Introduction in structural imaging

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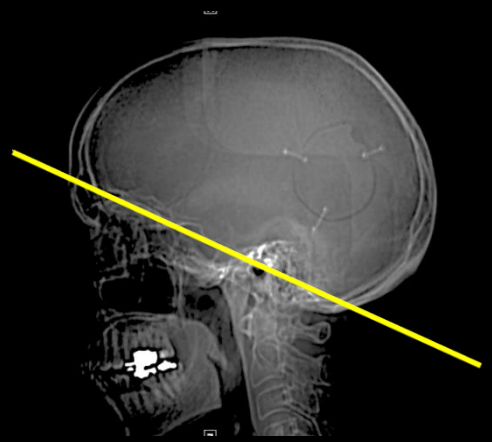
No conflict of interests

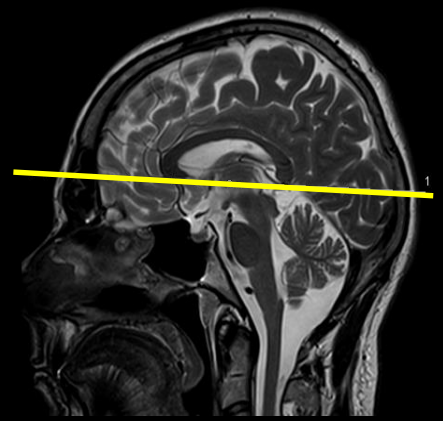
Outline

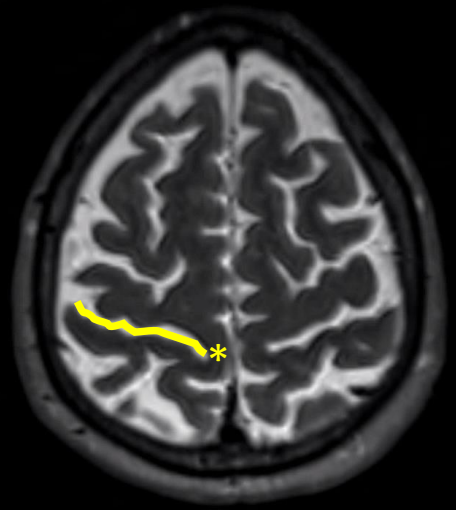
- General aspects
- Modalities CT and MRI
- Indications and contraindications
- Common sequences, applications and pitfalls
- Structured analysis and reporting (4 “Ds” of radiology reporting)

General aspects

- Axial images = caudal view („right-left reversed“)
- Tilt







* Central gyrus

Computertomography

- Measurement of the attenuation of x-rays (***Radiation!***)
- Multidetector CTs: continous data acquisition of a complete volume
- Short scan duration, thin slice thickness
- Widespread availability
- Fast
- Monitoring possible
- Less contraindications compared to MRI (e.g. pregnancy)
- Assessment of bone and soft tissue

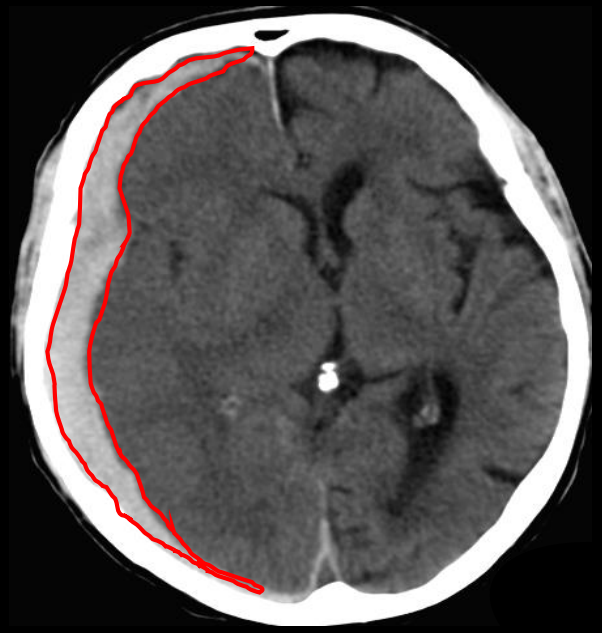
Neuroradiological CT indications

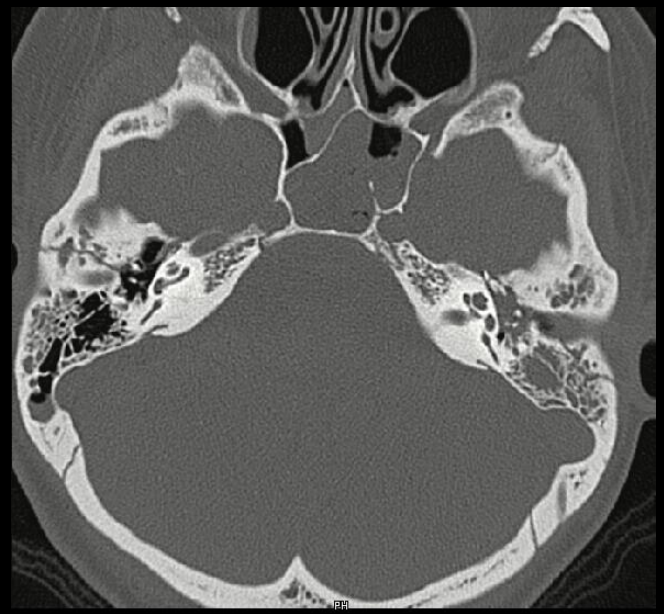
- Trauma
- Stroke (DD bleeding / ischemia)
- Acute increased intracranial pressure (tumor, hydrocephalus)
- Postoperative
- Assessment of the bone

Trauma

Extraaxial

Intraaxial





Subdural Hematoma

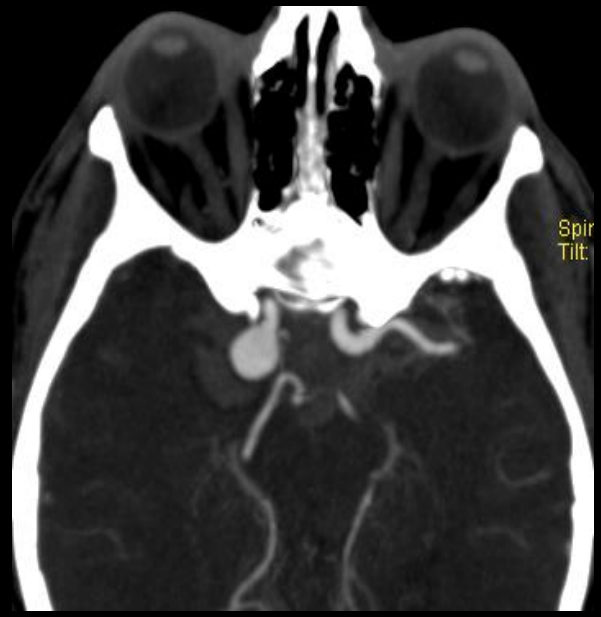
Epidural Hematoma

Contusions

Fractures

Subarachnoid hemorrhage

Posttraumatic



Aneurysmatic bleeding

CT-angiography (CTA)

Arterial: aneurysm, vessel occlusion, stenosis, arteriovenous malformations

Venous: sinus thrombosis

BUT Contrast media:

- Necessary for examination of blood vessels
- Contains iodine
- Contraindications:

  Allergy

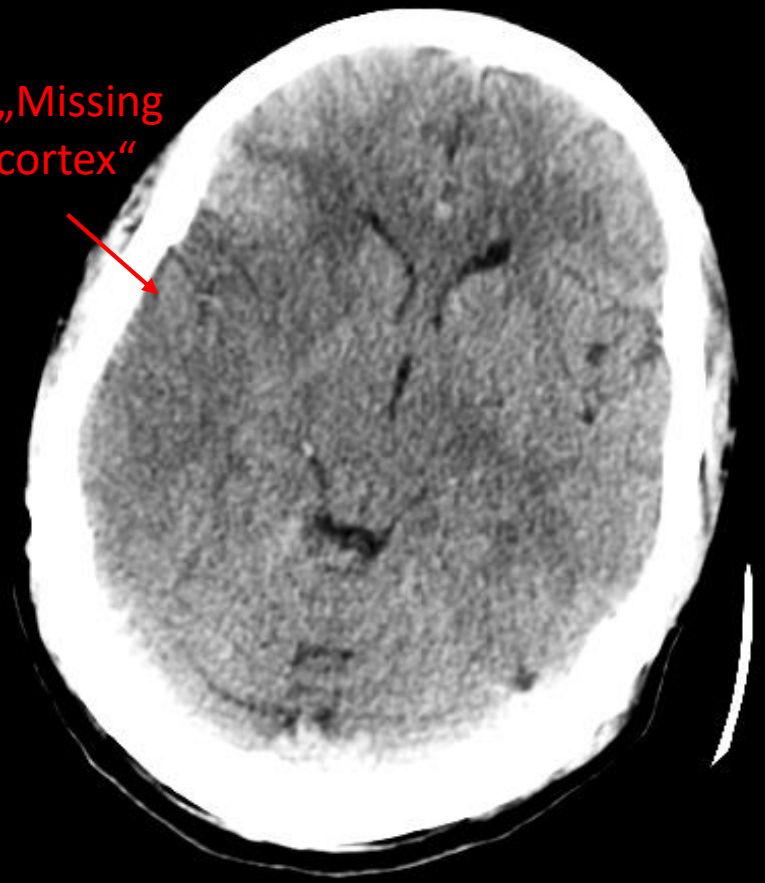
  Renal insufficiency

  Hyperthyroidism

Acute stroke imaging

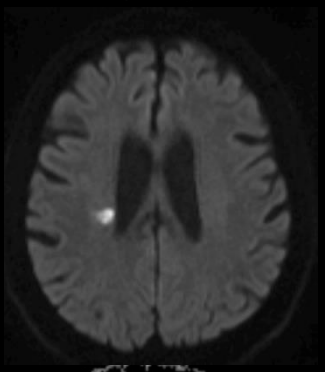
- Native CCT → to rule out acute hemorrhage
- CT angiography → to detect stenosis or vessel occlusion
- Perfusion- CT → normal versus reduced blood supply (reversible or irreversible)
  → normal brain versus ischemic brain

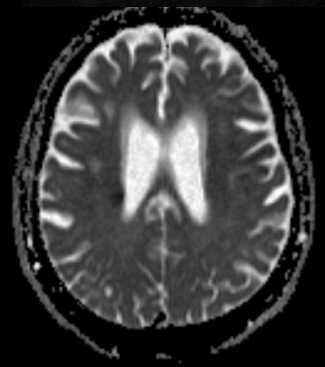
Early CT signs in stroke



Loss of gray-white interface
Slight swelling

Hyperdense media sign





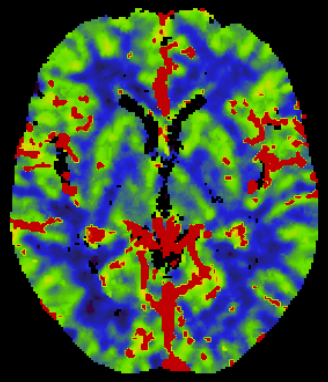
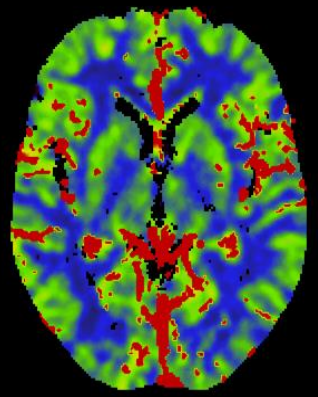
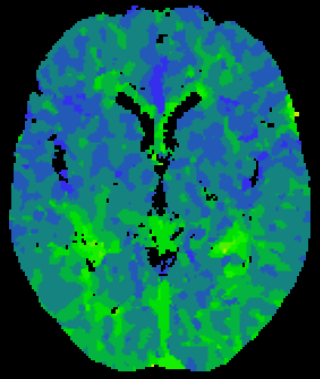
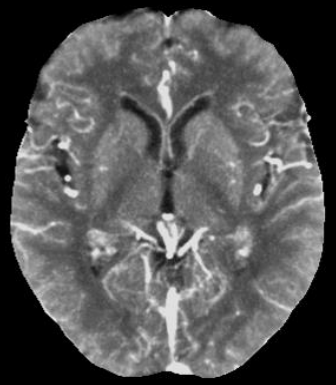
CT Perfusion

CBF:
Cerebral blood flow

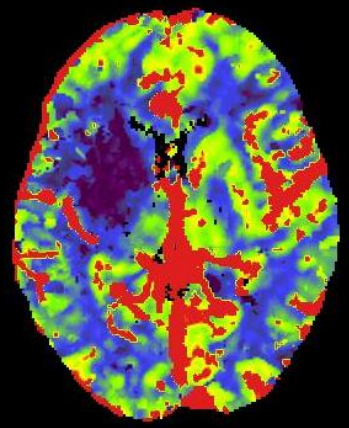
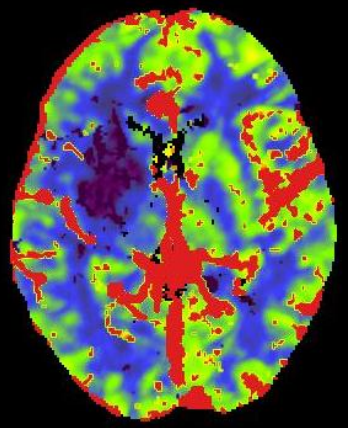
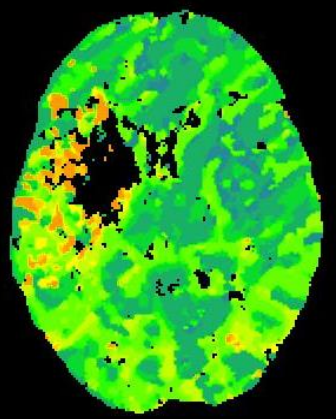
CBV:
Cerebral blood volume

TTP:
Time-to-peak

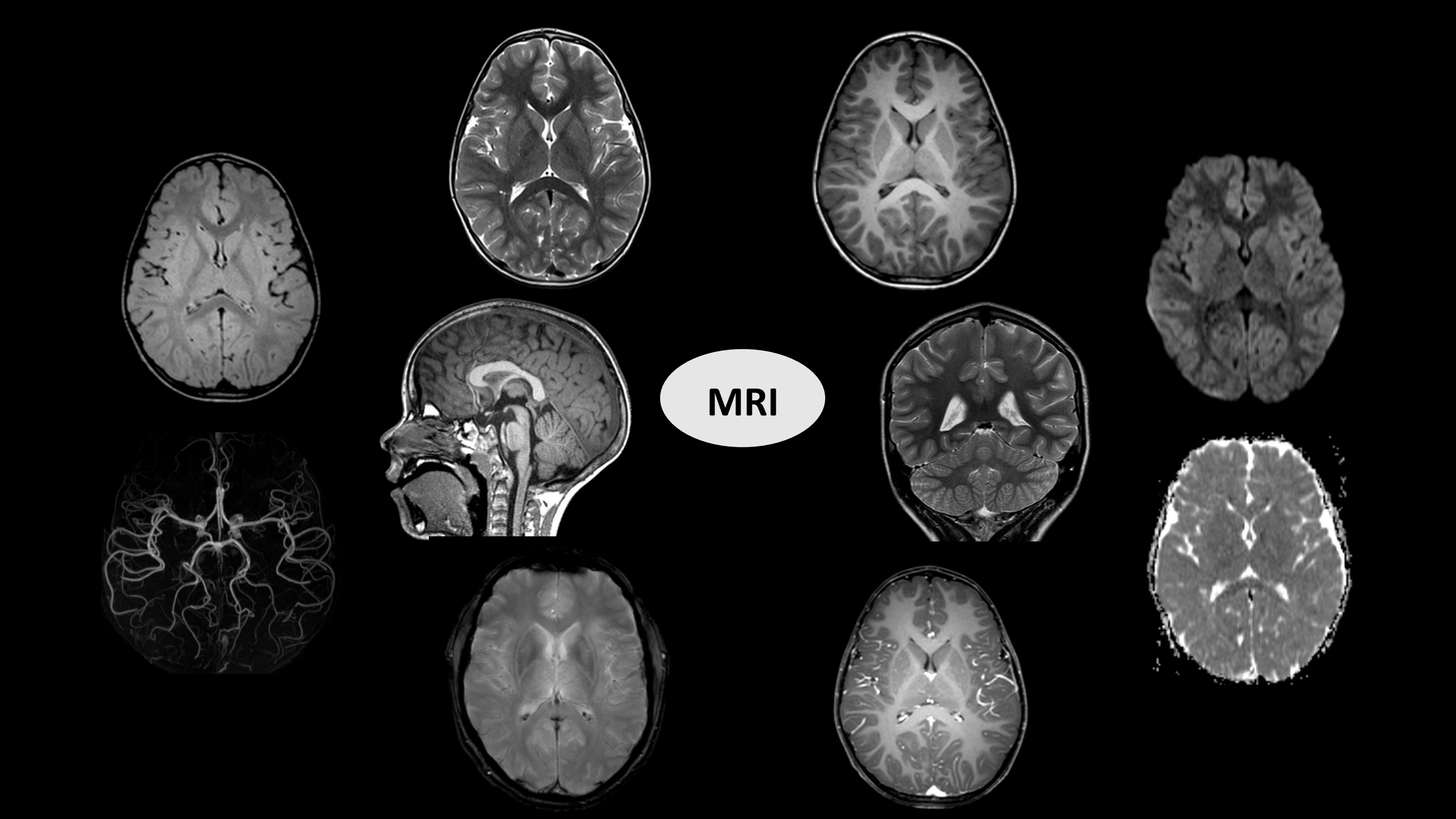
MIP

normal

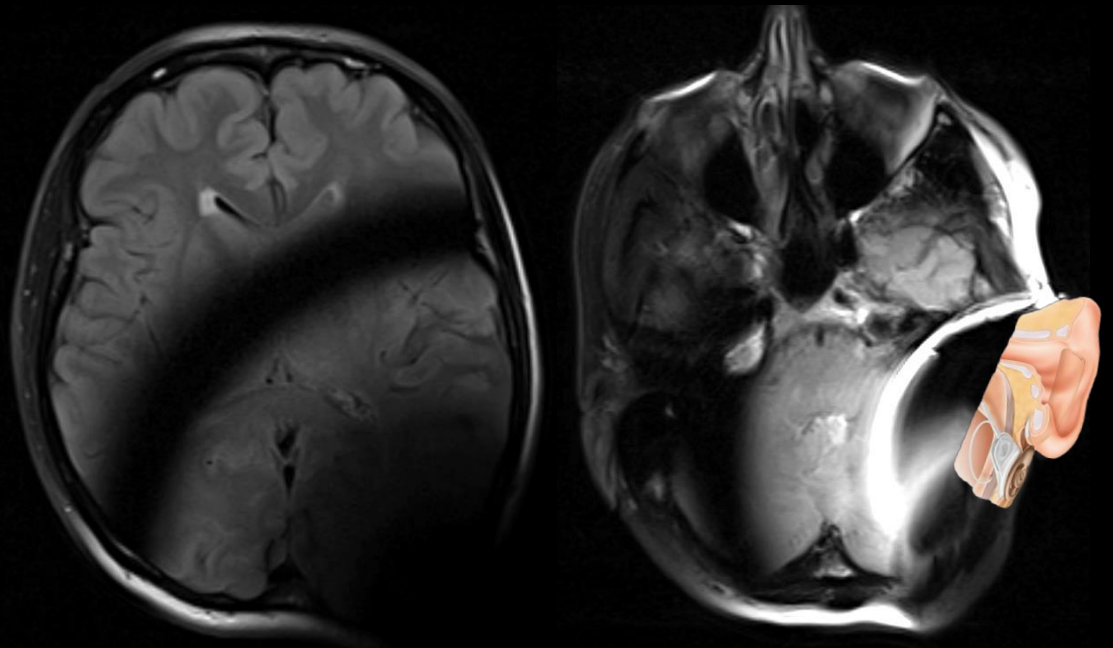





Left hemipraesis
since 1h


MRI

MRI

- High magnetic field, no radiation
- Brain MRI has different unique sequence types, each sequence takes time
- Contraindications: pacemaker, metallic implants, (pregnancy)



MRI with cochlear implant

Dislocation of the magnets due to MRI

Postoperative after correction

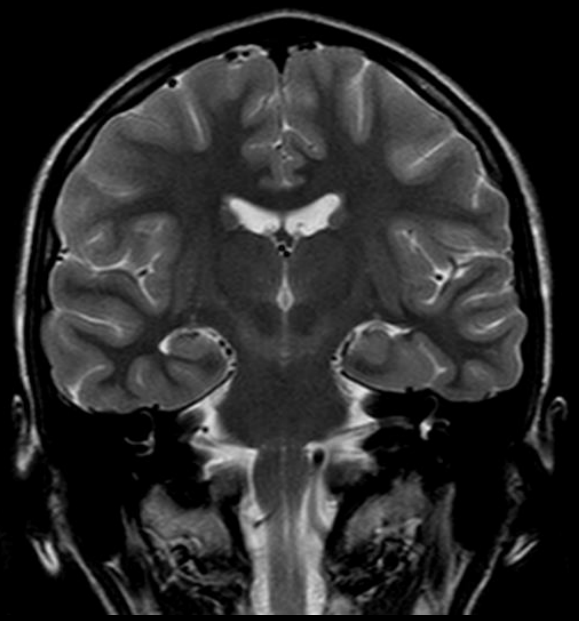
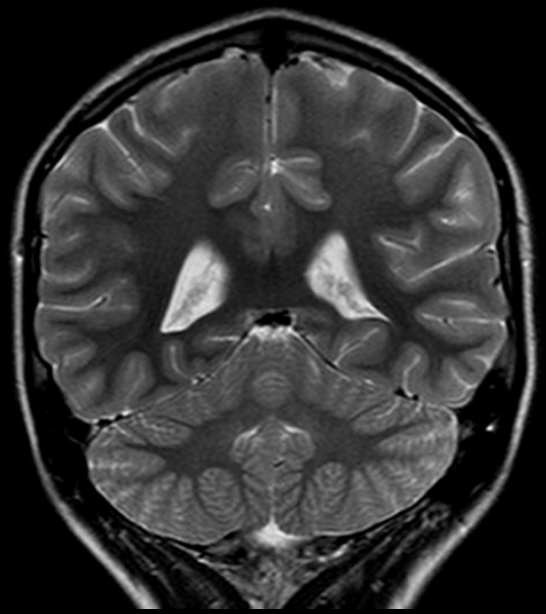
MRI

- Multiplanar:

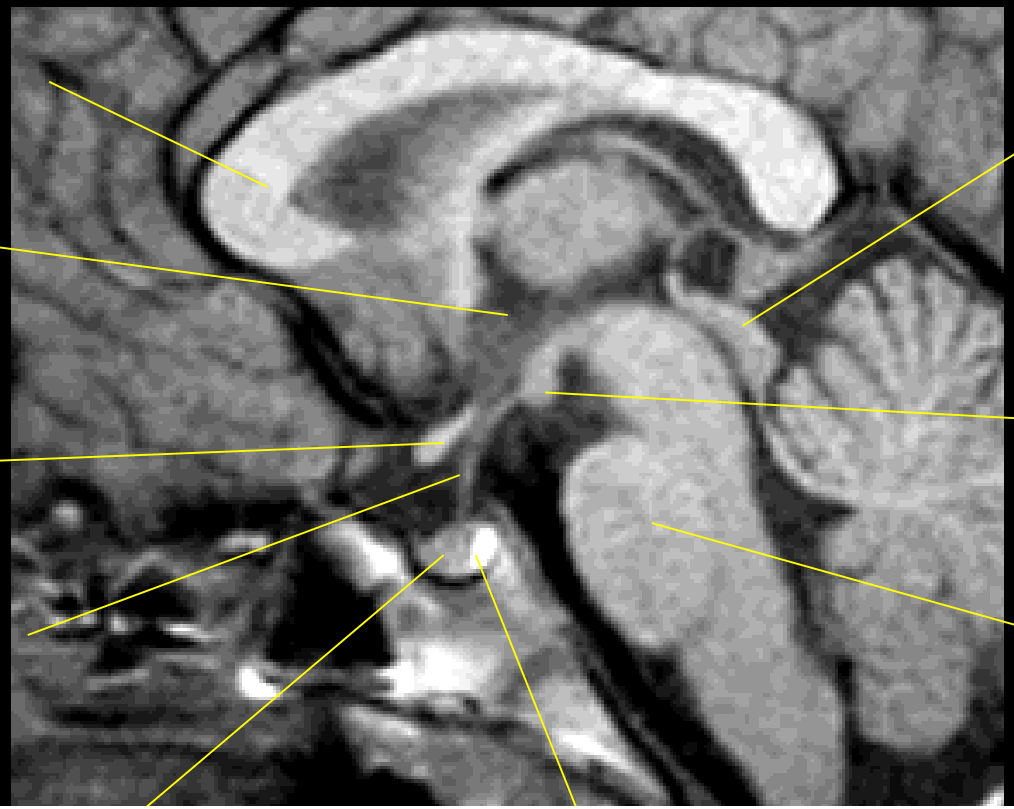
  Axial

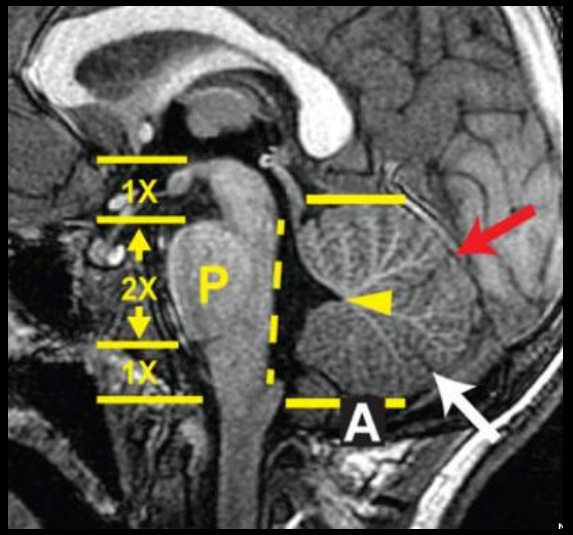
  Coronal = frontal view } Bilateral comparison

  Sagittal = lateral view } Midline structures

Midline structures





Doherty et al. Lancet Neurol 2013

Radiographics. 2018 Jan-Feb;38(1):218-235. doi: 10.1148/rg.2018170019.

Twenty-Five Diagnoses on Midline Images of the Brain: From Fetus to Child to Adult.

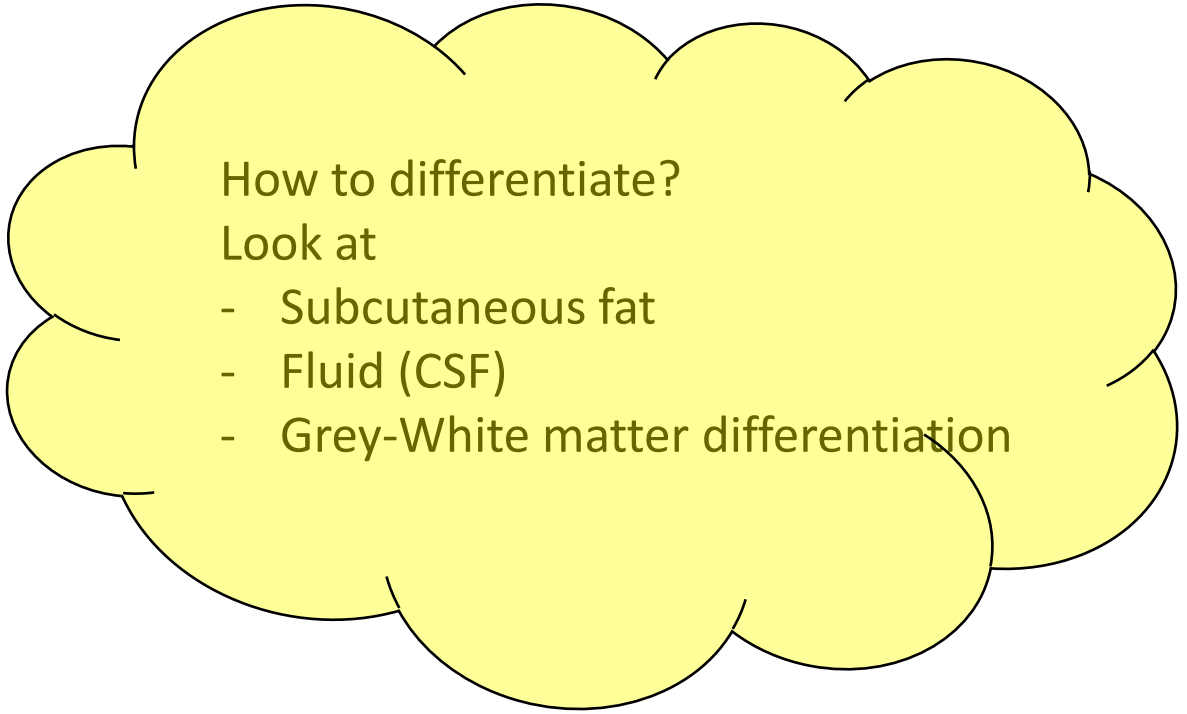
Choudhri AF[1], Cohen HL[1], Siddiqui A[1], Pande V[1], Blitz AM[1].

Sequences

Sequences

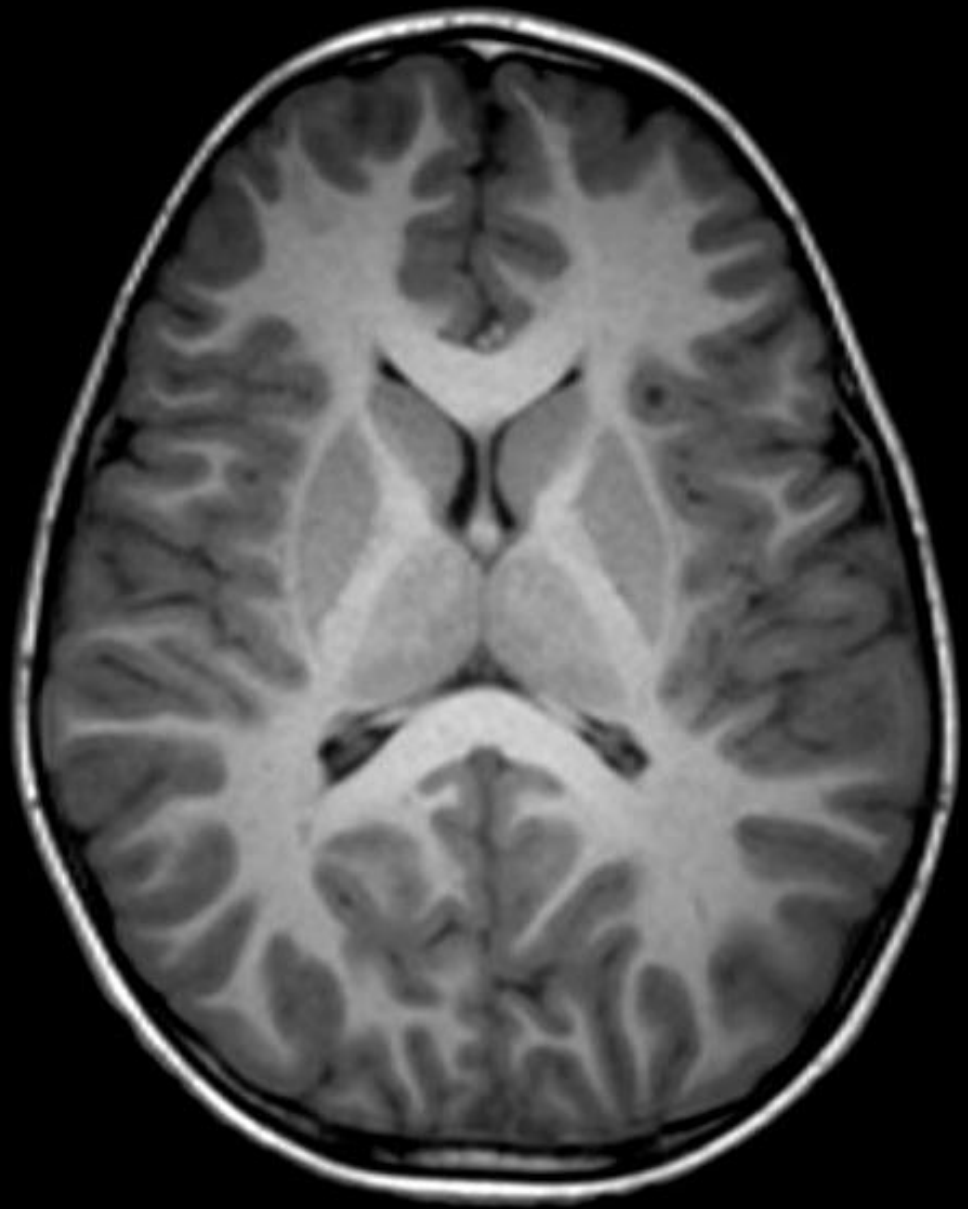
- T1w and MPRage
- T2w
- FLAIR
- T2* and SWI
- DWI and ADC

- DTI
- MRS



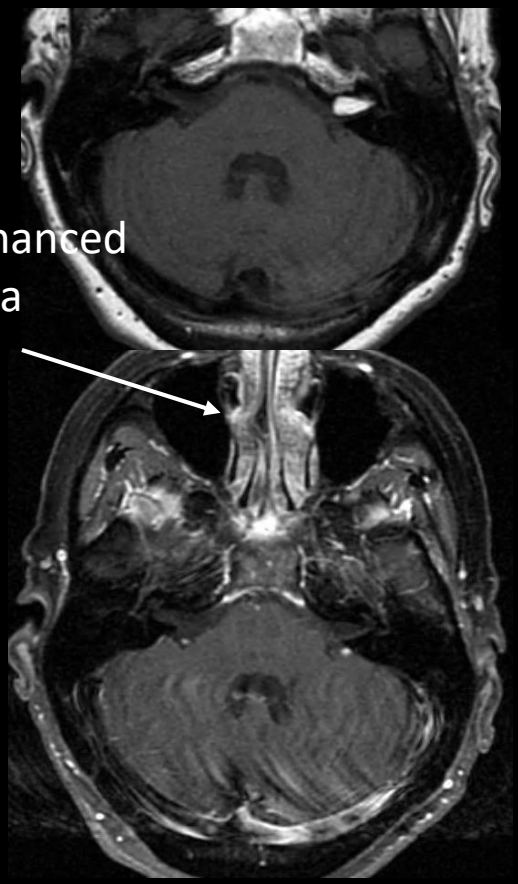
T1w SE Sequenz or 3D MPRage

- Anatomical detail, localize pathology
- Most pathology is T1 hypointense
- Associated edema is T1 hpyointense
- T1 bright pathology has a limited DD

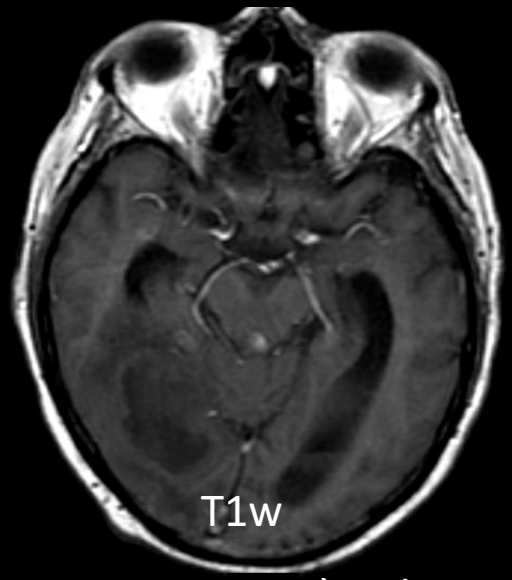


T1w SE Sequenz or 3D MPRage

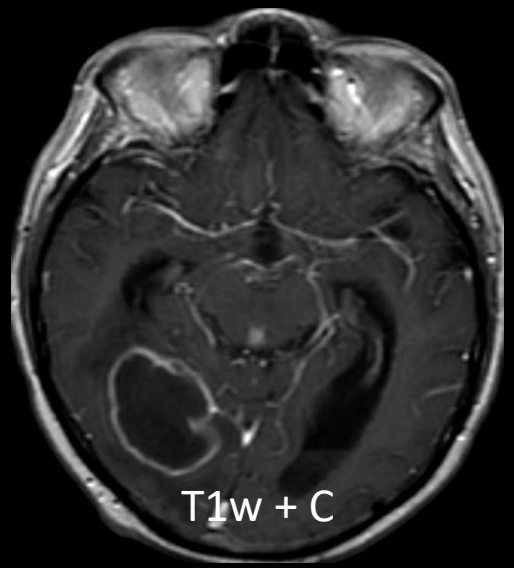
- Hyperintense: contrast enhancement, subacute blood, fat, melanin, manganese, slow flowing blood some calcifications



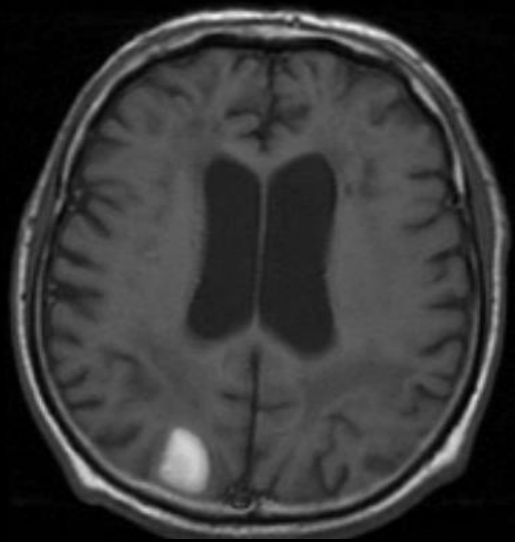
Contrast enhanced nasal mucosa

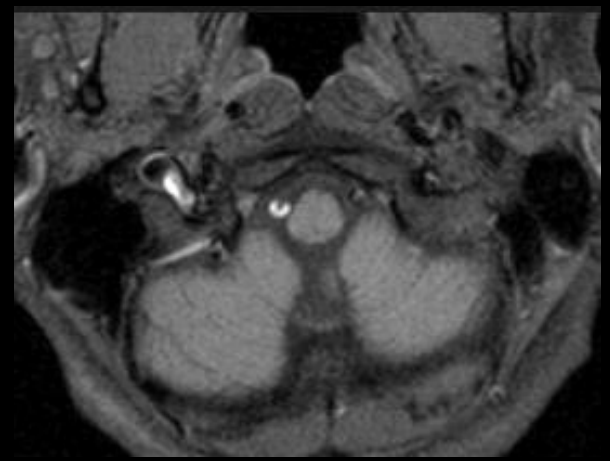


T1w



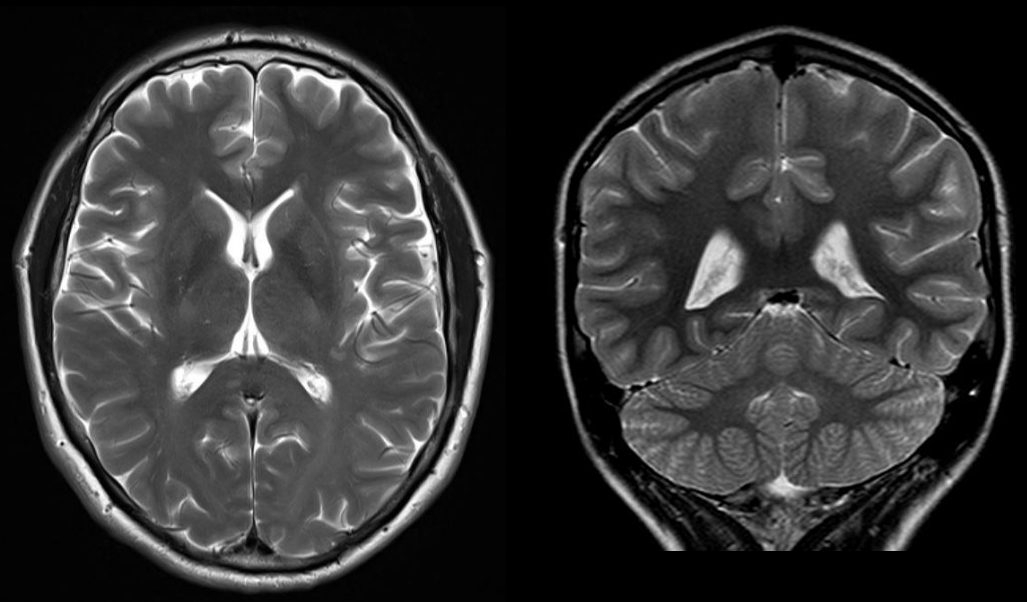
T1w + C





Don`t rely on vessel signal!

T2 TSE



- Detecting of pathology
- Characterize T2 signal of a lesion
- Most pathologies are hyerintense

  e.g. white matter disease, demyelination, edema
- T2 hypointense:

  Flow voids, CSF pulsation (Aquaeduct)

  Dense cells (e.g. Lymphoma)

  Blood products (acute, ealy subacute, chronic)

  Calcifications/ mineralization

- Cons: small cortical lesions more difficult to delineate

2D or 3D FLAIR

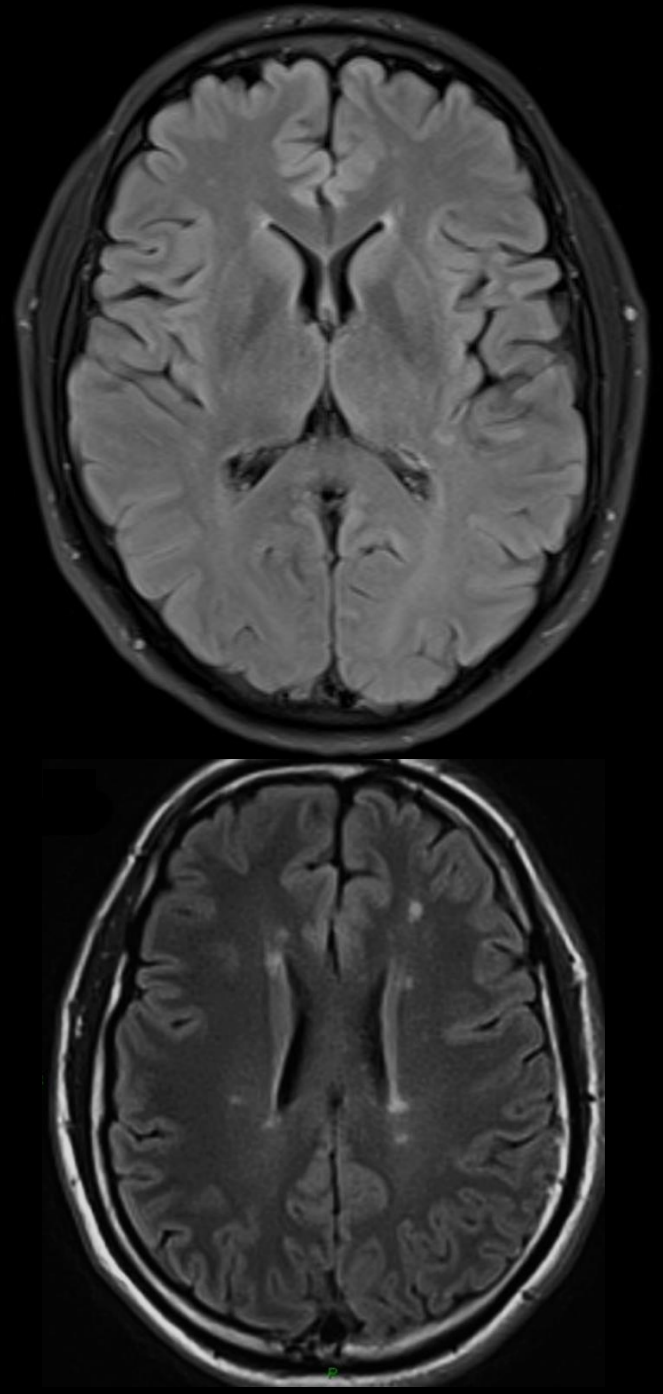
- Similar to T2w with signal from free water suppressed
- Very sensitive for lesion detection
- Most pathology is hyperintense

  Gliosis, demyelination, edema

  Protein-rich CSF
- Cons:

  Prone to artifacts (*)

  Infratentorial T2w images improved contrast



2D or 3D FLAIR

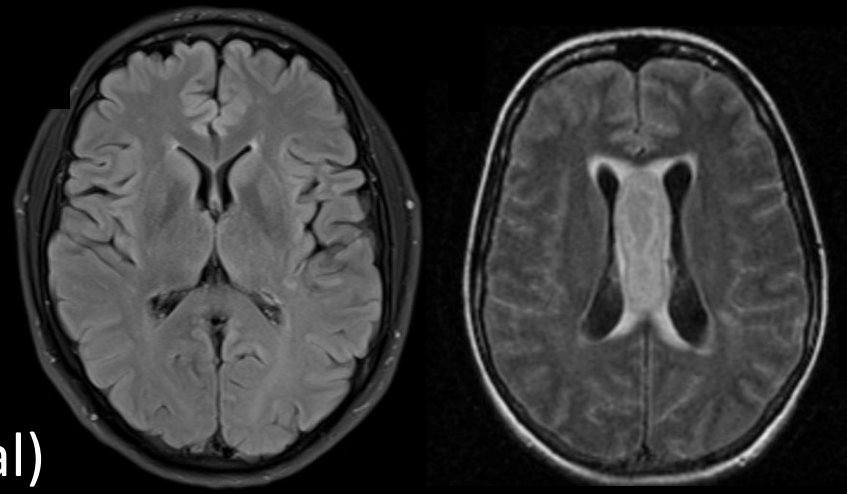
- Similar to T2w with signal from free water suppressed
- Very sensitive for lesion detection (periventricular, cortical)
- Most pathologies are hyperintense

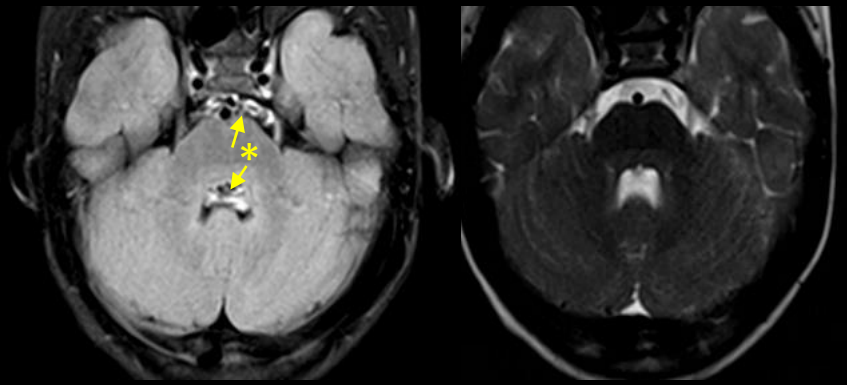
  Gliosis, demyelination, edema

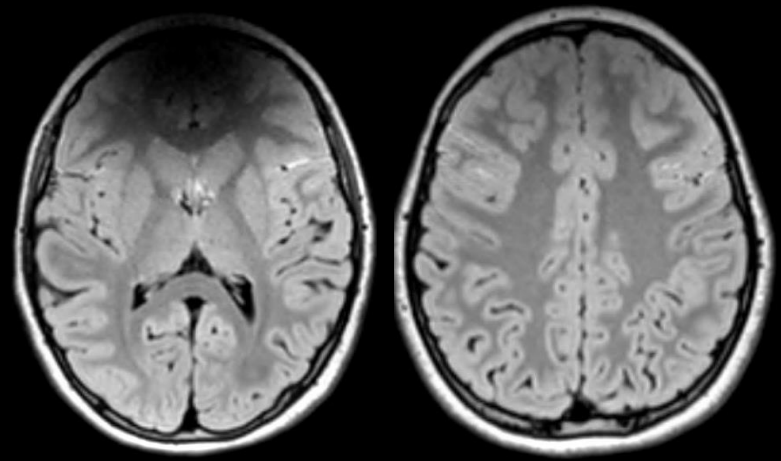
  Protein-rich CSF
- Cons:

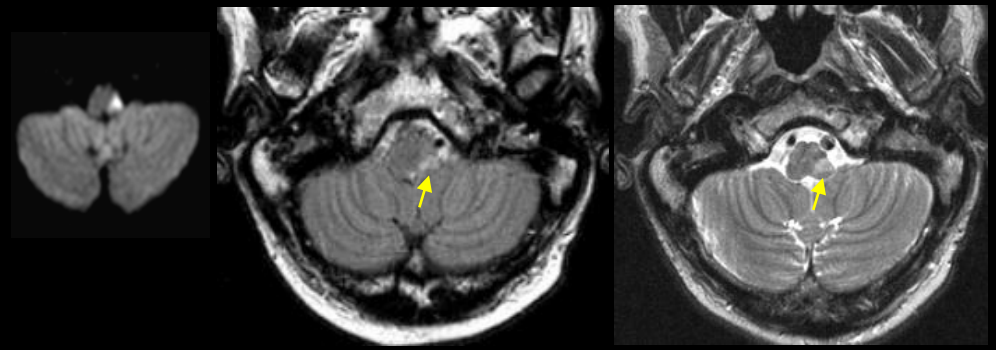
  Prone to artifacts (*)

  Infratentorial T2w images improved contrast







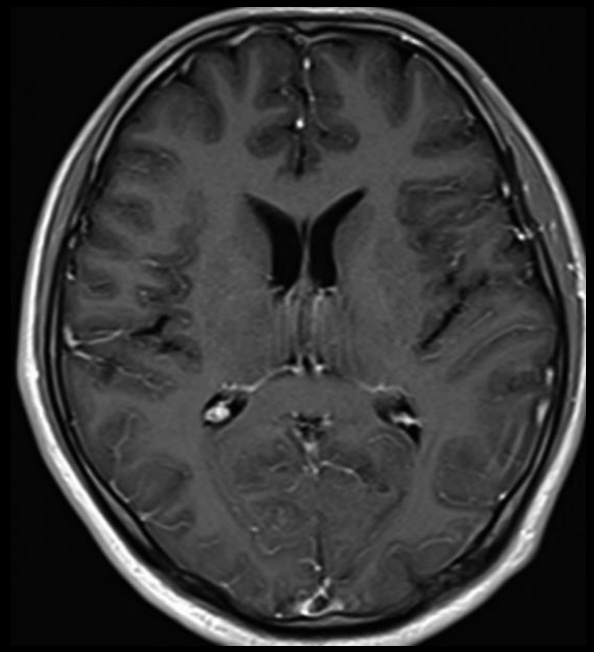


2D or 3D FLAIR contrast enhanced

Importance of Contrast-Enhanced Fluid-Attenuated Inversion Recovery Magnetic Resonance Imaging in Various Intracranial Pathologic Conditions

Eun Kyoung Lee, MD[1, 2], Eun Ja Lee, MD, PhD[1], Sungwon Kim, MD[1], Yong Seok Lee, MD[1]

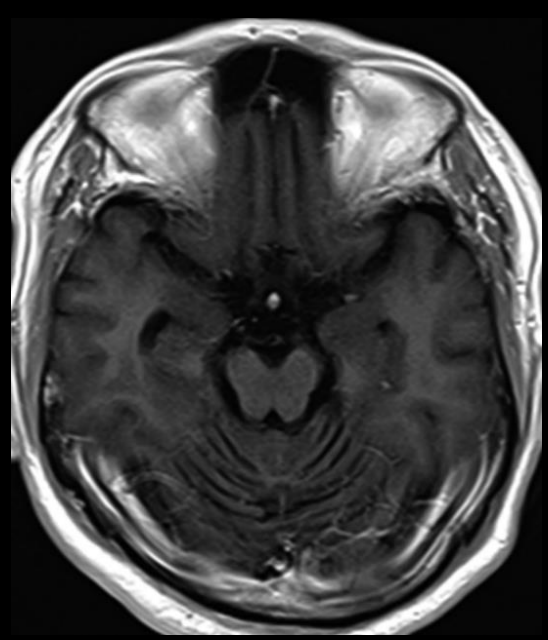
[1]Department of Radiology, Dongguk University Ilsan Hospital, Goyang 10326, Korea; [2]Department of Radiology, College of Medicine, Kangwon National University, Chuncheon 24289, Korea



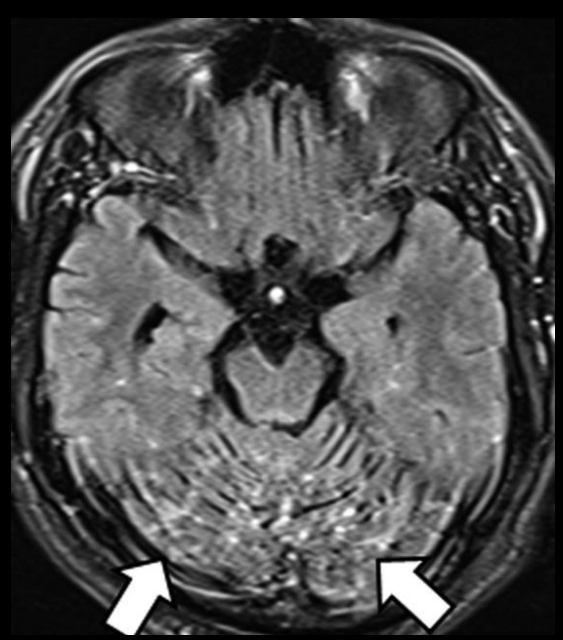
T1 + C

FLAIR + C

Viral meningoencephalitis



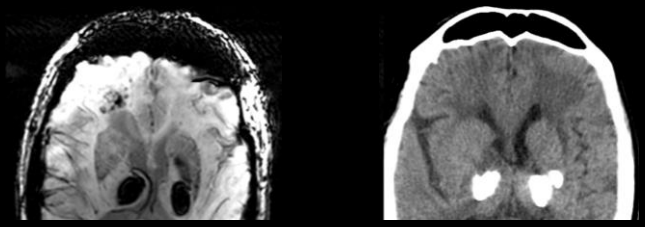
T1 + C

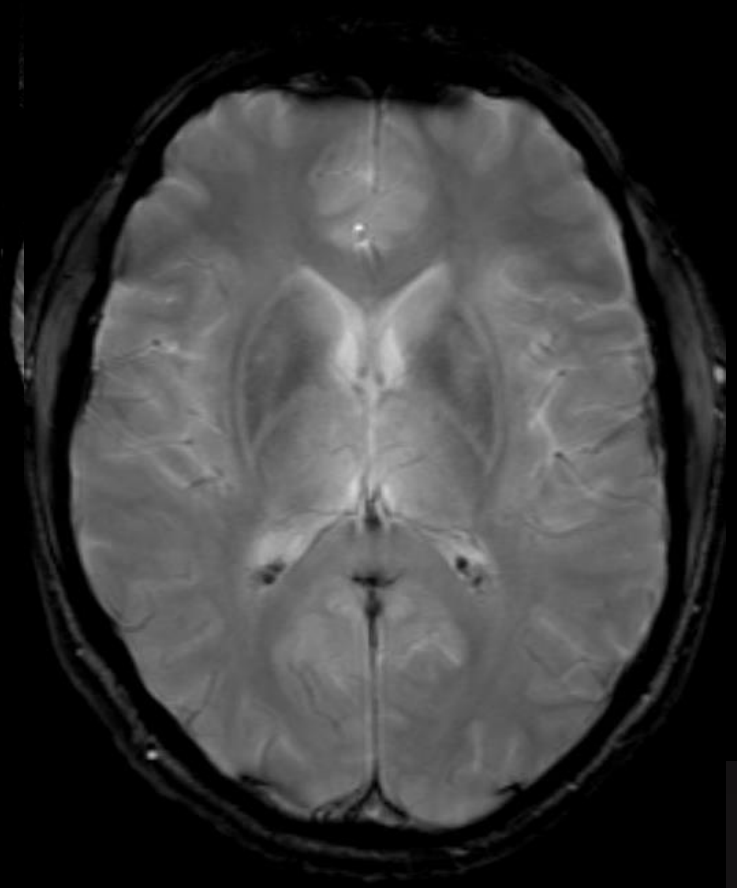


FLAIR + C

Leptomeningeal metastasis

T2* or Susceptibility weighted images

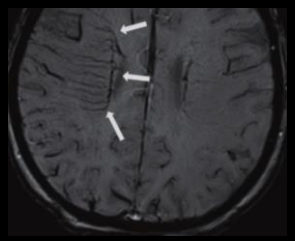


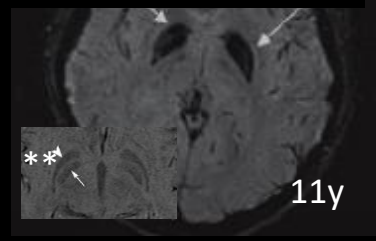


- GE-sequence, Detection of magnetic susceptibility
- Detection of
  - Calcium and blood degradation products (haemosiderin)
  - Cavernoma
  - Amyloid angiopathy, superficial siderosis
  - Hypertensive encephalopathy/ vasculitis (microbleeds)
  - Diffus axonal injury
  - Venous anomaly (PLOS ONE | DOI:10.1371/journal.pone.0120801*), sinus thrombosis
  - Mineralization/ neurodegeneration (NBIA)

  (Mineralization of the deep gray matter with age. AJNR 2008 Jan;29(1):176-83**)
- Cons: limited image quality due to artifacts

  (pneumatised skull sections, metallic foreign bodies)





Susceptibility-weighted Imaging: Technical Essentials and Clinical Neurologic Applications

Sven Haller, MD, MSc, • E. Mark Haacke, PhD • Majda M. Thurnher, MD • Frederik Barkhof, MD, PhD

Radiology 2021; 299:3–26

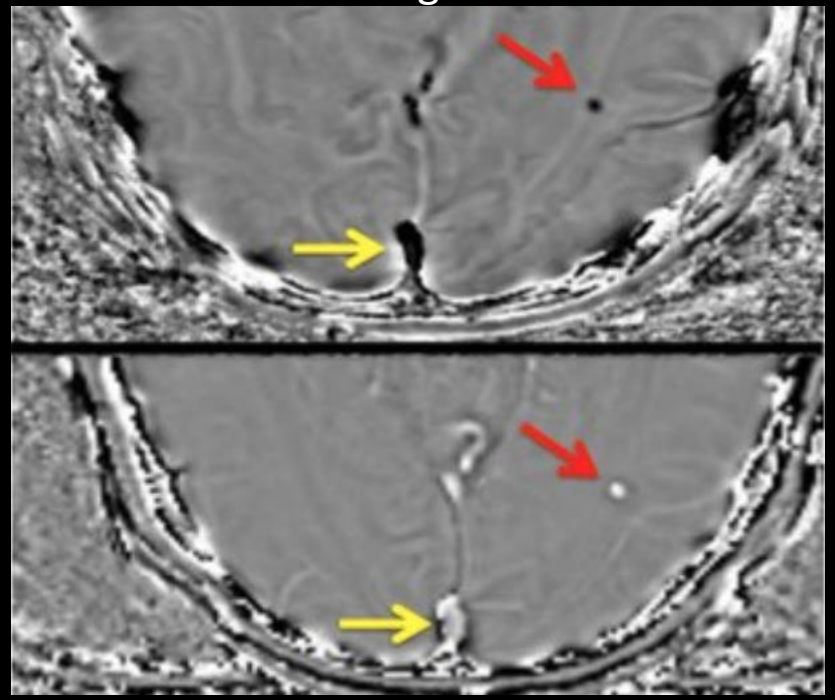
Differentiation blood/iron (paramagnetic) and calcifications (diamagnetic)

Table 1: Overview of Susceptibility-Sensitive Sequences for MRI Vendors

Handedness	Sequence Name	Paramagnetic: Probable Microbleed	Diamagnetic: Probable Microcalcification
Left-handed		Hyperintense on phase images	Hypointense on phase images
Siemens	SWI		
Canon	FSBB		
Philips	3D GRE raw data		
Right-handed		Hypointense on phase images	Hyperintense on phase images
United Neusoft	SWI		
GE Healthcare	SWAN		
Philips	3D SWIp		

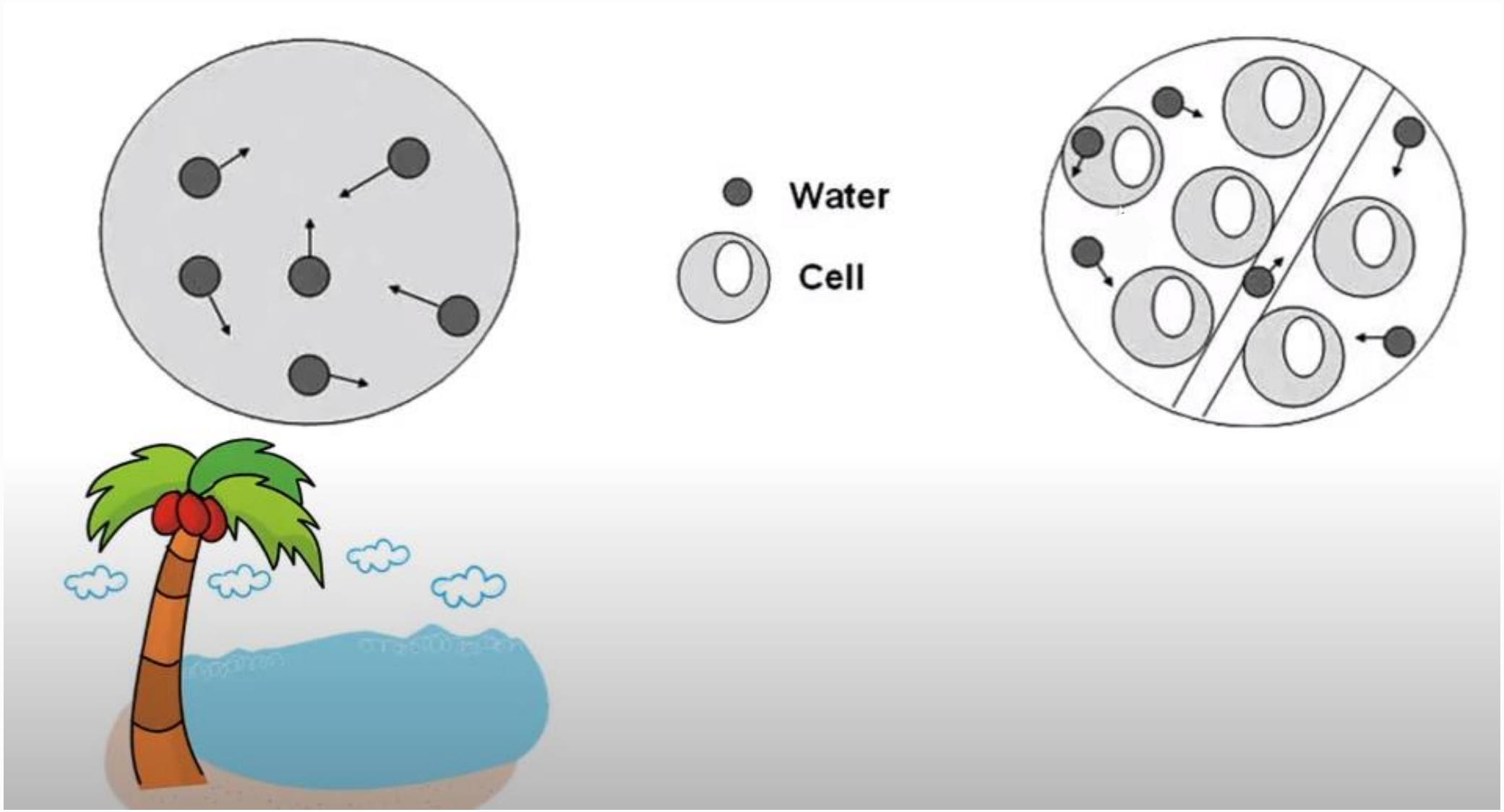
Note.— FSBB = flow sensitive black blood, GRE = gradient echo, SWAN = susceptibility-weighted angiography, SWI = susceptibility-weighted imaging, SWIp = SWI with phase enhancement, 3D = three-dimensional.

Microbleed on a right-handed scanner



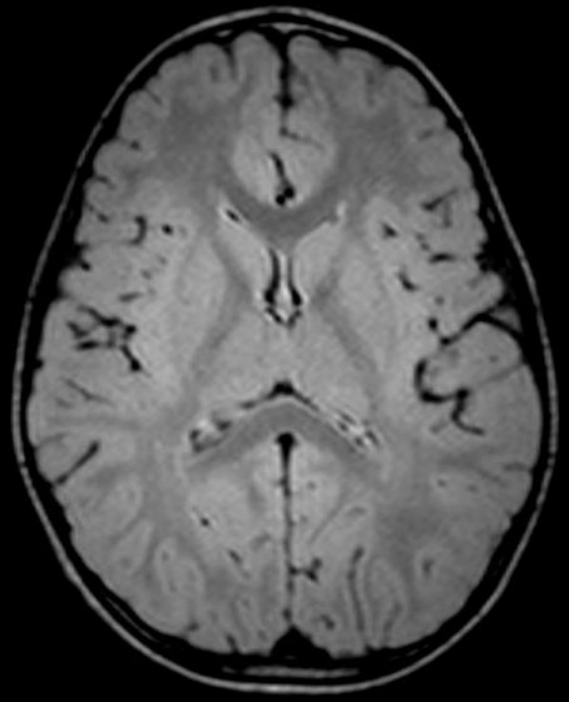
Microbleed on a left-handed scanner

Diffusion weighted imaging

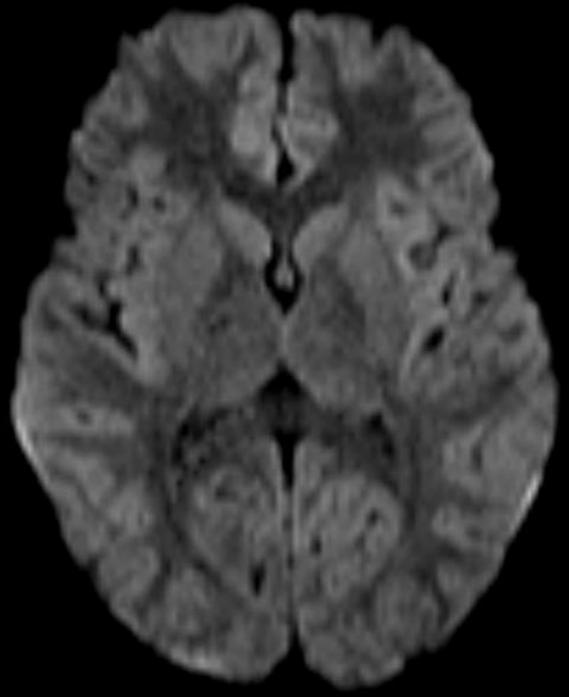


Diffusion weighted images and ADC

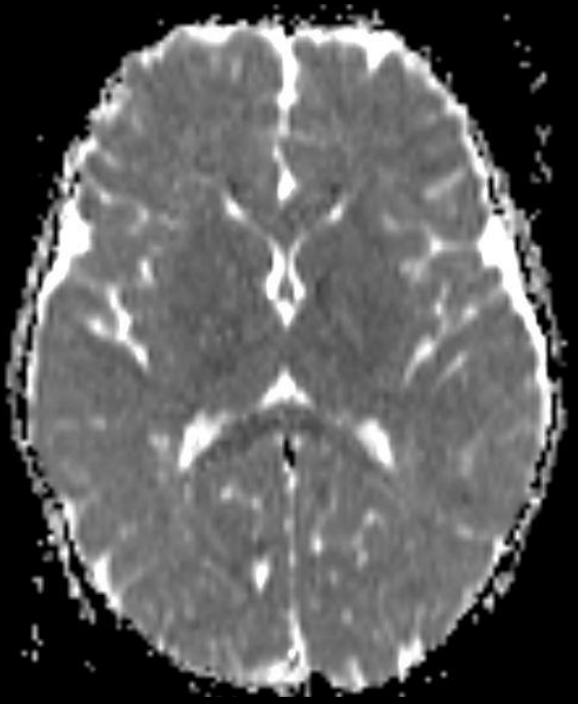
FLAIR



DWI

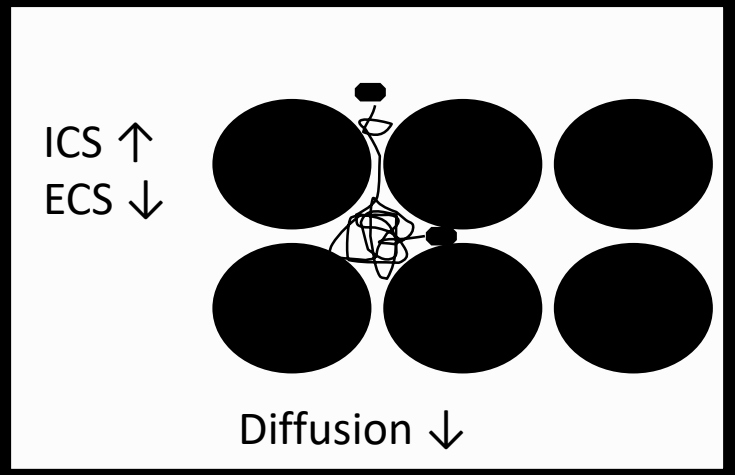


ADC

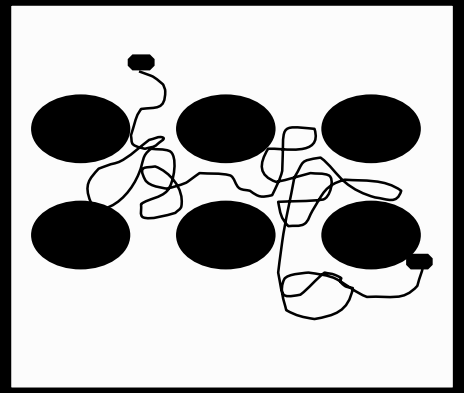


- DWI: appearance similar to FLAIR (hyperintense cortex, dark CSF)
- ADC: calculated from DWI (T2 effect eliminated), hyperintense CSF, hypointense brain

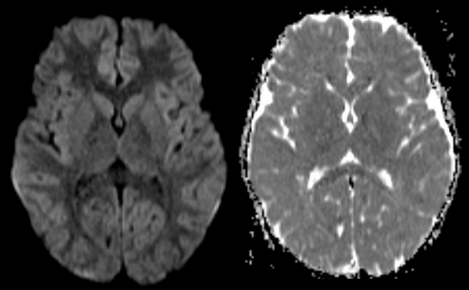
Diffusion weighted imaging

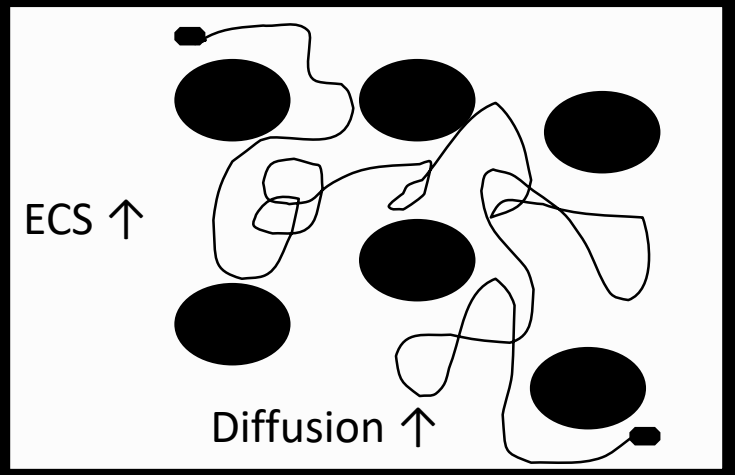


Cytotoxic edema

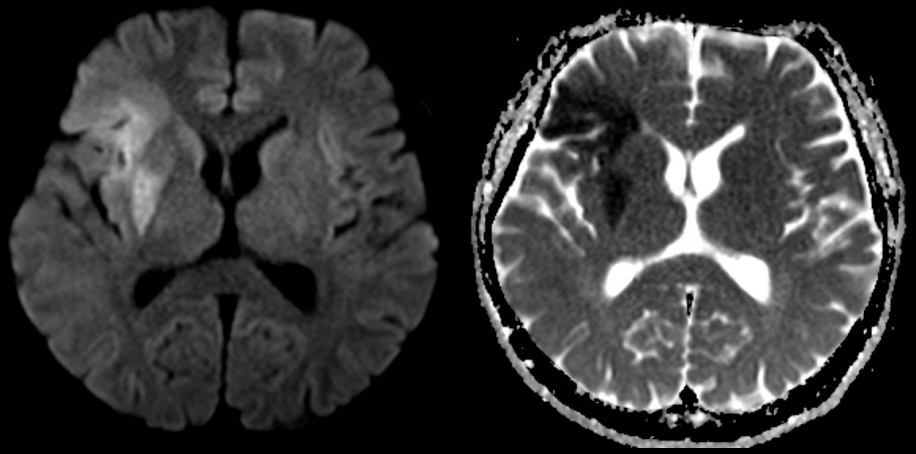


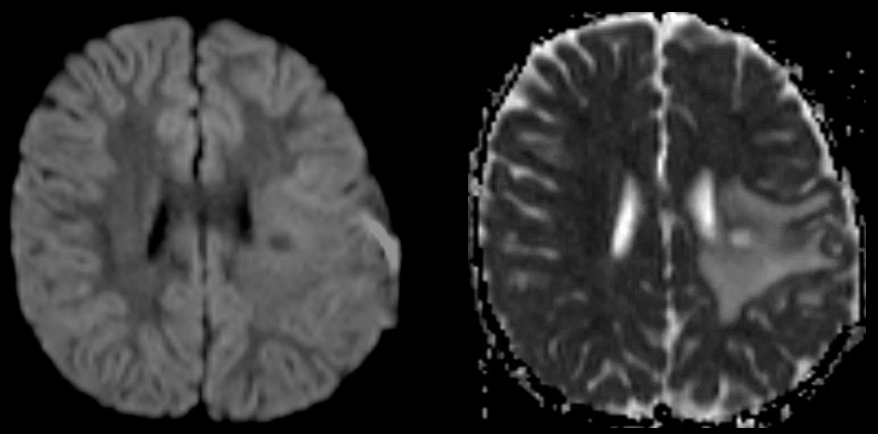
Normal parenchyma





Vasogenic edema





DWI and ADC-map

- DD vasogenic versus cytotoxic edema
- Restricted diffusion:

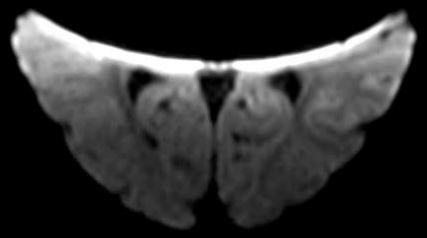
  Acute ischemia

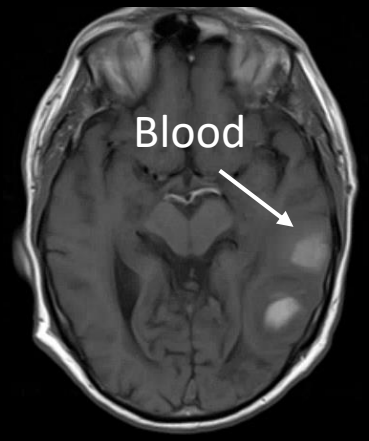
  Blood

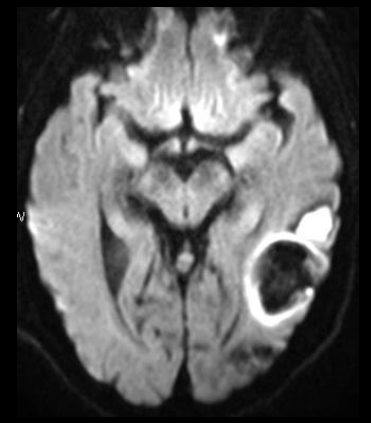
  Abscess

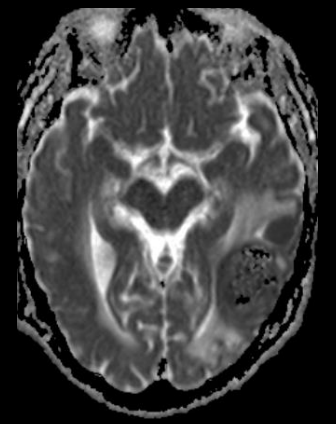
  Tumor (dense cells, e.g. lymphoma), Epidermoid

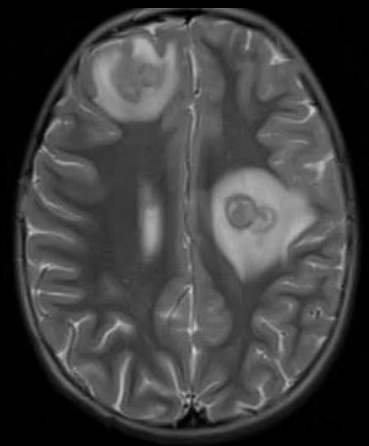
  Acute demyelination, encephalitis
- Artifacts (adjacent to bone, air, metals)

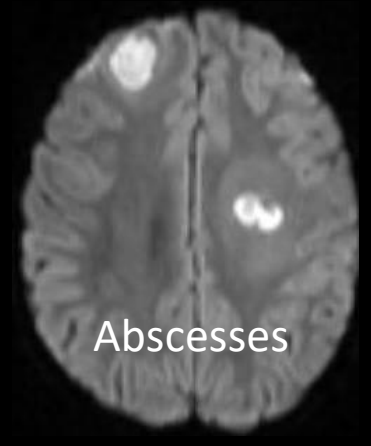


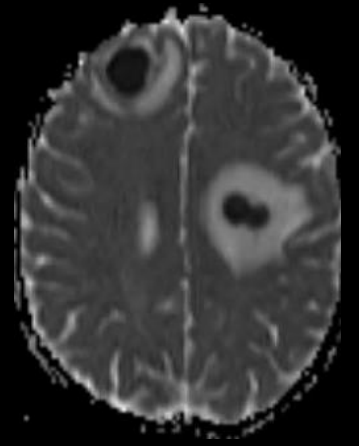


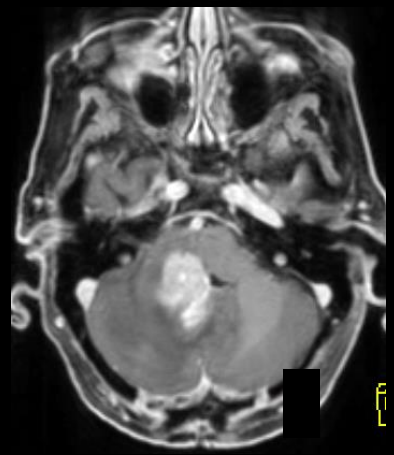


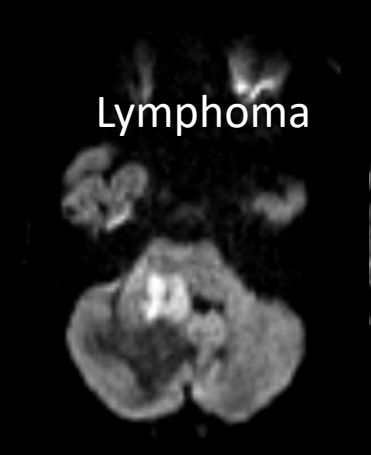


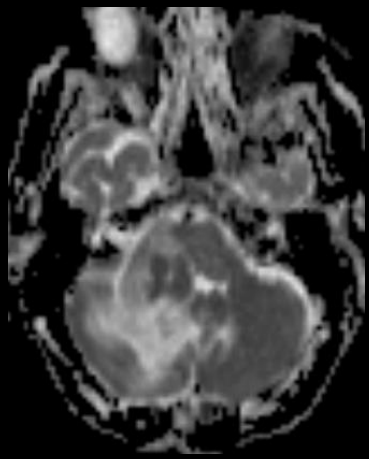




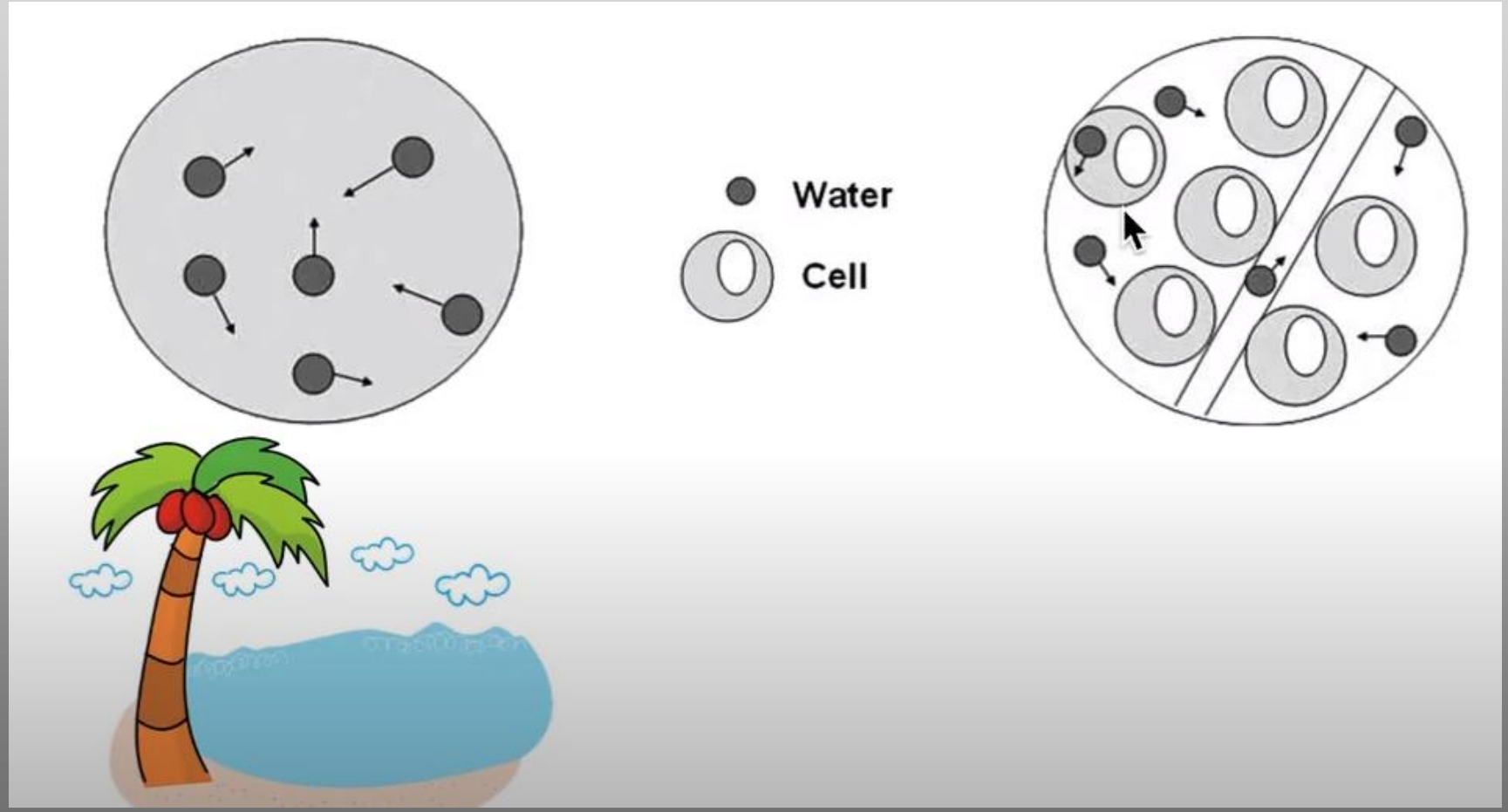


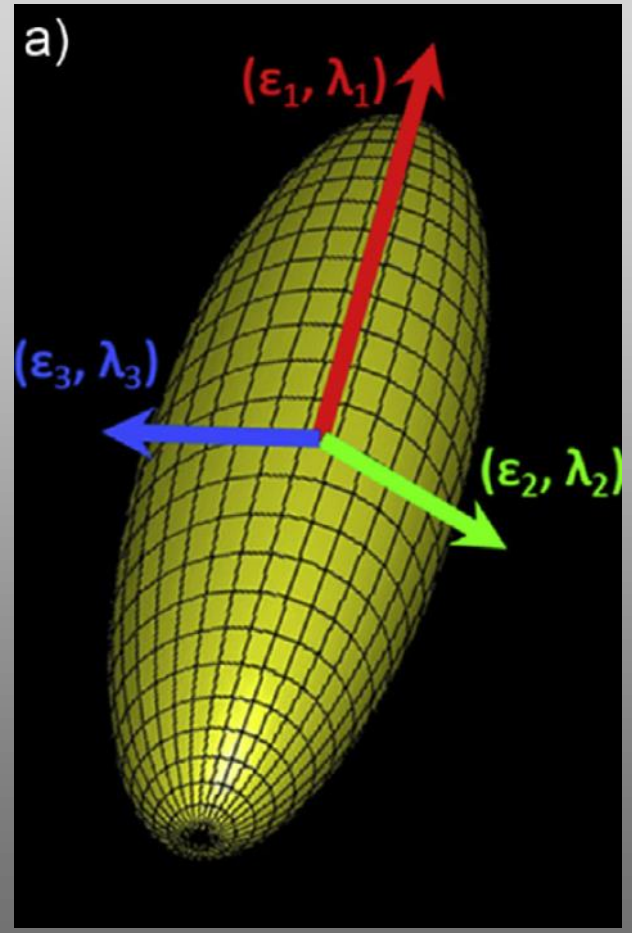




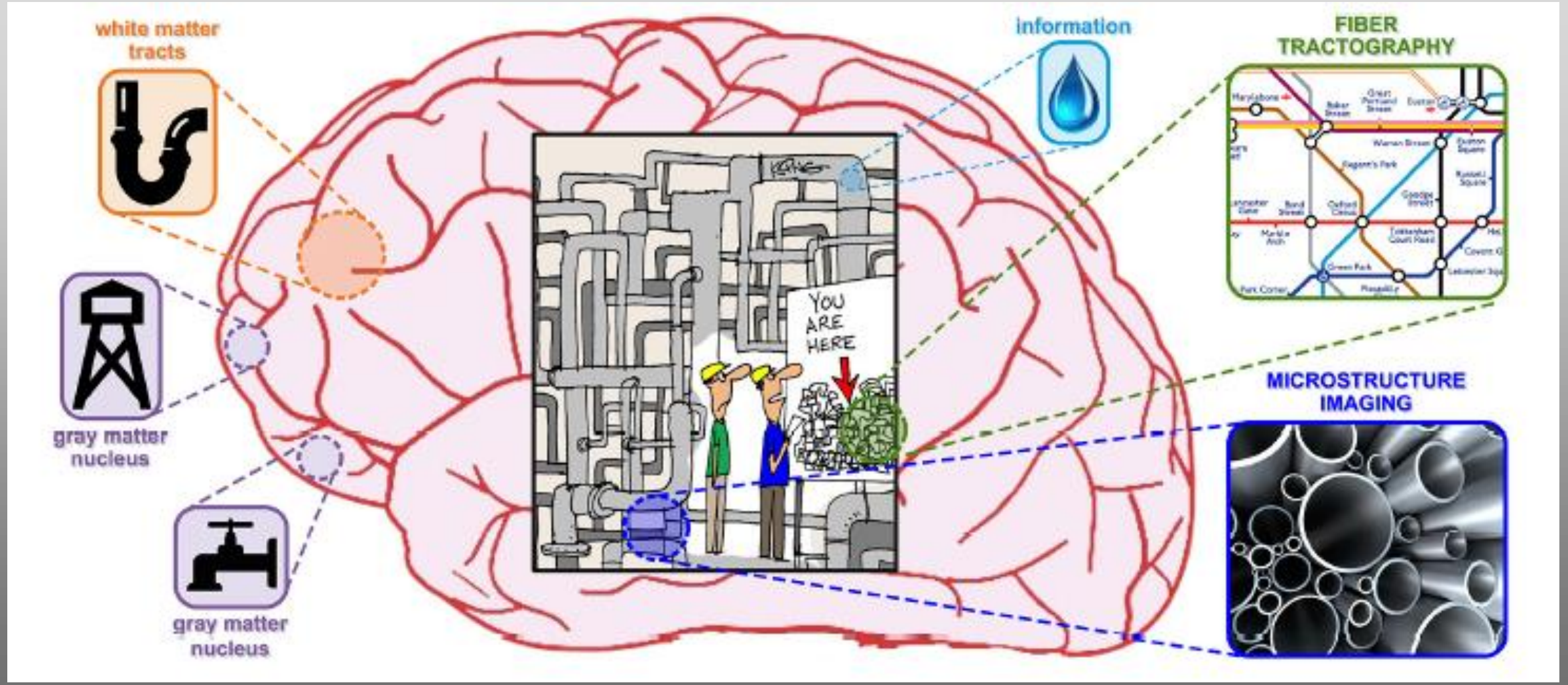


Diffusion-weighted imaging → Diffusion Tensor Imaging





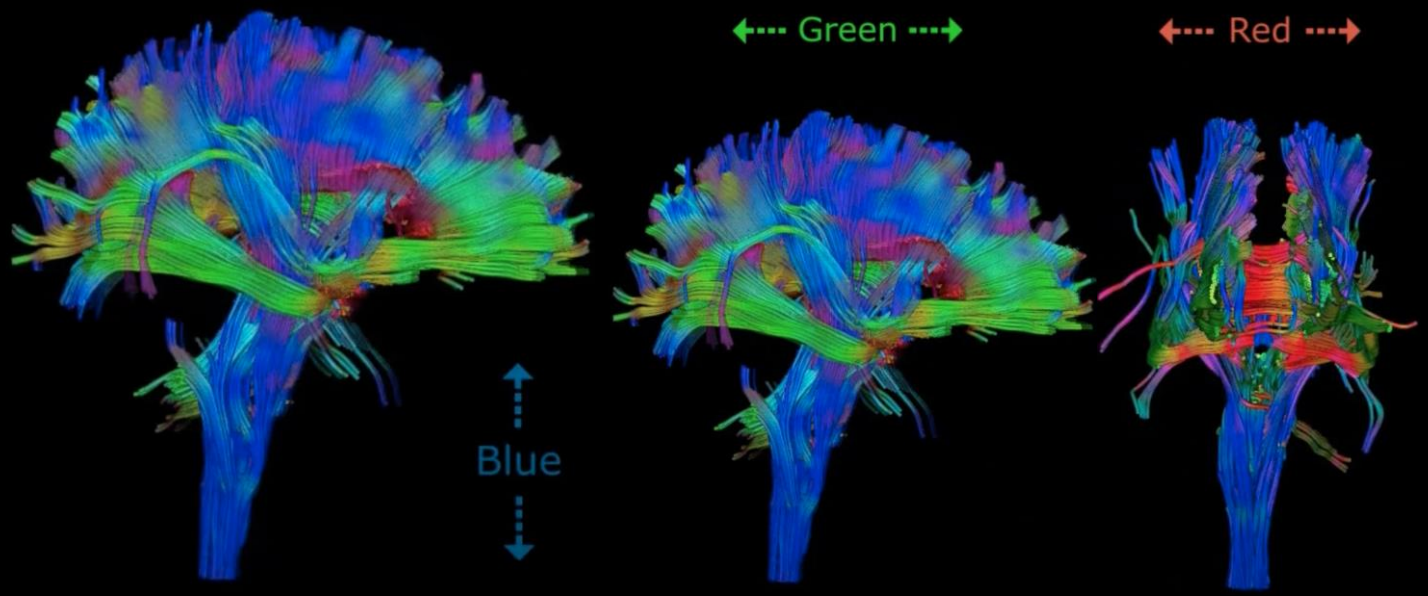
Diffusion Tensor Imaging

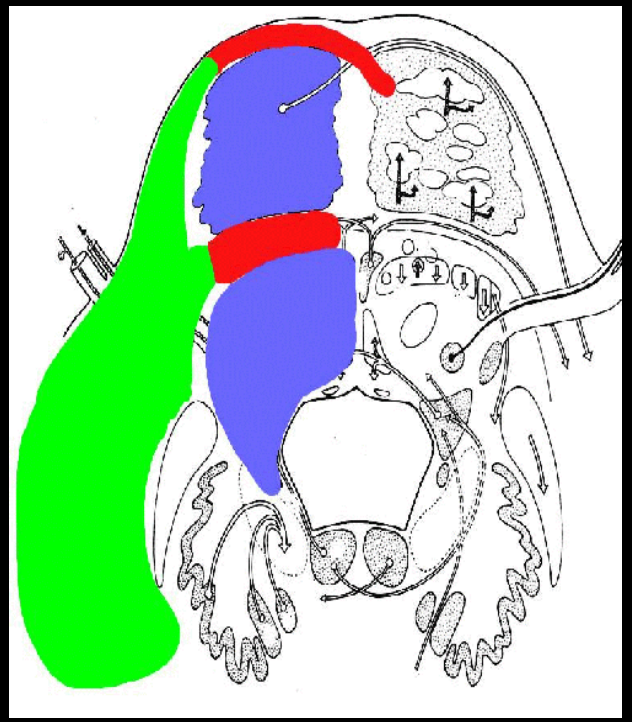


Daducci et al., Frontiers in Neuroscience 2016

Diffusion Tensor Imaging

- DWI: restricted diffusion yes/no?
- No information on the direction or magnitude of molecular movement





Diffusion Tensor Imaging

- Minimum of 6 gradient directions (better more than 30 → increase spatial resolution))
- Demonstration of white matter tracts by colour mapping (Tractography):

  blue: up and down

  green: front to back

  red: left to right
- Fractional anisotropy (FA): microstructural integrity (very sensitive, but not specific), ranges from 0 (isotropic diffusion) to 1 (anisotropic diffusion)
- Axial diffusivity (AD): related to axonal injury
- Radial diffusivity (RD): represents myelin degeneration (increases in demyelination)
- Visualisation of fiber tracts: displacement/ infiltration of fiber tracts in tumors
- Aberrant fiber tracts in congenital brain malformations
- Studies in different types of dementia (AD, LBD, FTD), PD, MSA, increasingly in psychiatric issues

Diffusion Tensor Imaging

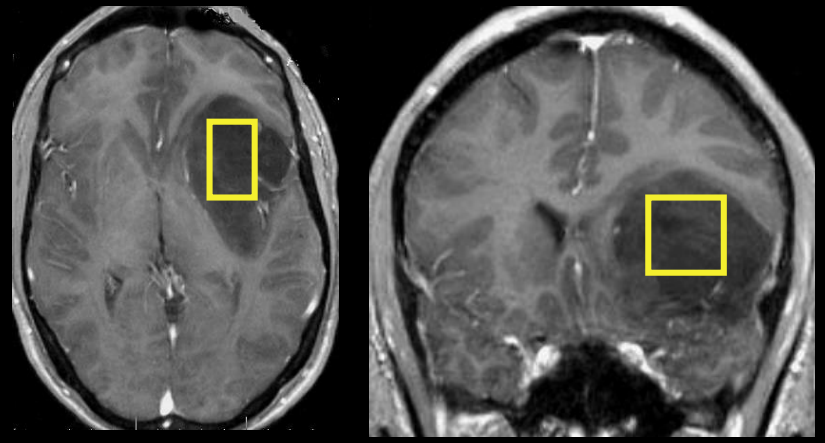
Potential Pitfalls of Using Fractional Anisotropy, Axial Diffusivity, and Radial Diffusivity as Biomarkers of Cerebral White Matter Microstructure

Chase R. Figley[1,2,3,4], Md Nasir Uddin[1,5], Kaihim Wong[1,3], Jennifer Kornelsen[1,2,3,4], Josep Puig[1,2,6] and Teresa D. Figley[1,2,3,4]*

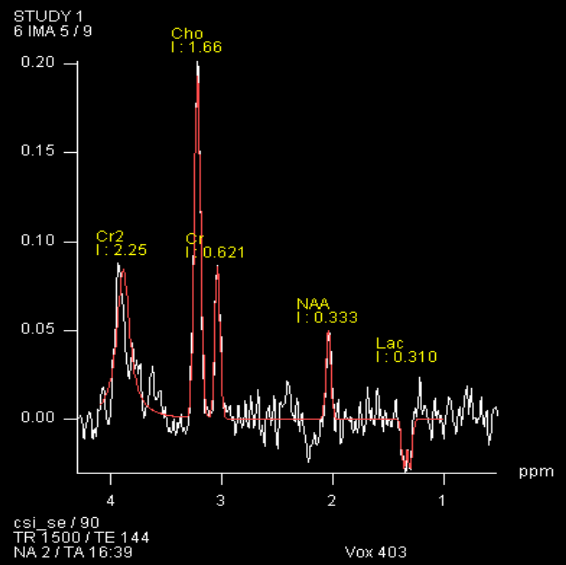
Front Neurosci. 2022 Jan 14;15:799576.

^{1}H MR Spectroscopy

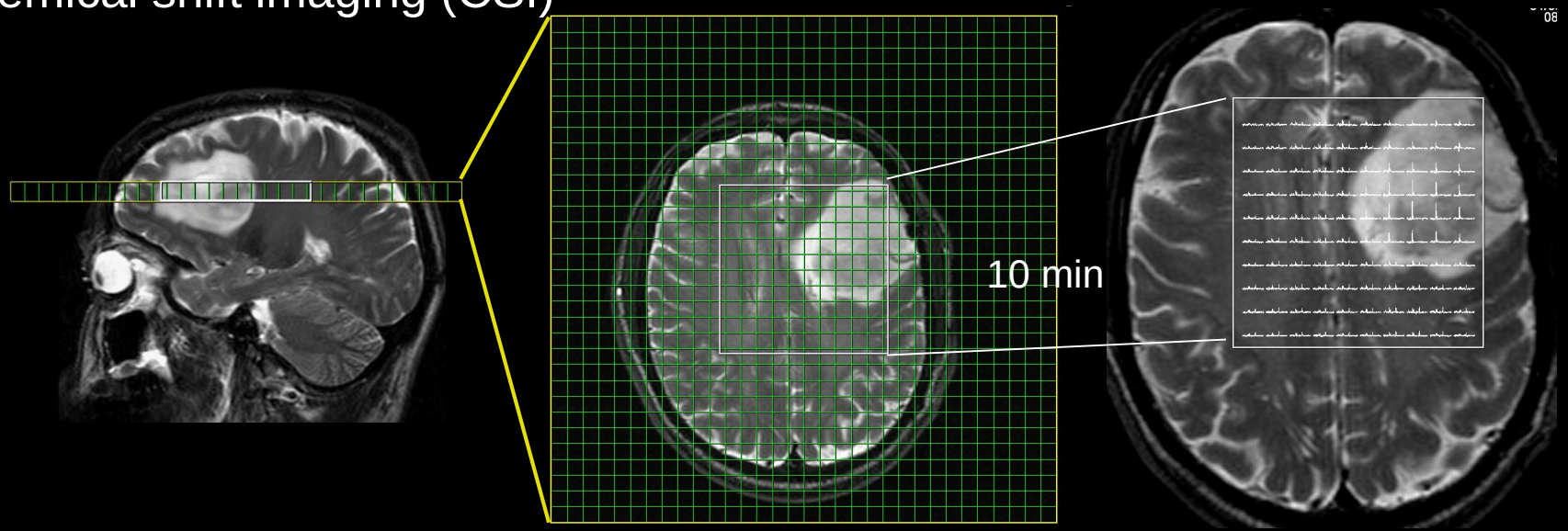
Single Voxel Spectroscopy (SVS)



5-15 min

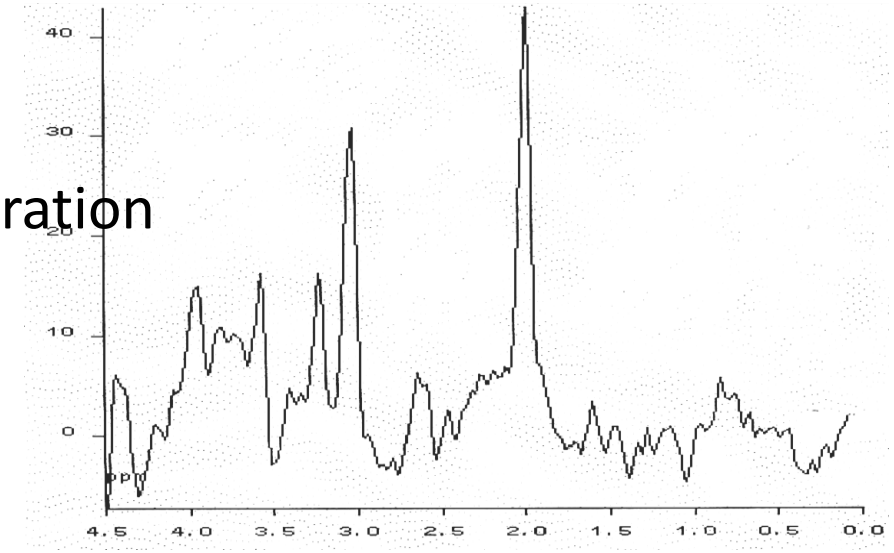


Chemical shift imaging (CSI)

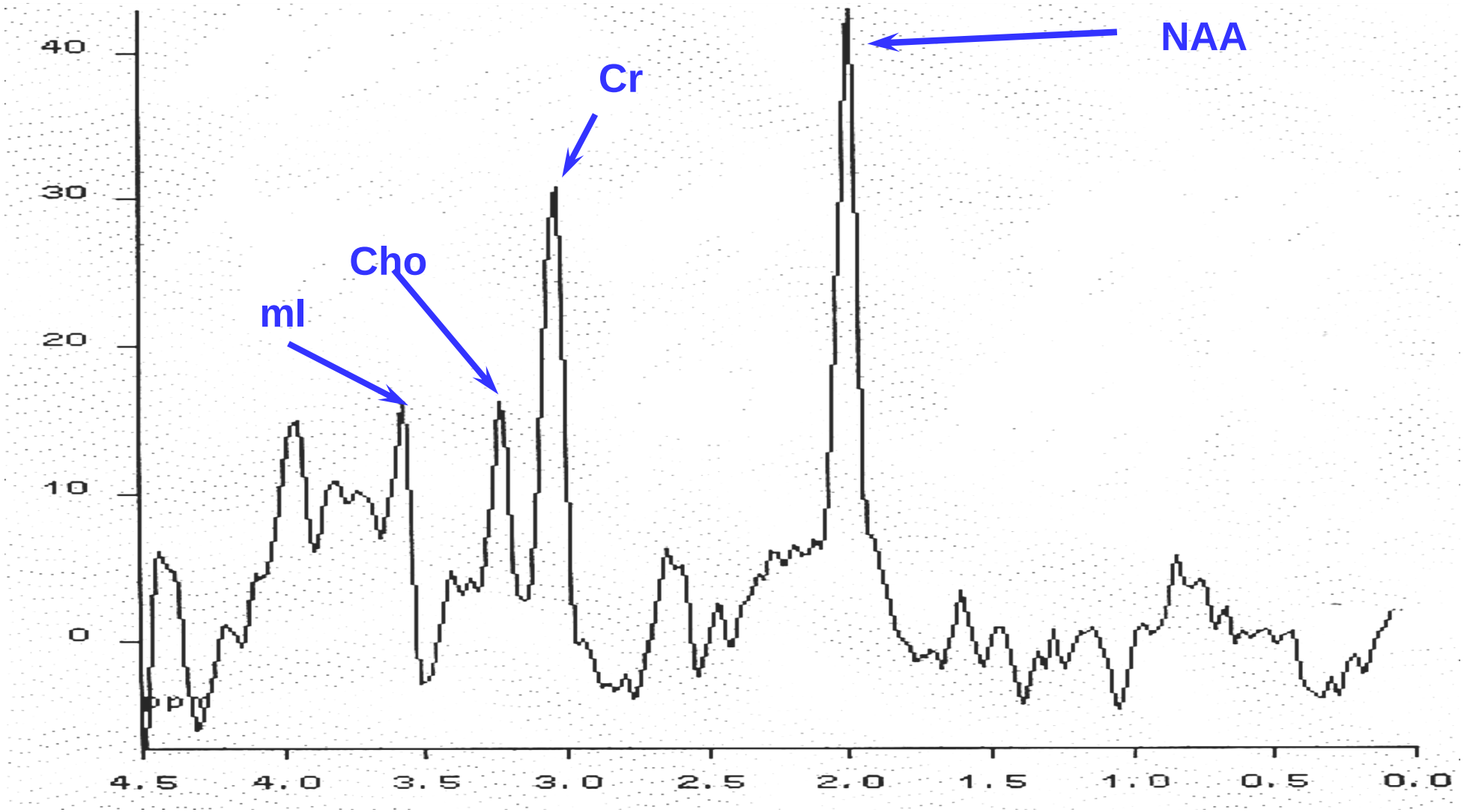


How to interprete the MRS curve?

- Spectrum represents the radiofrequency signals emitted from the proton nuclei of different metabolites in the ROI
- Metabolites always appear at the same frequency (expressed in parts per million (ppm) on the x-axis
- Vertical axis: height of the metabolite peak
- Area under the curve determines metabolite concentration



Normal adult spectrum



^{1}H MR Spectroscopy

- **NAA (N-acetyl aspartate): resonates at 2.0 ppm, neuronal marker**
- **Cr (Creatine): marker of aerobic energy metabolism, used as internal reference, at 3.02 ppm**
- **Cho (Choline): reflects membrane turnover, at 3.22 ppm**
- **mI (Myoinositol): glial function marker, at 3.56 ppm ***
- Lac (Lactate): indicates a pathological condition as final product of anaerobic metabolism; double peak at 1.33 ppm (inverts at intermediate TE of 135ms)
- Lipids: usually not detected at MRS, indicate necrosis or cell membrane degradation, at 0.9 and 1.3 ppm *
- Glx (glutamin and glutamate): at 2.1 to 2.55 ppm *
- Alanin: at 1.48ppm, meningeoma, abscess
- Succinate: at 2.4 ppm, abscess
- Acetate: at 1.92 ppm, abscess

*detectable only with short TE

Indications of MR Spectroscopy

- Tumoral pathologies:

  DD tumor from other focal lesions, identifying optimal biopsy site, monitoring treatment response
- Demyelinating inflammatory pathologies
- Infectious disease
- Hypoxia and ischemia
- Metabolic diseases

Systematic / structured image analysis ⇢ Detect abnormalities

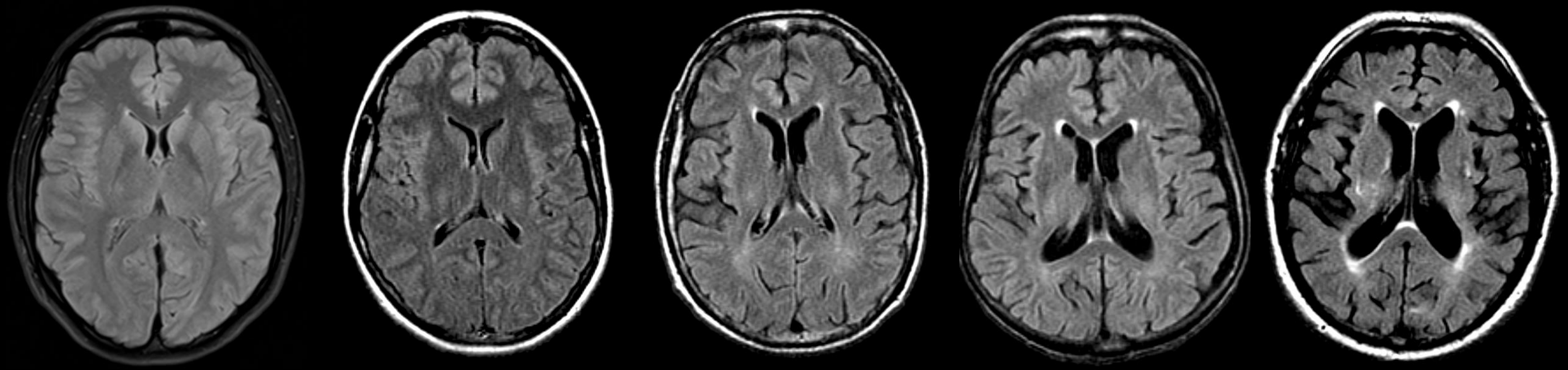
- Age, medical history and clinical findings of the patient
- Abnormalities in the surrounding soft tissue? Orbitae? Nasal sinuses?
- Normal basal cisterns?
- Wideness of the internal and external cerebrospinal fluid interspaces
- Asymmetries: tilted bedding or real asymmetry?
- Signal intensities and normal appearances of brain parenchyma (Cortex, WM, BG, Thalami)
- Midline structures, brainstem and cerebellum?
- Craniocervical junction
- Cerebral arteries and veins (Flow voids?)

Pattern recognition

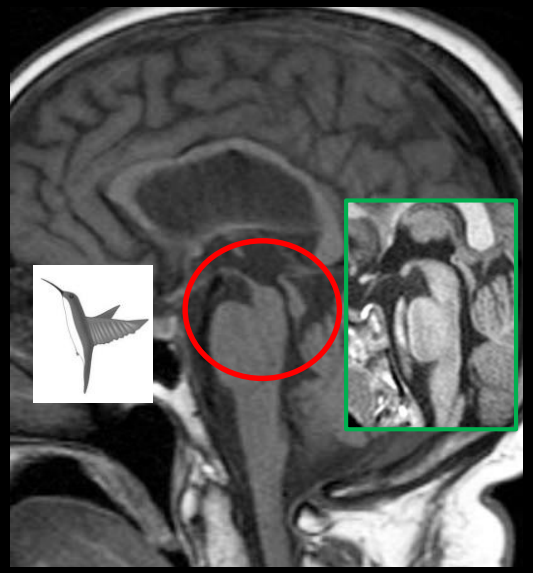
Normal patterns – variants – pathological patterns

Age dependent brain volume

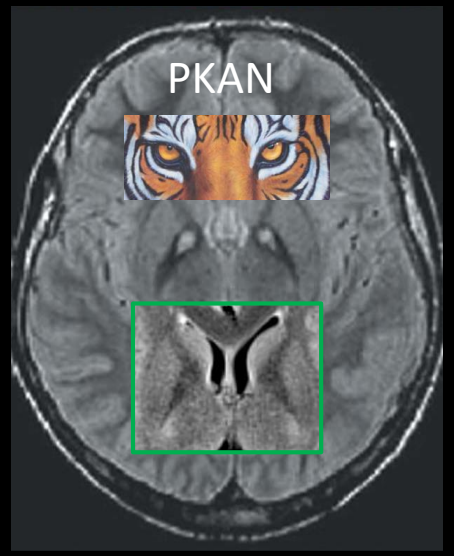
Volume decrease of GM
~ 2% per decade after 20

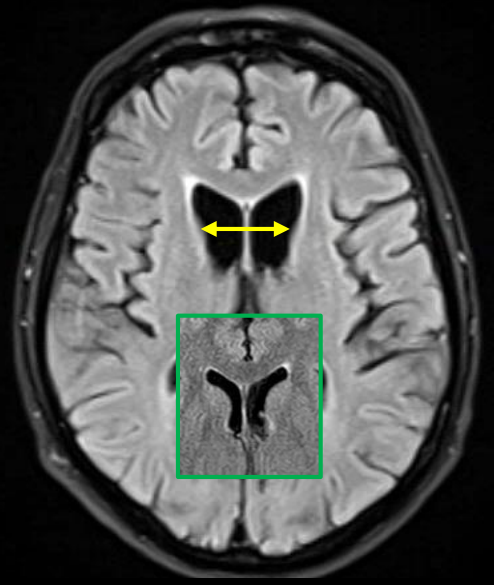


20 yrs 30 yrs 50 yrs 60 yrs 80 yrs

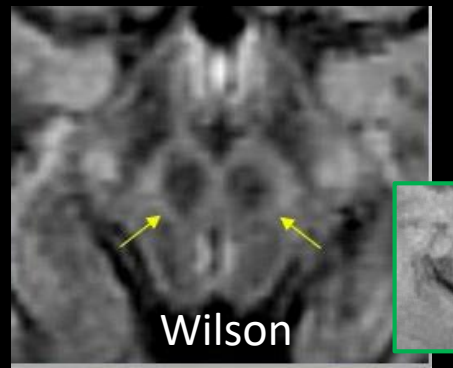


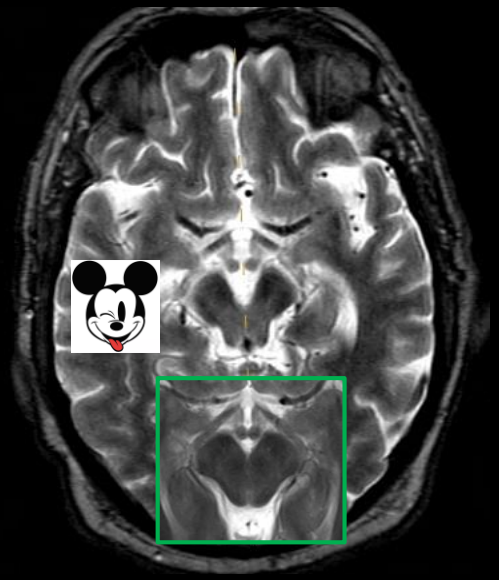
PSP

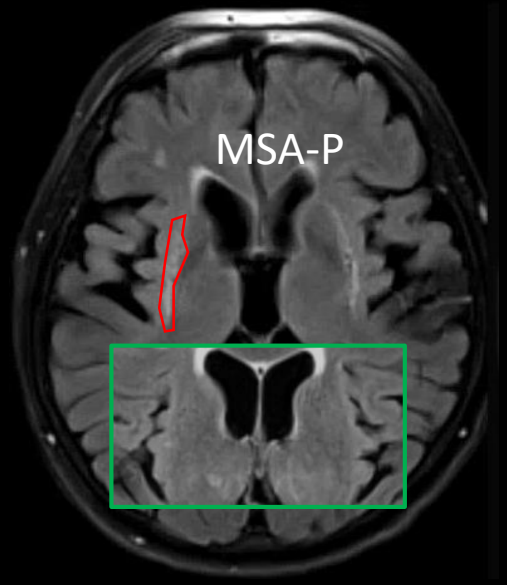


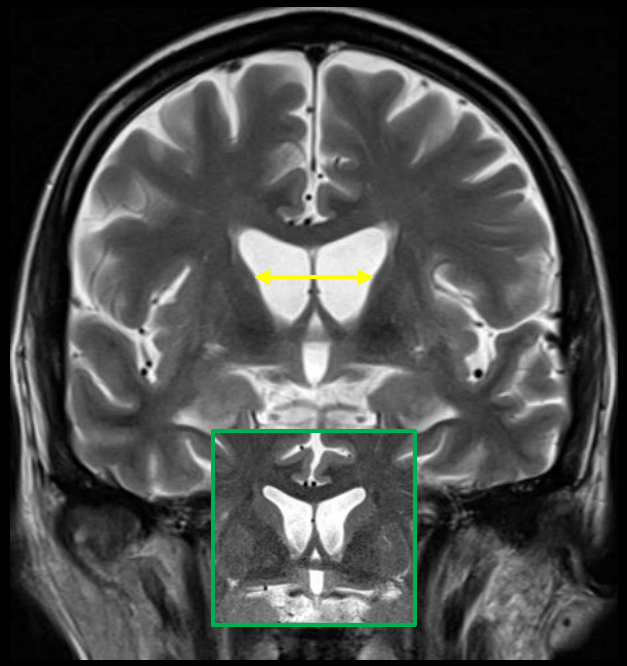


Huntington









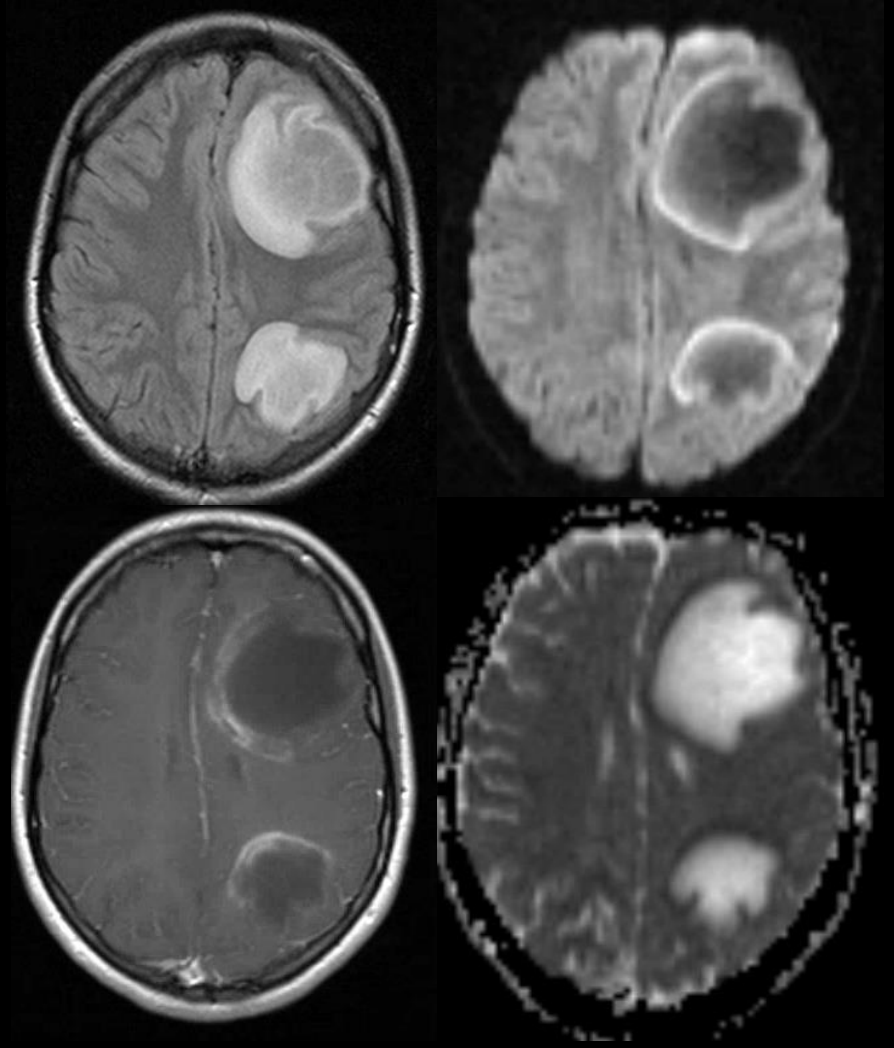
Describe findings – concisely, clearly, structured→ Diagnosis/DD

- Localisation:

  Intra- or extraaxial?

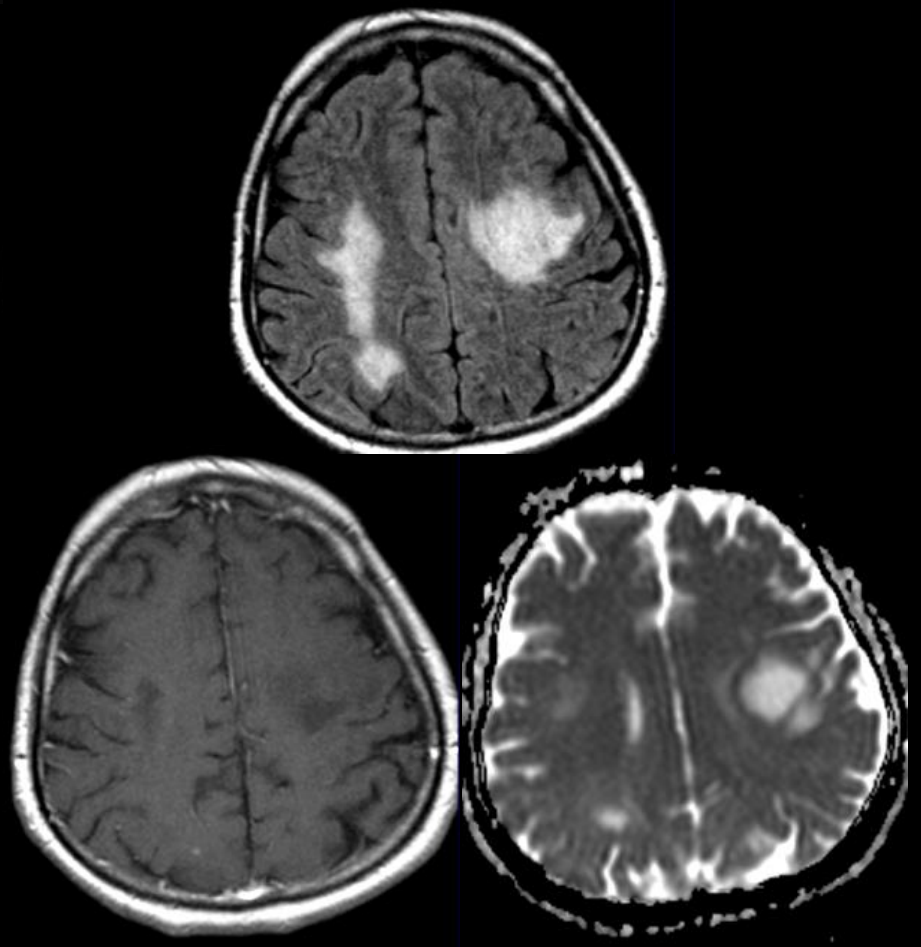
  If intraaxial which structure is involved? Cortex, WM (juxtacortical, subcortical,

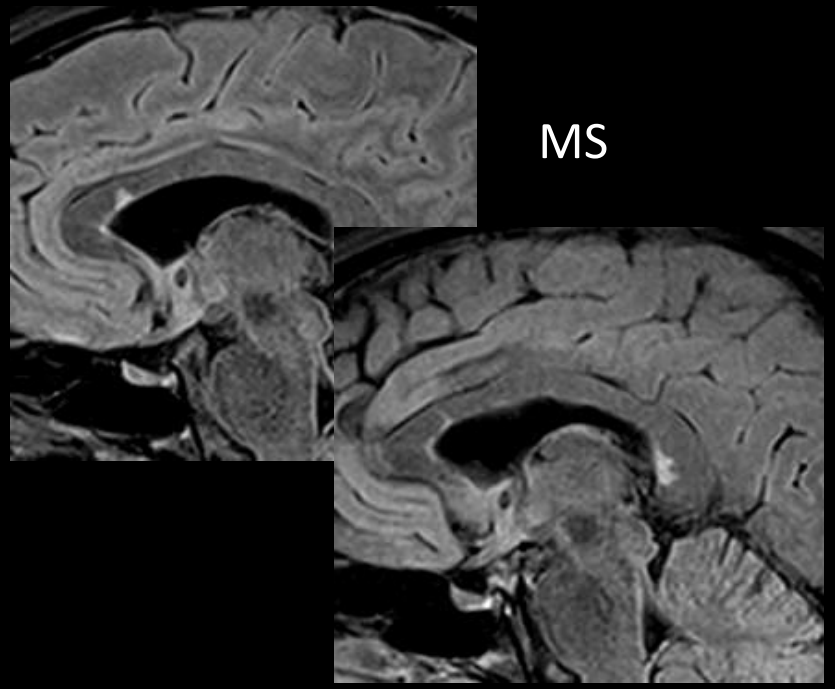
  deep WM, periventricular, infratentorial), BG, Thalami, brainstem, cerebellum
- Symmetric or asymmetric distribution?
- Number of lesions, shape, density (CT)/ signal intensity (MRI- different sequences)
- Sharply demarcated, irregular, homogenous or inhomogenous
- Space-occupying?
- Atrophy uni-/ bilateral? Asymmetric? Global? Which part is primarily affected?
- Contrast enhancement?



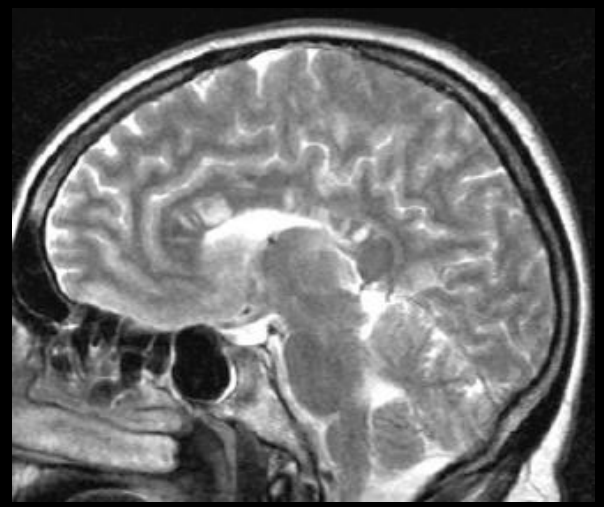
Tumefactive MS

PML





MS



Susac syndrome

Take home messages

Communication Clinician – Neuroradiologist

Image acquisition:	MRI >>CT
	Choose most appropriate MRI protocol (Field strength, sequences, orientation, additional sequences)
Structured Analysis:	4 D`s (Detect, Describe, Diagnosis/ Differentialdiagnosis, Decision)
	Age-related normal findings/ differences, pattern analysis
	Know variants
Interpretation:	In context of anamnesis and clinical findings

Thanks for your attention

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