EUROPEAN PAEDIATRIC NEUROLOGY SOCIETY

# EPNS Training Course - EPILEPSY
# Budapest, 8-9 March 2016

# MR imaging (How to find the focus, when focus cannot be found...)


**Prof. Dr. Péter Barsi**

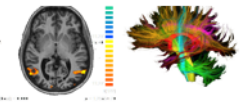
Semmelweis University

MR Research Centre

Budapest, Hungary


MRKK

Semmelweis Egyetem
MR Kutatóközpont
Budapest



# Summary

1. Goal of epileptology/neuroimaging
2. Introducing „the fish in the brain”
3. Basic concept of neuroimaging: MRI protocol
4. The most frequent pathologies:
    1. Hippocampal (mesial temporal) sclerosis (HS/MTS)
    2. Malformations of cortical development (MCDs) and phacomatoses
5. Conclusion, take-home message

# Risks of repeated seizures

- Hampered somatomental development
- Severe cognitive impairment
- Trauma
- Neurological deficit
- Social isolation/dysfunction
- Death (SUDEP – sudden unexplained death in epilepsy)

***Seizure control is the most important goal of epileptology.***

Guerrini R Epilepsy in Children Lancet 2006; 367: 499–524

# Selecting adequate AEDs is based on

- Age
- Seizure type
- Clinical context
- Neurophysiology (EEG)
- Neuropsychology
- Neuroimaging

Guerrini R Epilepsy in Children Lancet 2006; 367: 499–524

# Prognostic groups in epilepsy

1. *Benign* (20-30%): remission after several years without treatment
2. *Pharmacosensitive* (30%): easily controlled by medication, remission after several years
3. *Pharmacodependent* (20%): controlled by lifelong drug treatment
4. Pharmacoresistant (20-25%): cannot be adequately controlled by AEDs – surgery!

Guerrini R Epilepsy in Children Lancet 2006; 367: 499–524

# The results of proper imaging in epilepsy

1. Detection and DDx of epileptogenic lesion
2. Clarification of epileptogenic mechanism
3. Data for surgical therapy – results:
    1. Progressive pathologies resected
    2. Pharmacoresistent epilepsy
        1. completely cured
        2. turned pharmacosensitive
        3. some symptoms decreased

# Common causes of epilepsy in children

1. Malformations of cortical development (MCDs), phacomatoses
2. Hippocampal sclerosis, other disorders of the hippocampus
3. Vascular disorders
    1. Intrauterine/perinatal hypoxic brain damage – PVL
    2. Ischaemia and haemorrhage
    3. Vascular malformations
4. Infections
5. Dysgenetic and other cortical tumours
6. Paraneoplastic syndromes
7. Inborn errors and acquired abnormalities of metabolism
8. Post-traumatic changes

# Basic concept of neuroimaging in epilepsy

- NO CT!
- Routine MRI inadequate (hippocampus, small MCDs) –waste of time and money!
- Certain lesions are best seen on FLAIR while others on T1, but FLAIR is of no use before 2 years (myelination)

# ACR APPROPRIATENESS CRITERIA

# Epilepsy

J.P. Karis,
for the Expert Panel on
Neurologic Imaging

**Table 2: Clinical condition: epilepsy**

| | MRI head without contrast | MRI head without and with contrast | CT head without and with contrast | CT head without contrast | FDG-PET head | SPECT head | fMRI head | MEG/ MSI | MRA head |
|---|---|---|---|---|---|---|---|---|---|
| Chronic epilepsy, poor therapeutic response. Surgery candidate. | 8 | 8 | 6 | 5 | 7[a] | 5[a] | 5[a] | 5[b] | 3 |
| New onset seizure. ETOH, and/or drug related. | 7[c] | 8[c] | 6[c] | 5[c] | 2 | 2 | 2 | 2 | 2 |
| New onset seizure. Aged 18–40 years. | 8[c] | 7[c] | 6[c] | 5[c] | 4 | 4 | 2 | 2 | 2 |
| New onset seizure. Older than age 40. | 7[c] | 8[c] | 3[c] | 5[c] | 4 | 4 | 2 | 2 | 2 |
| New onset seizure. Focal neurological deficit. | 8[c] | 8[c] | 7[c] | 6[c] | 3 | 3 | 2 | 2 | 2 |

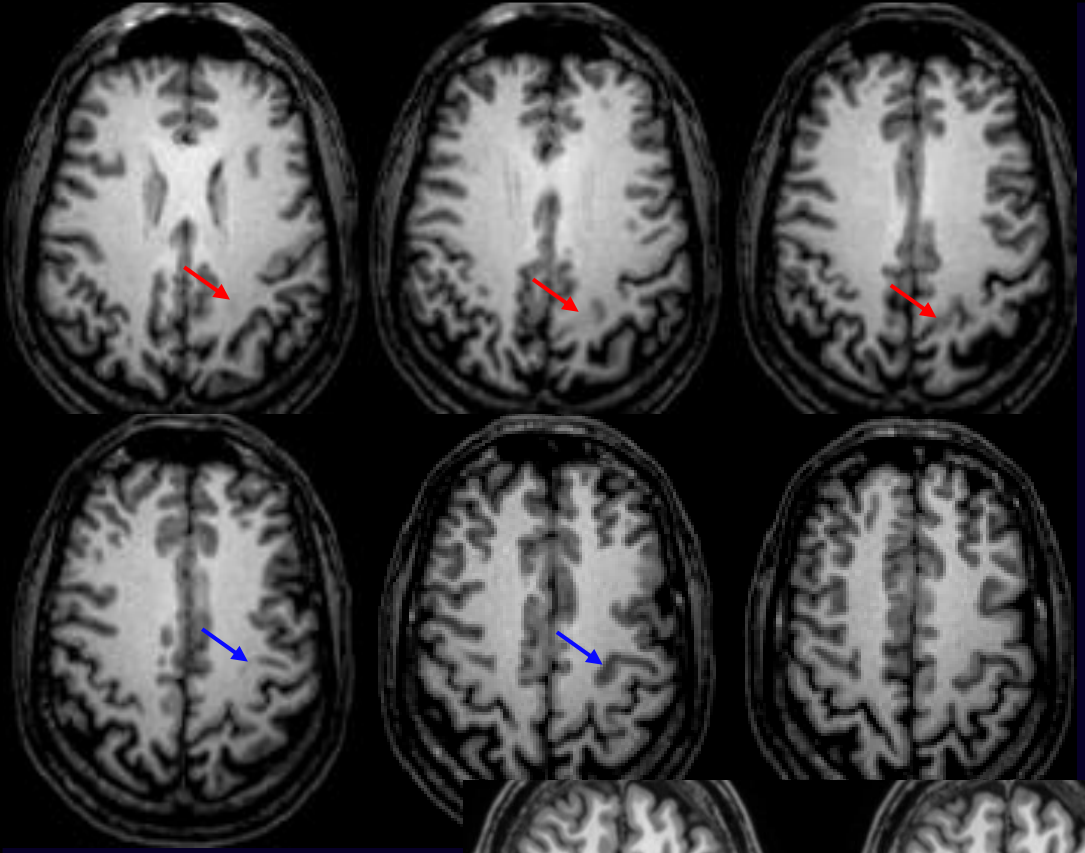
Rating Scale: 1, least appropriate; 9, most appropriate.
[a] May be helpful in pre-op planning.
[b] Data probably equivalent to BOLD and SPECT.
[c] In the acute or emergency setting, CT may be the imaging study of choice.

Karis JP ACR Appropriateness Criteria: Epilepsy AJNR Am J Neuroradiol 2008; 29:1222–24

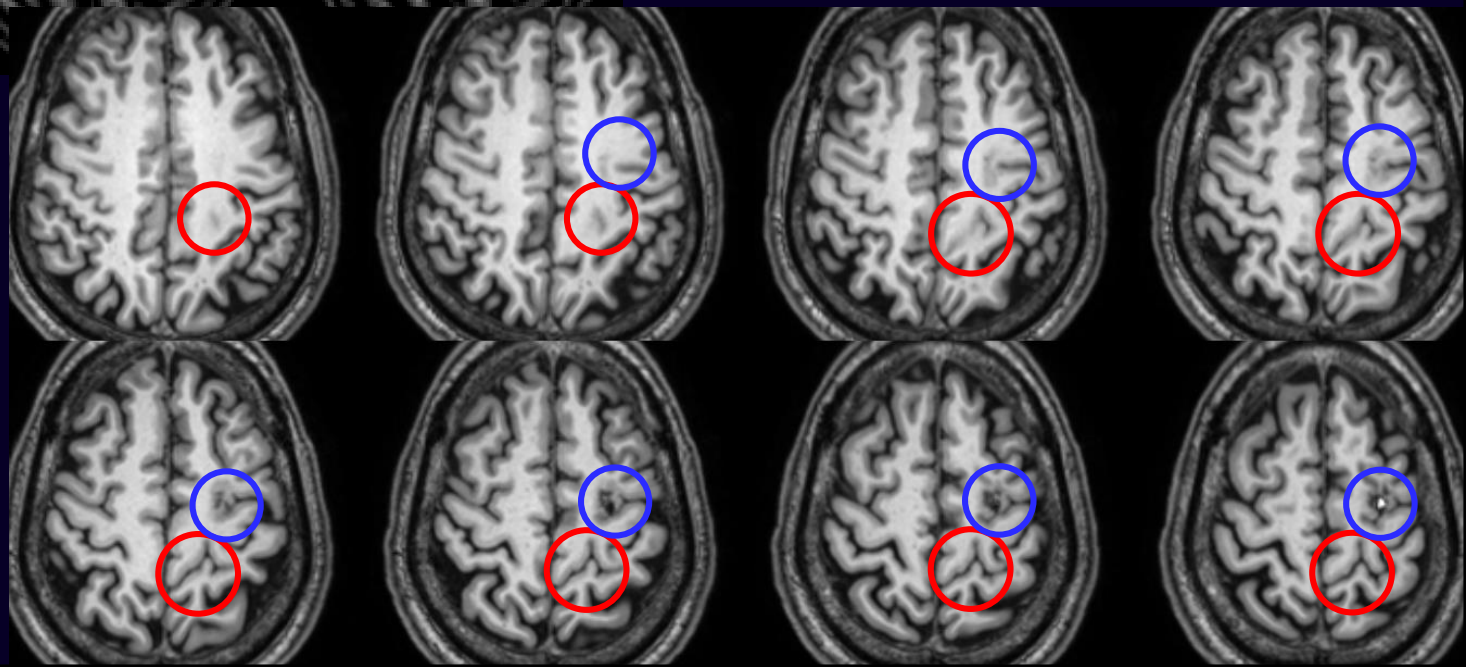
# Main targets of the MRI protocol

1. Hippocampus
2. Any further pathology including MCDs, tumours, etc.
3. Help in surgical planning
4. Optimal comparison at follow-up

# Same MRI protocol pre/postop



Preoperative: double left frontal cortical dysplasia

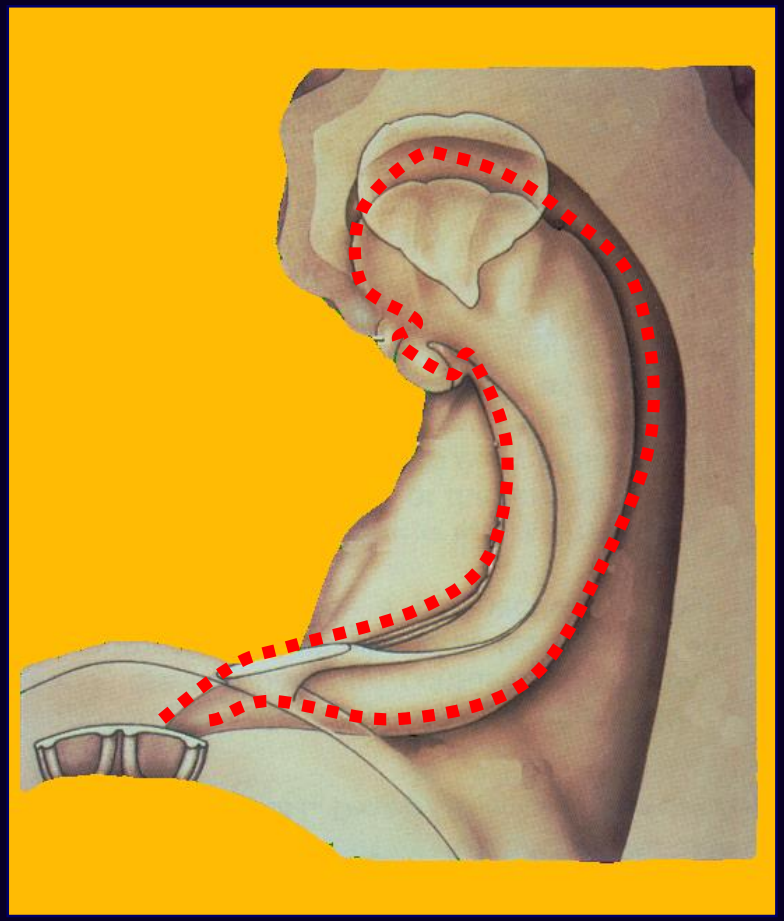


Postoperative: posterior dysplasia not operated

# Master Arantius, 1587

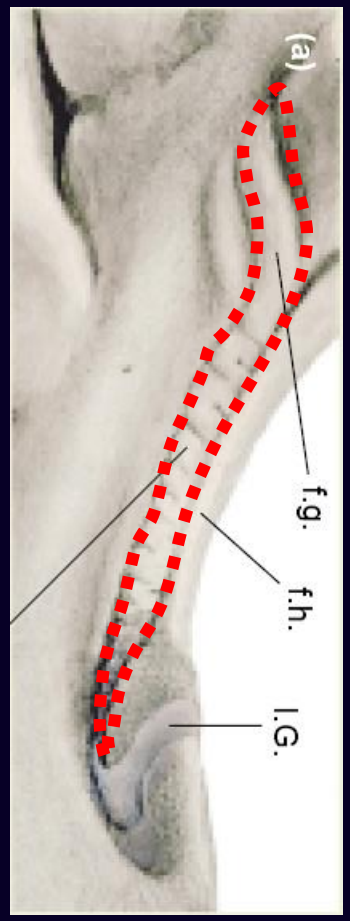
=

hippocampus proper



or

dentate gyrus

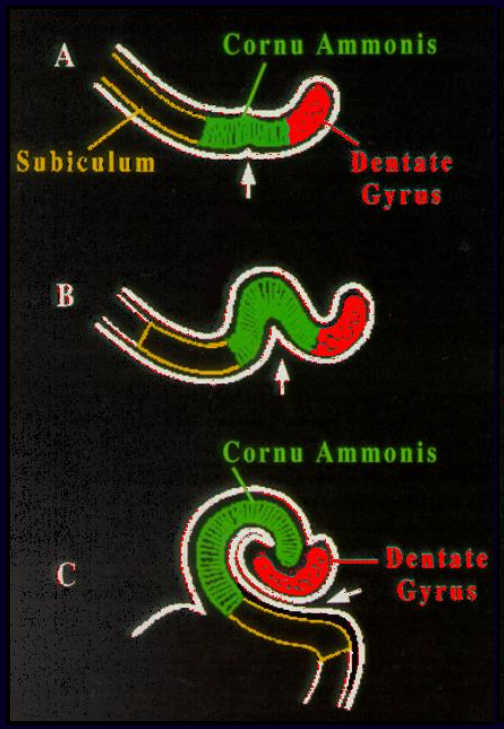


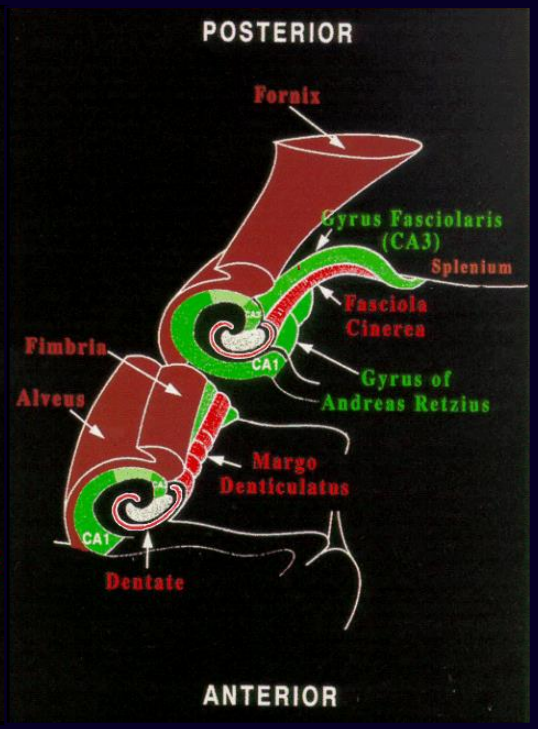

Walther C, Endeavour 2002; 26 (2): 41-44

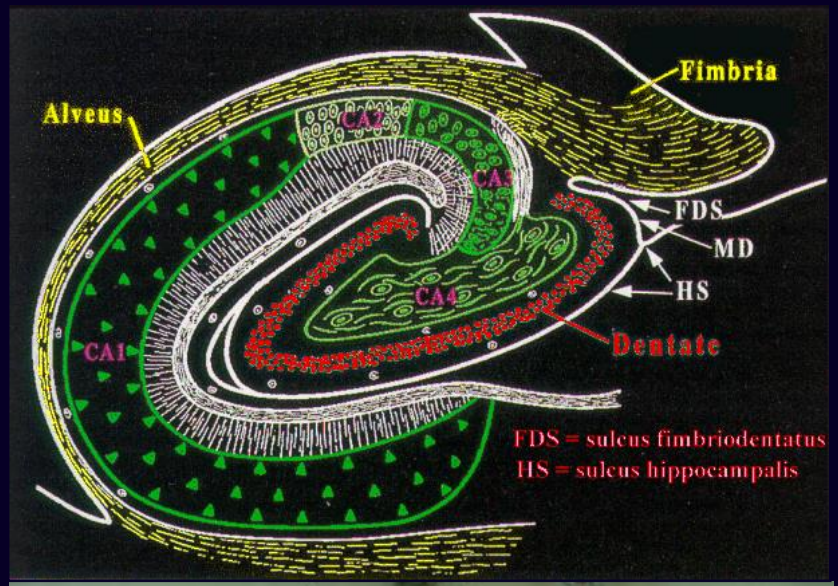
# What is the hippocampus?

1. Paleocortex, medial T lobe, part of limbic system
2. Widespread connections with
    1. telencephalon
    2. diencephalon
    3. mesencaphalon
3. Important role in the processing of
    1. memory and learning
    2. emotions and behaviour
4. Damage - epilepsy or memory disturbance

# Development of the hippocampus

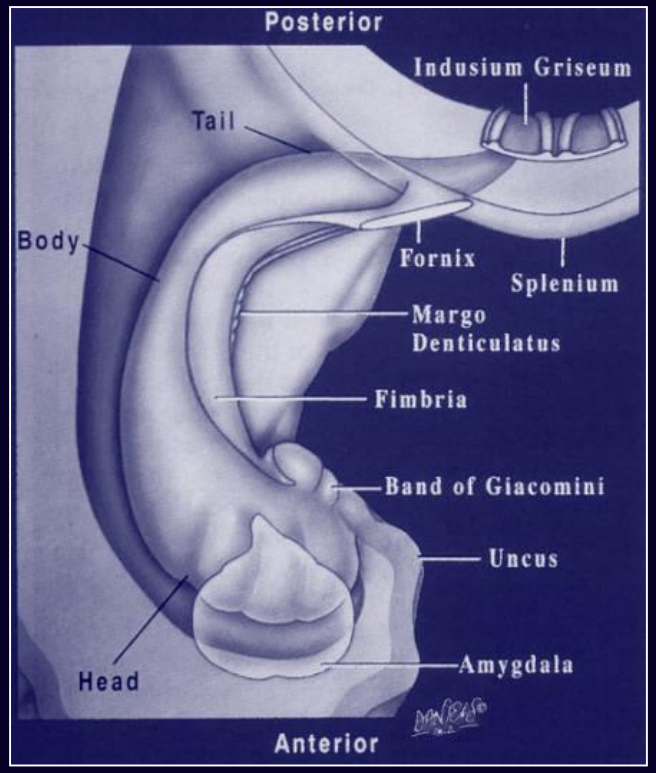


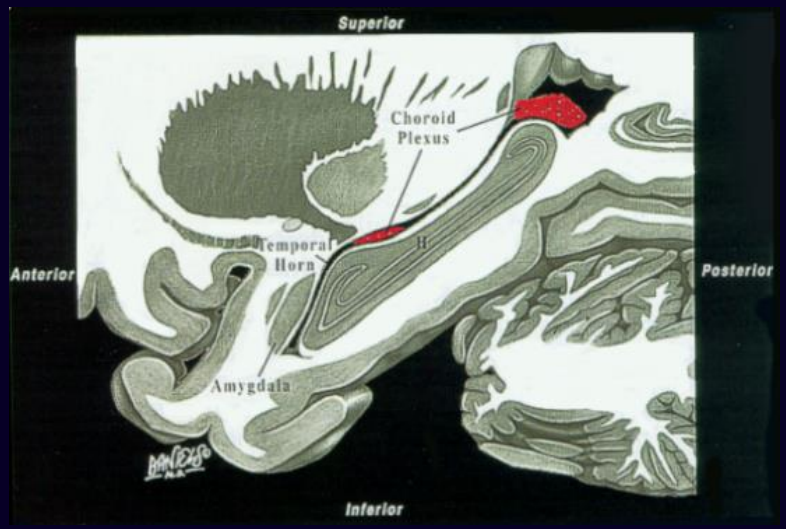

# Why is the hippocampus that important?

1. Focal epilepsies: 60% T lobe origin
2. T lobe epilepsies (frequently pharmacoresistant): 60% Hi origin
3. Surgical resection: improvement or complete recovery
4. Double pathology (HS with other lesions): possible causal relationship, epileptic discharges from the lesion causing secondary hippocampal damage




# MR methodology

**Hippocampus: long structure with small diameter → the most detailed images can be obtained by**

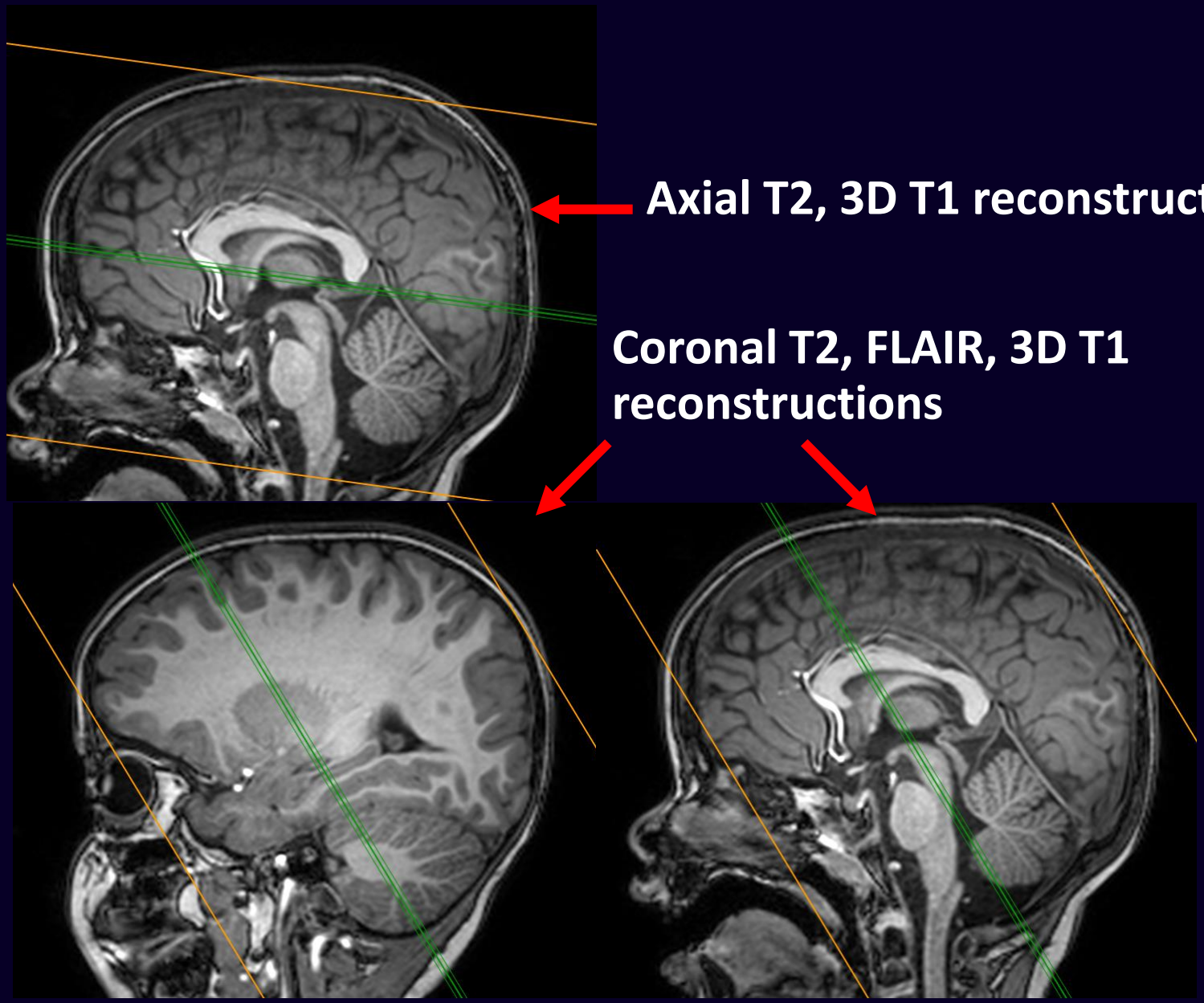



1. **Thin slices perpendicular to its long axis**
2. **High resolution**
3. **Different sequences**

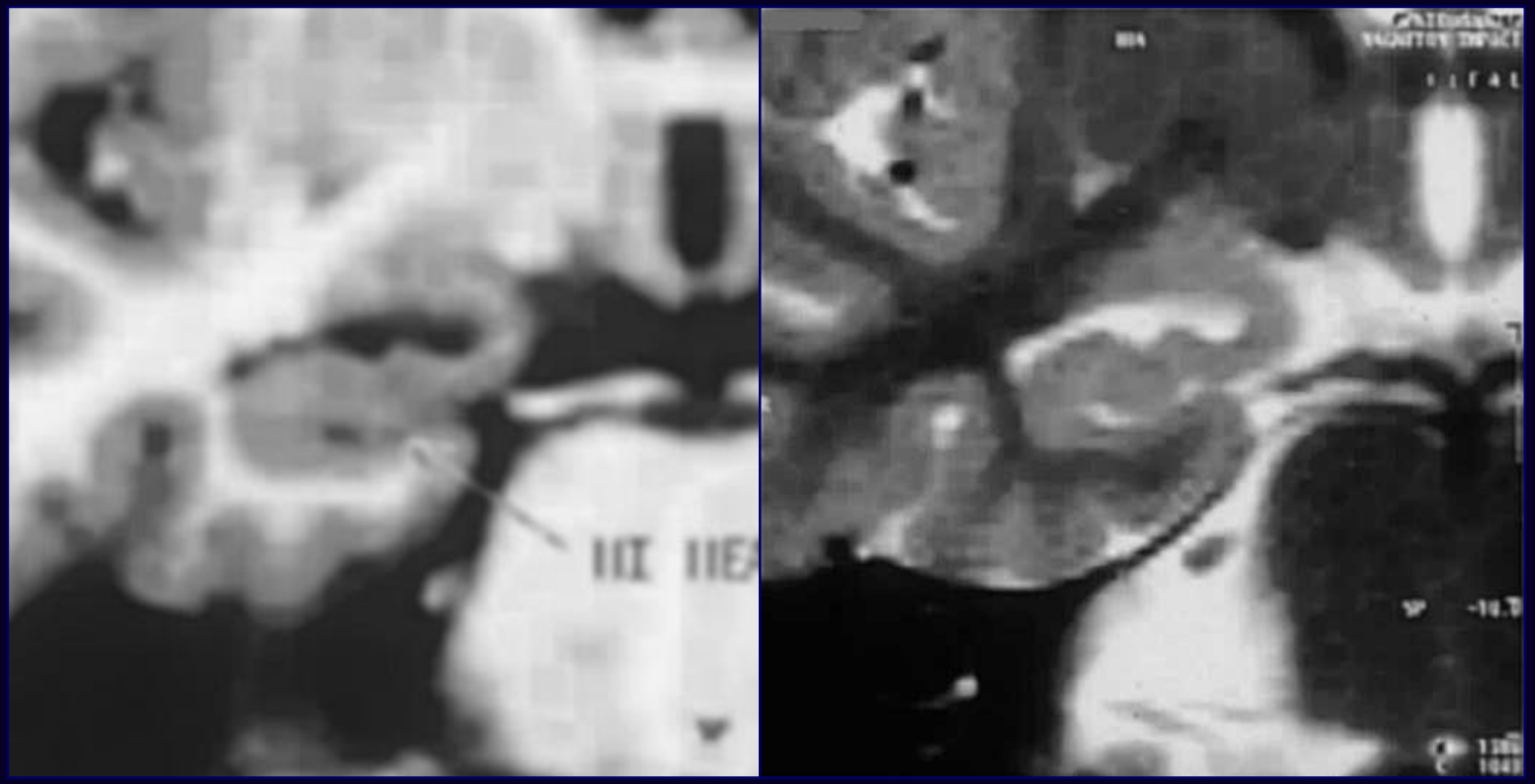
# MRI protocol in epilepsy

| Sequence | Goal |
|---|---|
| Careful positioning and scouts | Get rid of asymmetry |
| Axial TSE or FSE T2 with HR | Overview |
| 3D T1 / reconstructions | MCDs, surgical planning |
| Coronal T2: thin slice, HR, perpendicular to long axis of hippocampi, covering whole brain | Detailed evaluation of the hippocampi and whole brain |
| Over 2 years: 3D or coronal FLAIR, same as previous | Detailed evaluation of the hippocampi and whole brain |
| DWI/ADC or better DTI/ADC | DDx, surgical planning, lateralization |
| GRE T2* or SWI | DDx (haemosiderin, calcification) |
| Contrast enhanced 3D T1, MRP, MRS, MRA, fMRI | DDx, surgical planning, lateralization |

# MRI protocol in epilepsy: planning

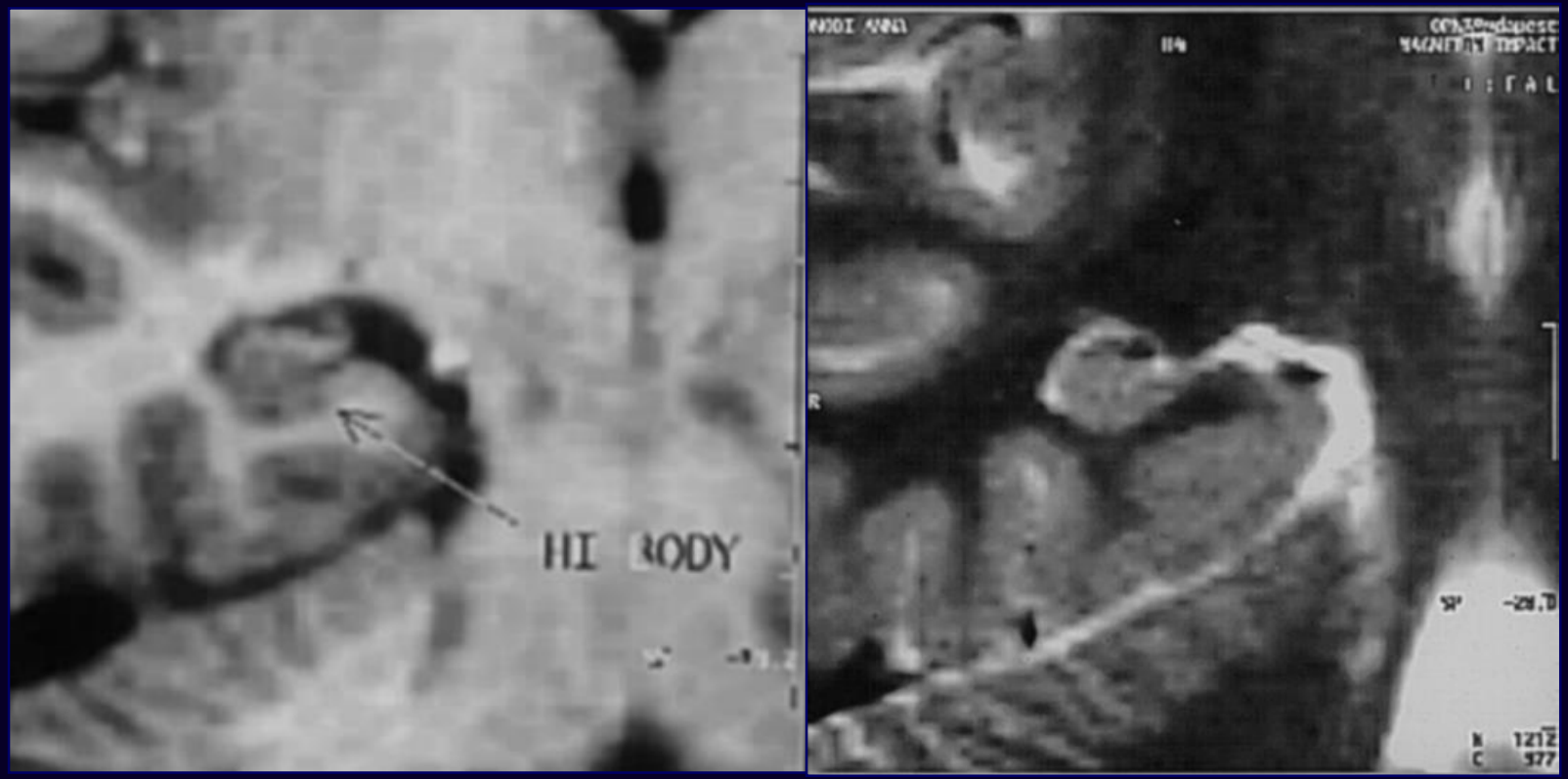


# Normal hippocampal head (1.0 T)



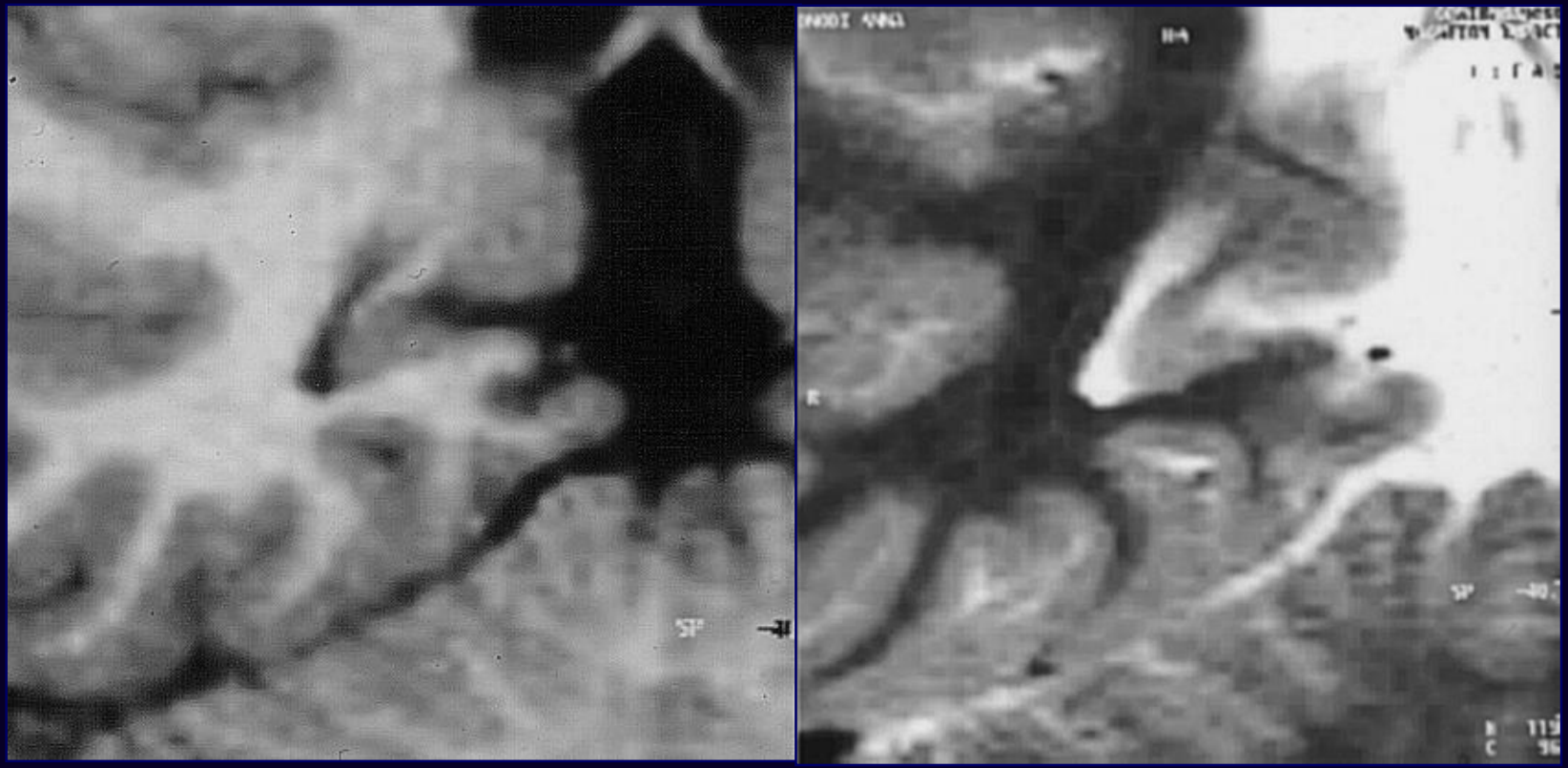
T1 T2

# Normal hippocampal body (1.0 T)



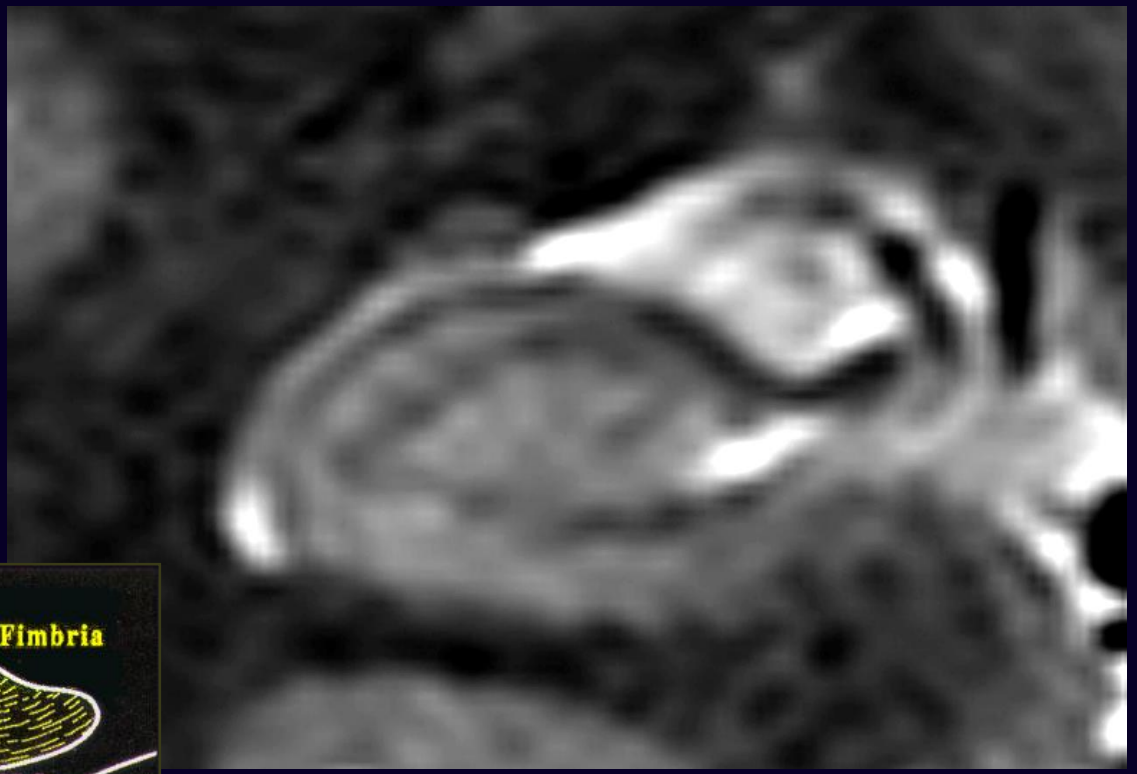

T1 T2

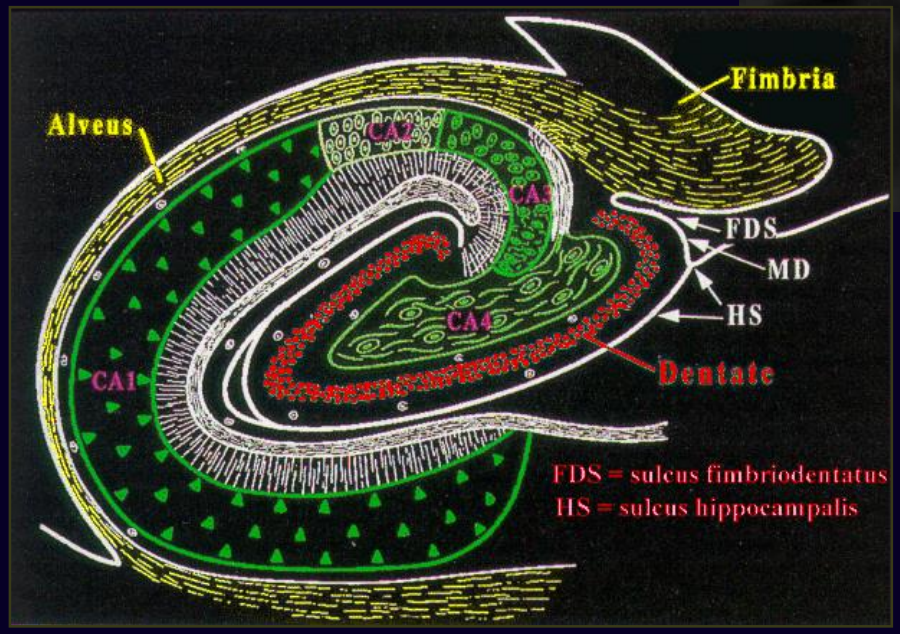
# Normal hippocampal tail (1.0 T)



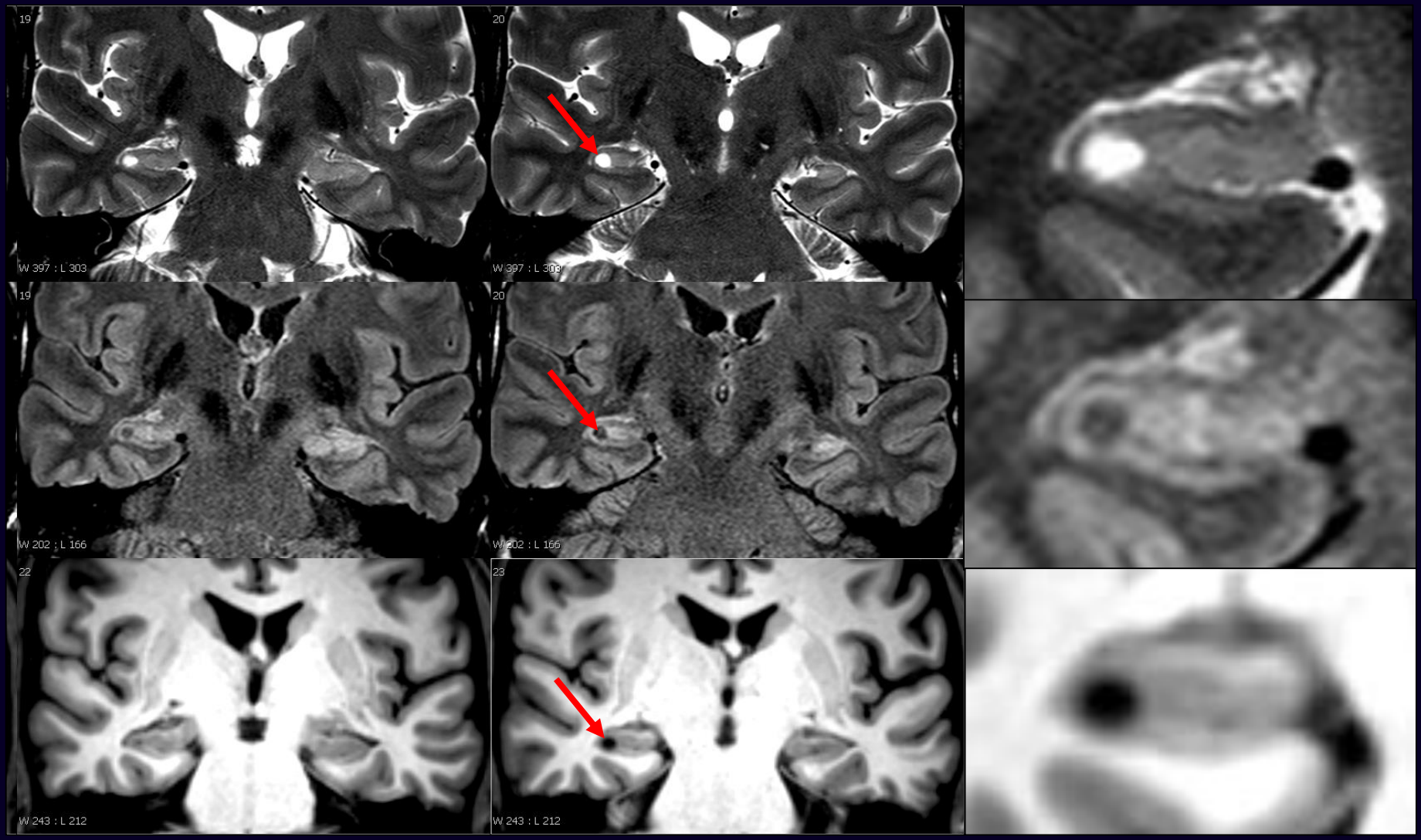
T1 T2

# NORMAL HIPPOCAMPUS: T2, 3.0 T

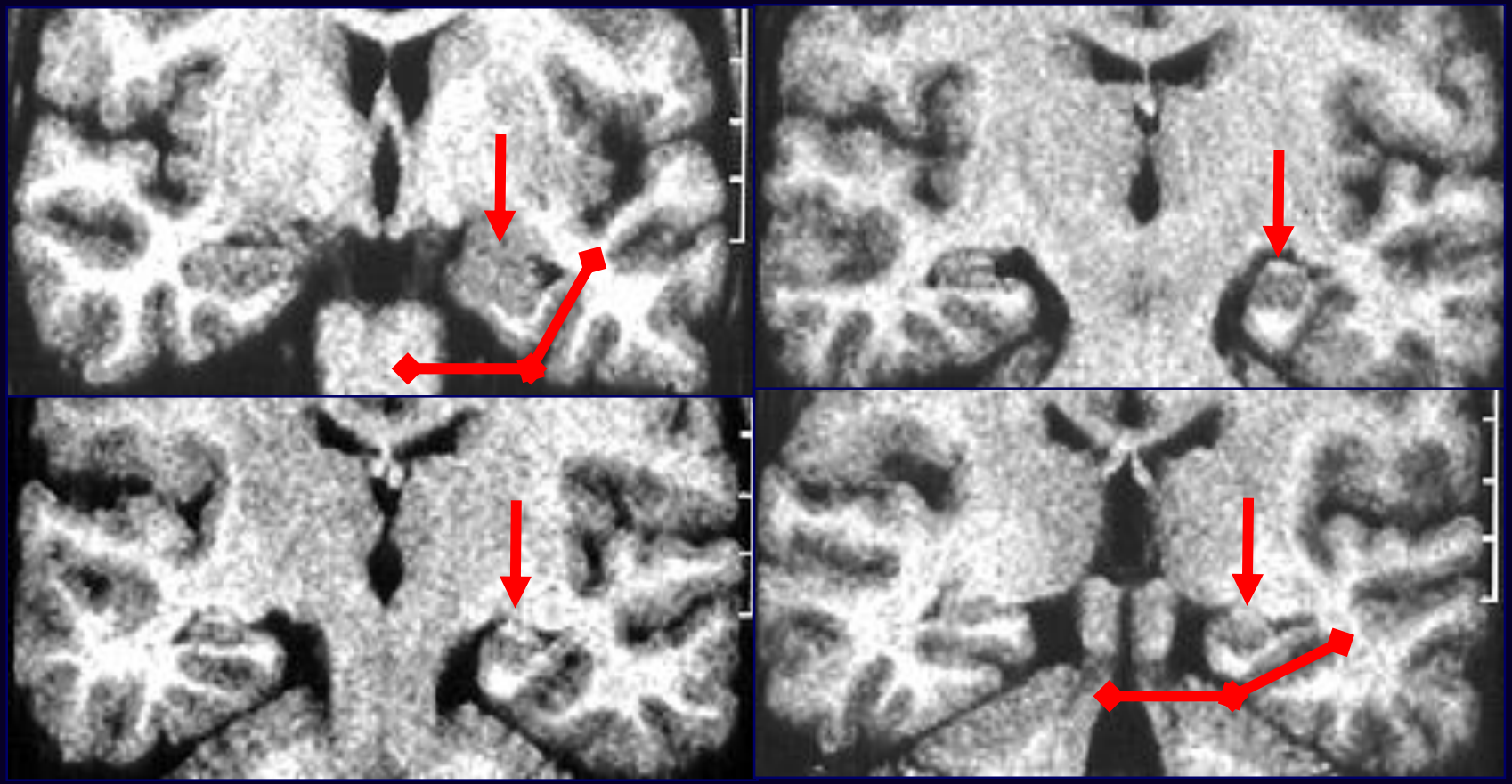





# Normal variation: widened hippocampal sulcus versus HS



# Developmental disturbance:
# Hippocampal malrotation



Barsi P et al, Neuroradiology 2000; 42: 339–345

# Hippocampal malrotation: Conclusions

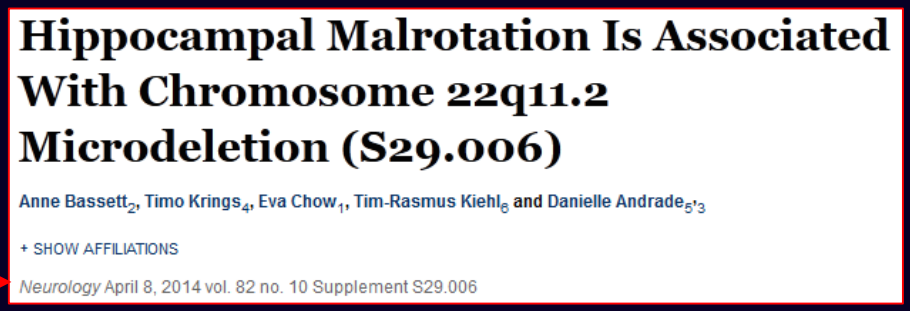
- Mild disorder with possible developmental origin
- Not the cause of epilepsy
- Possible warning sign of mild hemispheric developmental growth disorder

Barsi P, Kenéz J, Solymosi D et al, Neuroradiology 2000; 42: 339-345

# Hippocampal malrotation – a subject of debate

| Pro |
| --- |
| Depondt C et al, Neurology 2002; 58: 1429 |
| Thom M et al, Neurology 2002; 58: 1683 |
| Bernasconi et al, Brain 2005; 128: 2442 |
| Lewis DV et al, Epilepsia 2006; Sup. 4 p. 16 |
| Gamss RP et al, AJNR 2009; 30: 1571 |
| Stiers P et al, Epilepsia 2010; 51: 546 |
| Kuchukidze G et al, Neurology 2010;74:1575 |
| Yeghiazaryan NS et al, Epilepsy&Behavior 2010; 18: 502 |
| Voets NL et al, Neurology 2011; 76: 138 |
| McLean J – PhD Thesis, University of Glasgow, 2012 |
| Bassett A et al, Neurology 2014; 82/S10: S29.006 |

| Contra |
| --- |
| Bajic D et al, Eur Radiol 2008; 18: 138 |
| Bajic D et al, Eur Radiol 2009; 19: 2544 |
| Raininko R et al, AJNR 2010; 31: E39 |
| Bajic D – PhD thesis, Uppsala Univ, 2010 |



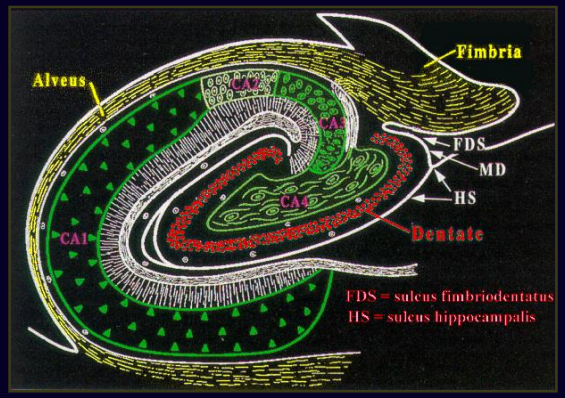
**Hippocampal Malrotation Is Associated With Chromosome 22q11.2 Microdeletion (S29.006)**

Anne Bassett[2], Timo Krings[4], Eva Chow[1], Tim-Rasmus Kiehl[6] and Danielle Andrade[5,3]

+ SHOW AFFILIATIONS

*Neurology* April 8, 2014 vol. 82 no. 10 Supplement S29.006

**Barsi P, Kenéz J, Solymosi D et al, Neuroradiology 2000; 42: 339-345**




# Hippocampal sclerosis (HS)

1. Most frequent epileptogenic abnormality
2. Basics: vulnerability of neurons of CA1, CA3 and CA4 sectors
3. Detected by MR with >90% sensitivity in cases of a neuronal loss >50%.

## PATHOLOGY

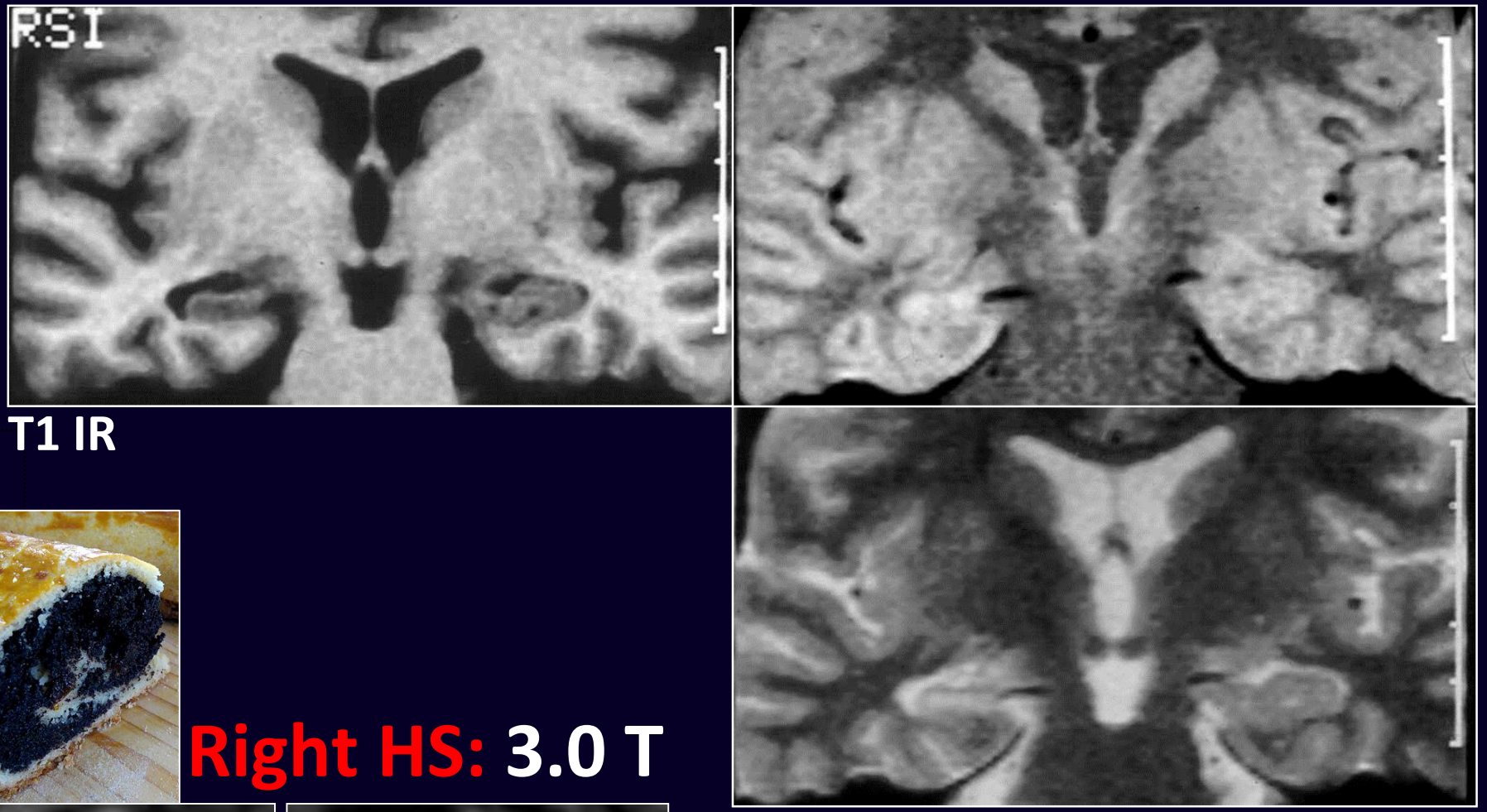
1. Atrophy
2. Disrupted internal structure
3. Gliosis
4. Widened T horn
5. Fornix atrophy
6. Mammillary atrophy

## MRI

1. Atrophy
2. Disrupted internal structure
3. T1 ↓, T2-FLAIR ↑
4. Widened T horn
5. Fornix atrophy
6. Mammillary atrophy

# Right HS: 0.5 T

PD

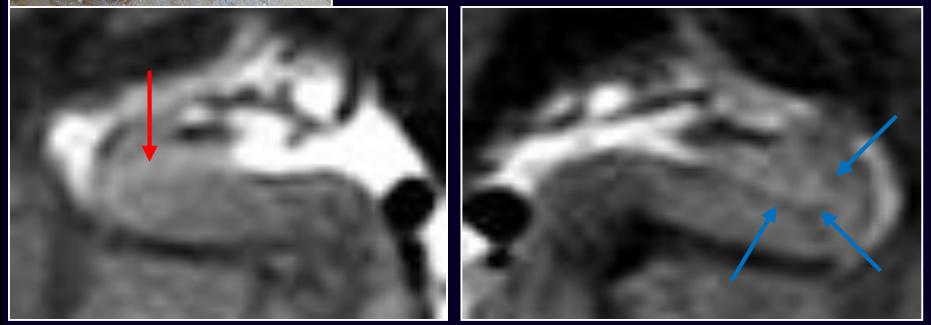



T1 IR

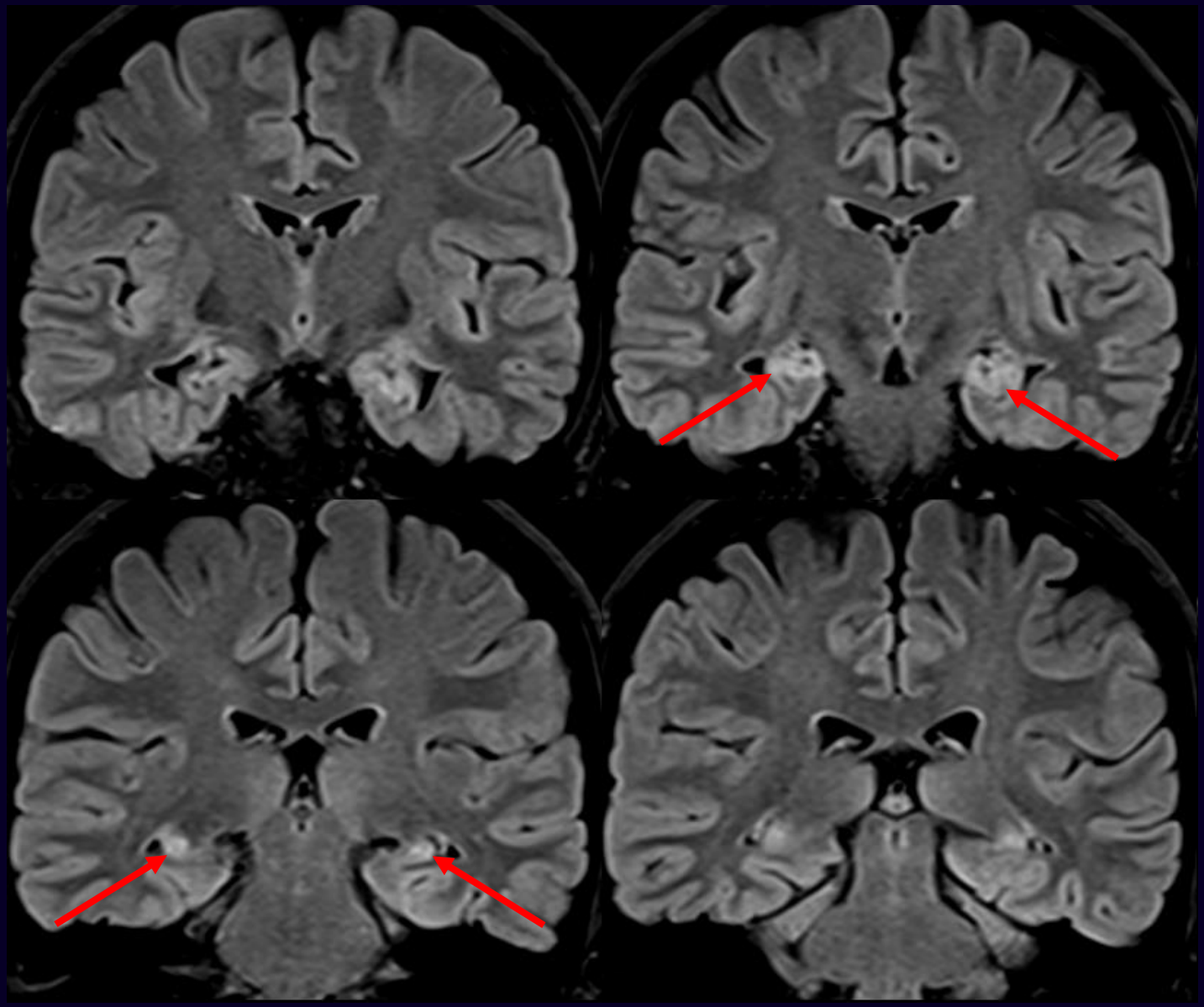
T2



# Right HS: 3.0 T

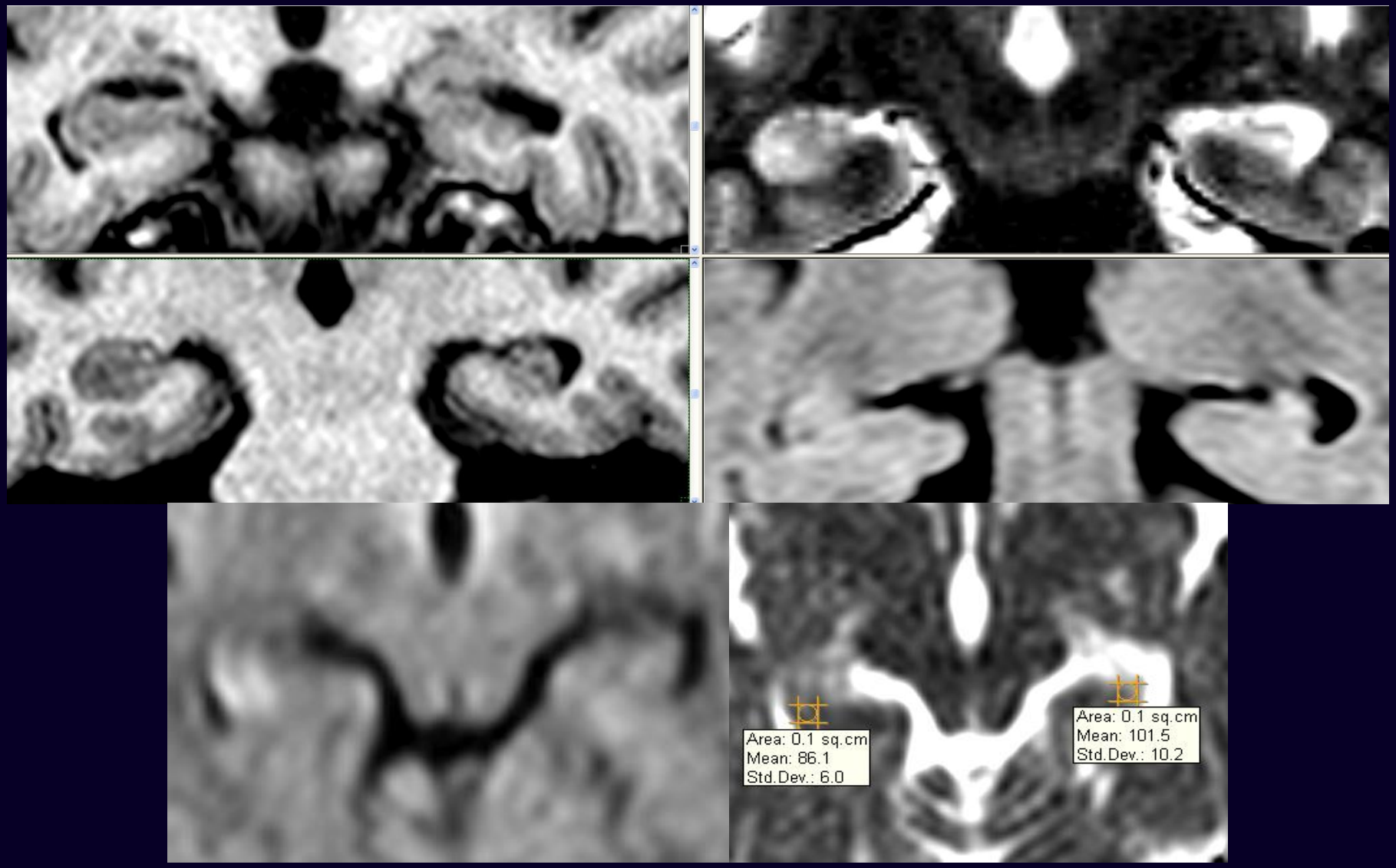


# Bilateral HS

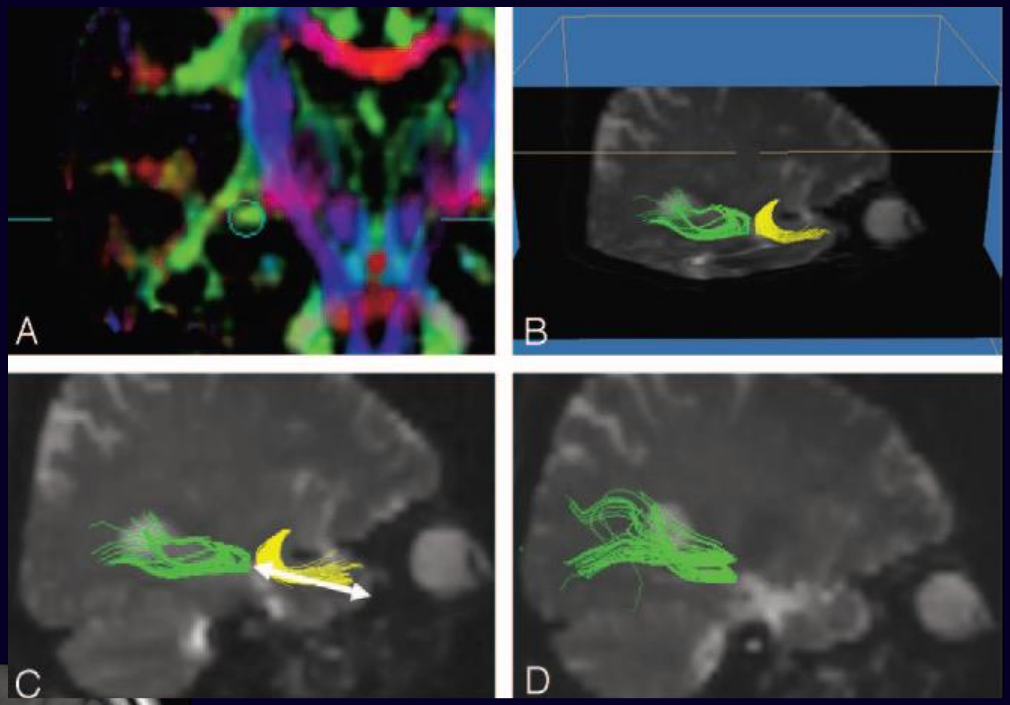


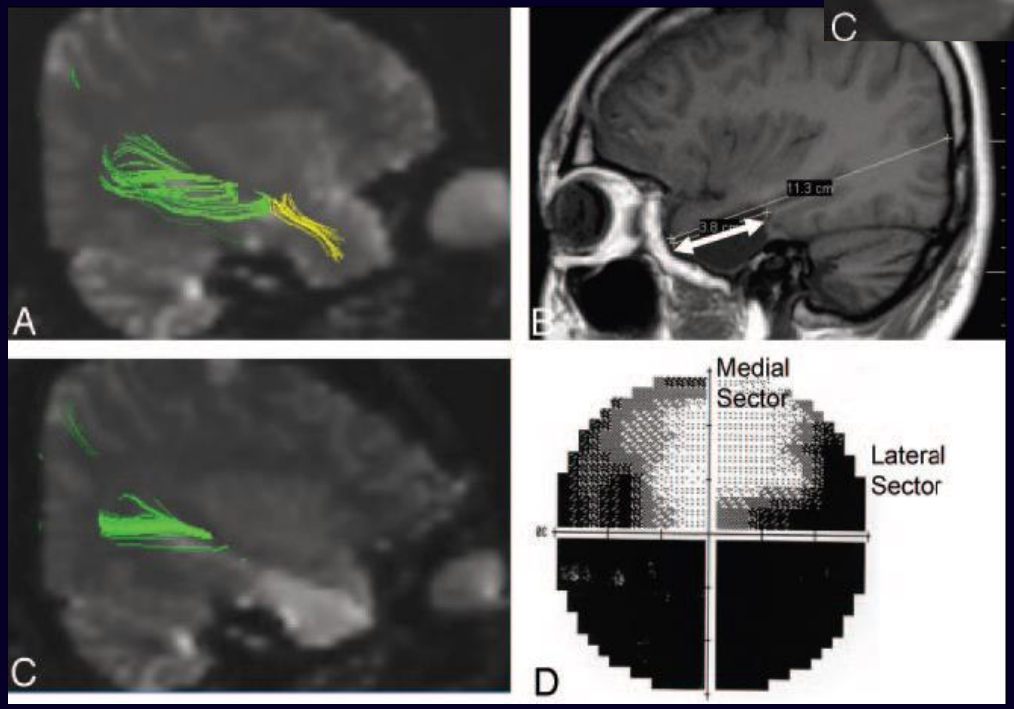
# Hippocampal sclerosis and status epilepticus

## 39 years old woman, left HS, right Hi oedema after STE



**Tractography of Meyer's loop before and after anterior T lobectomy to avoid visual field defect**



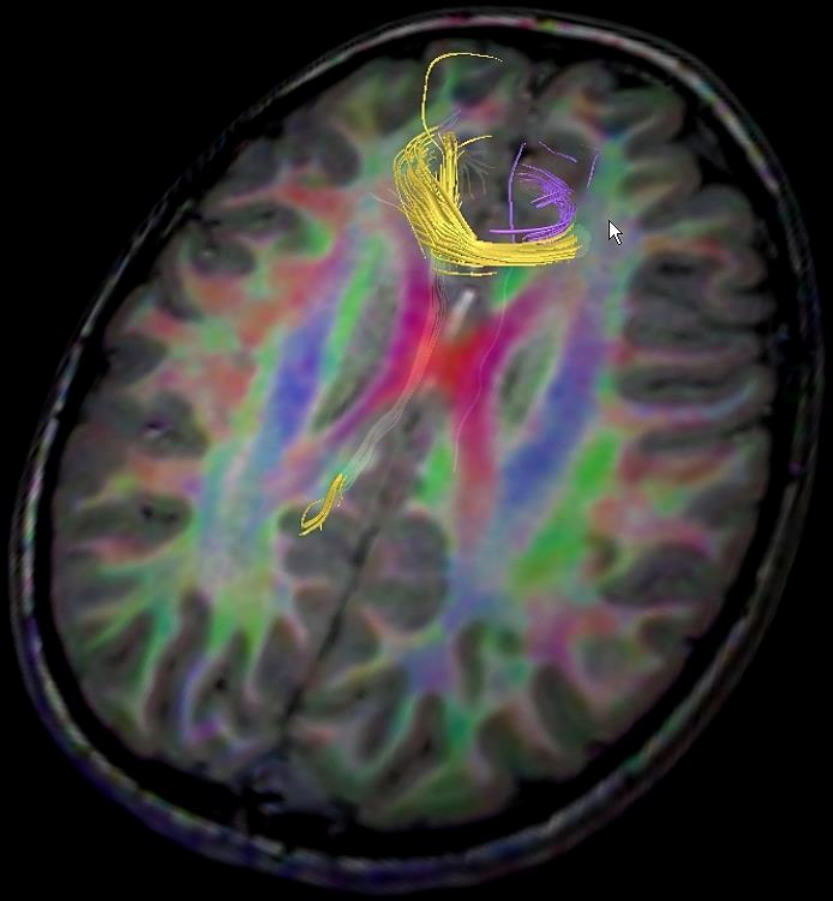



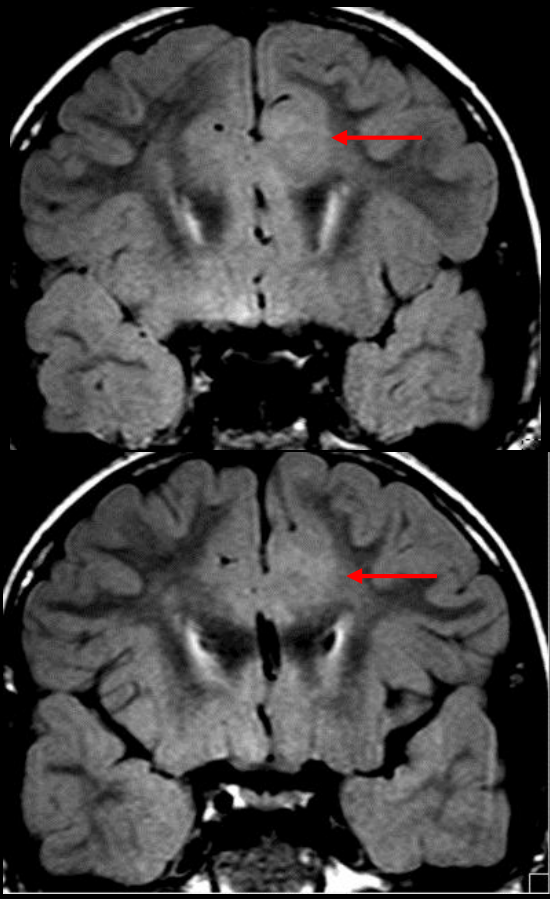

**Meyer's loop: green**
**Uncinate fasciculus : yellow**

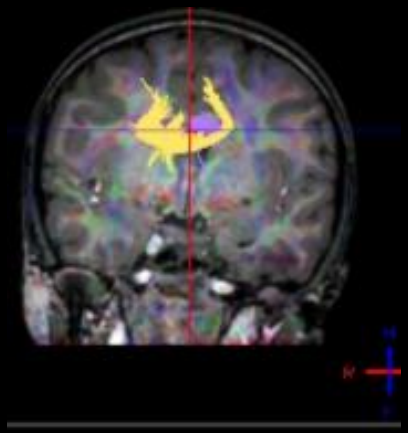
**Taoka T et al, AJNR 2008, 29: 1329-34**

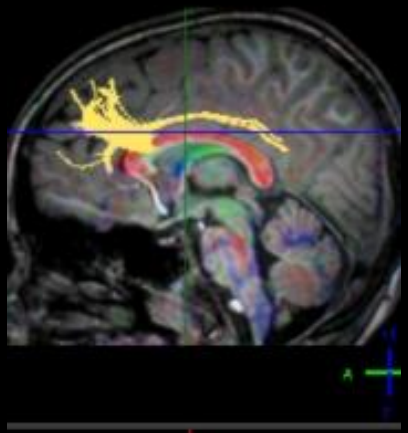
# Left frontal medial focal cortical dysplasia

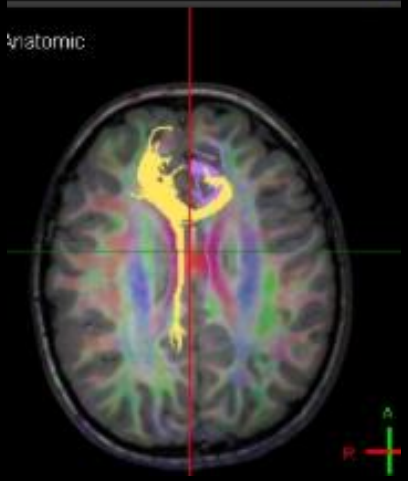
**Relative isolation of the lesion in regard to WM connections with other brain regions, probably explaining the focal nature of the seizures without a tendency for generalisation**



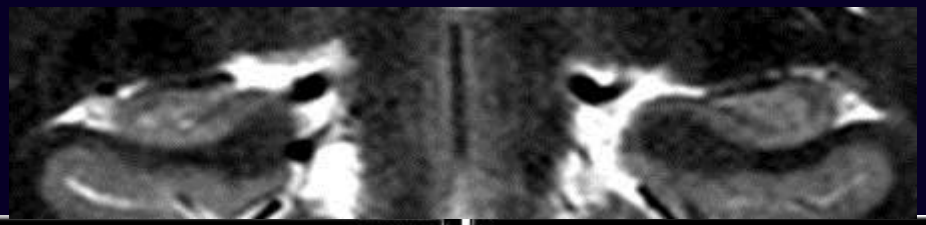




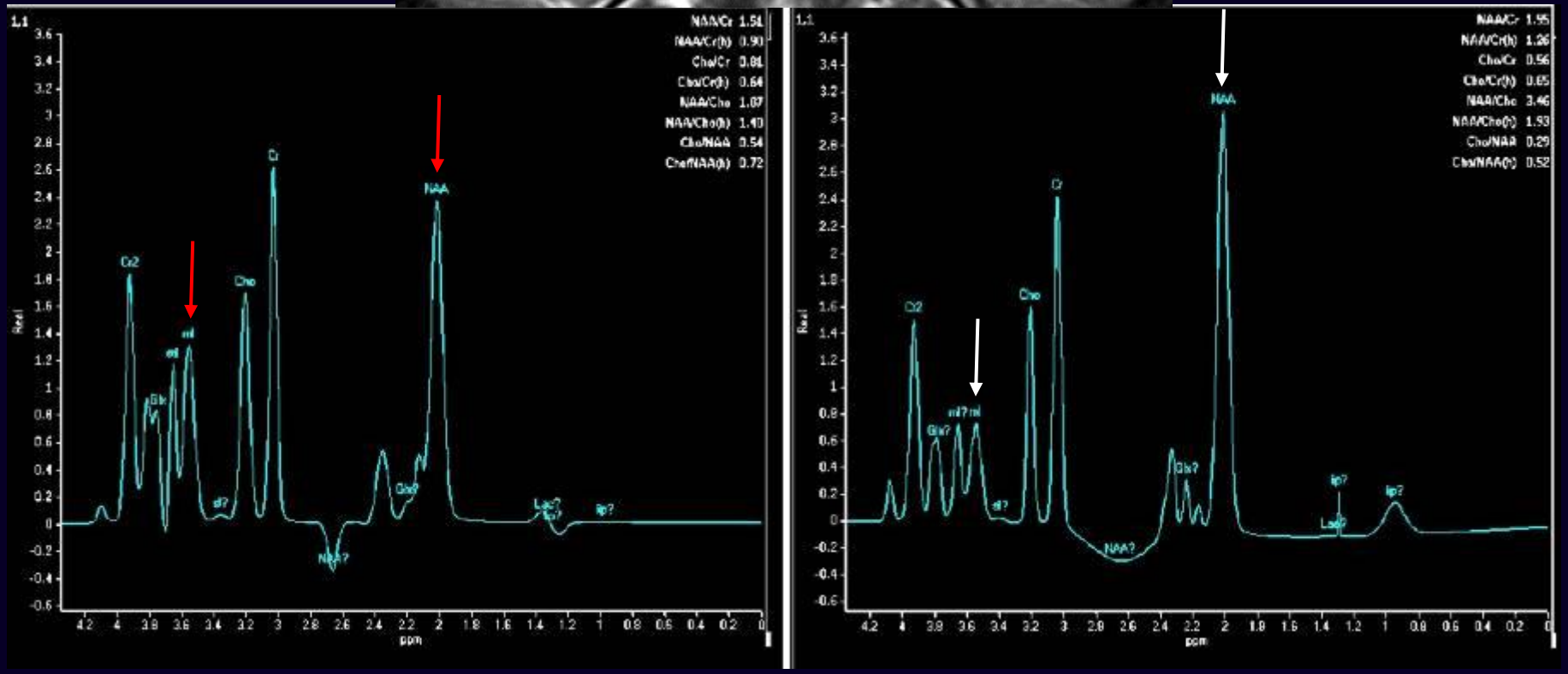




# Right hippocampal sclerosis



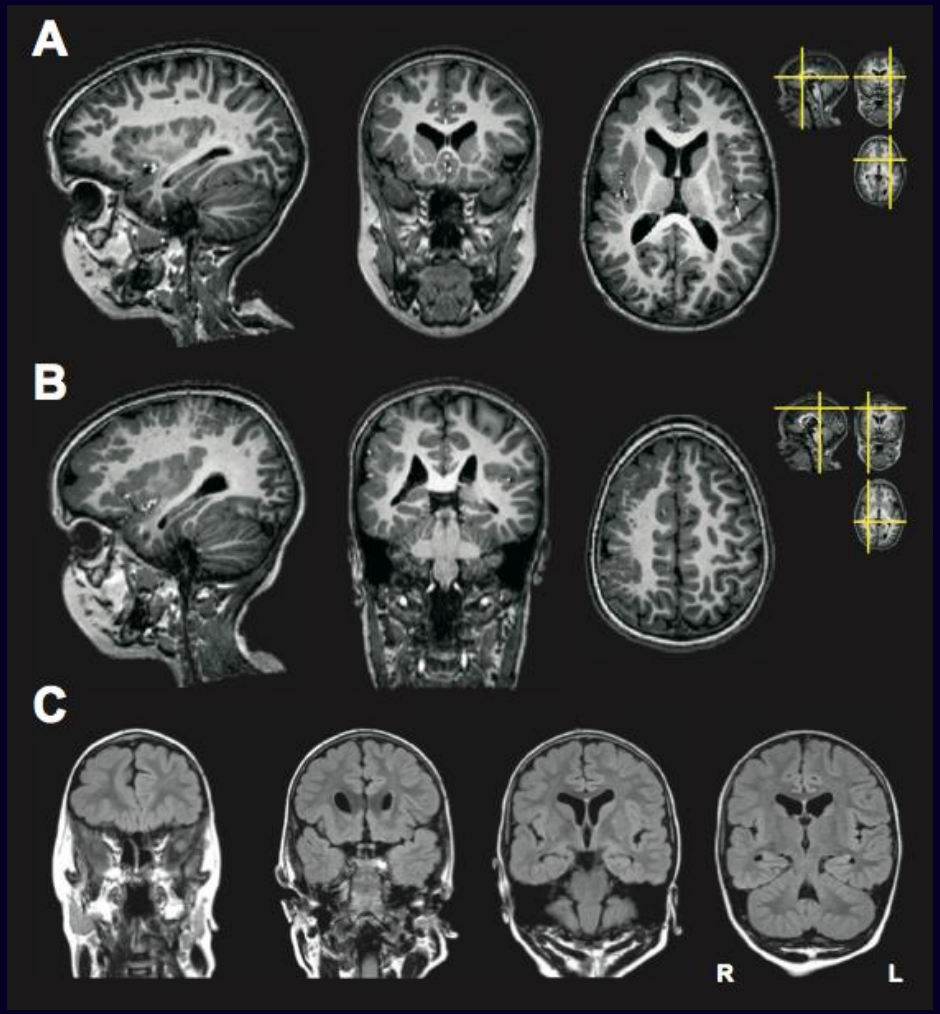
Bal



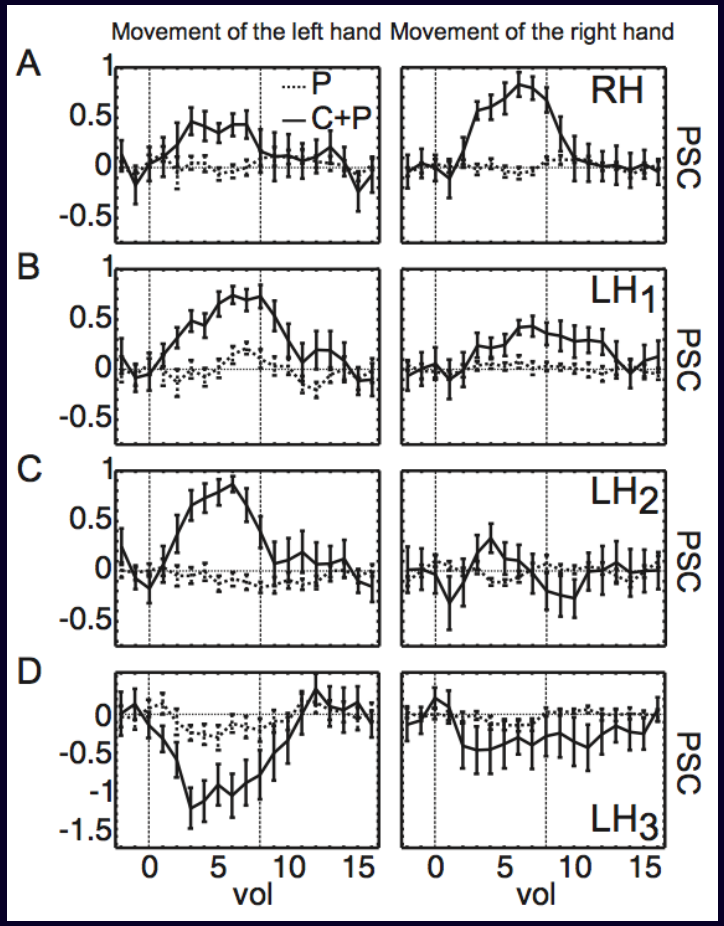

**TE=35 ms SV MRS**

**Decreased NAA and increased mI on the right side.**

# Clonazepam facilitates sensorimotor functional MRI in status epilepticus during sleep (ESES)




Extensive Rt H polymicrogyria

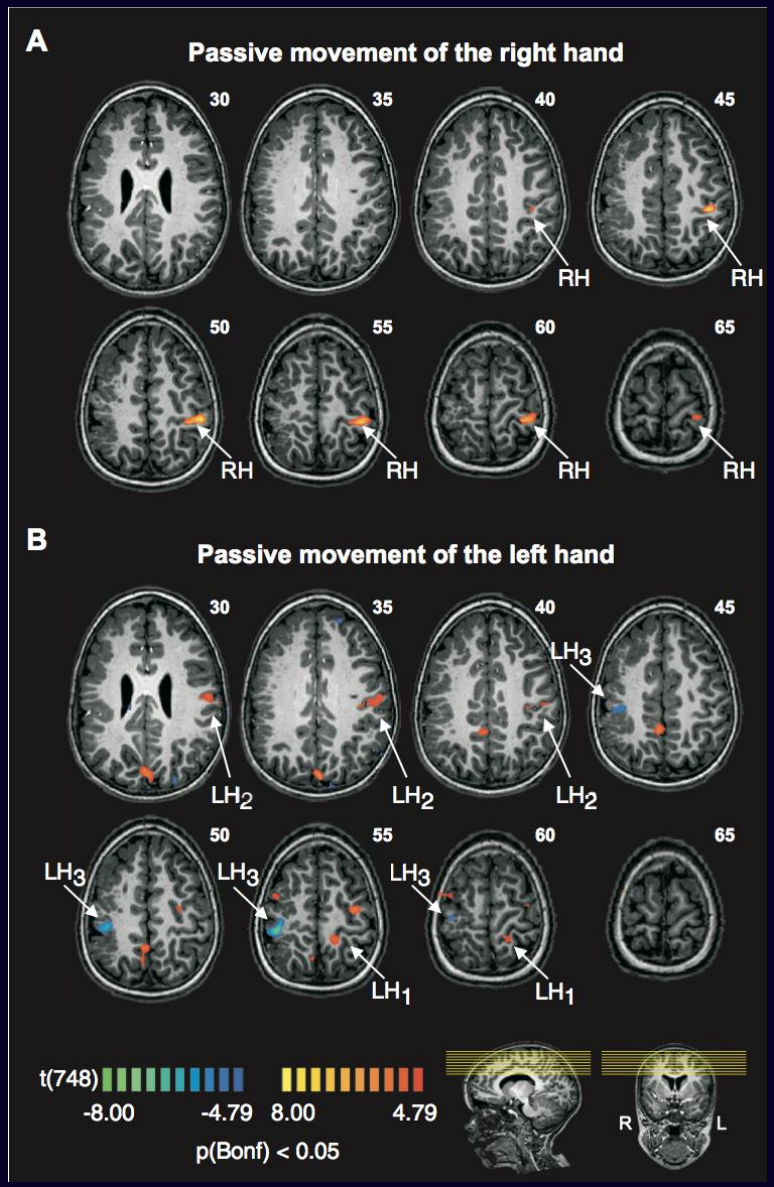



No activation with propofol alone

Activation with propofol and clonazepam

Kozák LR, Hegyi M, Barsi P et al, Clin Neurosci 2009; 62: 130

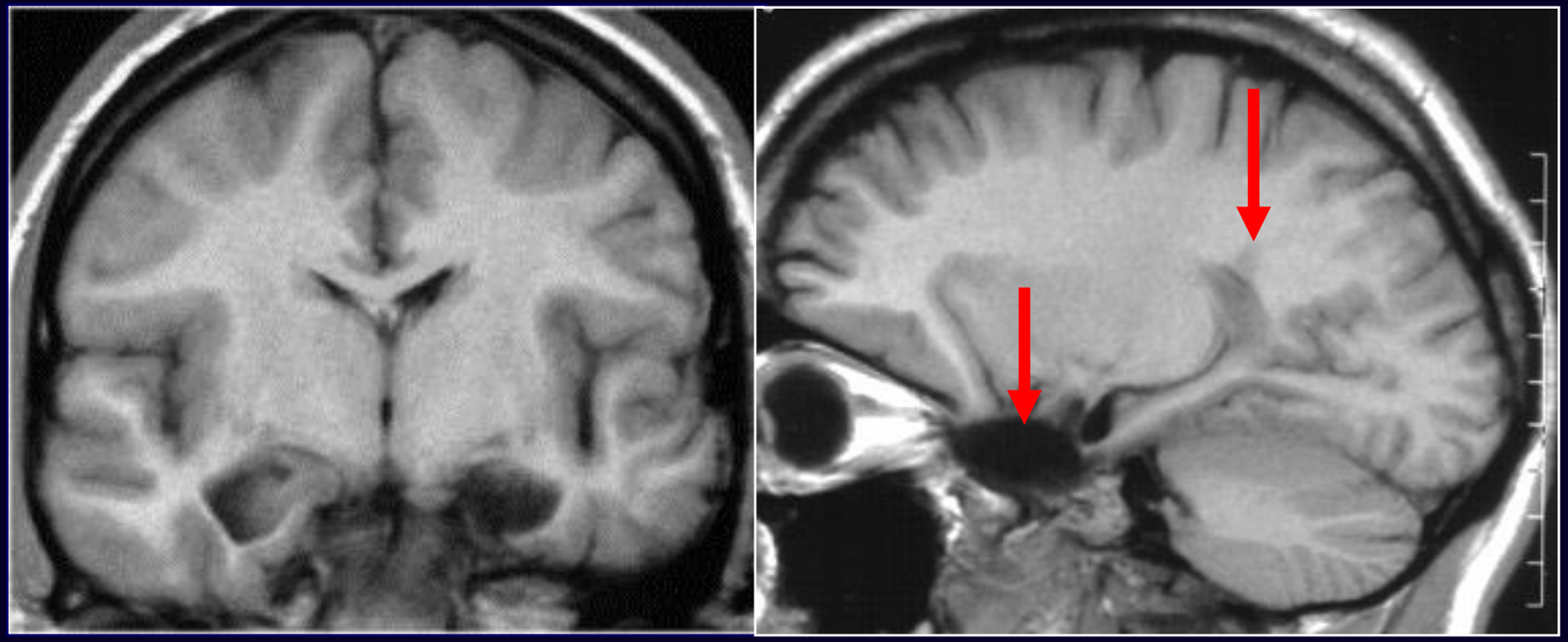
# Clonazepam facilitates sensorimotor functional MRI in status epilepticus during sleep (ESES)




**Successful fMRI with propofol and clonazepam shows redistribution of the right hemispheric sensorymotor function to the normal left side, opening a possible way for surgical planning.**

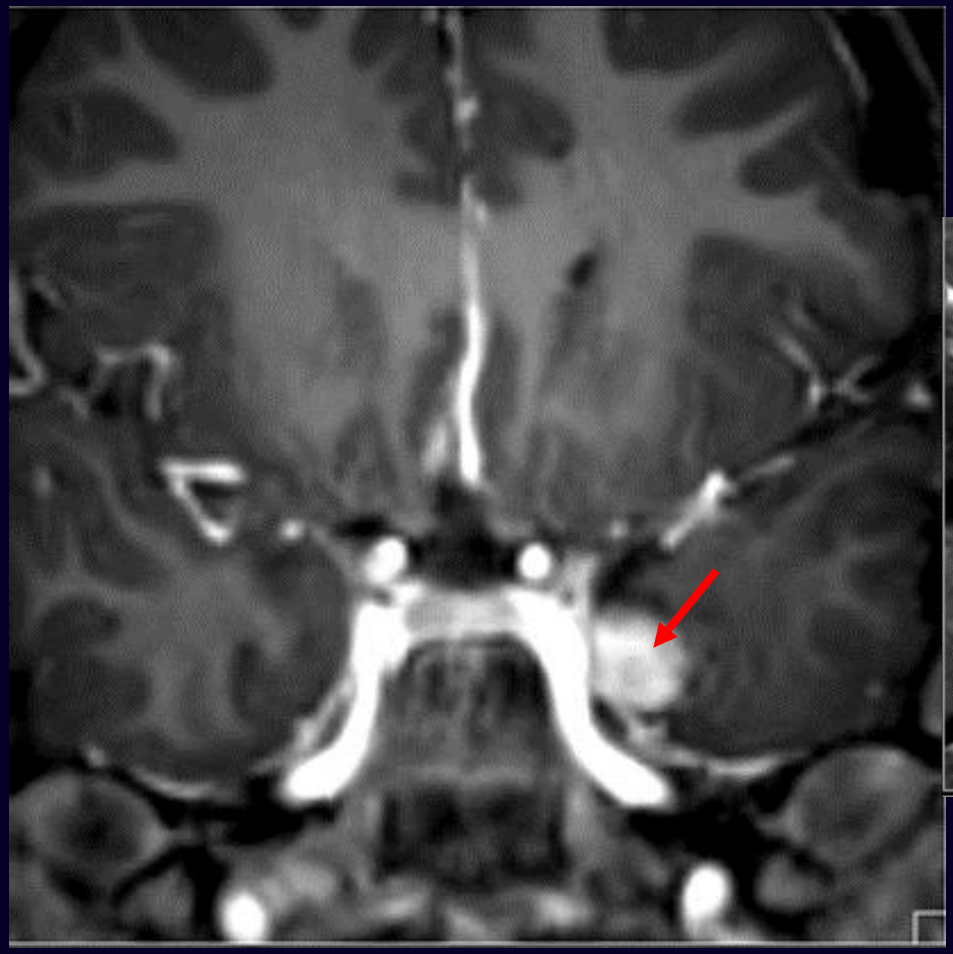
Kozák LR, Hegyi M, Barsi P et al, Clin Neurosci 2009; 62: 130

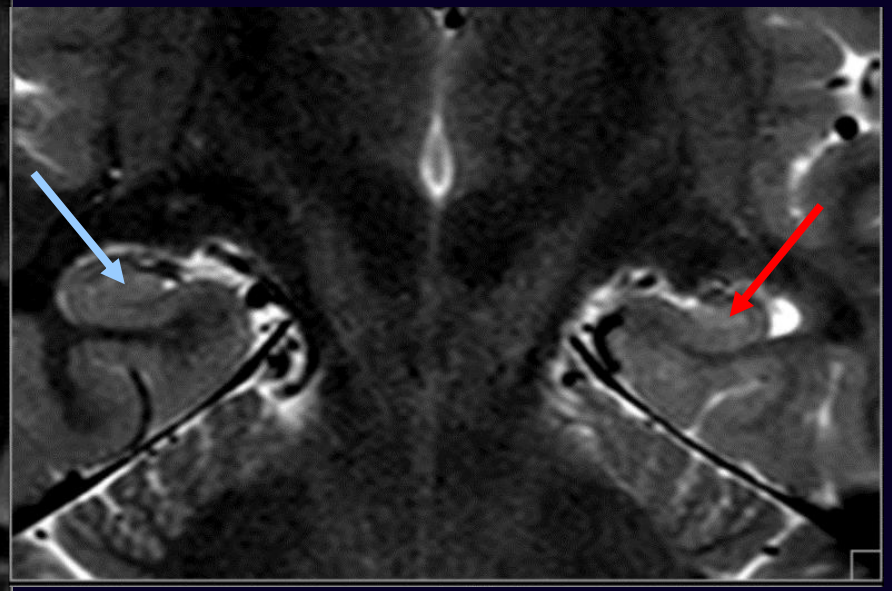
# Double pathology



**Follow-up MRI after left T lobectomy: bad epileptological result explained by a small gray matter heterotopia overlooked on initial MRI.**

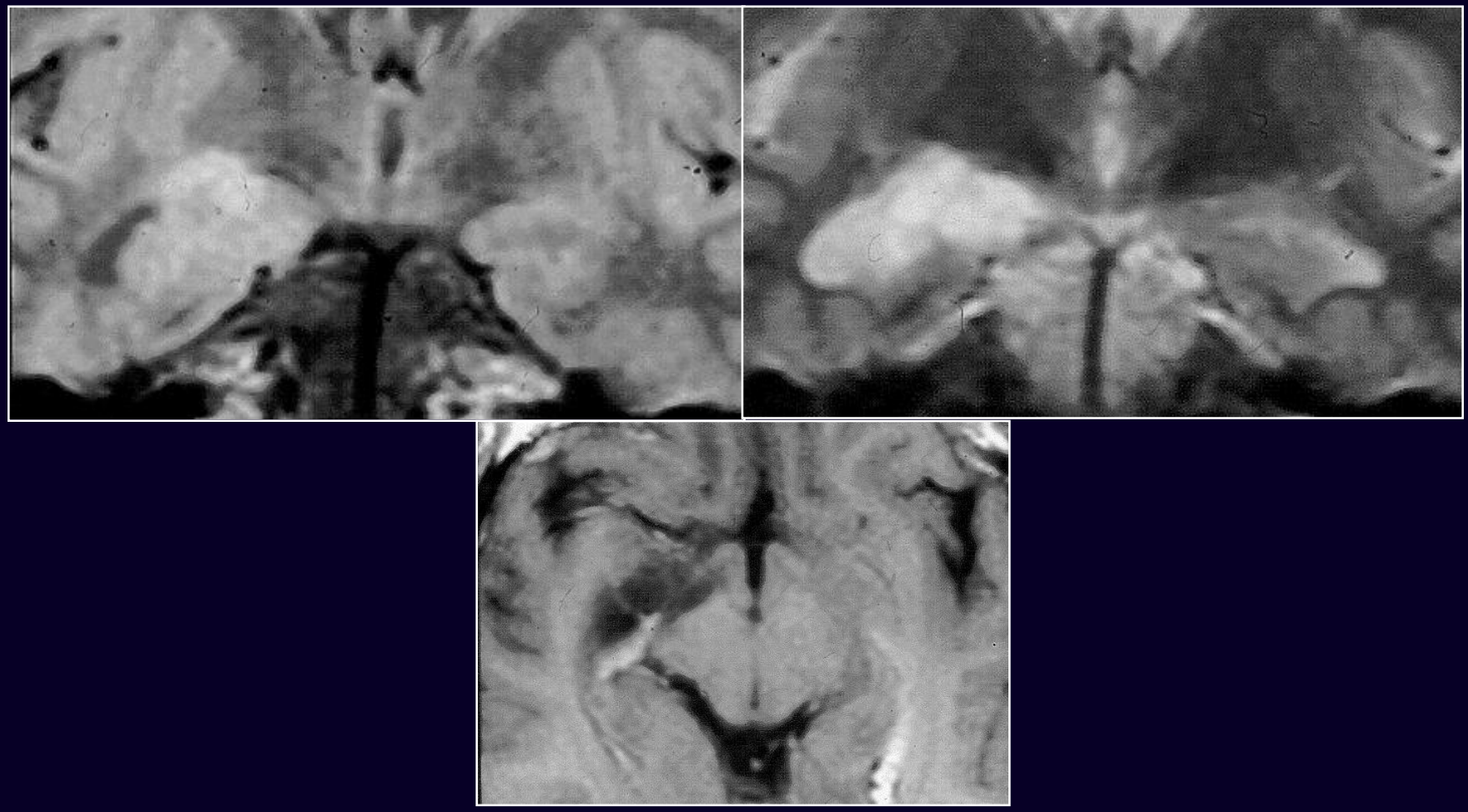
# Double pathology





Left T medial ganglioglioma and left HS

# Other hippocampal pathologies: glioma



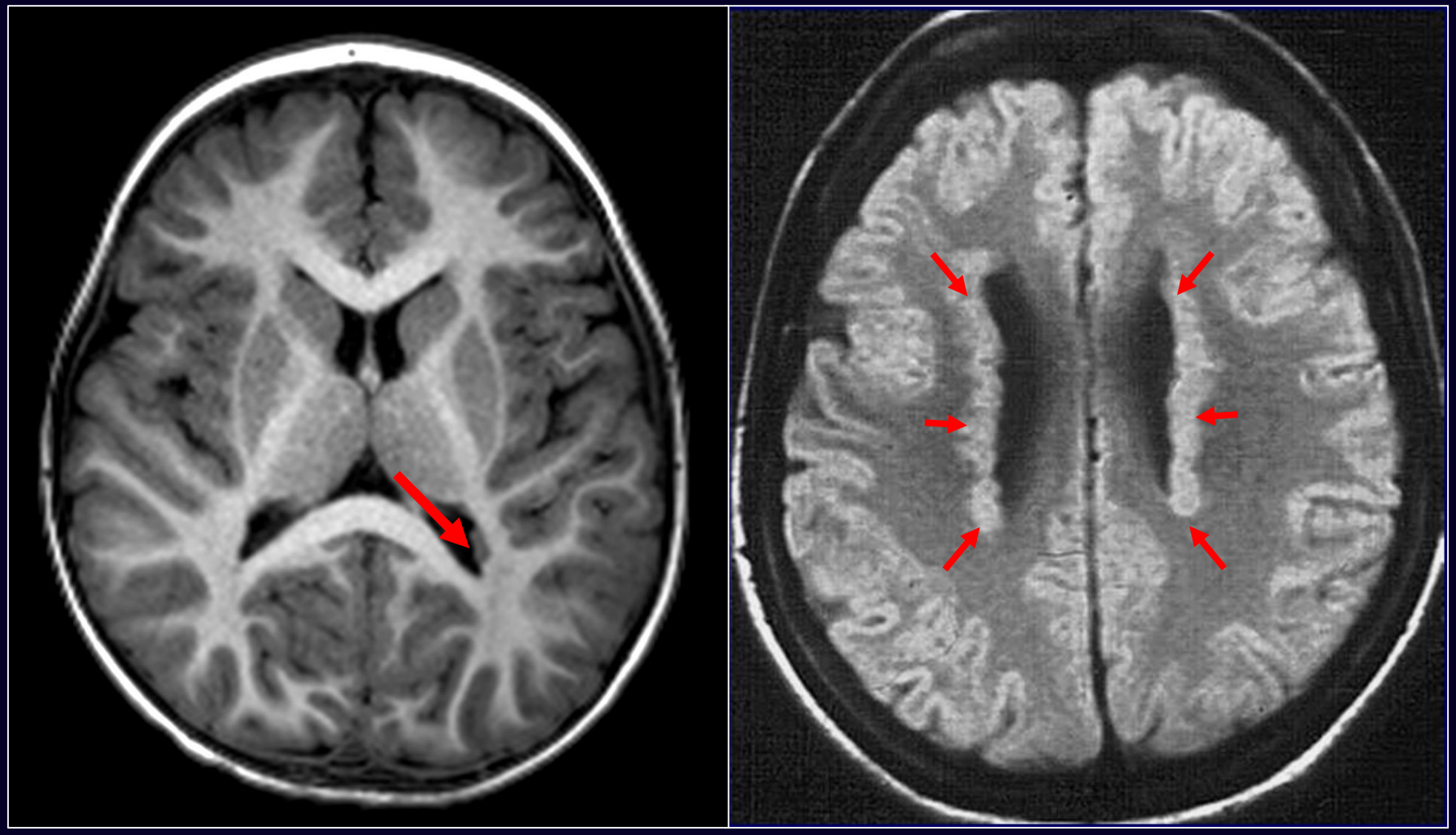
# Malformations of cortical development (MCDs)

# Unpleasant characteristics of malformations of cortical development

- Rare
- Frequent coincidence of different types
- Frequent lack of visible external symptoms
- Very small sometimes
- Size and severity of clinical symptoms not directly proportionate

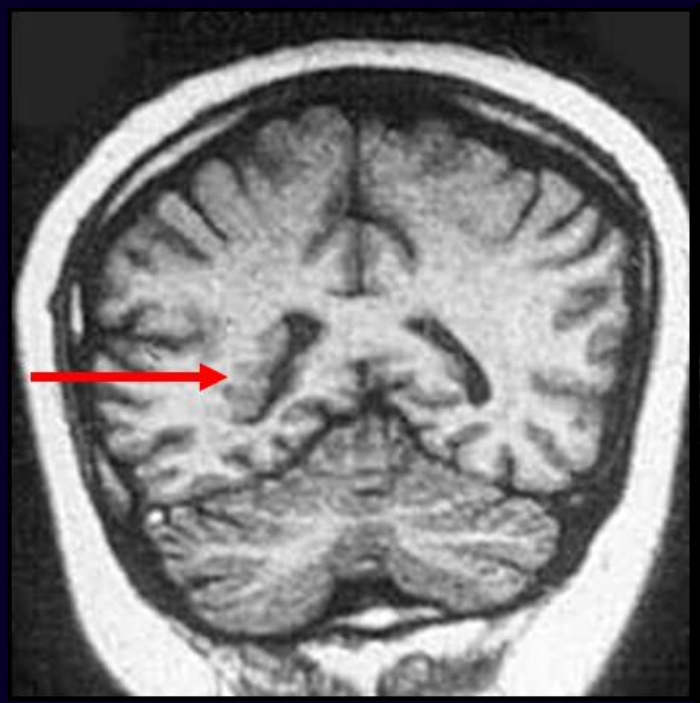
# Small or large

## Clinical state not necessarily proportionate

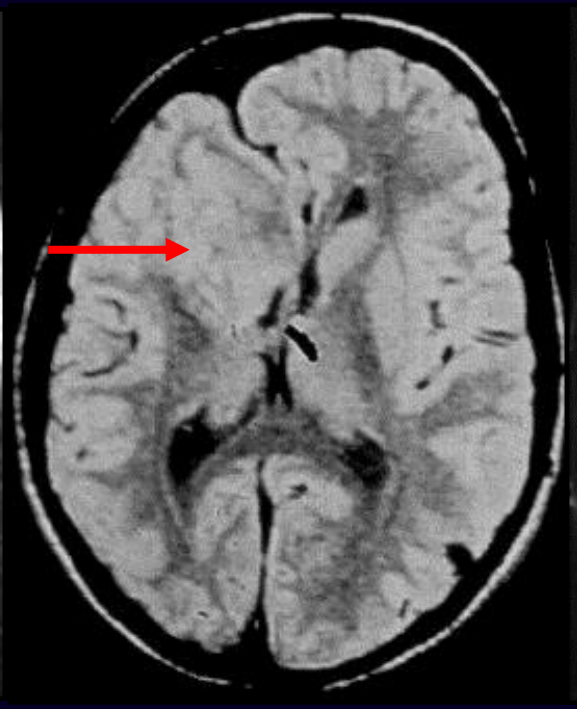


# The most frequent MCDs

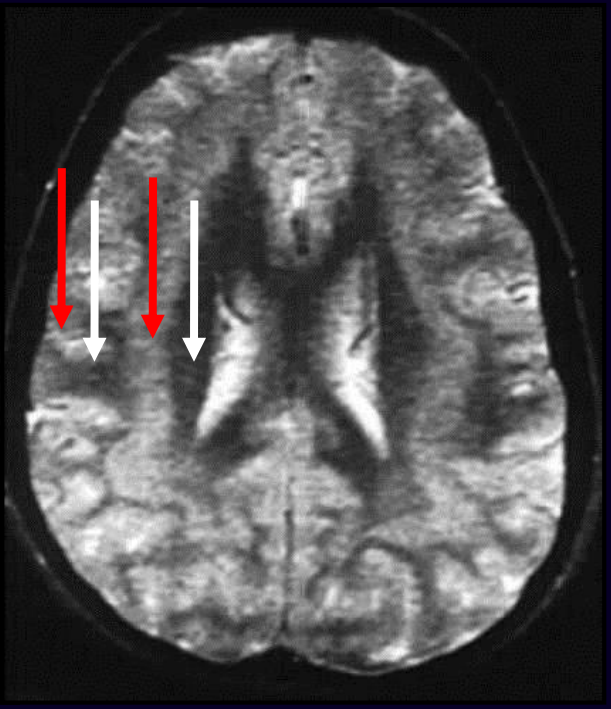
## Grey matter heterotopia



Subependymal



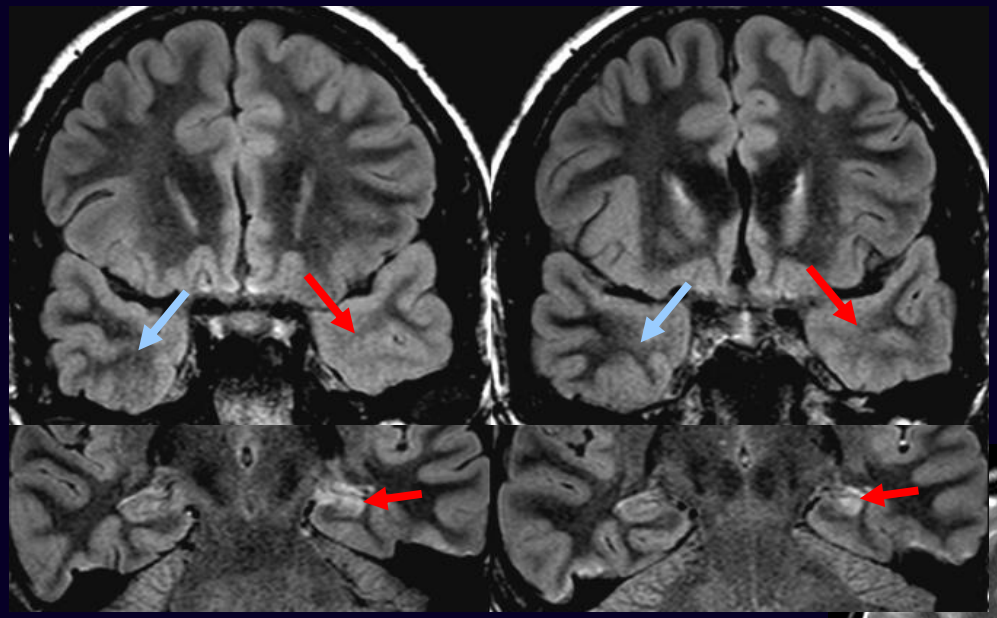
Focal subcortical



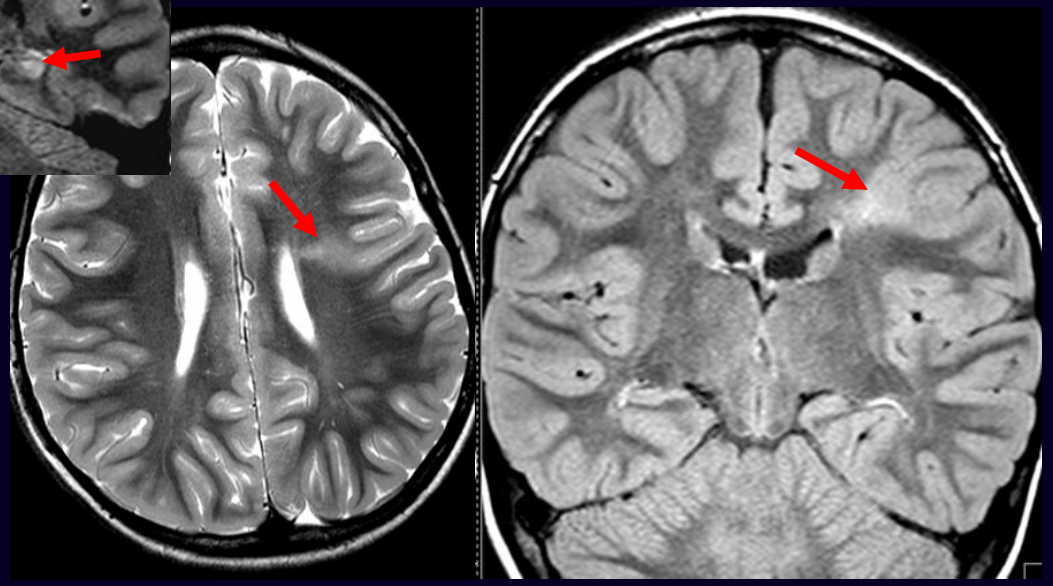
Diffuse subcortical

# The most frequent MCDs

## Focal cortical dysplasia (FCD)



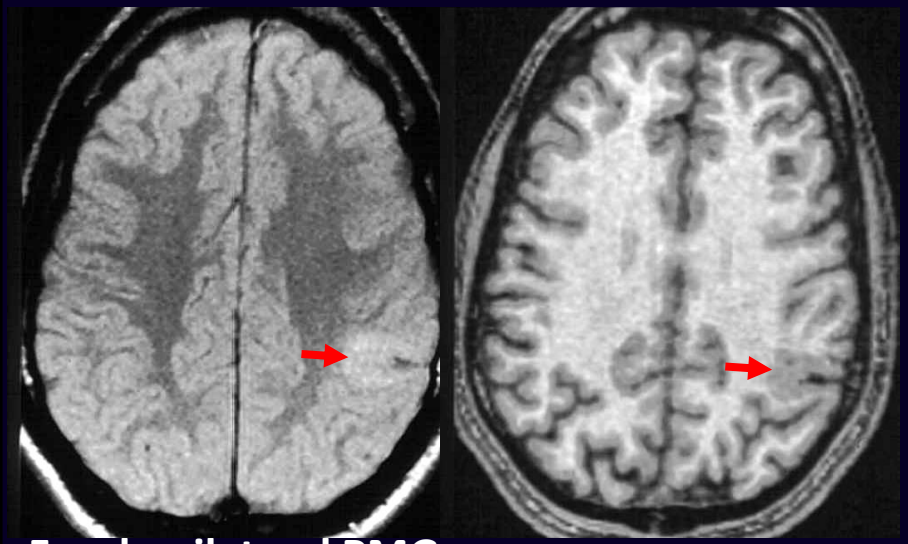
(Cyto)architectonic – Palmini 1b-2a – FCD 3a (with HS)



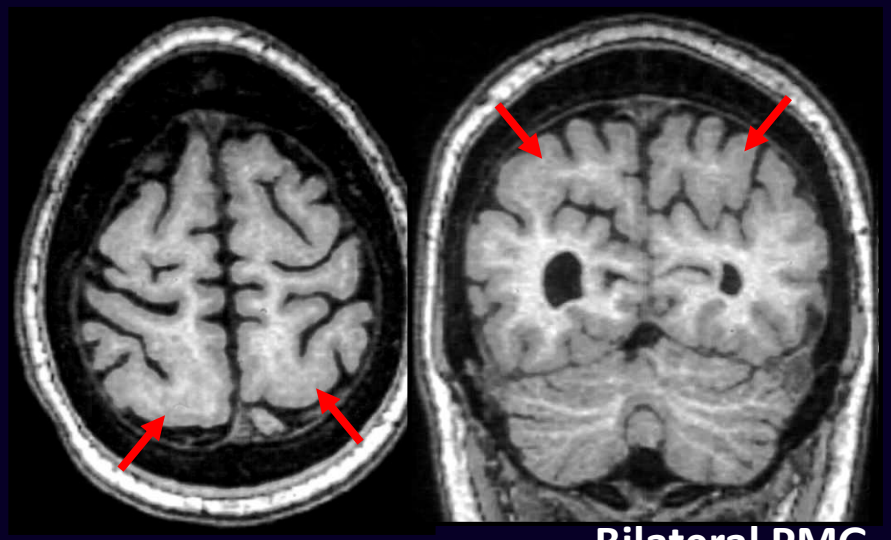
Taylor - Palmini 2b – FCD 2b

# The most frequent MCDs

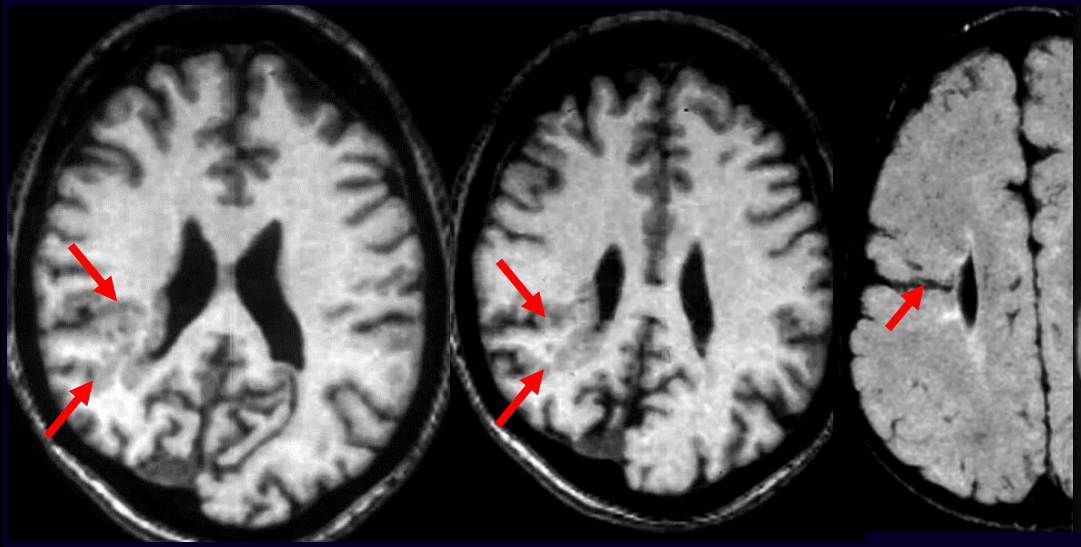
## Polymicrogyria and schizencephaly



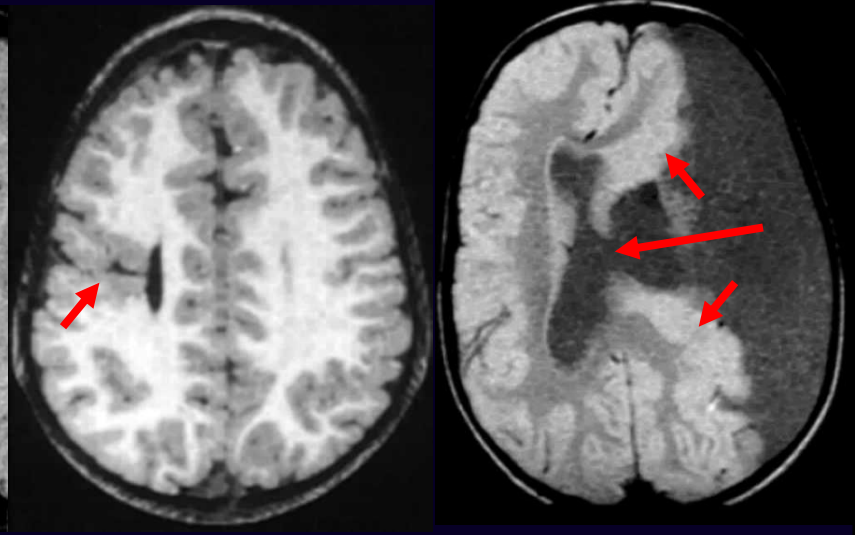
Focal unilateral PMG



Bilateral PMG



Closed lip SCH



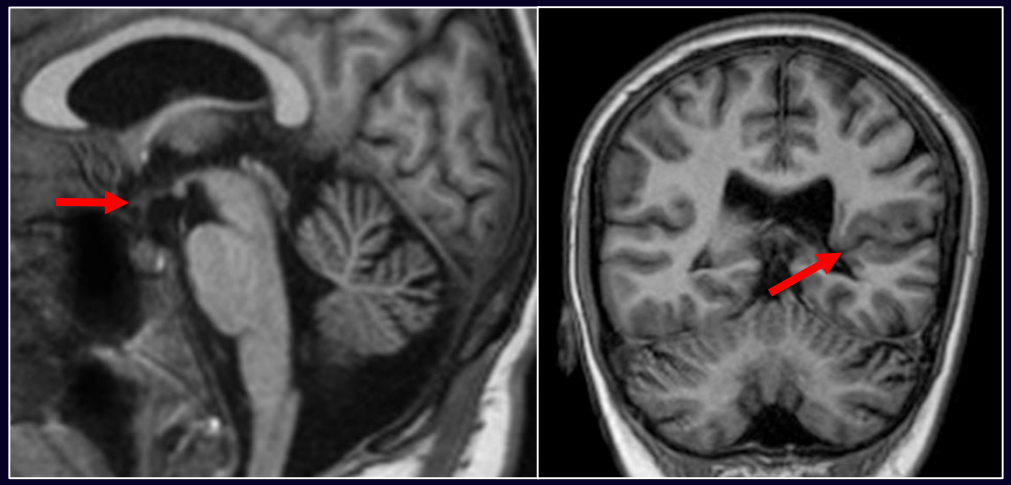
Open lip

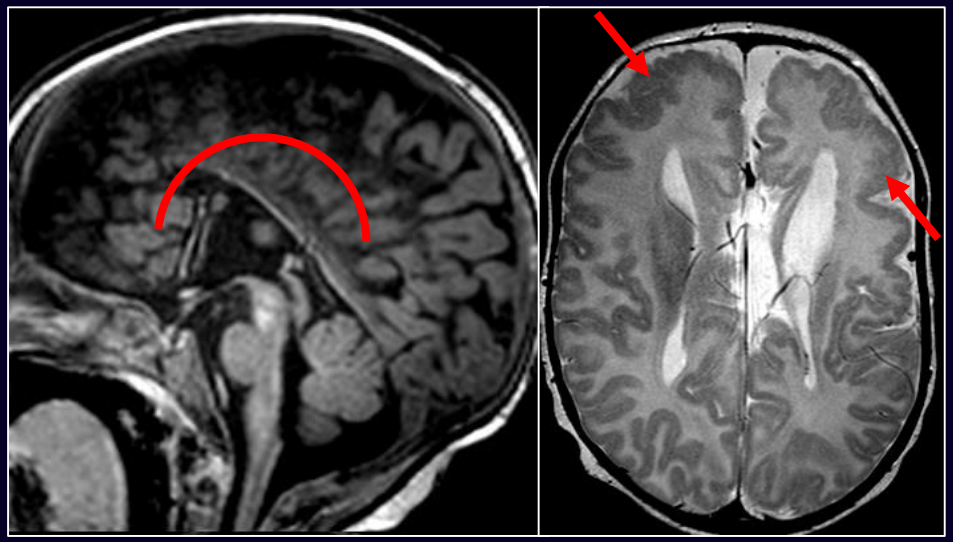
# The tools of the neuroradiologist

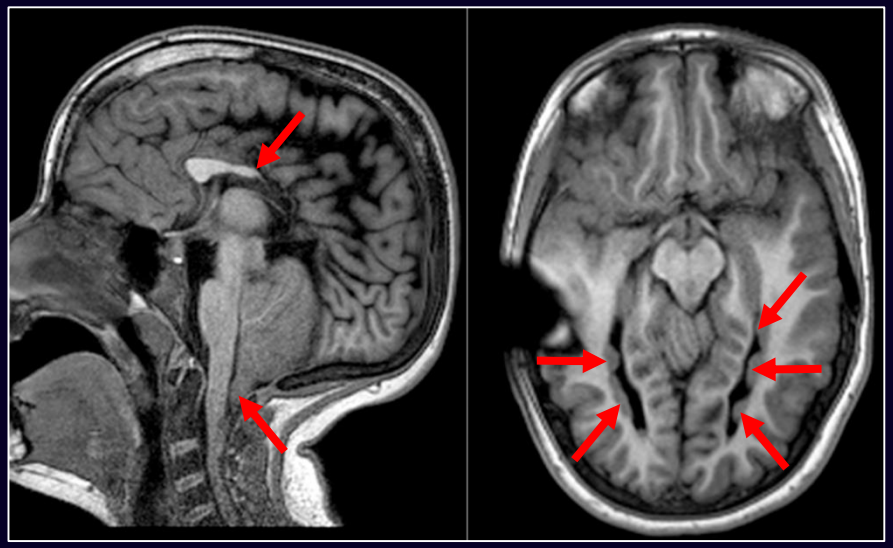
- Proper MR protocol
- Looking for patterns
- Healthy scepticism
- Handbooks
- Consultation

# How to find the MCDs?

## 1. Look at the midline!



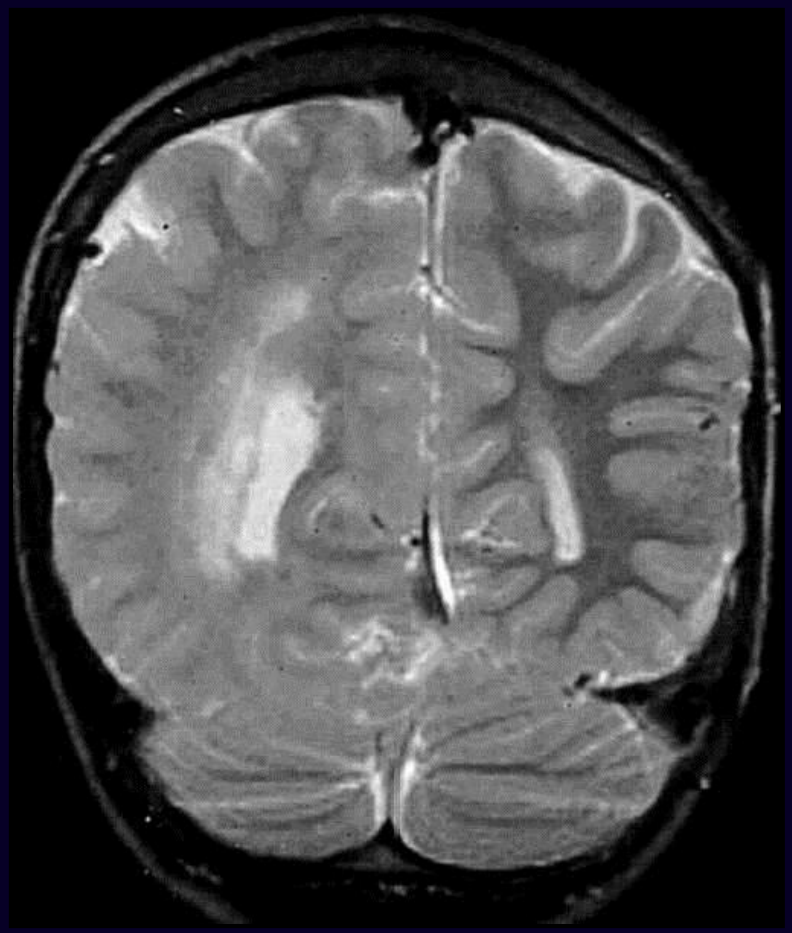


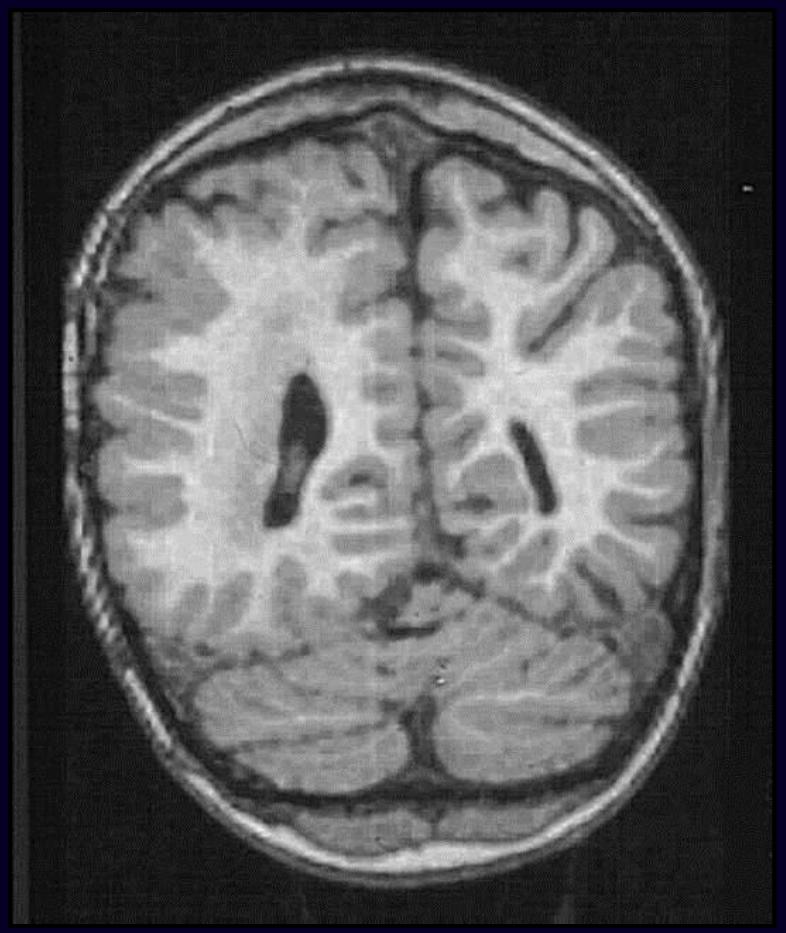


# How to find the MCDs?

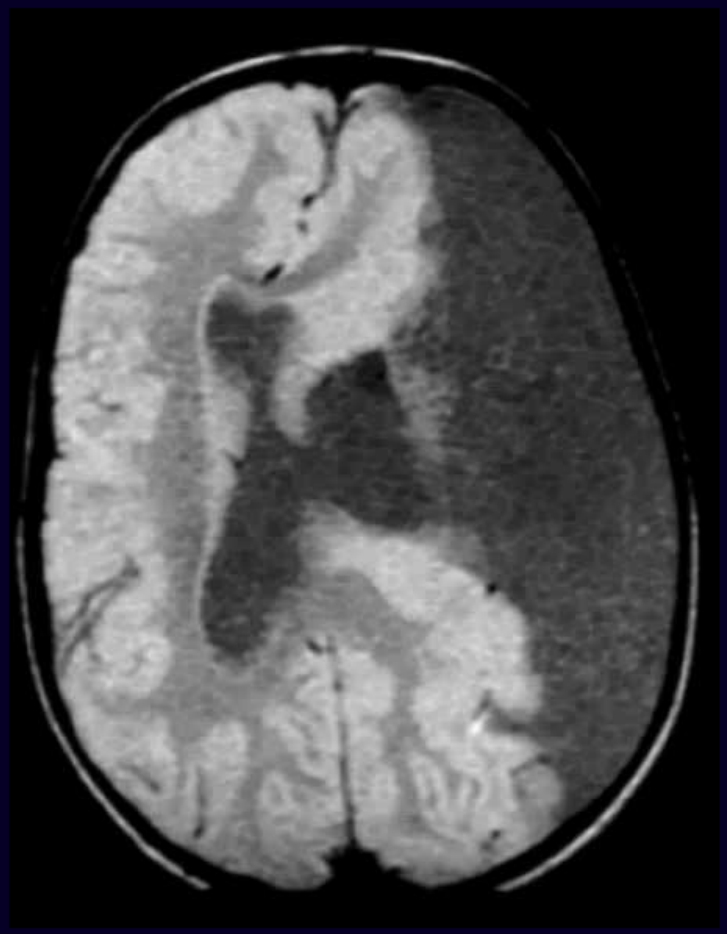
## 2. Asymmetries

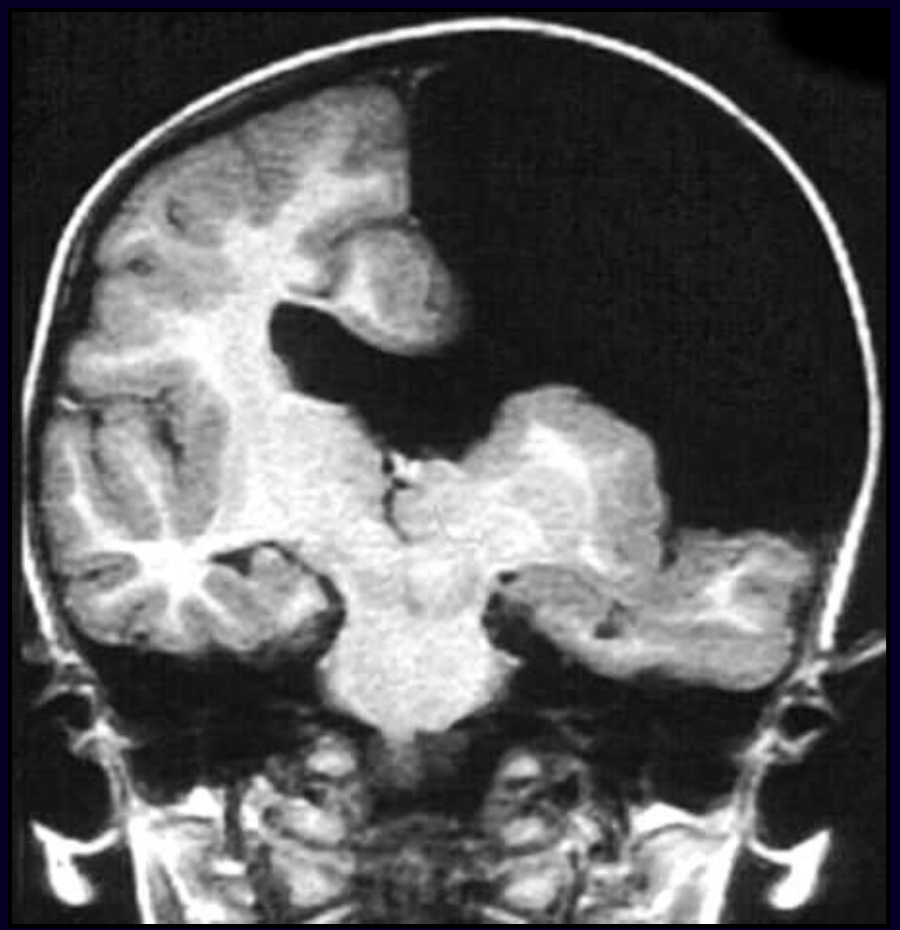
# Hemimegalencephaly



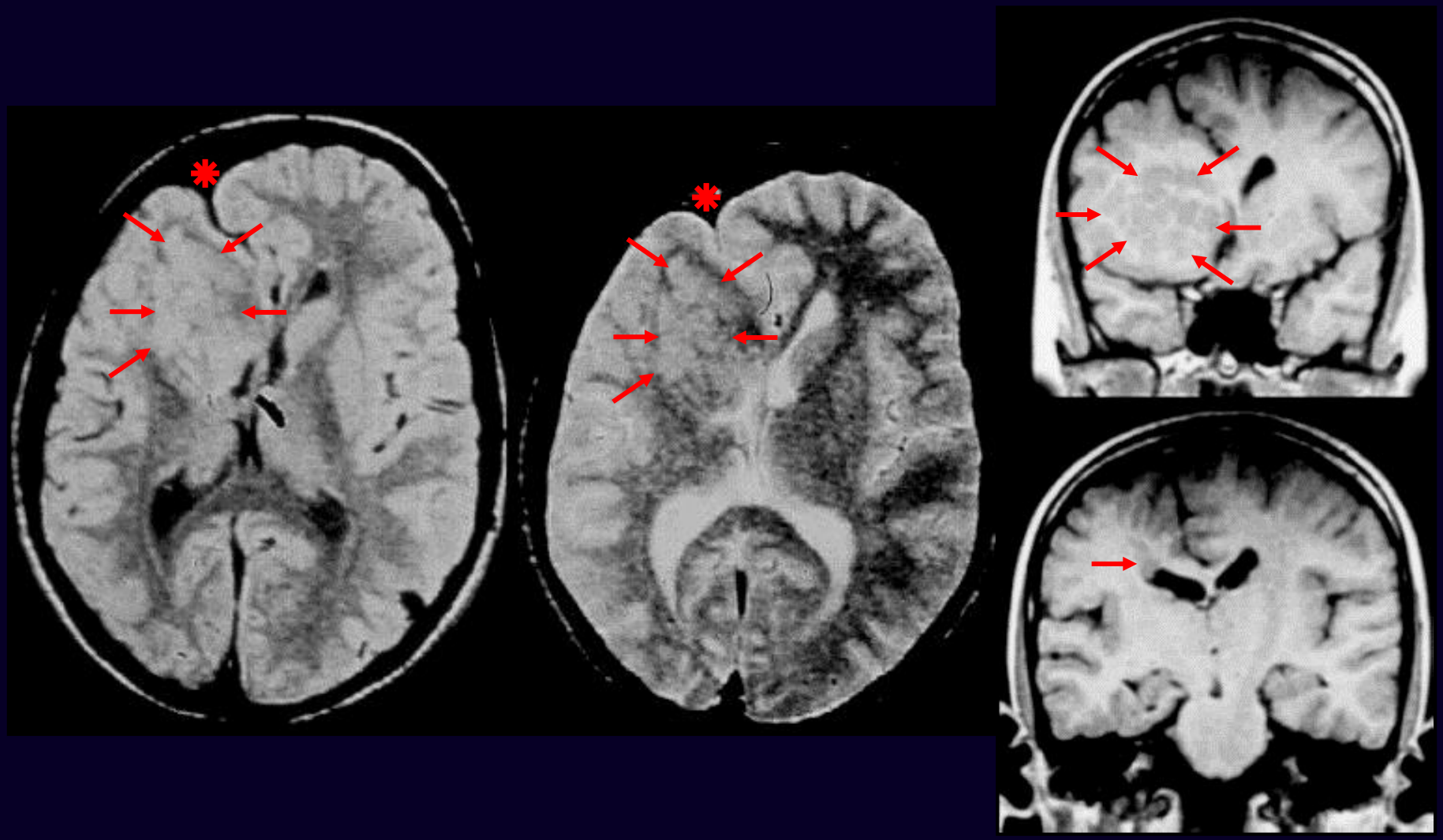


# Open lip schizencephaly



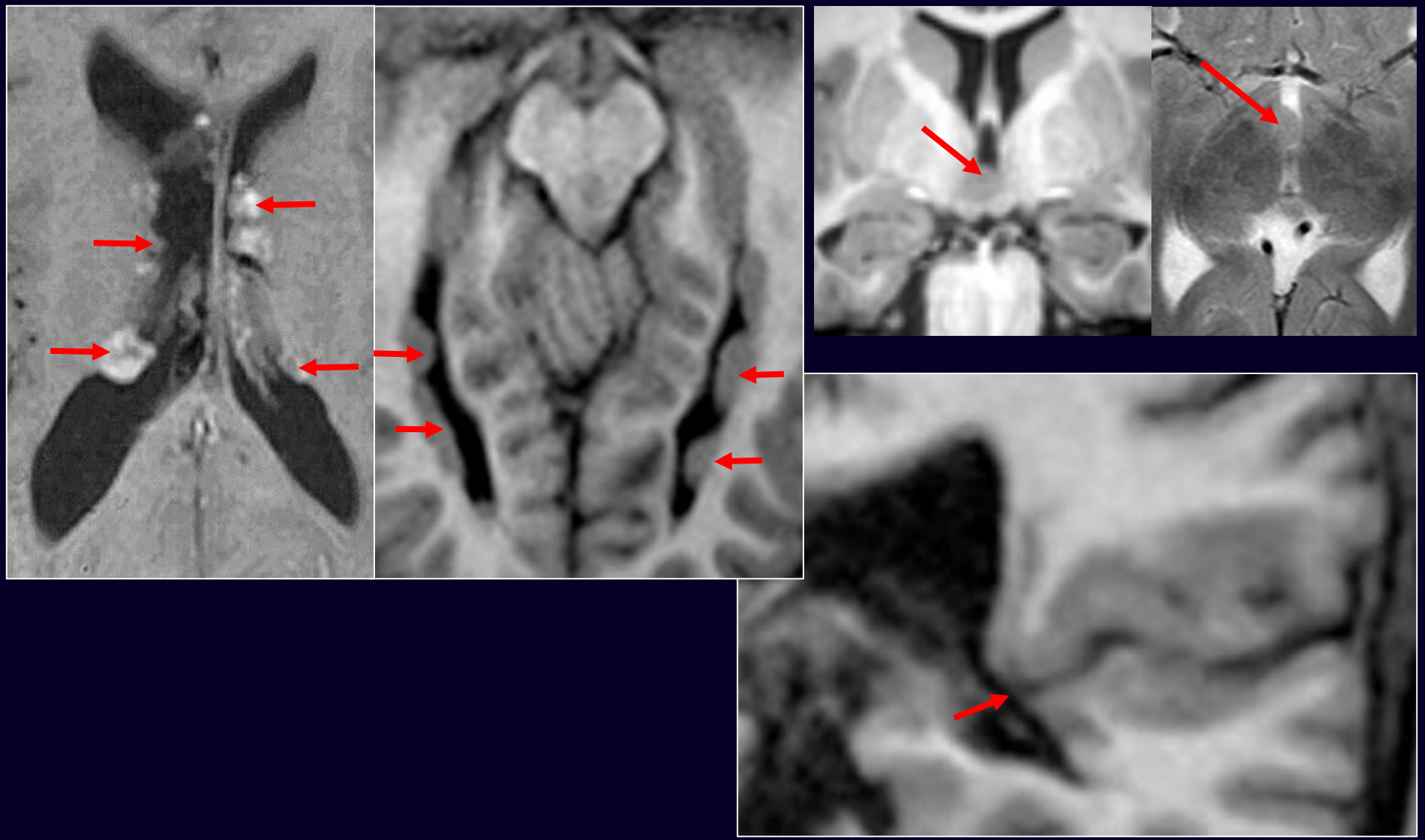


# Subcortical grey matter heterotopia



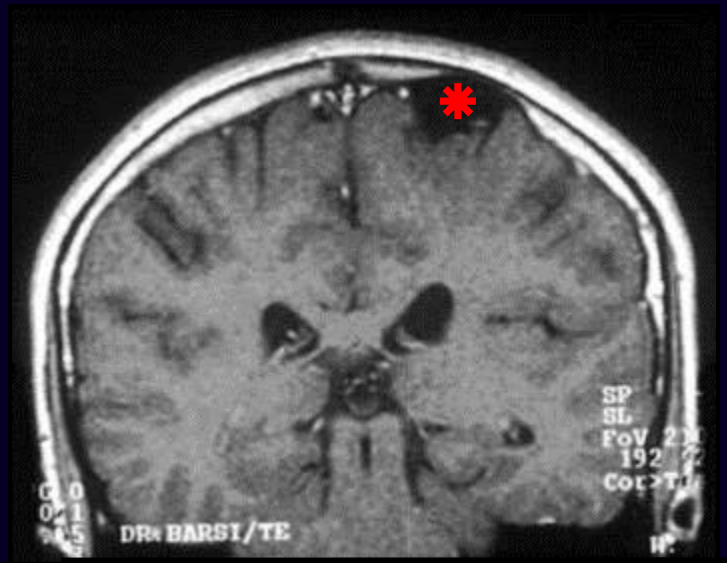
# How to find the MCDs?

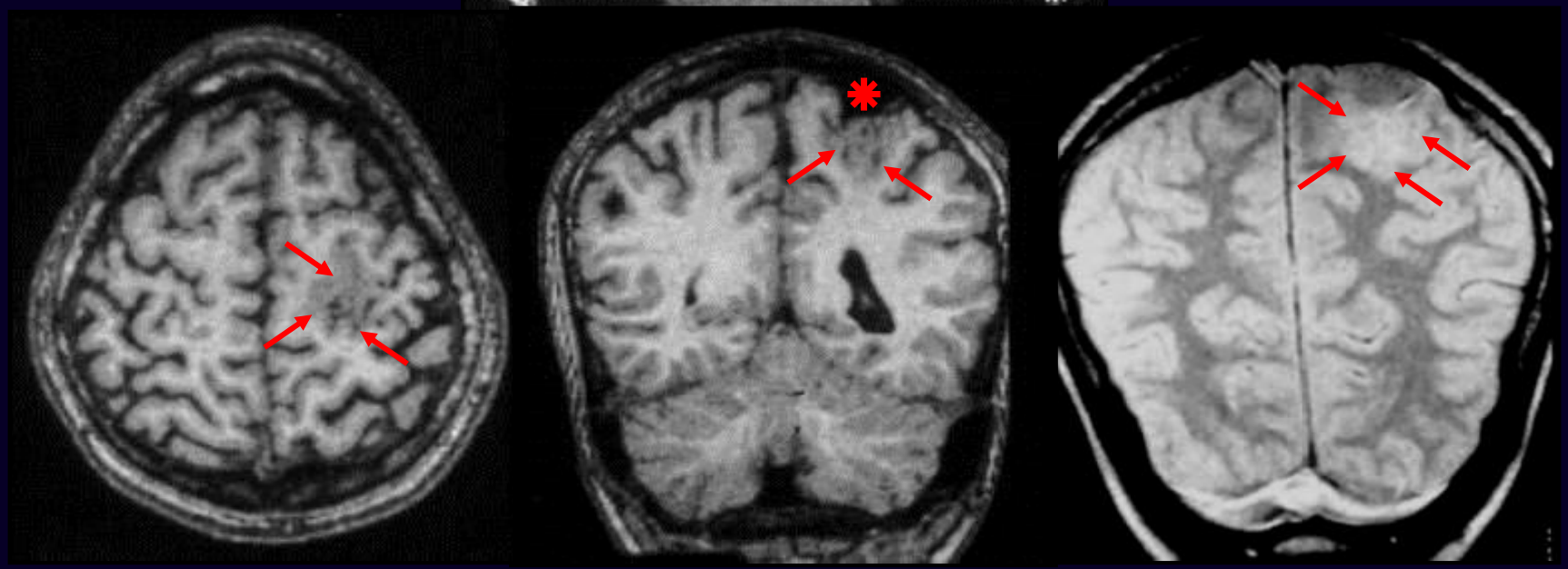
## 3. Look at the ventricular wall!



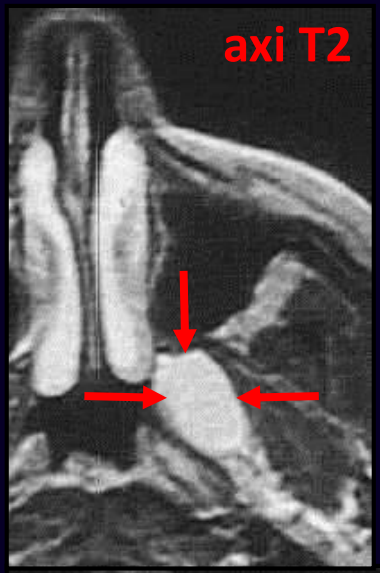
# … and other CSF abnormalities

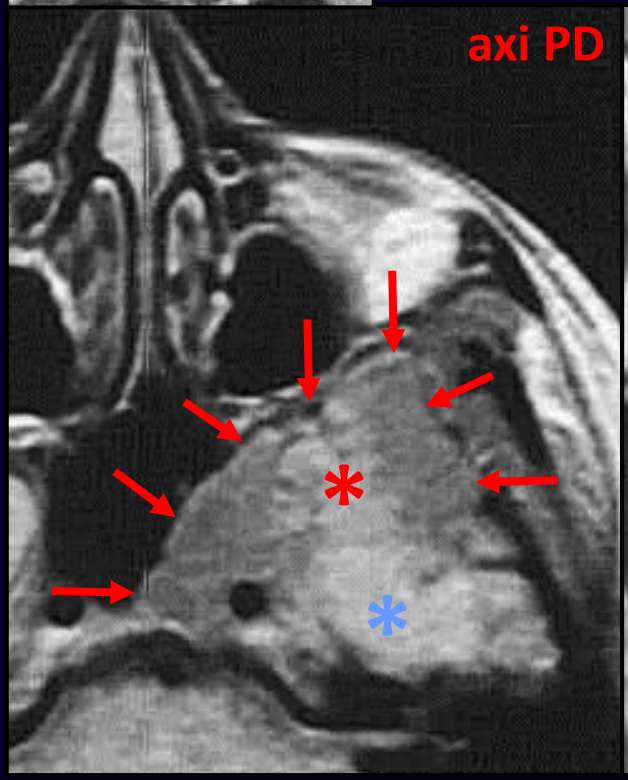
# Polymicrogyria and arachnoid cyst

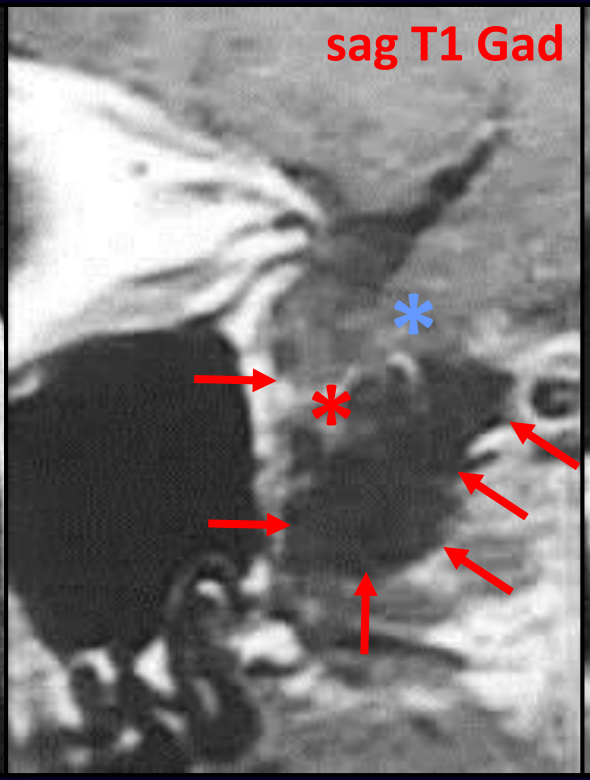


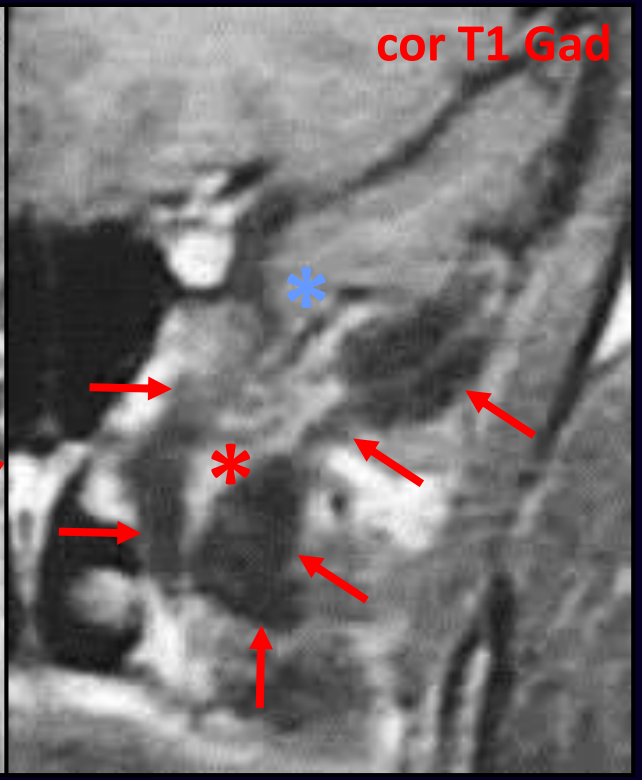



# Transsphenoidal meningoencephalocele and temporal polar cortical dysplasia



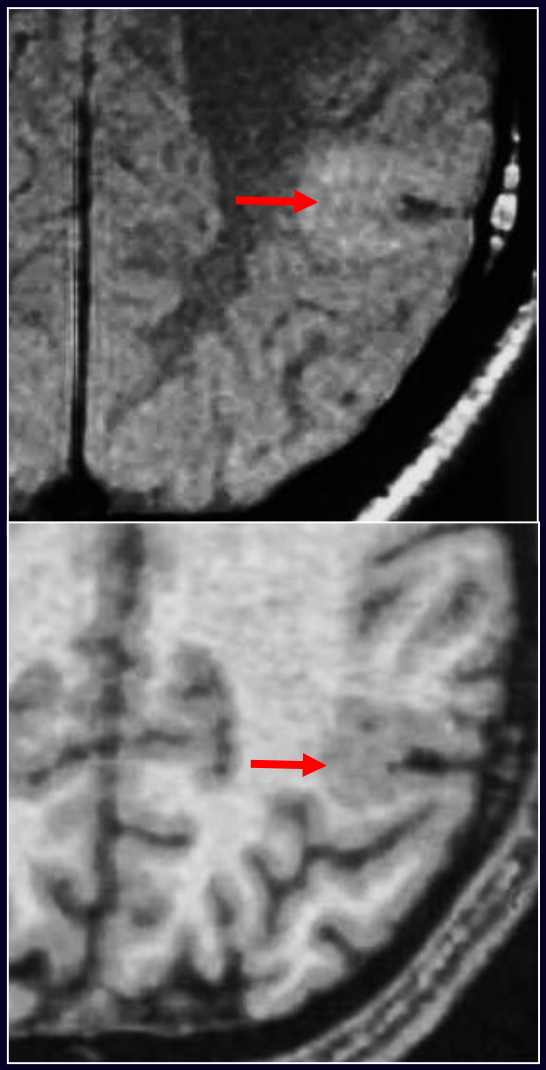



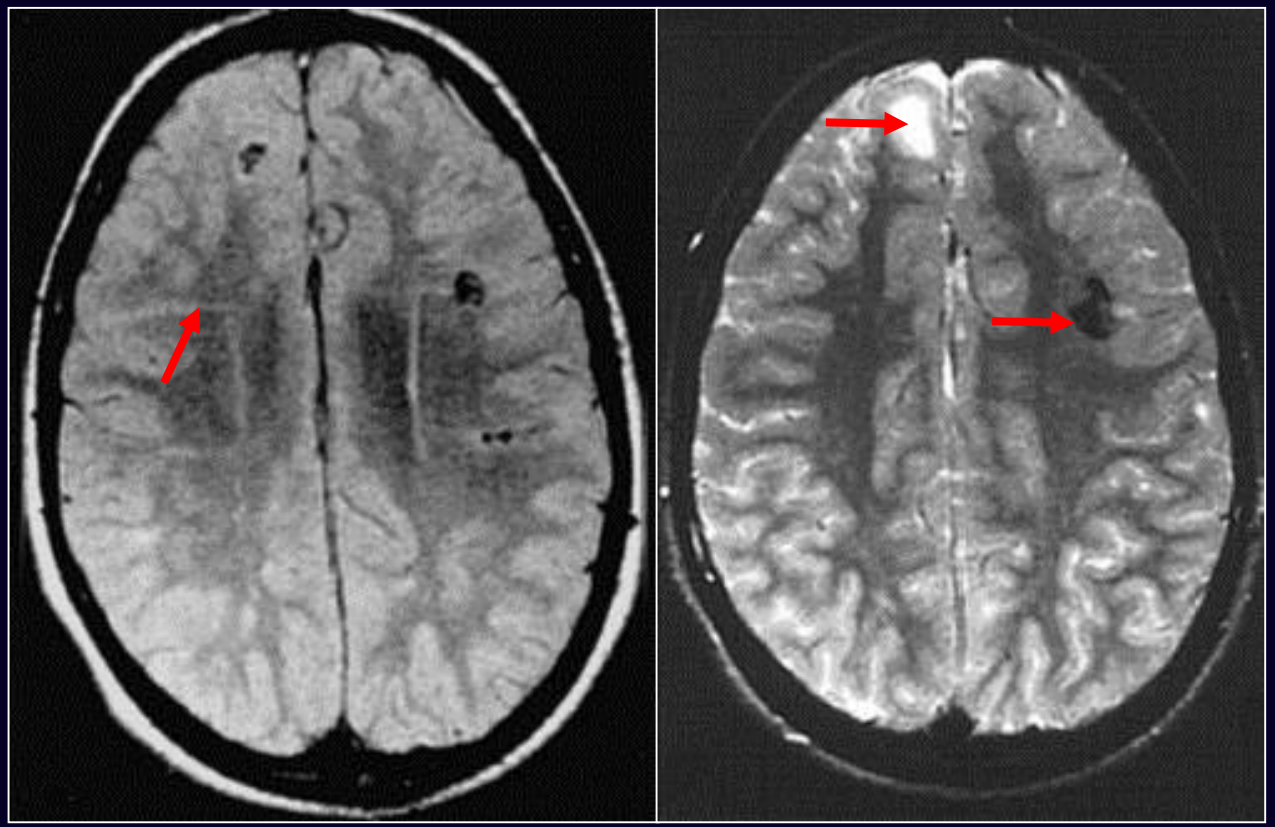



# How to find the MCDs?

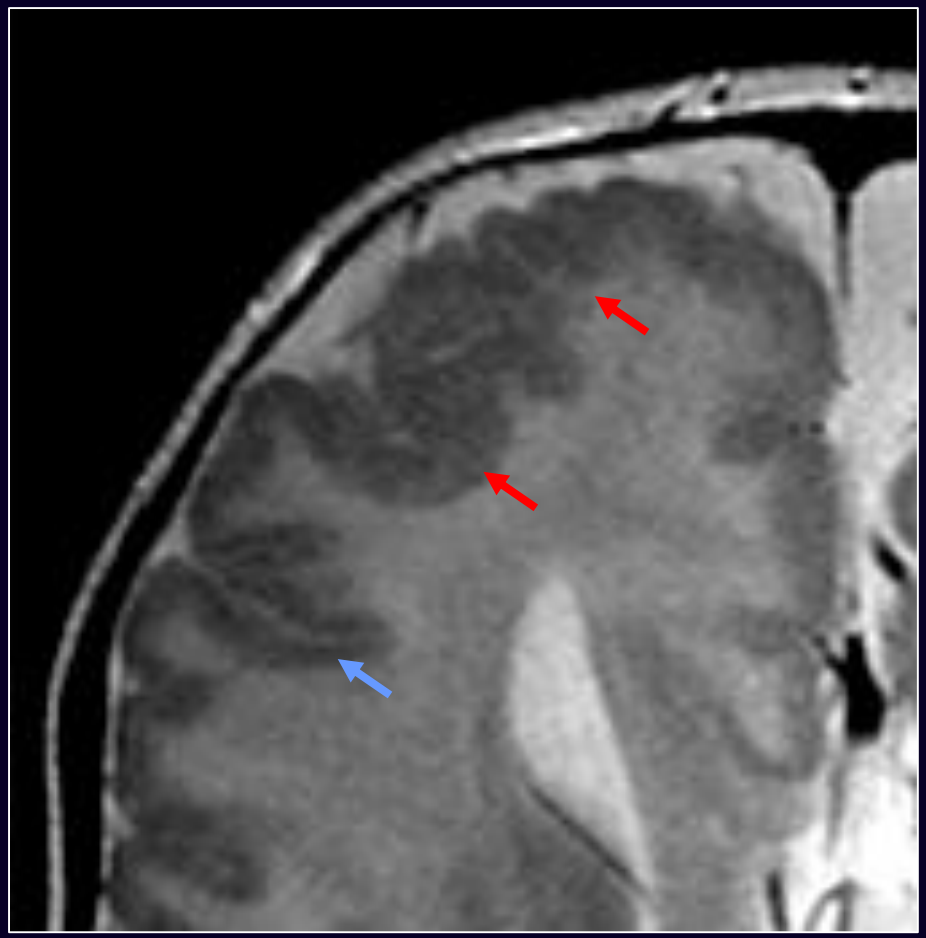
## 4. Look for abnormal signal intensity!

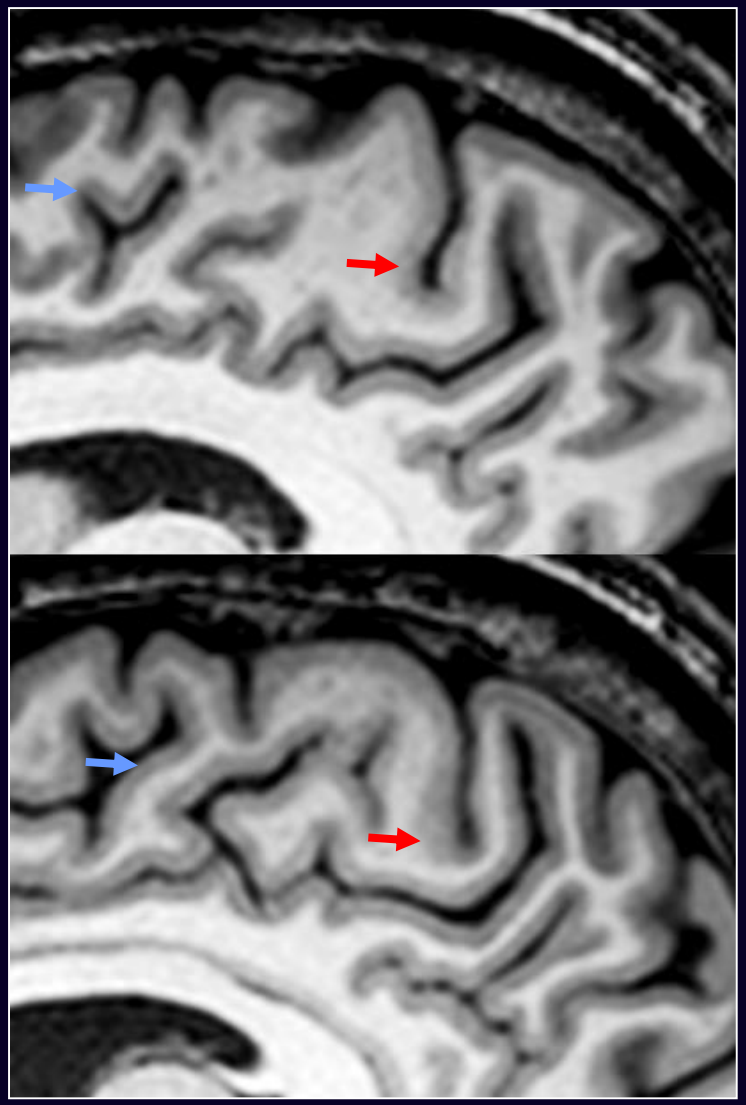




# How to find the MCDs?

## 5. Look at the cortex!

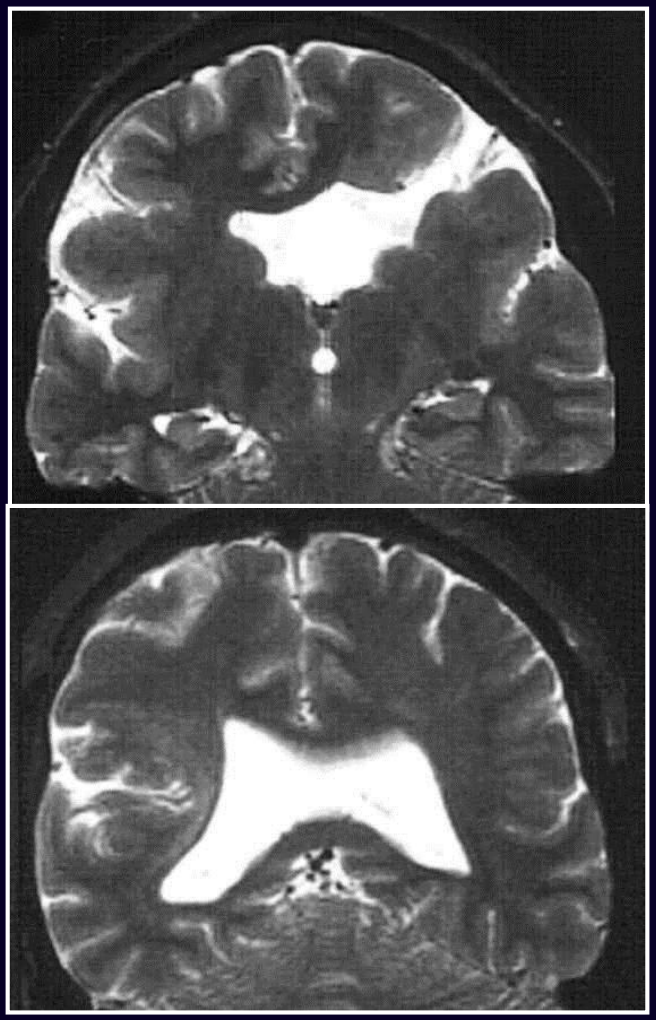


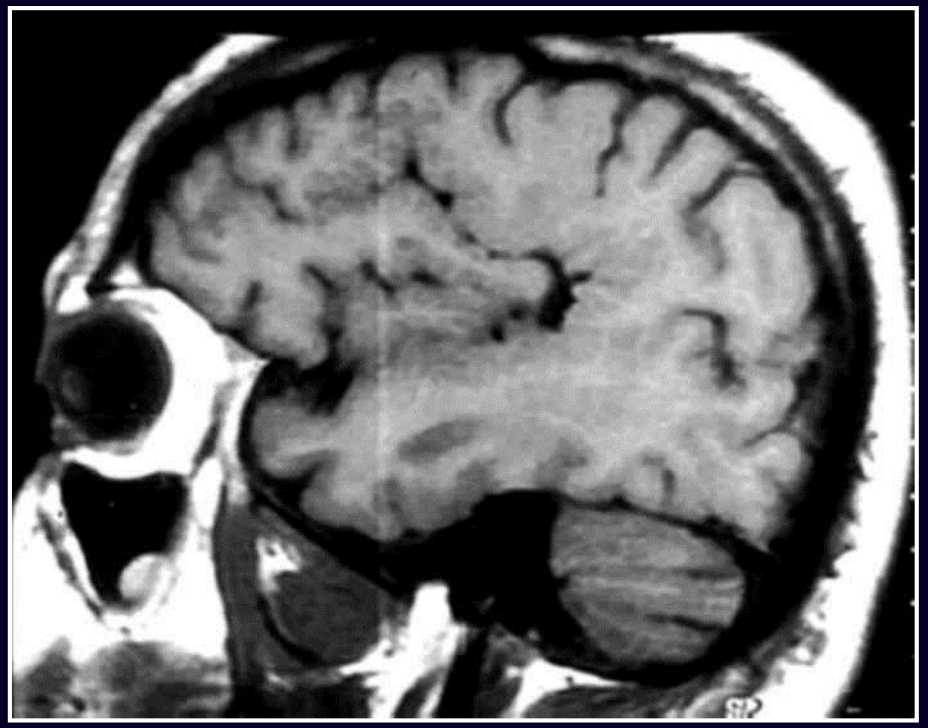


# How to find the MCDs?

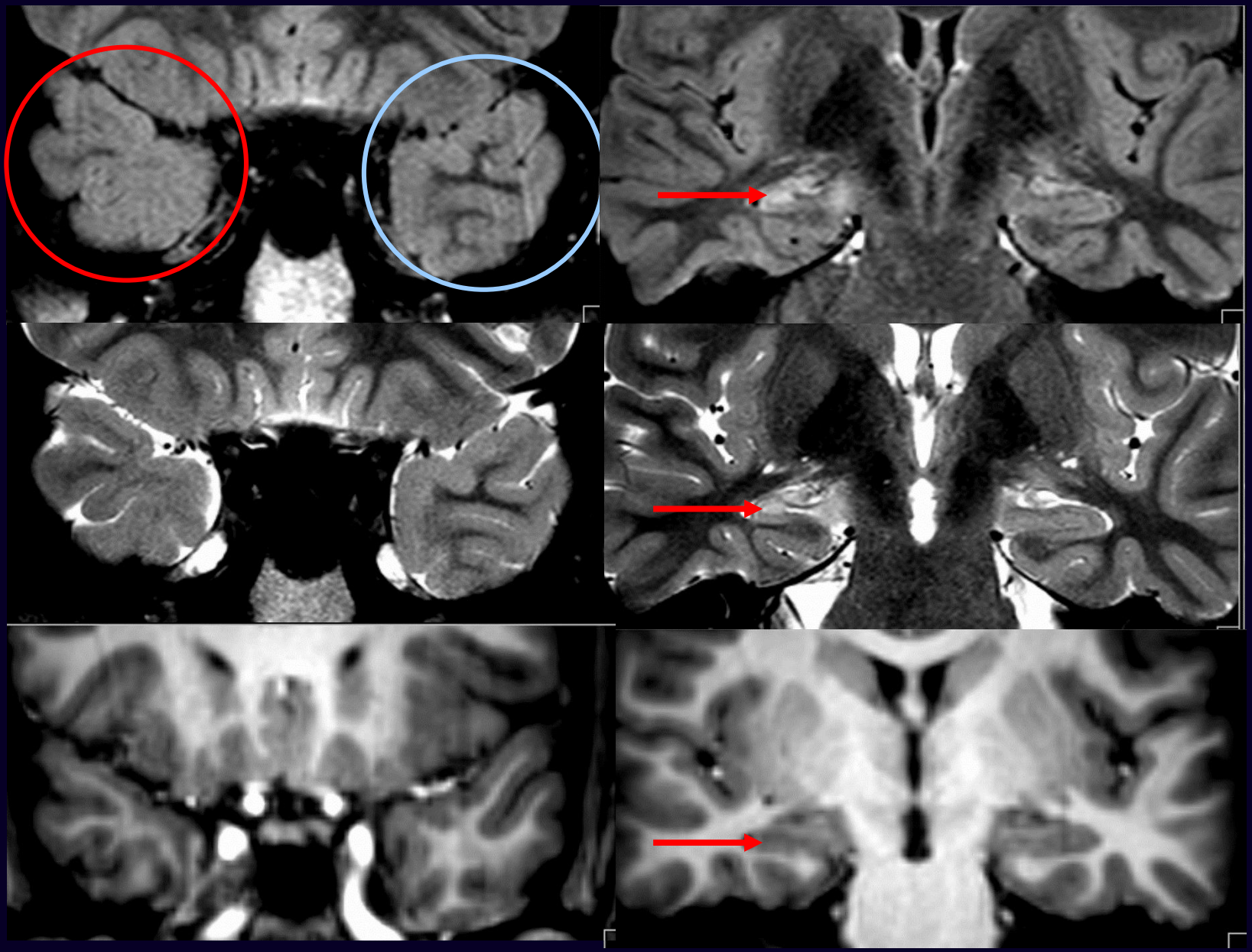
## 6. Knowledge of full spectra

# Septo-optic dysplasia (De Morsier):
## small optic chiasm/nerves, absent septum pellucidum, open lip schizencephaly and polymicrogyria

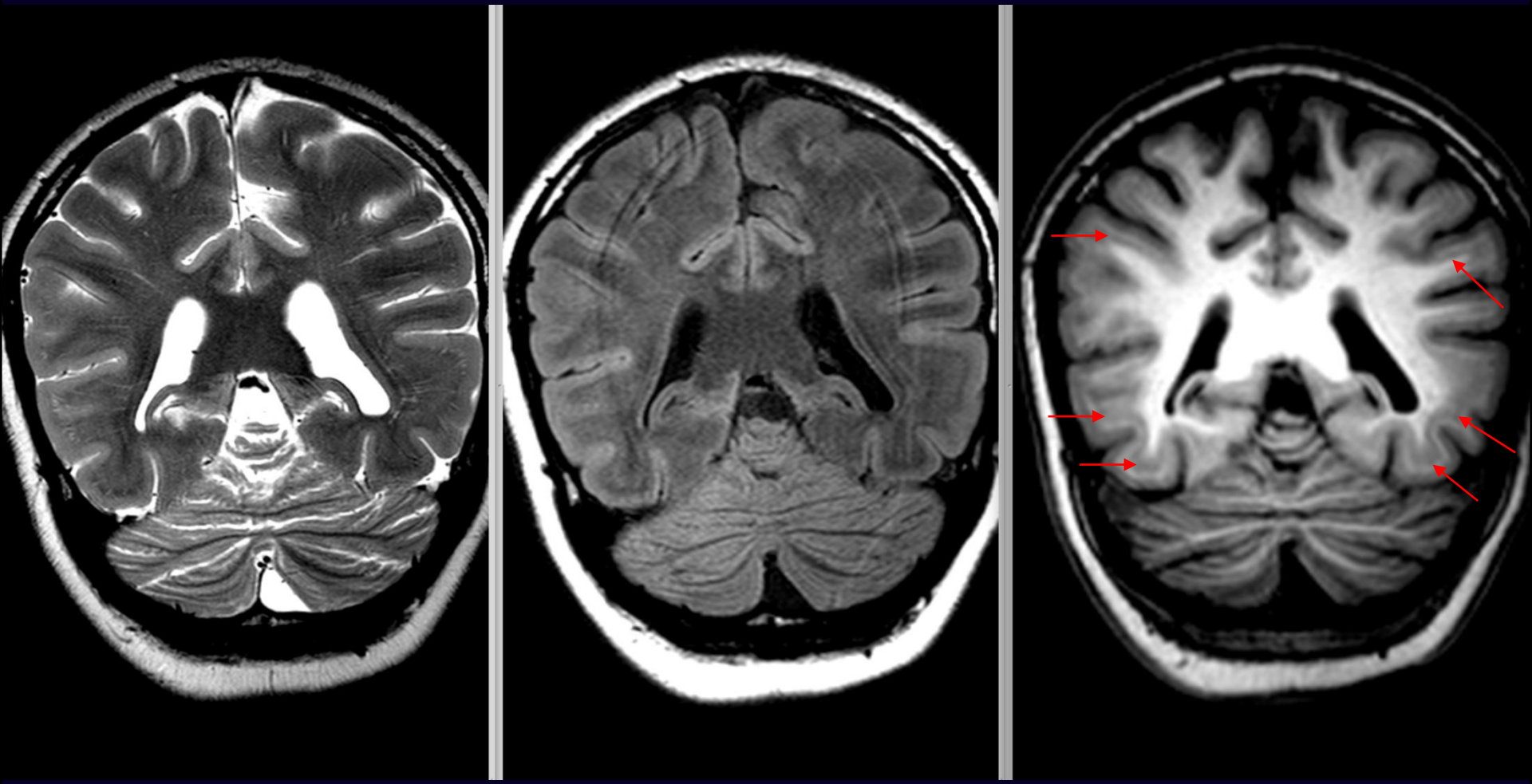




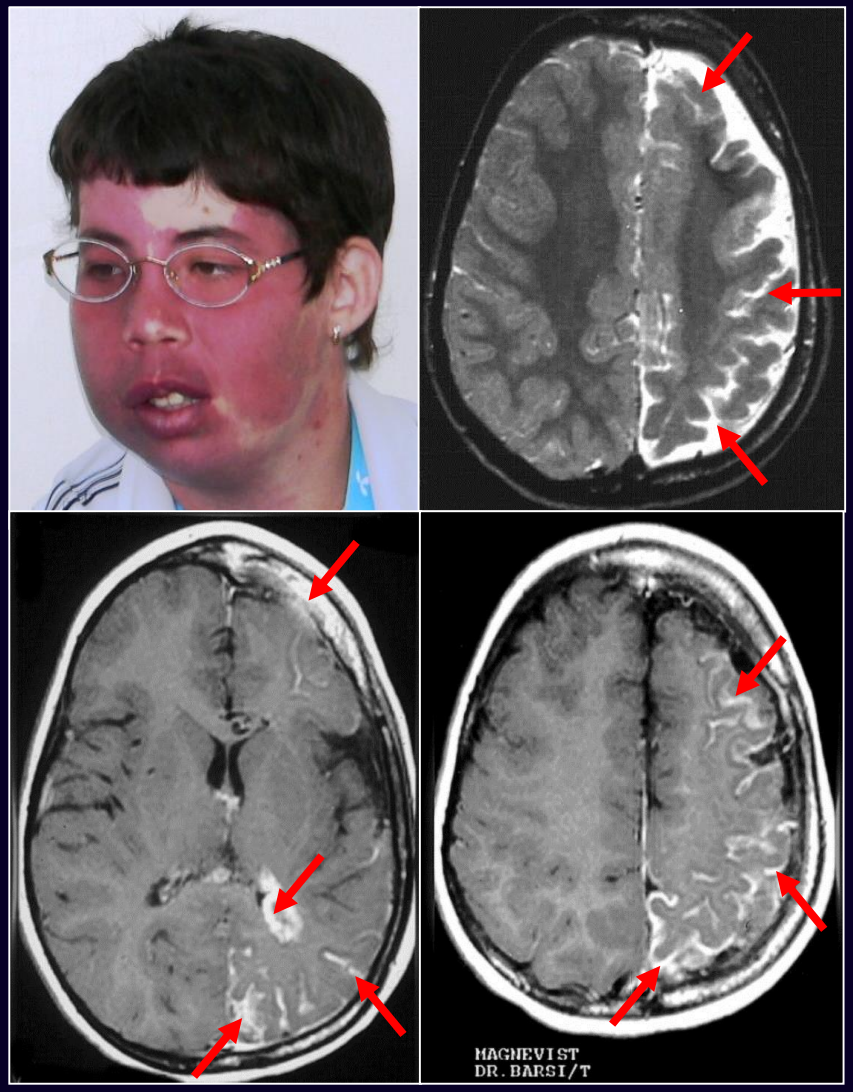
# Why should we use the MRI protocol?



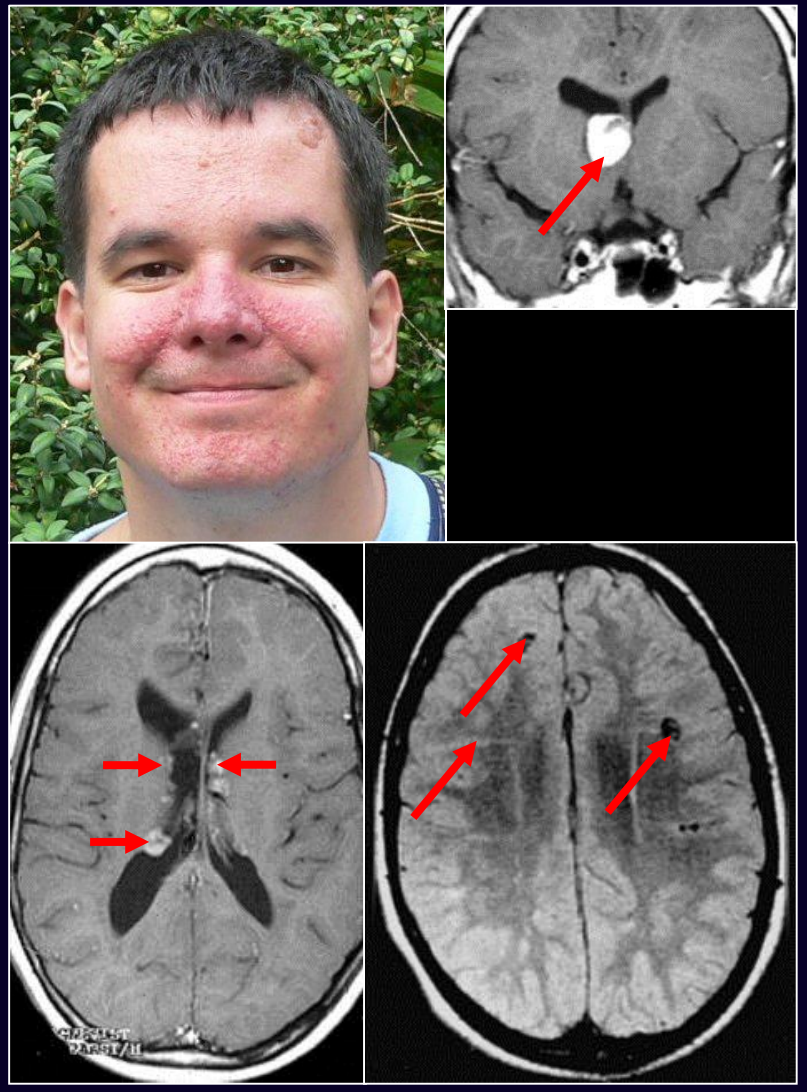
# Why should we use the MRI protocol?



# Phacomatoses

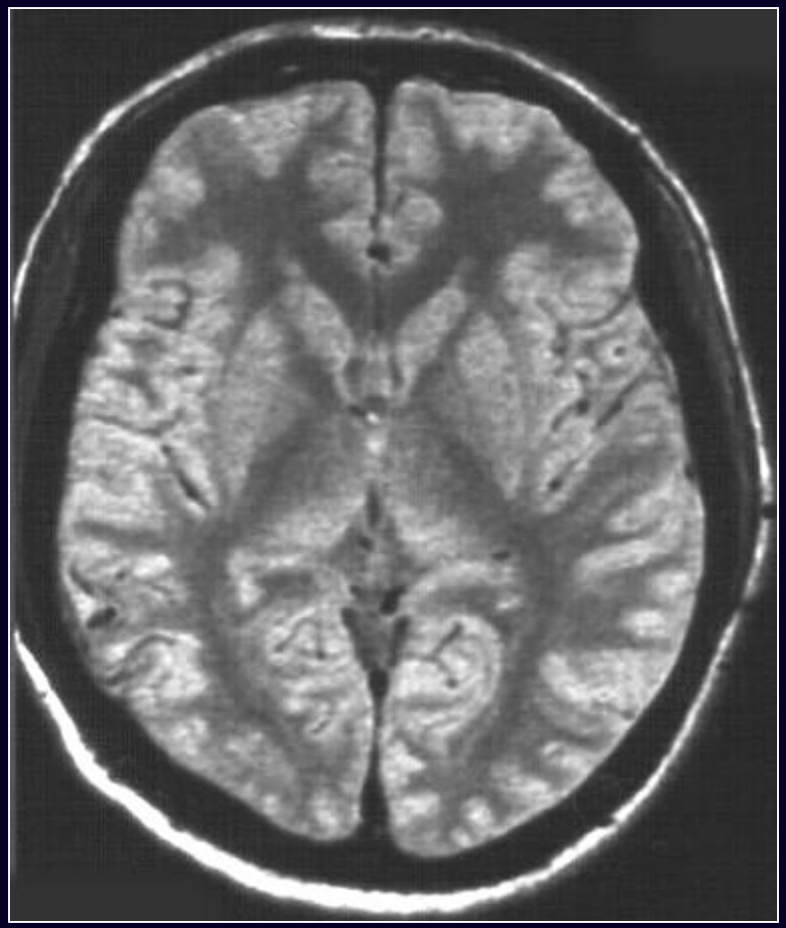


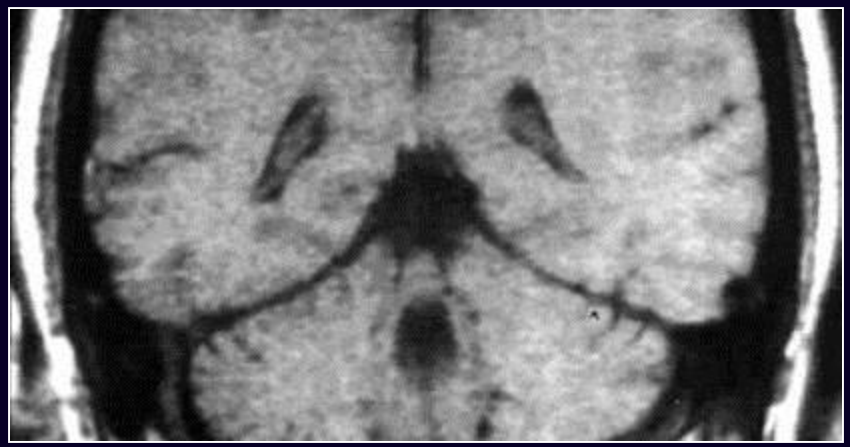

Sturge-Weber

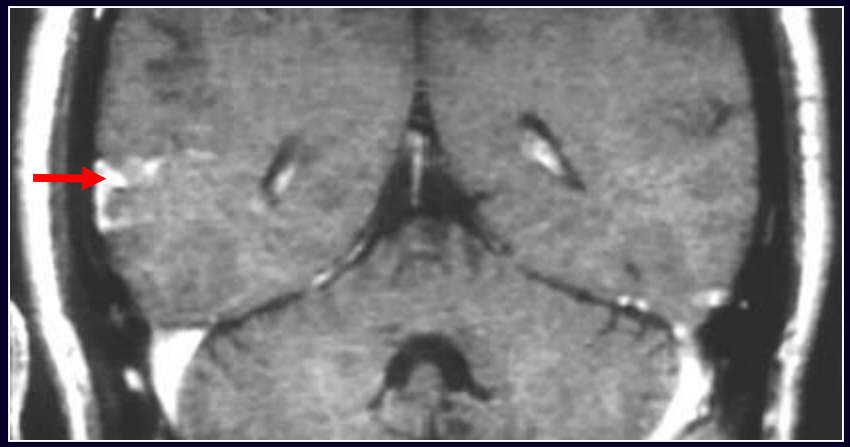


Tuberous sclerosis

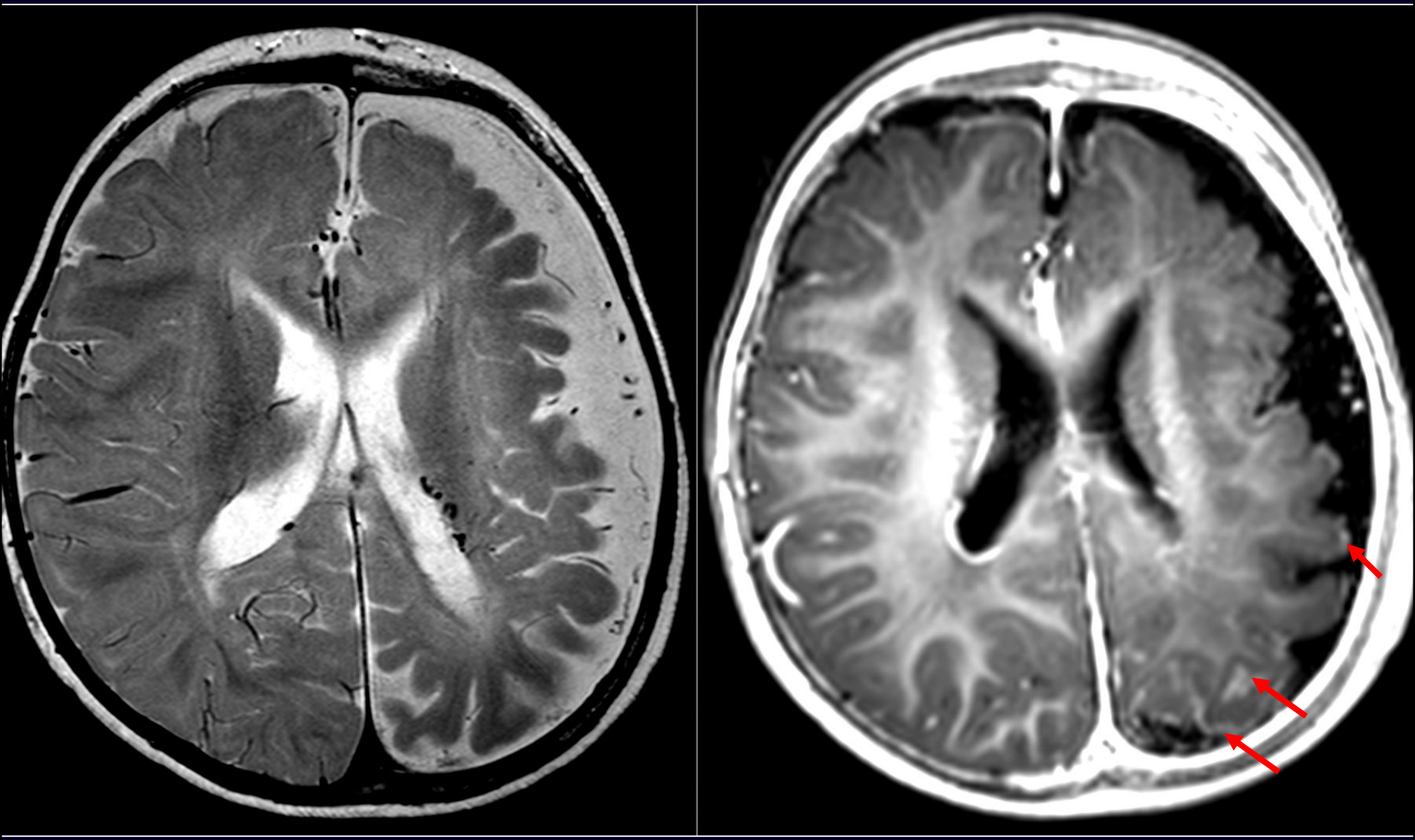
# Sturge-Weber syndrome





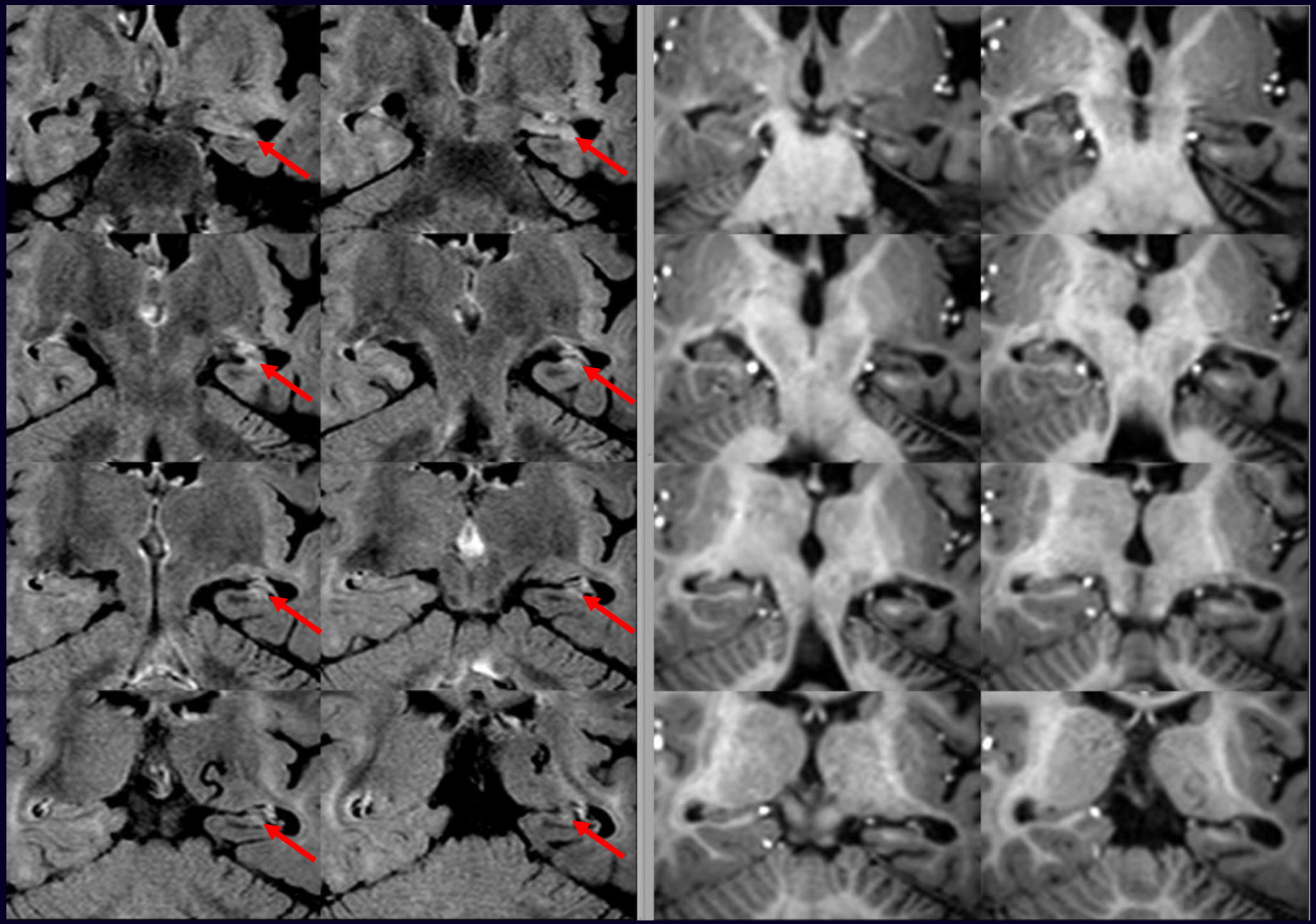


# Why should we use the MRI protocol?



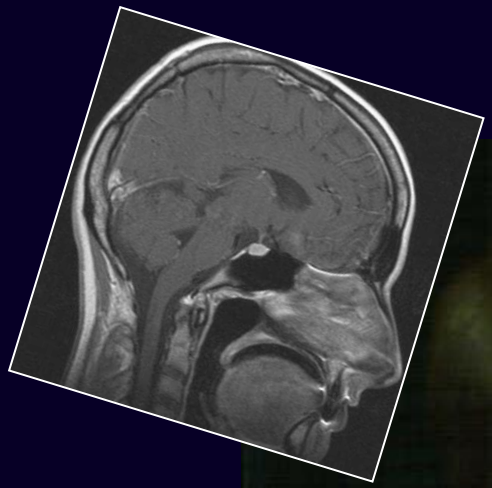
Axial T2 and CE T1

# Why should we use the MRI protocol?



# Conclusion – take home message

- Epilepsy
  - common in neurology
  - various pathologies
  - repeated seizures = severe consequences → goal: seizure-free state
- Importance of neuroimaging
  - Lesion type - main factor in selection of AED(s)
  - Surgery in pharmacoresistant cases
- Protocol: MRI
  - Most frequent lesions: MCDs, HS/MTS, PVL, tumours
  - Routine useless – Hi (double pathology), small MCDs
  - Unique features:
    - 3D GRE T1
    - Coronal T2, FLAIR (over 2 years)
  - Additional sequences – DDx, surgical planning
- Systematic work with images (midline, asymmetries, ventricular wall, abnormal signal/density, cortex, knowledge of full spectra, hippocampus!!!)
- Comprehensive consultation





# Thank you for your attention!