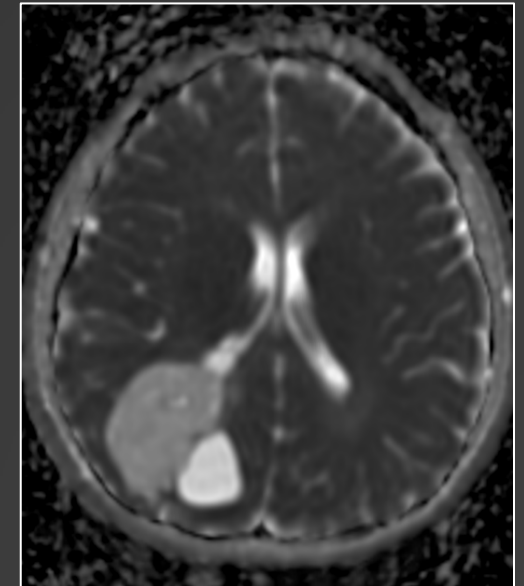
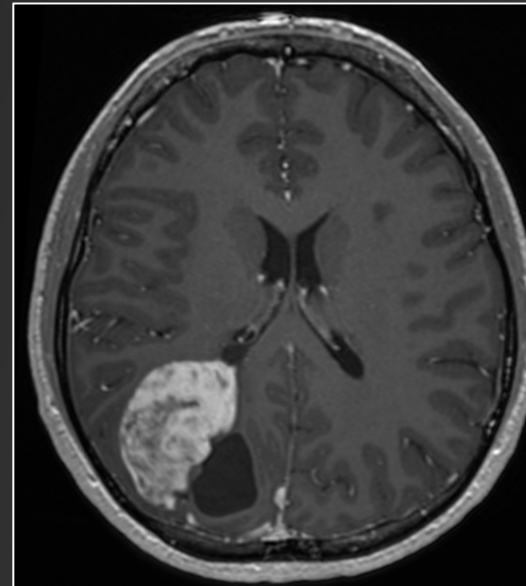
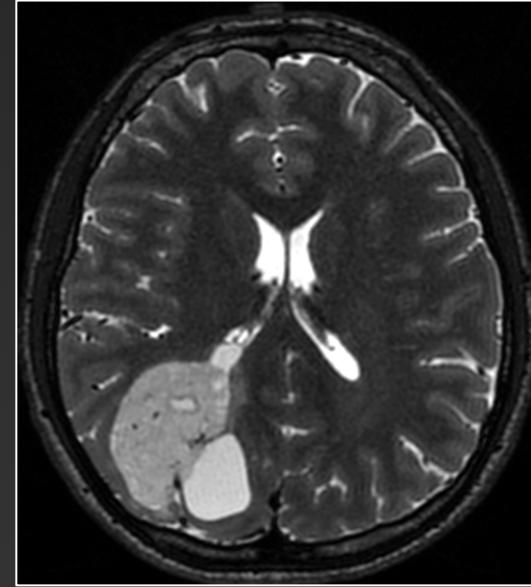
Low-grade epilepsy-associated tumors

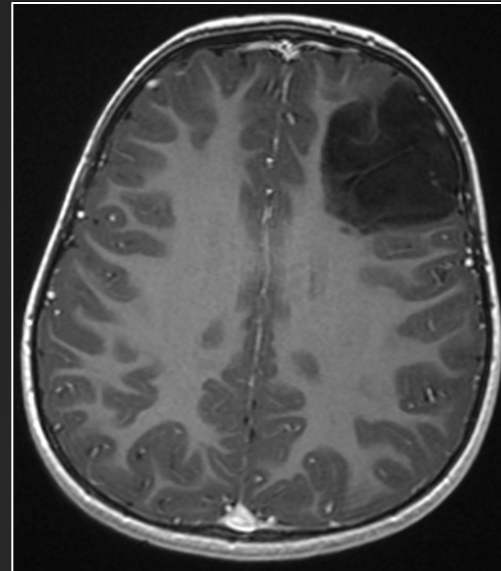
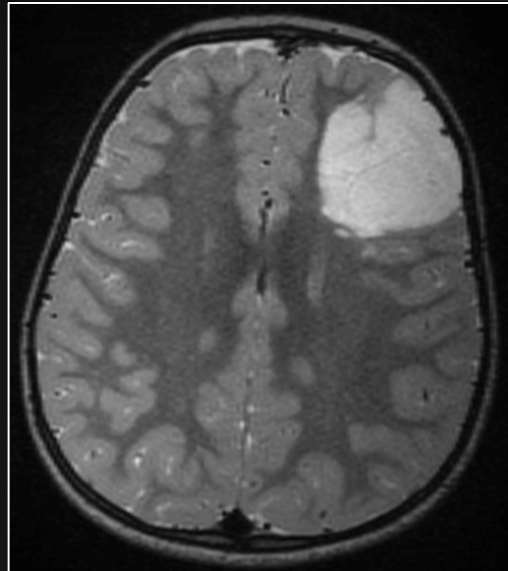
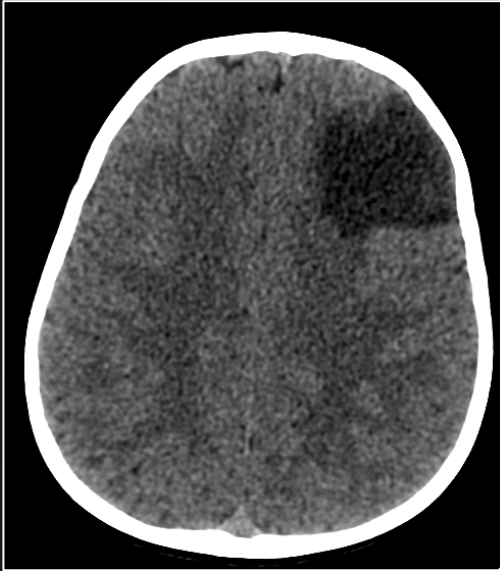
- Glio-neuronal tumors
- Slow progression
- Good prognosis: survival, epilepsy
- Age at onset: adolescence (except AG)
- Imaging: common characteristics
 - Mostly cortical
 - No diffusion restriction
 - Low perfusion



Ganglioglioma

- Cortical mass
- Temporal 80%
- Nodule +/- cyst
- Contrast enhancement





Dysembryoplastic neuroepithelial tumor (DNT)

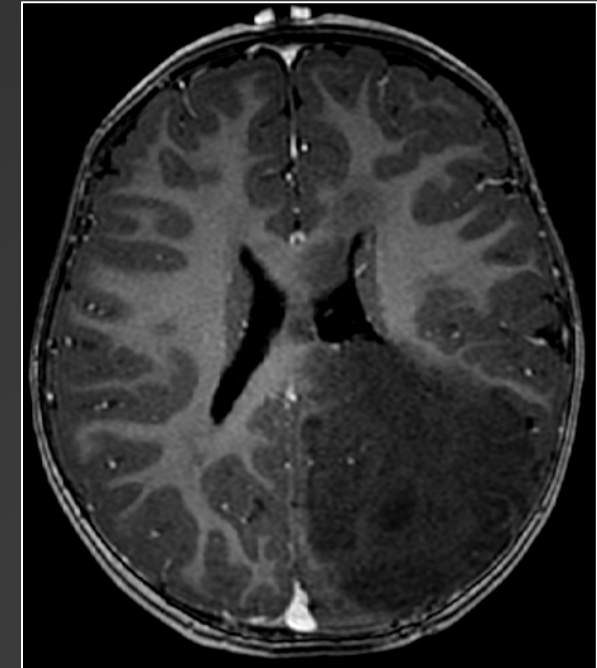
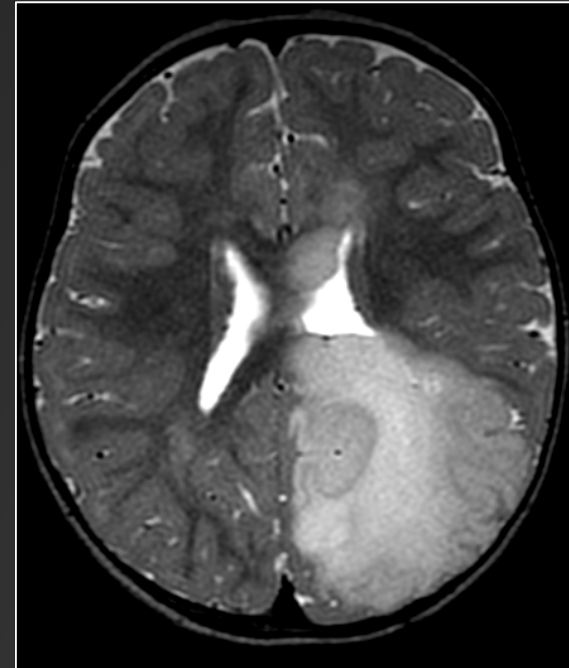
- Cortical
- Temporal 70%
- T2w high signal
- No contrast enhancement
- No mass effect

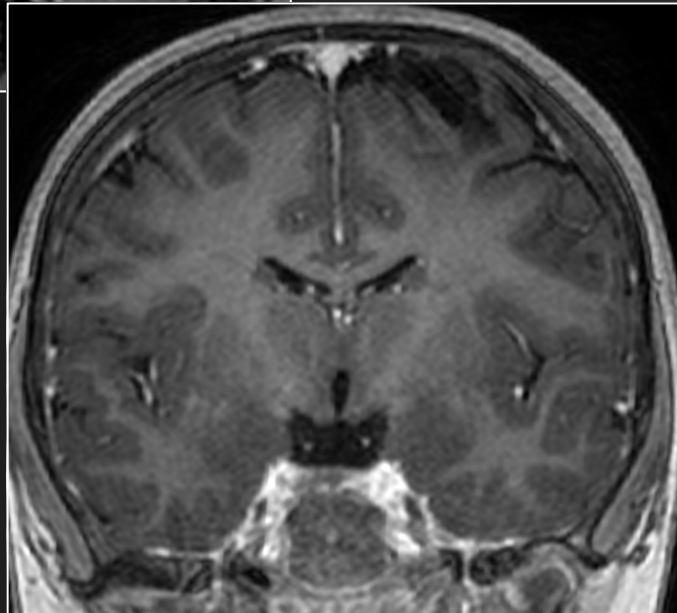
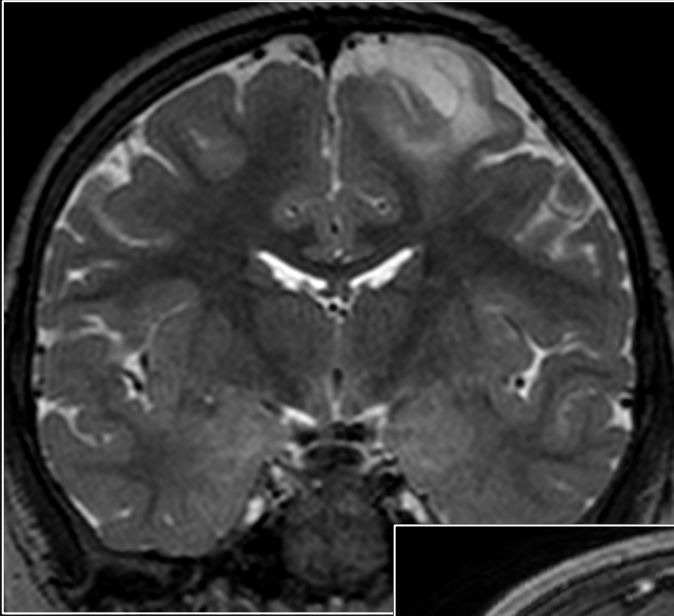
Rarer tumors

- Diffuse astrocytoma MYB or MYBL1 altered
- AG: Angiocentric Glioma
- PLNTY: Polymorphous Low-grade Neuroepithelial Tumor of the Young
- MVNT: Multinodular and Vacuolating Neuroepithelial Tumor
- PGNT: Papillary GlioNeuronal Tumor

Diffuse astrocytoma ***MYB* or *MYBL1* altered**

- IDG (Isomorphic Diffuse Glioma)
- Cortical
- T2w high signal
- No contrast enhancement
- No mass effect
- Homogeneous signal
- Ground glass





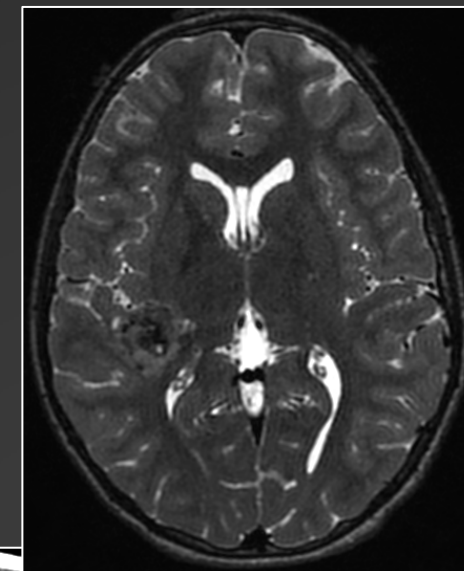
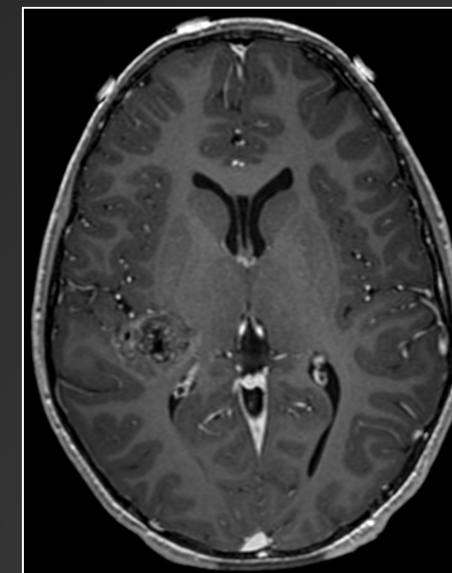
Angiocentric glioma

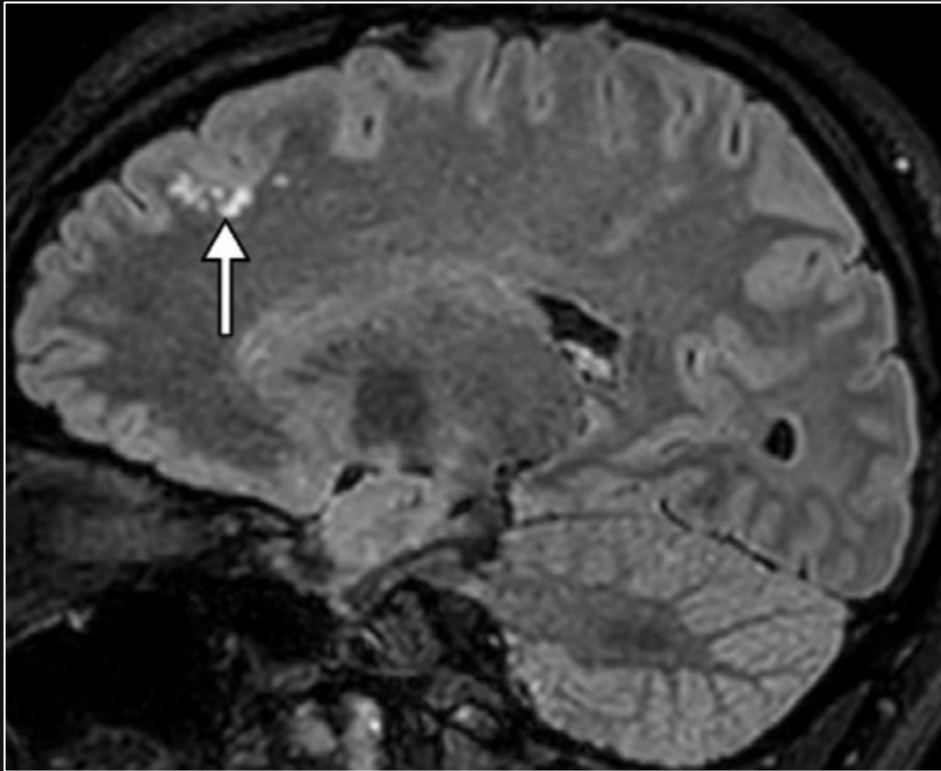
- *MYB-QKI*
- Younger patients (5yo)
- Cortical and white matter
- Extension towards ventricles
- T1w Hyperintense rim
- No contrast enhancement
- Low mass effect

PLNTY

Polymorphous Low-grade Neuroepithelial Tumor of the Young

- Cortex and subcortical WM
- Tissue (+/- cyst)
- T2w punctate low signal
- +/- contrast enhancement
- Coarse calcifications





Lecler et al. 2020

MVNT

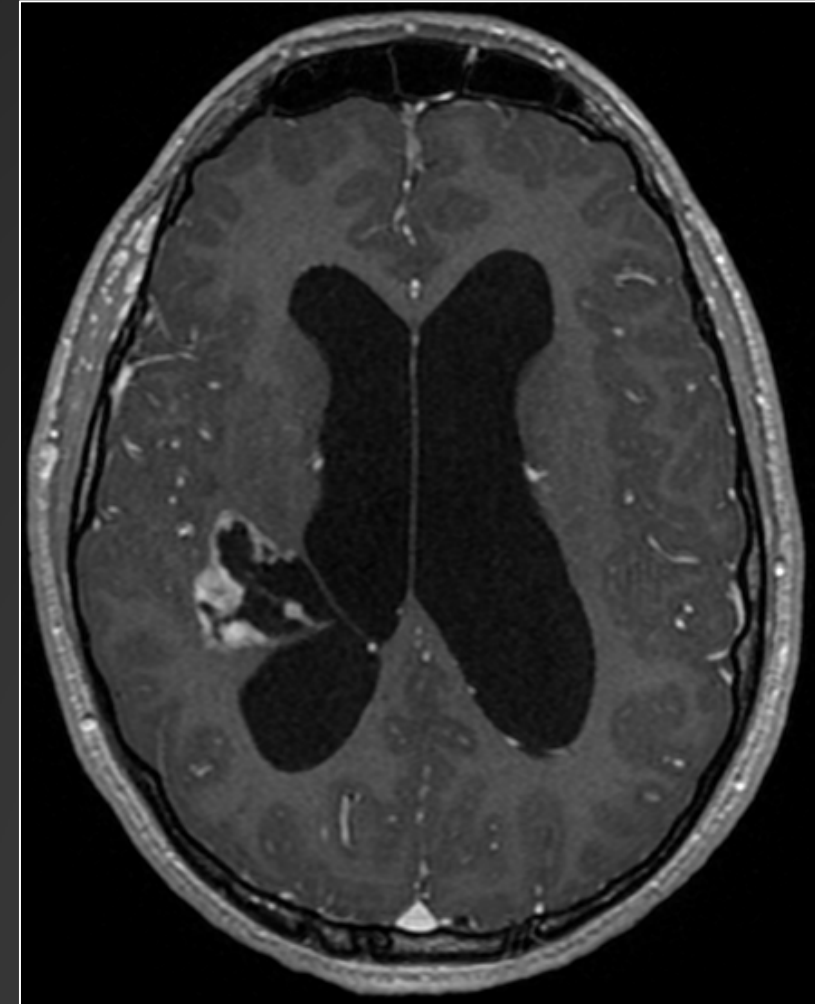
Multinodular and Vacuolating Neuroepithelial Tumor

- Subcortical WM
- Coalescent nodules
- T2w high signal
- No contrast enhancement
- Leave-alone lesion

PGNT

Papillary GlioNeuronal Tumor

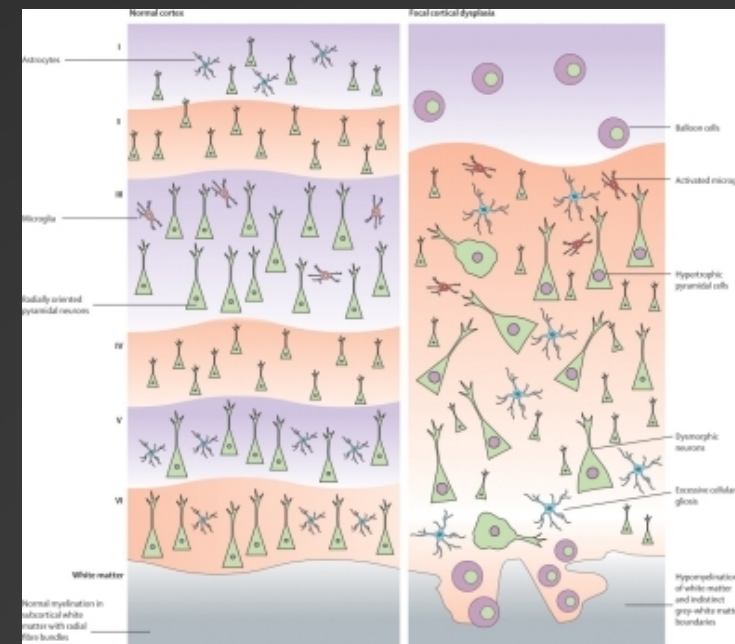
- Periventricular WM
- Tissue, cysts with septa
- Contrast enhancement



Focal Cortical Dysplasias

Pathological subtypes

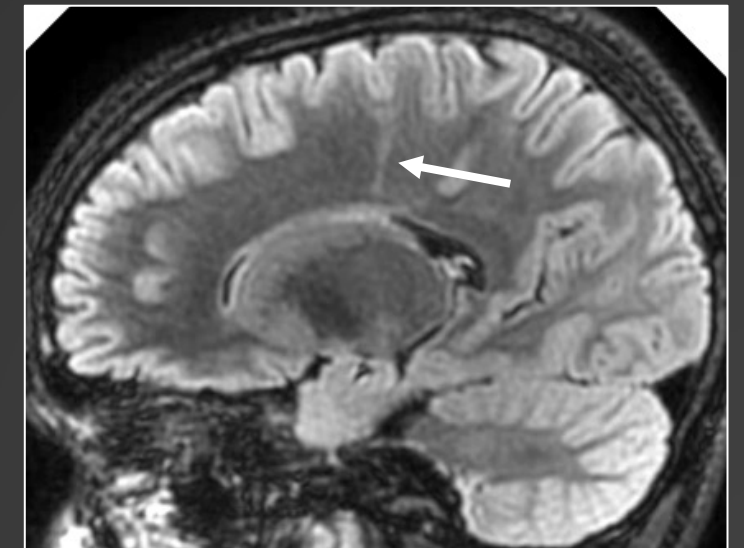
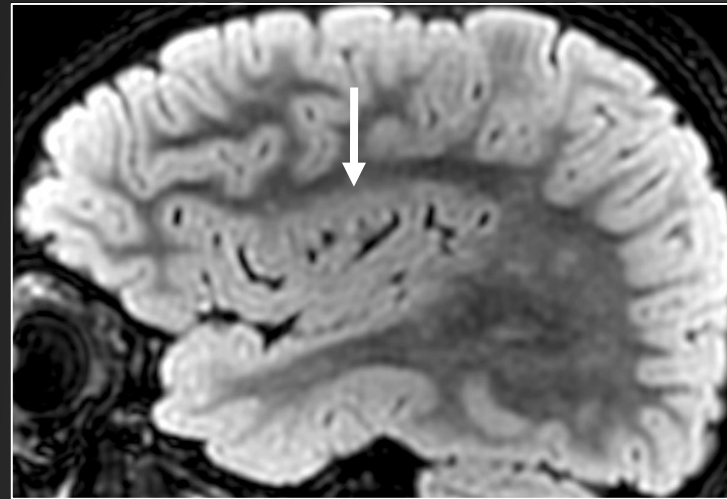
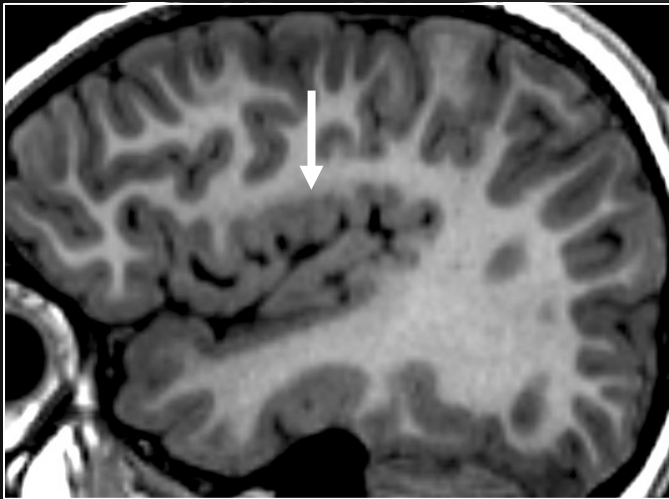
- Type I: abnormal organization of the 6-layered neocortex
 - Type Ia: Radial anomaly
 - Type Ib: Tangential anomaly
- Type II: disrupted cortical lamination and cytological abnormalities
 - Type IIa: Dysmorphic neurons, no balloon cells
 - Type IIb: Dysmorphic neurons and balloon cells
- Type III: FCD associated with
 - Type IIIa: hippocampal sclerosis
 - Type IIIb: brain tumor
 - Type IIIc: vascular malformation
 - Type IIIc: early life event
- mMCD: mild Malformations of Cortical Development
 - Excessive number of neurons in the molecular layer or the white matter
 - MOGHE: associated with oligodendroglial hyperplasia



Sisodiya et al. 2009

Usual imaging features

- Dysmorphic sulcus
- Increased cortical thickness
- Gray matter – white matter junction blurring
- Transmantle sign (Type II)

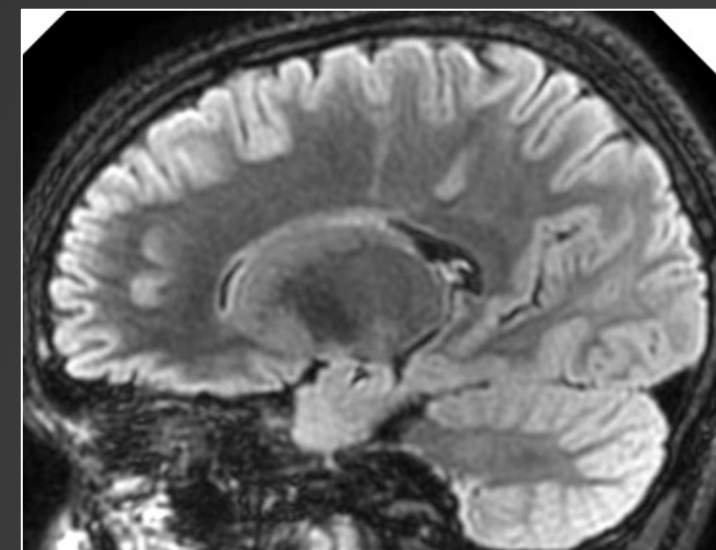
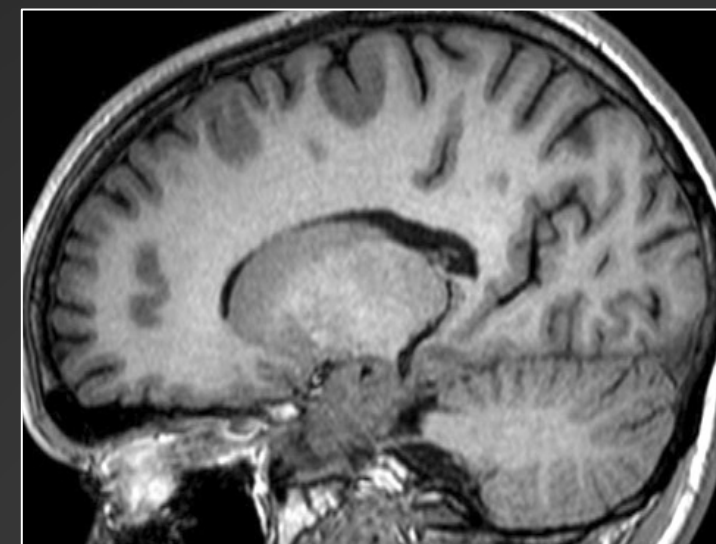


Usual imaging features

- Dysmorphic sulcus
- Increased cortical thickness
- Gray matter – white matter junction blurring
- Transmantle sign (Type II)

Often overlooked
“MR-negative”

- Dedicated optimized MRI protocols
- 3T > 1.5T (7T ?)

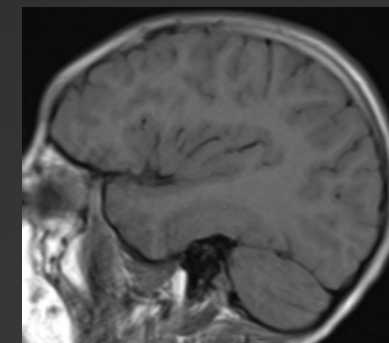


Focal Cortical Dysplasias: MR protocol and analysis

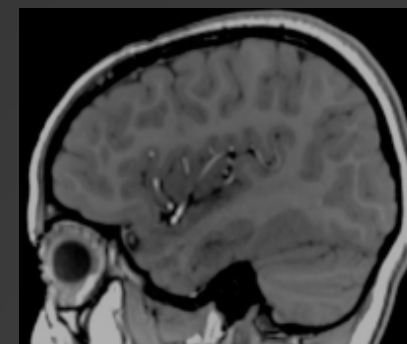
Necessary: HARNESS-MRI protocol

Harmonized Neuroimaging of Epilepsy Structural Sequences

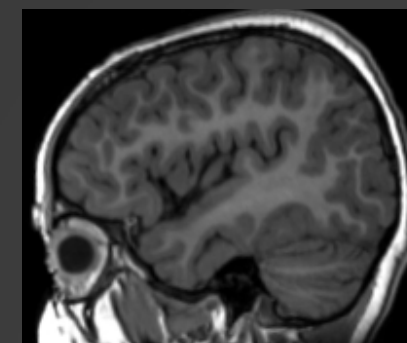
- High-resolution 3D T1wimages



2D T1w



3D T1w
non optimized

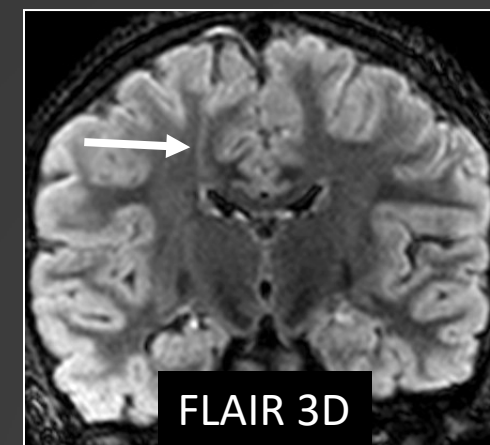
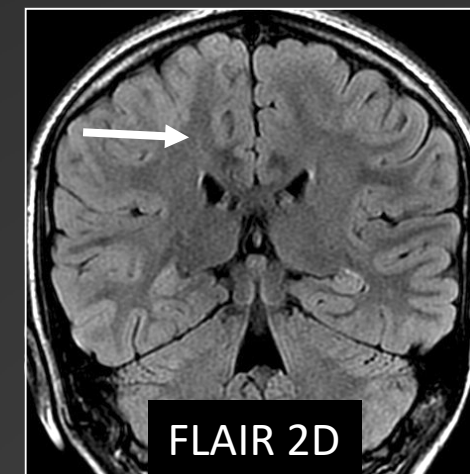


3D T1w
optimized

Necessary: HARNESS-MRI protocol

Harmonized Neuroimaging of Epilepsy Structural Sequences

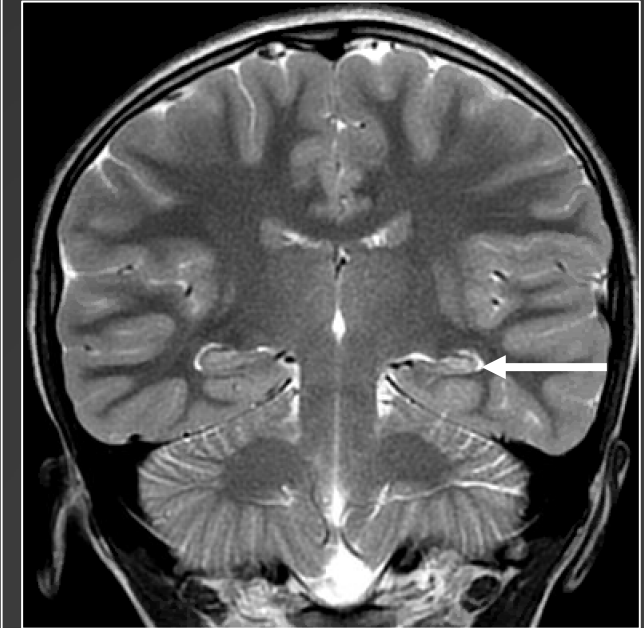
- High-resolution 3D T1wimages
- High-resolution 3D FLAIR images



Necessary: HARNESS-MRI protocol

Harmonized Neuroimaging of Epilepsy Structural Sequences

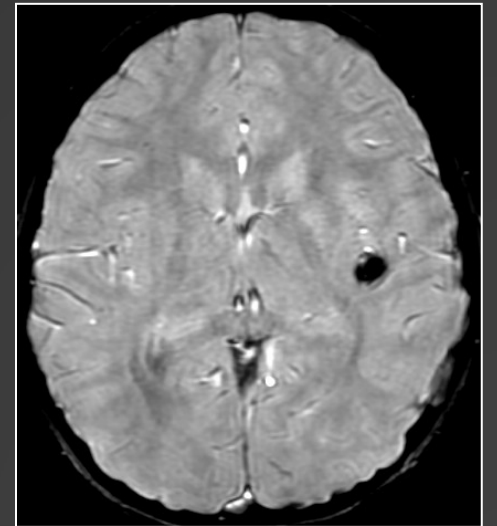
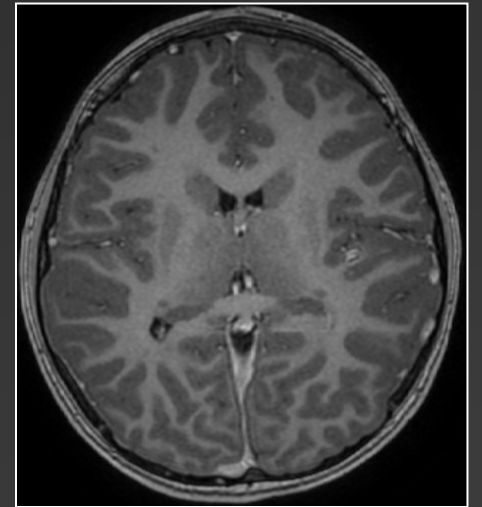
- High-resolution 3D T1wimages
- High-resolution 3D FLAIR images
- High-resolution 2D T2w images



Necessary: HARNESS-MRI protocol

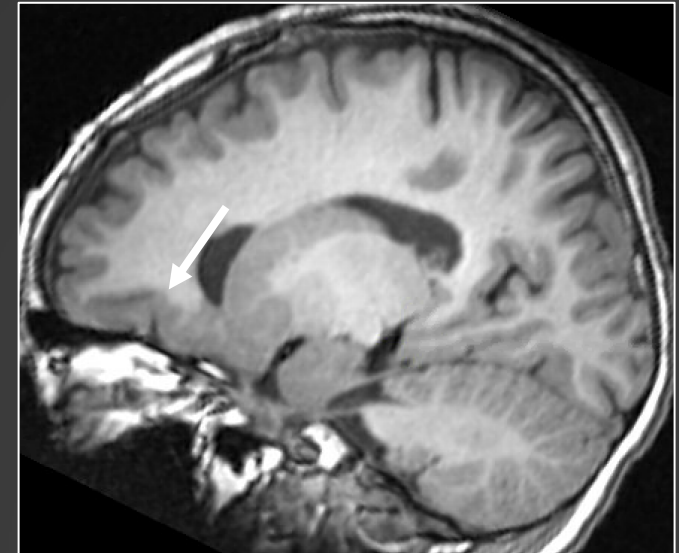
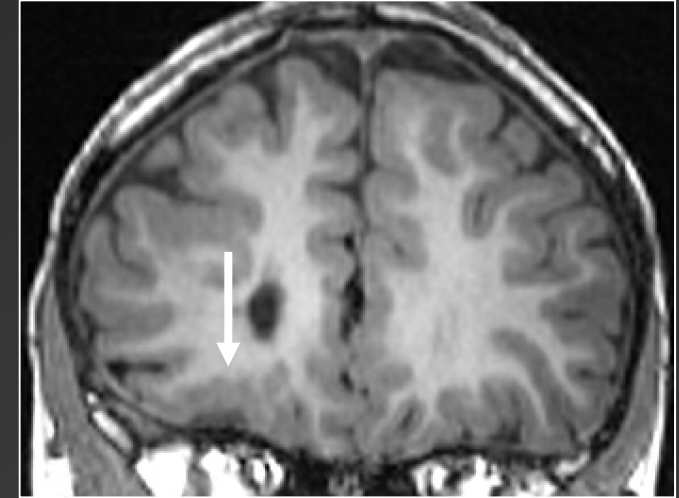
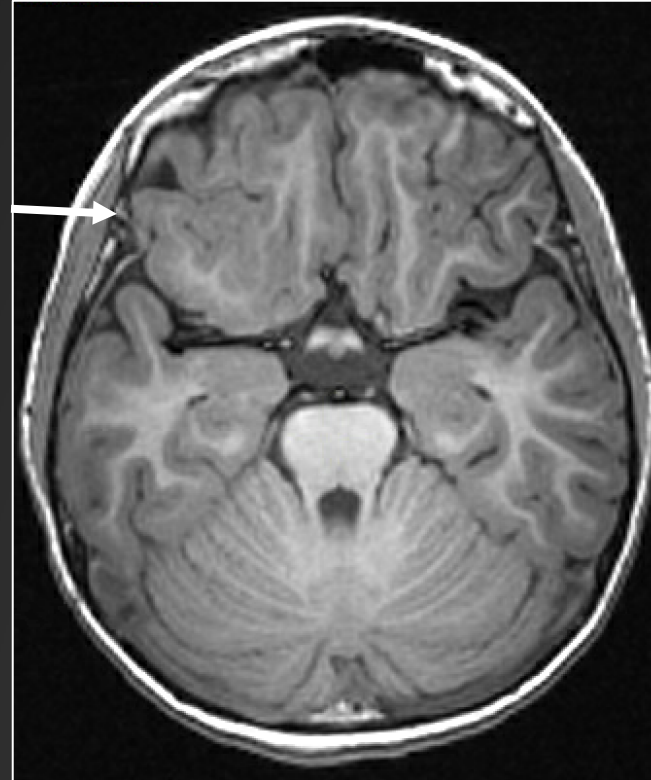
Harmonized Neuroimaging of Epilepsy Structural Sequences

- High-resolution 3D T1w images
- High-resolution 3D FLAIR images
- High-resolution 2D T2w images
- +/- T1w with gadolinium: tumors
- +/- SWI: cavernomas, vascular anomalies



MRI analysis

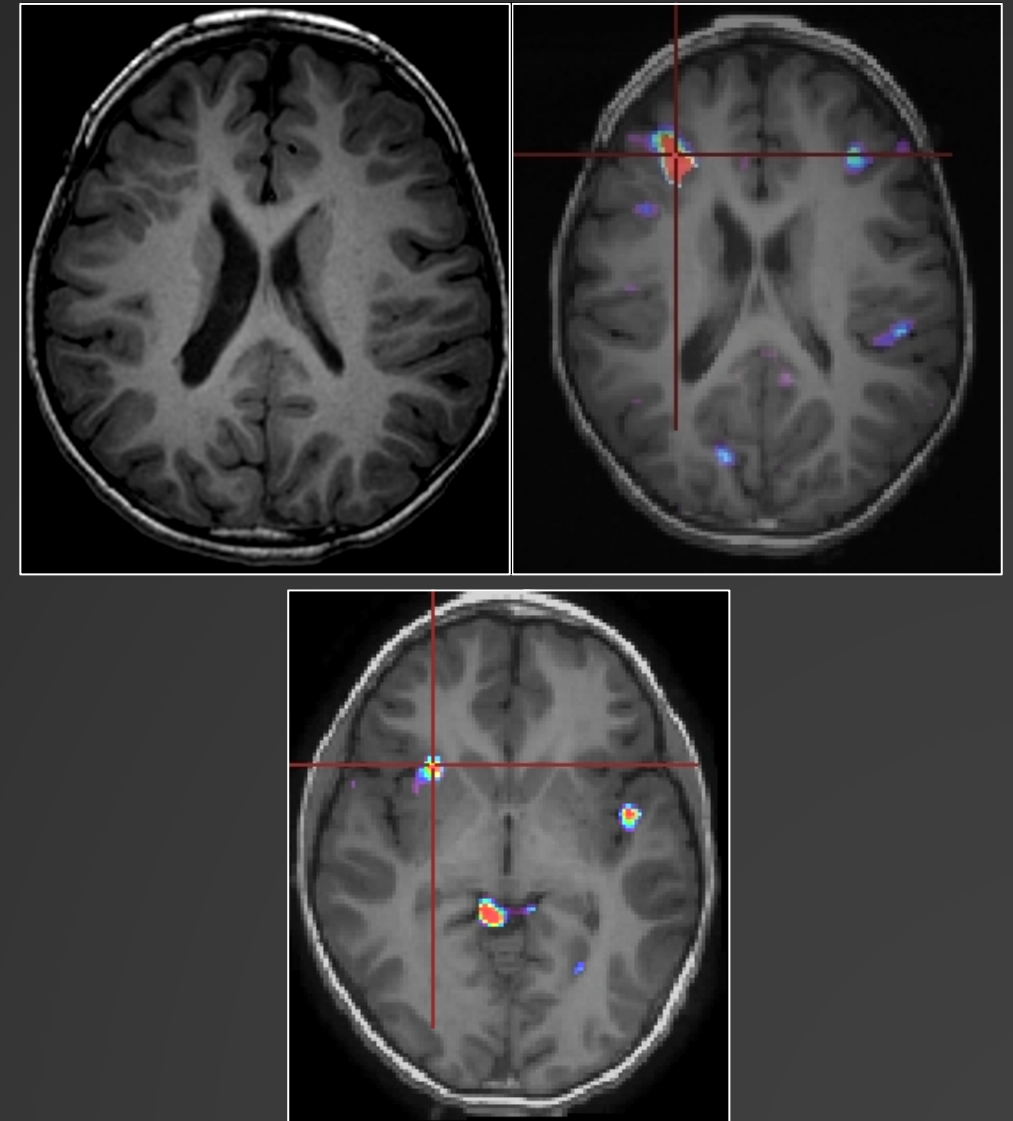
- EEG-guided
- Native thin images
- 3 planes



MRI analysis

Helped by image post-processing

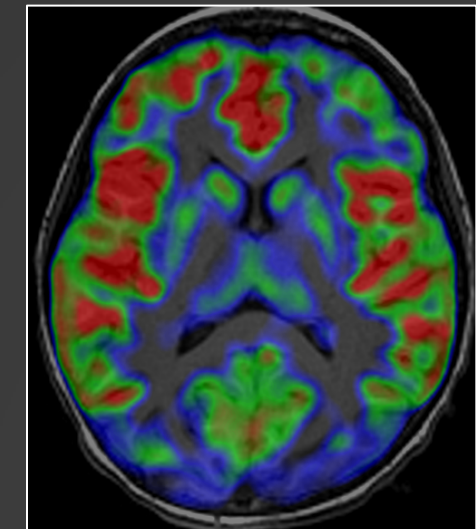
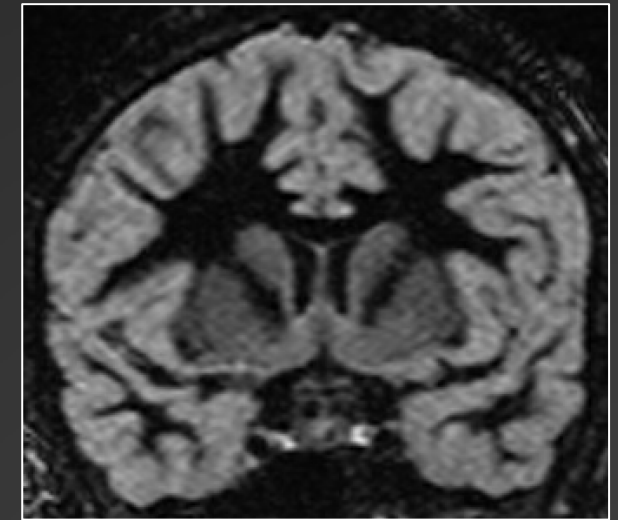
- Voxel-based Morphometry (VBM)
 - Gray matter increase
- Surface-based Morphometry
- Texture analysis

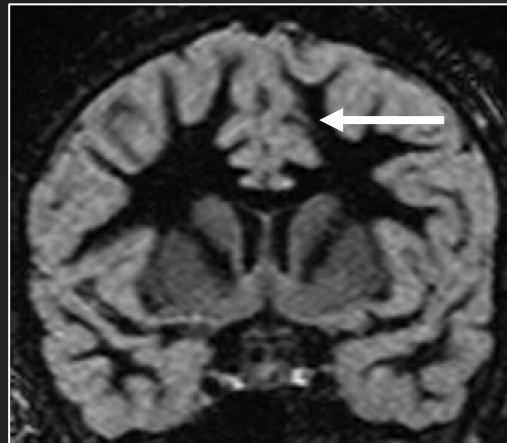
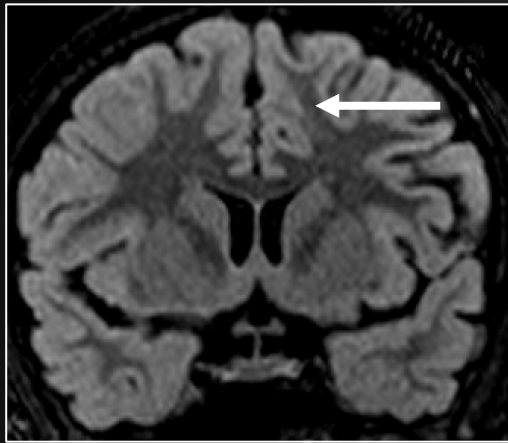
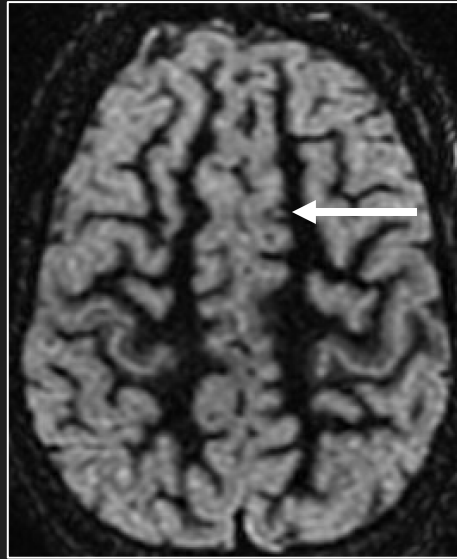
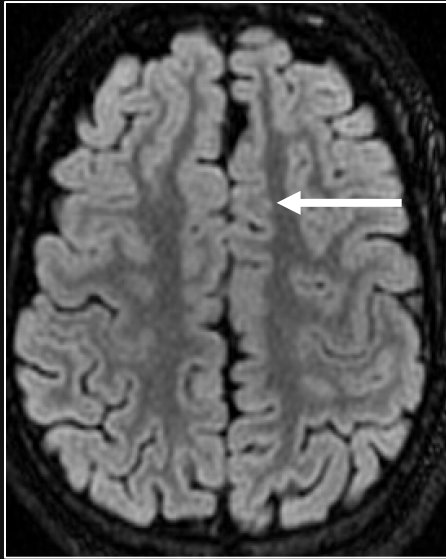


Focal Cortical Dysplasias: Advanced MR sequences

“Advanced” MR sequences

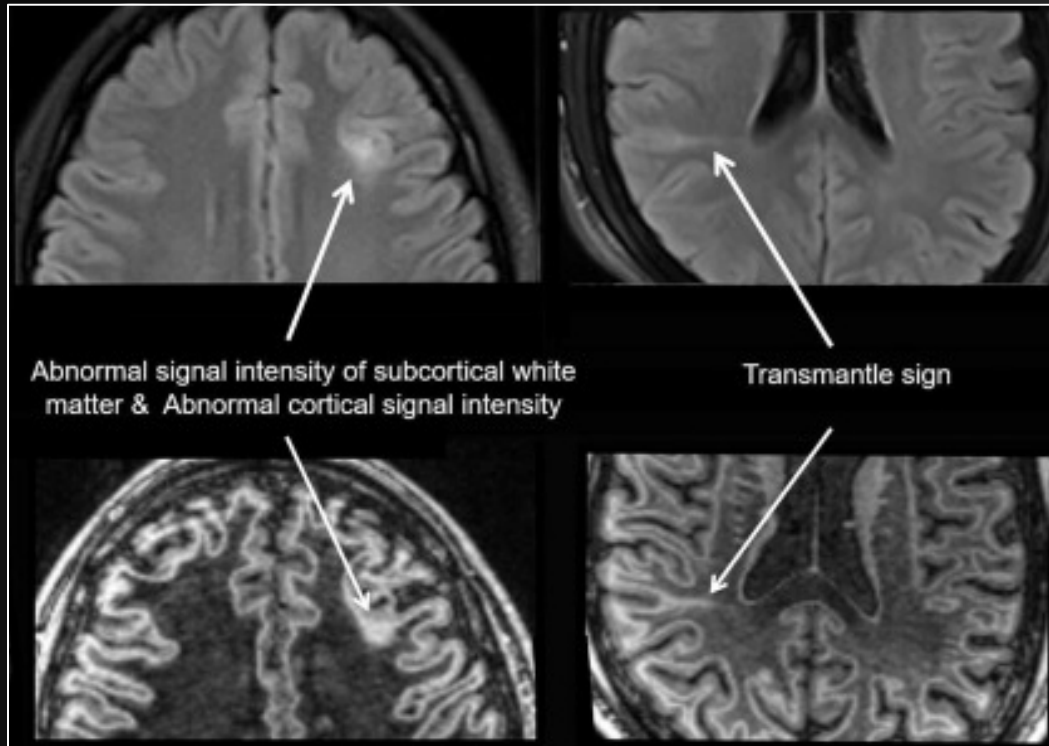
- Morphological:
 - Improvement of WM – GM junction analysis: T2w, T1w
- Functional:
 - Perfusion: ASL
 - EEG-fMRI
 - fMRI...





“Advanced” MR sequences

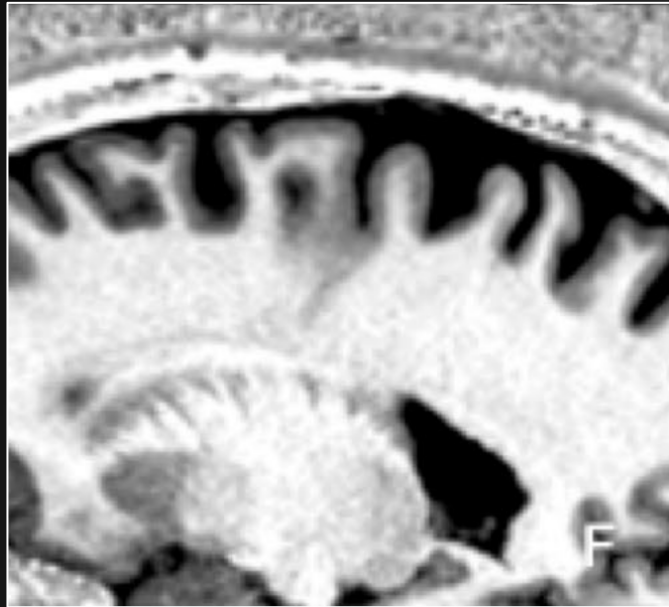
- Improvement of WM – GM junction analysis
 - T2w: Water and WM signal suppression:
 - **DIR**: Double Inversion Recuperation
 - **FLAWS**: Fluid and WM Suppression



Chen *et al.* 2018

“Advanced” MR sequences

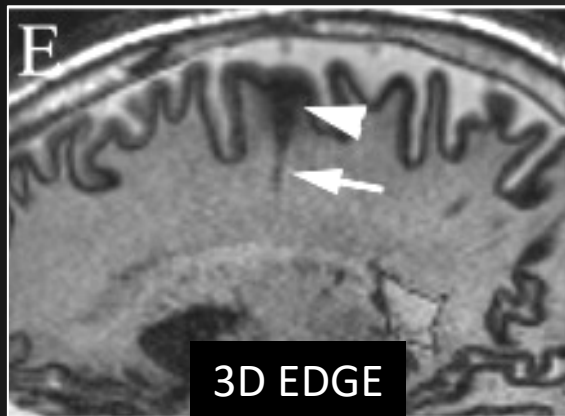
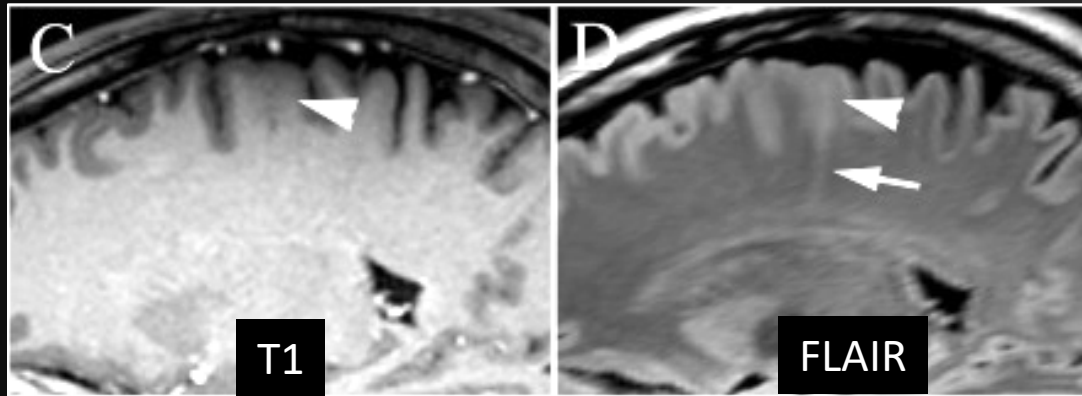
- Improvement of WM – GM junction analysis
 - T2w: Water and WM signal suppression:
 - DIR: Double Inversion Recuperation
 - **FLAWS**: Fluid and WM Suppression



Urbach *et al.* 2022

“Advanced” MR sequences

- Improvement of WM – GM junction analysis
 - T1w:
 - **MP2RAGE**
 - **3D-EDGE**



Middlebrooks *et al.* 2020

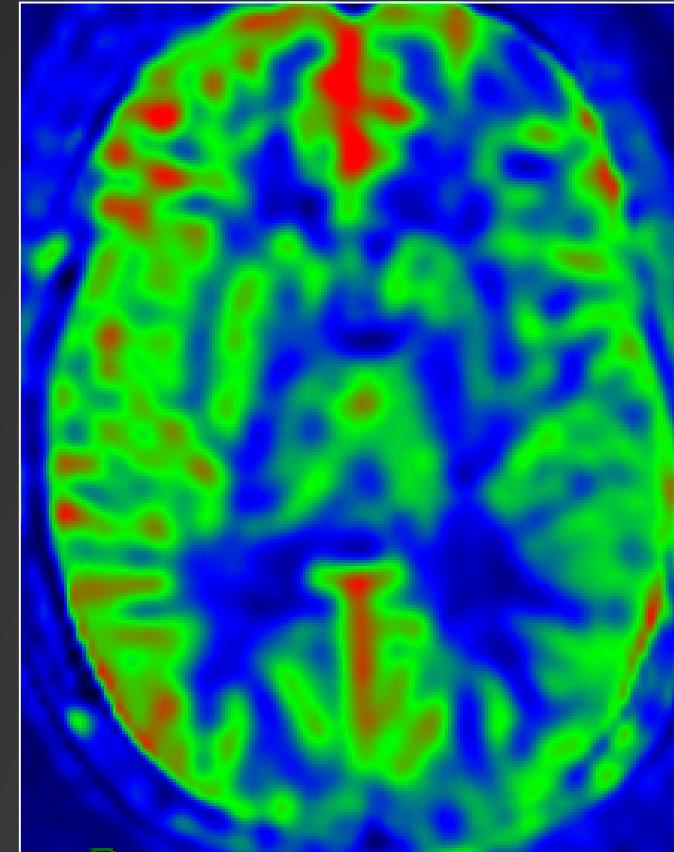
“Advanced” MR sequences

- Improvement of WM – GM junction analysis
 - T1w:
 - MP2RAGE
 - **3D-EDGE**

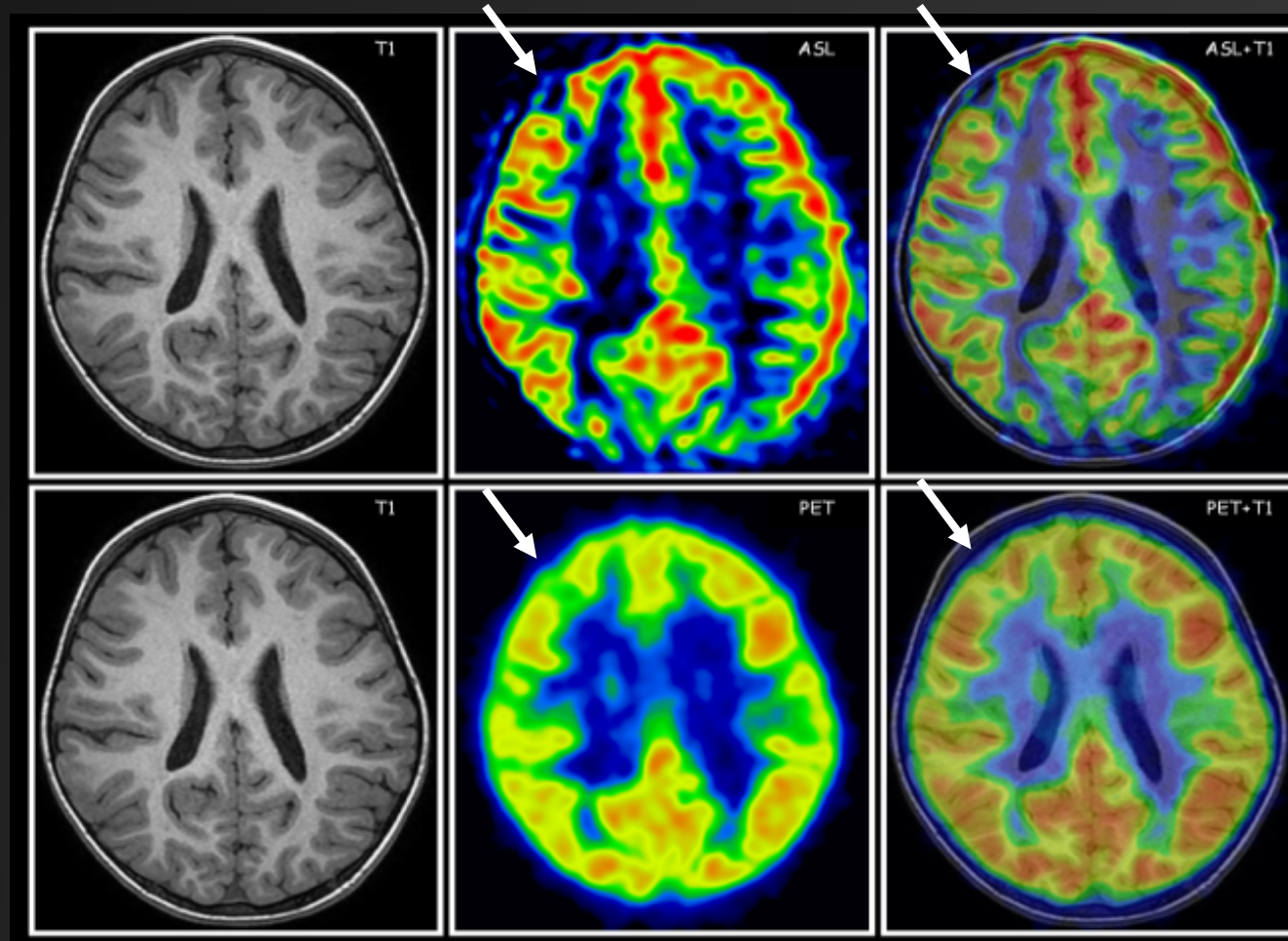
Focal Cortical Dysplasias: ASL

Arterial Spin Labeling (ASL)

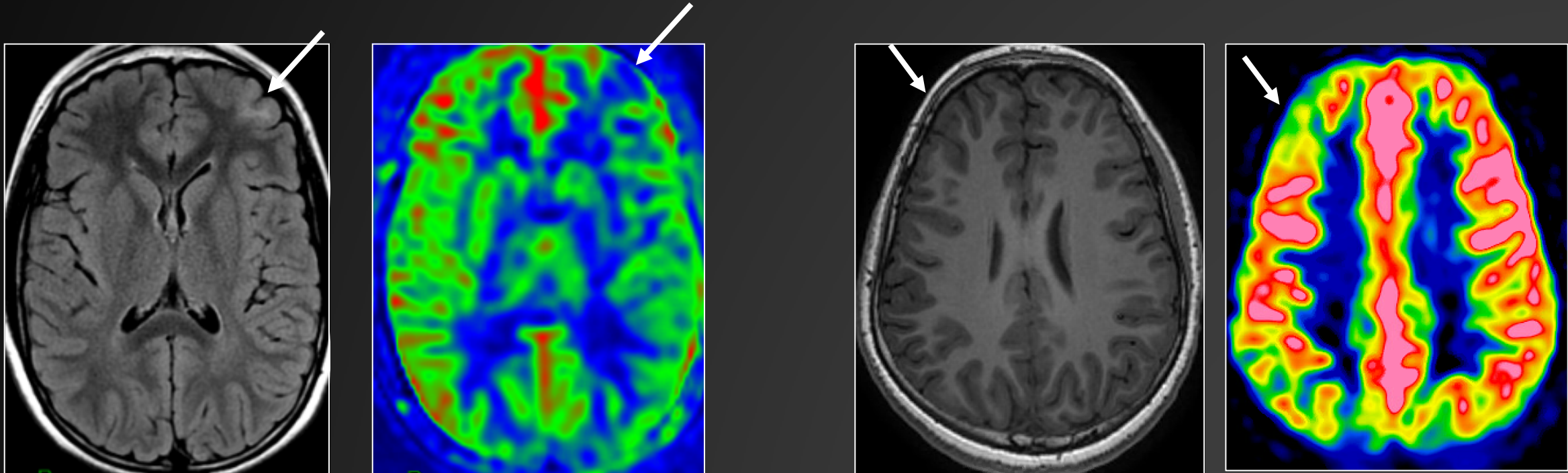
- Perfusion imaging without contrast injection
 - Correlated with $^{15}\text{O}_2$ -PET
 - In epilepsy: results close to FDG-PET
-
- Inter-ictal imaging: low cerebral blood flow
 - Ictal imaging: high cerebral blood flow



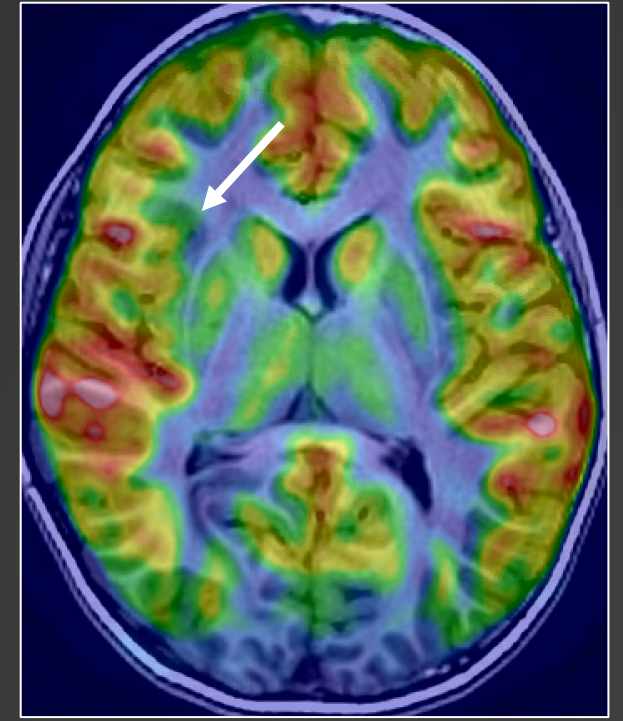
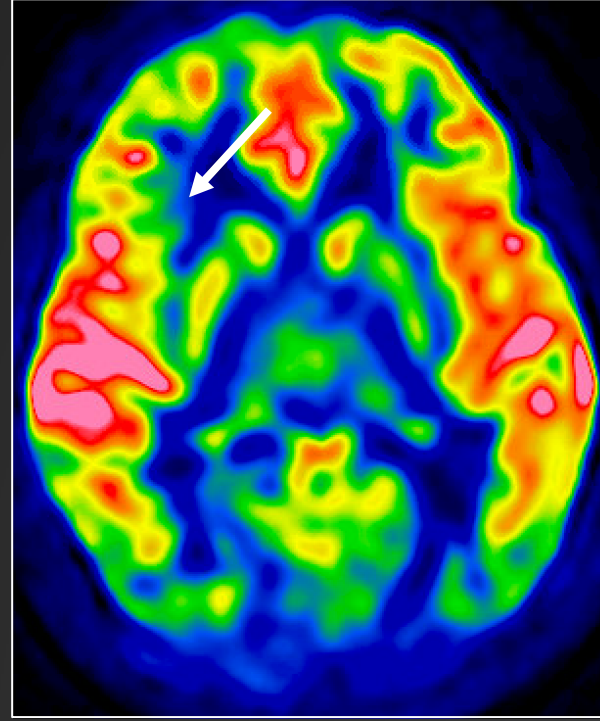
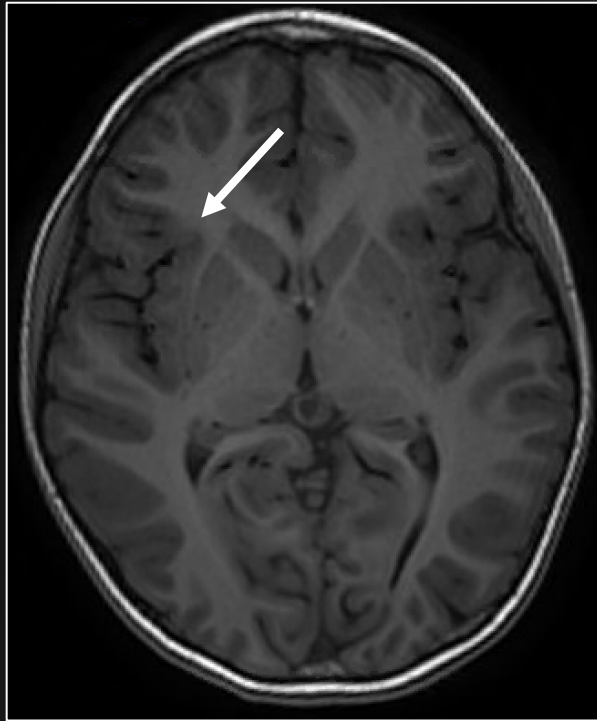
- Arterial Spin Labeling: Inter-ictal → low CBF



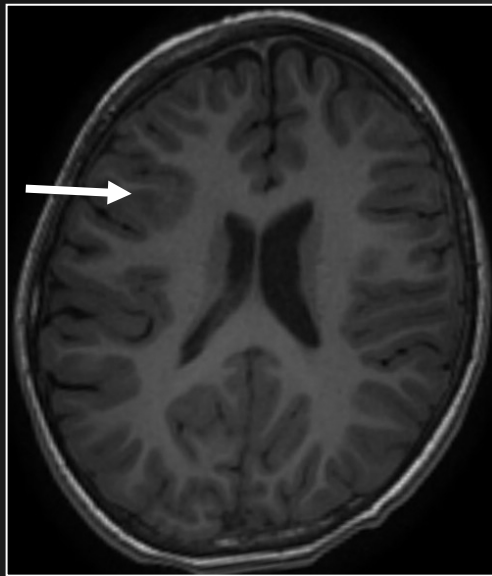
- Arterial Spin Labeling: Inter-ictal → low CBF



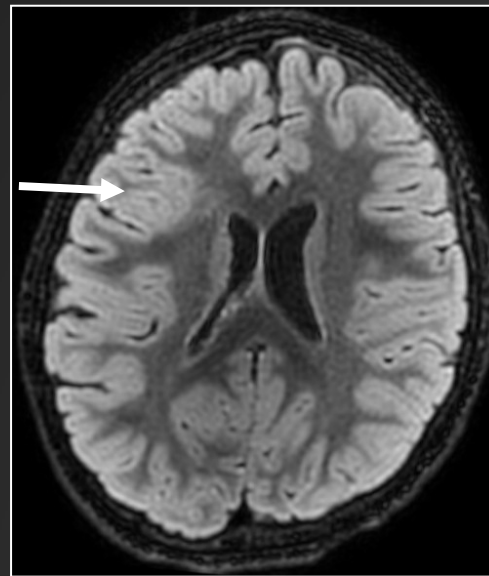
- Arterial Spin Labeling: Inter-ictal → low CBF
 - Better efficiency with registration on T1w images



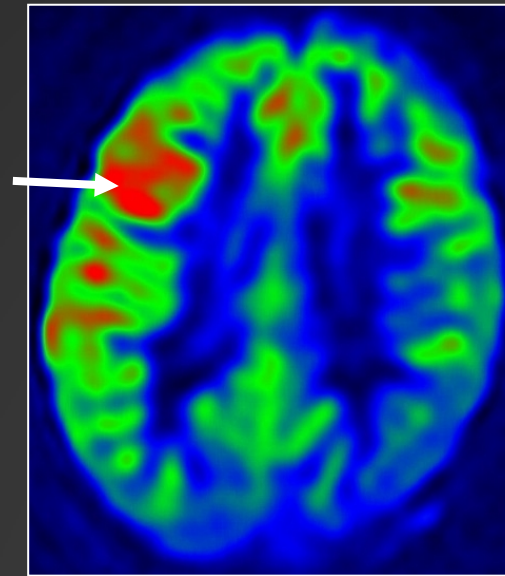
- Arterial Spin Labeling: Ictal → high CBF



T1



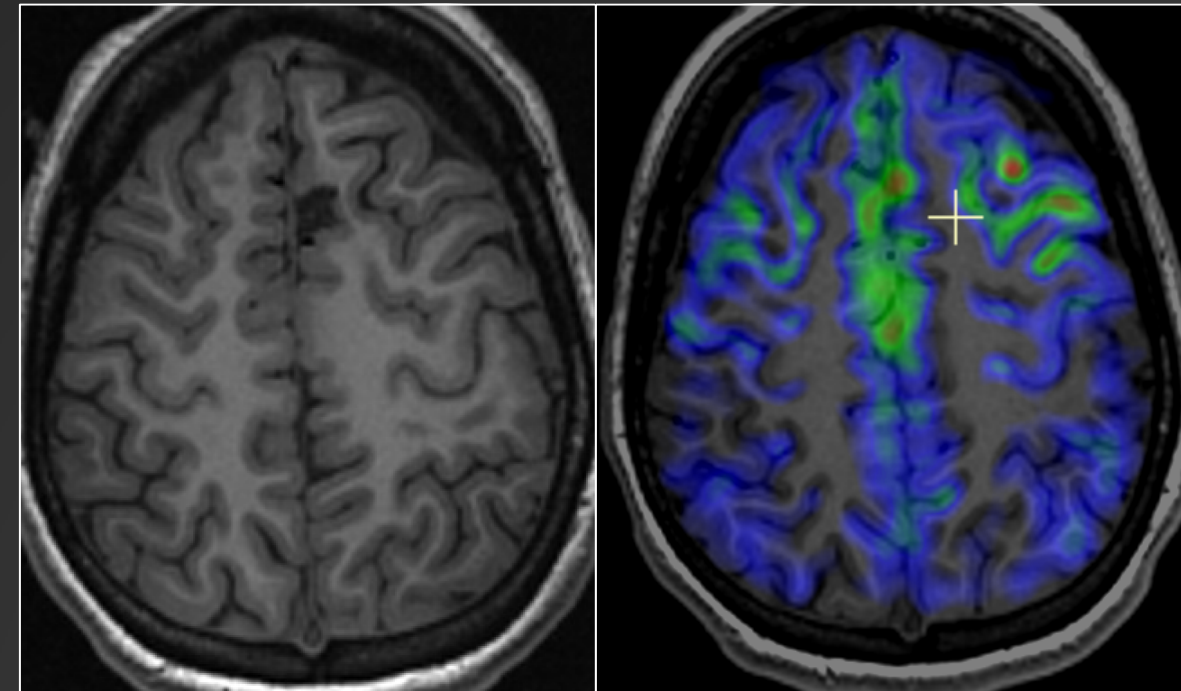
FLAIR



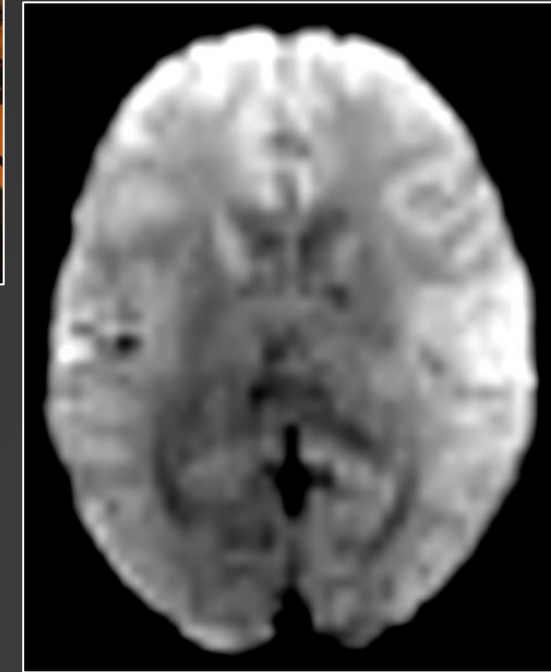
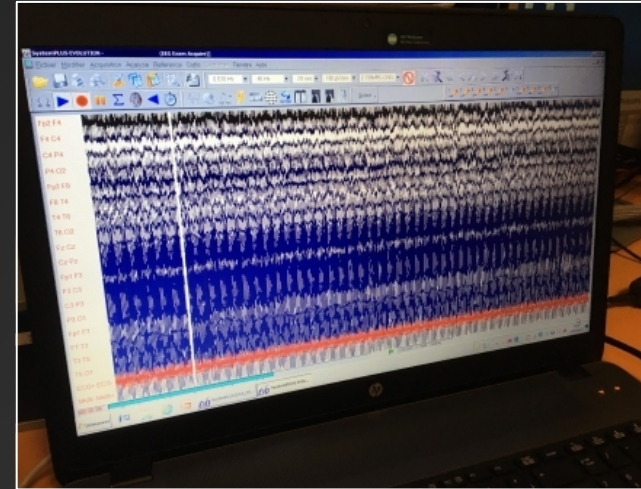
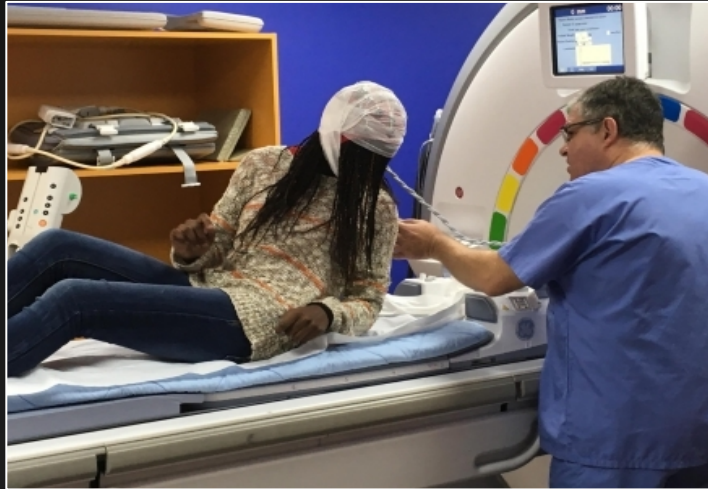
ASL

Arterial Spin Labeling (ASL)

- Sensitivity:
 - MR visible FCD: very high
 - MR “negative” FCDs:
 - Sensitivity 60%
 - Limits:
 - Very small FCDs
 - Ill limited FCDs: large hypoperfusion
- Feasibility
 - Fast (4 minutes), no post-processing
 - Visual analysis

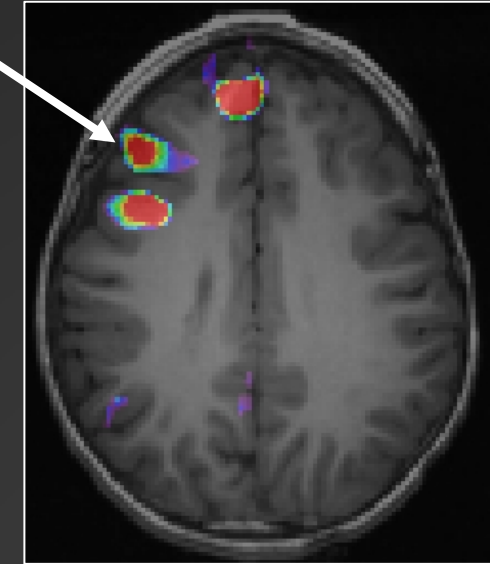
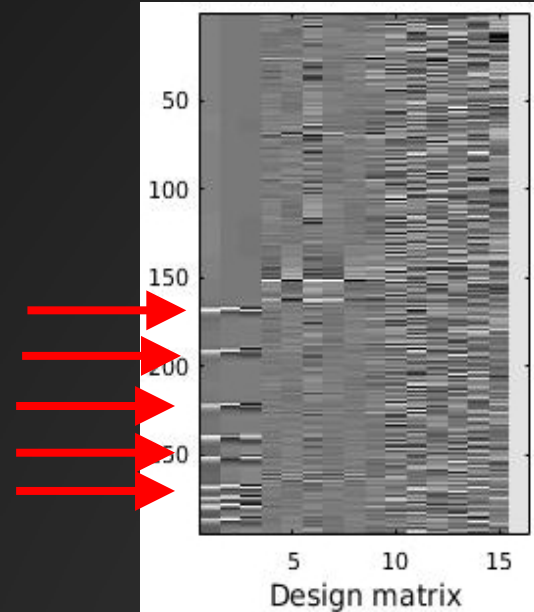
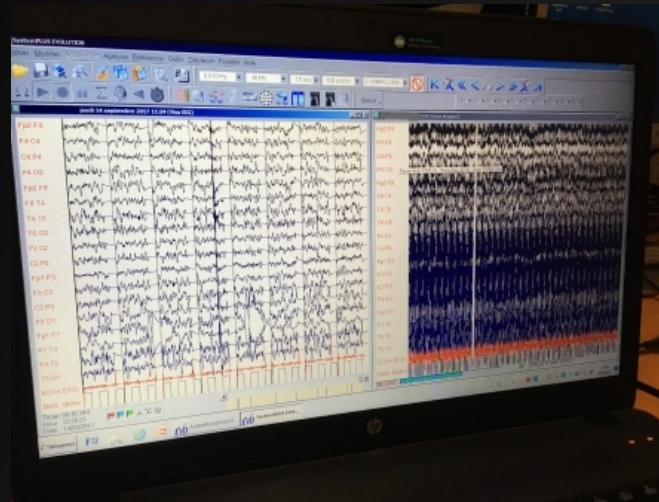


Focal Cortical Dysplasias: EEG-fMRI



EEG-fMRI

- Resting state BOLD functional MRI
- With concomitant EEG within the MR magnet

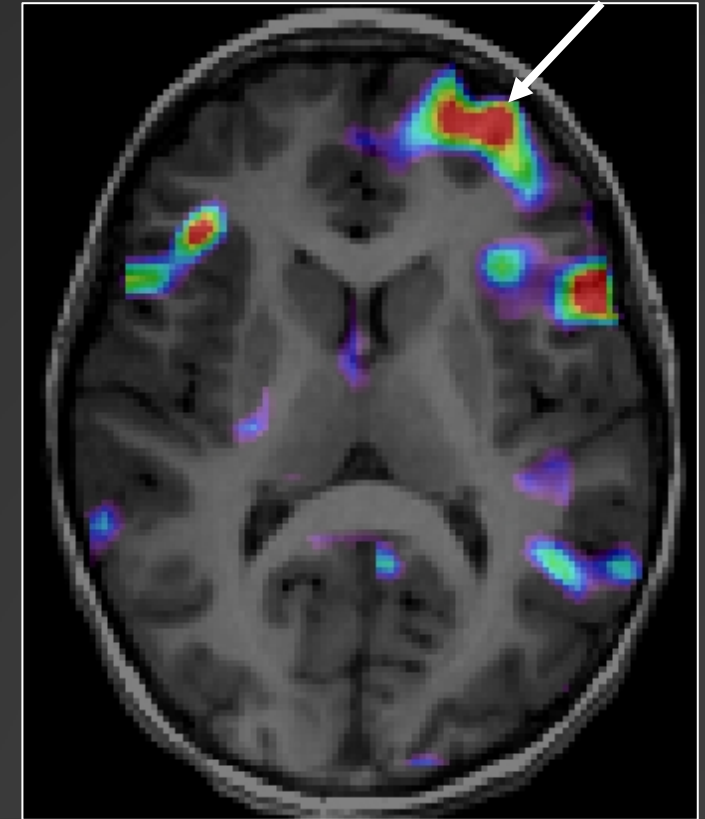


EEG-fMRI

- Inter-ictal epileptiform discharge: fMRI event
→ Activation map

EEG-fMRI

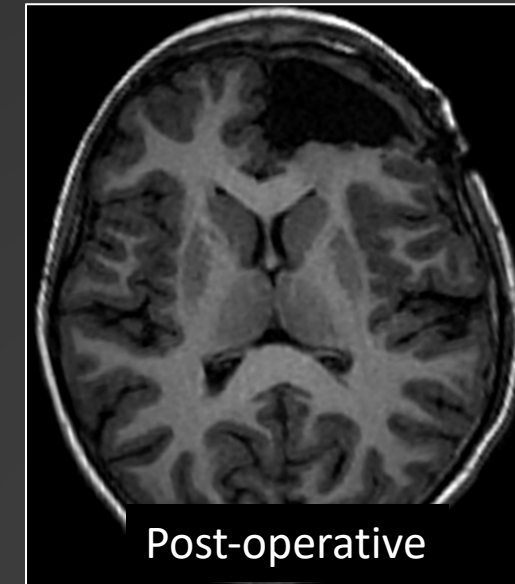
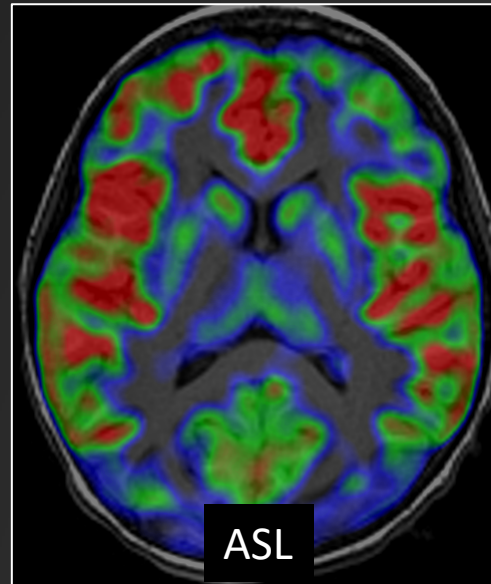
- Sensitivity in MR “negative” FCDs: 50%
 - Necessary:
 - Quiet child (10 minutes)
 - Frequent inter-ictal epileptiform discharges
 - Limits
 - Feasibility
 - Time consuming
 - Other irrelevant clusters



Focal Cortical Dysplasias: Conclusion

Combination of techniques

- Remains the best technique !
- Clinical context, EEG
 - + Morphology (optimized)
 - + Post-processing
 - + ASL
 - +/- EEG-fMRI
 - + PET-FDG
 - + fMRI ?

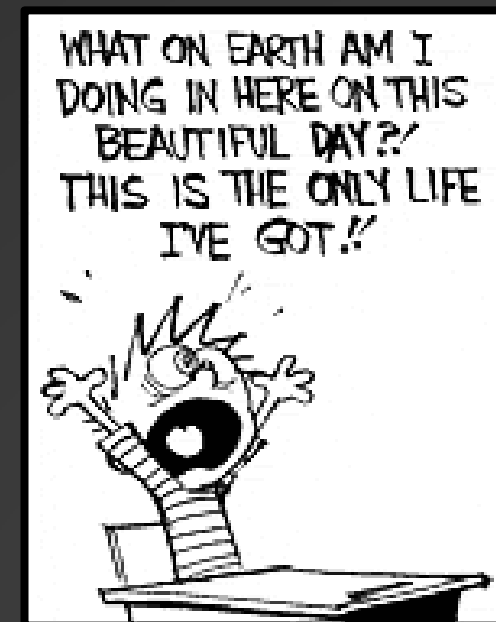


Combination of techniques

- Remains the best technique !
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 - +/- EEG-fMRI
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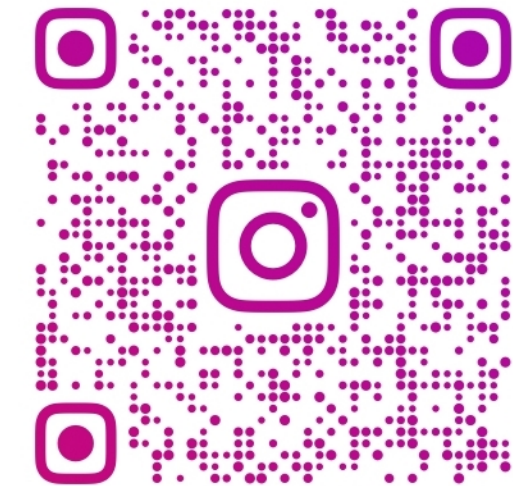
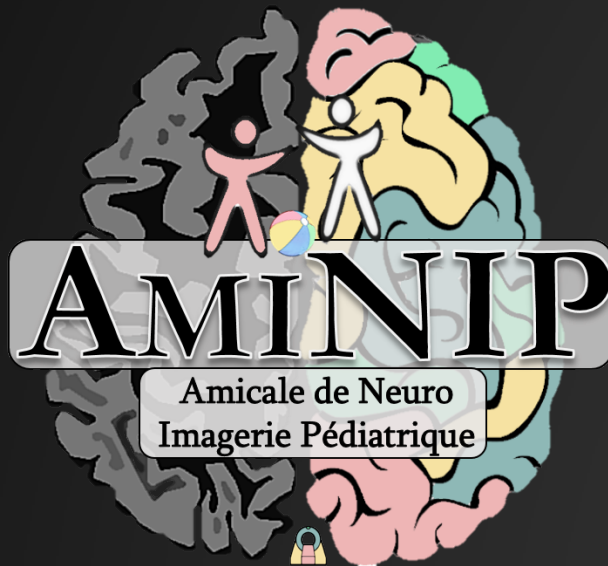
Take your time !



Bill Watterson

- Urbach H, Kellner E, Kremers N, Blümcke I, Demerath T. MRI of focal cortical dysplasia. *Neuroradiology*. 2022 Mar;64(3):443–52.
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Paediatric neuroradiology cases



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