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34th Review in Internal Medicine 2026

Essential in Neuroimaging

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Division of Neurology, Department of Medicine

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Mahidol University

Siriraj Neuroimmunology Center (SiNiC)

2010	M.D. (1st Class Honors)
2016	Diplomate, Thai Board of Internal Medicine
2018	Diplomate, Thai Board of Neurology
2020	Fellowship in Neuro-Ophthalmology
2025	Research Fellowship in Neuro-Ophthalmology

Interests: Neuro-Ophthalmology, Neuro-Otology, Cranial Nerve Disorders
Neuro-Immunology, Neuroanatomy

SiNiC
Siriraj Neuroimmunology Center

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- No financial interest
- For educational purposes only
- Some materials in this presentation belong to the presenter’s copyright

Types of Neuroimaging

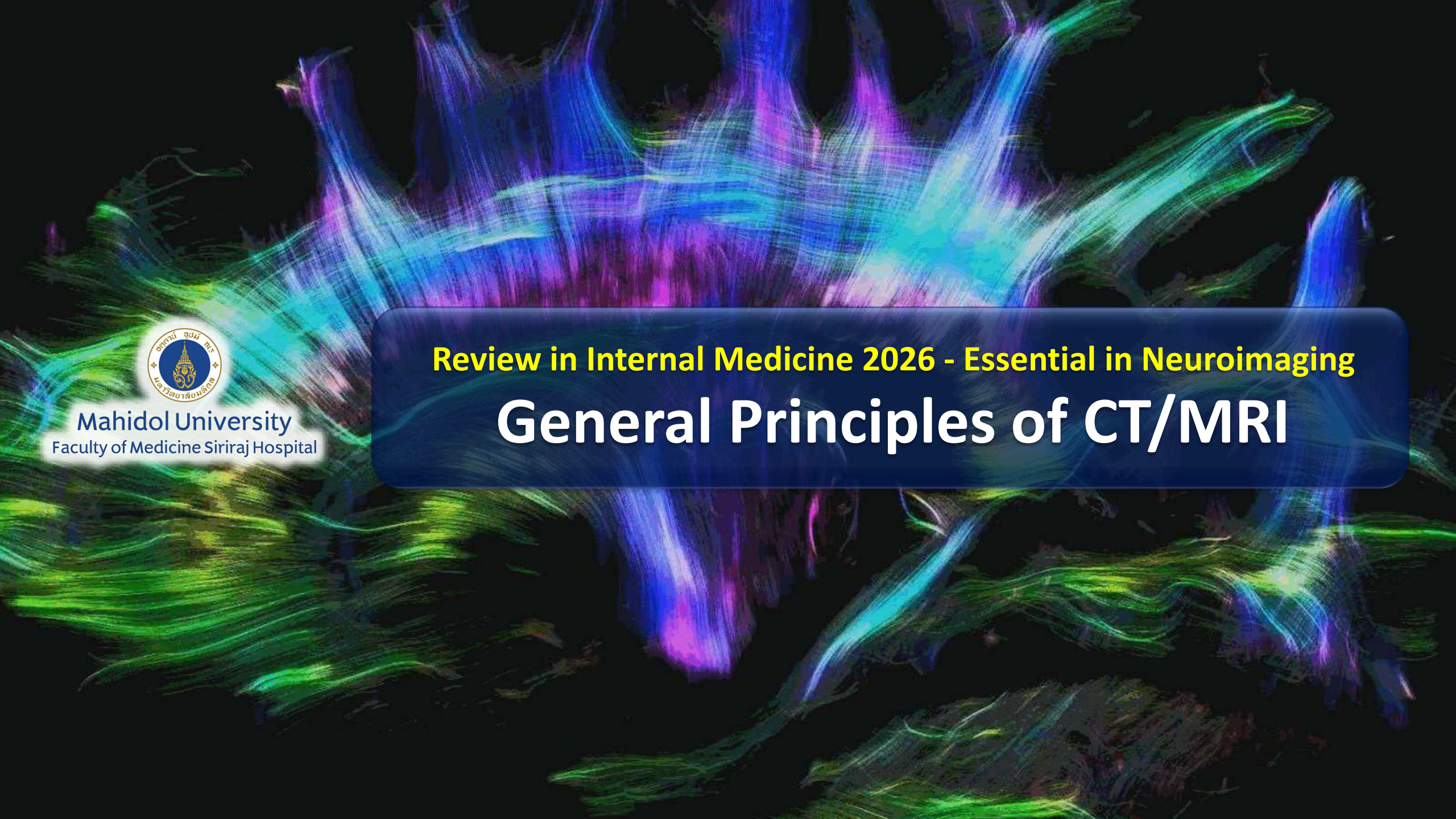
Types of imaging	Low signal <----------> High signal		
Plain film	Radiolucent		Radio-opaque
CT	Hypodensity Hypoattenuation	Isodensity Isoattenuation	Hyperdensity Hyperattenuation
MRI	Hypointensity	Isointensity	Hyperintensity
Ultrasonography	Hypoechoic	Isoechoic	Hyperechoic
SPECT/ PET	Hypometabolism		Hypermetabolism

<u>Others</u>: Angiography (contrast-based, flow-based [MRA-TOF])

CT computed tomography, MRI magnetic resonance imaging, MRA magnetic resonance angiography, SPECT single photon emission computed tomography, PET positron emission tomography, TOF time-of-flight

Outline: Essential in Neuroimaging

- Basic principles of imaging
- Neuroimaging in selected conditions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Review in Internal Medicine 2026 - Essential in Neuroimaging
General Principles of CT/MRI

Computed Tomography (CT)

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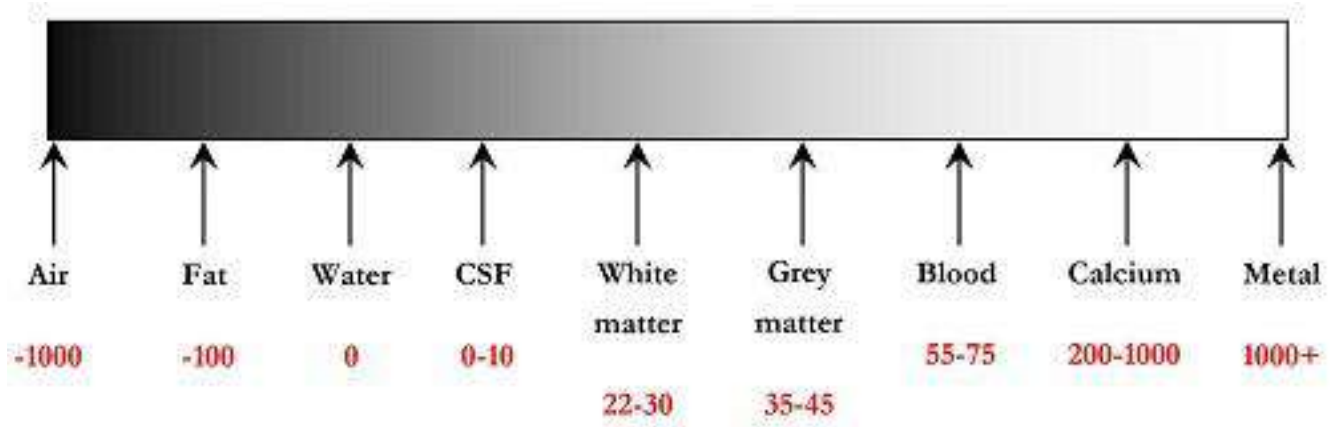
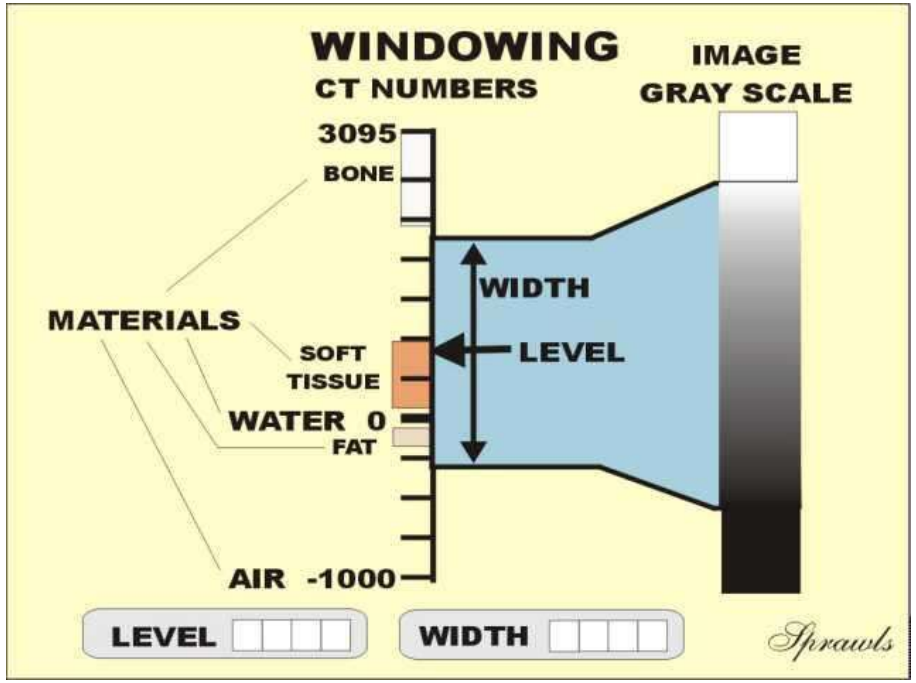
- **Brightness (attenuation value) ∝ Density (Hounsfield Unit)**

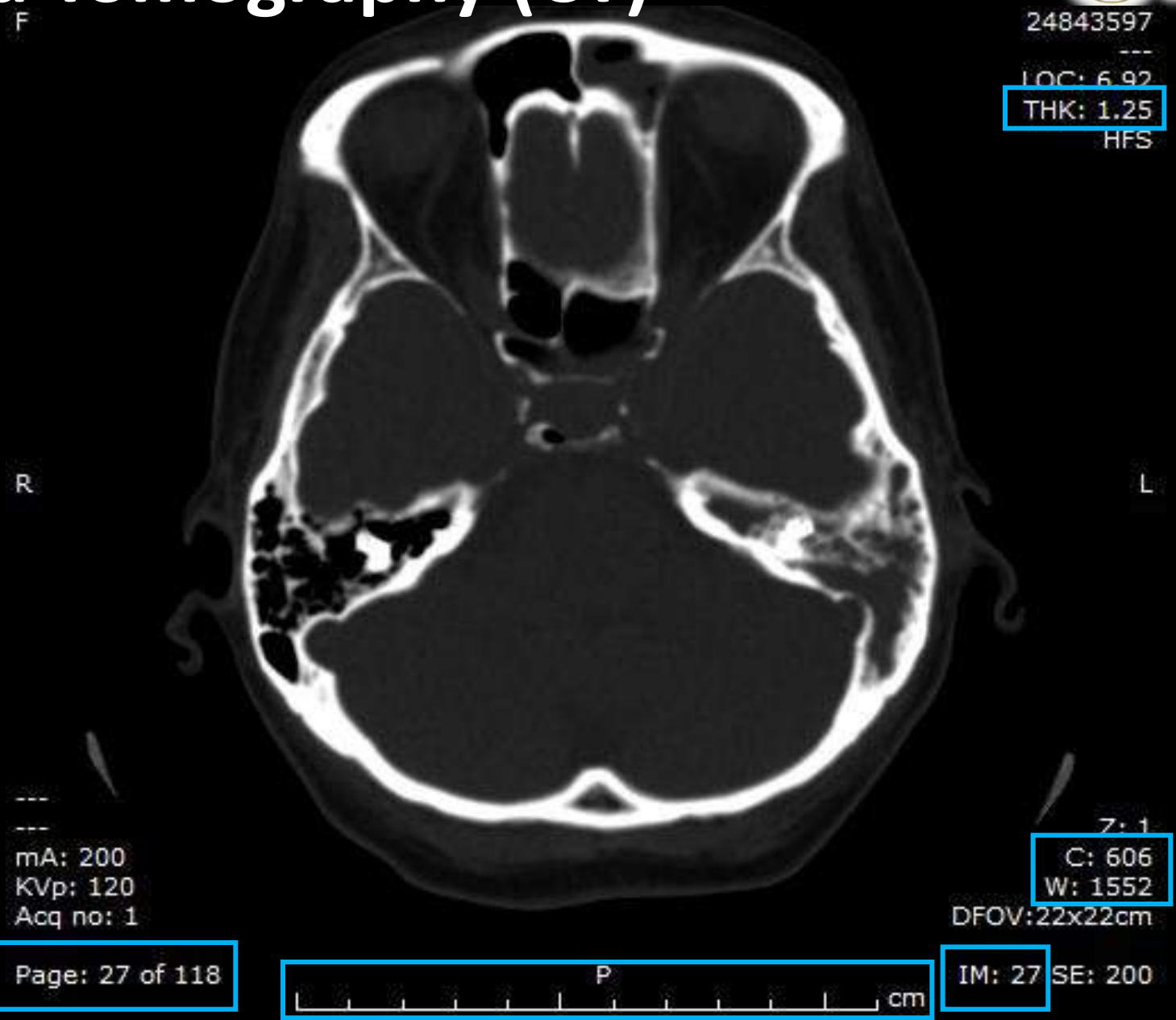
$$HU = \frac{[\text{Attenuation value of given voxel}] - [\text{Attenuation of water}]}{[\text{Attenuation of water}]} \times 1000$$





Kamalian S, et al. Handbook of Clinical Neurology (3rd series), 2016; 135: 3-20

Computed Tomography (CT)



Computed Tomography (CT)

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80 HU

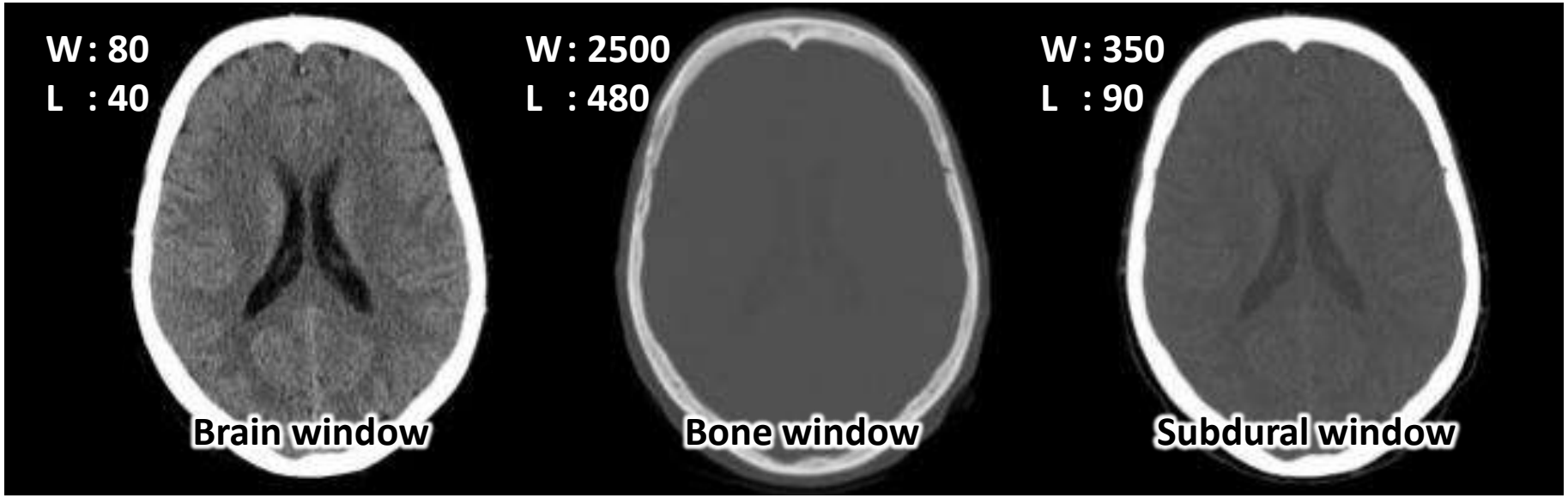
40 HU

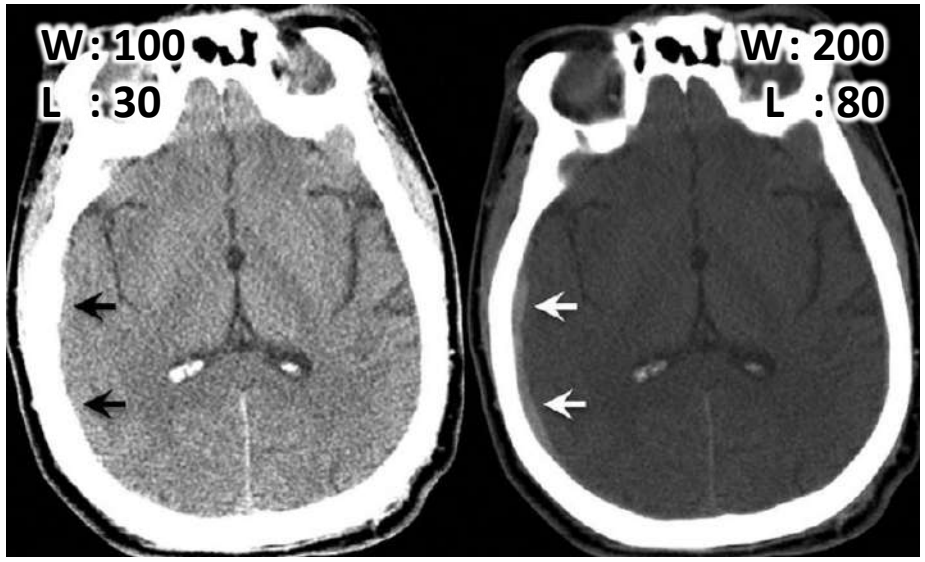
0 HU

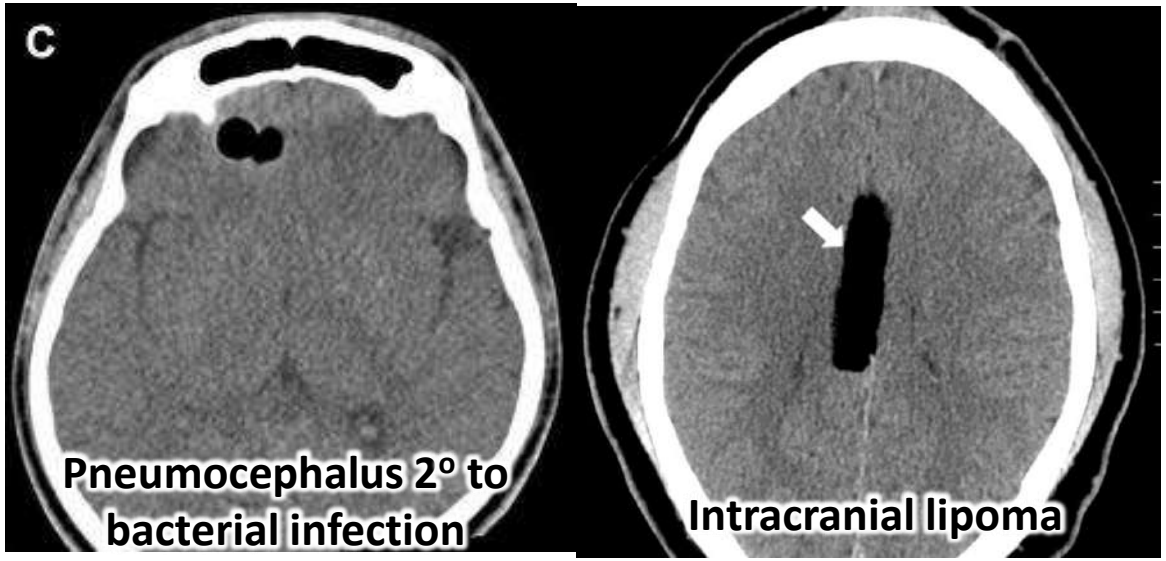
0 to + 80

-770 to +1730

-95 to +275

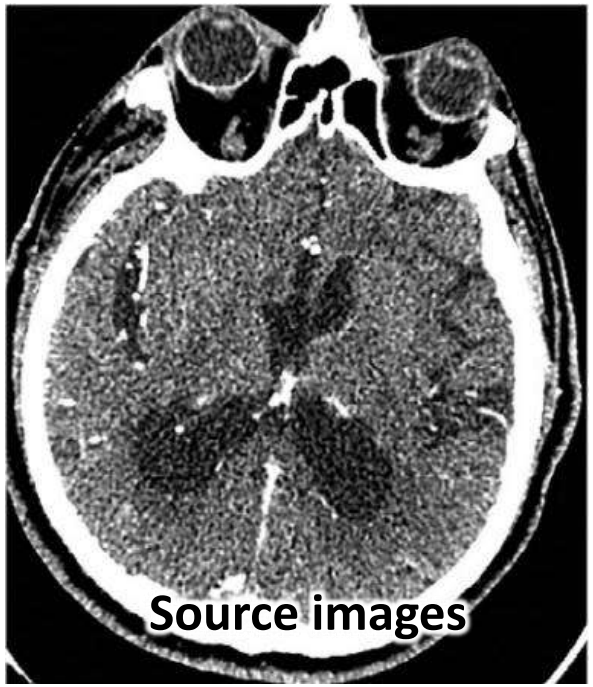


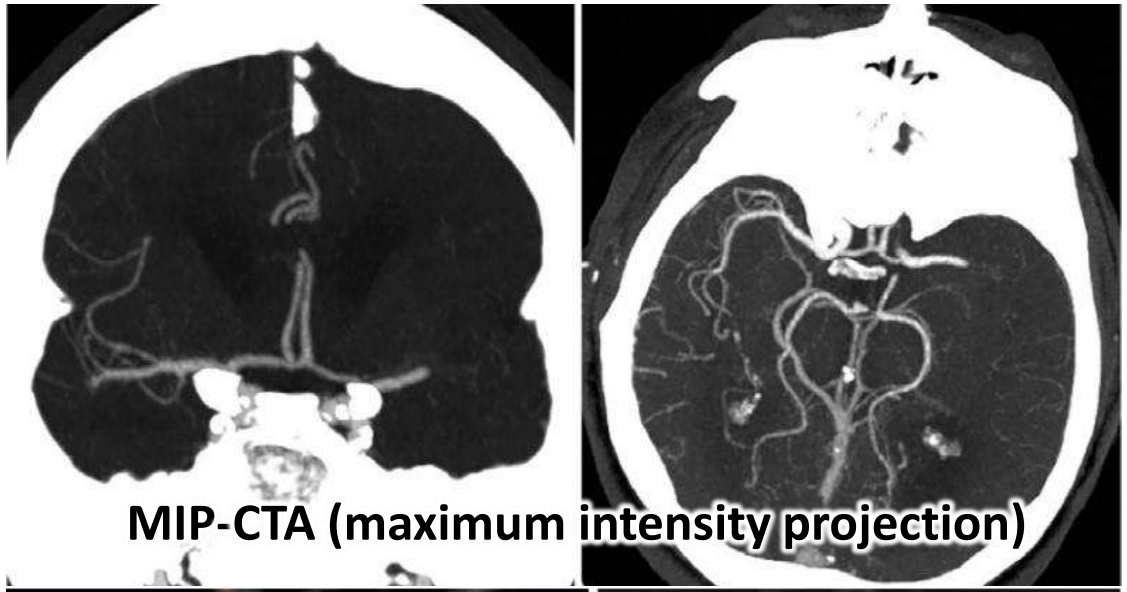


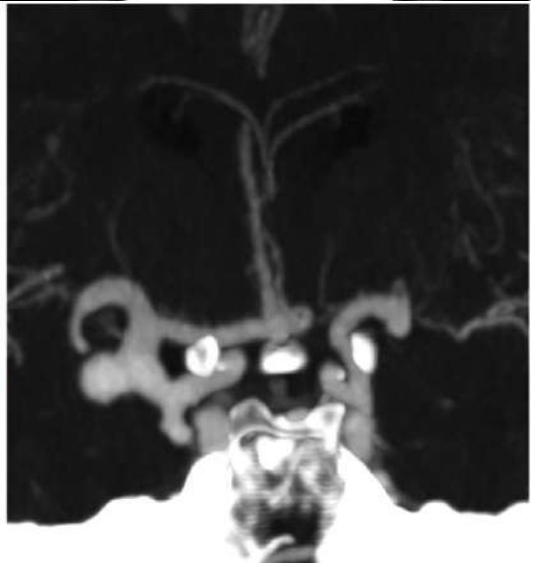


Kamalian S, et al. Handbook of Clinical Neurology (3rd series), 2016; 135: 3-20

CT Angiography (CTA)

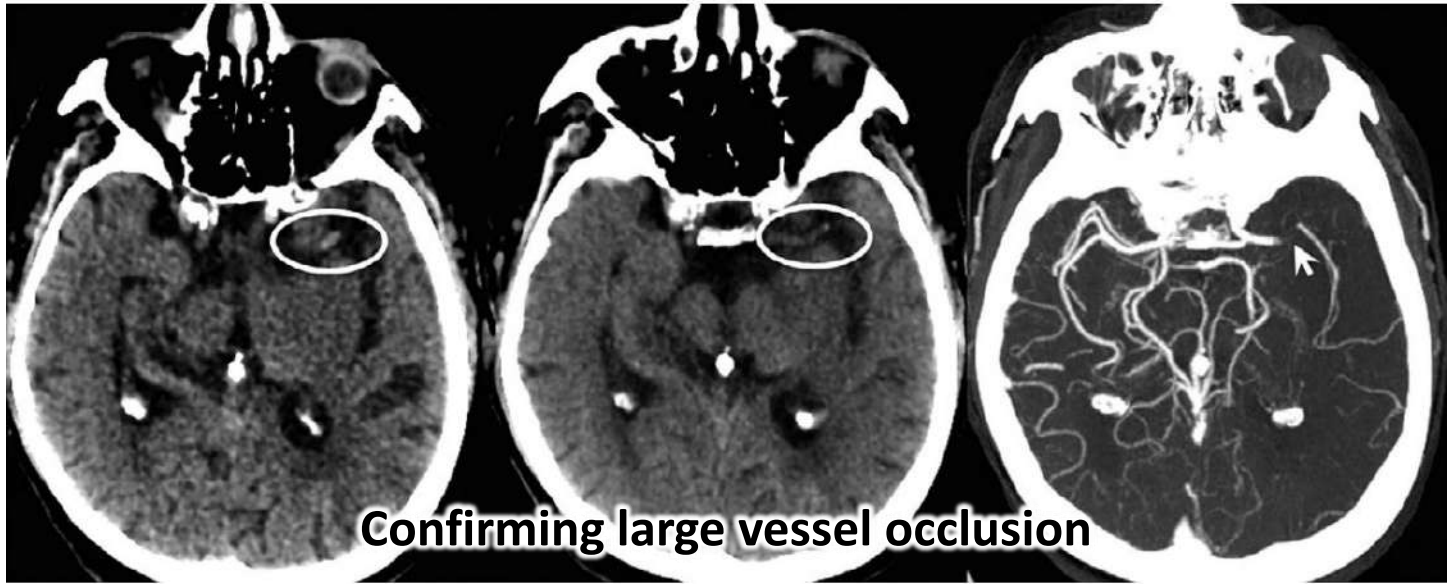




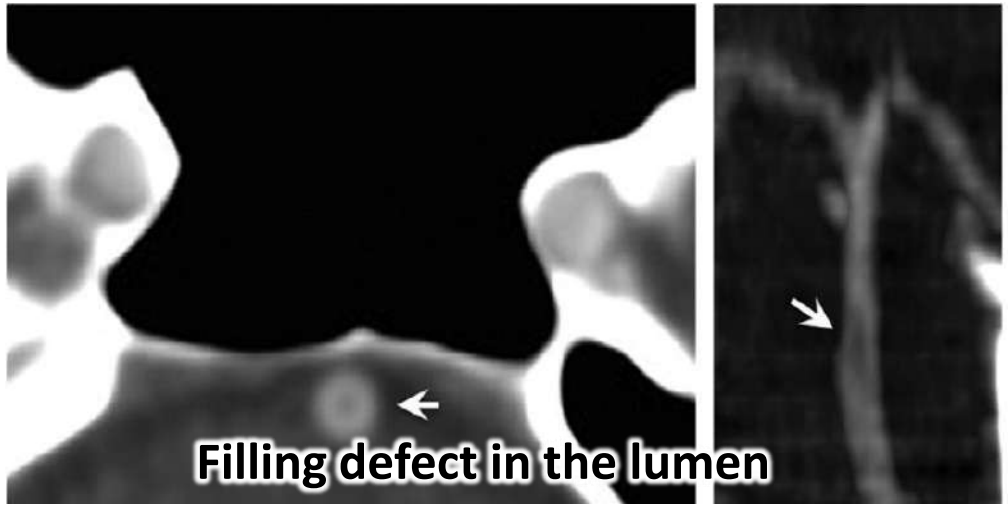


Kamalian S, et al. Handbook of Clinical Neurology (3rd series), 2016; 135: 3-20

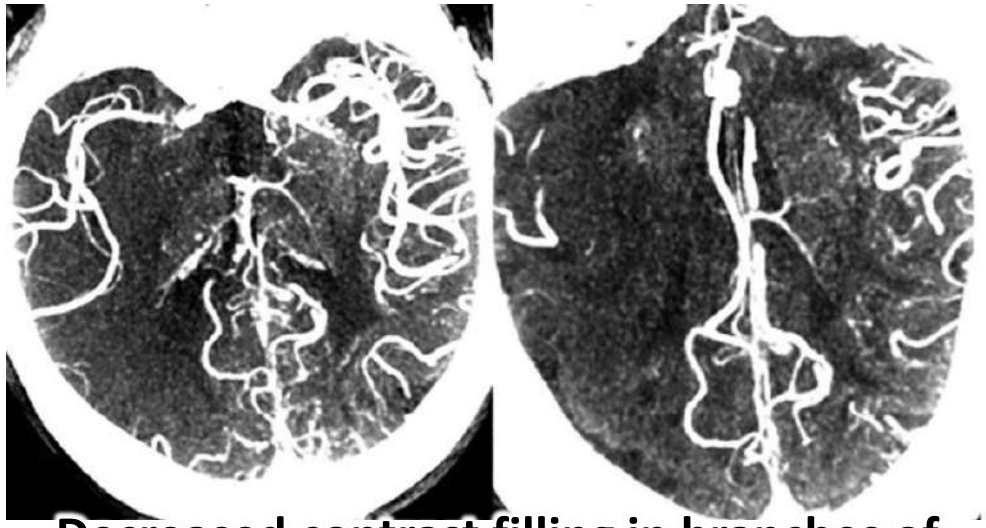
CT Angiography (CTA)



Confirming large vessel occlusion



Filling defect in the lumen



Decreased contrast filling in branches of right MCA & capillary bed

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Magnetic Resonance Imaging (MRI)

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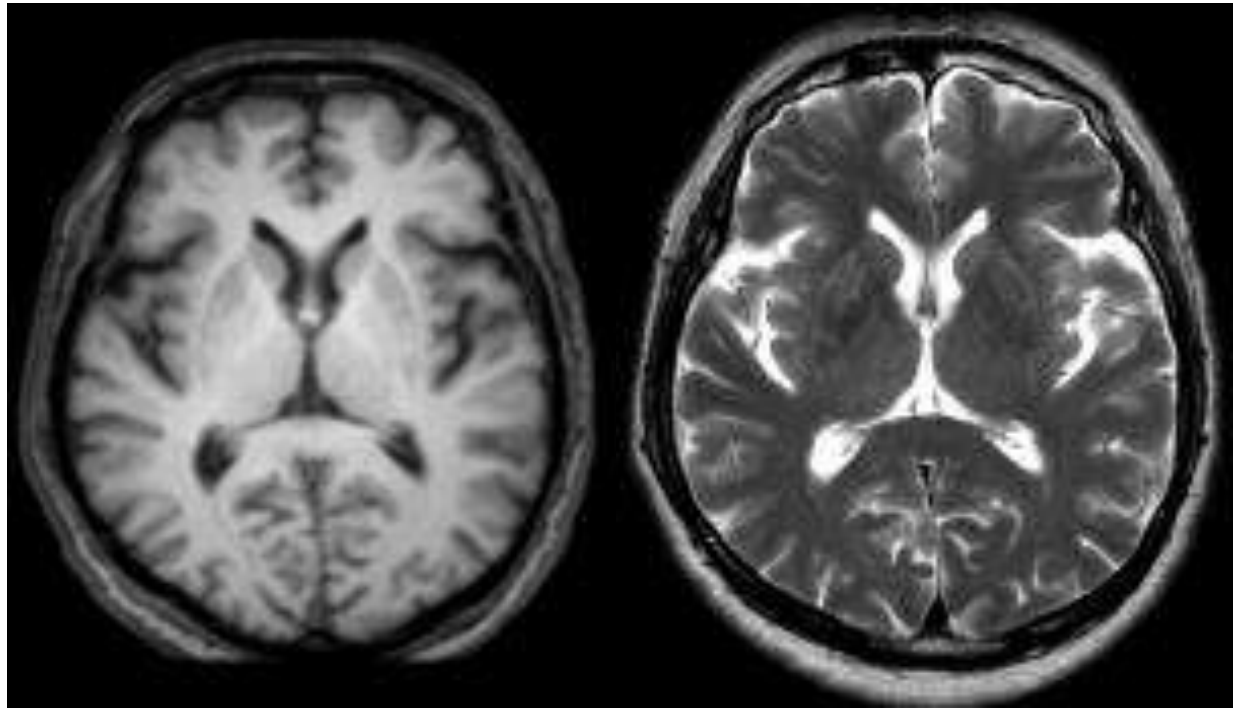

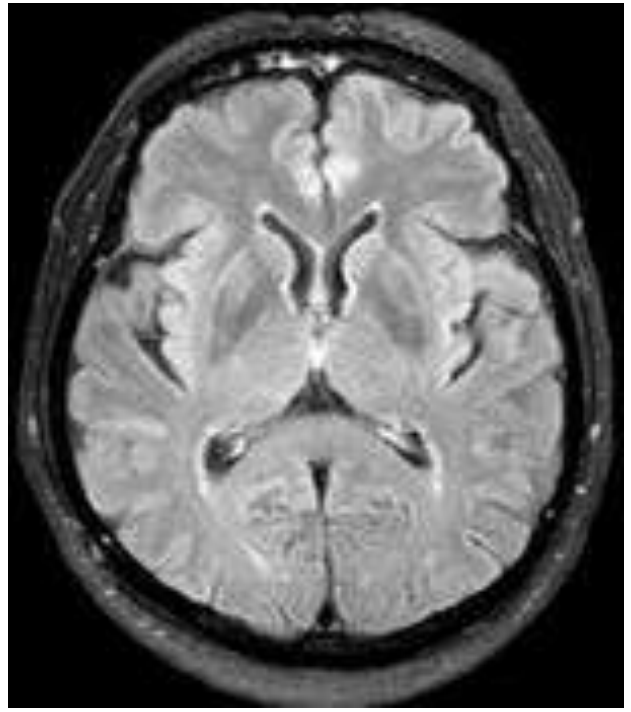

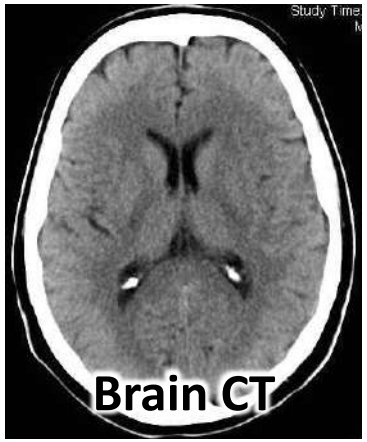

T1W
Normal anatomy/structures
Atrophy

T2W
Pathology

T2/FLAIR
Better visualization of lesions adjacent to CSF spaces

	T1W	T2W	T2FLAIR
Gray matter	Gray	White	White
White matter	White	Gray	Gray

FLAIR : FLuid Attenuated Inversion Recovery

Signal Intensity on T1W & T2W MRI

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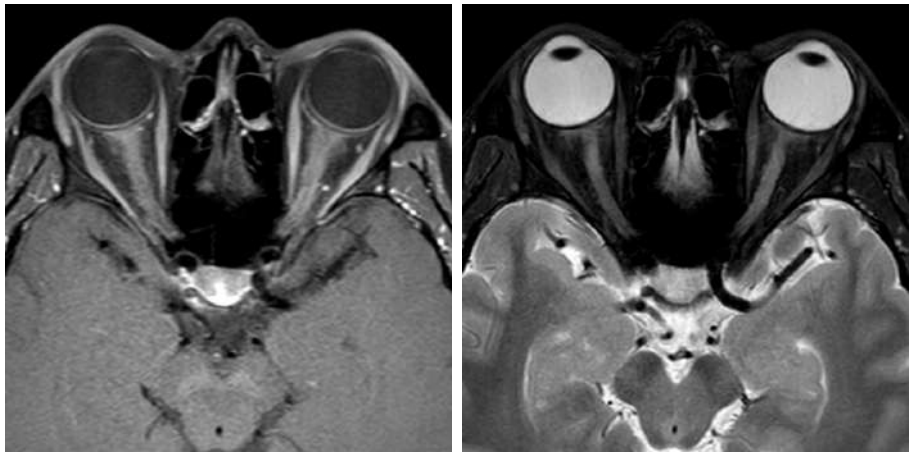
T1 weighted sequence

(black)	low SI	intermediate SI	high SI
air, calcium, cortical bone, rapidly flowing blood	*fluid, ligaments/ muscles/tendons, abdominal organs, cartilage*	*high-protein tissue (abscess, complex cysts, synovial fluid)*	*fat, blood, gadolinium (= contrast), melanin, protein*

T2 weighted image

(black)	low SI	intermediate SI	high SI
air, calcium, cortical bone, rapidly flowing blood **hemosiderin**	*ligaments, tendons, liver, pancreas, adrenals, cartilage*	*fat, liver, pancreas, adrenals, muscles, cartilage*	*fluid, CSF, bladder, bile/ gallbladder, kidneys*

- **Most pathology: ↑T2, ±↓T1**
- **Interesting conditions:**
  - **High T1**
  - **Low T2**
  - **Blood vessel – flow void**



https://www.startradiology.com/the-basics/mri-technique/

Contrast Enhancement on MRI

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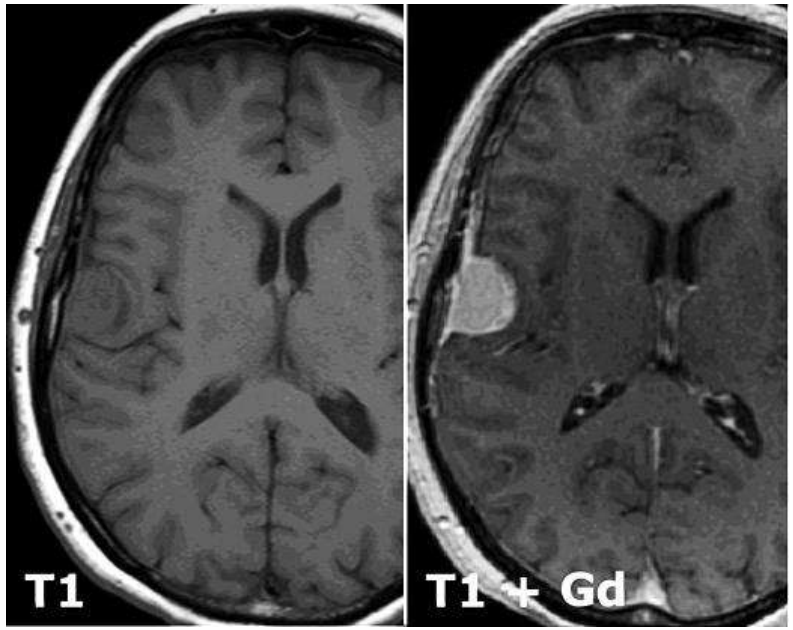
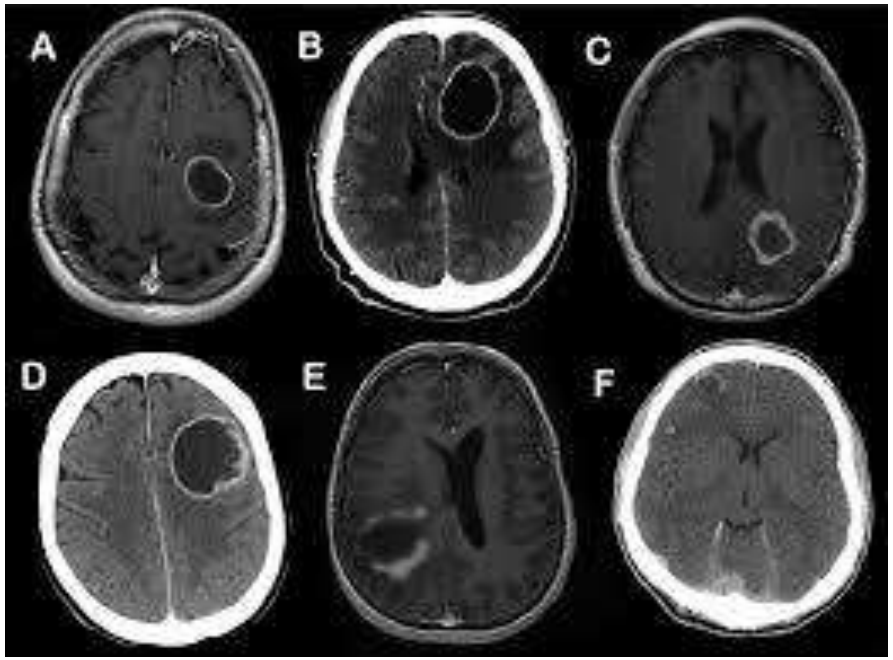
- Detect lesions (tumors, metastasis, abscess)
- Characterization of lesions
- Imaging of vessel/vascular pathology (MR angiography)



Ring-enhancing lesions (“MAGIC-DR”)

- M – Metastasis
- A – Abscess
- G – Glioblastoma multiforme
- I – Infarction
- C – Contusion
- D – Demyelinating disease
- R – Radiation necrosis



A = metastasis *B = abscess* *C = radiation necrosis*
D = GBM *E = demyelination* *F = contusion*

https://www.startradiology.com/the-basics/mri-technique/
https://images.radiopaedia.org/blog/magic-dr?lang=us

Fat Saturation (Fat Suppression)

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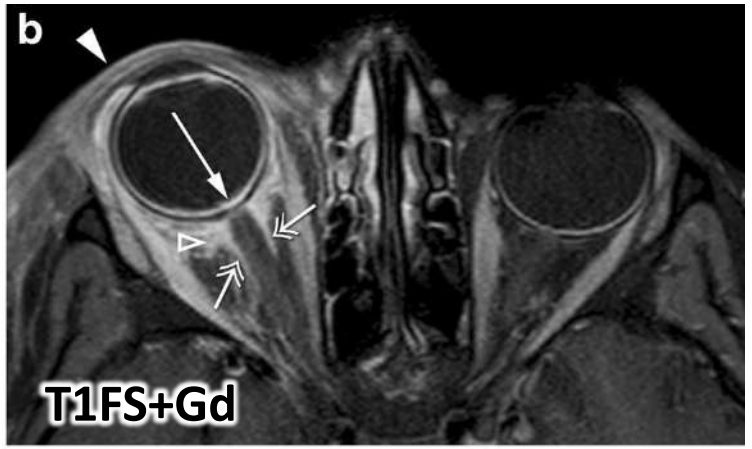
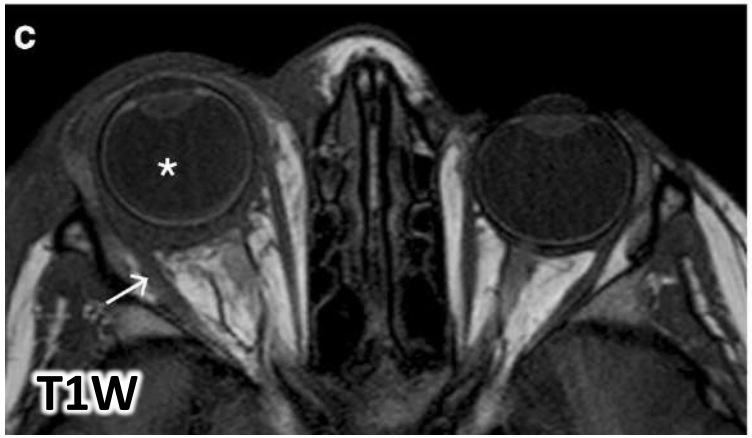
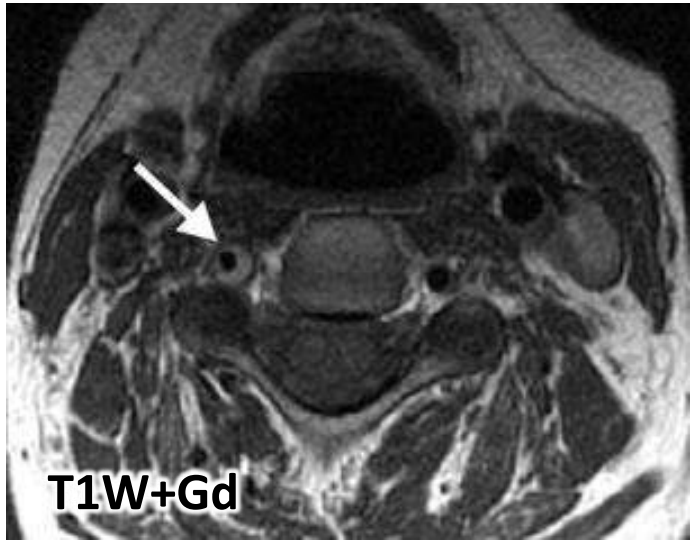
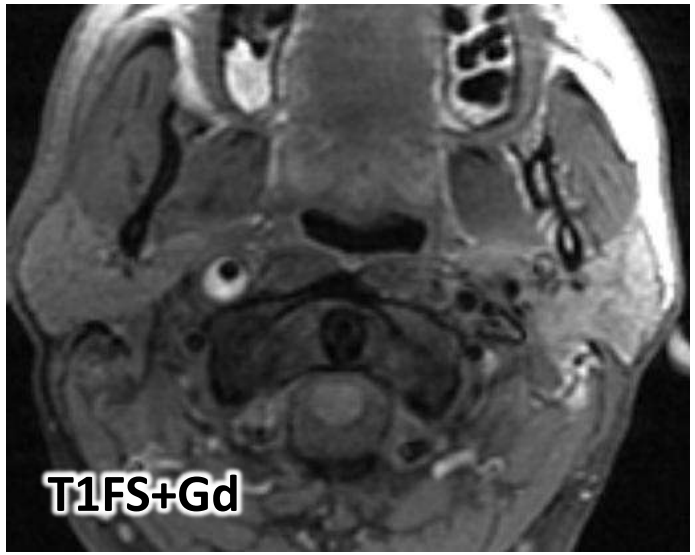


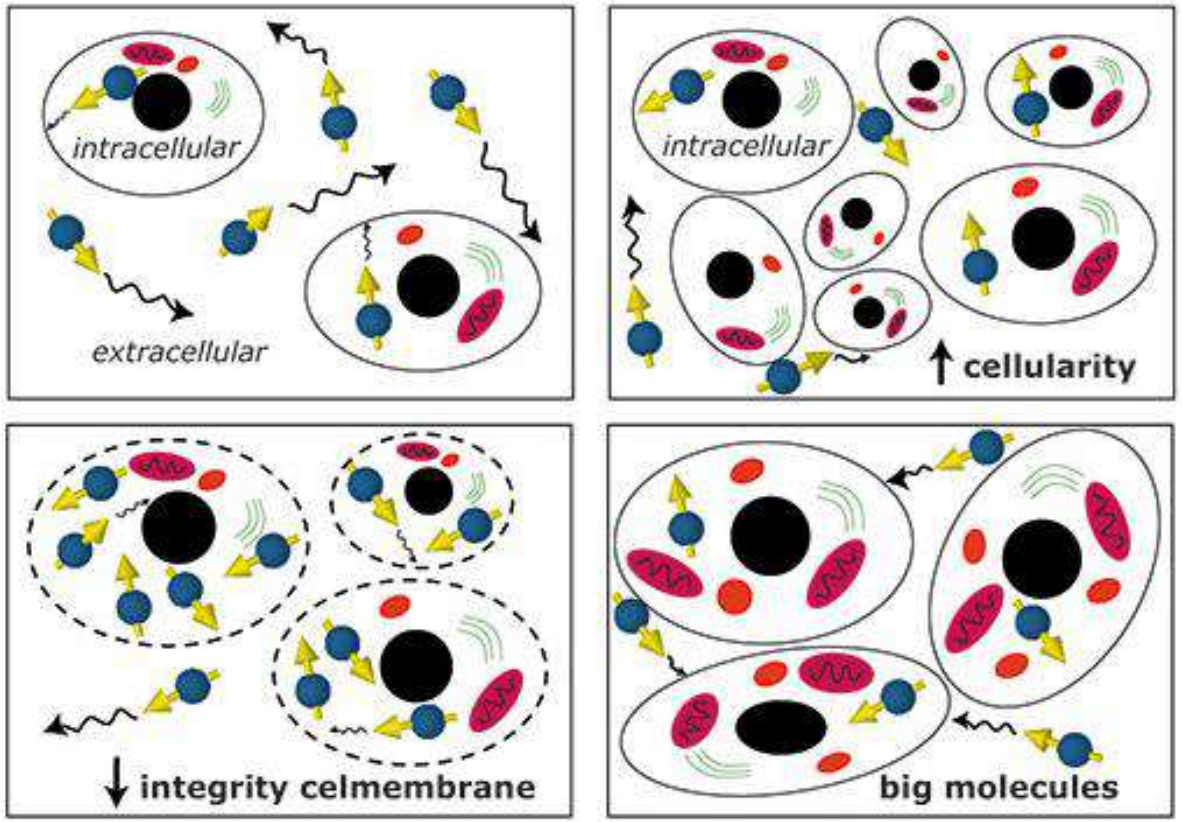






Ferreira TA, et al. CT and MR imaging of orbital inflammation. Neuroradiol 2018; 60: 1253-1266
https://www.researchgate.net/figure/A-T1-weighted-and-B-T2-weighted-cervical-spine-MRI-images-of-patient-2-In-T1_fig4_270688443
https://radiopaedia.org/articles/internal-carotid-artery-dissection-1

Diffusion Weighted Imaging (DWI)



Degree of proton motion depends on :

- **Cellularity (cell-rich tissue = ↓diffusion)**
- **Integrity of cell membrane (infarction = failure of ion pump & ↓diffusion)**
- **Blockage of fluid (tissue with large molecule = ↓diffusion)**

Restricted diffusion – common DDx

- **Ischemia, mitochondrial failure**
- **Abscess, loculated fluid**
- **Tumors with high N:C ratio (e.g. lymphoma)**

https://www.startradiology.com/the-basics/mri-technique/
DWI diffusion weighted imaging
ADC apparent diffusion coeffecient

Diffusion Weighted Imaging (DWI)

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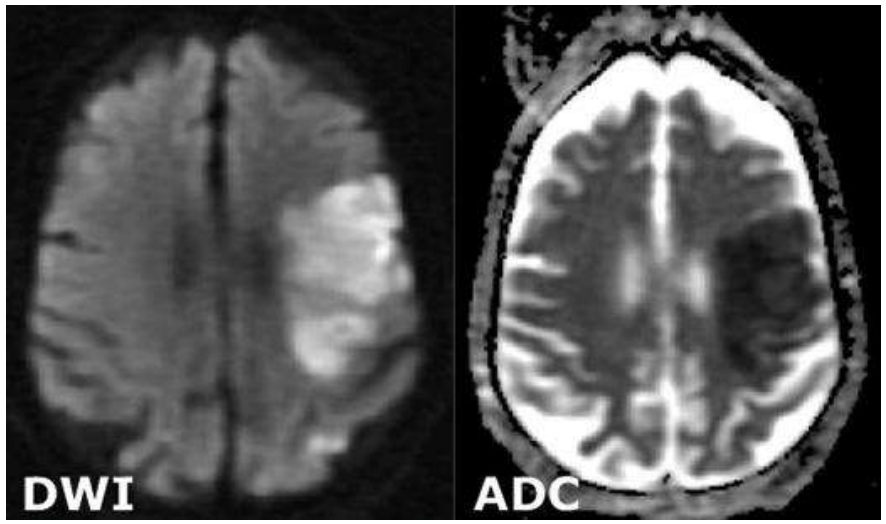
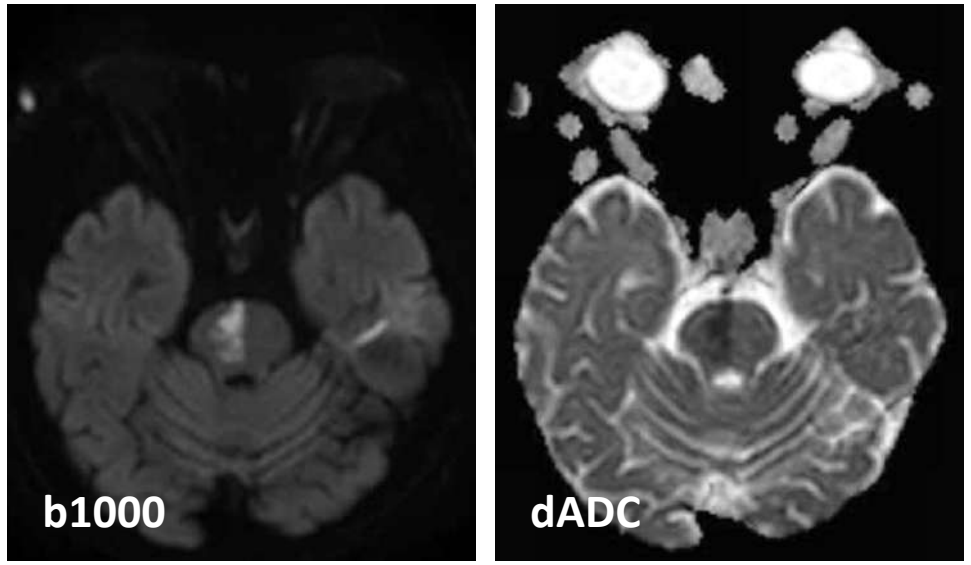
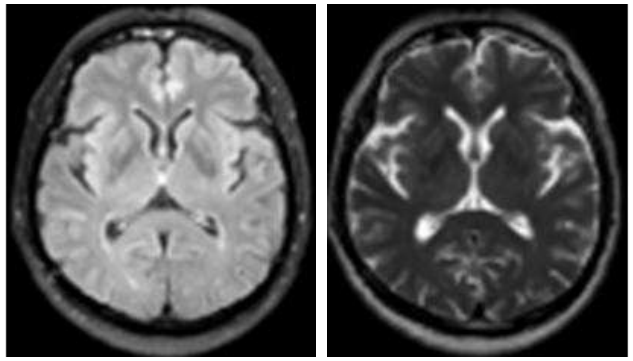




Look at b1000



Diffusion weighted image

	DWI	ADC	Examples
Diffusion restriction	○	●	*cytotoxic edema (acute ischemia), abscess/inflammation, acute demyelination*
Increased diffusion	●	○	*cerebrospinal fluid (CSF)*
T2 shine-through	○	○	*vasogenic edema, gallbladder, endometrium*

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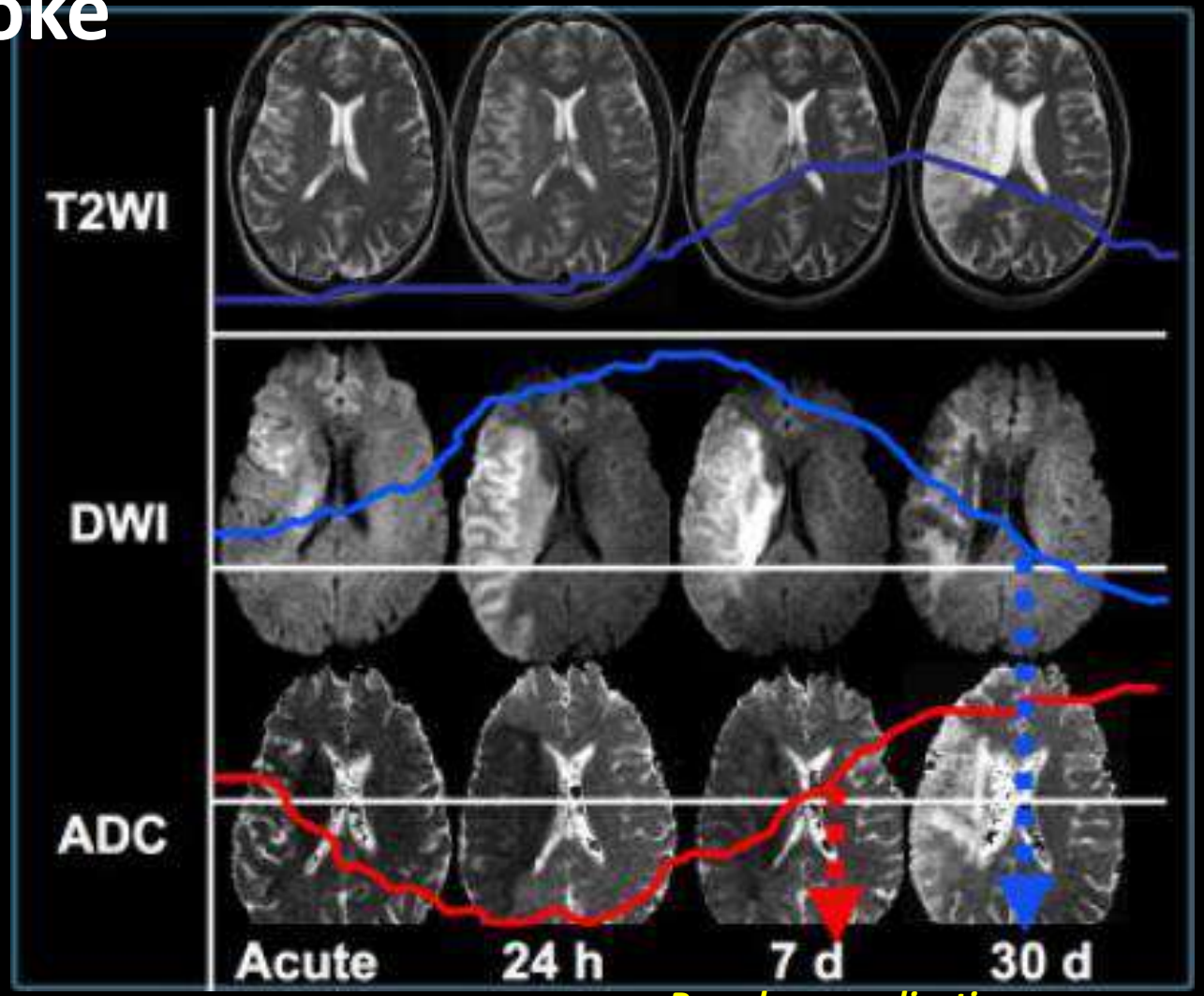
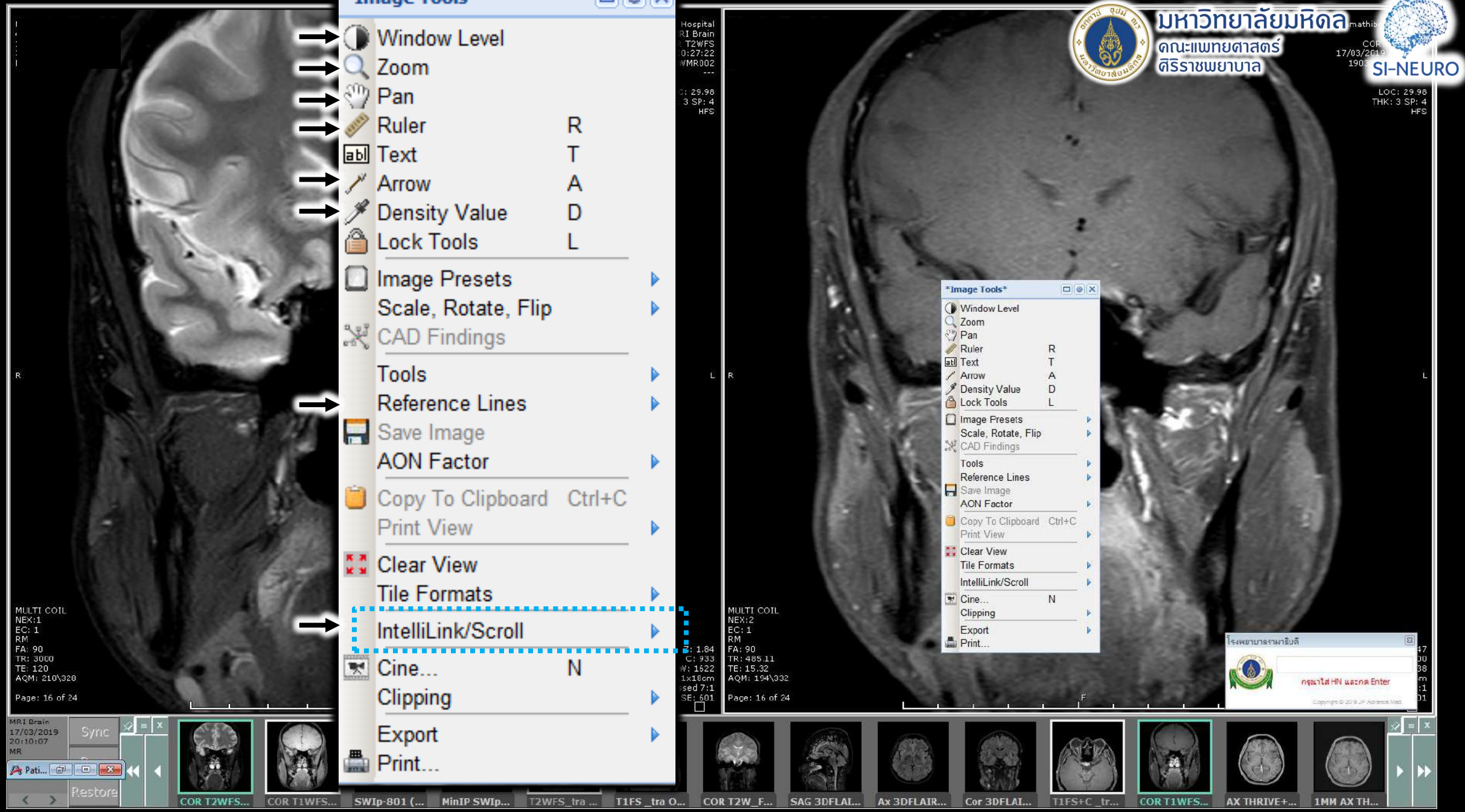
DWI diffusion weighted imaging
ADC apparent diffusion coeffecient

Evolution of MRI Findings in Acute Ischemic Stroke



Pseudonormalization of ADC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COR T2W_F...
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Ax 3DFLAIR...
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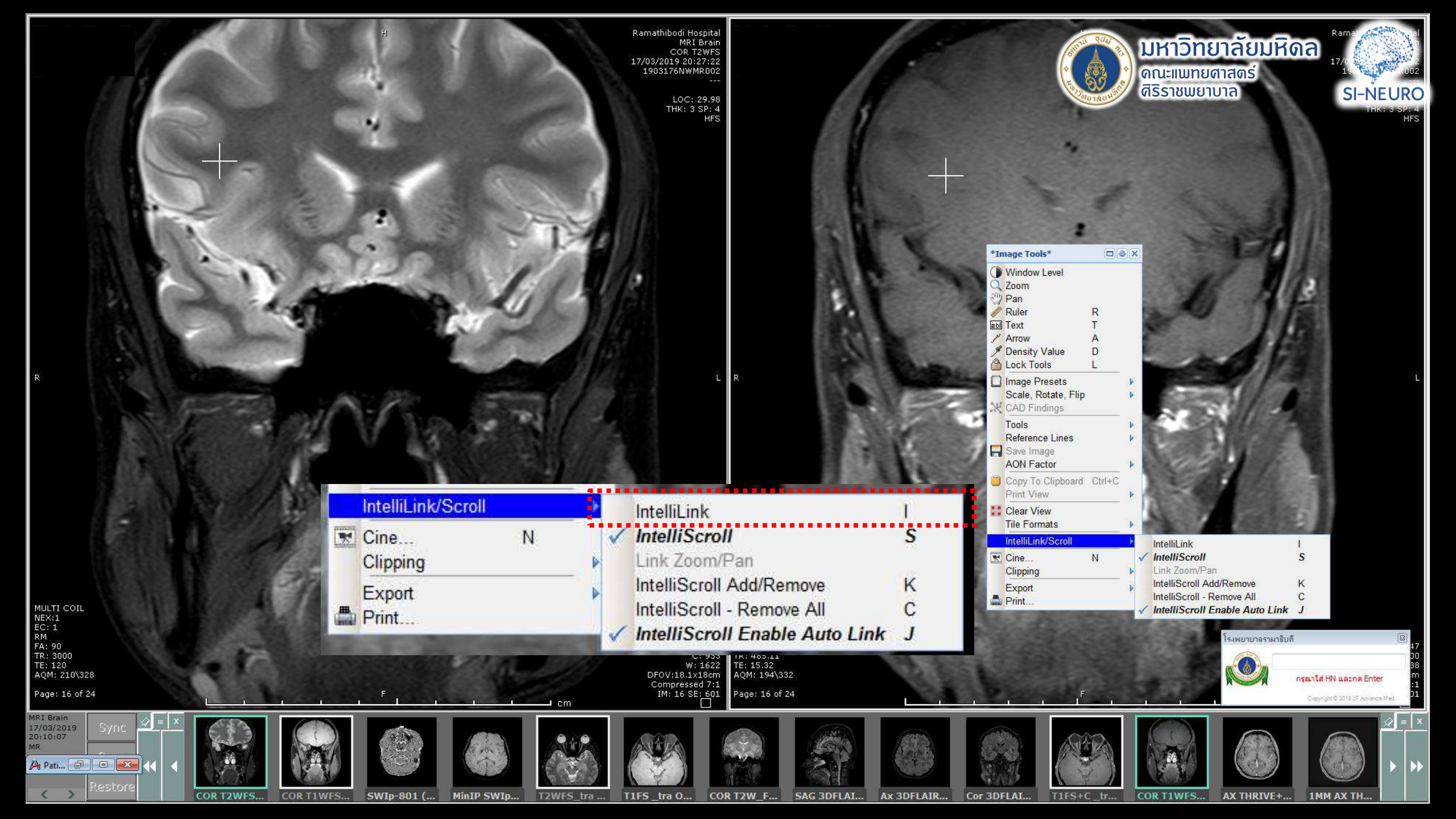
T1FS+C _tr...
COR T1WFS...
AX THRIVE+...
1MM AX TH...


Ramathibodi Hospital
MRI Brain
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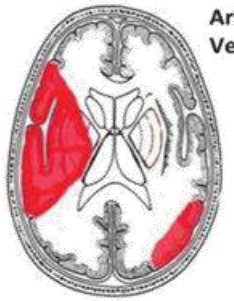
AX THRIVE+...
1MM AX TH...

Figure 2 Diagnostic patterns on restricted diffusion

Vascular territory /1

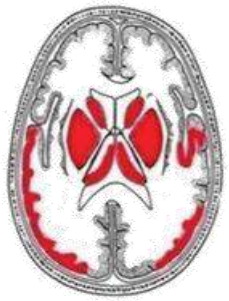


Arterial infarction
Venous infarction

Cortex /2

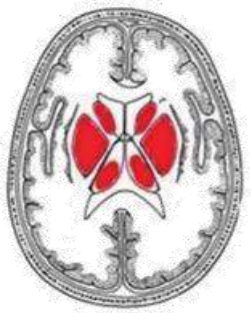
CJD *
H-I
Hypoglycemia
Hyperammonemia
HSE
Seizure
Ethylene glycol
Mitochondrial disease *
Intravascular lymphomatosis *
Arterial infarction
Venous infarction

Cortex – Deep Gray /3



CJD B/T *
H-I B/T
CO B/T
Hypoglycemia B
Hyperammonemia B/T
Seizure T

Deep Gray /4

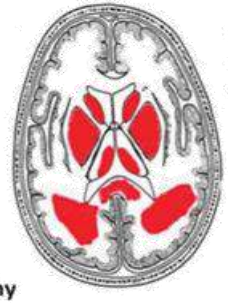


CJD B/T *
H-I B/T
Hypoglycemia B
Hyperammonemia B/T
Seizure T
CO B/T
Cyanide B
Encephalitis,viral T
Osmotic myelinolysis B/T
Wernicke encephalopathy T
Methanol B
Hyperglycemia B *
Venous infarction B/T
Arterial infarction B/T

White Matter / diffuse /5

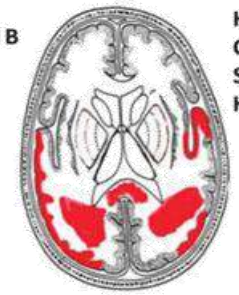
H-I
CO
Hypoglycemia
Chemotherapy *
Heroin
Leukodystrophy *
Encephalitis, viral
phenylketonuria *
Methanol
Wernicke encephalopathy
Radiation therspy *
Ethylene glycol
RCVS / PRES

Deep Gray-White Matter /6



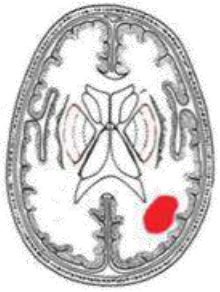
Methanol B
H-I B/T
CO B/T

Cortex-White Matter /7



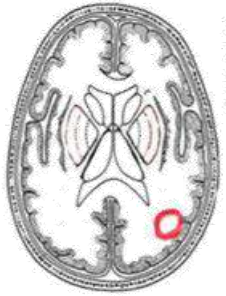
H-I
CO
Seizure
Hypoglycemia

White Matter / focal /8



Abscess *
Neoplasm *
Stroke
Head injury *
Demyelinating
Toxopasmosis *
Radiation therapy *
RCVS / PRES

Ring /9



Infection *
Neoplasm *
Demyelinating *
Vascular

*Subacute/chronic. B = basal ganglia; CJD = Creutzfeldt-Jakob disease; CO = carbon monoxide; HSE = herpes simplex encephalitis; H-I = hypoxic-ischemic; PRES = posterior reversible encephalopathy syndrome; RCVS = reversible cerebral vasoconstrictive syndrome; T = thalamus.

Finelli PF. Diagnostic approach to restricted-diffusion patterns on MR imaging. Neurol Clin Pract 2012; 2: 287-293

Gradient Echo/Susceptibility Weighted Sequence

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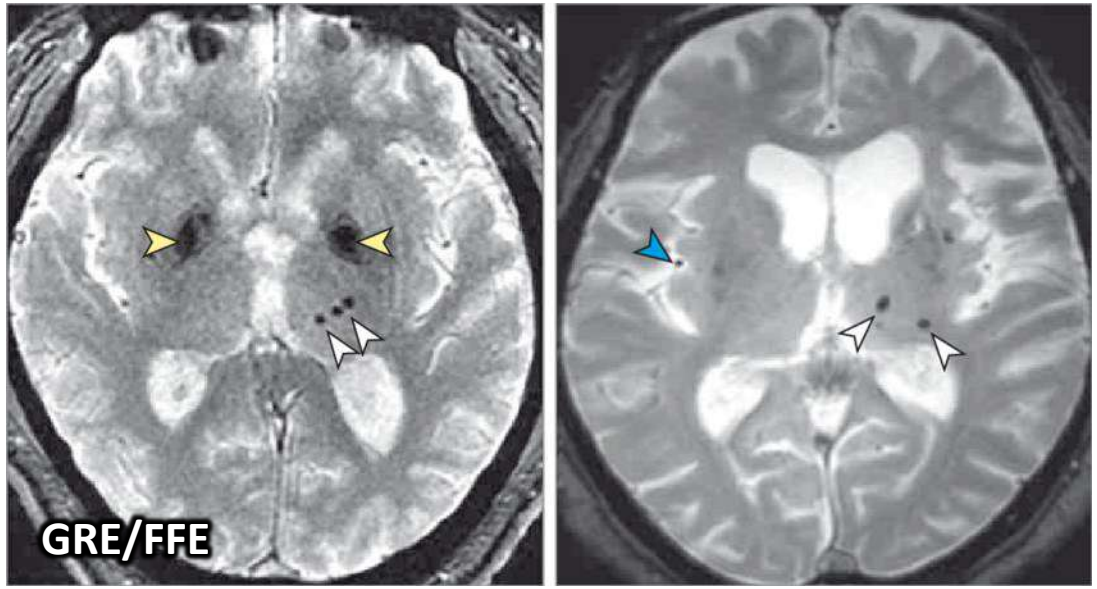
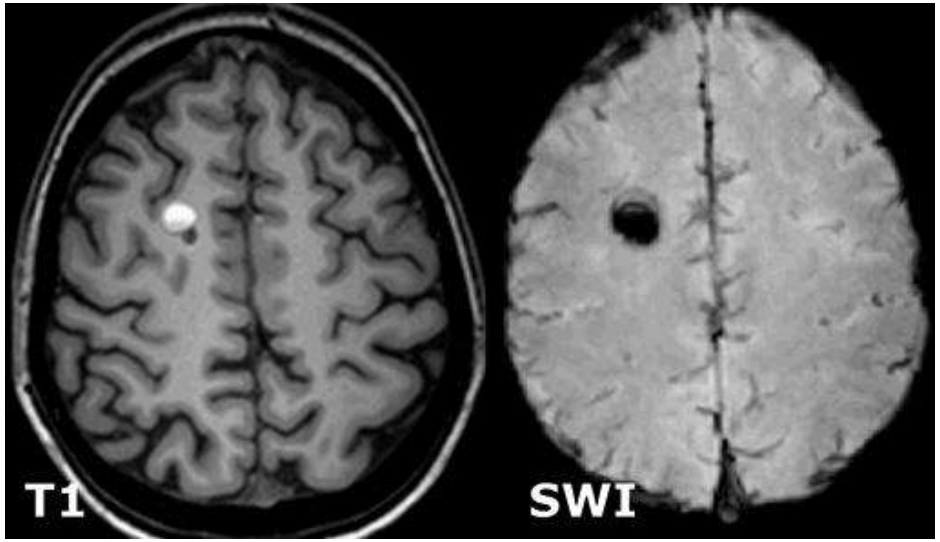
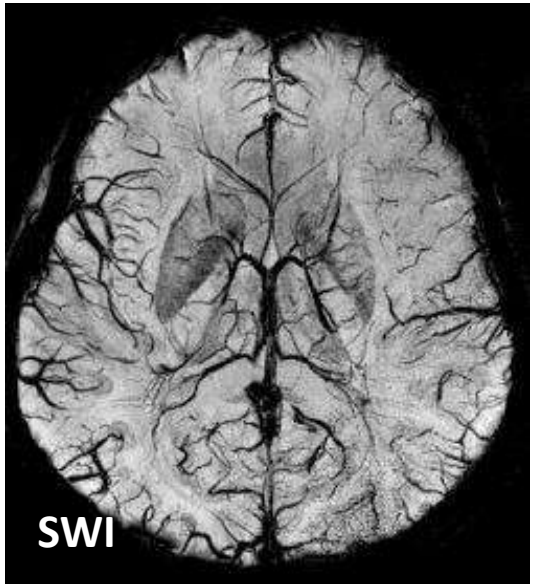
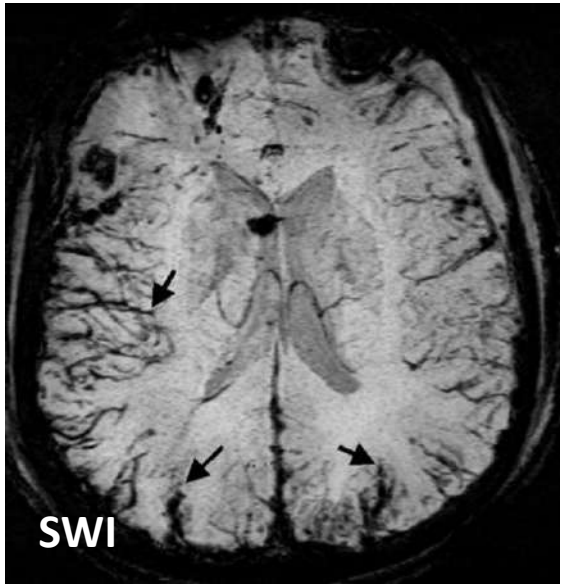




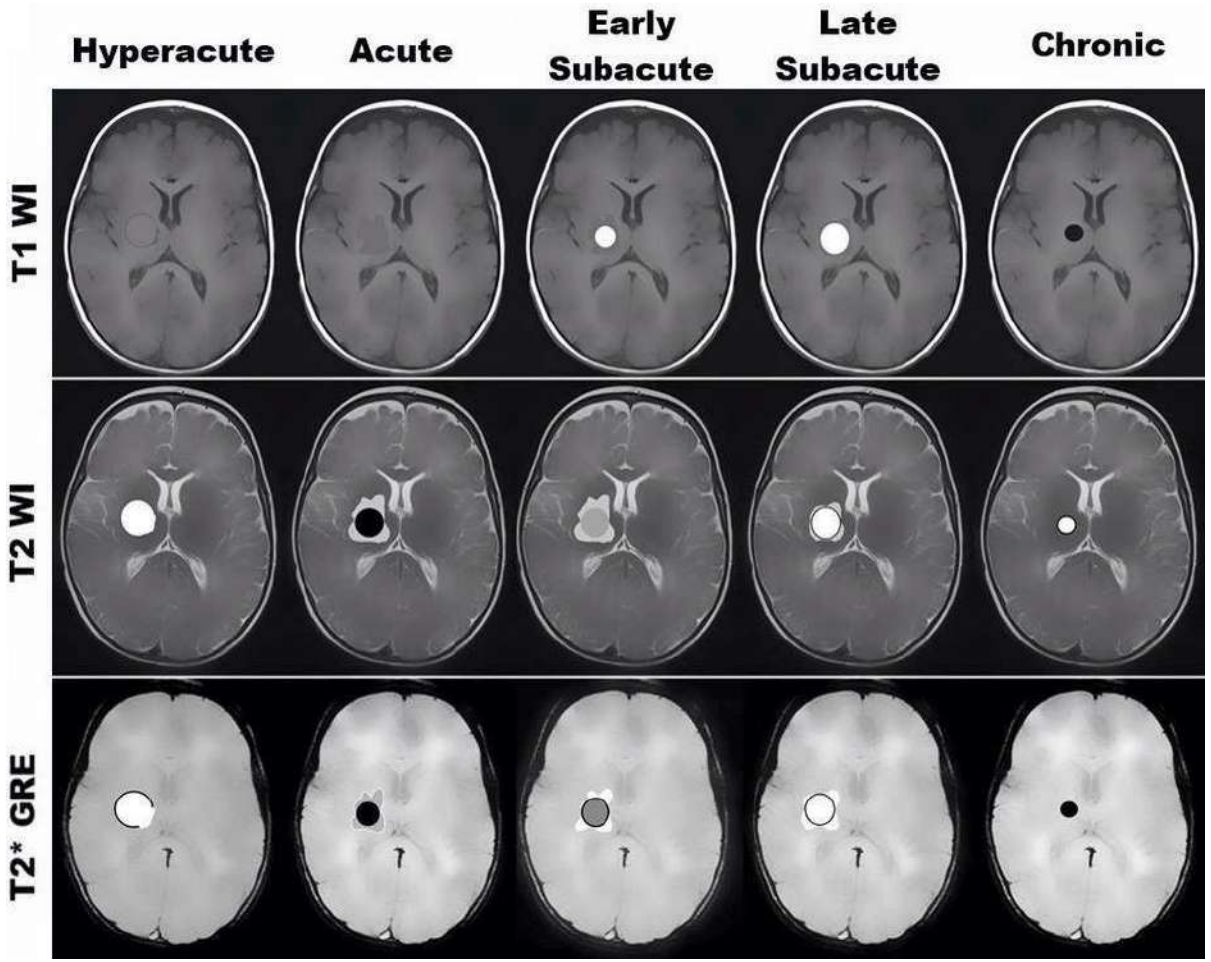
- Detecting paramagnetic/diamagnetic compounds (e.g. Ca2+, Fe2+)
- Blood outside the vessel = blooming artifact





Lim JS, et al. Arch Neurol 2015; 72(3).
https://www.startradiology.com/the-basics/mri-technique/
https://en.wikipedia.org/wiki/Susceptibility_weighted_imaging
Mittal S, et al. Am J Neuroradiol 2009; 30(2): 232-52

Stages of Intracranial Hemorrhage



Stages	Timing	MRI-T1W	MRI-T2W	CT	Location	Blood product
Hyperacute	<1 d	I	B	B	Intracellular	OxyHb
Acute	<2 d	I	D	B	Intracellular	DeoxyHb
Early subacute	<2 wks	B	D	I	Intracellular	MetHb
Late subacute	<2 mo	B	B	I	Extracellular	MetHb
Chronic	>2 mo	D	D	D	Extracellular	Hemosiderin

I – Bleed

I – Die

Bleed – Die

Bleed - Bleed

Die - Die

http://www.learnneurosurgery.com/mri--ct-blood.html
https://www.pinterest.com.mx/pin/93731235978895675/

Special MRI Sequences

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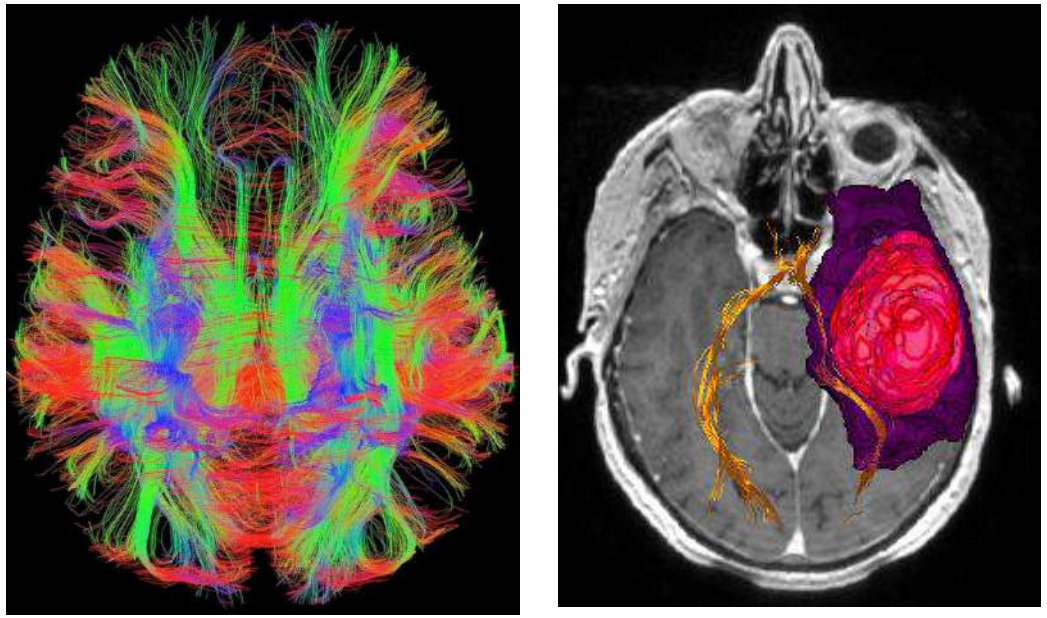
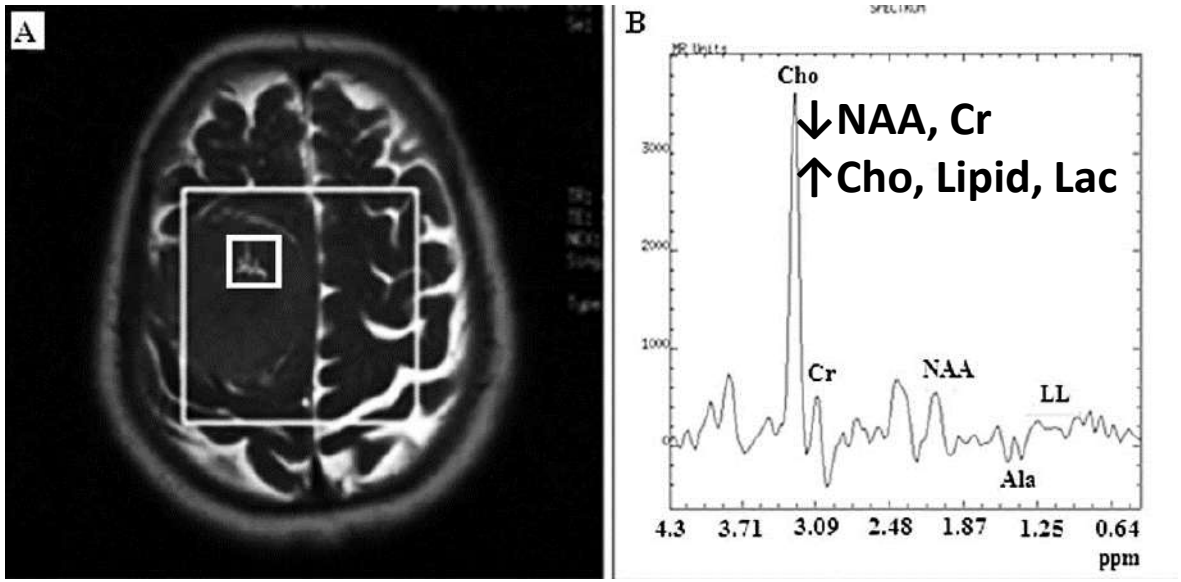
Diffusion tensor imaging (DTI)



MR Spectroscopy (MRS)



- **Useful in differentiating:**
  - **Brain neoplasm vs non-neoplasm**
  - **Primary brain tumor vs metastasis**
  - **Recurrent tumors vs radiation necrosis**
  - **Etc.**

https://www.startradiology.com/the-basics/mri-technique/
https://www.jove.com/video/51946/dti-of-the-visual-pathway-white-matter-tracts-and-cerebral-lesions
https://ep.bmj.com/content/103/4/213
https://radiopaedia.org/articles/mr-spectroscopy-1?lang=us

CT/MRI Brain in Selected Conditions

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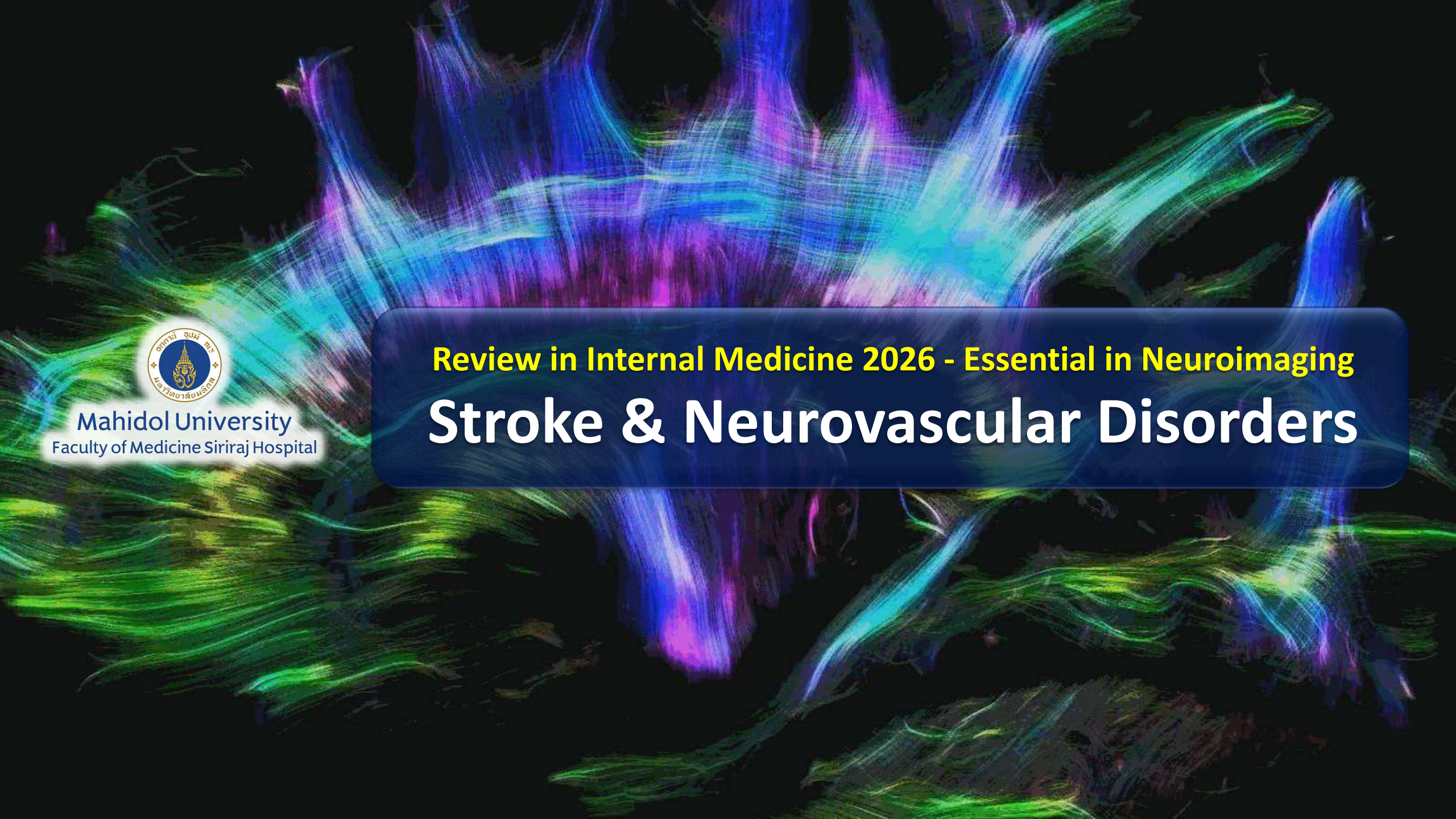
- Stroke (ischemic/hemorrhages)
- Infections
- Inflammations
- Neurodegenerative diseases
- Toxic-metabolic causes
- Miscellaneous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Review in Internal Medicine 2026 - Essential in Neuroimaging
Stroke & Neurovascular Disorders

1.Ischemic Stroke

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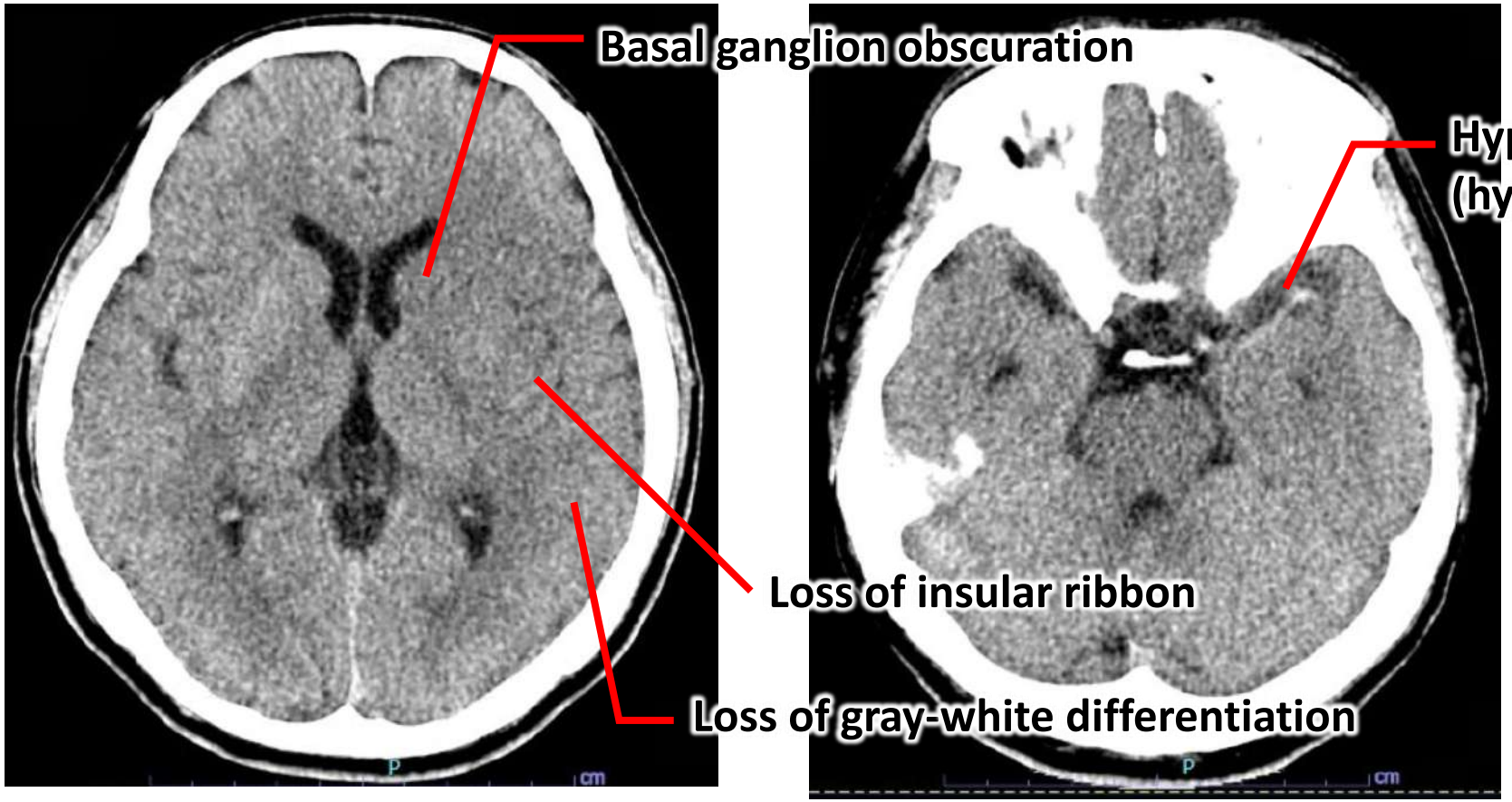
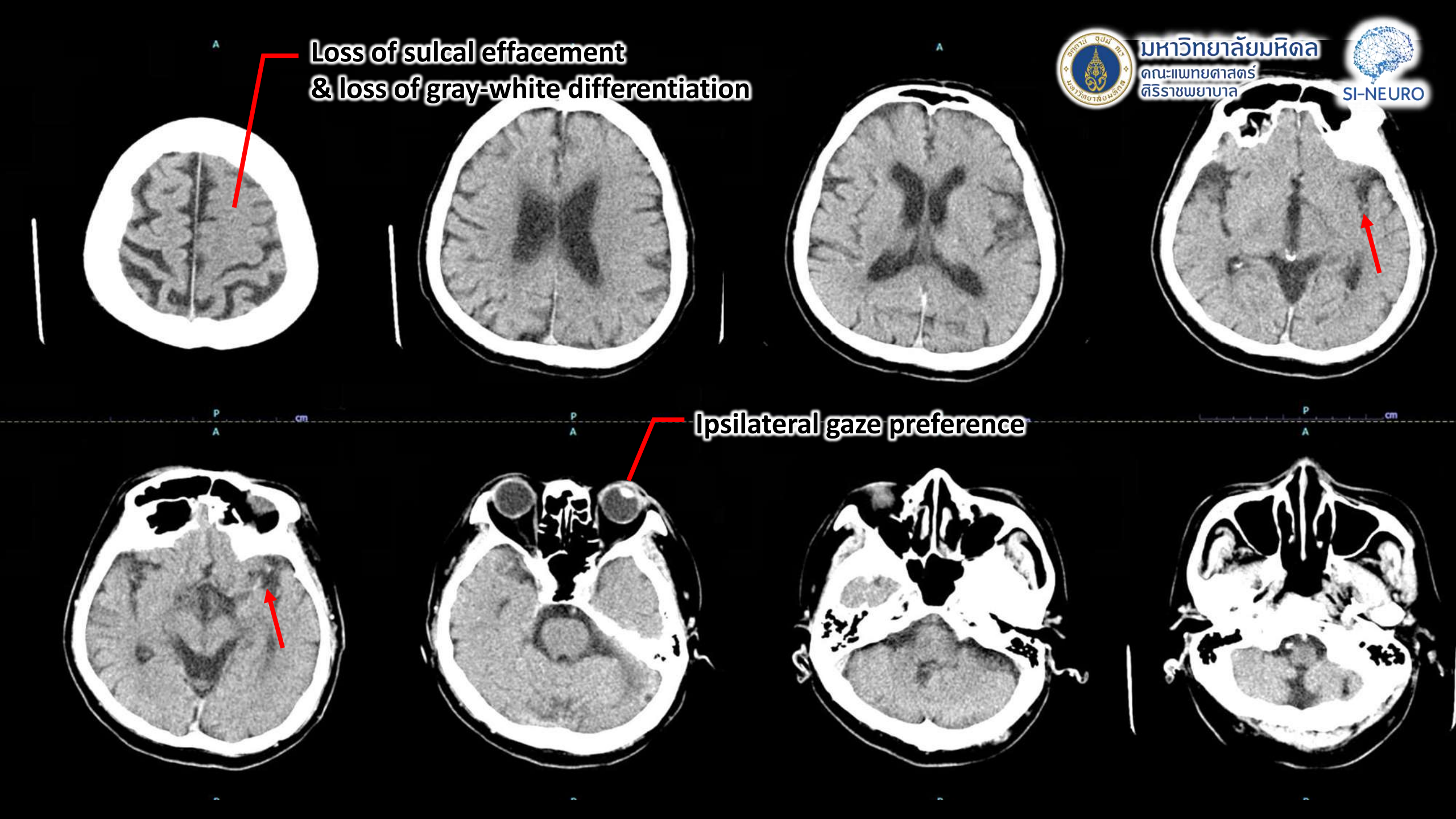
- **Early ischemic changes on CT**




Loss of sulcal effacement
& loss of gray-white differentiation
Ipsilateral gaze preference
มหาวิทยาลัยมหิดล
คณะแพทยศาสตร์
ศิริราชพยาบาล
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1.Ischemic Stroke

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- Increase a chance of detection

W 57, C 33

W 45↓, C 43↑

Alberta Stroke Program Early CT Score (ASPECTS)

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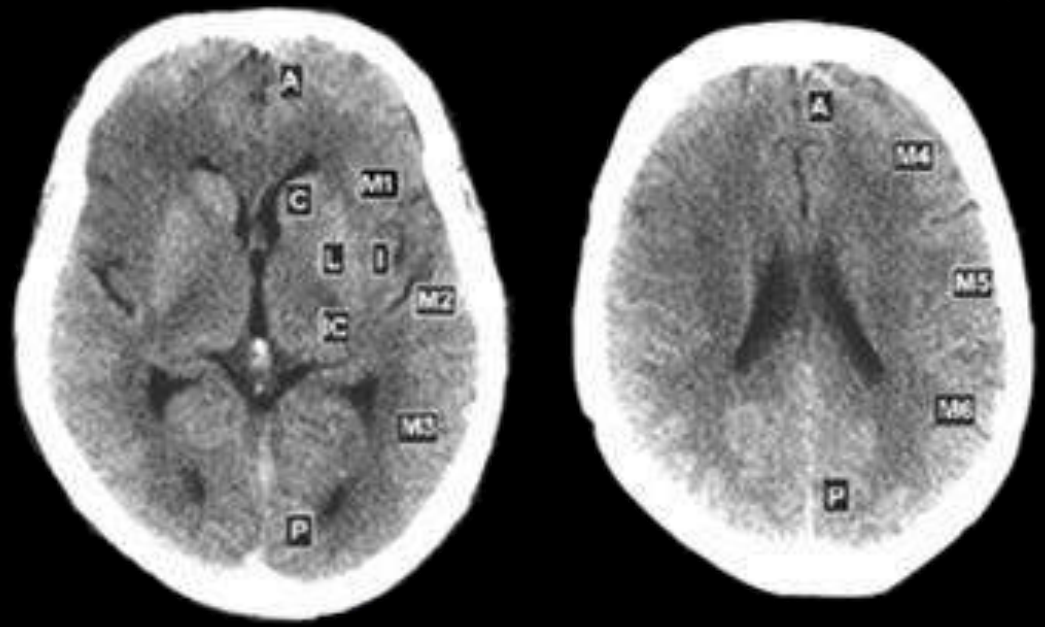
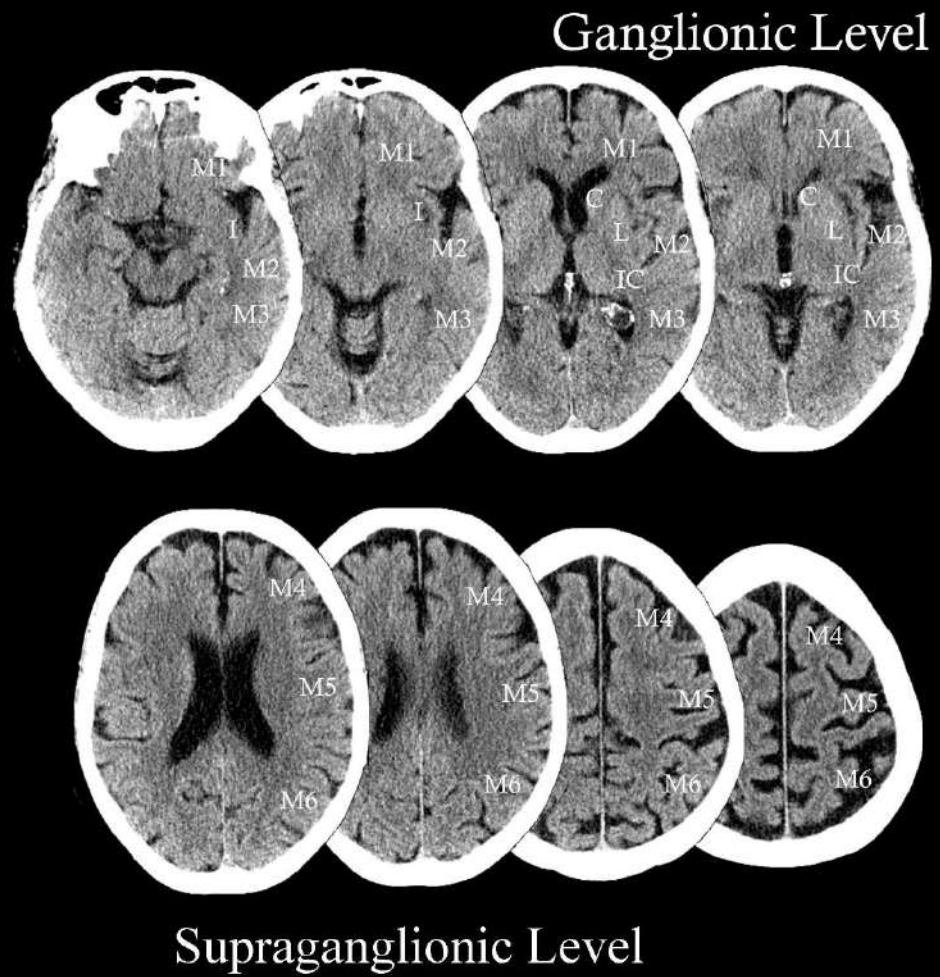
10 = normal



Courtesy University of Calgary Stroke Program.



ASPECT score of ≤ 7 : worse outcome at 3 months & poor revascularization, higher sICH with rtPA

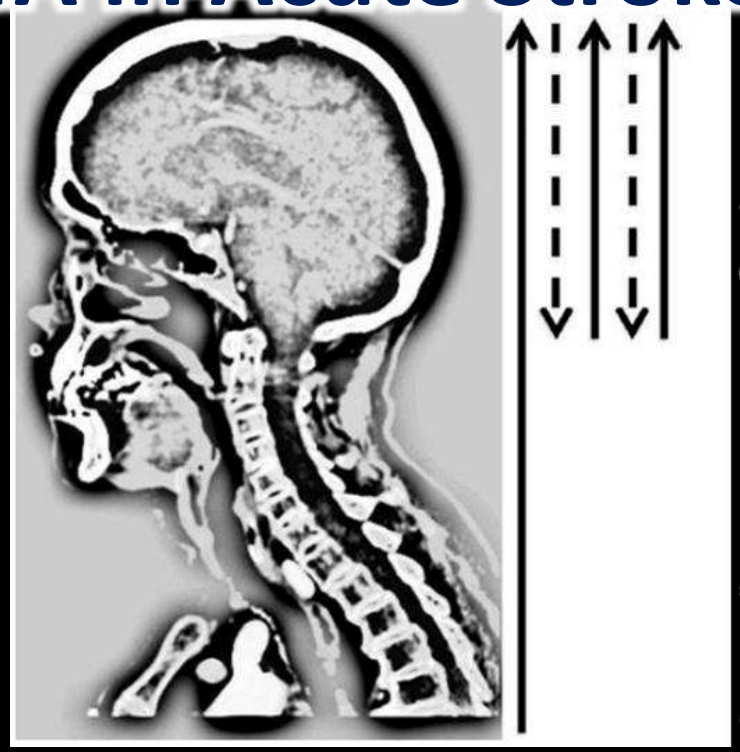
ASPECT score ≥ 6: Candidate for mechanical thrombectomy

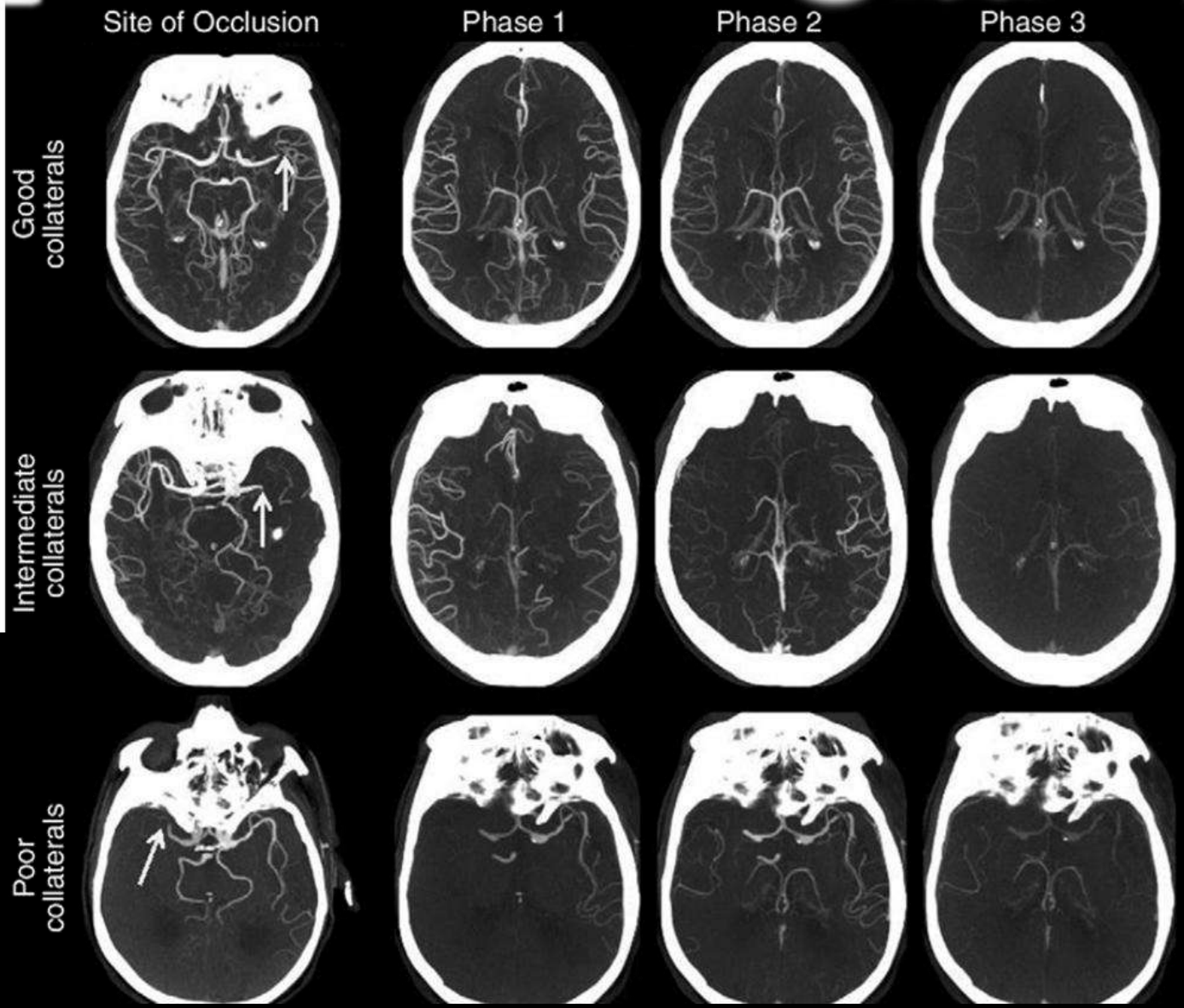
C caudate nucleus, L lentiform nucleus, IC internal capsule, I insular cortex

http://www.emergency-live.com/en/equipment/first-automated-stroke-imaging-evaluation-via-electronic-alberta-stroke-program-early-ct-score-in-a-mobile-stroke-unit/

http://www.aspectsinstroke.com/

CTA in Acute Stroke





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Menon BK, et al. Radiology 2015.; 275(2): 510-20

DWI-FLAIR Mismatch

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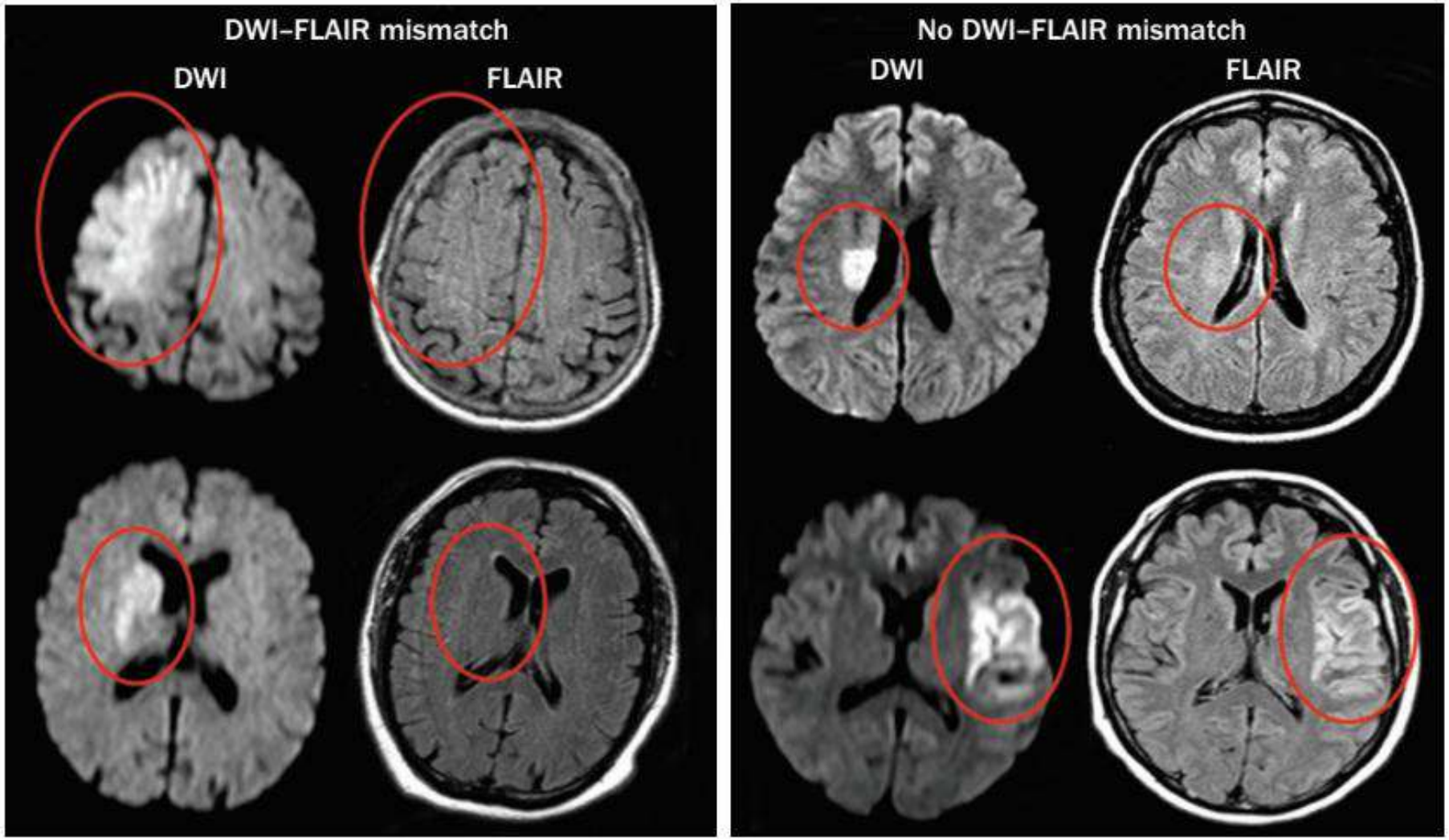
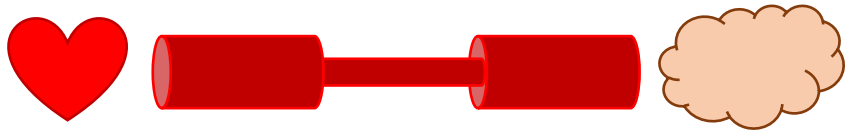
- Detecting ischemic stroke of <4.5 h after onset (WAKE-UP)

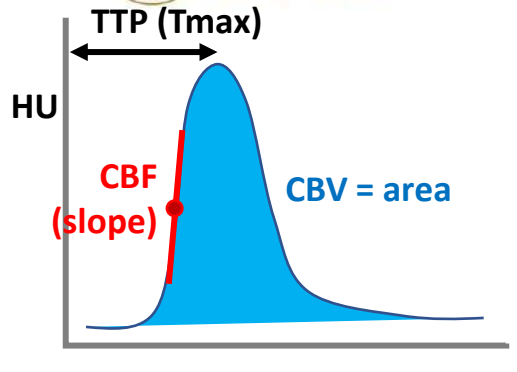


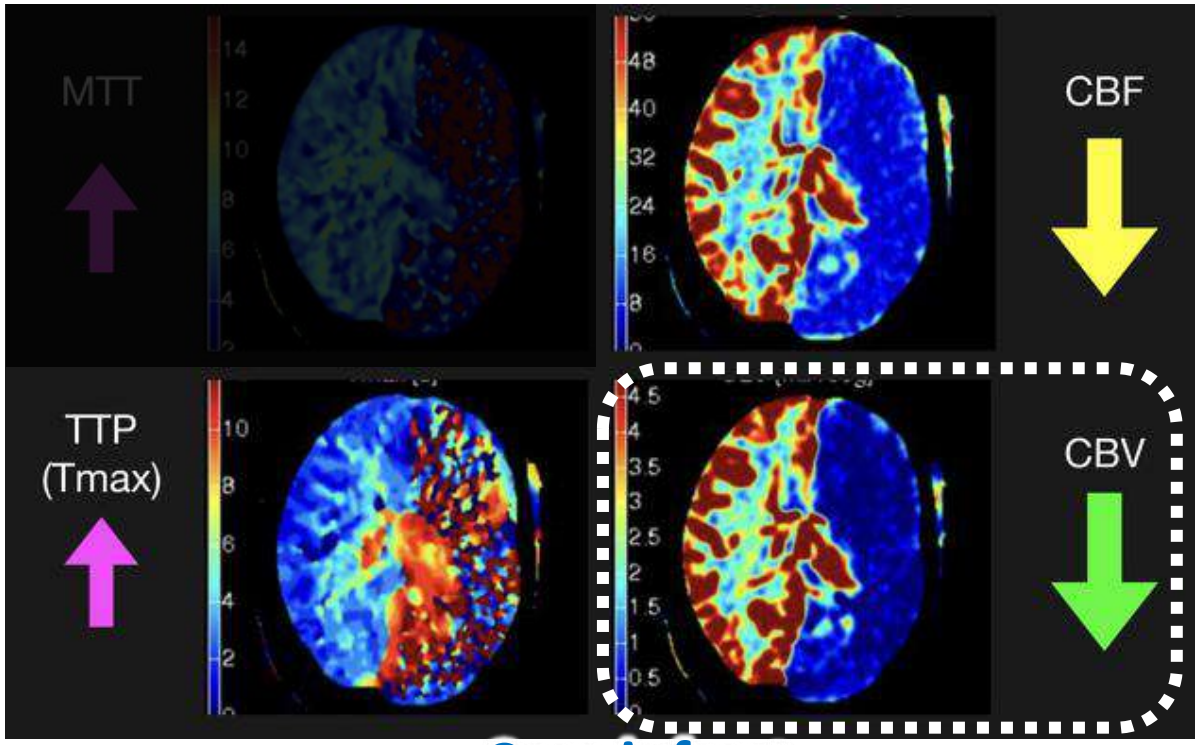
Kingwell K. Nat Rev Neurol 2011; 7: 655

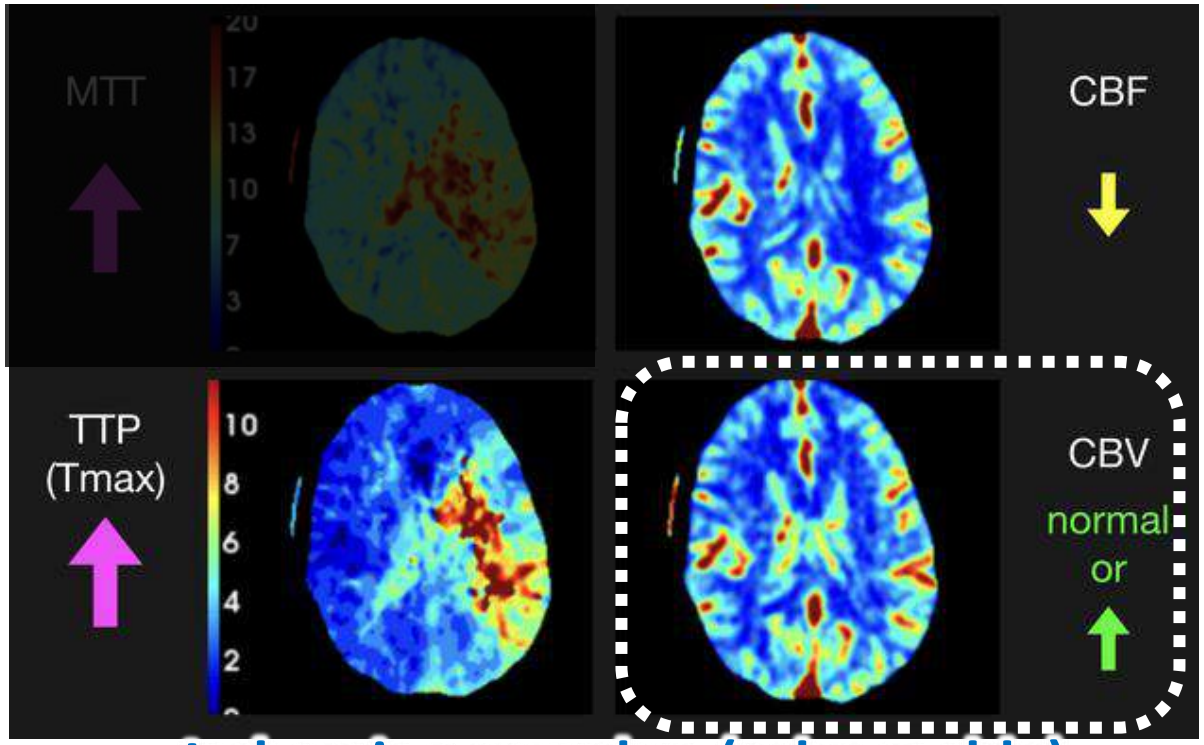
CT Perfusion

- **Detecting ischemic penumbra & ischemic core**









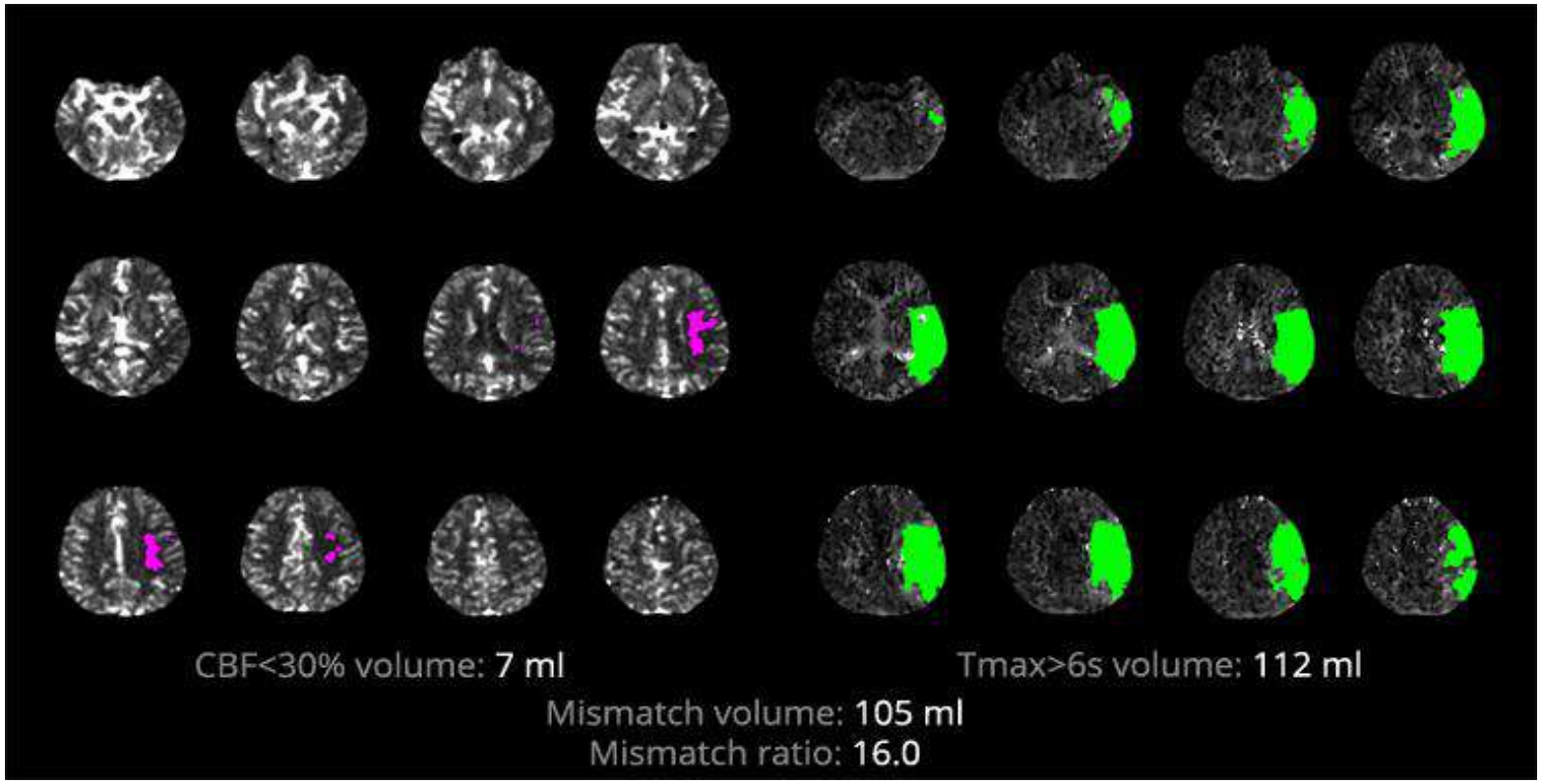
Core infarct

Ischemic penumbra (salvageable)

https://radiopaedia.org/articles/ct-perfusion-in-ischaemic-stroke

MTT mean transit time, TTP time to peak, CBF cerebral blood flow, CBV cerebral blood volume

CT Perfusion in Acute Stroke



	DEFUSE-3	DAWN
Time window	6-16 h since LKW	6-24 h since LKW
Age	18-90 y	≥18 y
Prestroke mRS	≤2	≤1
NIHSS	≥6	≥10
Arterial occlusion	ICA and/or M1	ICA and/or M1
Key imaging-based inclusion criteria		
Ischemic core vol	≤70 mL	≤20 mL if age>80
		≤30 mL if age<80 and NIHSS 10-20
		≤50 mL if age <80 and NIHSS >20
Mismatch vol	≥15 mL and mismatch ratio of ≥1.8	Not required

Infarct core

Ischemic area (infarct+penumbra)

RAPID software

Turc G, et al. J Neurointerventional Surg 2019;.

4.6.3. Extended Time Windows for Intravenous Thrombolysis

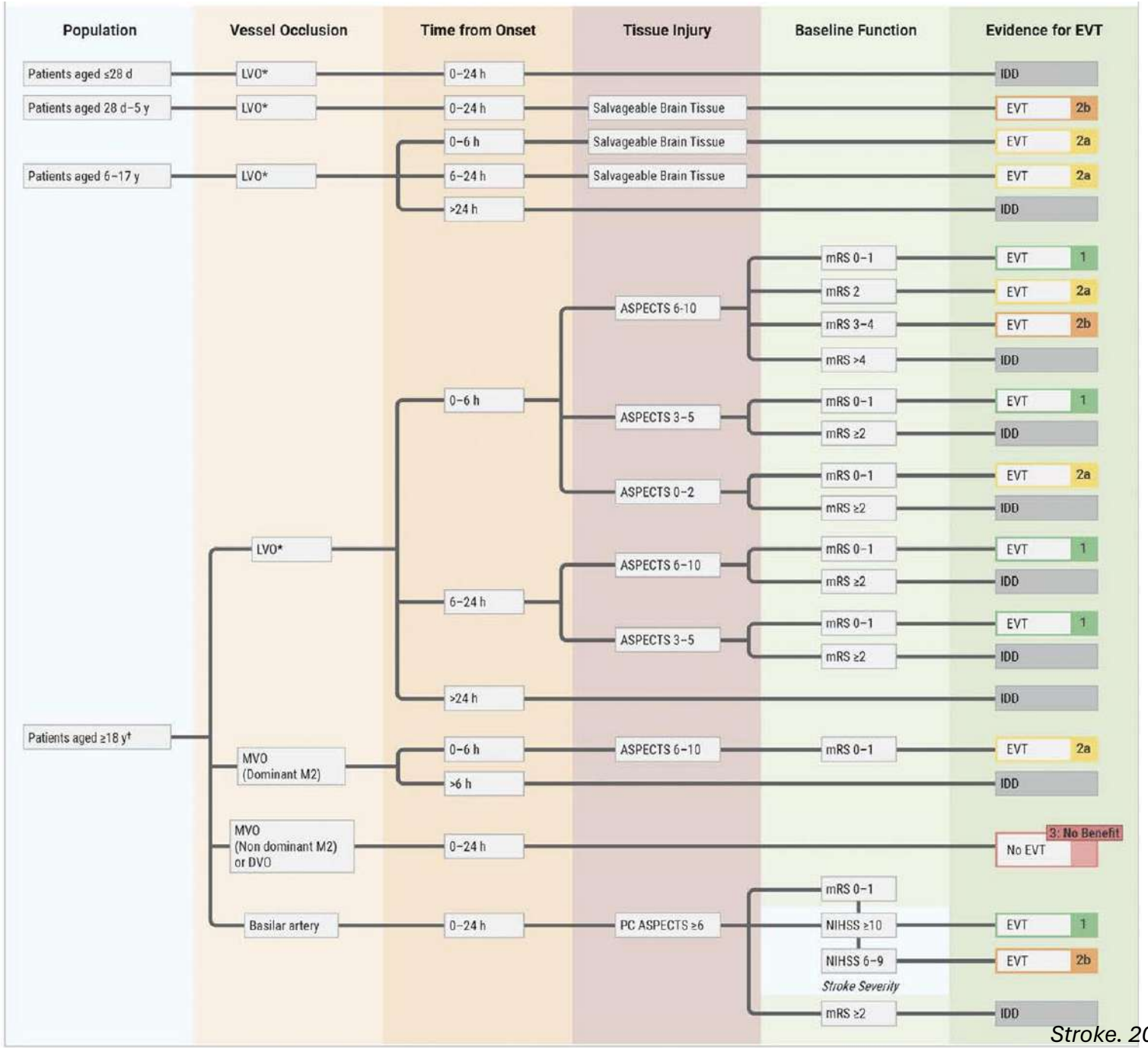
Recommendations for Extended Time Windows for Intravenous Thrombolysis
Referenced studies that support the recommendations are summarized in the online data supplement.

COR	LOE	Recommendations
2a	B-R	1. In patients with AIS who (a) have unknown time of onset and are within 4.5 hours from symptom recognition and (b) have an MRI-DWI lesion smaller than one-third of the MCA territory and no marked signal change on FLAIR, IVT administered within 4.5 hours of stroke symptom recognition can be beneficial to improve functional outcomes.[1]

Recommendations for Extended Time Windows for Intravenous Thrombolysis (Continued)

COR	LOE	Recommendations
2a	B-R	2. In patients with AIS who have salvageable ischemic penumbra detected on automated perfusion imaging and who (a) awake with stroke symptoms within 9 hours from the midpoint of sleep or (b) are 4.5–9 hours from last known well, IV thrombolysis may be reasonable to improve functional outcomes.[2,3]
2b	B-R	3. In patients with AIS due to LVO with salvageable ischemic penumbra, presenting within 4.5 to 24 hours from symptom onset or last known well, and who cannot receive EVT, treatment with IVT directed by individuals with expertise in thrombolytic stroke care may be beneficial to improve functional outcomes.[2–5]

Stroke. 2026;57:e00–e00. DOI: 10.1161/STR.0000000000000513



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LEGEND

- COR 1
- COR 2a
- COR 2b
- COR 3-No Benefit
- COR 3-Harm

(Class of Recommendation)

Stroke. 2026;57:e00–e00. DOI: 10.1161/STR.0000000000000513

CT/MR Perfusion

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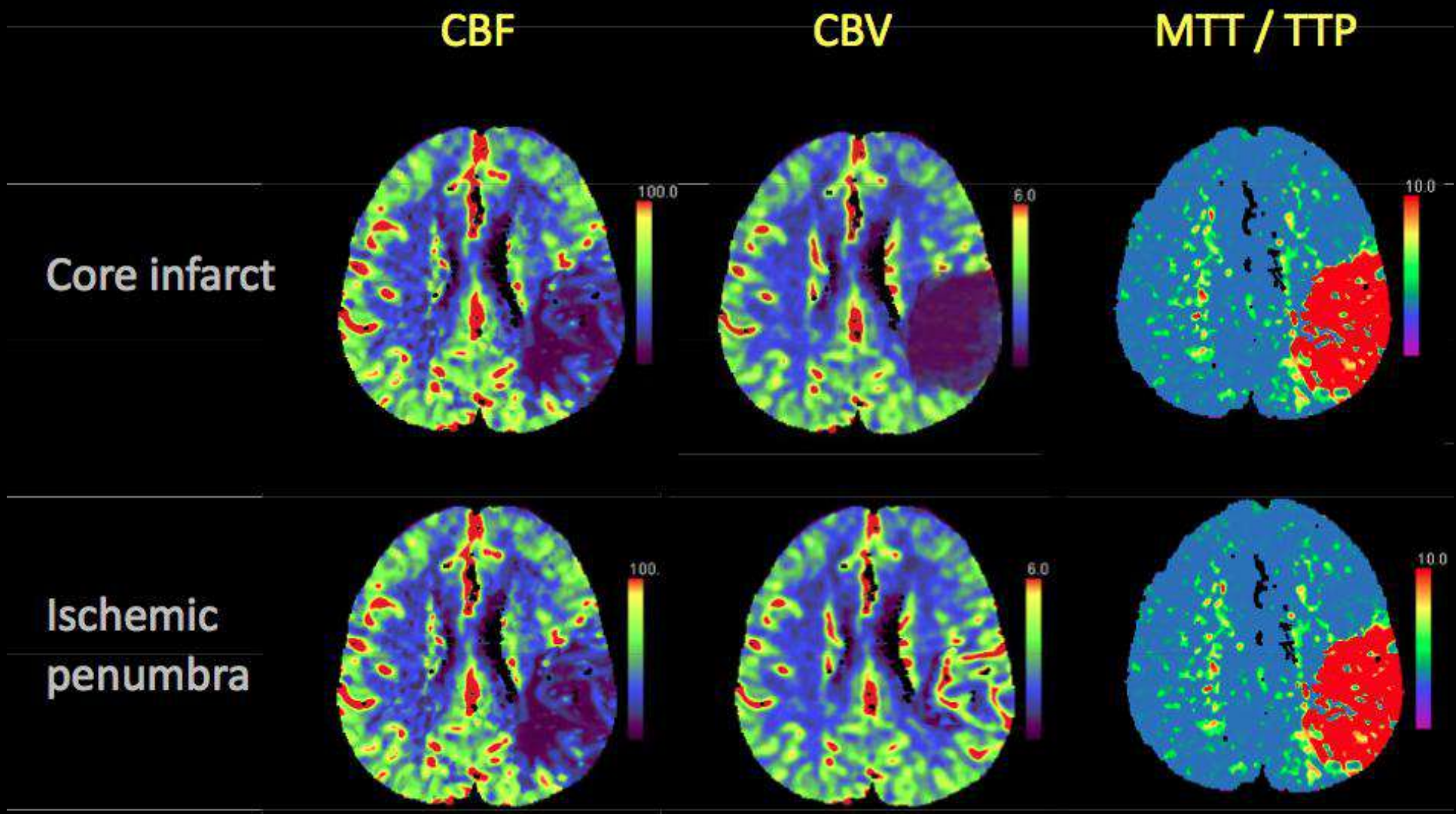
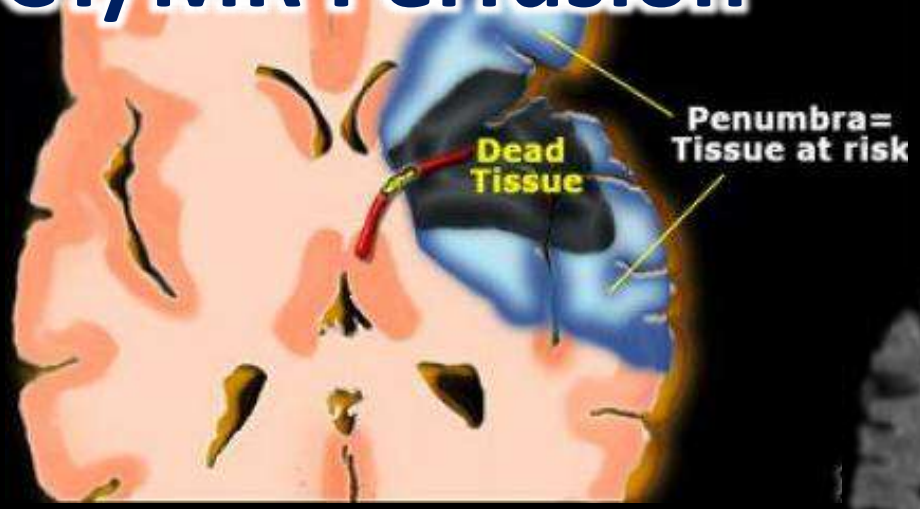


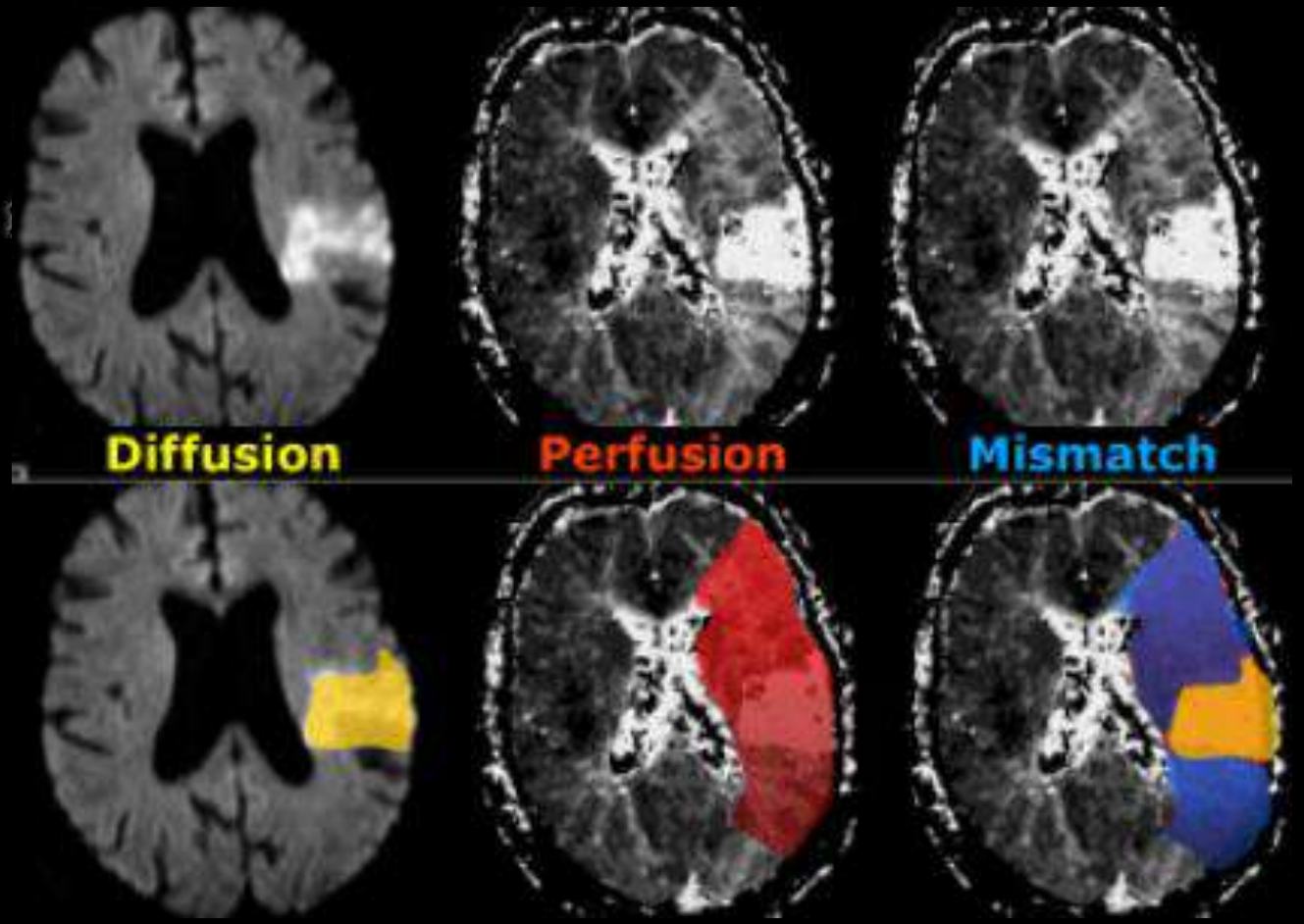
CT/MR Perfusion



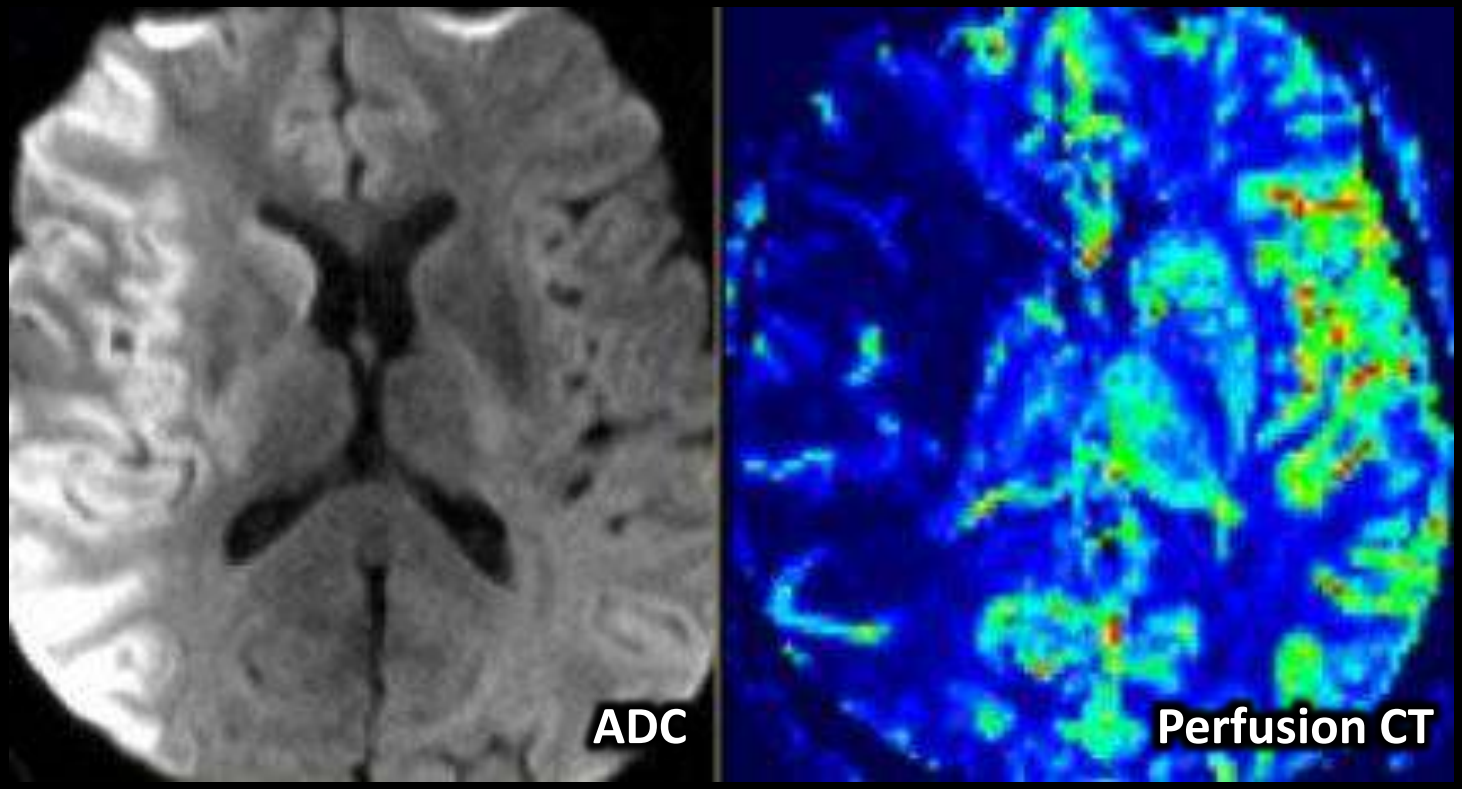
Diffusion-perfusion mismatch

= Area of penumbra

(might benefit from lytic therapy)



CT/MR Perfusion



Perfect match between ADC & perfusion CT

= No area of reversible damage

(might not benefit from lytic therapy)

Review on Vascular Territories

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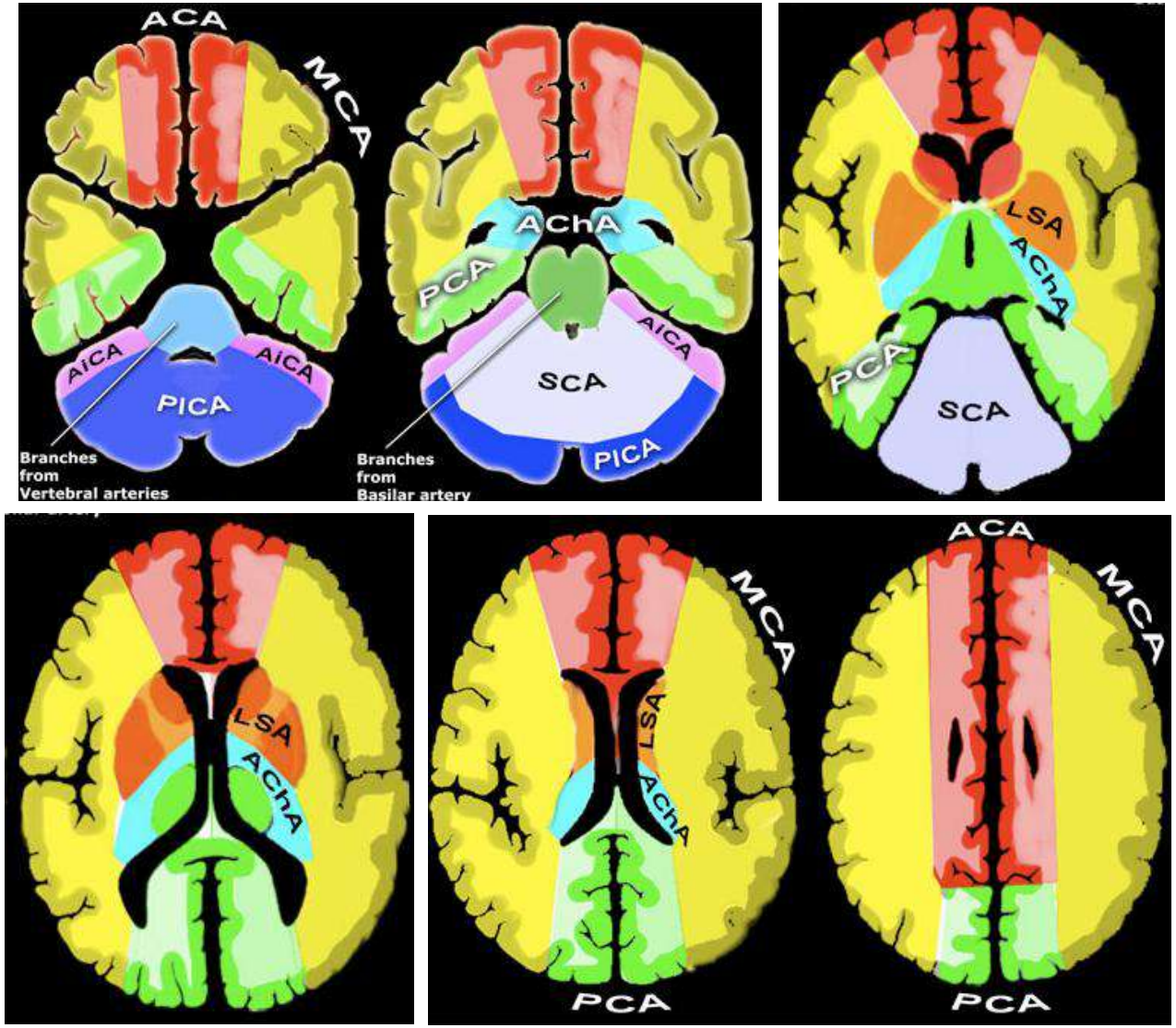

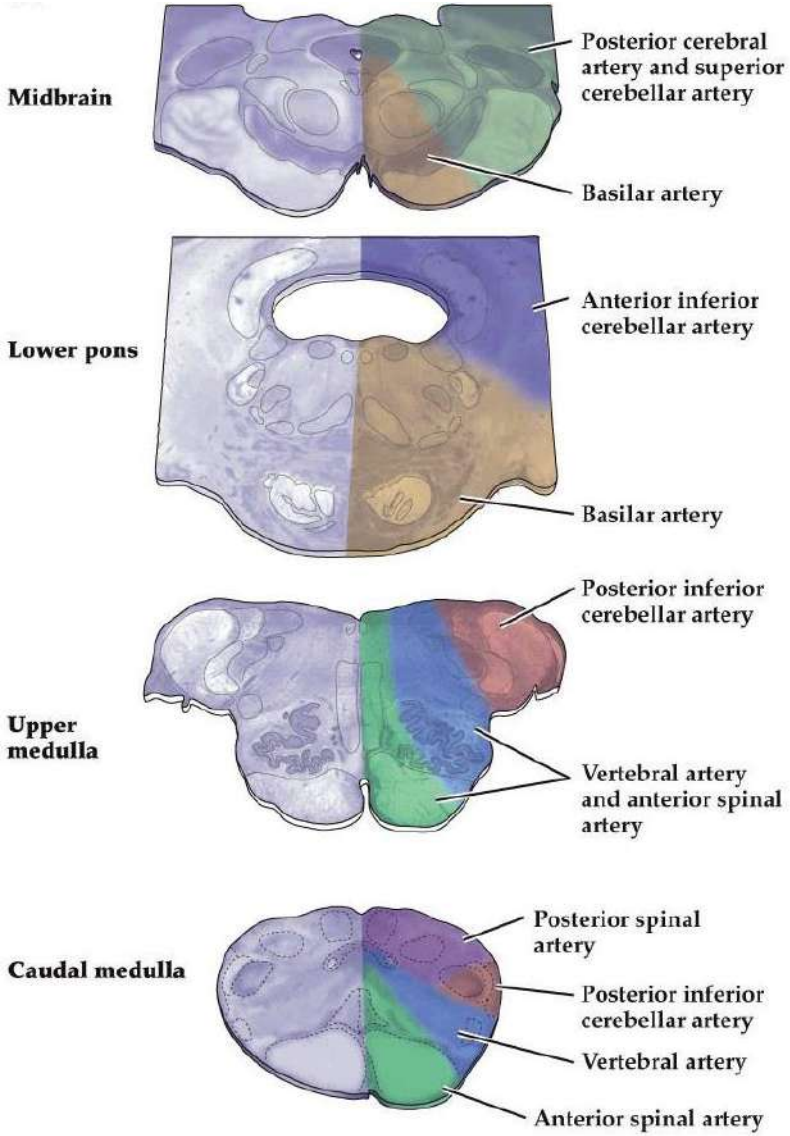

ACA anterior cerebral a, MCA middle cerebral a, PCA posterior cerebral a, LSA lateral striate a, AChA anterior choroidal a, SCA superior cerebellar a, AICA anterior inferior cerebellar a, PICA posterior inferior cerebellar a.

https://brain.oit.duke.edu/lab02/lab02.html
https://radiologyassistant.nl/neuroradiology/brain-ischemia/vascular-territories

Anterior Circulation Stroke

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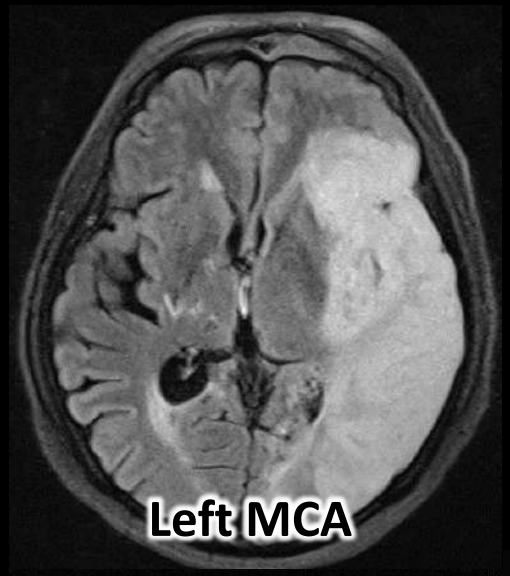
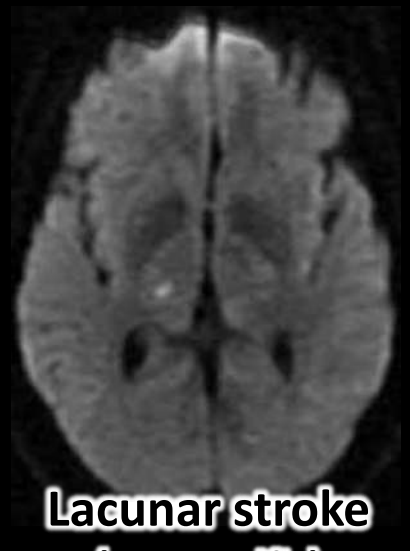


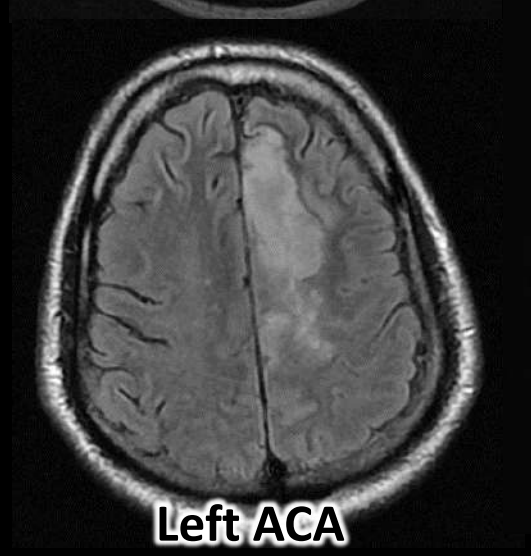
Left MCA

Right ICA

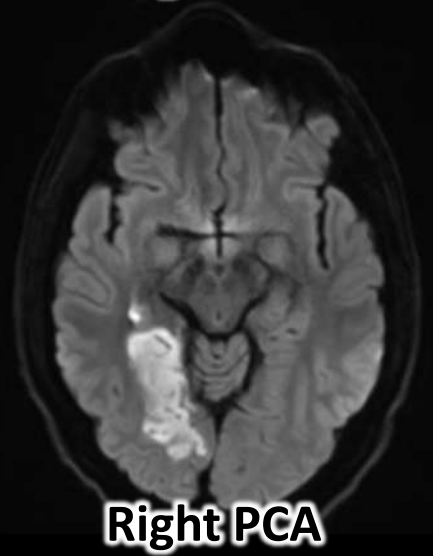
Right anterior choroidal artery



Lacunar stroke
(nonspecific)

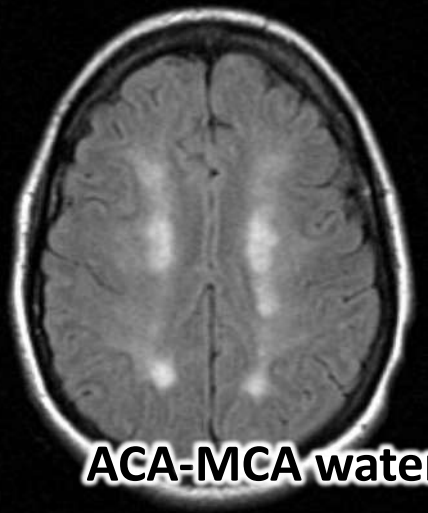


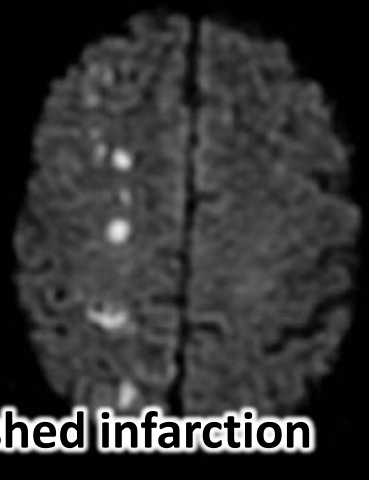
Left ACA



Right PCA

Left lenticulostriate a.





ACA-MCA watershed infarction

https://radiopaedia.org/

Posterior Circulation Stroke

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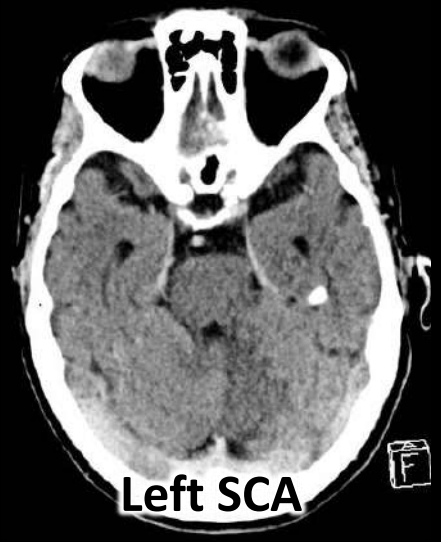
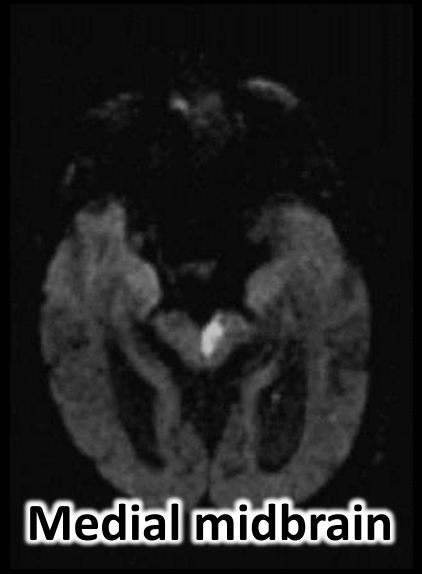
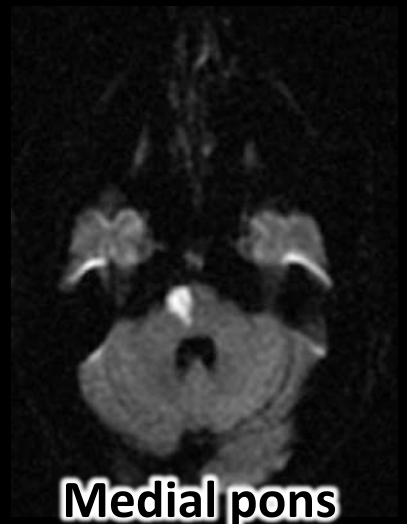

Left SCA


Right PICA

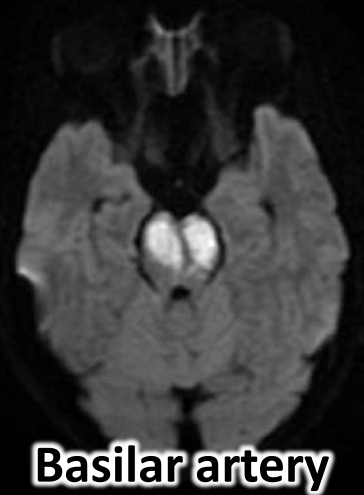

Medial midbrain

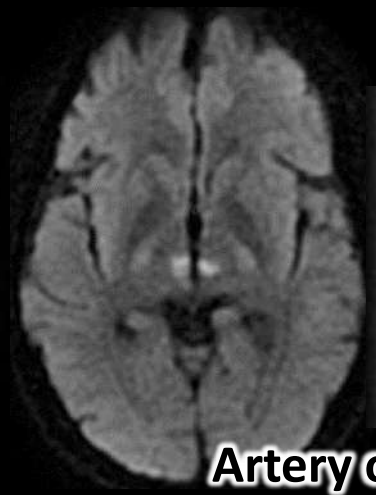

Medial pons

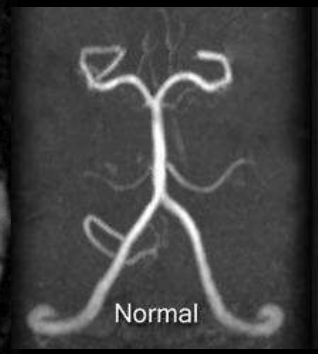

Medial medulla

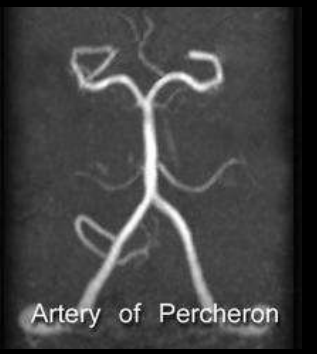

Left AICA


Lateral pontine


Basilar artery

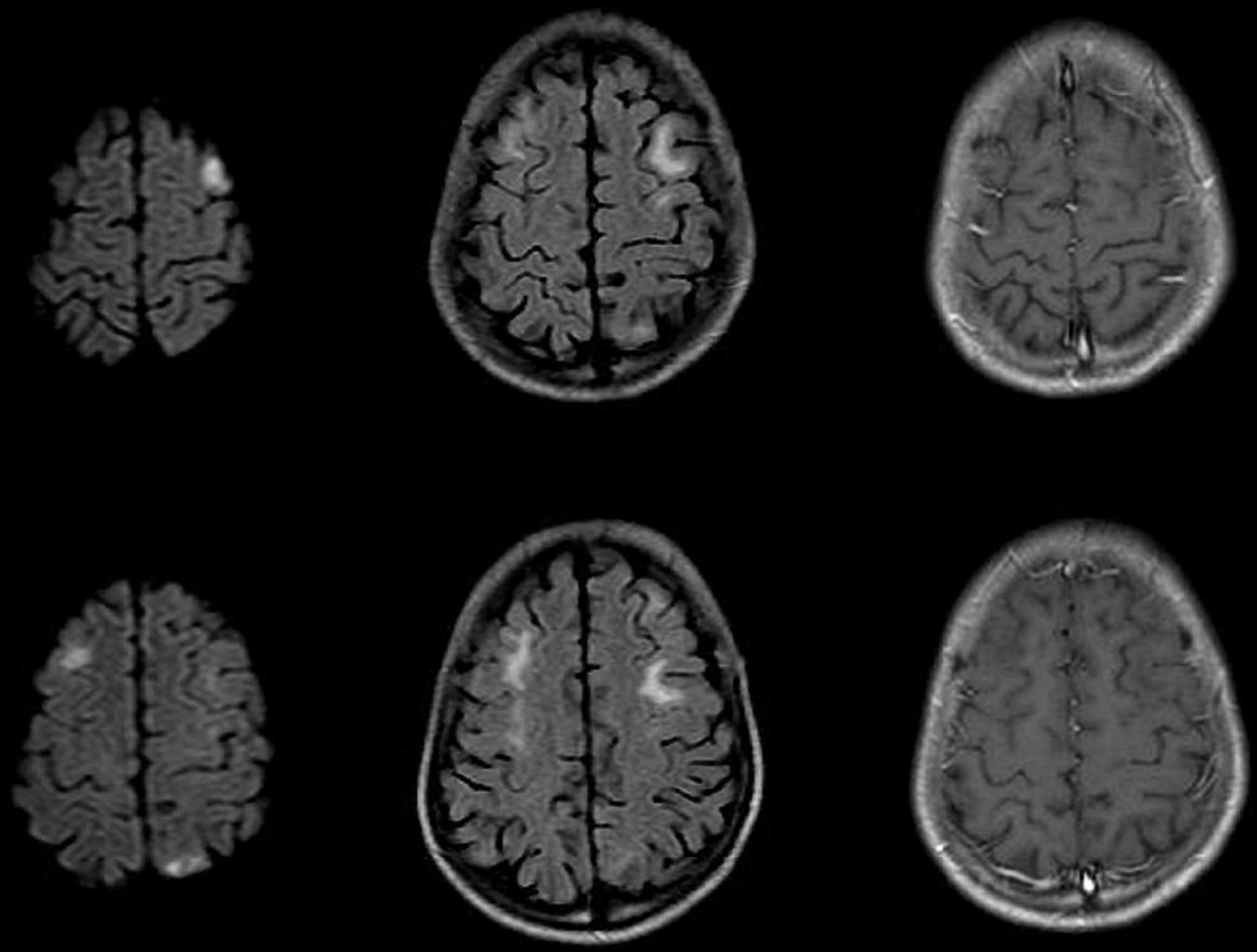

Artery of Percheron





https://radiopaedia.org/

Multiple Strokes

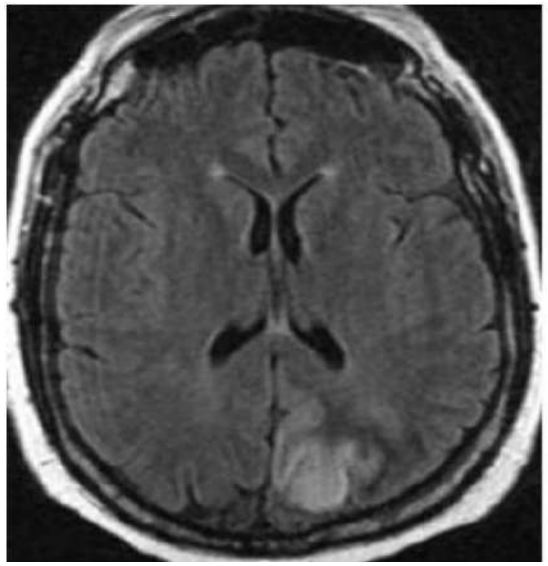


- Cardioembolism
- Watershed infarct
- Thrombophilia
- Infective endocarditis, vasculitis (hemorrhage, SAH)
- Reversible cerebral vasoconstriction syndrome (RCVS)
- Etc.

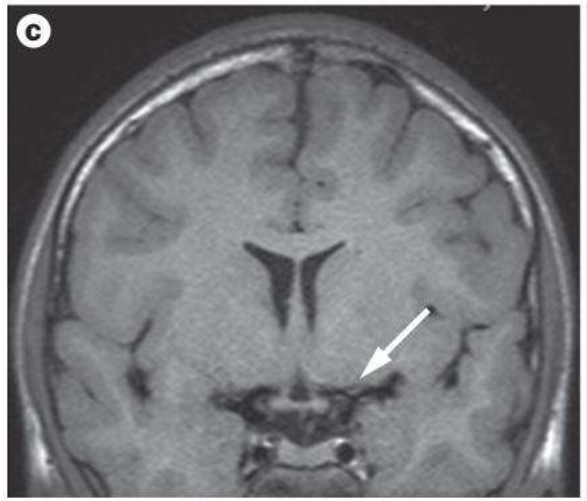
https://radiopaedia.org/

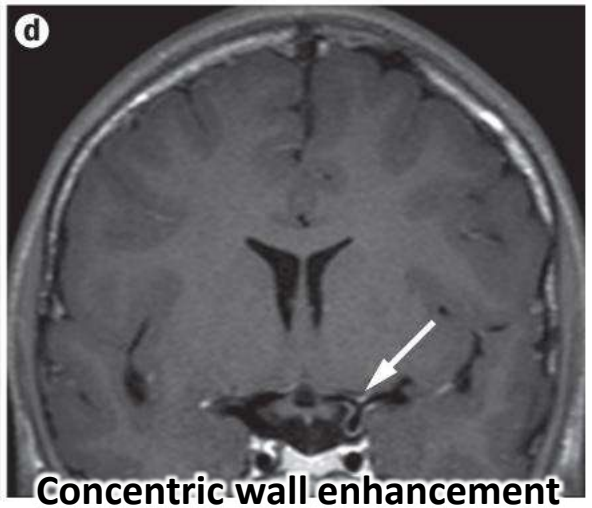
CNS Vasculitis

- Multiple infarcts
- Bilateral, diff vascular territories
- Various stages of healing



Multifocal arterial narrowing





Concentric wall enhancement

Twilt M, Benseler M. Nat Rev Rheumatol 2012; 8: 97-102
Absel Razek AAK, et al. Radiographics 2014; 34(4): 873-94
Obusez EC, et al. Am J Neuroradiol 2014; 35: 1527-32

RCVS

- Convexity non-aneurysmal SAH
- Lobar hemorrhage
- Watershed infarction
- Vasogenic edema

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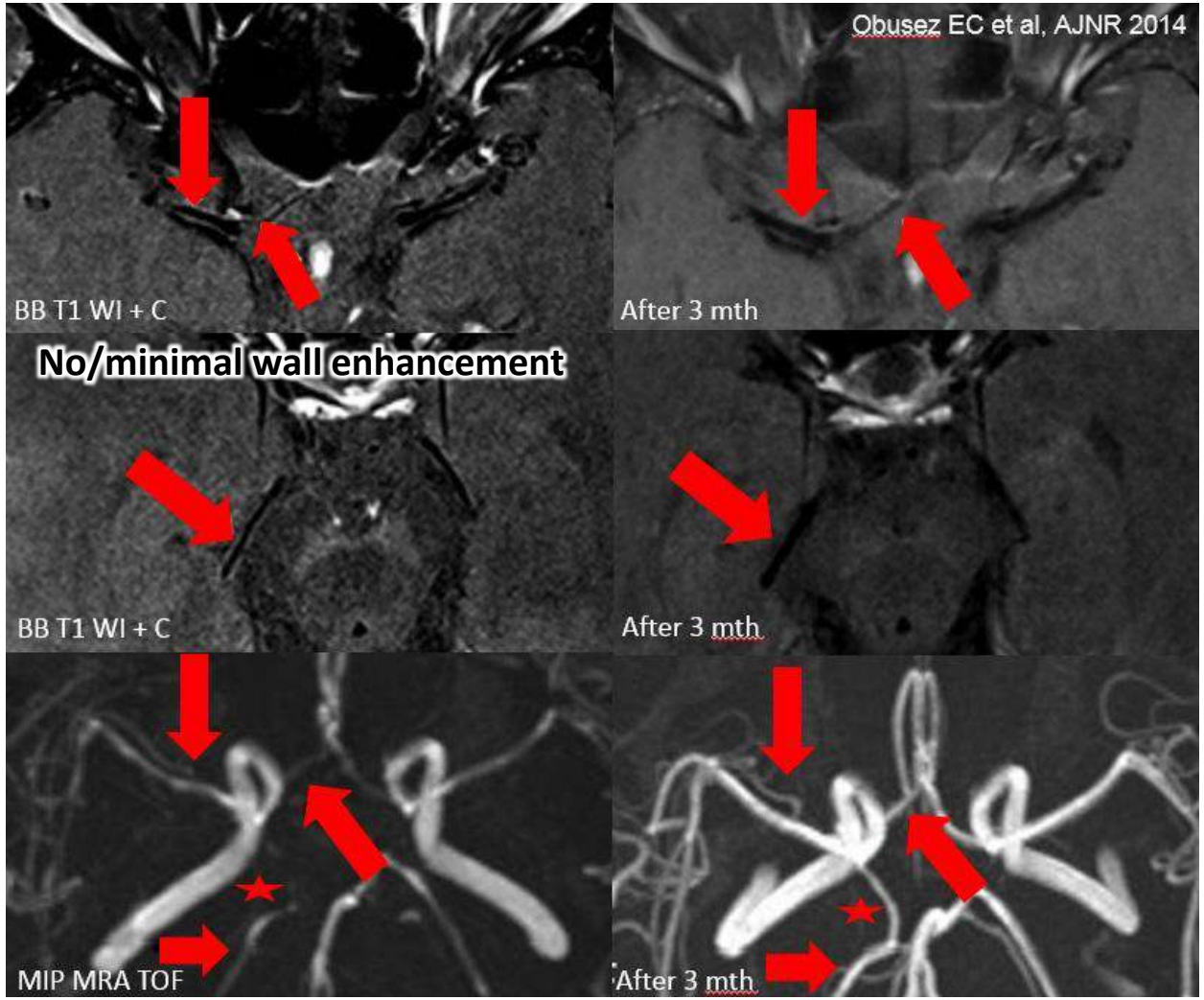

Resolution of arterial narrowing at 3 months F/U

Comparison Between Vasculopathies

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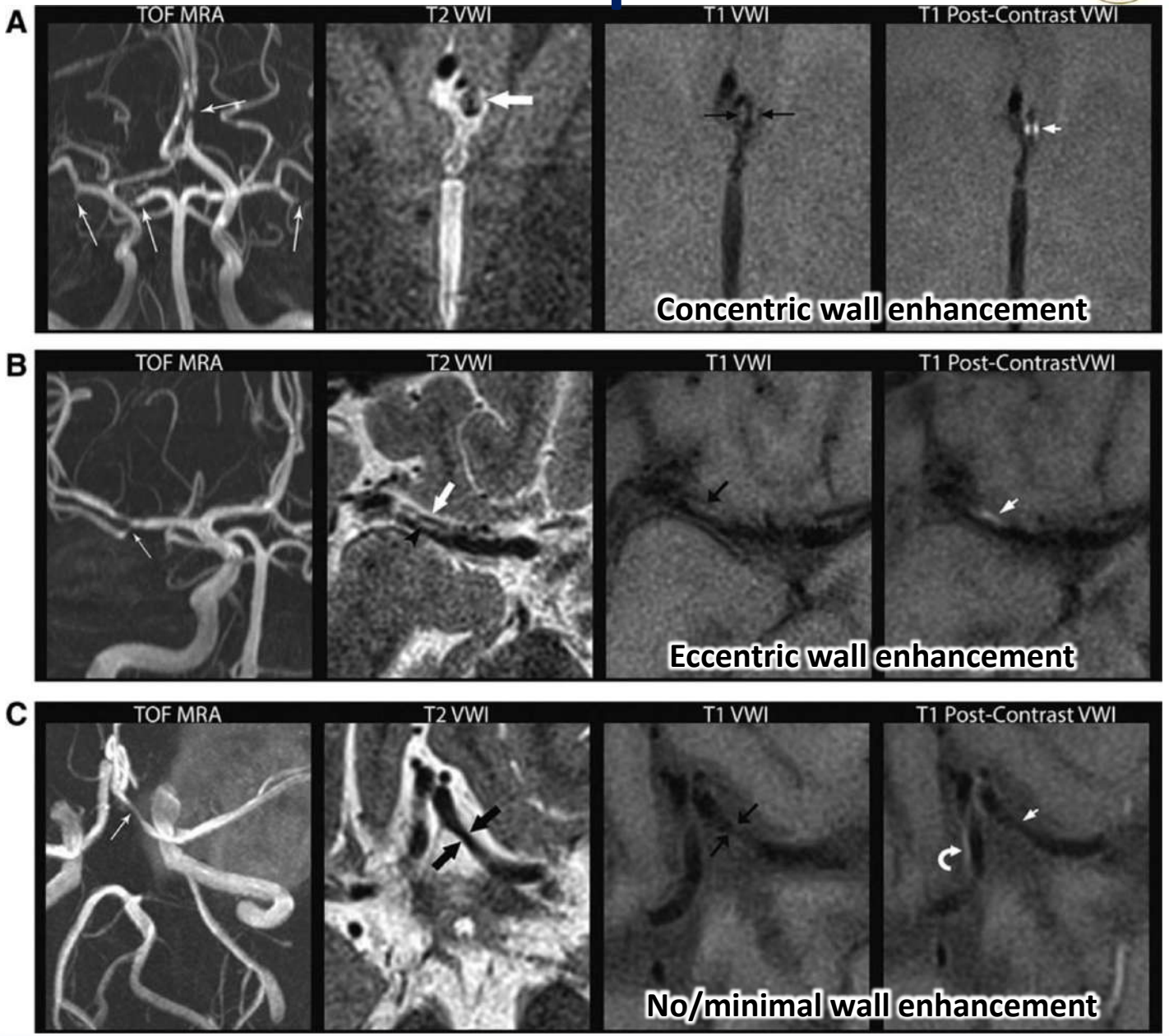
CNS vasculitis

Intracranial atherosclerosis

RCVS



Mossa-Basha M, et al. Stroke 2015; 46(6): 1567-73

Reversible Cerebral Vasoconstriction Syndrome

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Postpartum
Postpartum alone[a], postpartum + exposure to drugs[a], eclampsia, preeclampsia
Exposure to drugs, alcohol, medications and blood products
Cannabis[a], cocaine[a], ecstasy, amphetamine derivates, lysergic acid diethylamine
Binge alcohol drinking[b]
Selective serotonin reuptake inhibitors[a]
Nasal decongestants[a], phenylpropanolamine[a], pseudoephedrine[a], ephedrine[a]
Ergotamine tartrate, methergine, bromocriptine[a], lisuride, sumatriptan, isometheptine
Tacrolimus (FK-506), cyclophosphamide, erythropoietin, intravenous immune globulins, red blood cell transfusion, interferon alpha[b]
Nicotine patches[a]
Catecholamine-secreting tumour
Pheochromocytoma, bronchial carcinoid tumour
Miscellaneous
Hypercalcemia, porphyria, head trauma, spinal subdural hematoma, postcarotid endarterectomy, neurosurgical procedures

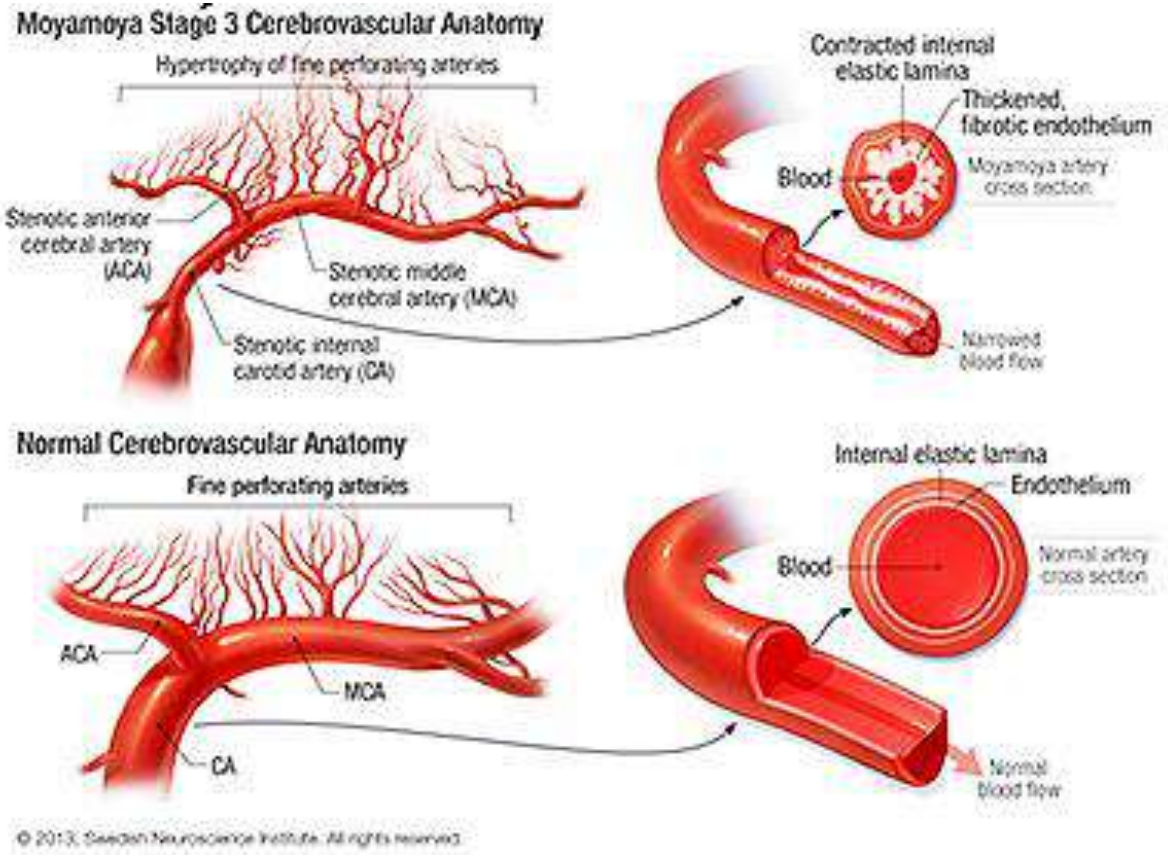
Associated conditions

Large artery lesions
Cervical artery dissection[a], Unruptured saccular cerebral aneurysm[a], cerebral arterial dysplasia[a]

[a]present in both the literature (Bousser *et al.*, 200l; Singhal, 2004*a*;

Ducros A, et al. Brain 2008; 130(12): 3091-101

Moyamoya Syndrome



More common	Less common
Neurofibromatosis type I	Structural cardiac anomalies
Sickle cell disease	PHACEs syndrome
Down syndrome (trisomy 21)	Hyperthyroidism
Post-cranial radiation	Congenital dwarfing syndromes
	Alagille syndrome

https://www.swedish.org/services/neuroscience-institute/our-services/cerebrovascular-center/conditions-we-treat/moyamoya
Smith ER. J Korean Neurosurg Soc 2015; 57(6): 415-21

Moyamoya Syndrome

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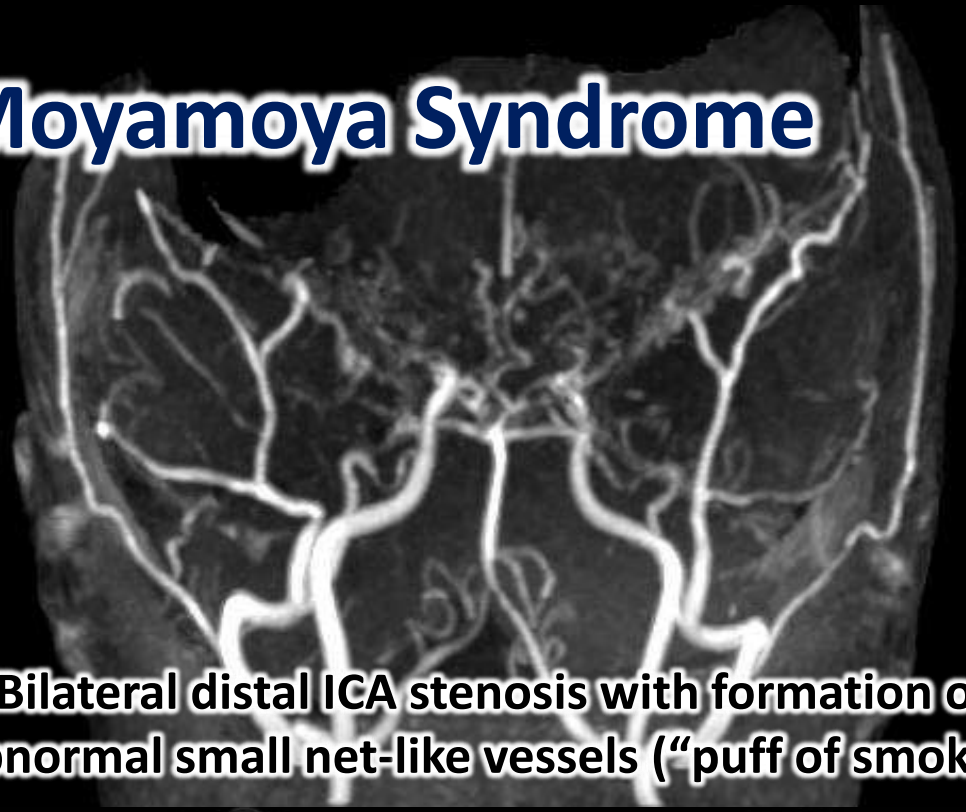
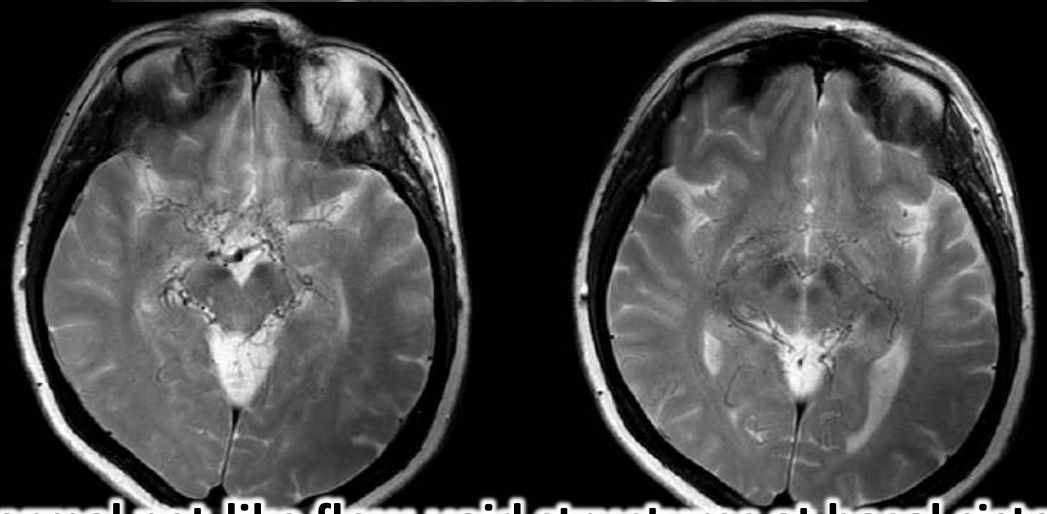


Bilateral distal ICA stenosis with formation of abnormal small net-like vessels (“puff of smoke”)

Serpentine sulcal pial collaterals (high FLAIR signal intensity & contrast enhancement)



Abnormal net-like flow-void structures at basal cistern

Other features:

- Watershed infarcts
- ICH (more likely in adults)
- Generalized brain atrophy

Posterior Reversible Encephalopathy Syndrome (PRES)

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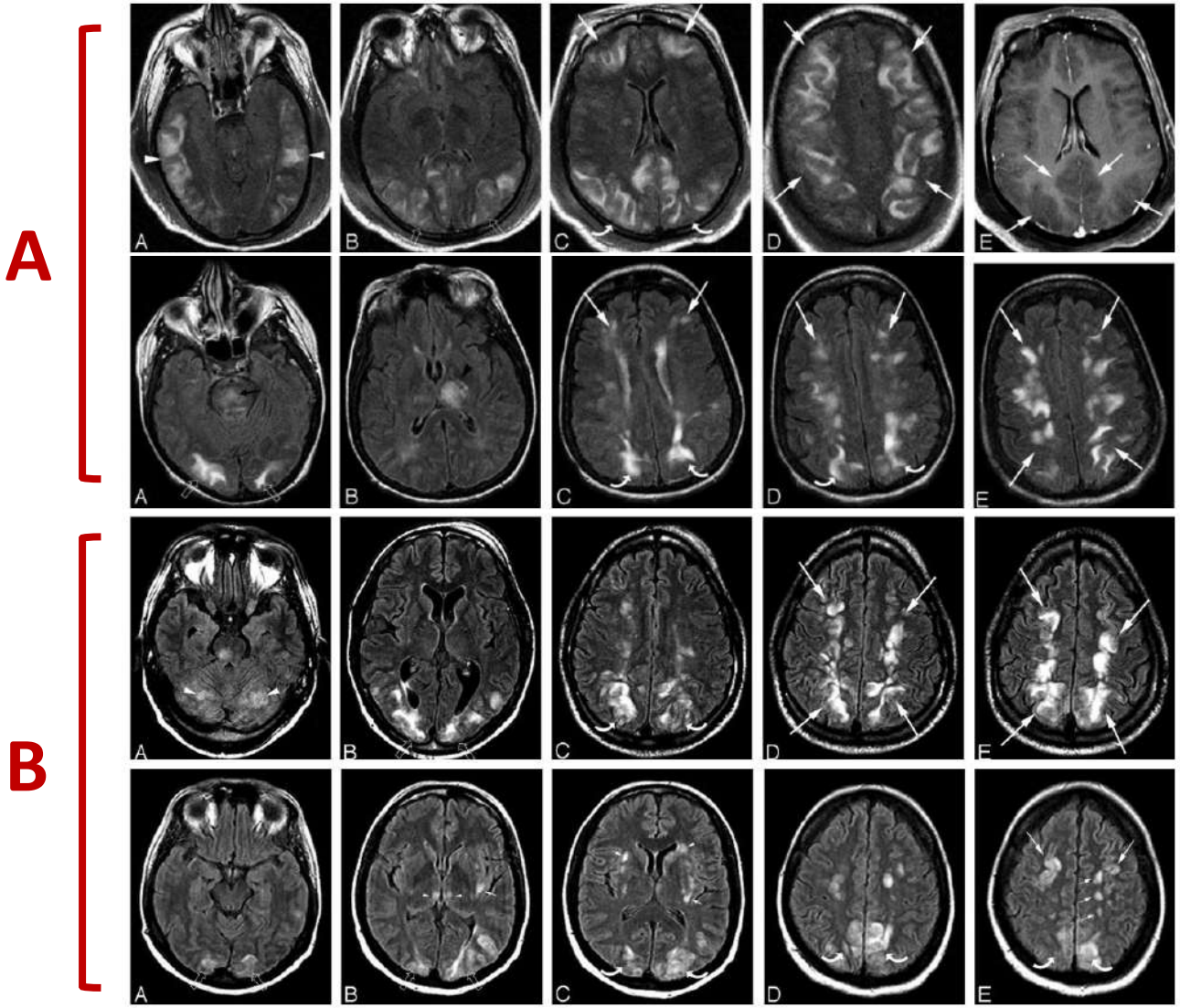

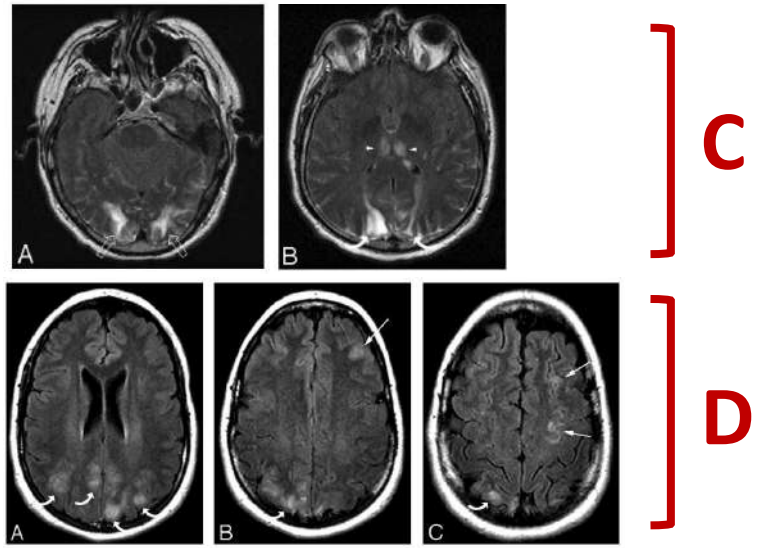

A = Holohemispheric watershed

B = Superior frontal sulcus

C = Dominant parietal/occipital

D = Partial/asymmetric PRES

Others (e.g. brainstem, basal gg.)

Bartynski WS, Boardman JF. Am J Neuroradiol 2007; 28: 1320-27

Posterior Reversible Encephalopathy Syndrome (PRES)

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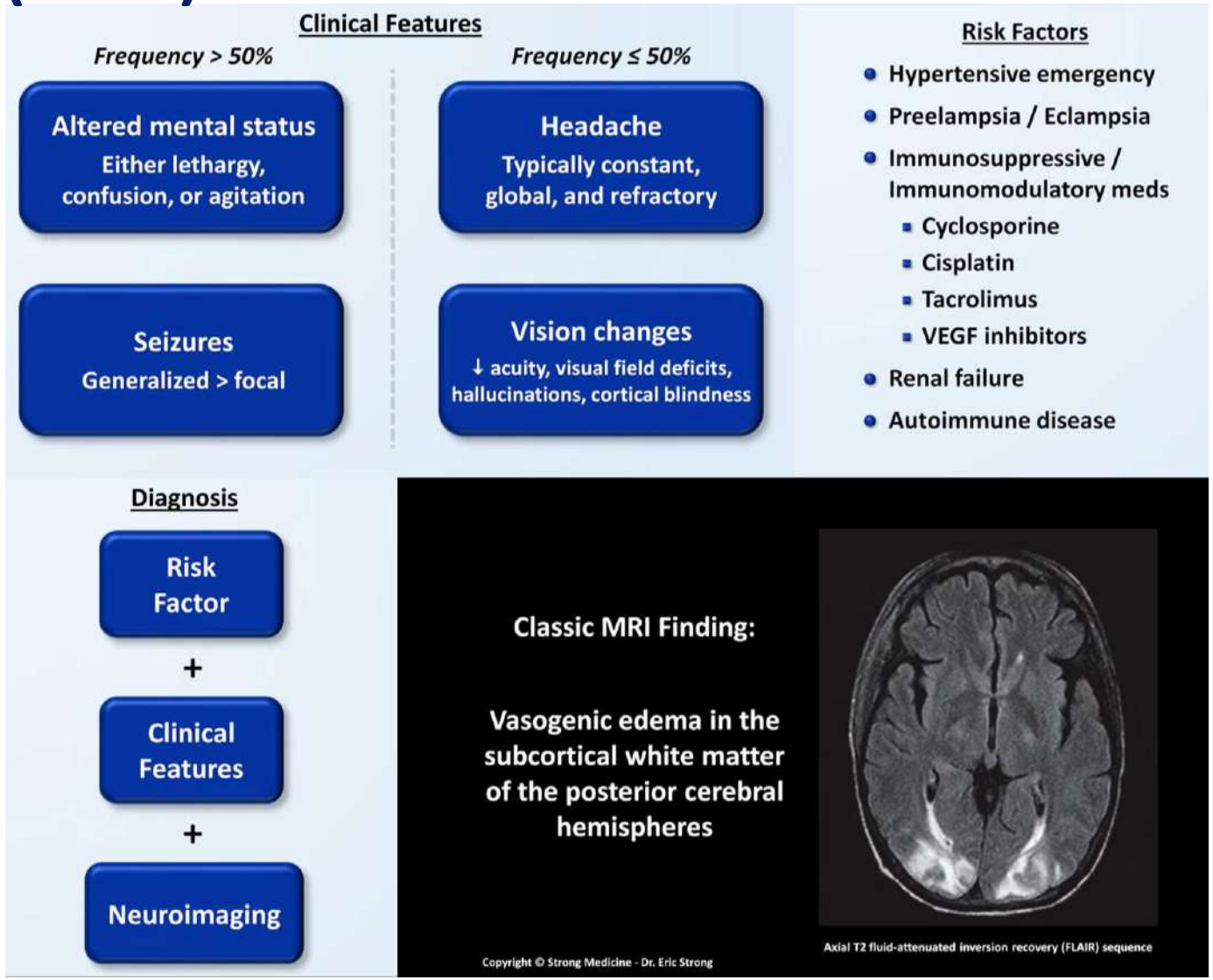


Hypertension
Acute or chronic renal diseases
Solid organ/bone marrow transplantation
Preeclampsia/eclampsia
Infection/sepsis/shock
Vasculitis
- Systemic lupus erythematosus
- Polyarteritis nodosa
- Cryoglobulinemia
- Wegener's granulomatosis

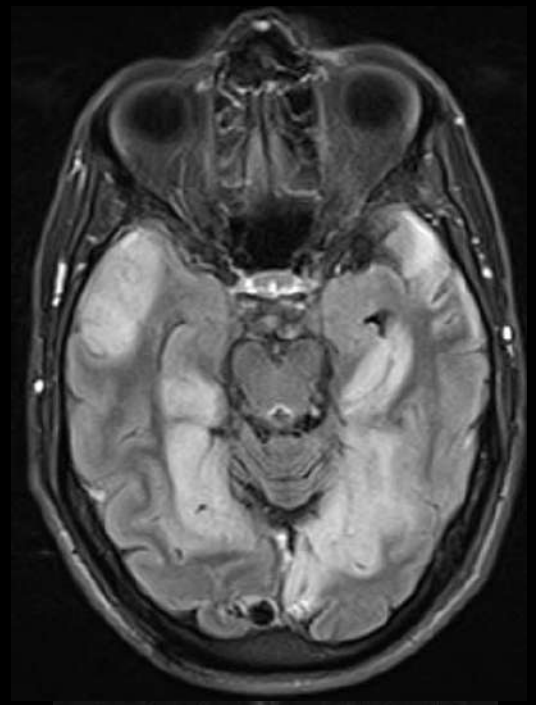
Immunosuppressive, immunomodulatory, and chemotherapeutic drugs
- Bevacizumab
- Cisplatin and other platinum-based agents
- Combination chemotherapy
- Cyclosporine A
- Cytarabine
- Gemcitabine
- Intravenous immunoglobulin
- Tacrolimus
- Tyrosine kinase inhibitors (pazopanib), sorafenib, sunitinib

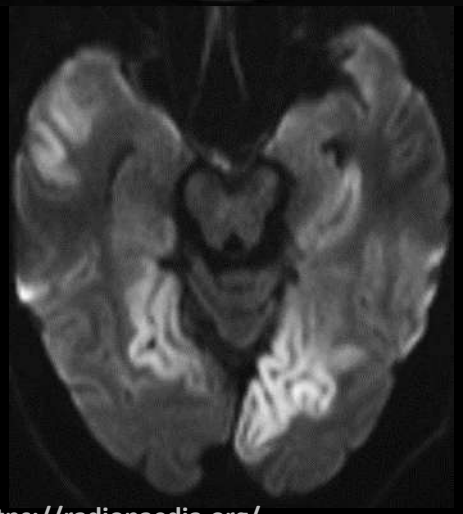
Porphyria
Hypercalcemia, hypomagnesmia
Blood transfusion
Contrast media exposure (cerebral, coronary angiography)
Thrombotic thrombocytopenic purpura/hemolytic uremic syndrome

Sigurta A, et al. Medicine 2016: 95(22): e3758
https://www.grepmed.com/images/12333/diagnosis-syndrome-pres-posterior-encephalopathy-15

MELAS

Mitochondrial encephalopathy with lactic acidosis and stroke-like episodes

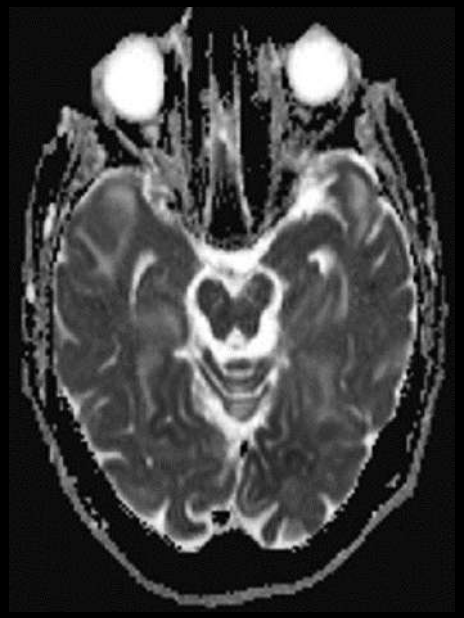




- **Multiple infarcts, bilateral**
- **P-O, P-T involvement**
- **Swollen gyri +/- enhancing**
- **↑ DWI, but ↔/↓ ADC (vasogenic edema)**

- **Chronic: Atrophy, basal gg calcifications**

- **Seizure, encephalopathy, muscle weakness, deafness**



https://radiopaedia.org/

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Cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalpathy

Widespread confluent white matter hyperintensity, involving anterior temporal lobe, external capsule

***NOTCH3* gene**

Recurrent TIA/stroke
Migraine-like headache
Early-onset dementia
Depression, psychosis

Cerebral Venous Sinus Thrombosis (CVST)

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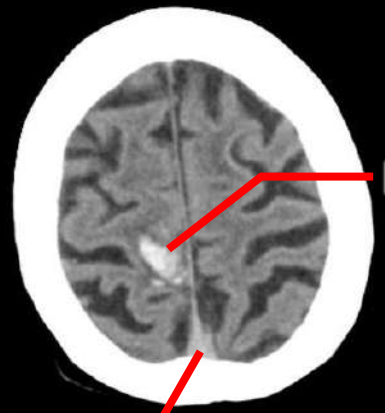
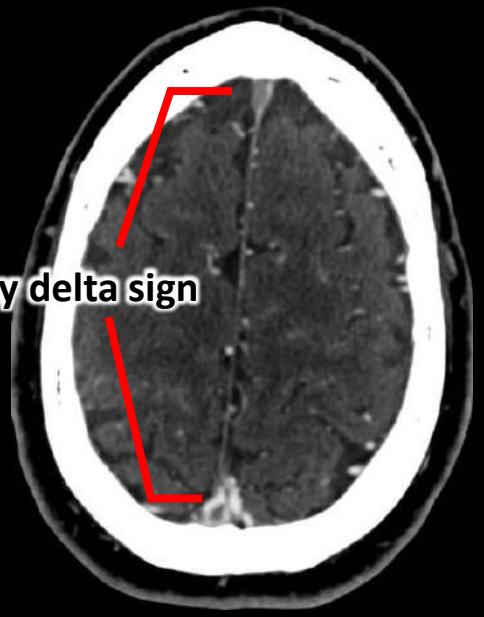


Hyperdense clot in SSS

ICH

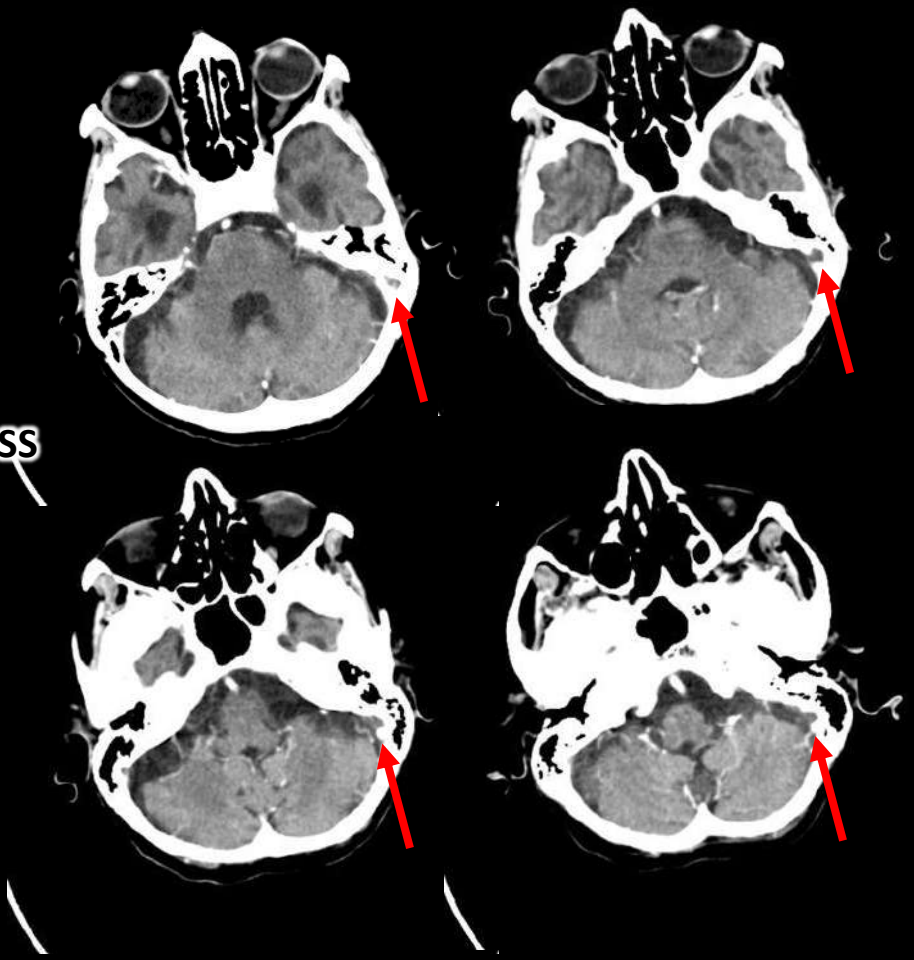
SAH

Delta sign



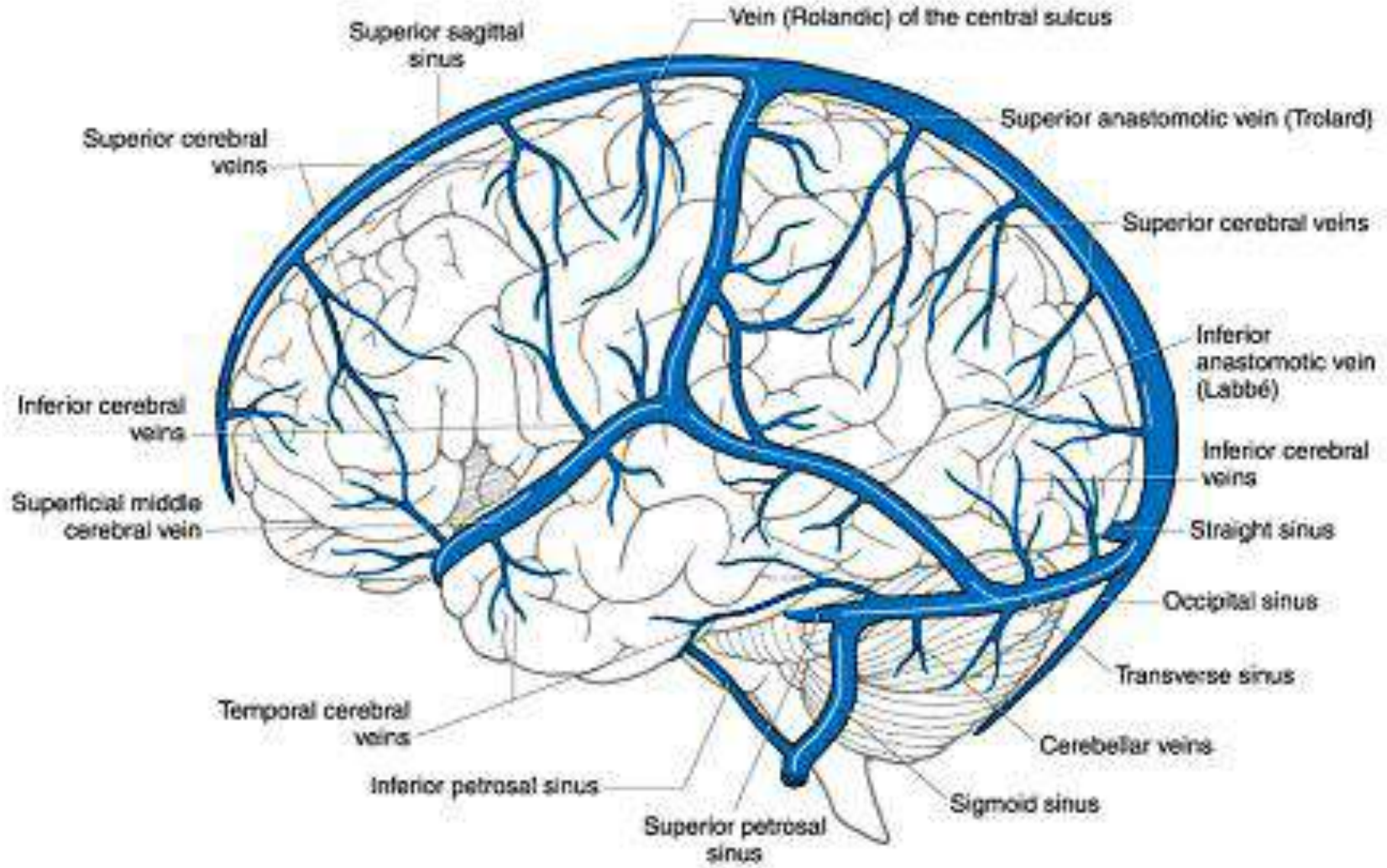
Empty delta sign

Filling defect in SSS



https://radiopaedia.org/

Cerebral Venous Sinus



Arachnoid Granulation

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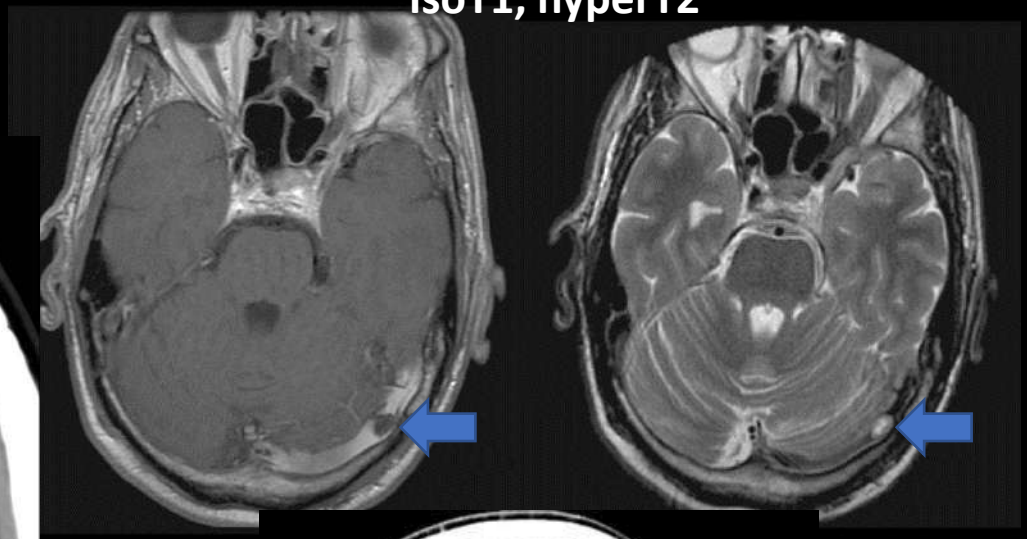
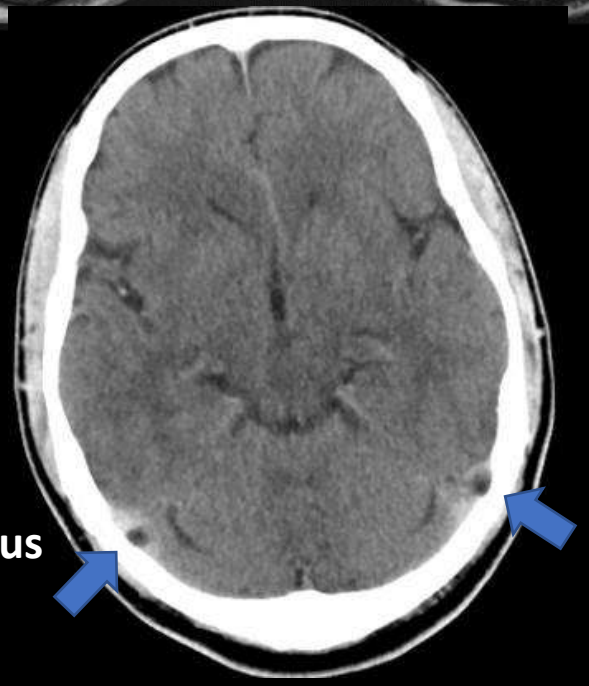
Superior sagittal sinus

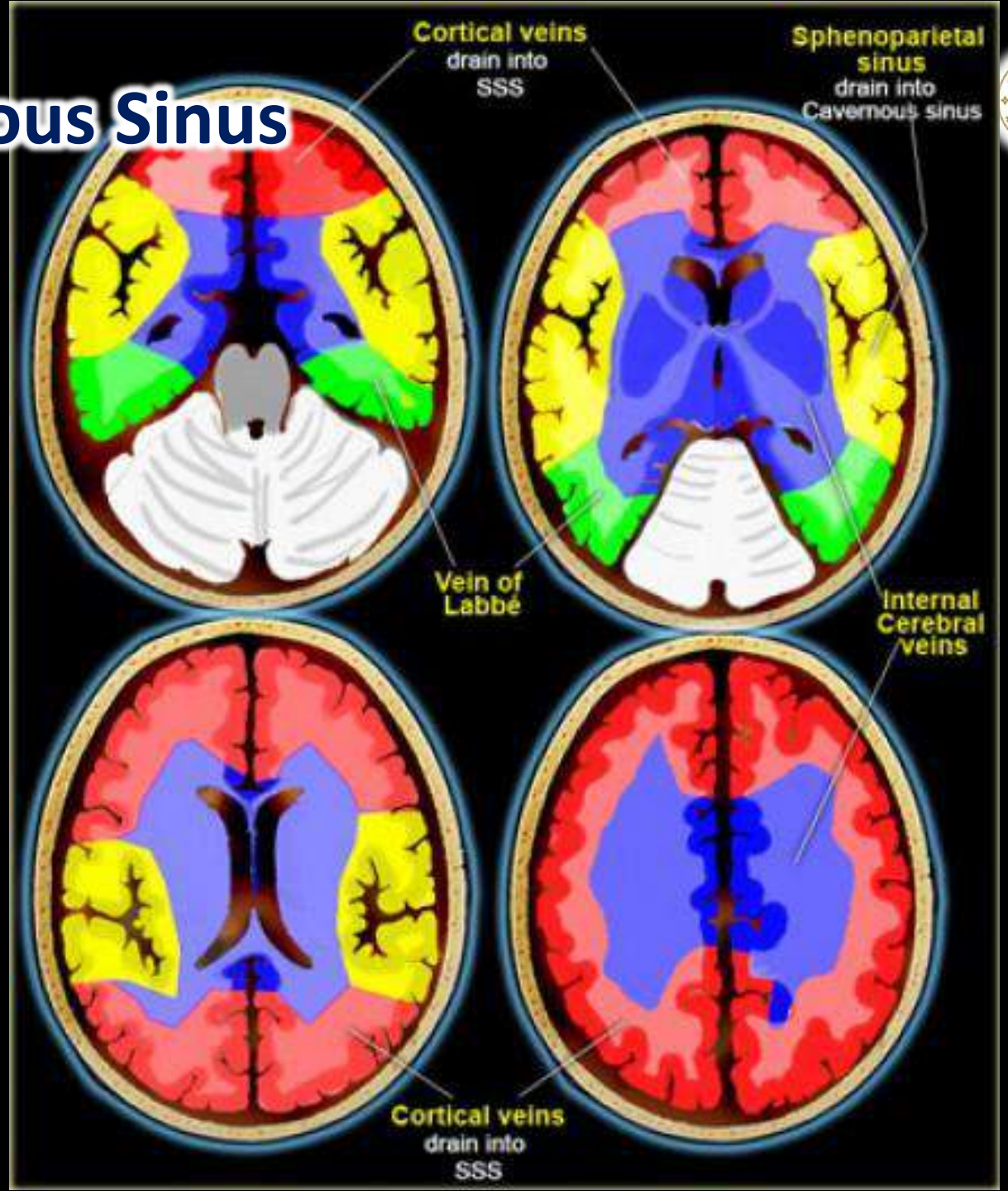
IsoT1, hyperT2





Transverse sinus

Cerebral Venous Sinus



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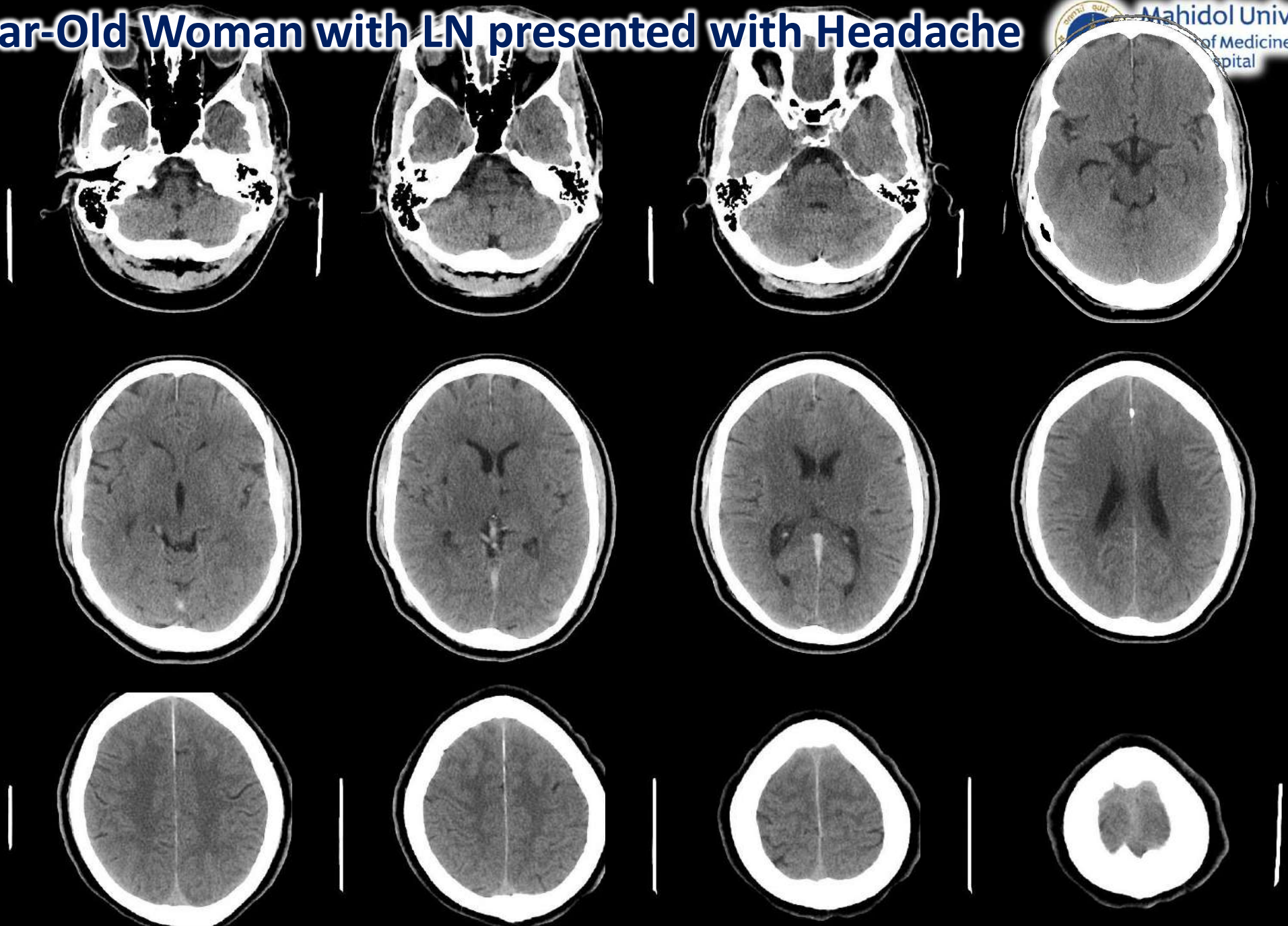
24-Year-Old Woman with LN presented with Headache



Deep Cerebral Venous System

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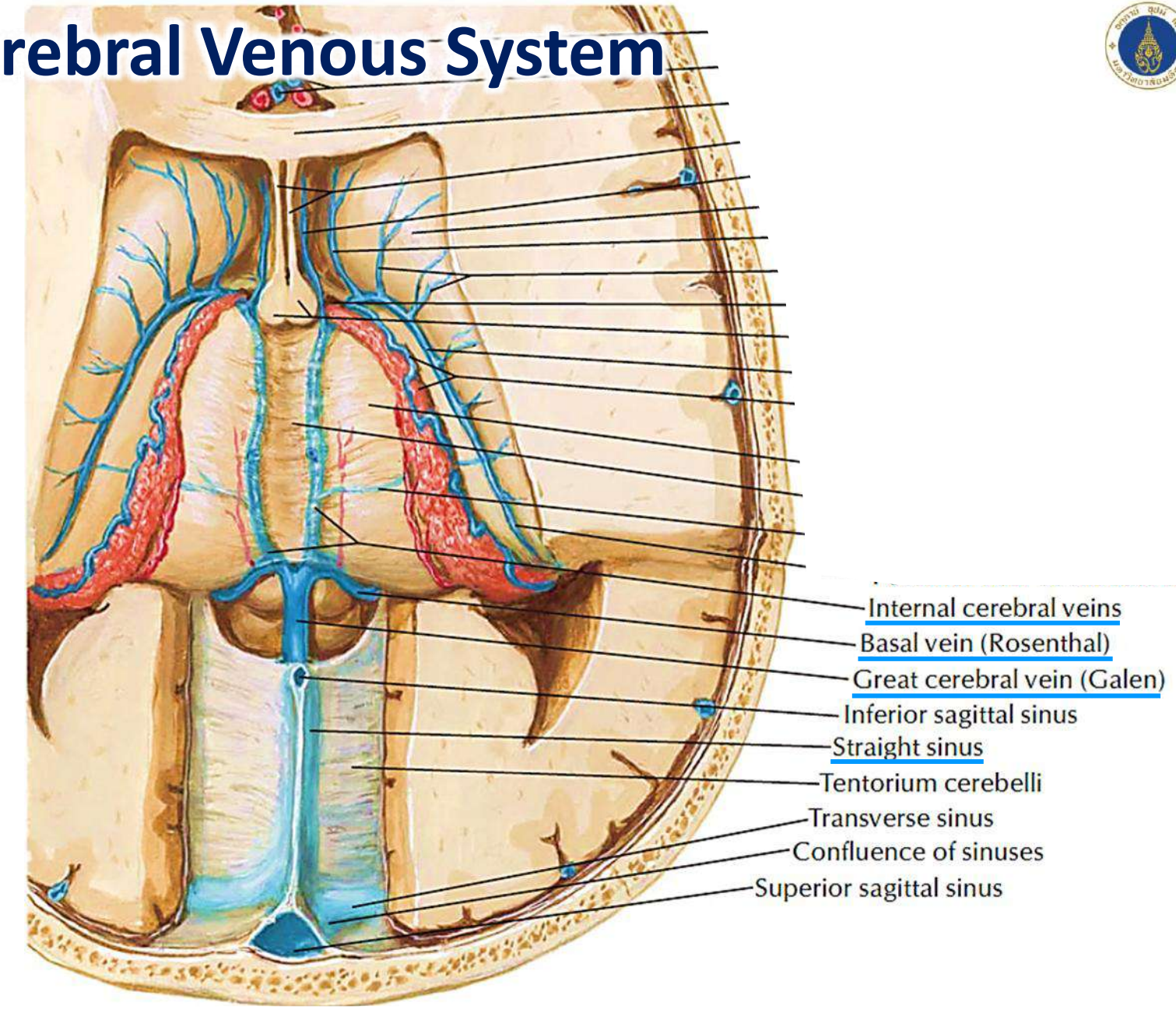

Intracranial Hemorrhages

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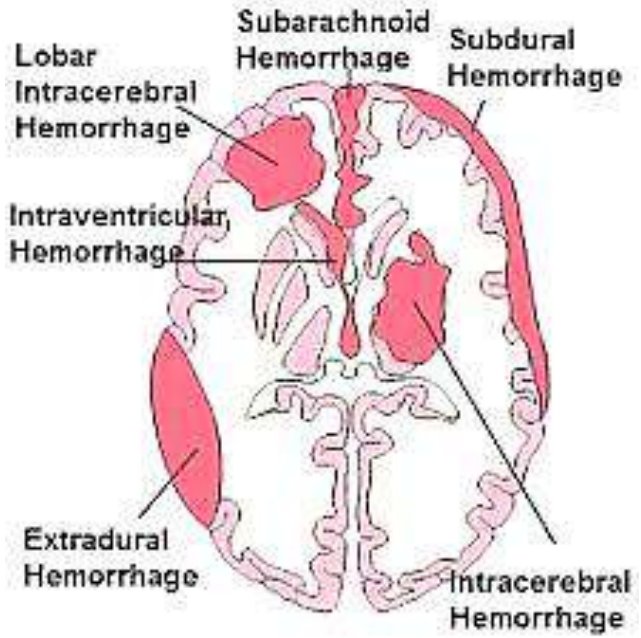
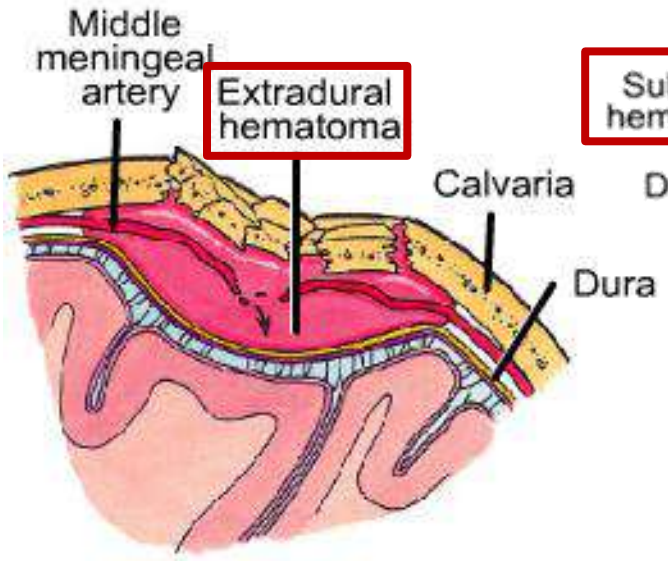
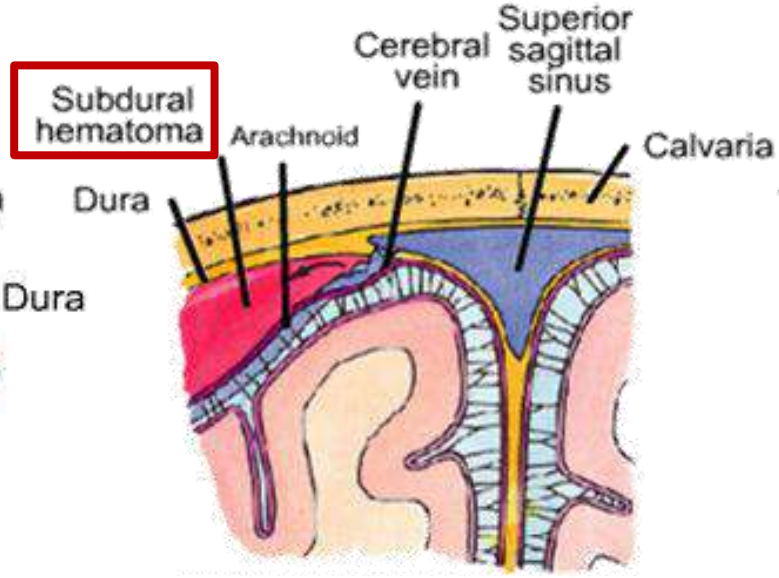
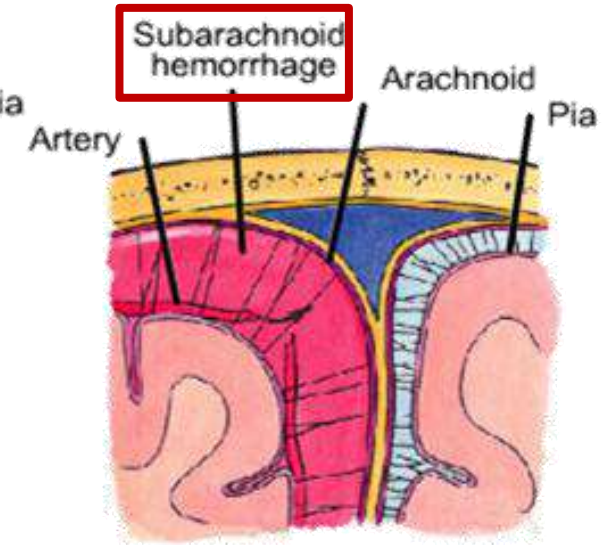
1. **Epidural :** Middle meningeal artery (pterion)
   Lucid interval
2. **Subdural :** Bridging vein from sup^{r} cerebral v.
3. **Subarachnoid :** Aneurysm rupture, thunderclap headache
4. **Intraparenchymal**
5. **Intraventricular**









Intracranial Hemorrhages

Epidural hematoma

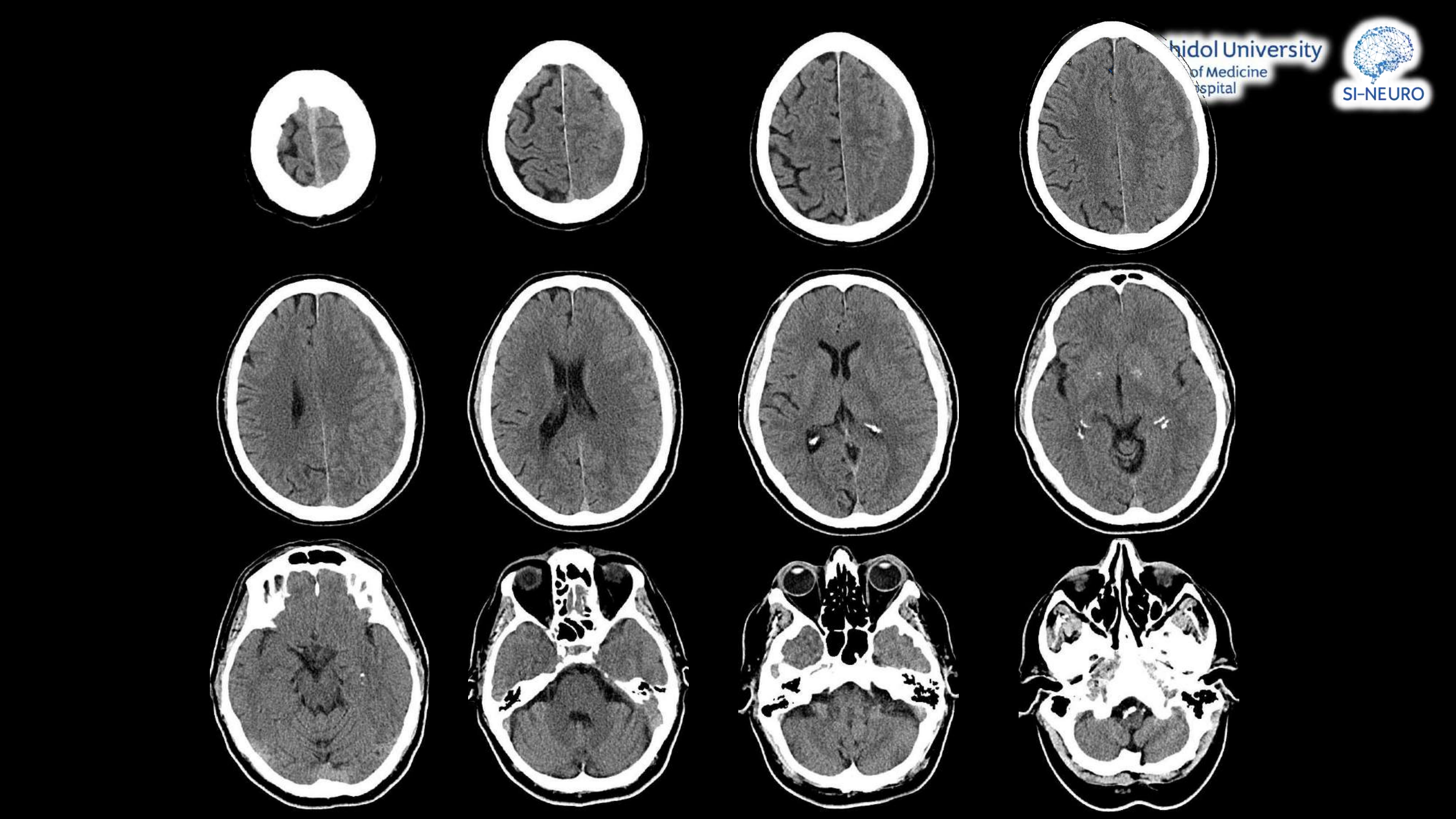
Lens-shaped

Subdural hematoma

Crescent-shaped

Subarachnoid hemorrhage

Star-shaped at basal cistern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Intracerebral Hemorrhages

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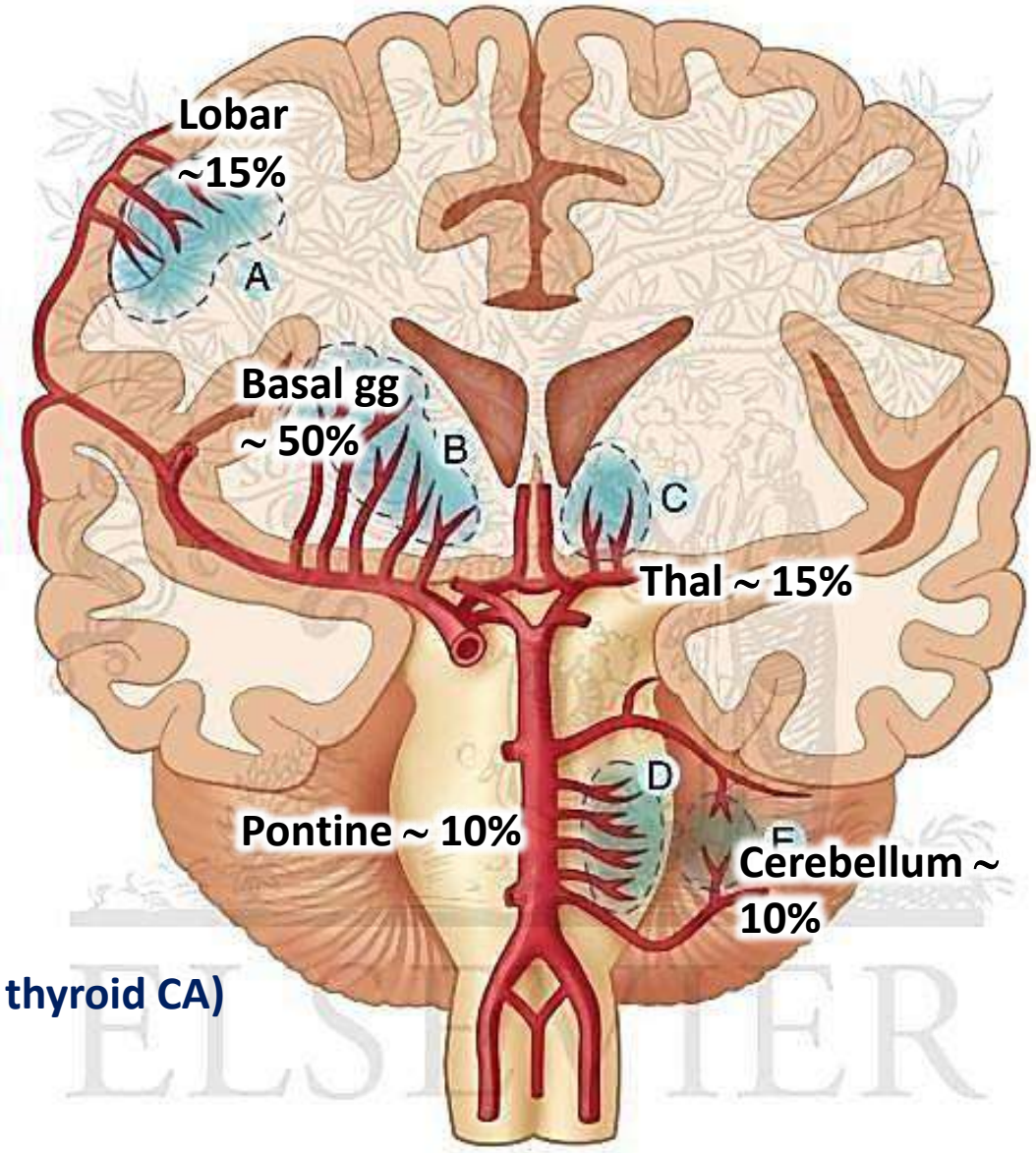
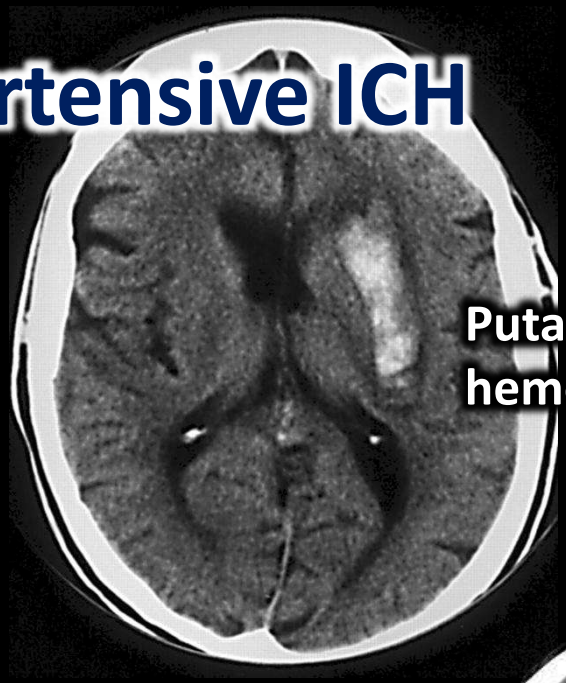
Etiologies

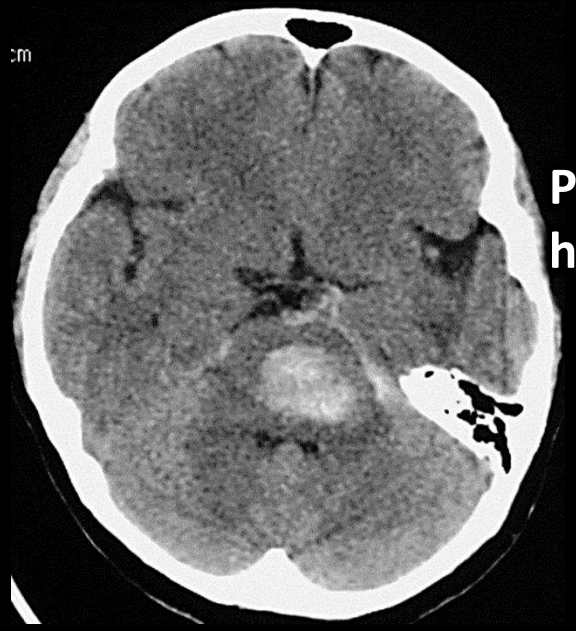
- Hypertension
- Cerebral amyloid angiopathy (lobar)
- AVM, AVF, aneurysm
- Vasculopathy
  - Vasculitis
  - Moyamoya, FMD, PRES, RCVS, drugs
- Hemorrhagic transformation
- Cerebral venous sinus thrombosis
- Septic embolism
- Brain tumors/hemorrhagic metastases
- Bleeding disorders (Melanoma, RCC, chorioCA, thyroid CA)
- Trauma, CNS infection (HSV), AHEM, etc.



Hypertensive ICH

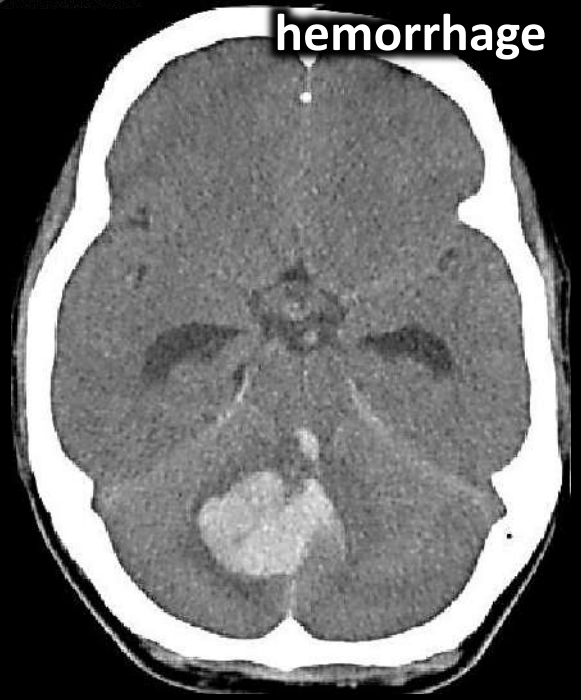


Putaminal hemorrhage



Pontine hemorrhage

Thalamic hemorrhage



Cerebellar hemorrhage

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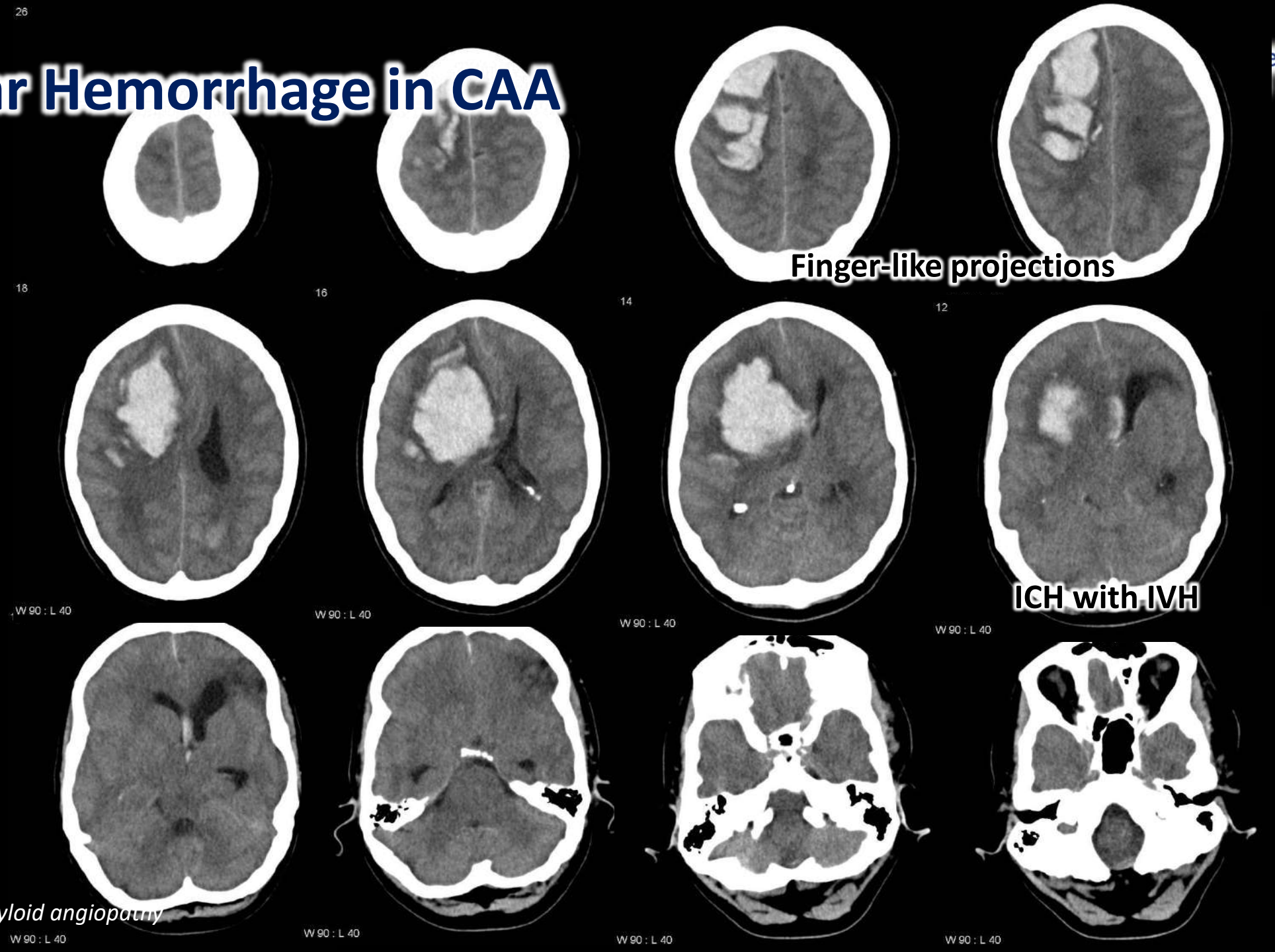
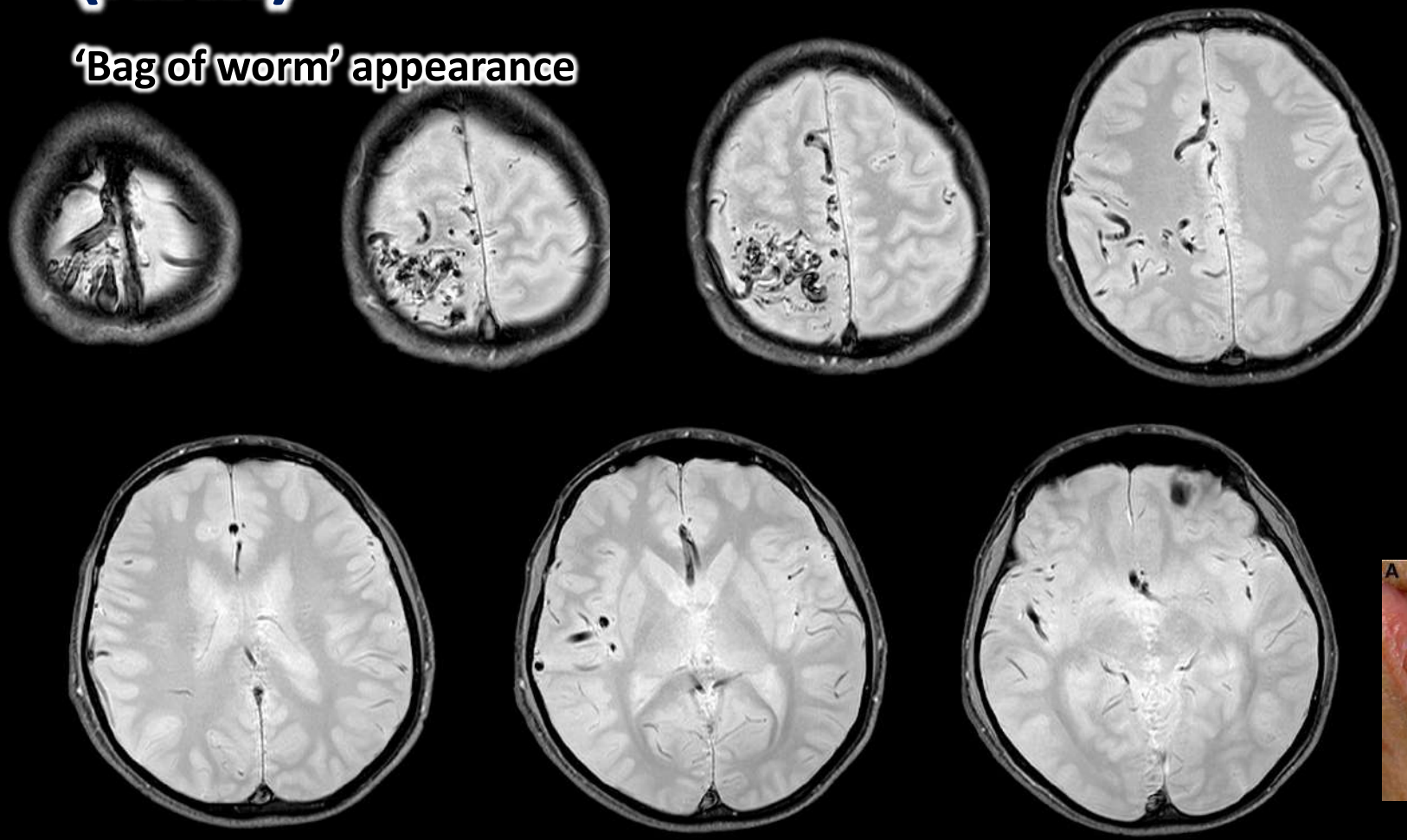
Lobar Hemorrhage in CAA

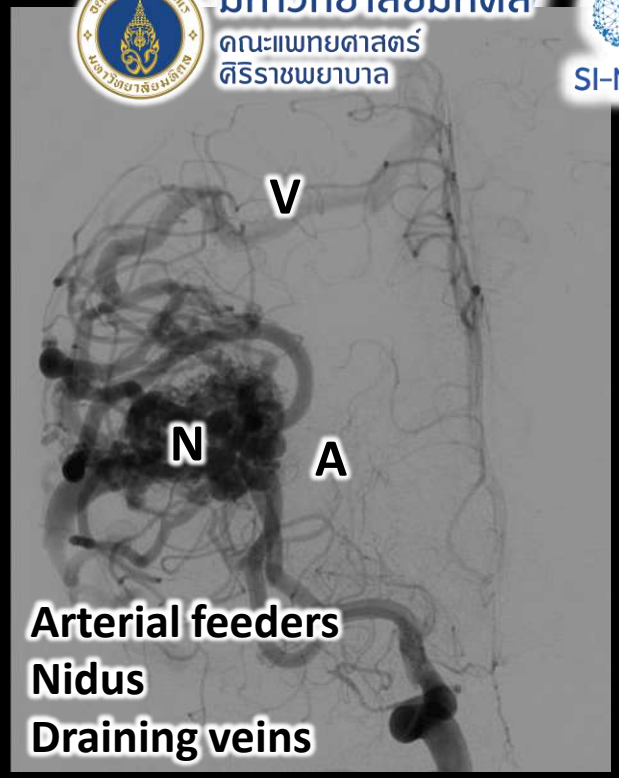


CAA cerebral amyloid angiopathy

Cerebral Arteriovenous Malformation (AVM)

‘Bag of worm’ appearance





If multiple, think of (1) hereditary hemorrhagic telangiectasia (Osler-Weber-Rendu)
(2) Wyburn-Mason syndrome

https://radiopaedia.org/

Veldhuis EC, et al. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105(2): e38-41

Dural Arteriovenous Fistula (DAVF)

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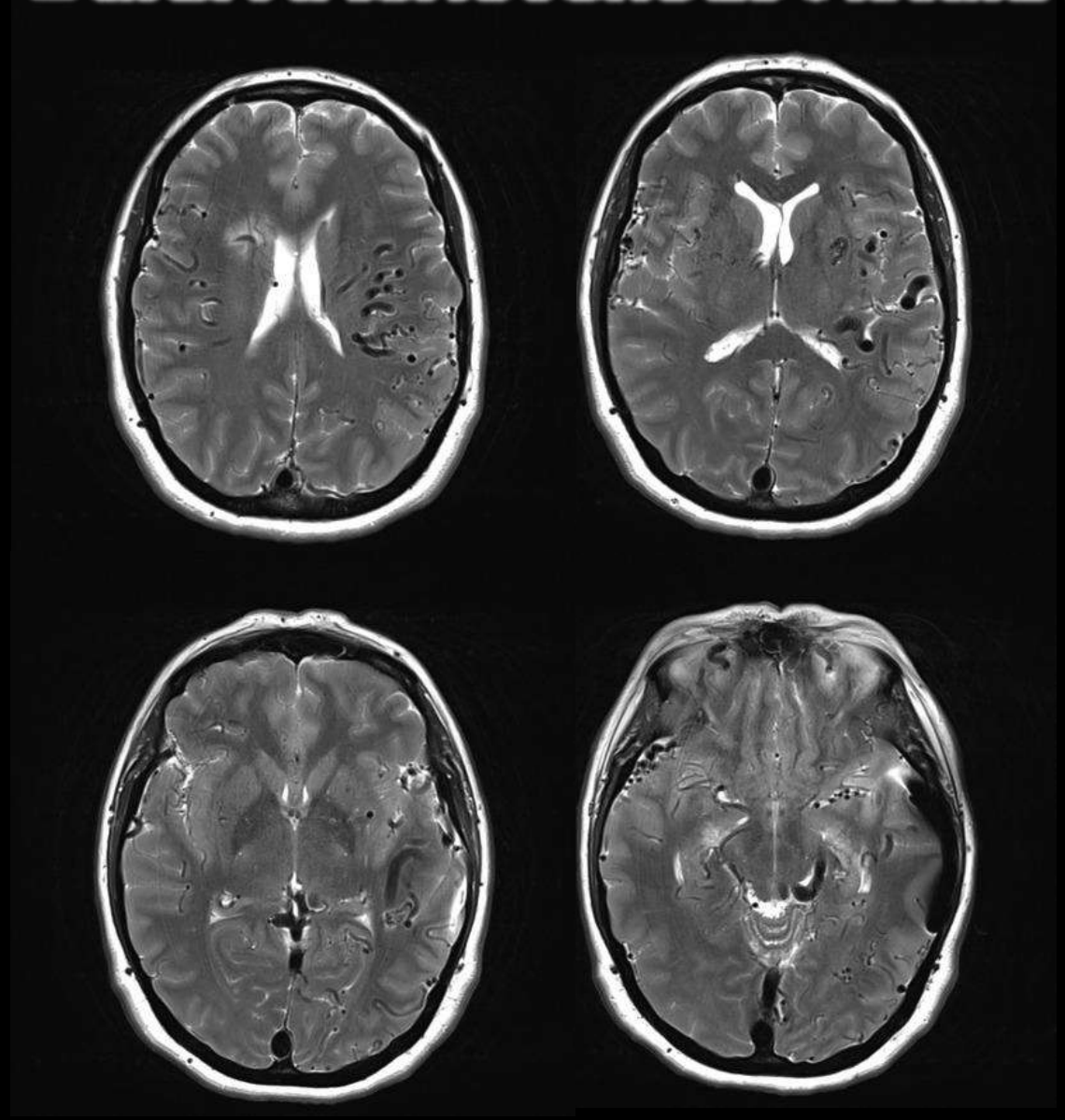

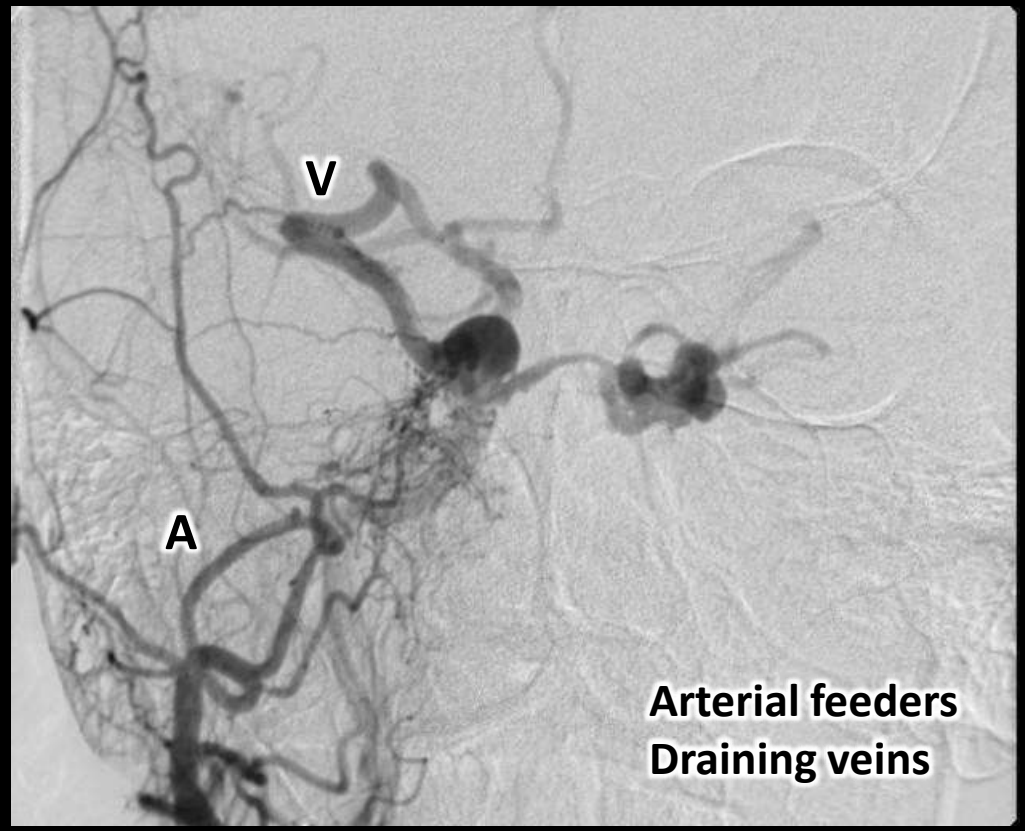

- Most common: Transverse/sigmoid sinus, cavernous sinus

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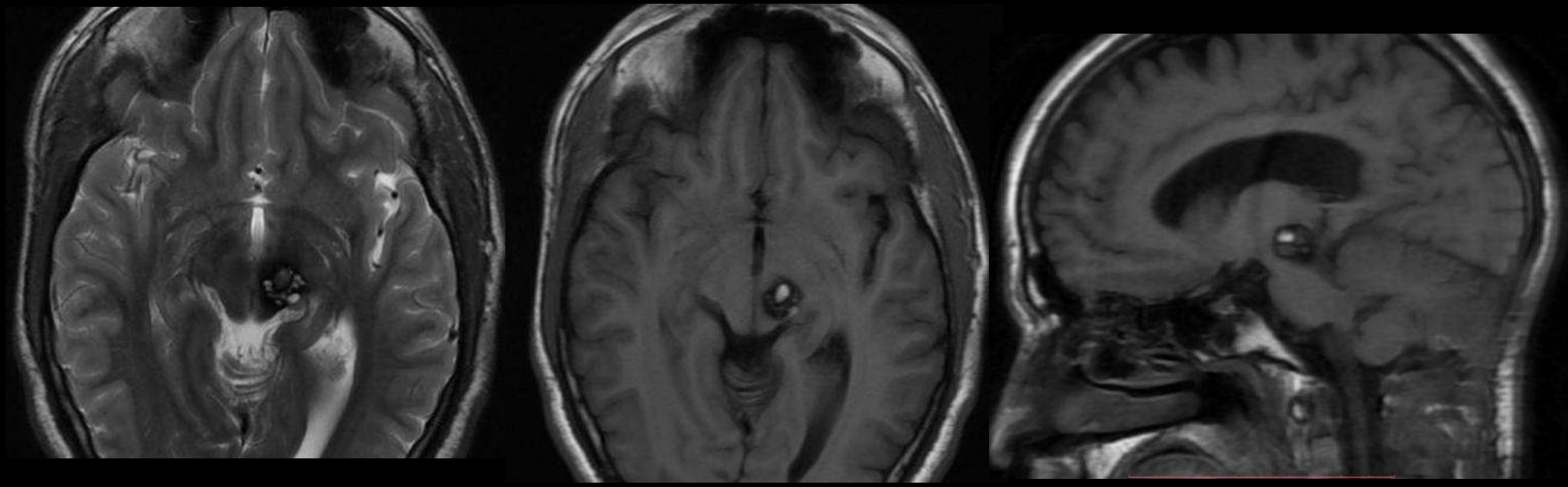
Brainstem Cavernoma

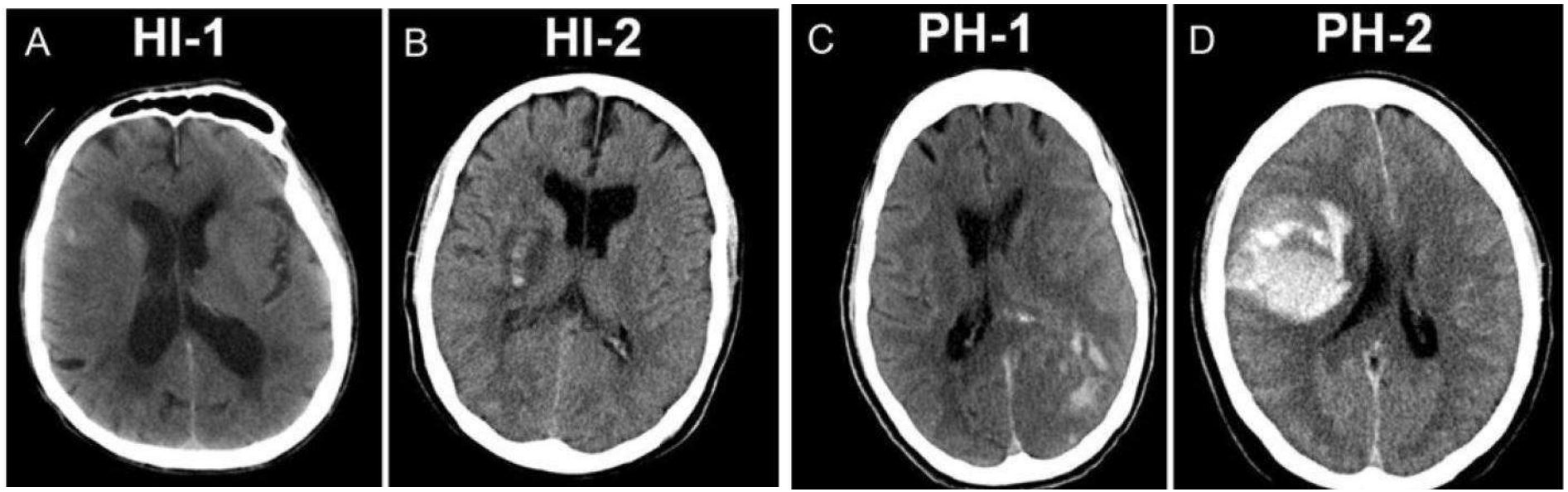


- Cavernous venous malformation
- “popcorn” or “berry” appearance with rim of signal loss (hemosiderin)

Hemorrhagic Transformation

- Occurs in 30-40%, develops in 24-36 h

ECASS classification		
Hemorrhagic infarction	HI-1	Small petechiae along the margins of the infarcted area
	HI-2	Confluent petechiae within the infarcted area, but without mass effect
Parenchymal hemorrhage (mass effect)	PH-1	Hematoma < 30%, mild mass effect
	PH-2	Hematoma > 30% of infarcted area with a notable mass effect

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Review in Internal Medicine 2026 - Essential in Neuroimaging
Neuroinfectious Diseases

Meningitis

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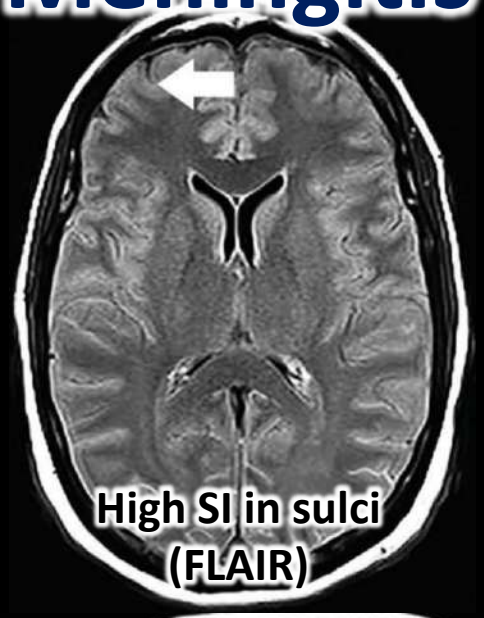
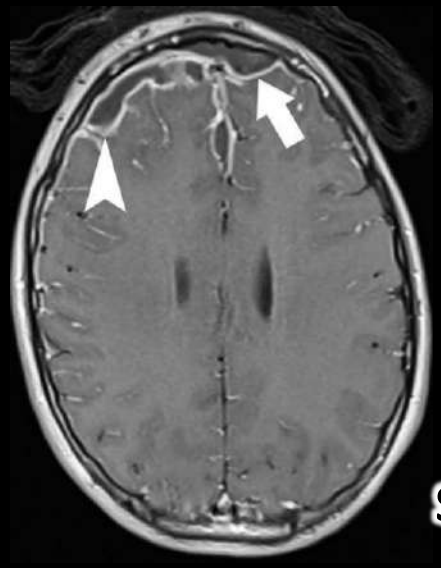
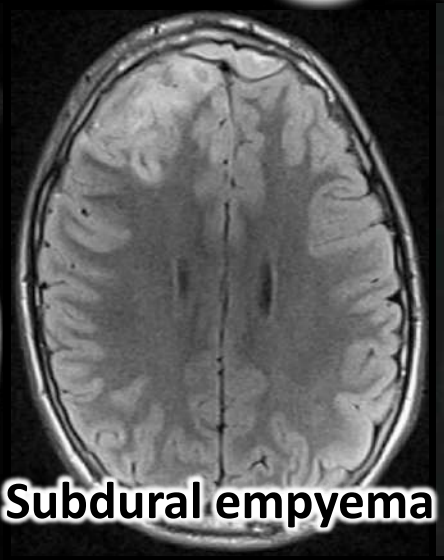


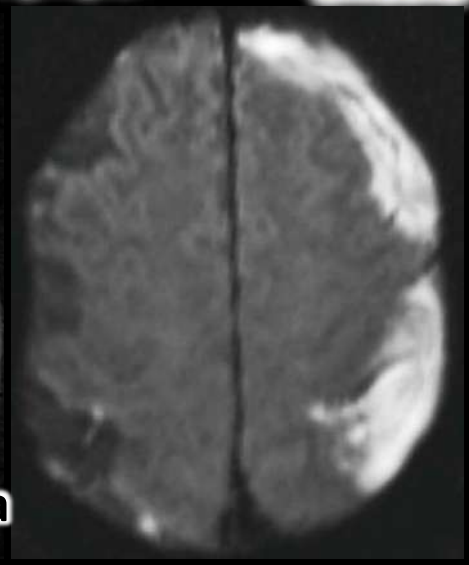
High SI in sulci (FLAIR)

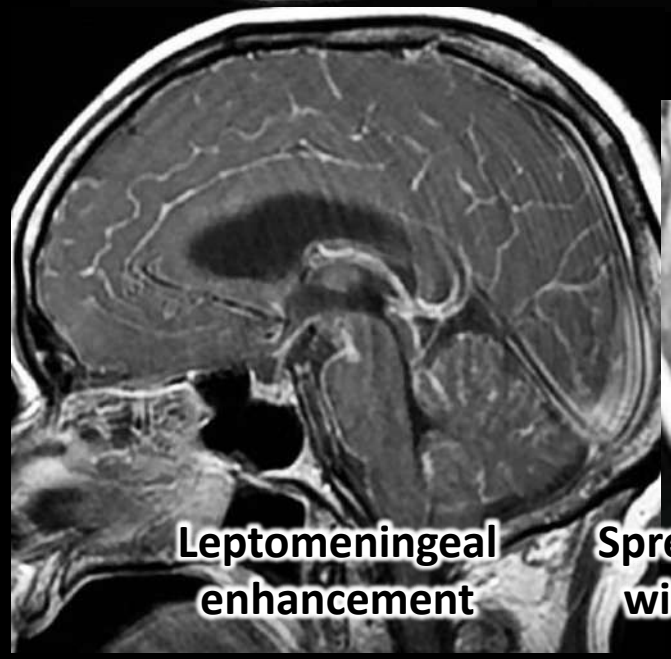
Leptomeningeal enhancement



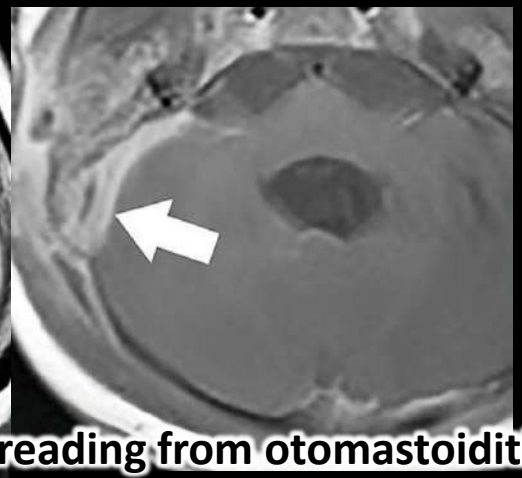


Subdural empyema



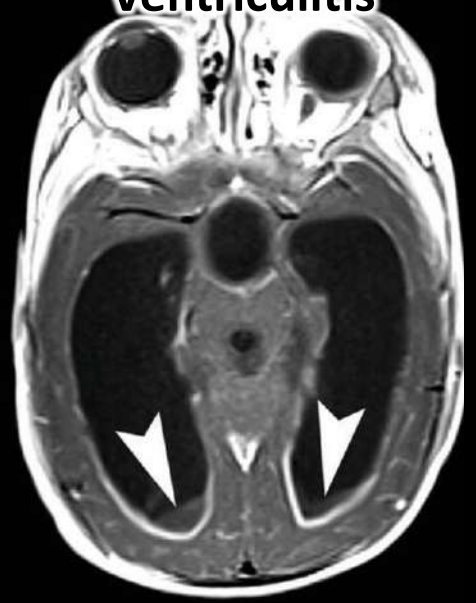


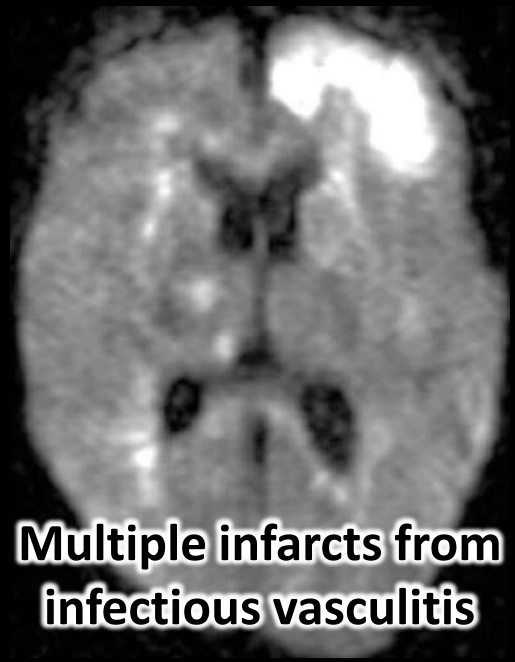
Leptomeningeal enhancement



Spreading from otomastoiditis with thrombophlebitis in TS

Ventriculitis





Multiple infarcts from infectious vasculitis

HSV Encephalitis

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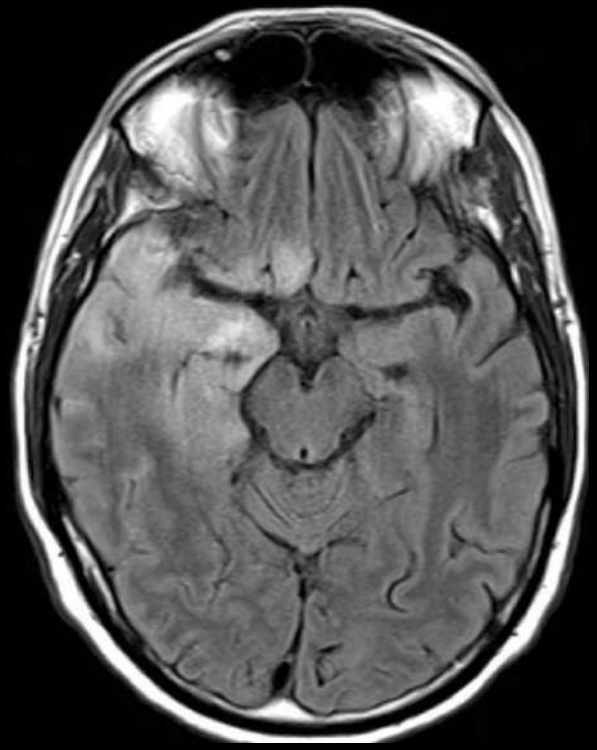
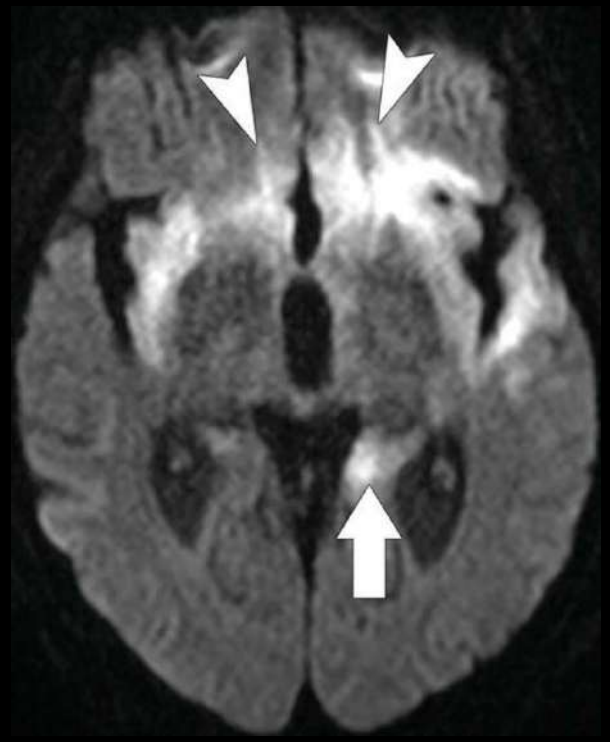
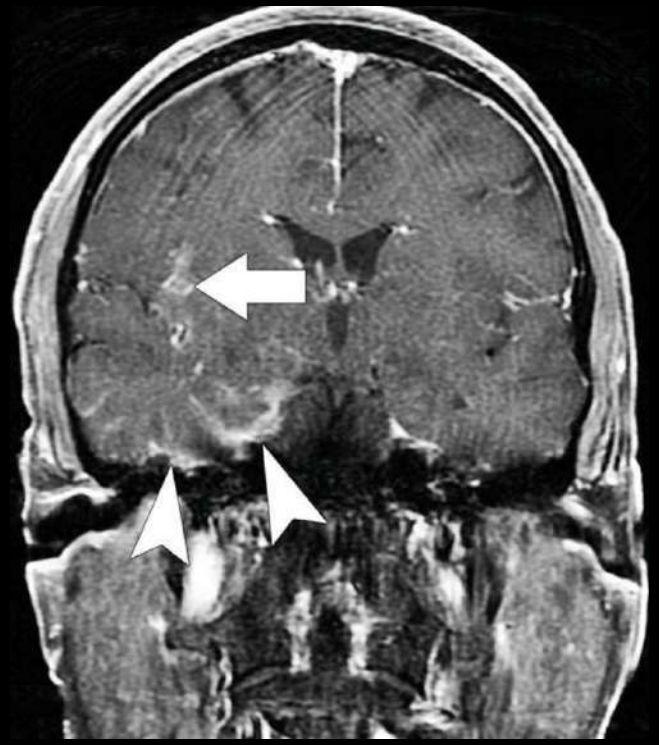
Hypodense at medial temporal lobe



HyperT2 at medial temporal & inf frontal areas



High DWI at bilateral limbic lobes



Enhancement at insular & temporal lobes

Viral Encephalitides

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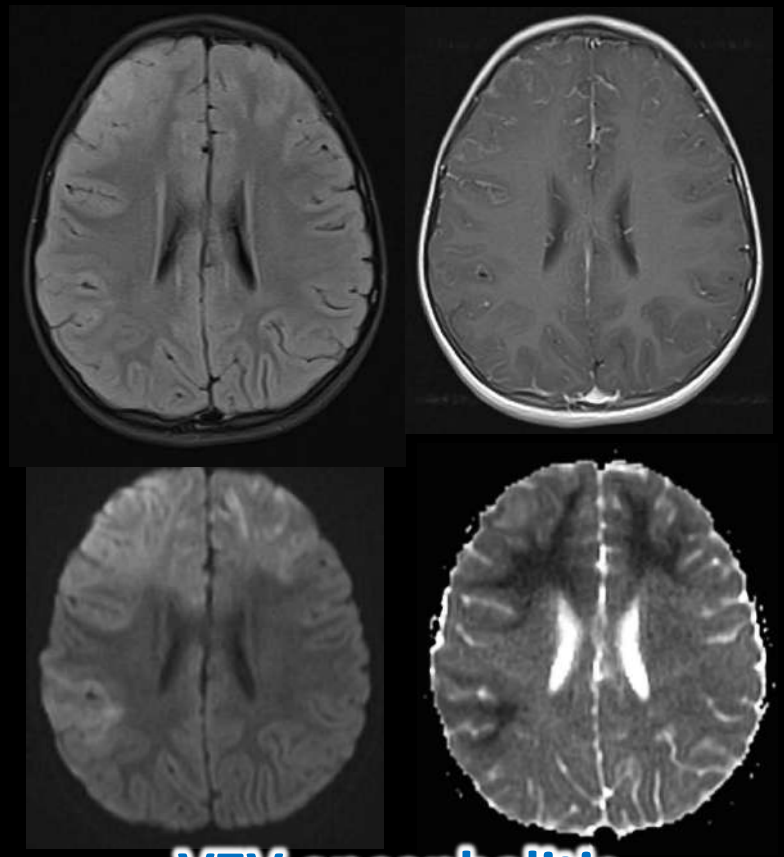
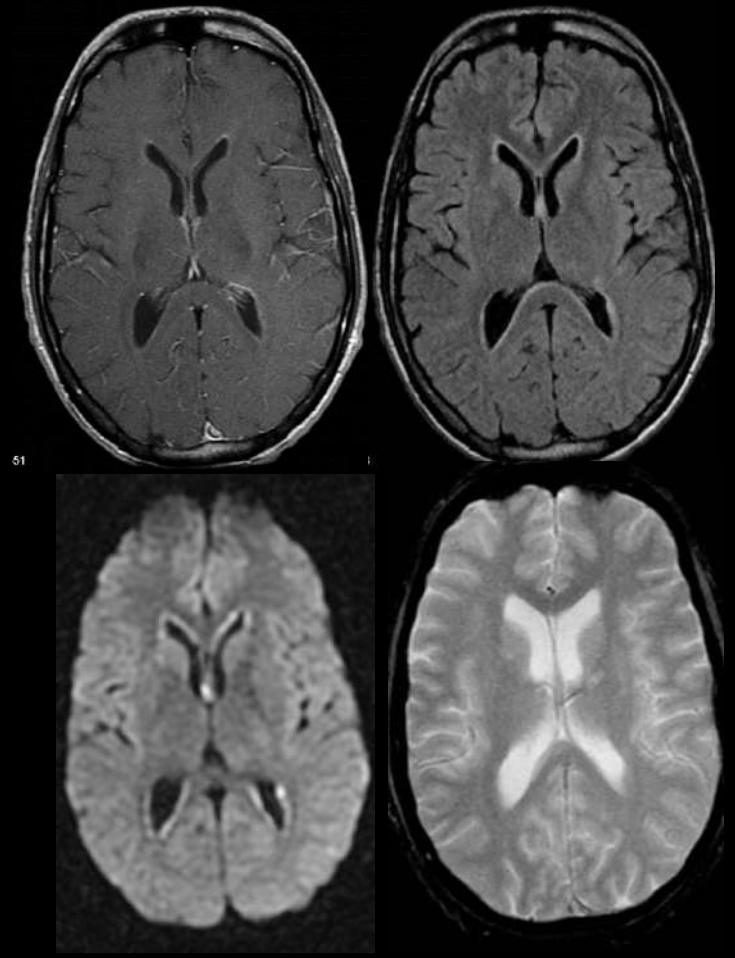
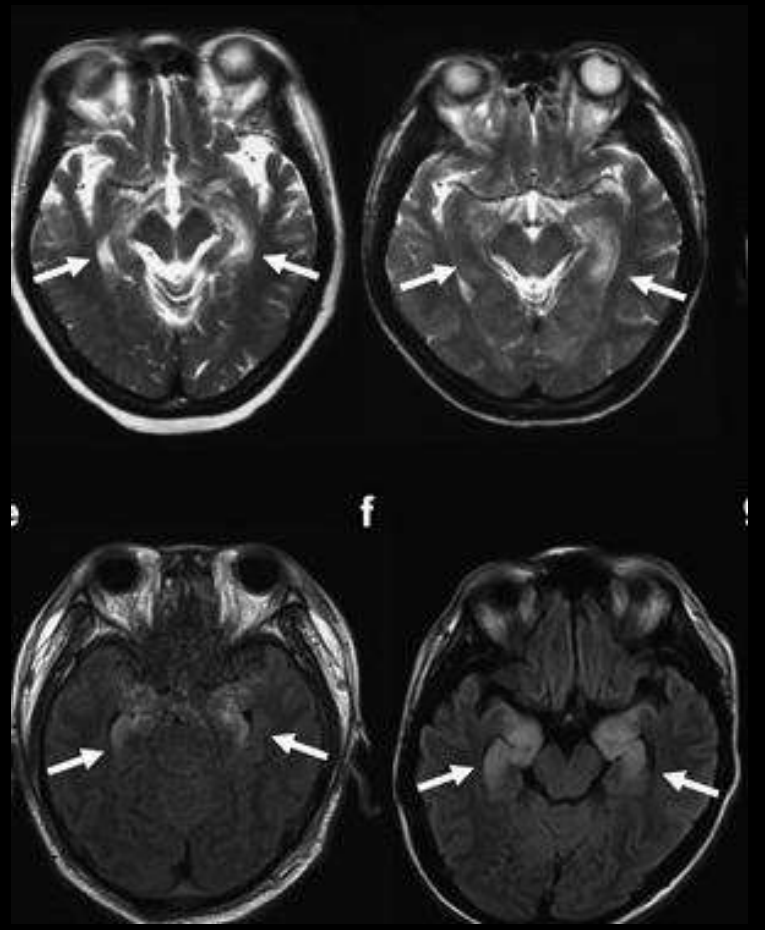


VZV encephalitis

Brain (gray-white junction)
Spinal cord
SAH, infarction

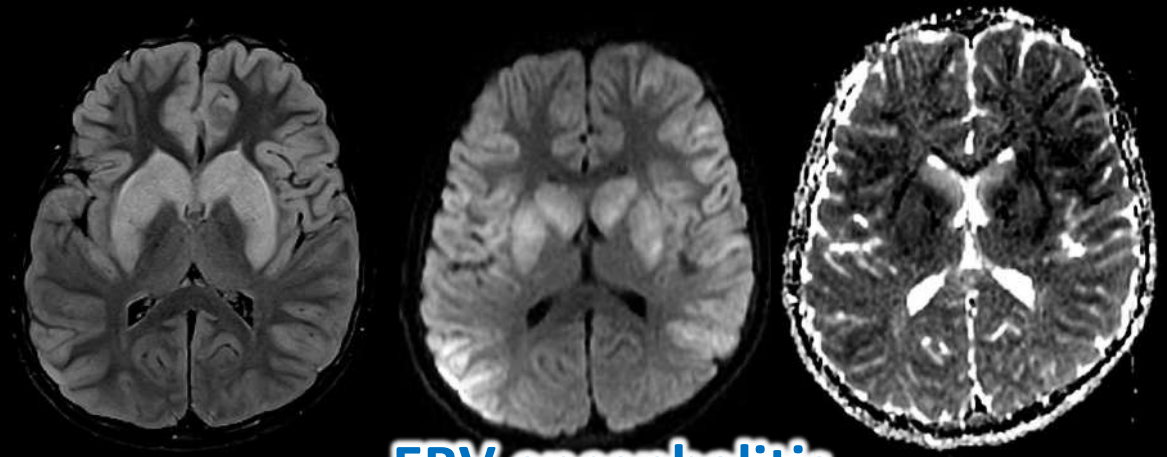


CMV encephalitis (ventriculitis)



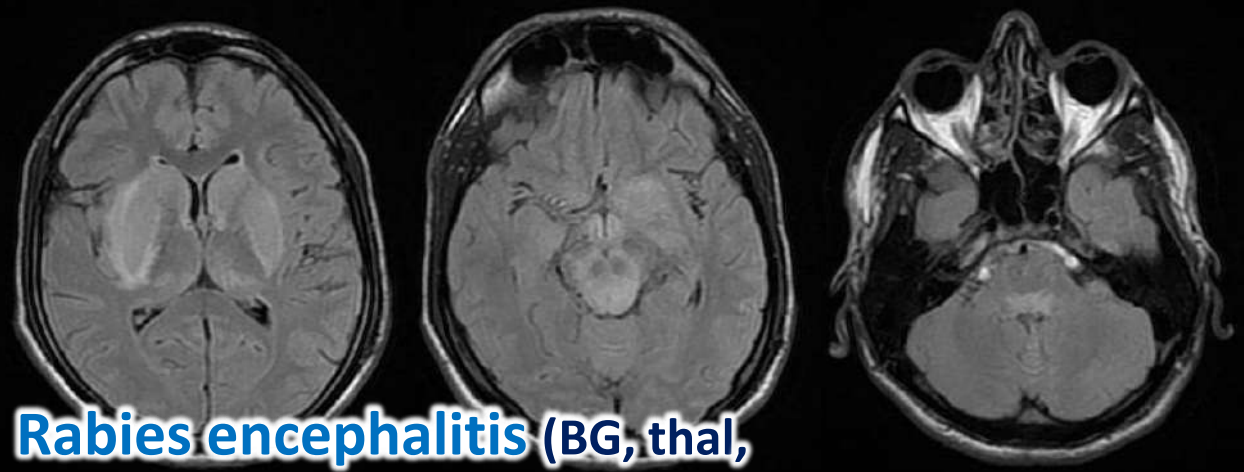
HHV-6 encephalitis (bilat limbic enceph)

Viral Encephalitides

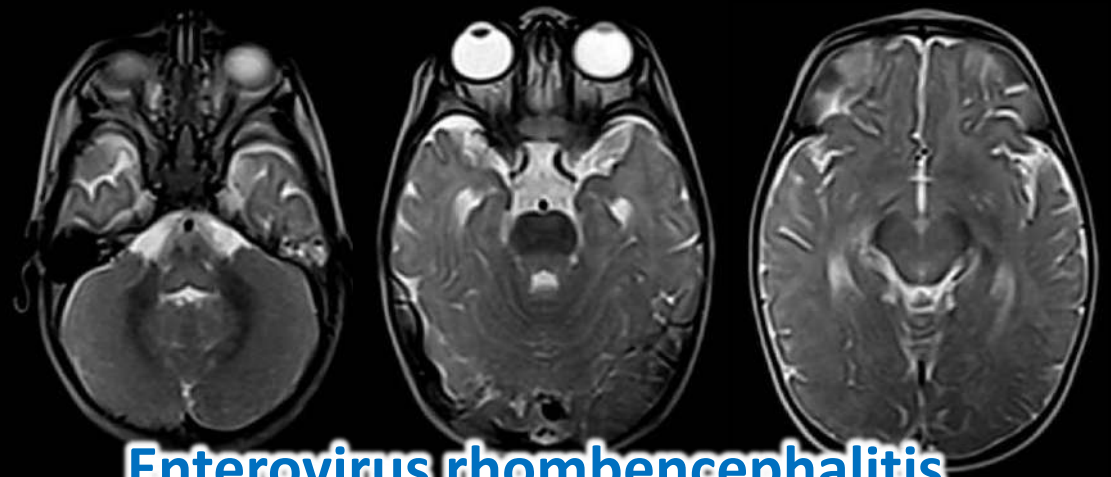


EBV encephalitis
(deep gray + WM involvement)

Japanese encephalitis virus
(bilat thalamic involvement)



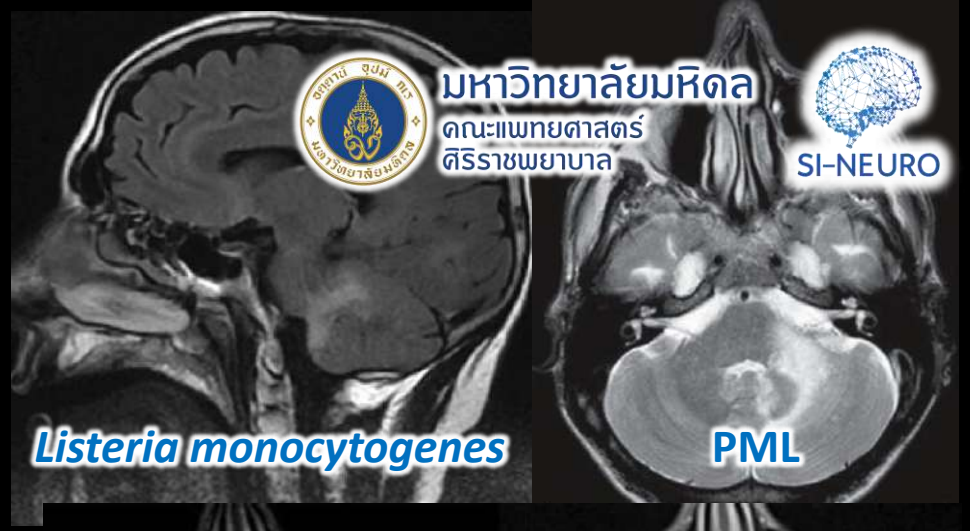
Rabies encephalitis (BG, thal, brainstem, limbic involvement + swelling)

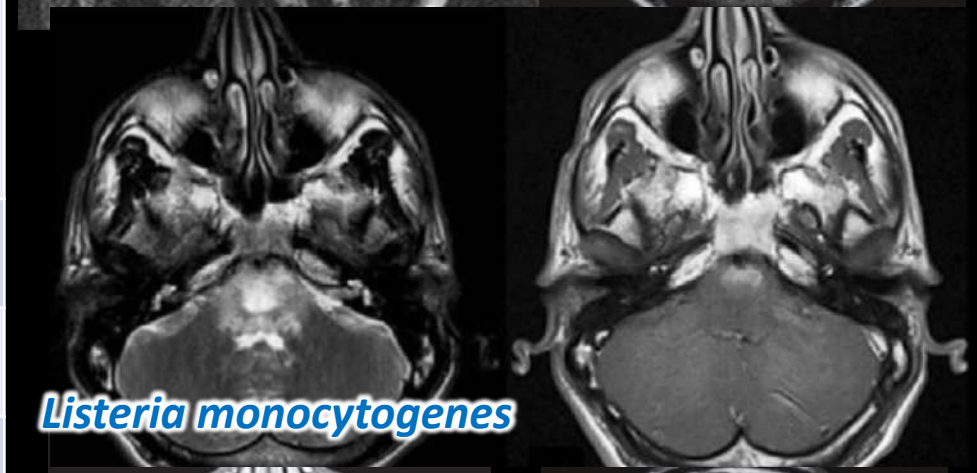


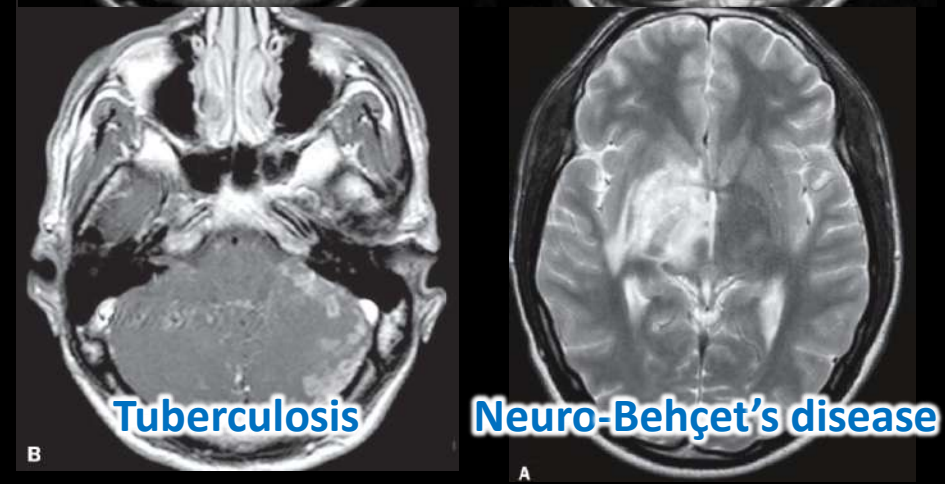
Enterovirus rhombencephalitis
(dorsal brainstem, dentate nuclei, spinal cord)

Rhombencephalitis

Causes	Common	Uncommon	Rare
Bacterial	Listeria	TB, Borrelia, mycoplasma	*H.influenzae*, pneumococcus, melioidosis, tularemia, brucellosis, *Coxiella burnetiid*, nocardia
Viral	HSV-1, HSV-2 Enterovirus-71 JE virus	EBV, CMV, EV-D68 Coxsackie A16	SARS-CoV-2, Coxsackie B3, VZV, adenovirus, mumps, hepatitis S, rabies, parechovirus, West Nile virus, Eastern equine virus, St.Louis, dengue, Chandipura vesiculovirus
Fungal	-	-	*Aspergillus flavus*, mucormycosis, Paracocciodomycosis
Parasites	-	-	Schistosomiasis, cysticercosis, toxoplasmosis
Inflammatory	Neuro-Behçet MOGAD Bickerstaff's	SLE, NMOSD, ADEM, immune checkpoint inhib.	Sjögren, relapsing polychondritis, sarcoidosis, Vogt-Koyanagi-Harada, Kikuchi-Fujimoto, anti-SRP Ab
Paraneoplastic	-	Anti-Hu, -Ma2, amphiphysin, -Ri, -CRMP5, -Tr, -NMDA receptor, -IgLON5 receptor -glycine receptor	Anti-GAD65, -GABA-b receptor, -DPPX receptor, VGCC Ab







Creutzfeldt-Jakob Disease (CJD)

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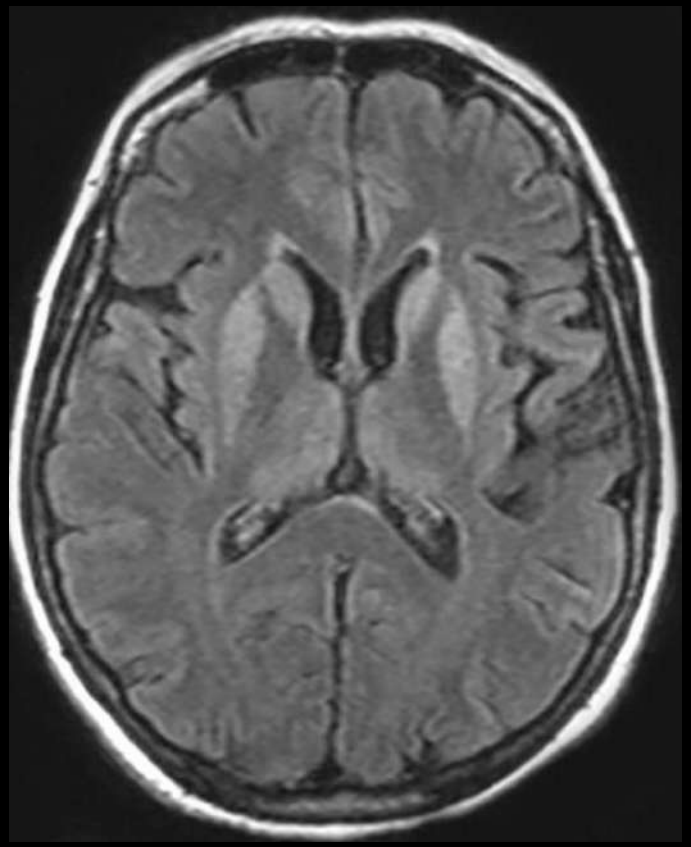
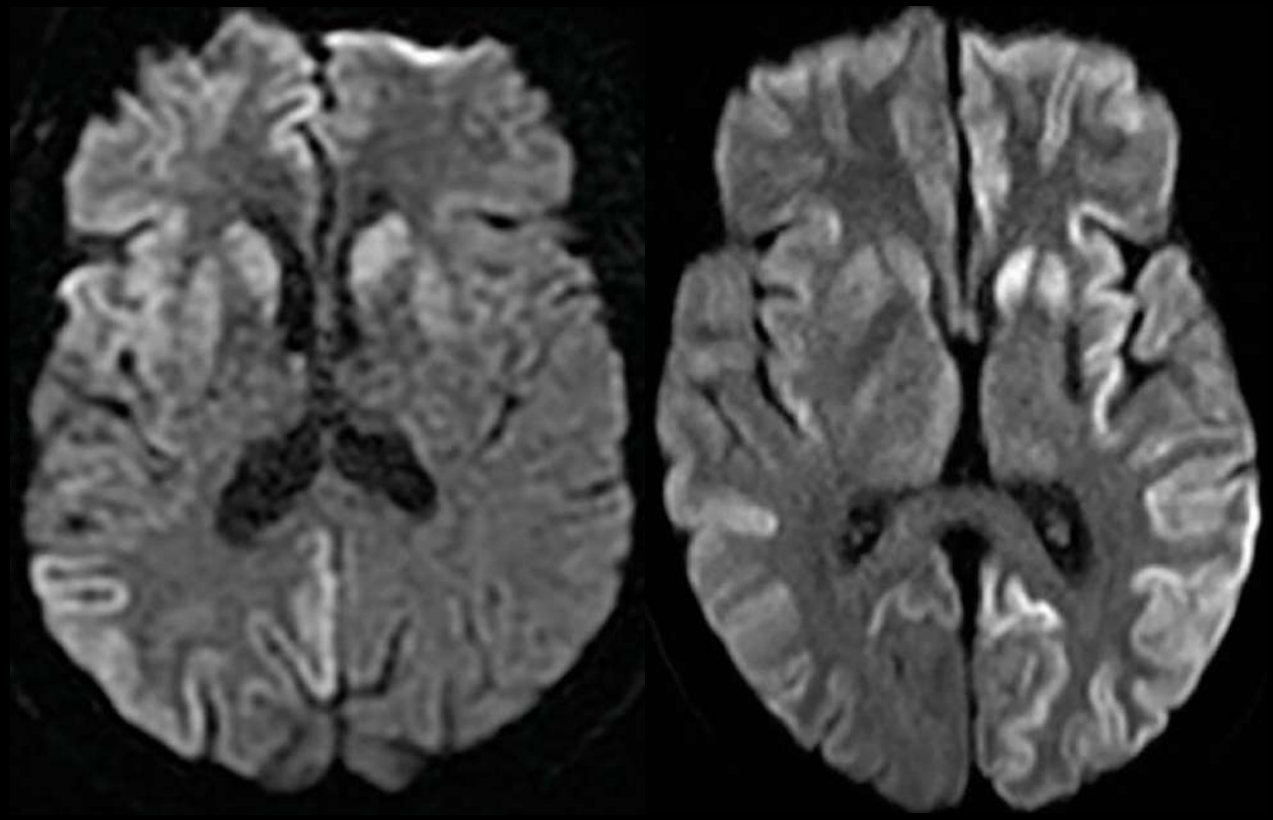
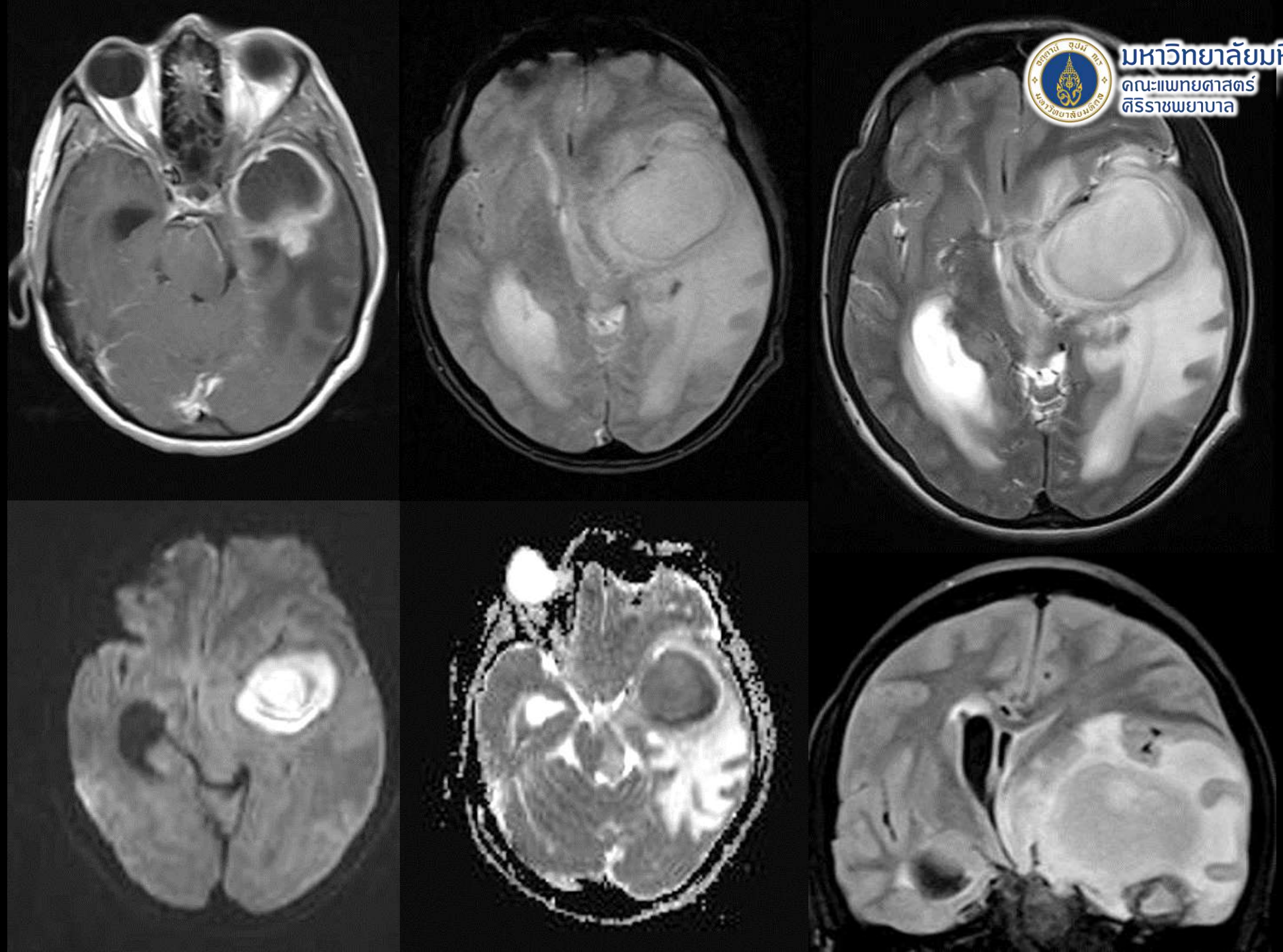


HyperT2 at bilateral basal ganglia & thalami (T2FLAIR)



High DWI at cortex (cortical ribbons) and deep gray structures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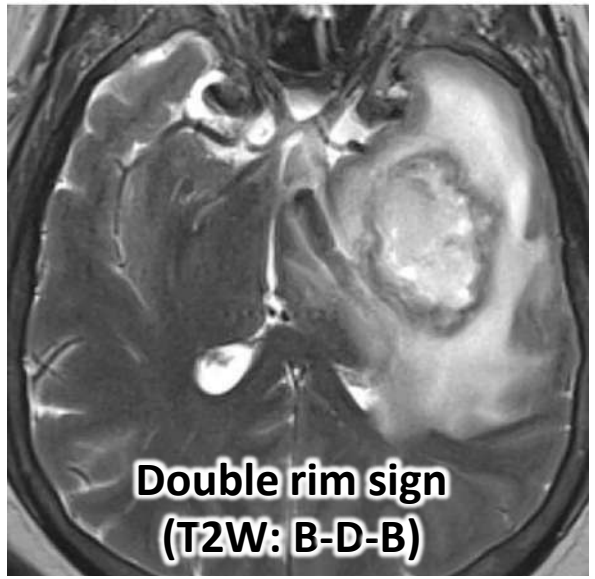
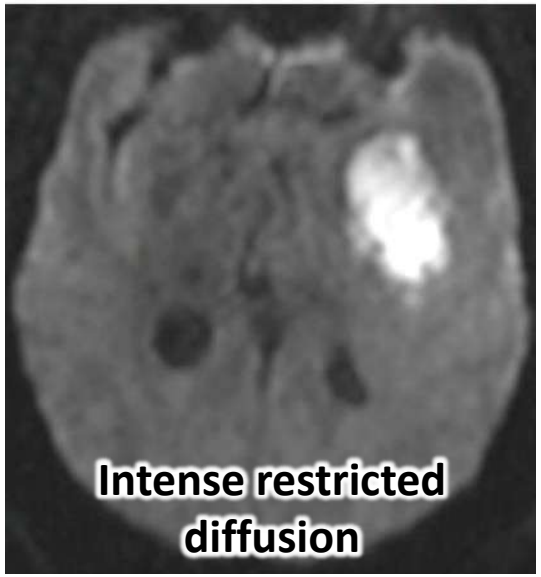
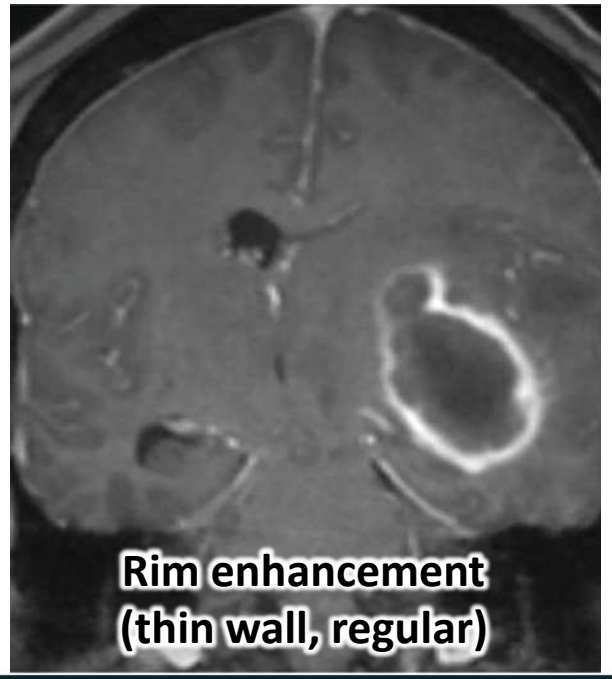
Brain Abscess

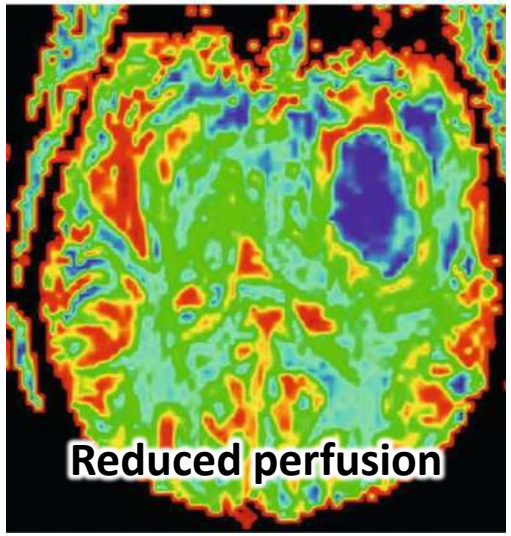






- Solitary/multiple, G-W junction (F-P)
- 4 stages

Early cerebritis	Days	Ill-defined hypoT1, hyperT2
Late cerebritis	Weeks	Same, ↑enhancement
Early capsular	1-2 wk	Same, surrounding hyperT2 (edema), rim enhance Daughter lesion, ventriculitis
Late capsular	>2 wk	Less edema, increasing capsule, DWI bright core



Tuberculoma

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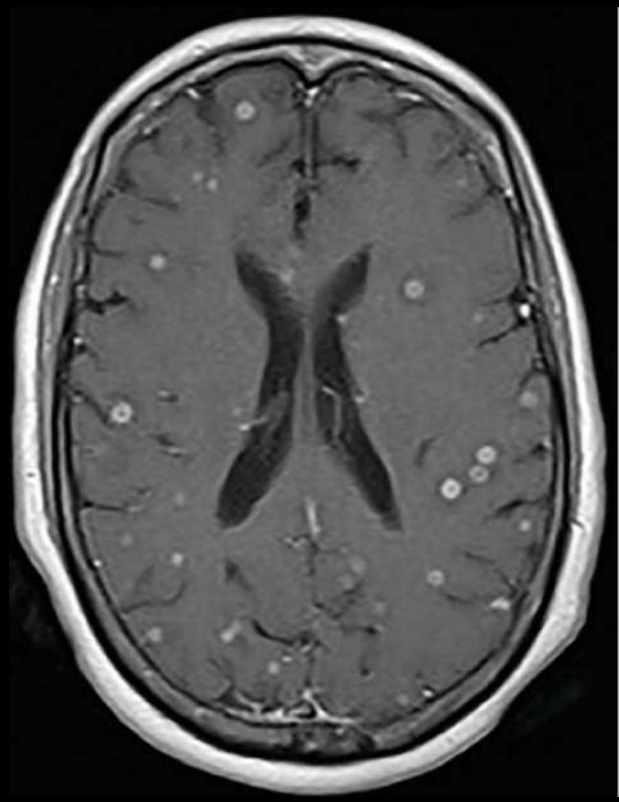
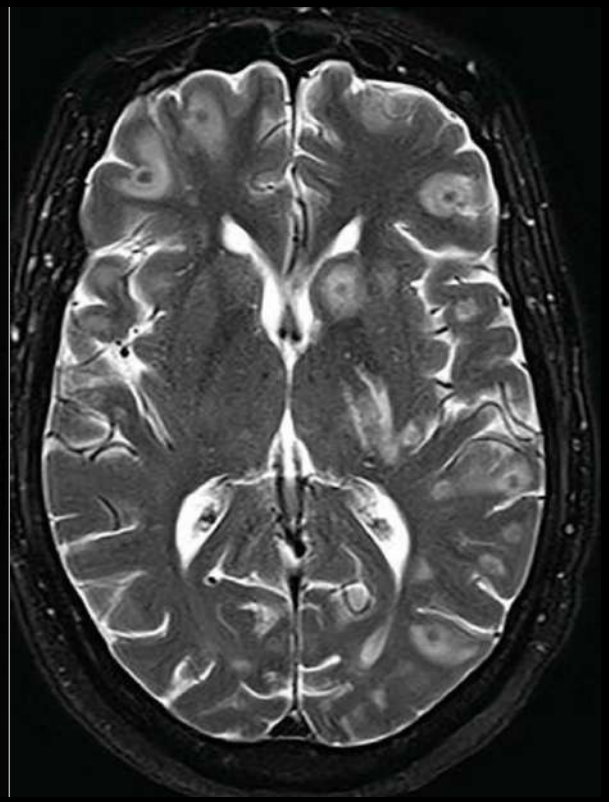
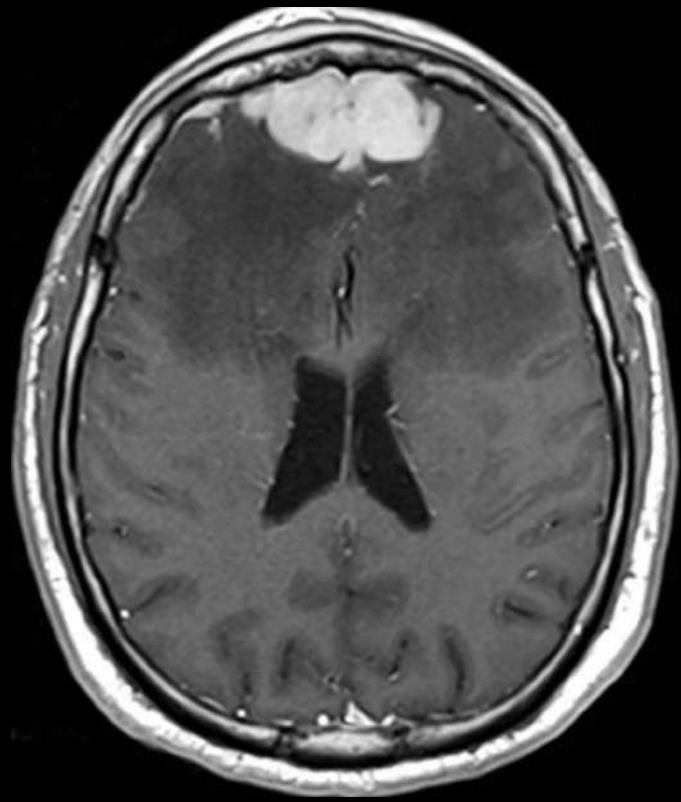
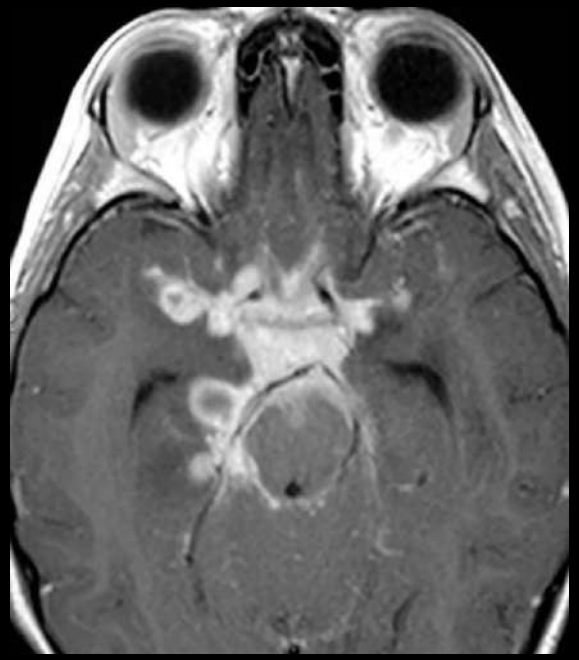




Miliary involvement
(Ring enhancement, central low T2)

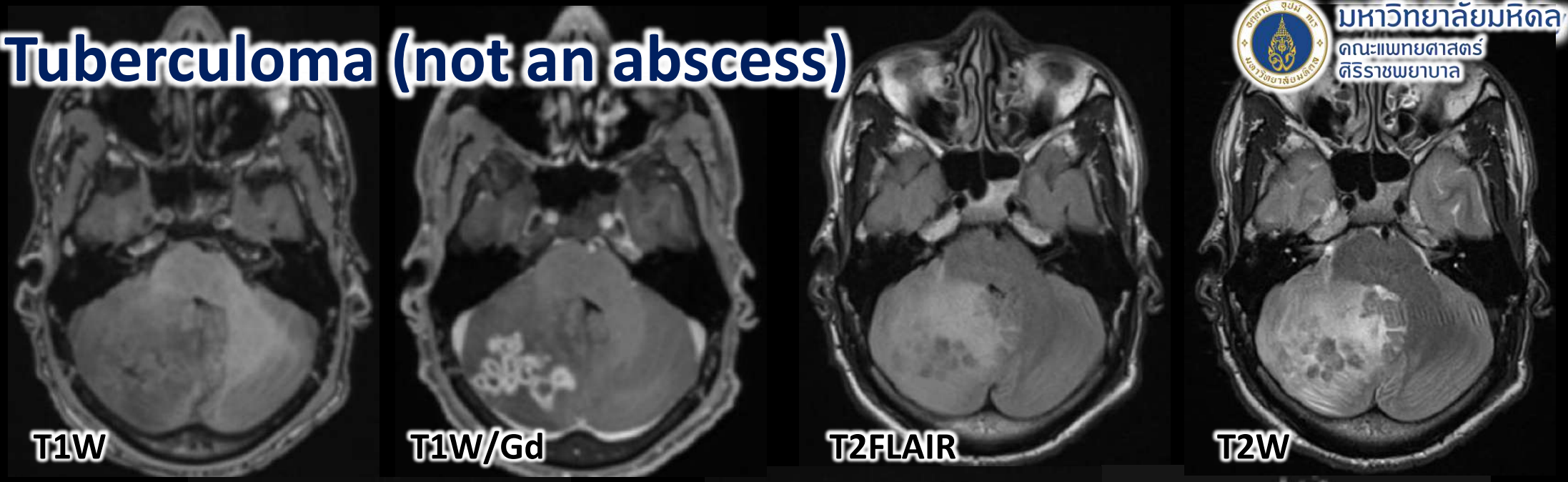


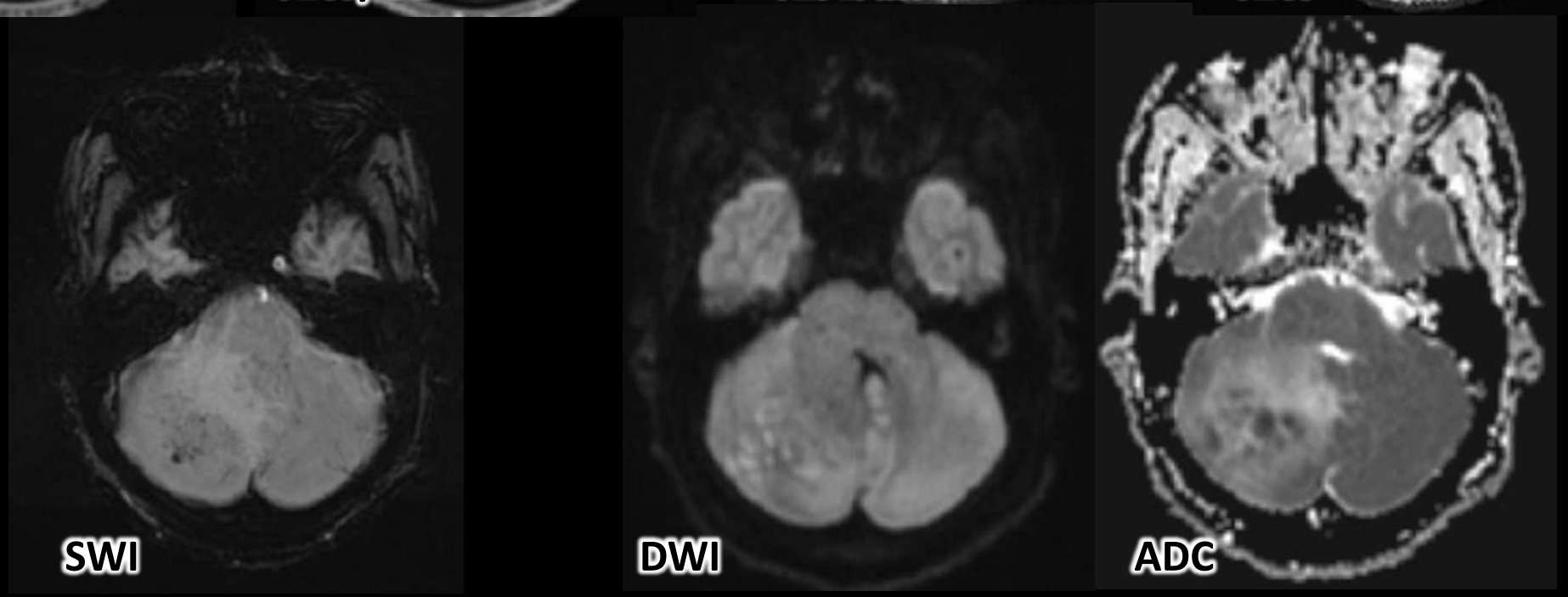
Frontal tuberculoma
(parenchymal/meningeal components)



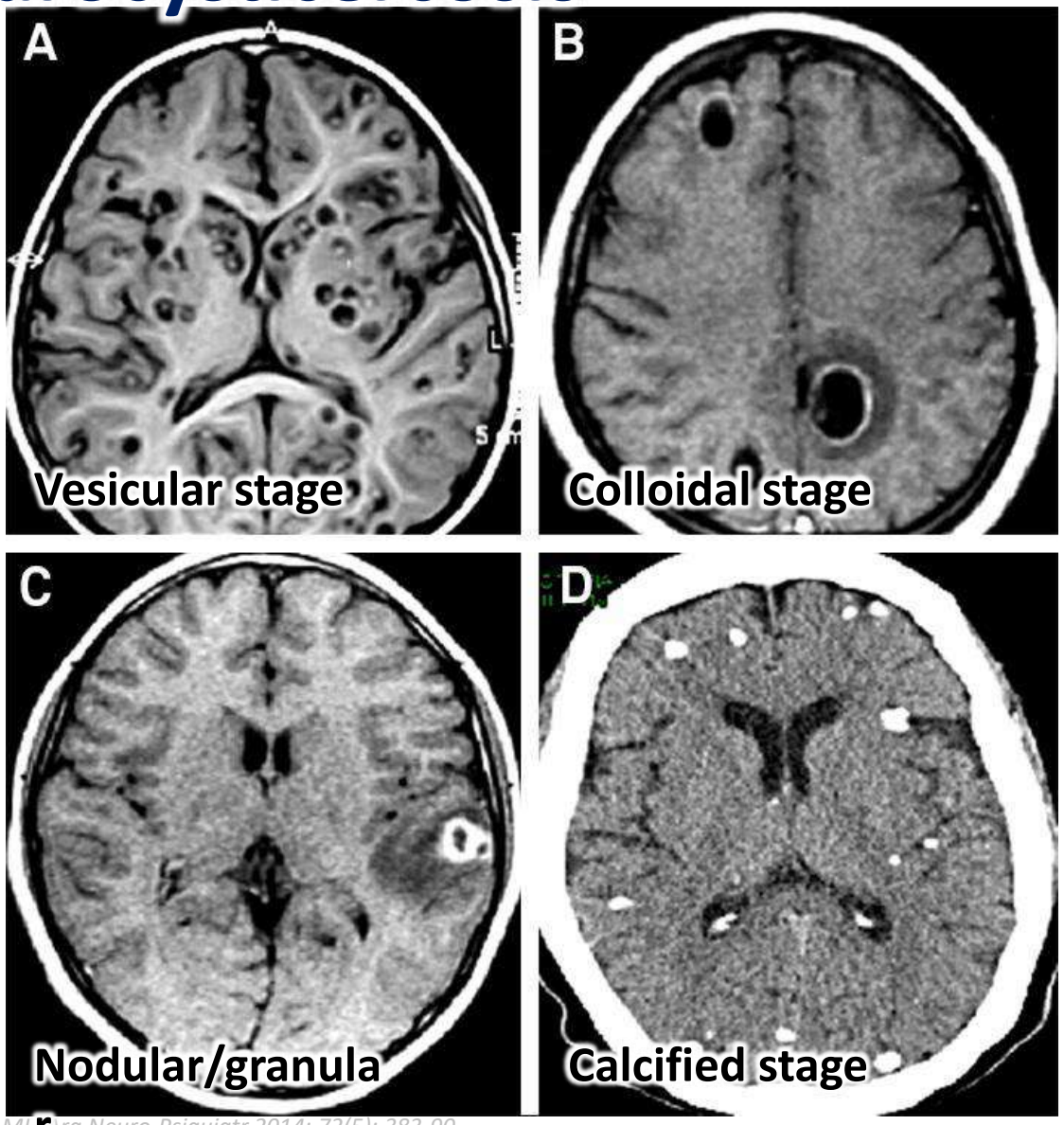
Basal cistern with conglomerate enhancement

Tuberculoma (not an abscess)





Neurocysticercosis



Box 1: When to consider a diagnosis of neurocysticercosis

- Cystic lesions, solitary enhancing lesions or punctuate calcifications observed on neuroimaging studies
- Resolution of intracranial cystic lesions after treatment with albendazole or praziquantel
- New-onset seizure in an adult
- Evidence of household contact with *Taenia solium* infection
- Origination from region where neurocysticercosis is endemic
- History of repeated travel to disease-endemic regions

First stage	
Vesicular	Cyst and scolex.
Second stage	
Colloidal	Ring enhancement and edema.
Third stage	
Nodular-granular	Decreased enhancement and edema. Initiation of calcification.
Fourth stage	
Calcified	Calcification on CT or MR imaging.[a]

Carpio A, Romo ML. Arq Neuro-Psiquiatr 2014; 72(5): 383-90
Barry MA. Clin Pharmacol Ther 2012; 92(2): 170-81
Burneo JG, et al. Canadian Med Assoc J 2009; 180(6): 639-42

Neurocysticercosis

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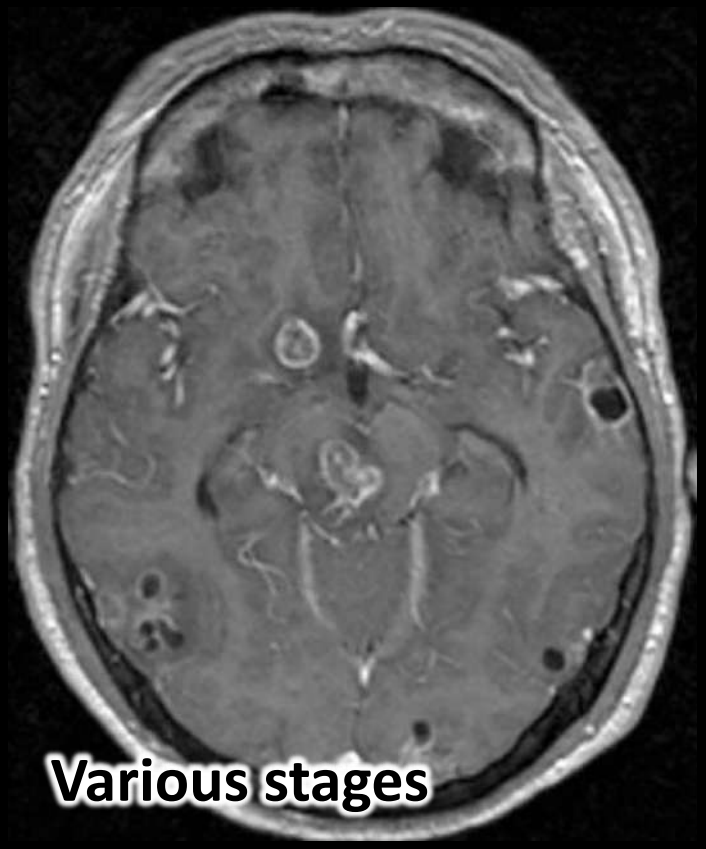
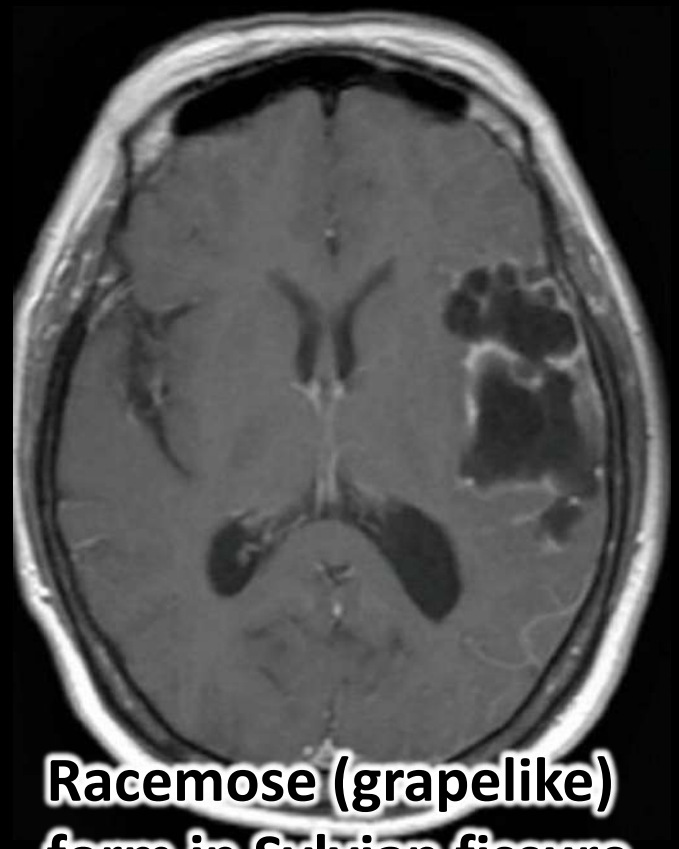


Various stages



Racemose (grapelike) form in Sylvian fissure

Intraventricular cysticercosis

Intramedullary cysticercosis

Neurocysticercosis

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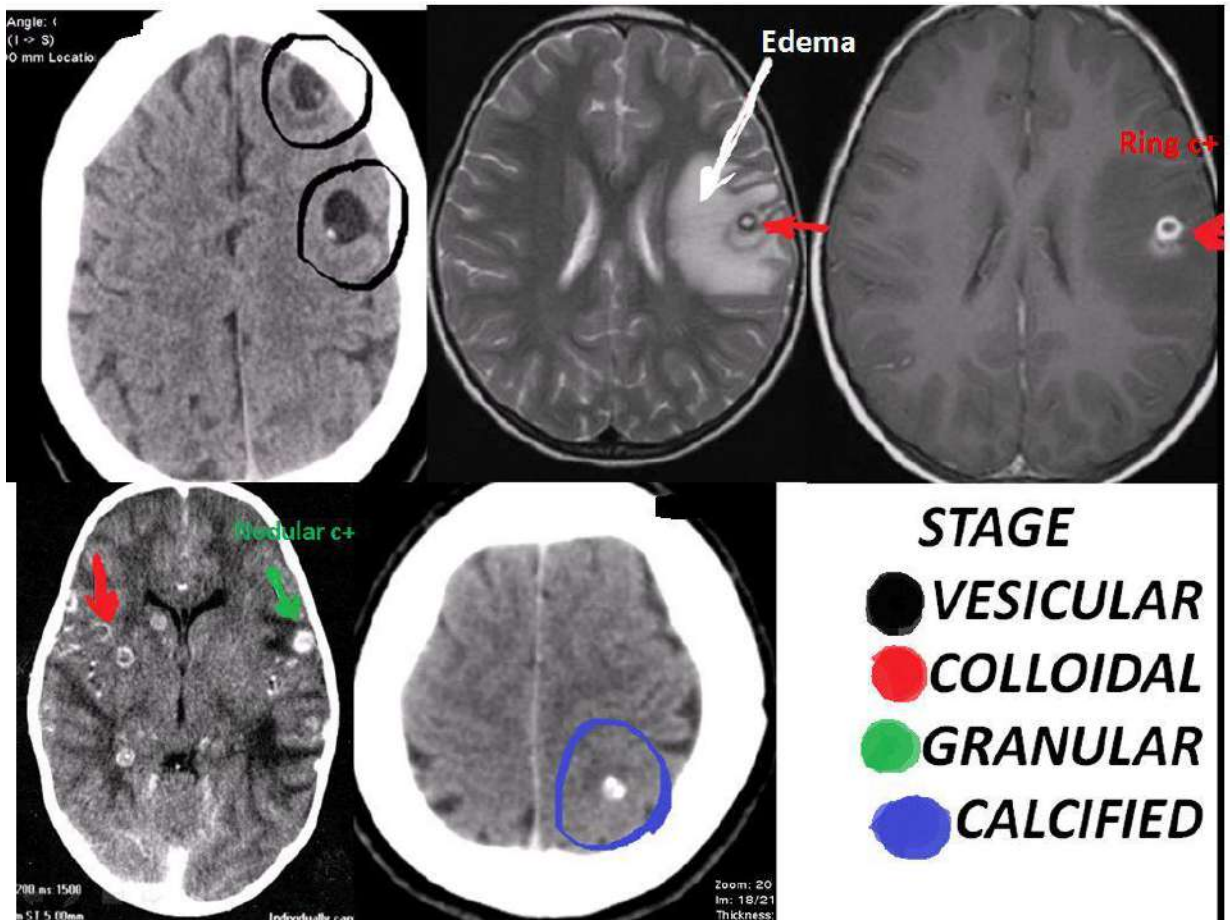

Form of the disease	Therapy
Parenchymal	
Viable or enhancing (degenerating) cysticerci (single or multiple)	Albendazole (15 mg/kg/day in two divided daily doses)[a] for at least 1 week along with corticosteroids
Cysticercal encephalitis	Corticosteroids (antihelminthics are contraindicated)
Calcified lesions	No antiparasitic therapy is recommended
Extraparenchymal	
Intraventricular cysts	Removal of cysts via neuroendoscopy
Subarachnoid cysts	Antiparasitic drugs for at least 1 month Corticosteroids started before antiparasitics and tapered very slowly Surgical excision may be considered for giant cyst in Sylvian fissure Ventriculoperitoneal shunt placement before antiparasitics if hydrocephalus is present
Spinal cysts	Surgical resection; antiparasitic therapy may be used
Ocular cysts	Surgical resection

[a]Alternatively, praziquantel can be given at a dosage of 50 mg/kg/day divided in three doses for 2 weeks or in a single-day regimen in three doses of 25mg/kg at 2-h intervals.

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39 YO HIV-Infected Man with Rt Facial Palsy

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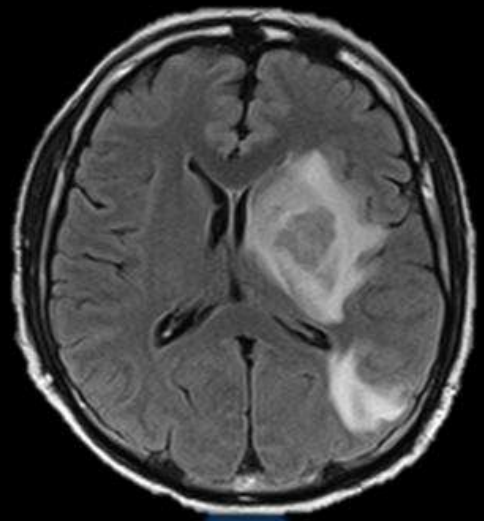
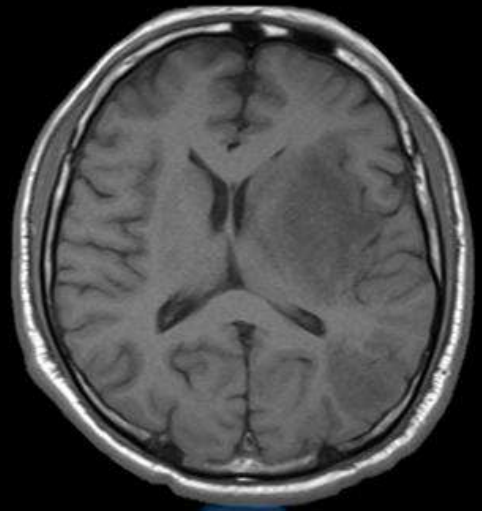
CT w/contrast



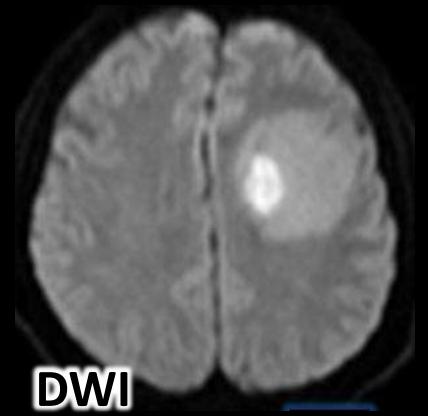
T2



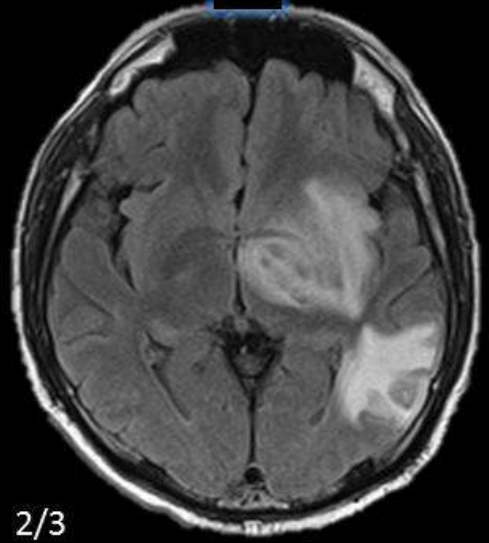
T1

Ring-enhancing lesions

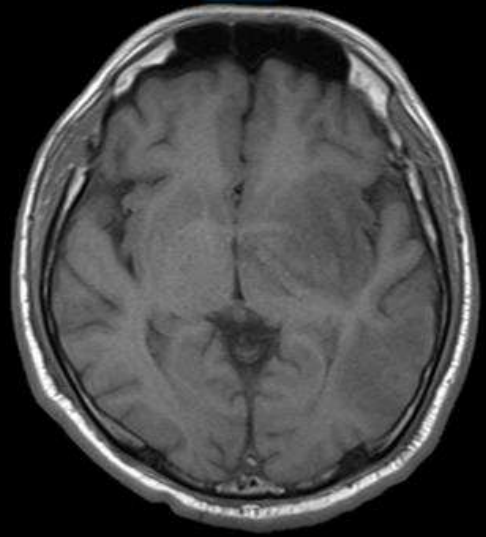
T1+c

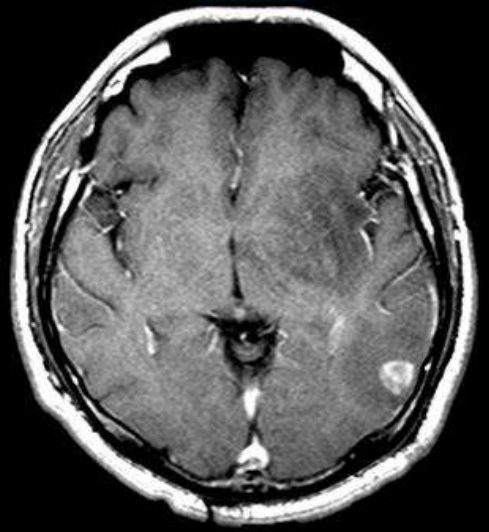


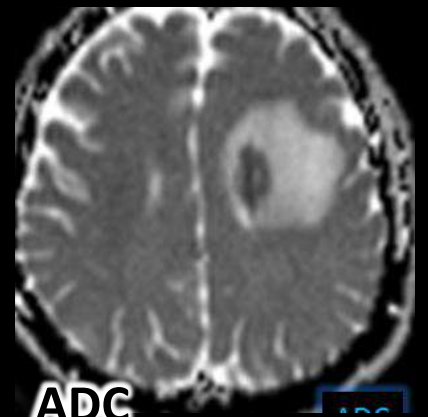
DWI (restricted diff)



2/3







ADC

CNS Lesions in HIV-Infected Patients

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With mass effect

- Toxoplasmosis
- Primary CNS lymphoma
- Cryptococcosis
- Other brain abscess

Without mass effect

- PML
- HIV encephalopathy
- CMV encephalitis

Features	Cerebral toxoplasmosis	Primary CNS lymphoma
Number	Multiple	Single
Location	Basal ganglia Corticomedullary junction	Subependymal Corpus callosum
Enhancement	Ring/nodular	Solid (if HIV – ring)
Hemorrhage	Occasionally, at rim	None
ADC	High	Low (restricted diffusion)
MRS	↑lactate, lipid; ↓Cr, NAA	
	↓Choline	↑Choline
MR perfusion	Decreased rCBV	Increased rCBV

2o CNS lymphoma – likely leptomeningeal

Cerebral Toxoplasmosis vs. PCNSL

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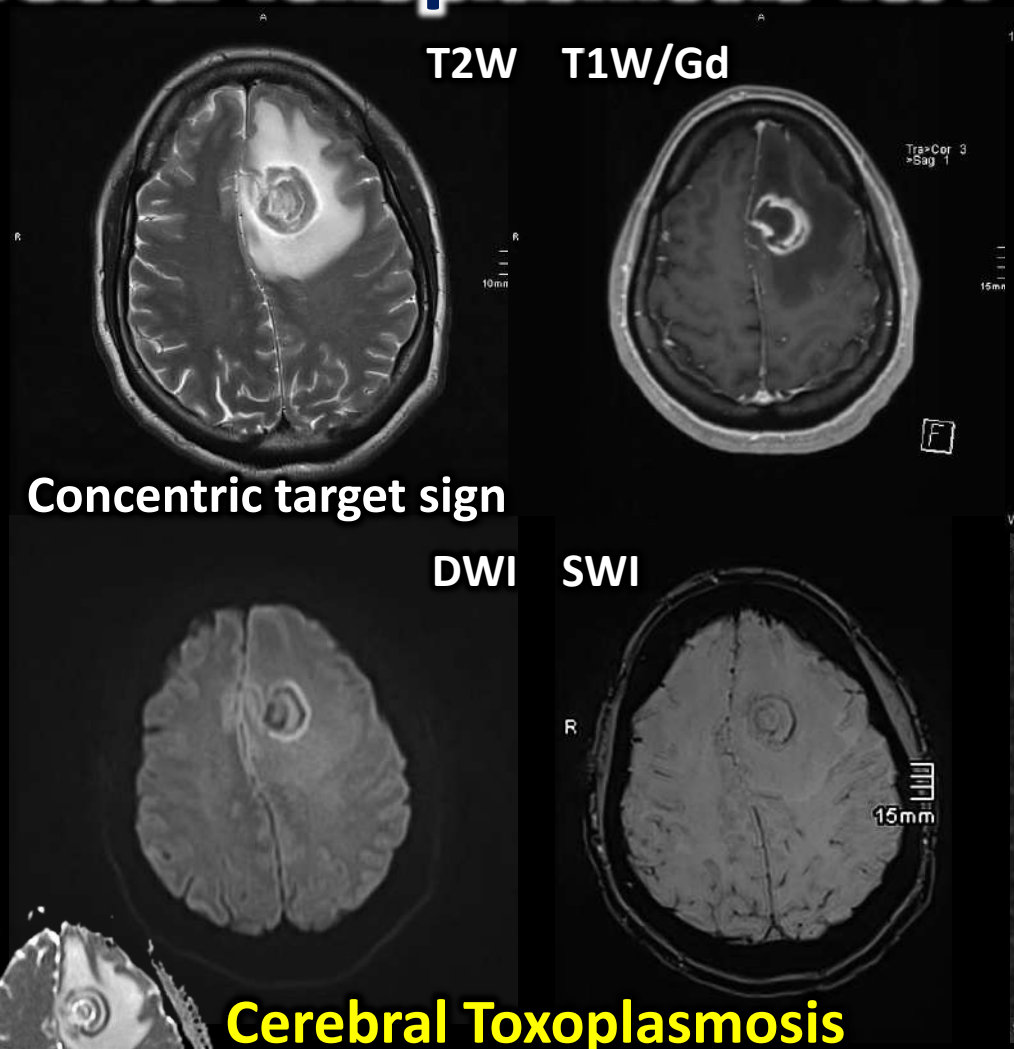
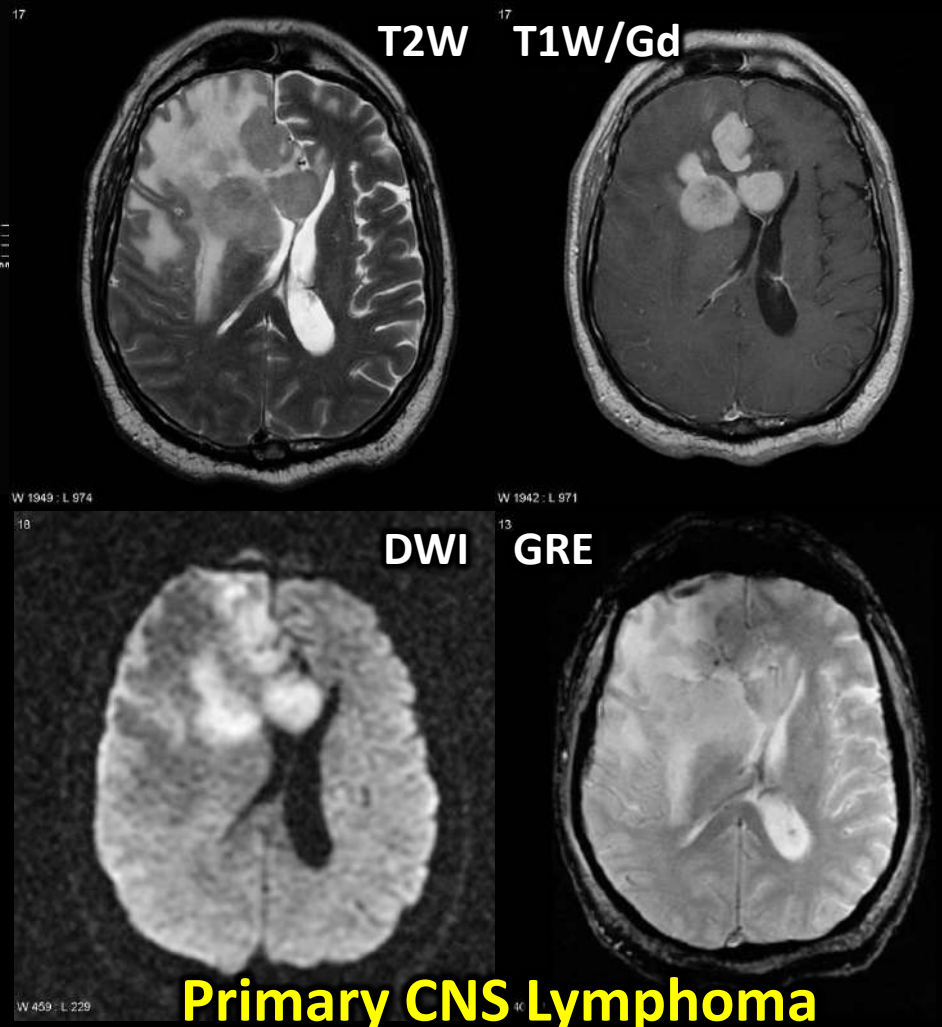


Cerebral Toxoplasmosis



Primary CNS Lymphoma

Lymphoma in immunocompromised host –
may be ring-enhancing lesions

Cerebral Toxoplasmosis

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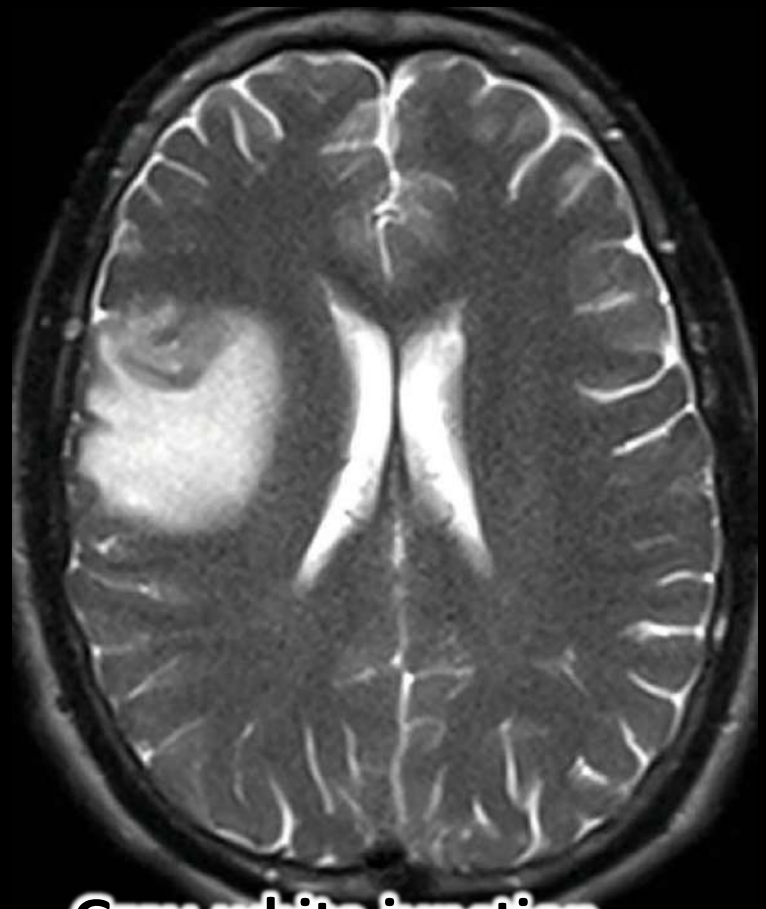
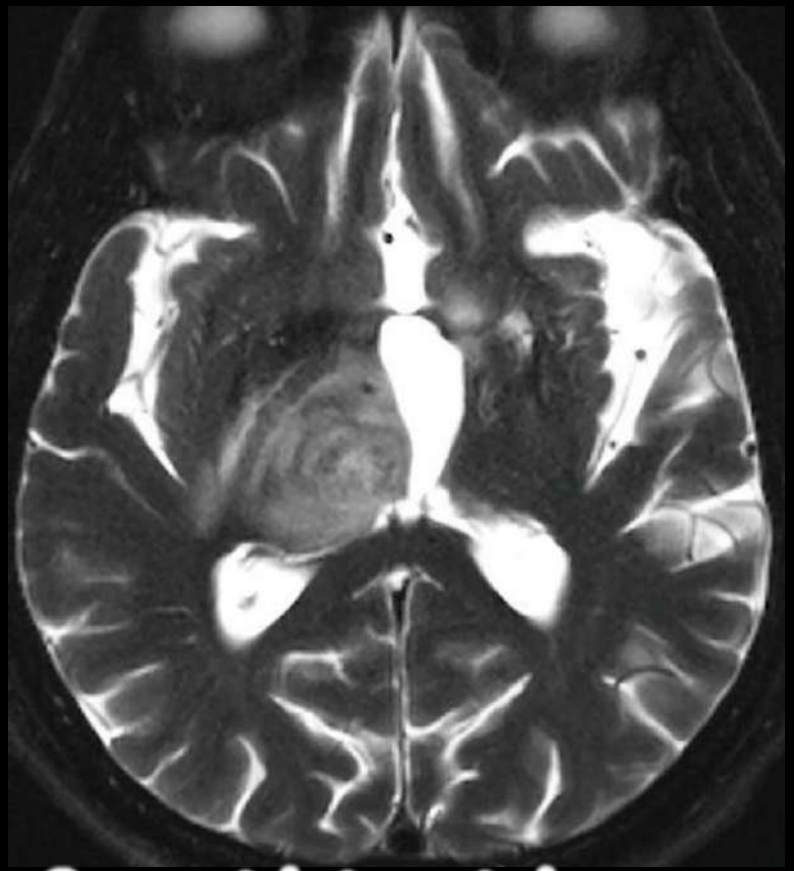


Gray-white junction

Eccentric target sign
(T1W-Gd)



Concentric target sign
(T2W)

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Cryptococcosis

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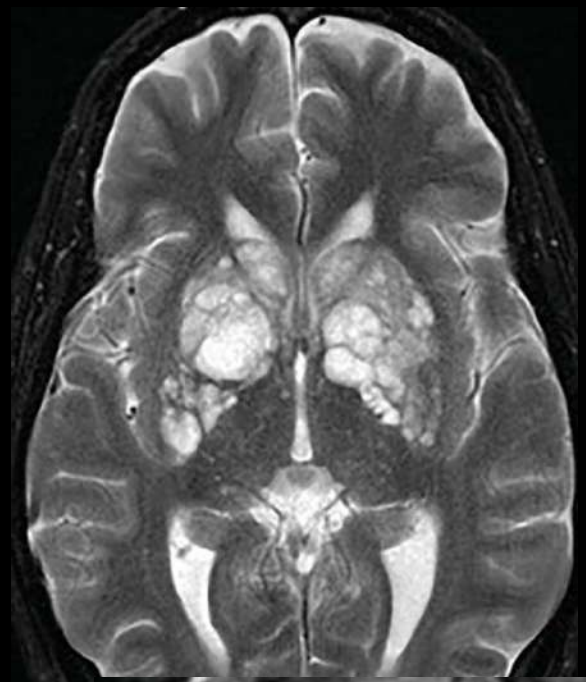
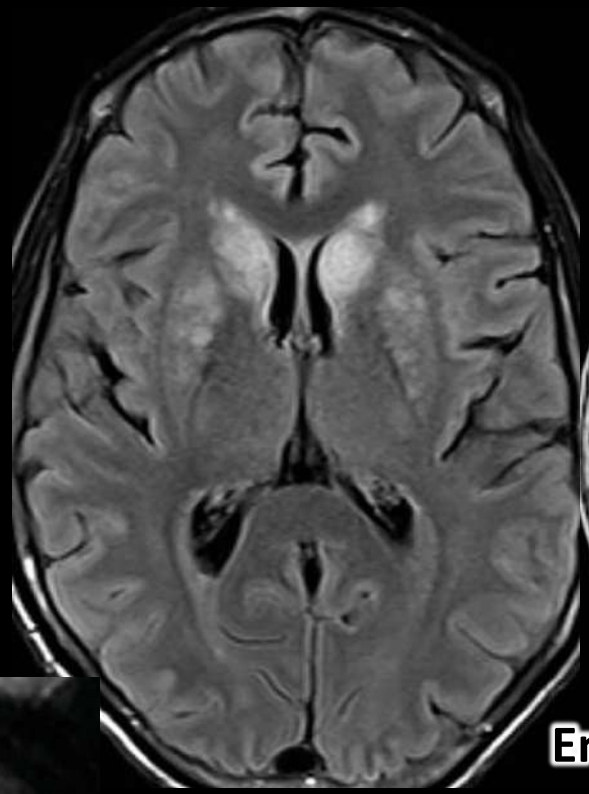
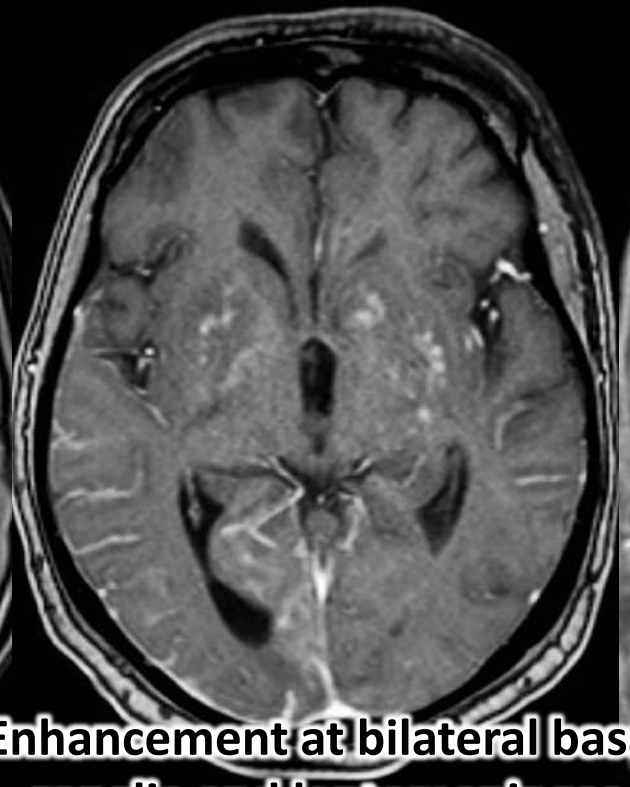
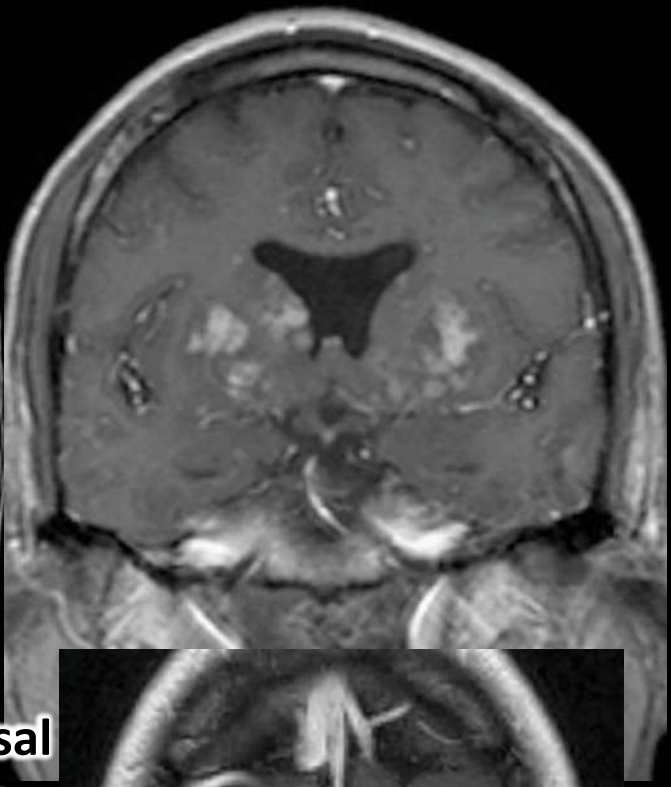
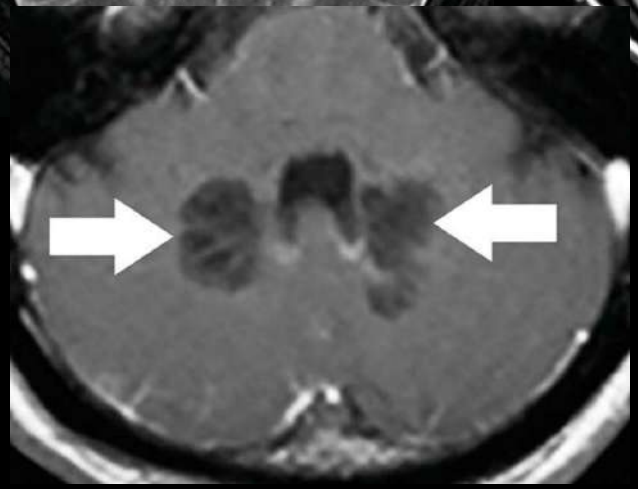








Enhancement at bilateral basal ganglia and leptomeninges



Multiple gelatinous pseudocysts at bilateral basal ganglia & middle cerebellar peduncles

Cryptococcoma

Progressive Multifocal Leukoencephalopathy (PML)

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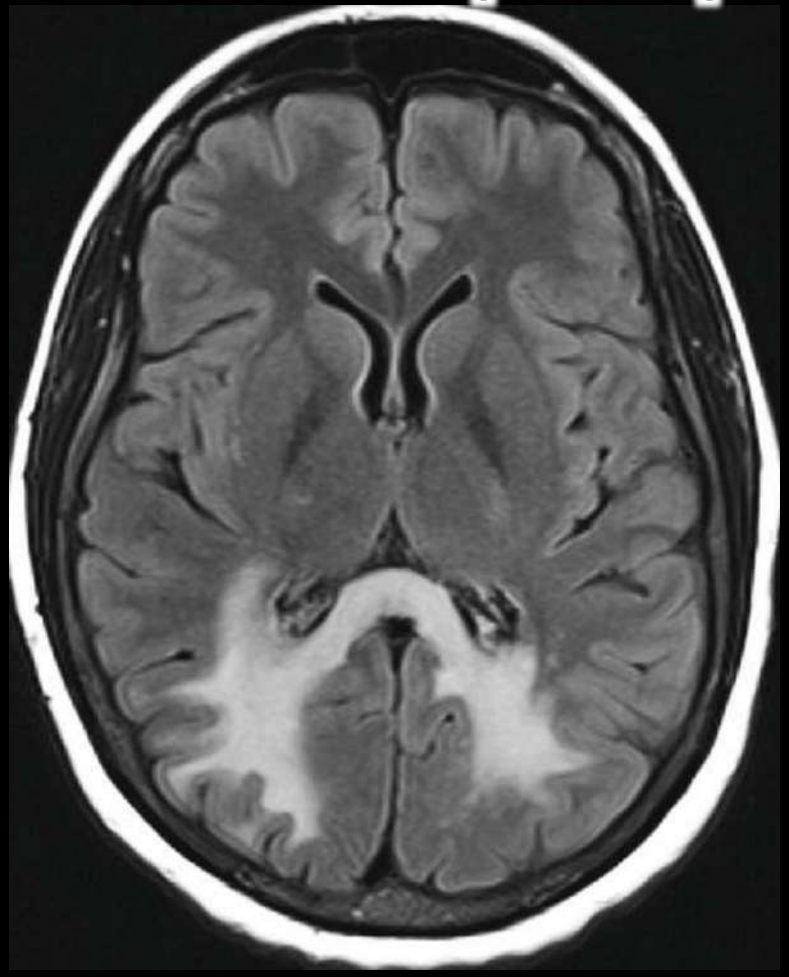

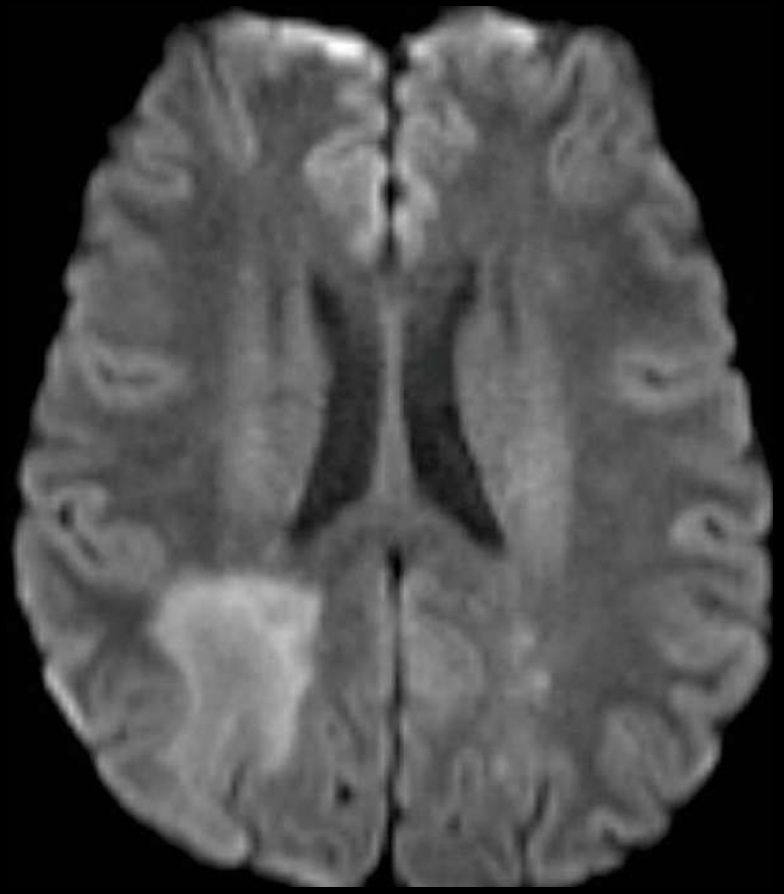

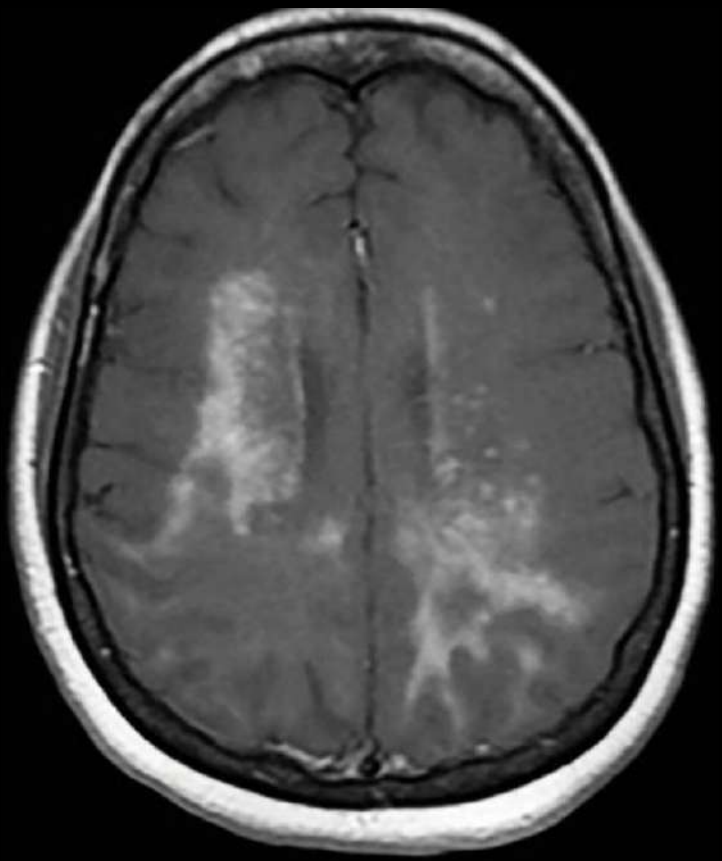

PML-IRIS

Multifocal confluent hyperT2 subcortical white matter lesions, involving U-fibers
(typically NO enhancement)

CMV Encephalitis

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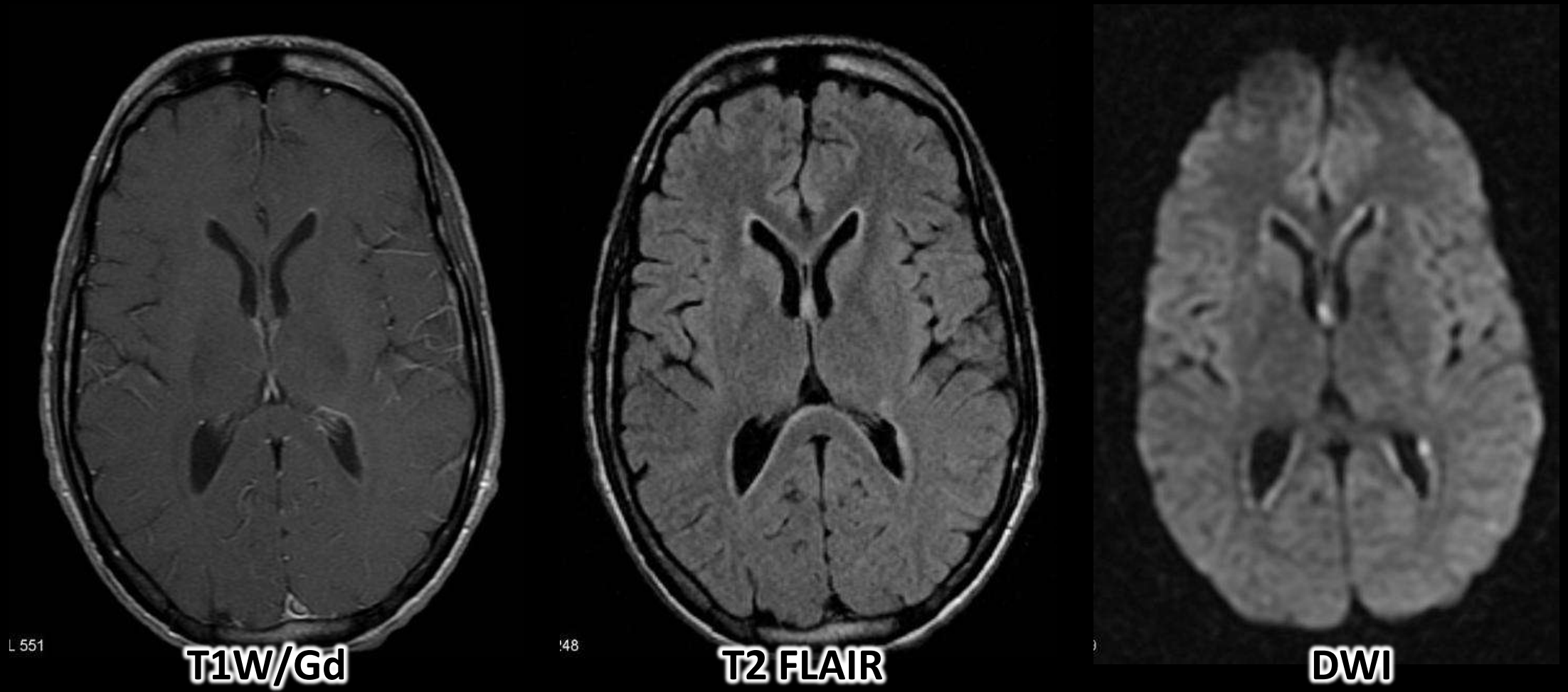
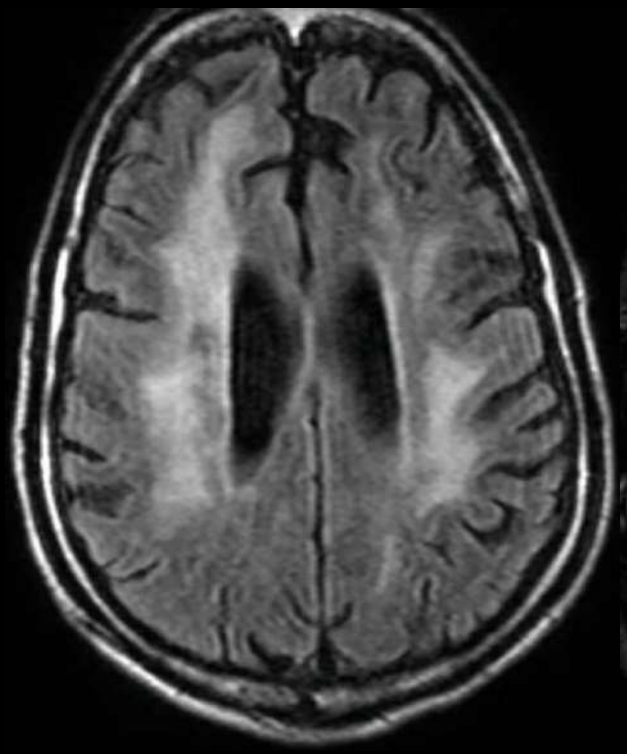
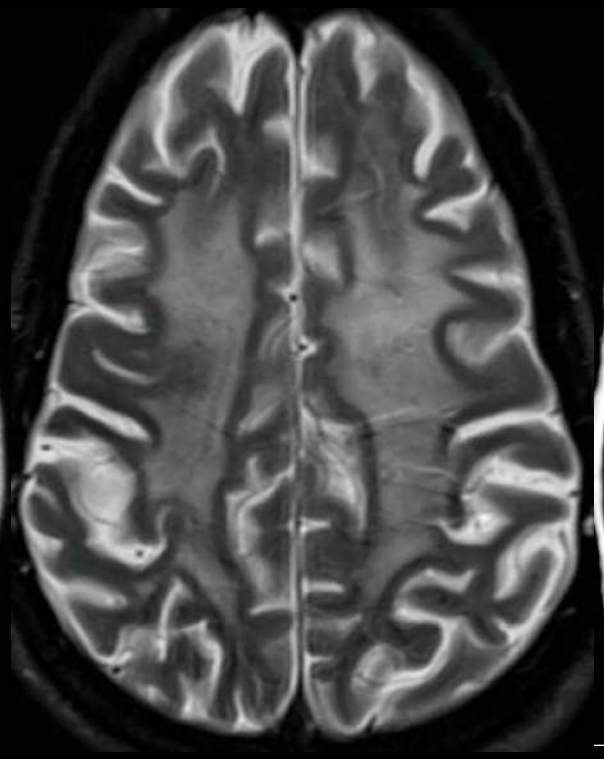


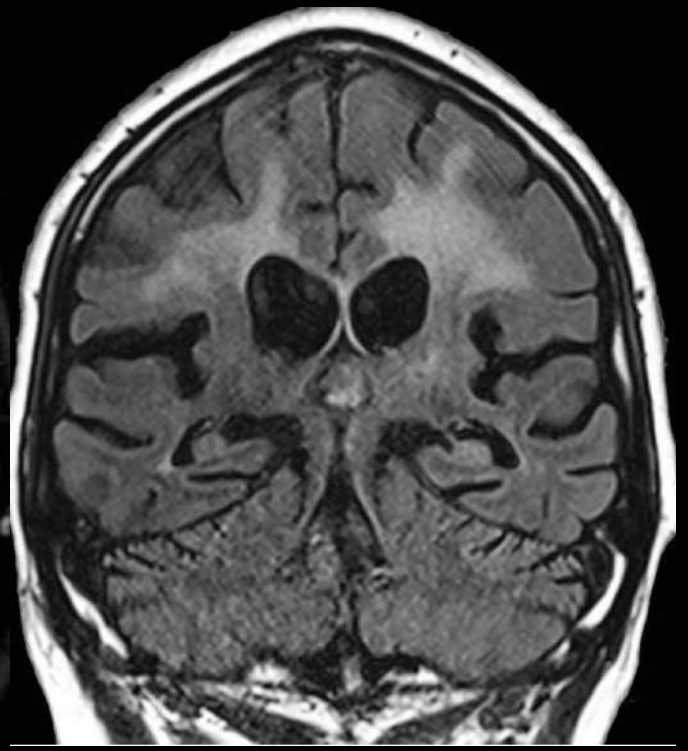
T1W/Gd | T2 FLAIR | DWI

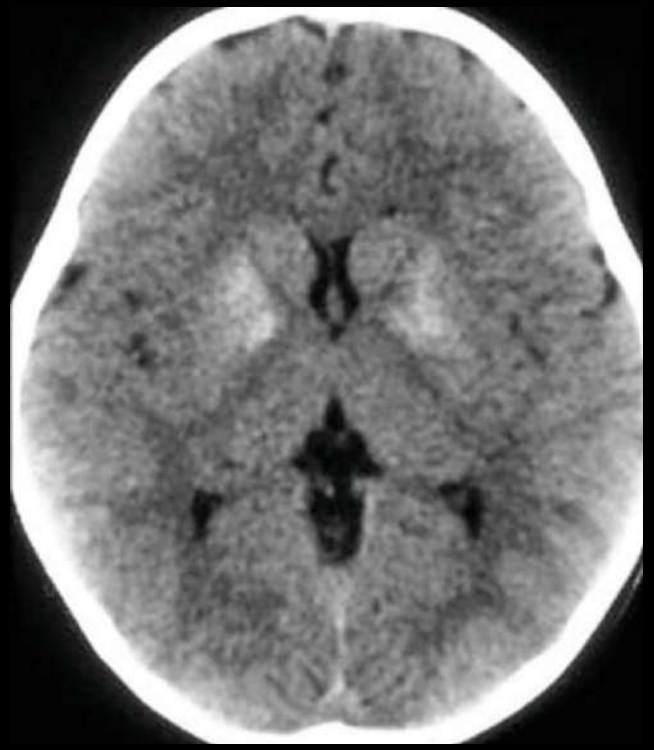
Periventricular hyperT2 with enhancement

HIV Encephalopathy









Bilateral symmetric large confluent hyperT2 WM lesion with marked atrophy of cortex and deep gray structures

Basal ganglia calcification in congenital AIDS

Pyogenic Spondylodiscitis

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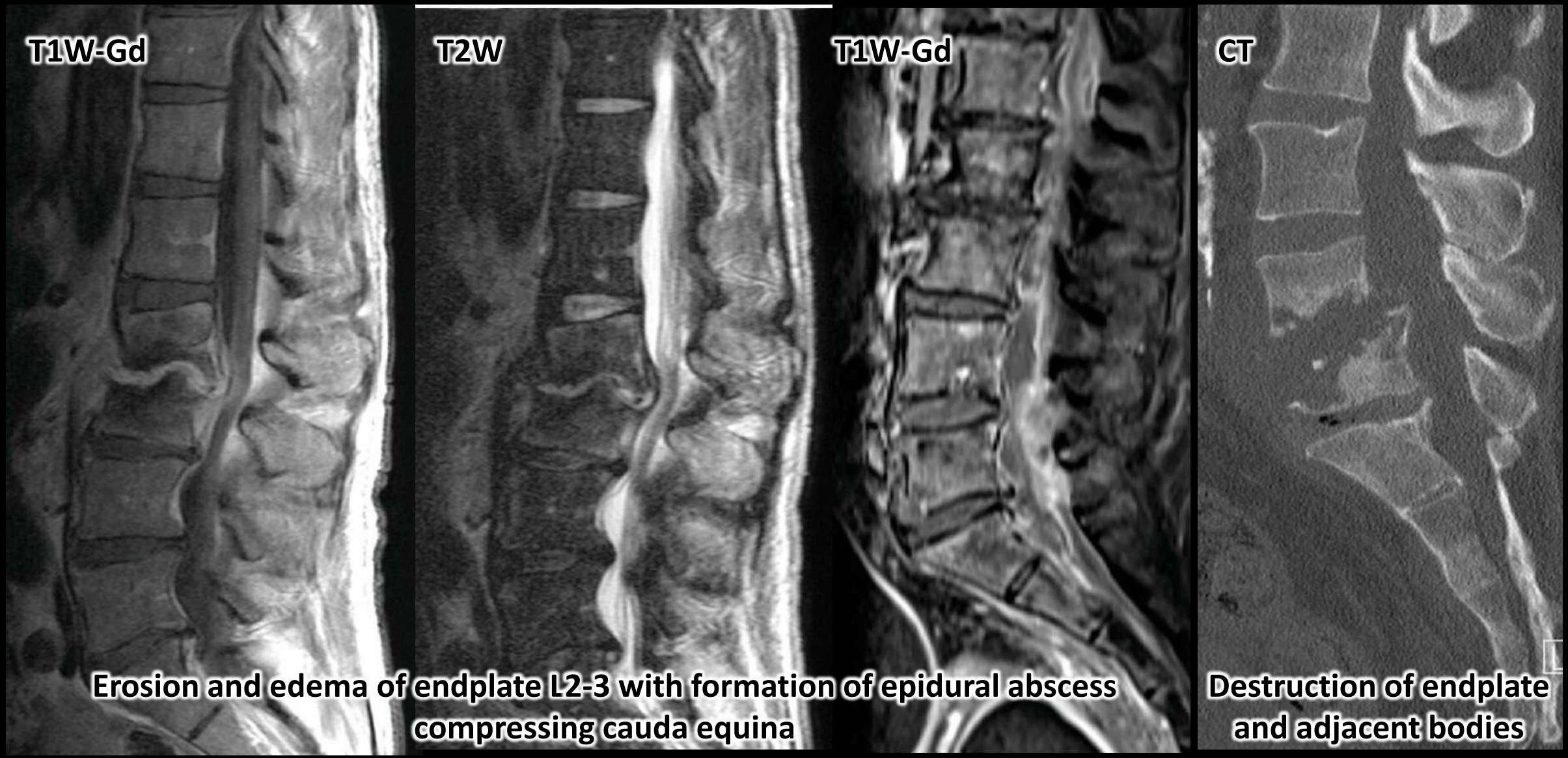

Erosion and edema of endplate L2-3 with formation of epidural abscess compressing cauda equina

Destruction of endplate and adjacent bodies

TB Spondylodiscitis

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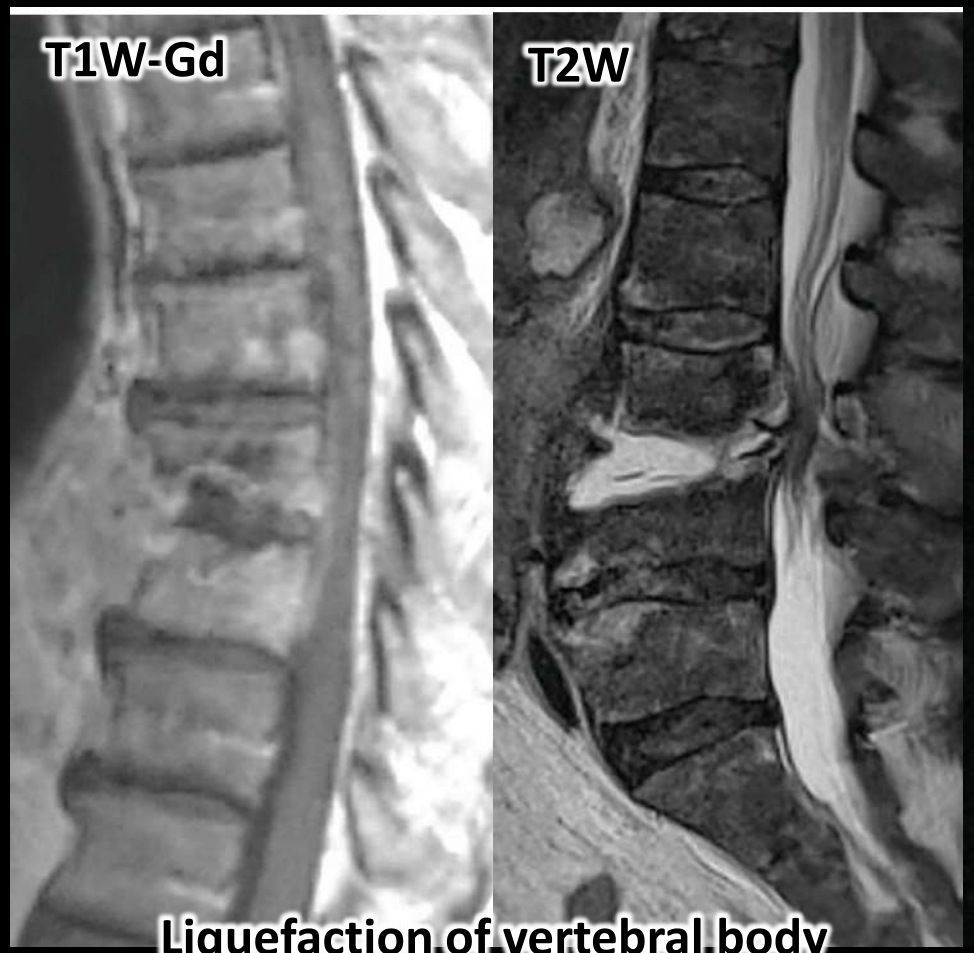
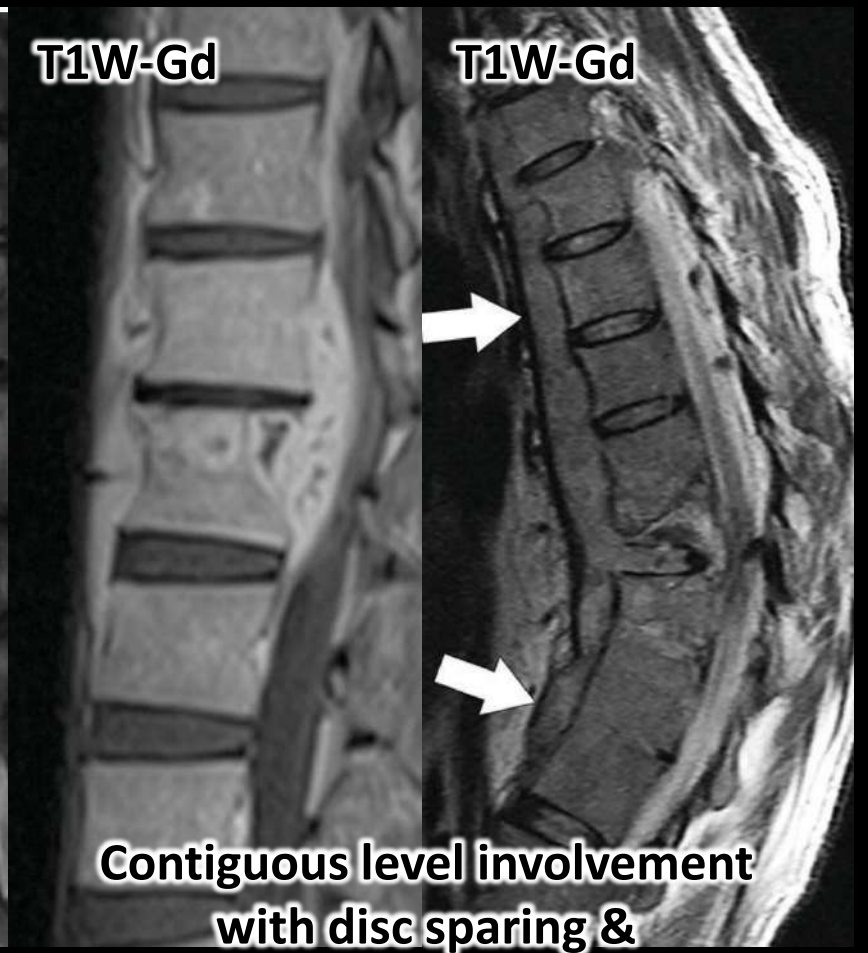
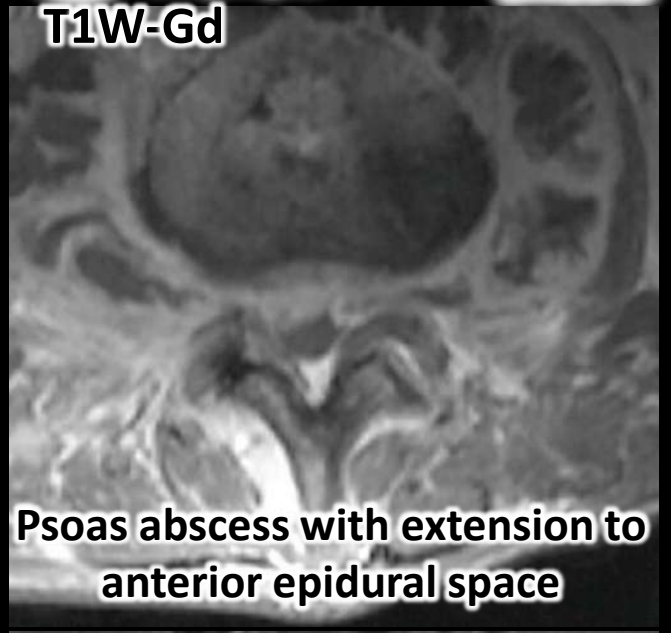


Liquefaction of vertebral body and adjacent endplate



Contiguous level involvement with disc sparing & subligamentous spreading, gibbus deformity



Psoas abscess with extension to anterior epidural space

Psoas & erector spinae abscesses

TB vs. Pyogenic Spondylodiscitis

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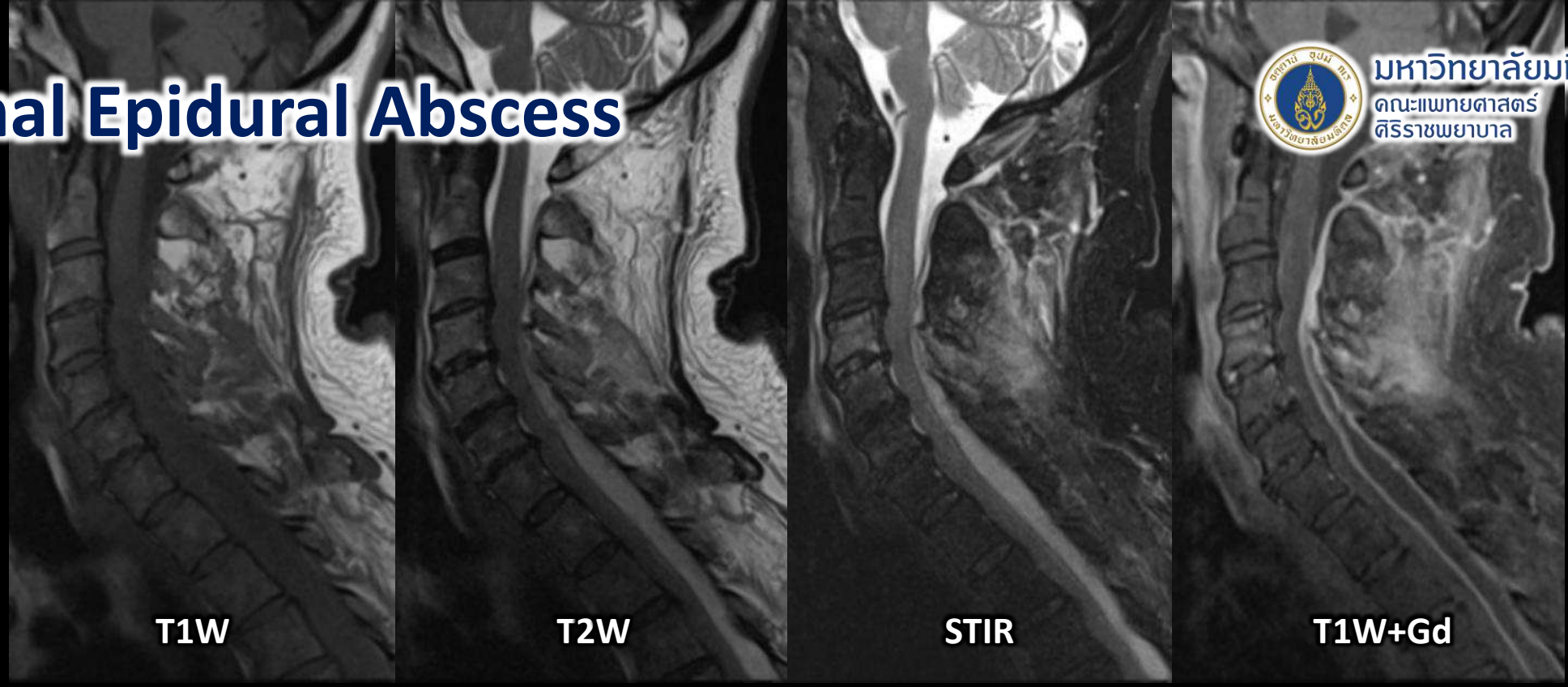
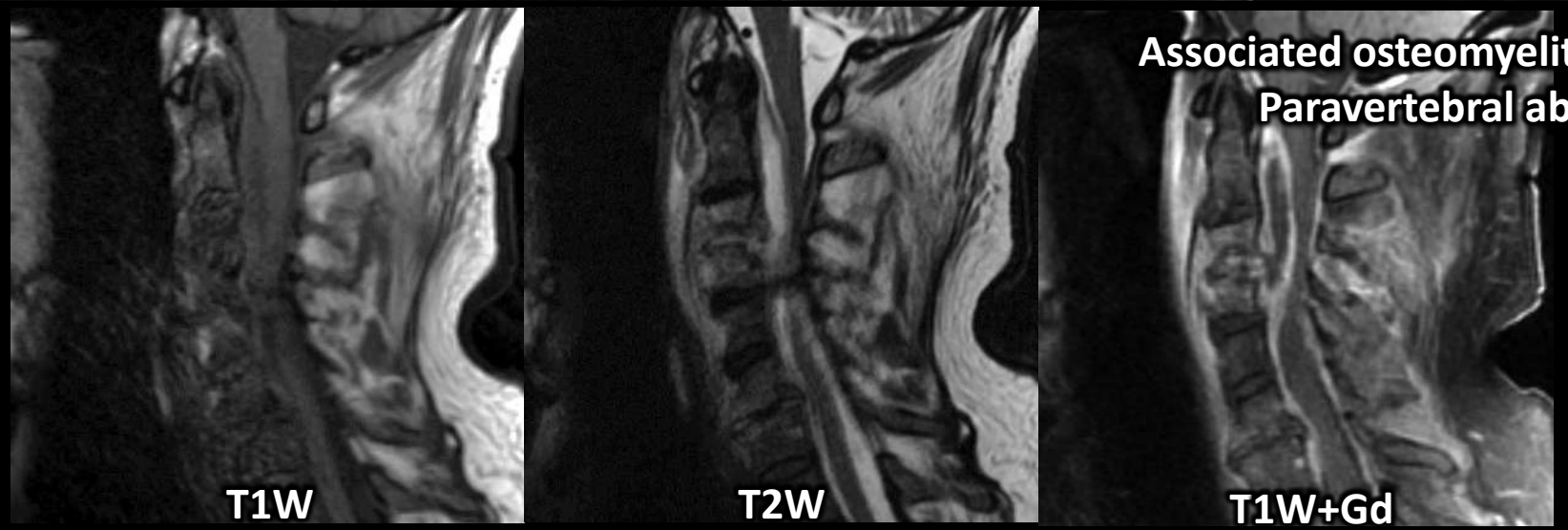
Characteristics	TB spondylodiscitis	Bacterial spondylodiscitis
Location	Lower T-Upper L	Lower L
Numbers of involved vertebral bodies	Multiple, contiguous	Single, or scattered
Erosion of intervertebral disc	Late	Early
Sclerosis	Present	Absent
Rim enhancement	Involving intraosseous vertebra	Involving disc
Paravertebral mass	Paraspinal/intraspinal abscess Calcification Thin & smooth wall	No calcification Less often Thick & irregular wall

Hashmi MA, et al. Asian J Neurosurg 2014; 9(2): 102-4
https://learningradiology.com/notes/bonenotes/extramedullarycorrect.html

Spinal Epidural Abscess





Associated osteomyelitis/discitis
Paravertebral abscess (TB)

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คณะแพทยศาสตร์
ศิริราชพยาบาล

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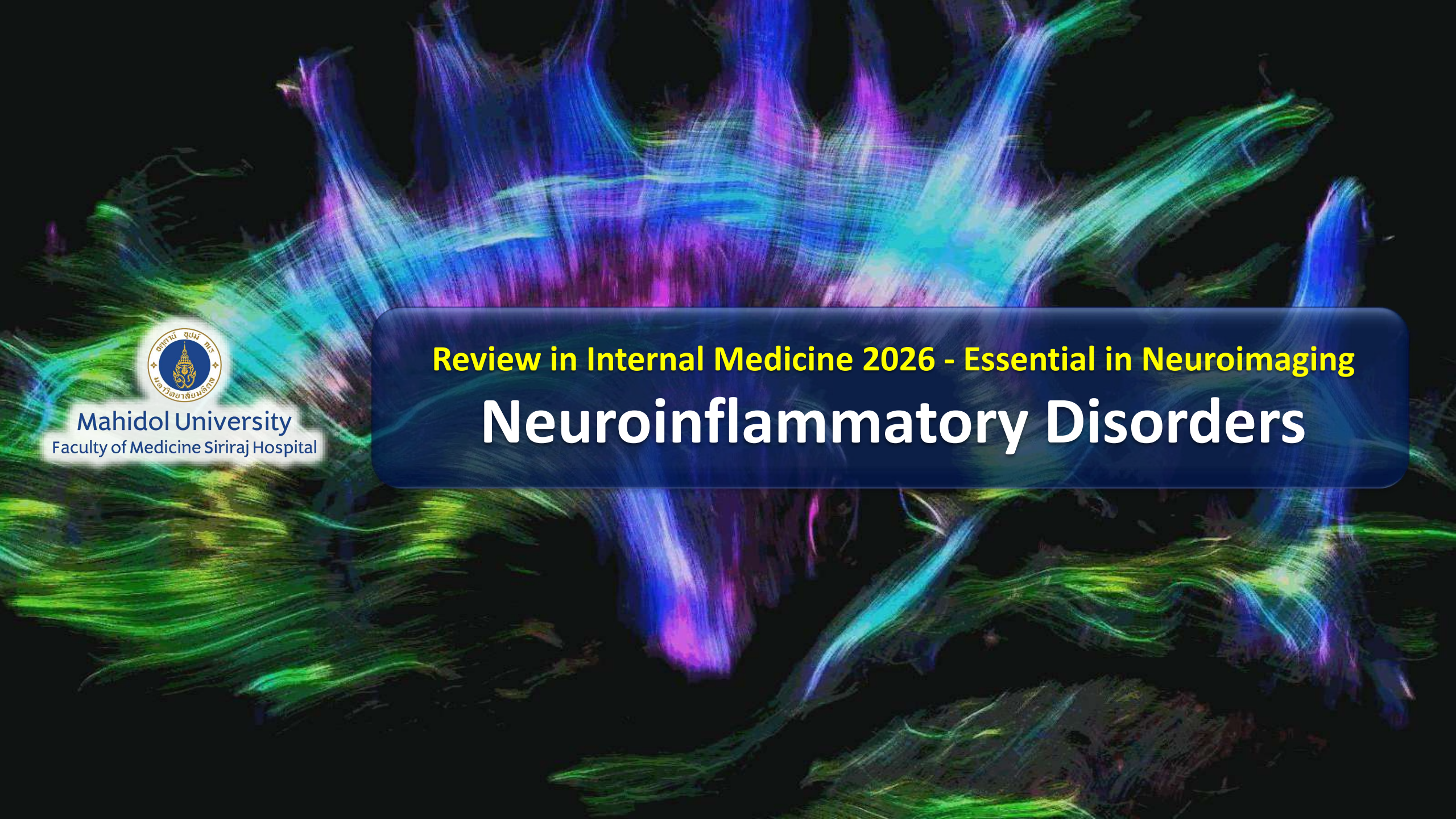
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Neuroinflammatory Disorders

Neuroinflammatory Disorders

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CNS Demyelinating diseases

- NMOSD
- Multiple sclerosis
- MOGAD
- ADEM

Autoimmune encephalitis

- NMDAR encephalitis
- Etc.

Other Demyelinating diseases

- Osmotic demyelinating syndrome
- (PML)
- Neurosarcoidosis
- Neuro-Behcet disease

Autoimmune Encephalitis

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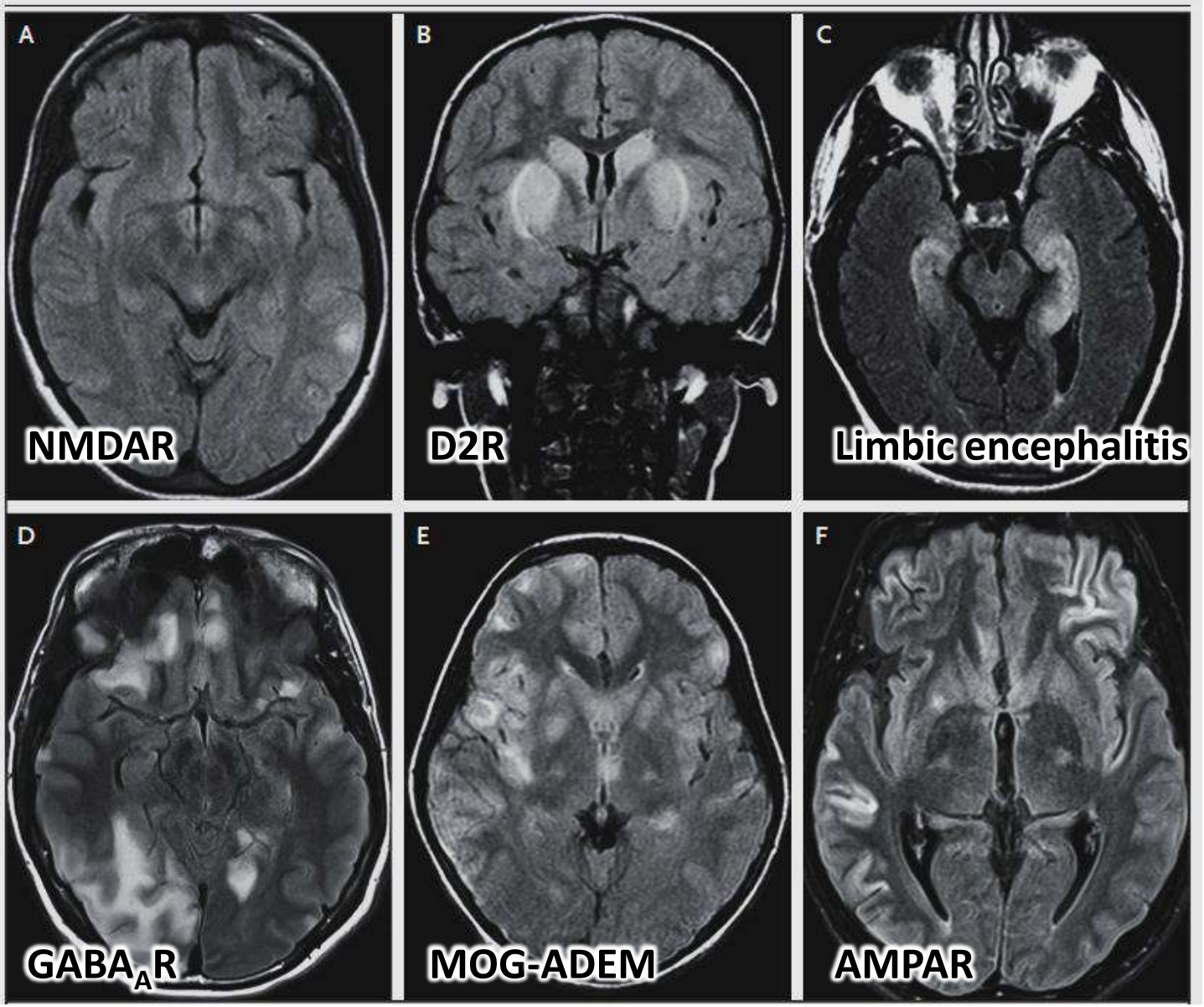

Based on clinical features + serology

A: Normal/mild signal change
B: Striatal (putamen/caudate) hyperintensity
C: HyperT2 at bilateral medial temporal lobes
D: Cortical & subcortical hyperT2 lesions
E: Extensive bilateral multifocal lesions
F: Widespread cortical damage

Dalmau J, et al. N Engl J Med 2018; 378(9): 840-51

CNS Demyelinating Diseases

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Acute/subacute
Focal/multifocal neurodeficits

Idiopathic Inflammatory Demyelinating disease

Caveats:
- Some MS therapy may worsen NMO (e.g. IFN-β, natalizumab, fingolimod)
- MS patients would benefit from disease-modifying therapy rather than immunosuppressive therapy

Exclude 2º causes
- Infection (PML, SSPE, TSP)
- Autoimmune disease (SLE, RA, SjS)
- Vasculitis (Behçet's disease)
- Toxic leukoencephalopathy
- Osmotic demyelinating syndrome
- Marchiafava-Bignami disease

NMOSD | **MOGAD** | **Multiple Sclerosis** | **Others** | **ADEM**

- *Clinical overlapping*
- *Typical: Optic neuritis/myelitis/brainstem/mixed*

- *Encephalopathy*
- *Seizure*
- *Multifocal involvement*

2015 IPND Criteria for NMOSD

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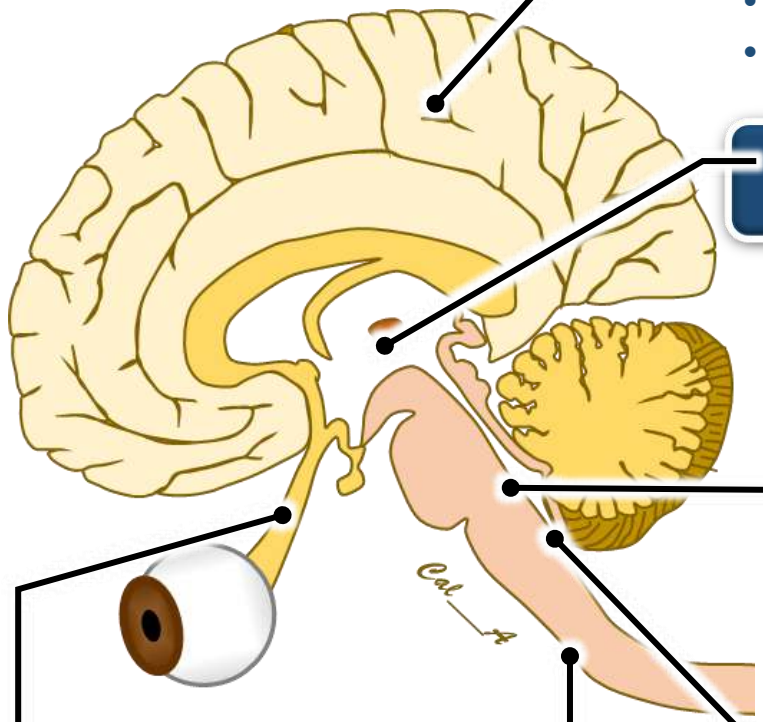
AQP4 IgG +ve

- Exclude other causes
- Just 1 core clinical feature

AQP4 IgG –ve /unknown

- Exclude other causes
- ≥2 core clinical features
- ≥1 of ON/Myelitis/APS
- Need additional MRI criteria



6.Cerebral syndrome

- Hemianopia, hemiparesis
- Seizure, encephalopathy

5.Diencephalic syndrome

- Symptomatic narcolepsy
- SIADH, autonomic dysfunction

4.Brainstem syndrome

- Vertigo, ataxia, cranial neuropathy
- Internuclear ophthalmoplegia

3.Area postrema syndrome

- Intractable hiccup/N-V

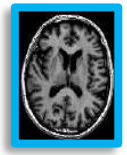
1.Optic neuritis

- Color visual loss
- VA drop/VF defect
- RAPD positive

2.Acute myelitis

- Paraparesis/Sensory level
- Brown-Sequard syndrome
- Bowel-bladder dysfunction

MRI Criteria for NMOSD Diagnosis



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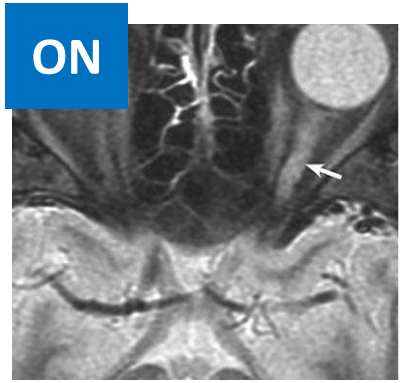
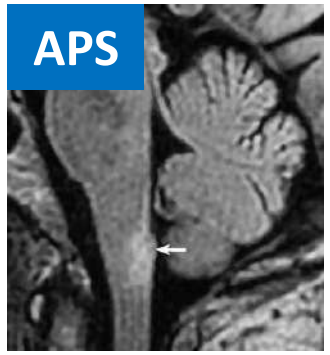
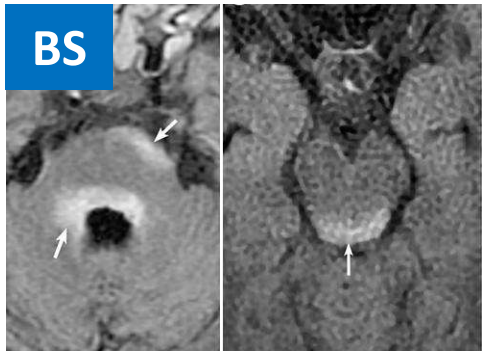
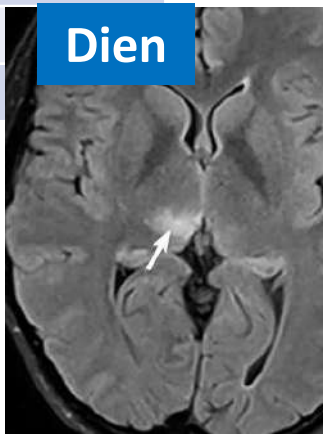
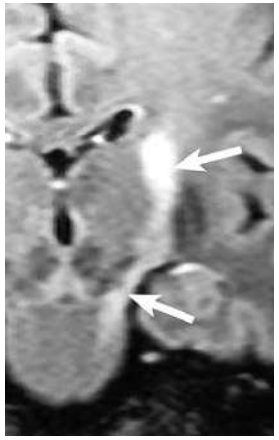
Core features	Typical MRI findings
1. Myelitis (TM)	Longitudinally extensive transverse myelitis (LETM) >3 vertebral levels
	Long-segment cord atrophy
2. Optic neuritis (ON)	Longitudinally extensive (>50% length)
	Involving optic chiasm / optic tract
3. Area postrema syndrome (APS)	hyperT2 / enhancing lesion at dorsal medulla
4. Brainstem syndrome (BS)	Periependymal lesion near 4th ventricle
5. Symptomatic diencephalic syndrome	Periependymal lesion near 3rd ventricle (thalamus / hypothalamus)
6. Symptomatic cerebral syndrome	Periependymal lesion near lateral ventricles
	Long corpus callosal lesion (>50% length)
	Corticospinal tract sign
	Tumefactive lesion (cloud-like)

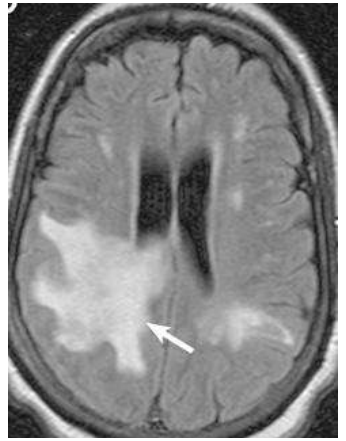












Required <u>only</u> in:

- **Symp diencephalic syndrome**
- **Symp cerebral syndrome**
- **Other features in AQP4-IgG neg/unknown**

MOG-Ab Associated Disease (MOGAD)

Criteria	Features	
A) Core clinical events	Optic neuritis (ON), Myelitis (TM), ADEM Cerebral cortical encephalitis with seizures (FLAMES) Cerebral/brainstem deficits	
B) Positive MOG-IgG test	Cell-based assay (clear positive) OR	
	Low positive/without reported titre/CSF positive + AQP4-IgG negative + 1 supportive MRI feature	
Supportive clinical/ MRI features	ON	Bilat simultaneous >50% optic nerve length Perineural enhancement Optic disc edema
	TM	LETM (>3 vertebral segments) Central cord, or H-sign Conus medullaris lesion
	Brain/ brainstem syndrome	Multiple ill-defined hyperT2 Deep gray involvement Ill-defined lesion at pons/MCP/medulla Cortical lesion +/- meningeal enhancement
Exclude possibility of multiple sclerosis		

MOG Myelin oligodendrocyte glycoprotein, FLAMES FLAIR-hyperintense lesions in anti-MOG-IgG encephalitis with seizures

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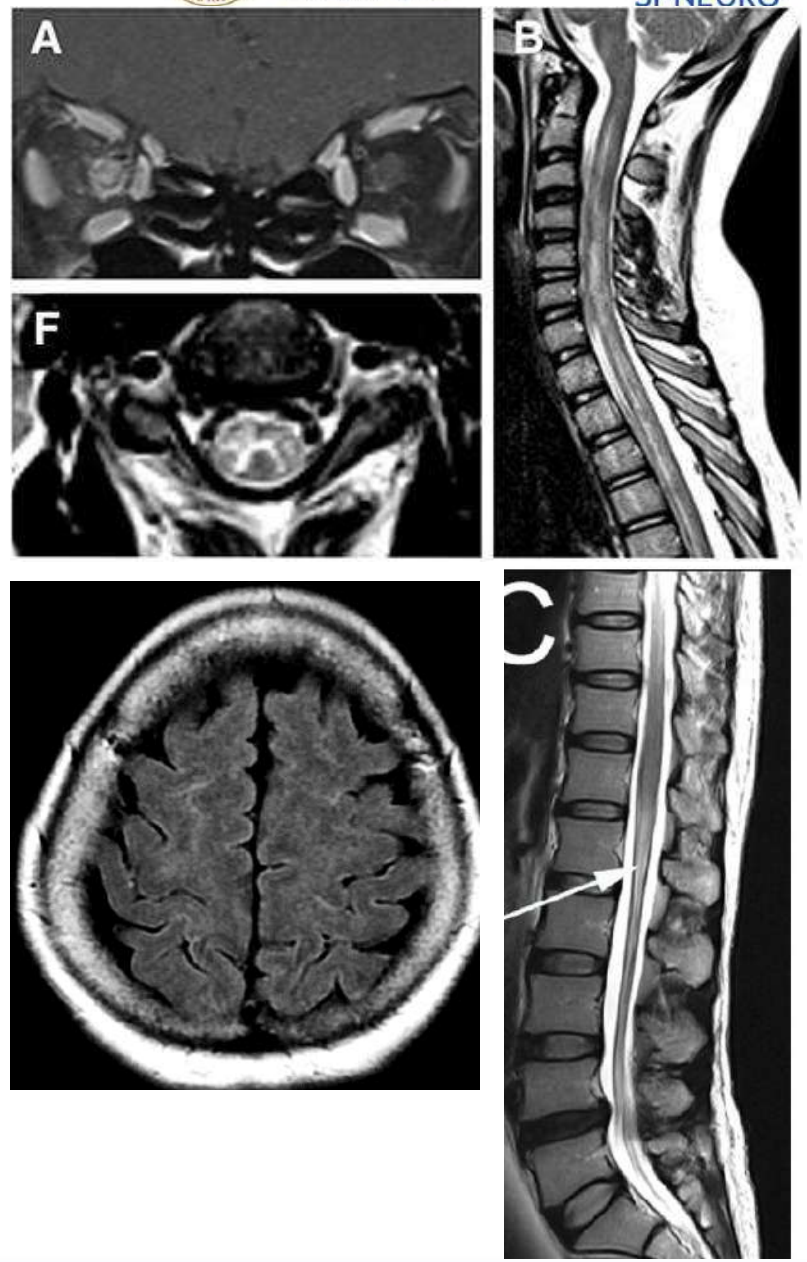

Multiple Sclerosis: 2017→2024 Criteria

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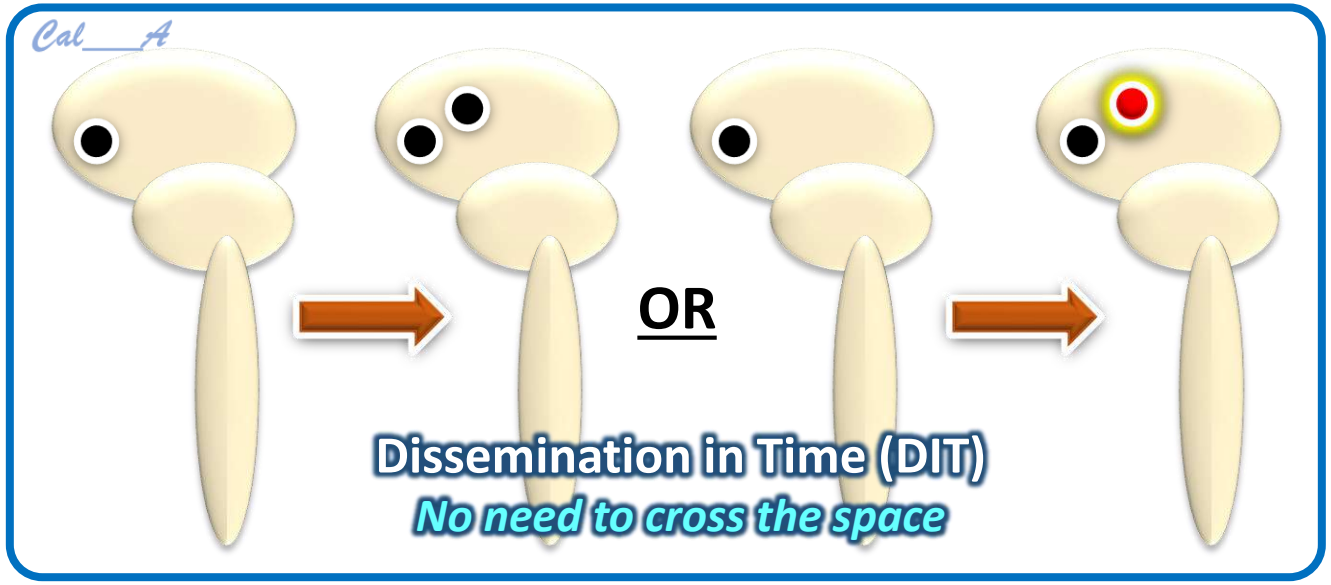
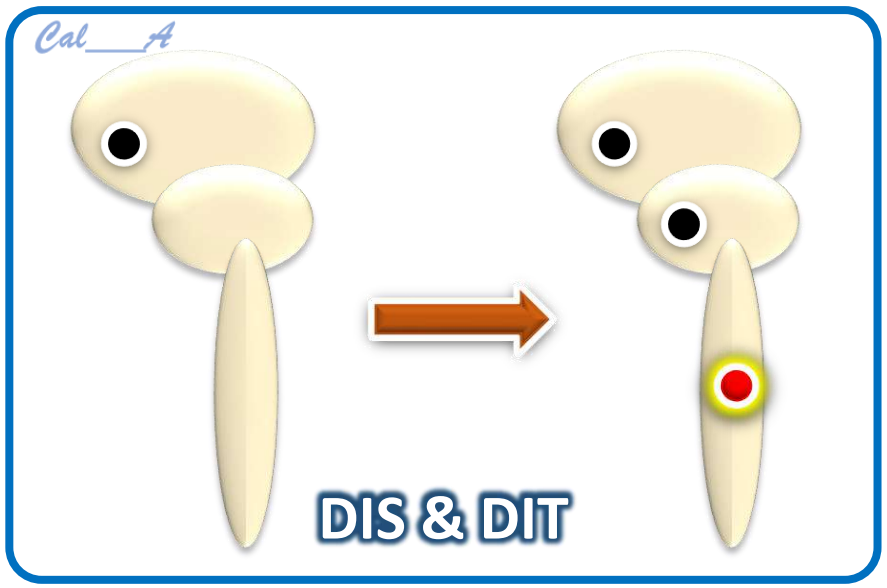
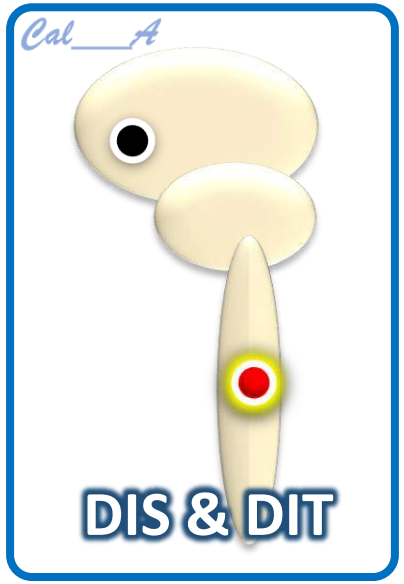


- High T2 lesion
- Gd enhancing

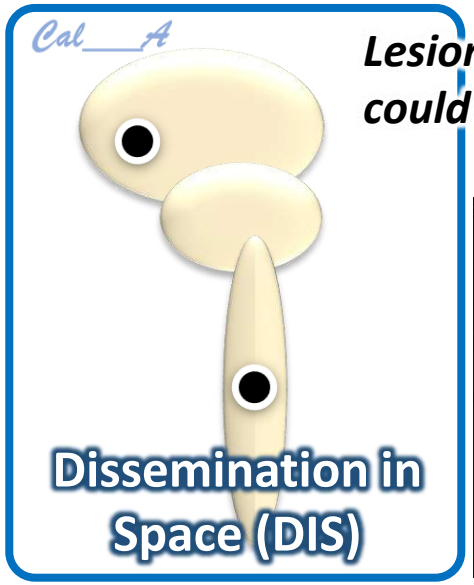




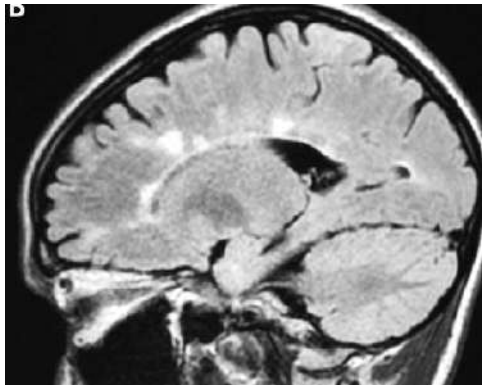
DIT:

- Simultaneous enhanced & non-enhanced lesions at any time, regardless of symptom
- New T2 and/or enhanced lesion on follow-up MRI, irrespective of time
- Oligoclonal band may replace DIT

Multiple Sclerosis

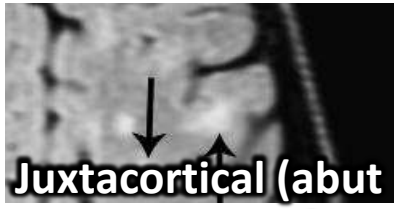


Lesion > 3 mm (esp.ovoid) could be considered



≥2 of 5 :

- 1 Cortical/juxtacortical (U-fibers)
- 1 Periventricular (∟ lateral ventricle)
- 1 Infratentorial
- 1 Spinal cord
- 1 Optic nerve (NEW)



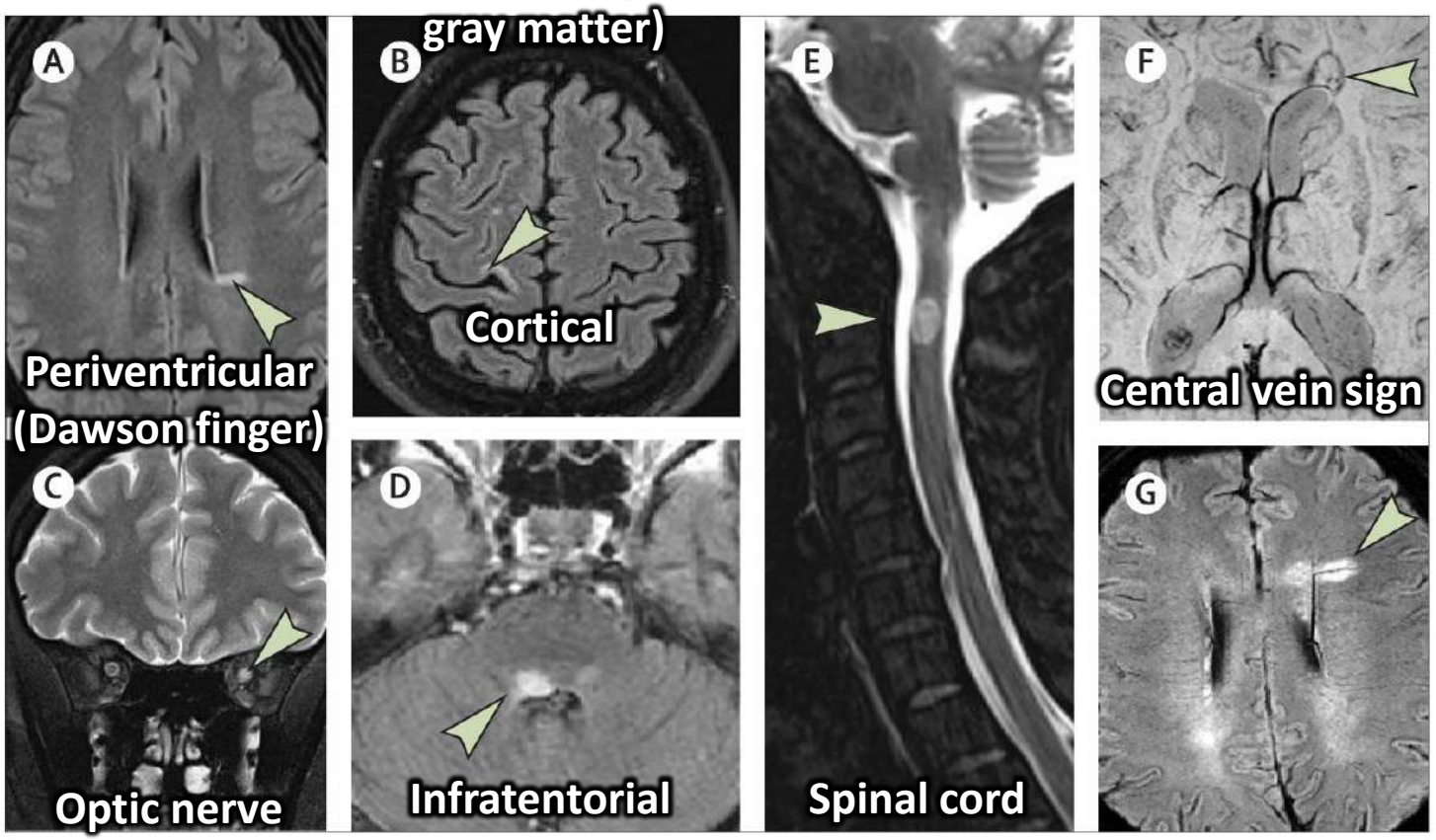
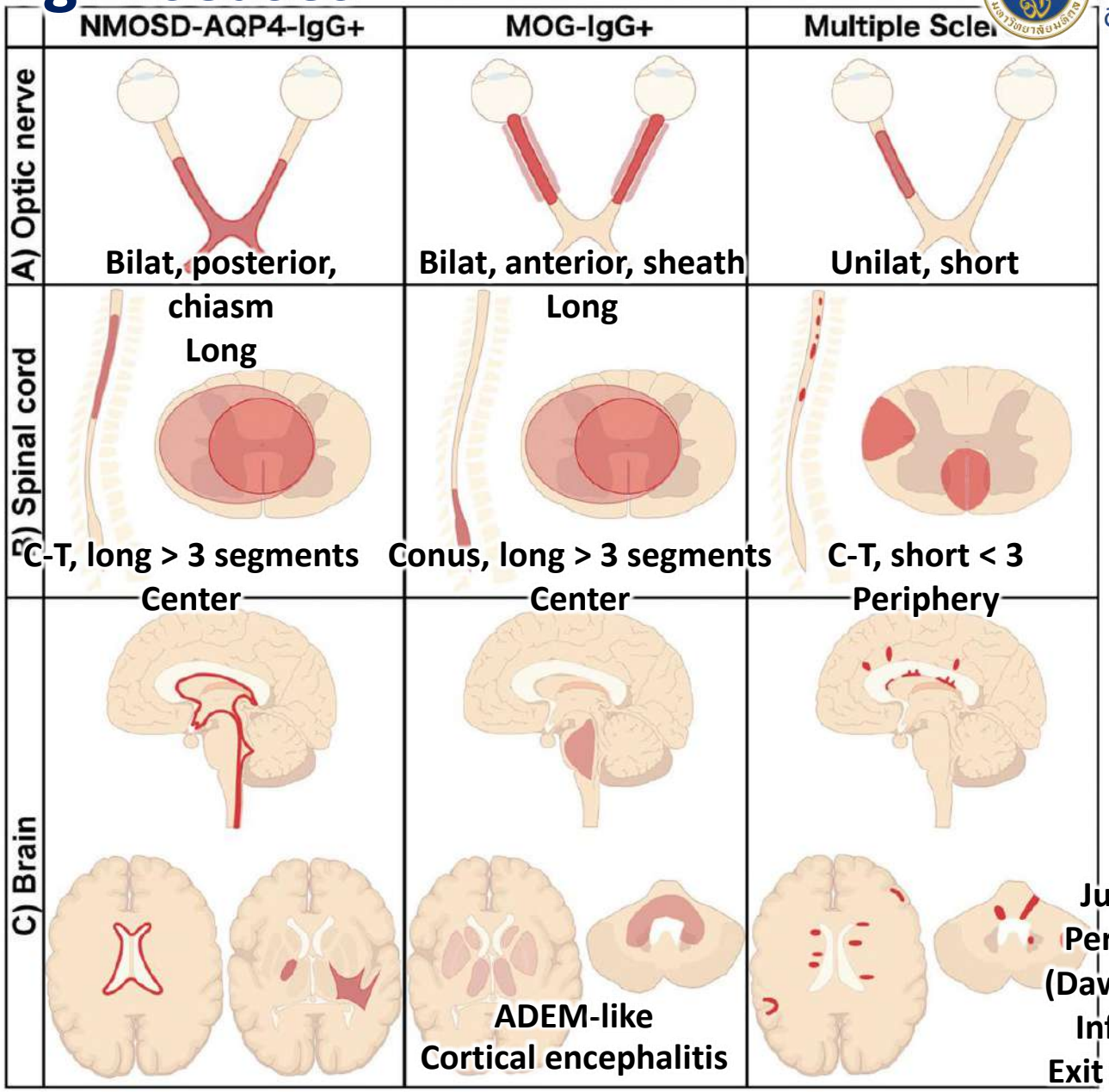


Figure 1: **Typical MRI appearance of multiple sclerosis lesions**
Characteristic anatomical locations of multiple sclerosis lesions identified on T2-weighted images, including (A) periventricular, (B) cortical or juxtacortical, (C) optic nerve, (D) infratentorial, and (E) spinal cord lesion (arrows). Novel MRI features identified on susceptibility-based images, including the (F) paramagnetic rim lesion and (G) central vein sign (arrows).

Continuum (Minneap Minn) 2013; 19(4): 1058-73
Lancet Neurol 2025; 24(10): 850-865

CNS Demyelinating Diseases

Dutra BG, et al. Radiographics 2018; 38: 169-93



Neuromyelitis Optica Spectrum Disorder (NMOSD)

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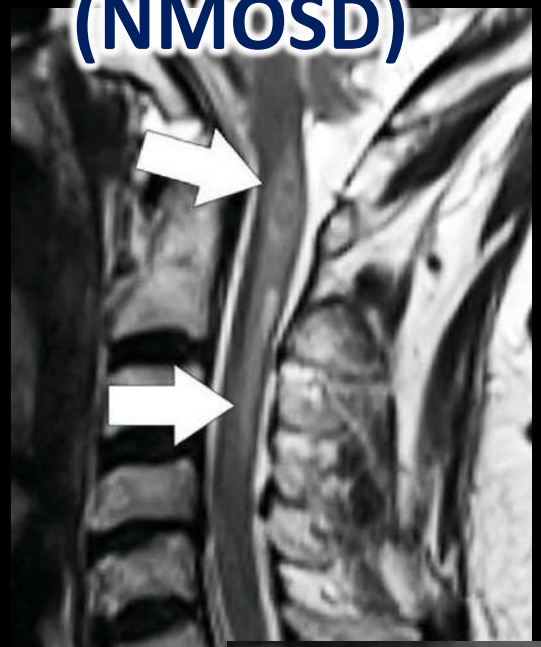
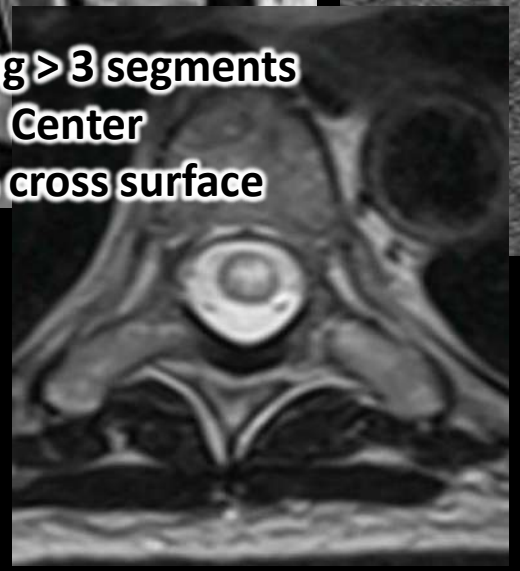
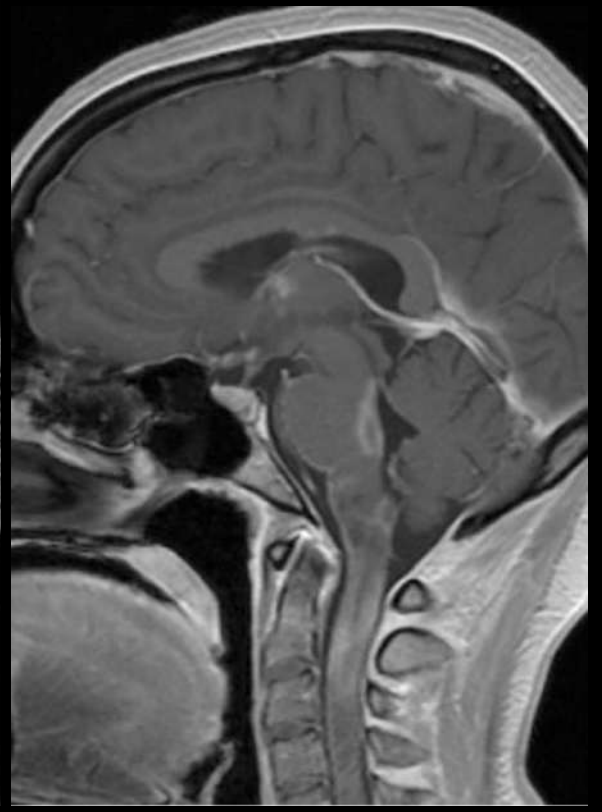


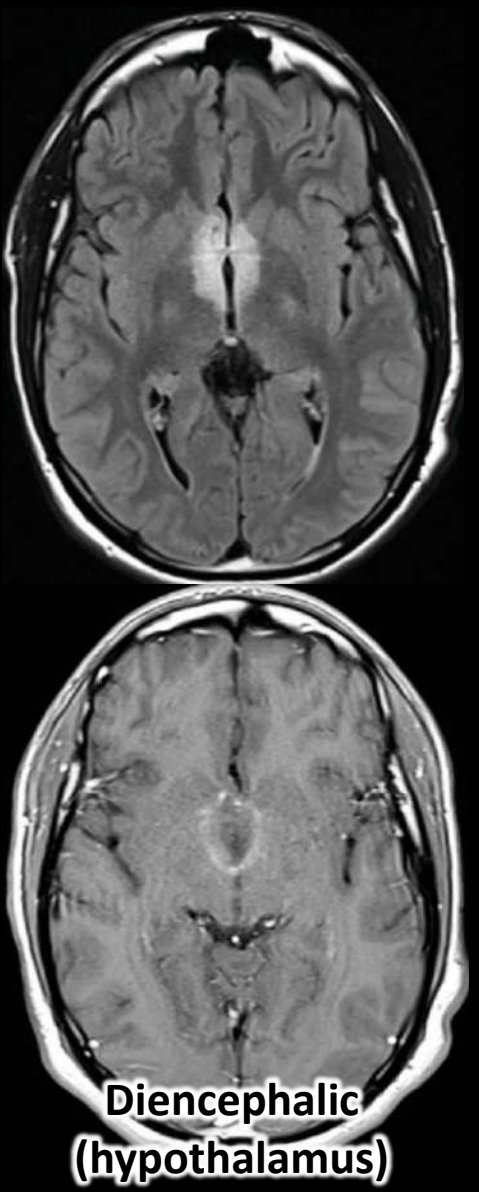


C-T, long > 3 segments
Center
>50% cross surface

Bilat, posterior, chiasm
Long



Cervicomedullary junction
Open ring enhancement
Area postrema syndrome



Diencephalic
(hypothalamus)

Acute Disseminated Encephalomyelitis (ADEM)

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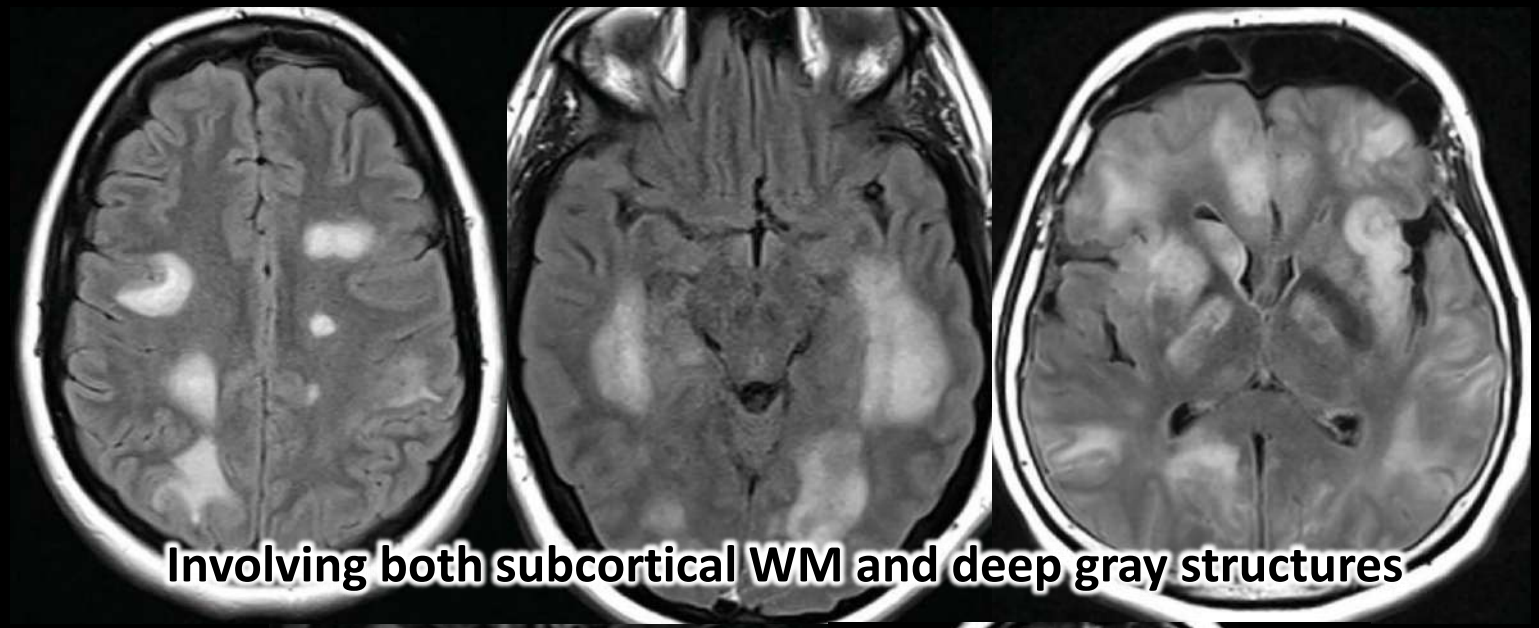

Involving both subcortical WM and deep gray structures

Open ring enhancement

Multiple Sclerosis (MS)

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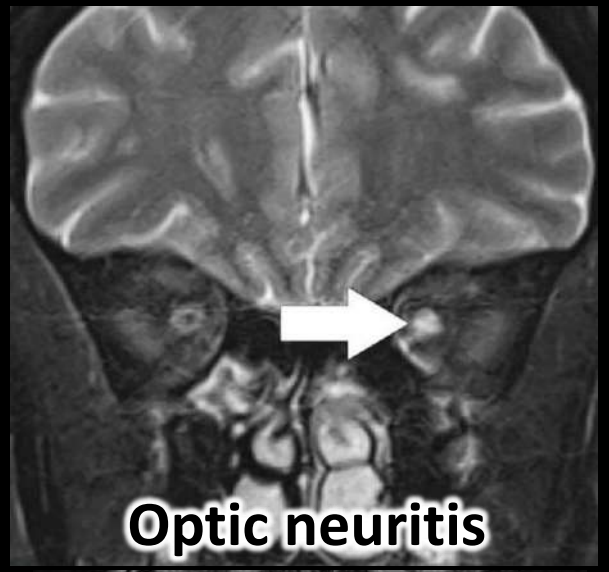
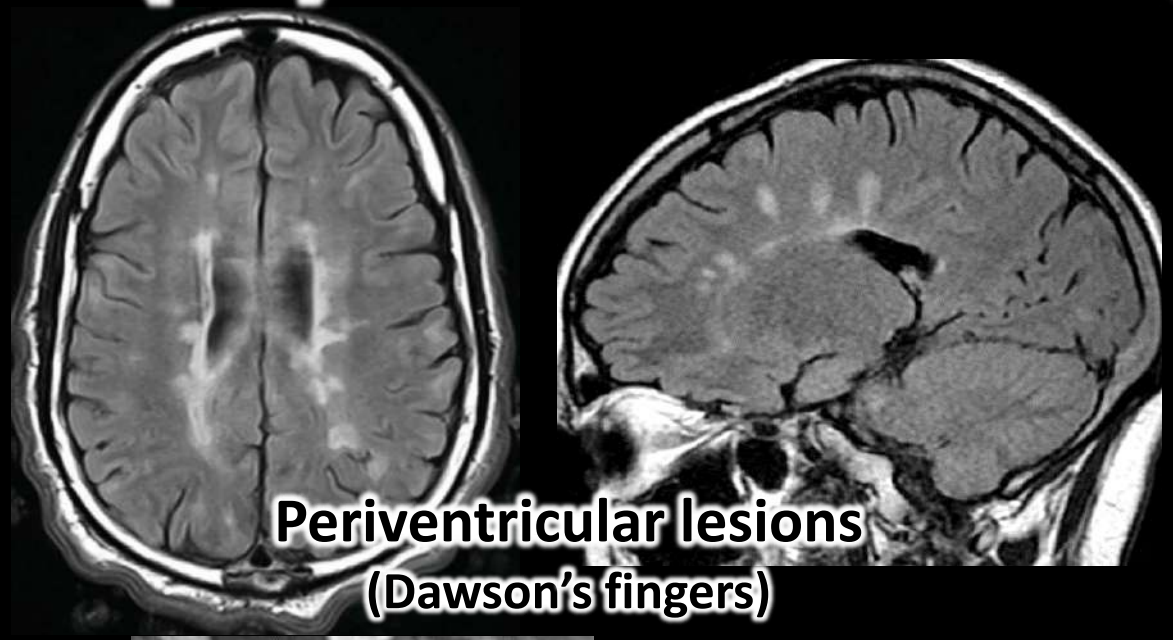


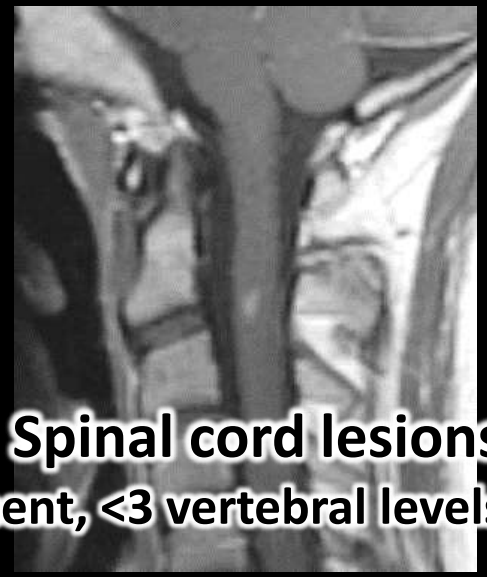
Optic neuritis



Periventricular lesions
(Dawson's fingers)

Juxtacortical lesion
(adjacent to gray matter)

Infratentorial lesion
(near CN.V exit)



Spinal cord lesions
(short segment, <3 vertebral levels, peripheral)

Osmotic Demyelinating Syndrome (ODS)

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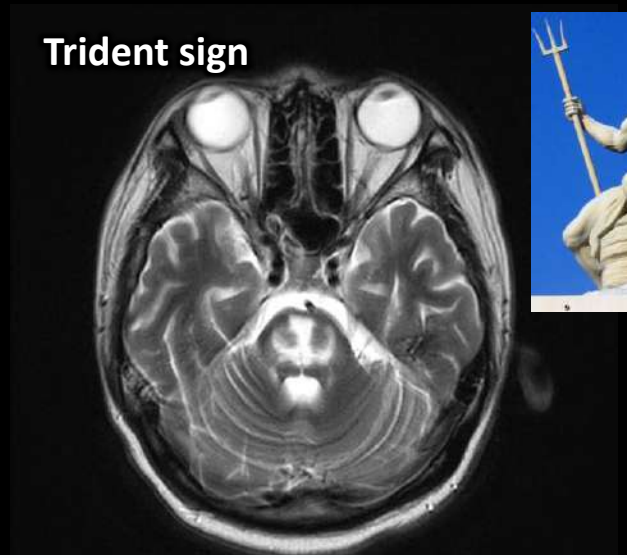
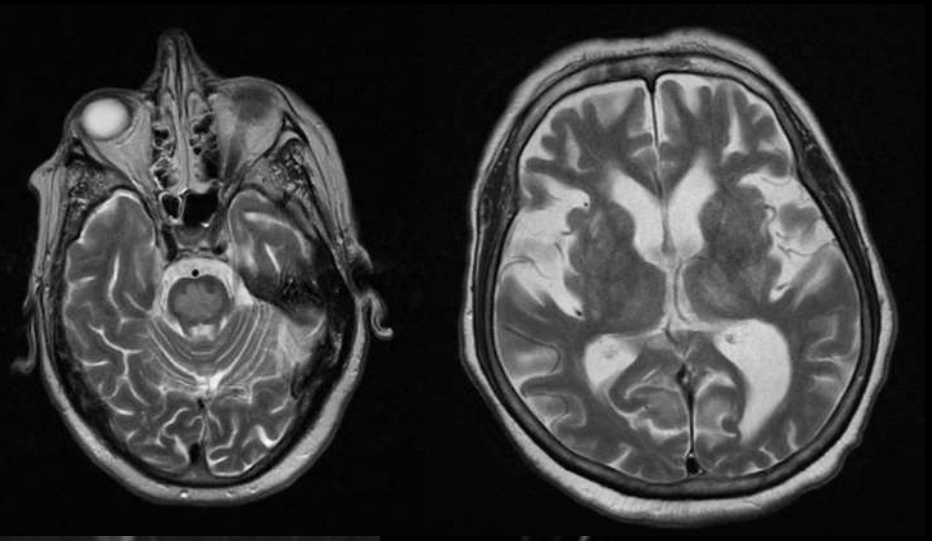
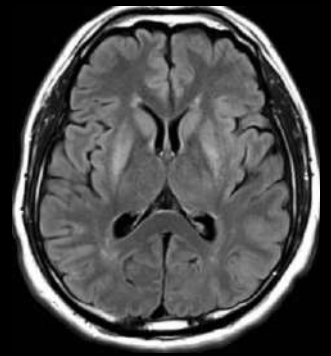






eller-Schunk[2], Christoph Schankin[1]

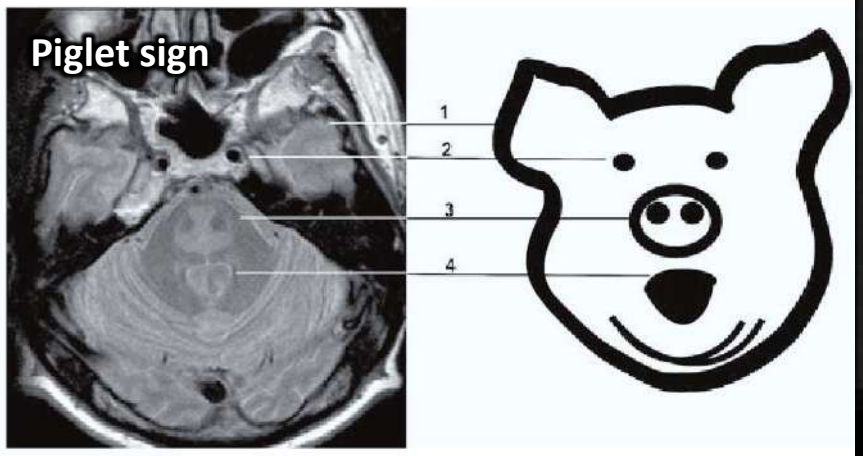
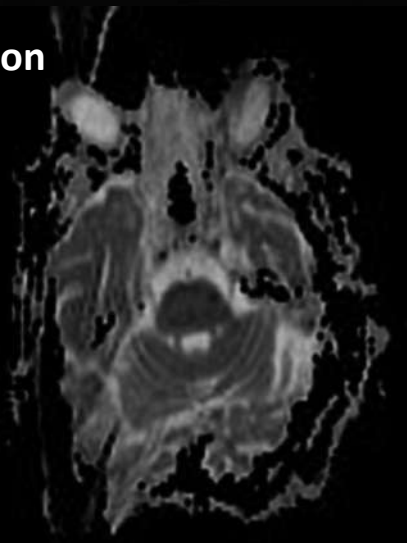
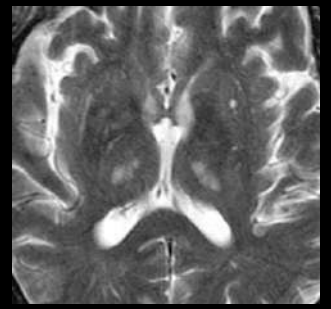


Figure 1. PdT2-weighted magnetic resonance imaging in central pontine myelinolysis. The axial scan resembles the face of a piglet with 1, Pole of temporal lobe/ear; 2, internal carotid





Central pontine myelinolysis (CPM)
Extrapontine myelinolysis (EPM)

Other White Matter Lesions

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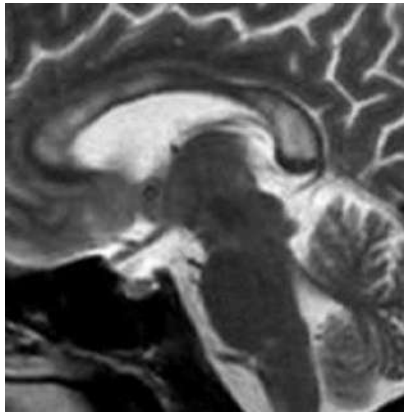
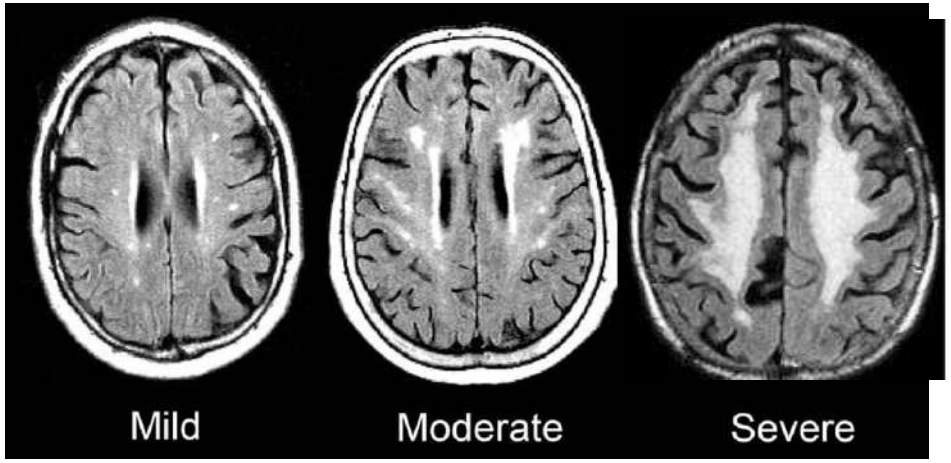


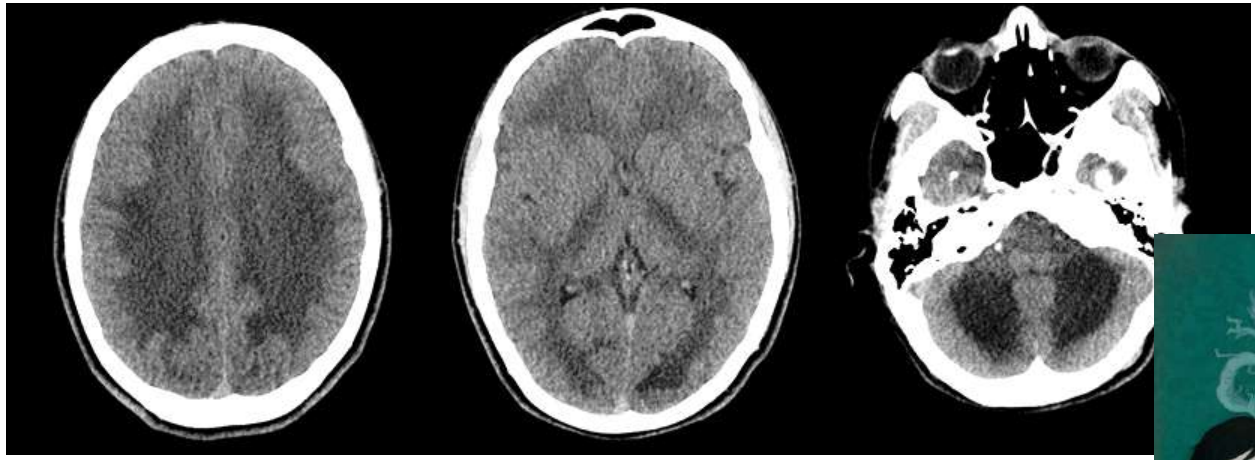
Sandwich sign in T2W



Small vessel disease
→ Vascular dementia
(Binswanger disease)

Marchiafava-Bignami disease

- Chronic alcoholism, malnutrition
- Rapid cognitive decline (transcortical apraxia, alexia without agraphia, visuospatial dysfunction), dysarthria, spasiticity



Chasing-the-dragon
(toxic leukoencephalopathy due to heroin)

Toxic Leukoencephalopathy

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Thalami, Mammillary Bodies and Tectum:
Wernicke Encephalopathy

Selective Globi Pallidi T2 High Signal:
CO Poisoning

Globi Pallidi T1 High Signal:
Chronic Hepatic Encephalopathy

Selective Putamina T2 High Signal:
Methanol Poisoning

Thalami and Globi Pallidi T2 Low Signal:
Toluene Intoxication
Parathyroid Disorders

Unilateral Striatum T1 High Signal:
Diabetic Striatopathy

Dentate Nuclei:
Metronidazole
Isoniazid
Methyl-Bromide
Wernicke Encephalopathy

Insular and Cingulate Cortex:
Hyperammonemic Encephalopathy

Periventricular White Matter Symmetric Restricted Diffusion:
ATL

ATL With Posterior Predominance:
Heroin Inhalation

"Butterfly Wing":
Heroin Inhalation

Corticospinal Tracts Involvement:
Chronic Hepatic Encephalopathy
Cobalamin Deficiency

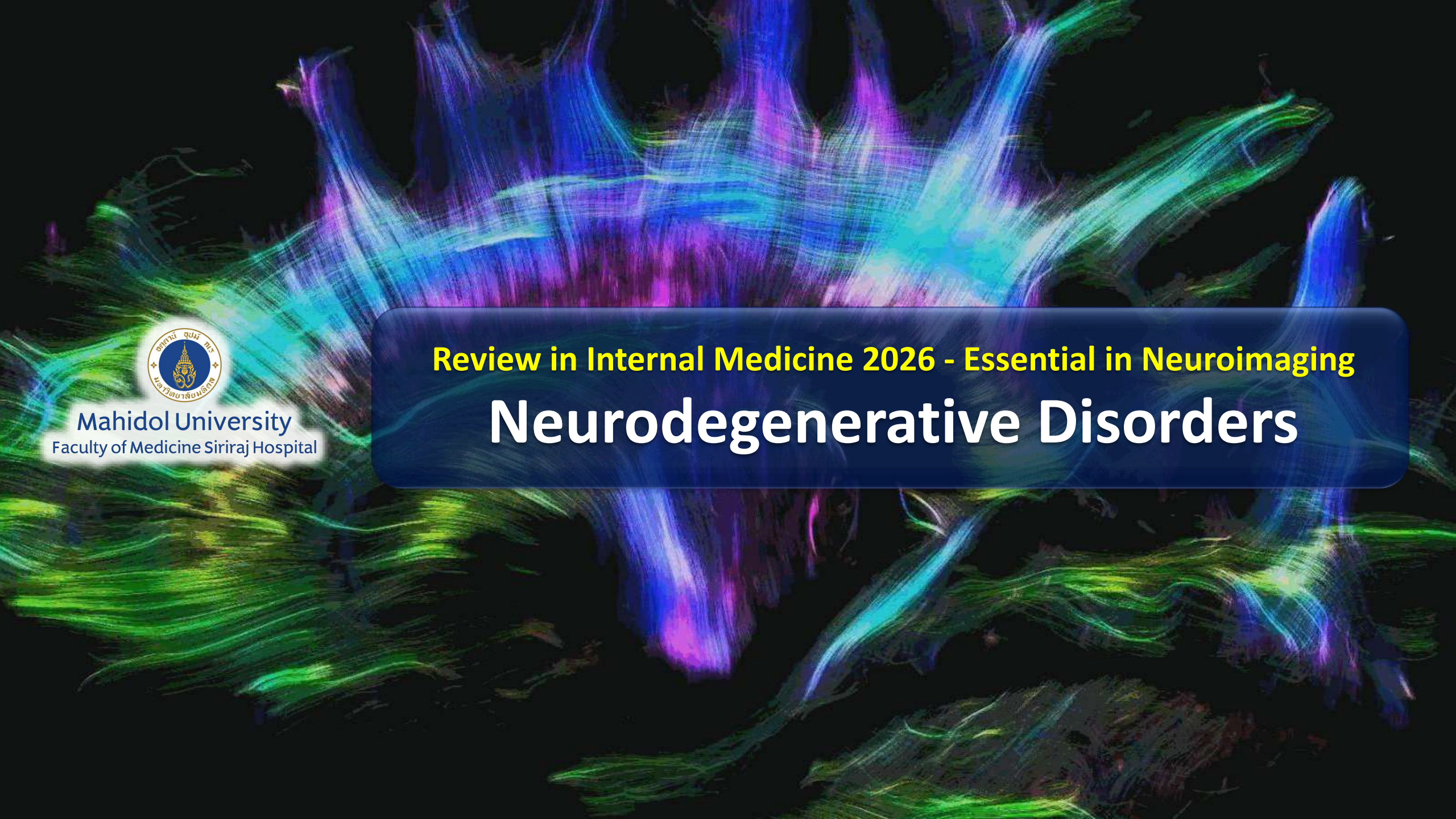
Splenium:
CLOCCs

Corpus Callosum:
MBD
CLOCCs

Parieto-Occipital Vasogenic Edema:
PRES

Central Pons:
ODS

ATL acute toxic leukoencephalopathy; CLOCC cytotoxic lesion of corpus callosum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Review in Internal Medicine 2026 - Essential in Neuroimaging
Neurodegenerative Disorders

Neurodegenerative Disorders

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Cognitive Dysfunctions

- Alzheimer's disease
- Vascular dementia
- Dementia with Lewy bodies
- Frontotemporal dementia
- Normal pressure hydrocephalus

Parkinsonism

- Idiopathic Parkinson disease
- Parkinsonism plus syndromes
  - DLB
  - PSP
  - CBS
  - MSA
- 2º parkinsonism (e.g. NPH)
- Heredodegenerative parkinsonism
  - Wilson disease
  - Huntington disease
  - PKAN

Neurodegenerative Disorders

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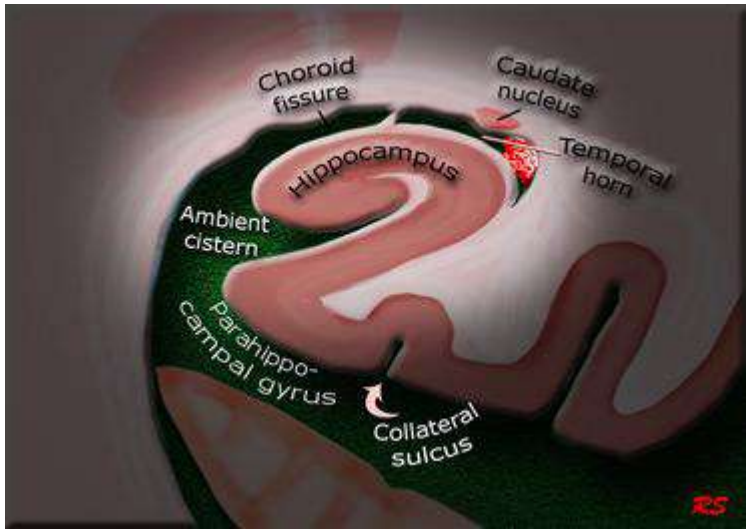
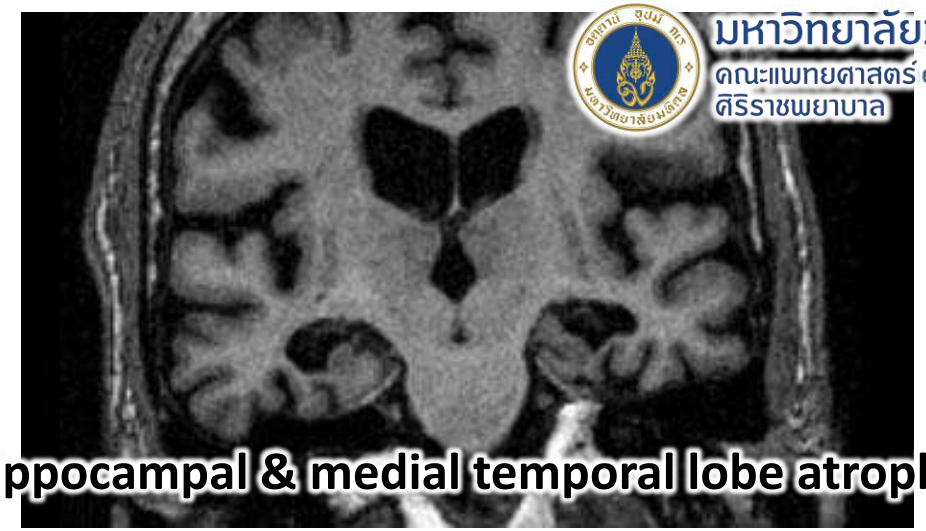
Dementia	Motor symptoms/signs	Clinical clues
Alzheimer's disease	-	Loss of episodic memory
Vascular dementia	Spasticity, BBK Lower body parkinsonism	Loss of working memory
Normal pressure hydrocephalus	Lower body parkinsonism Magnetic gait	Loss of working memory Urinary incontinence
Dementia with Lewy bodies	Parkinsonism	Dementia (<1 y from motor onset) REM sleep behavior disorder Visual hallucination Supersensitivity to typical antipsychotics
Parkinson disease with dementia	Parkinsonism (asymmetrical) Rest tremor, rigidity Postural instability	Dementia (>3-5 y from motor onset)
Frontotemporal dementia	-	Behavioral change, loss of sympathy Hypersexuality/hyperorality Executive dysfunction Language problem (nonfluent aphasia)

Typically normal MRI

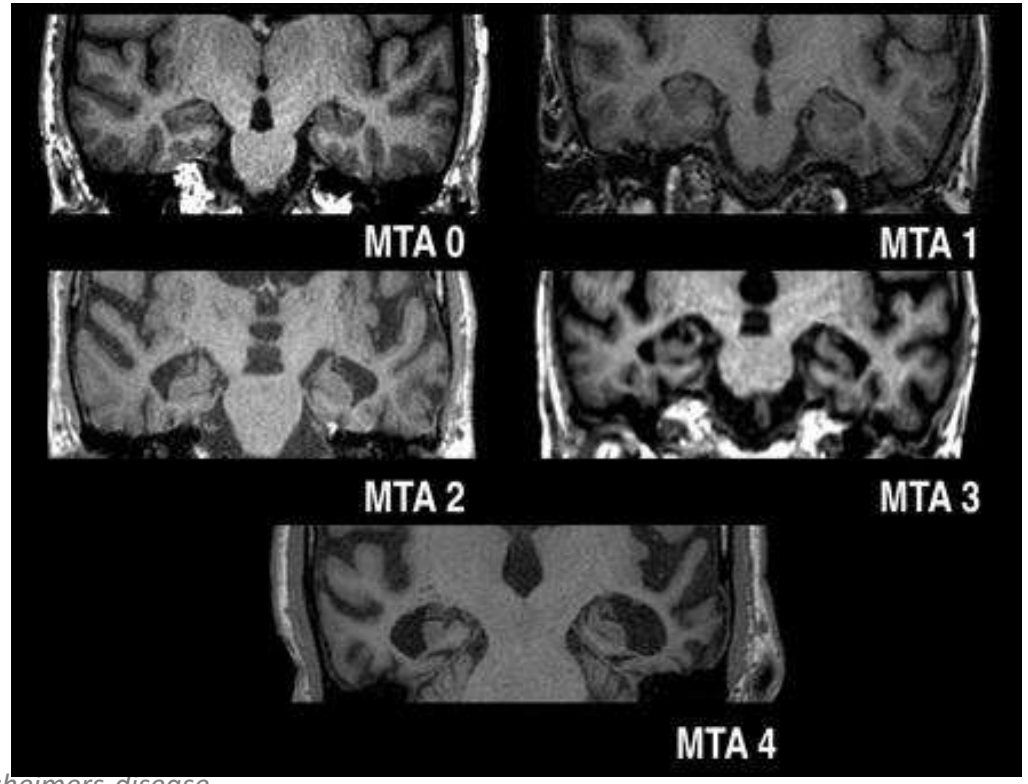
Alzheimer's Disease



MTA visual rating scale			
Score	Width of choroid fissure	Width of temporal horn	Height of hippo-campal formation
0	N	N	N
1	↑	N	N
2	↑↑	↑↑	↓
3	↑↑↑	↑↑↑	↓↓
4	↑↑↑	↑↑↑	↓↓↓



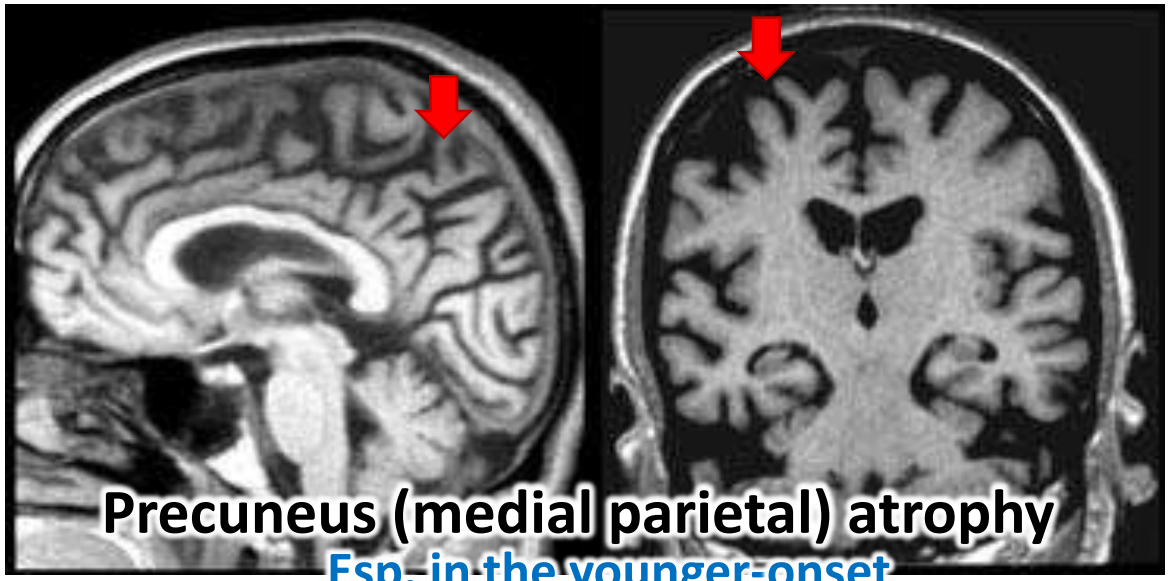
Hippocampal & medial temporal lobe atrophy



MTA medial temporal atrophy

https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease

Alzheimer's Disease

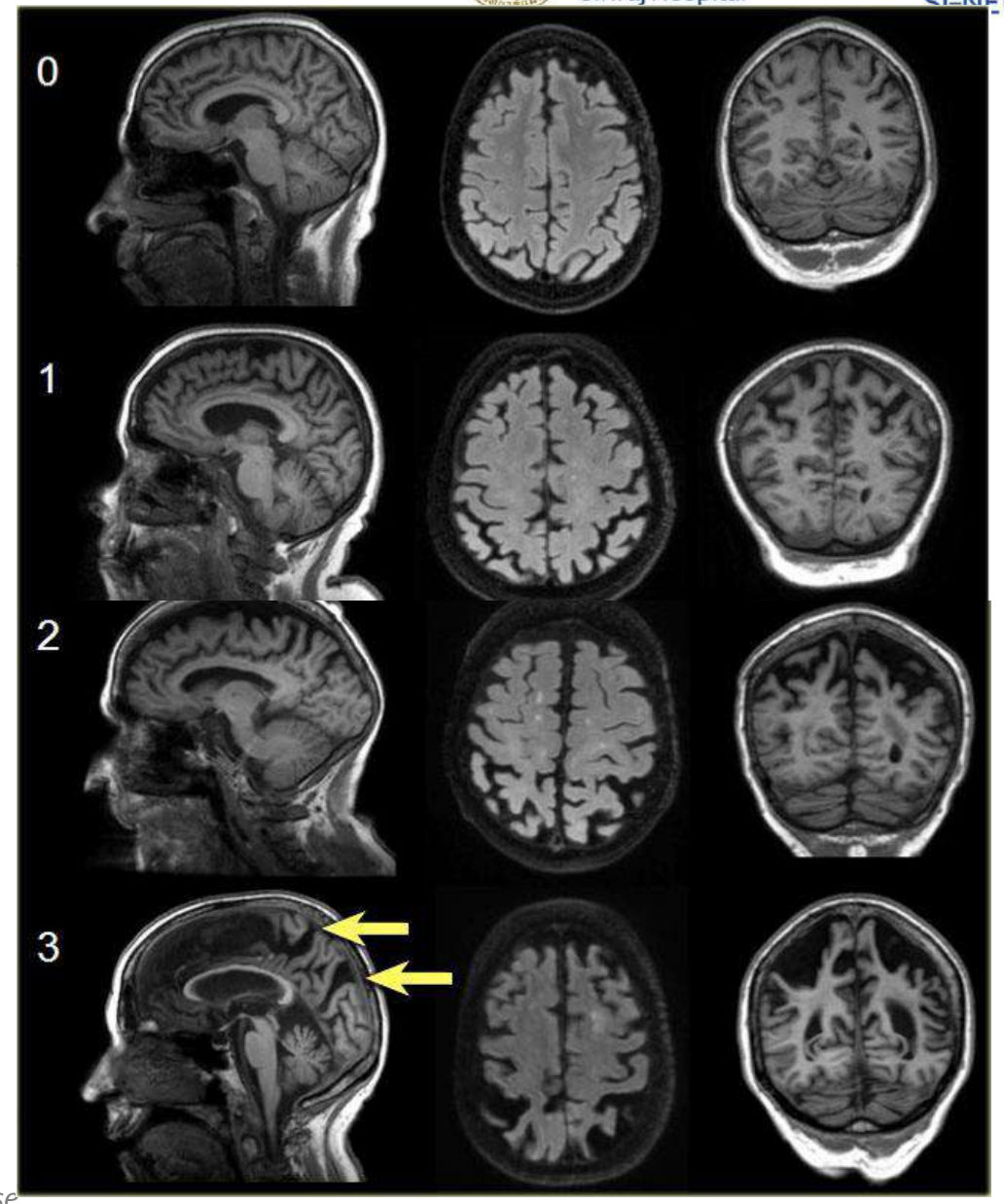


Precuneus (medial parietal) atrophy

Esp. in the younger-onset

Koedam score for Parietal Atrophy

Grade 0	No cortical atrophy	Closed sulci of parietal lobes and cuneus
Grade 1	Mild parietal cortical atrophy	Mild widening of posterior cingulate and parieto-occipital sulci
Grade 2	Substantial parietal atrophy	Substantial widening of sulci
Grade 3	End-stage „knife-blade" atrophy	Extreme widening of posterior cingulate and parieto-occipital sulci

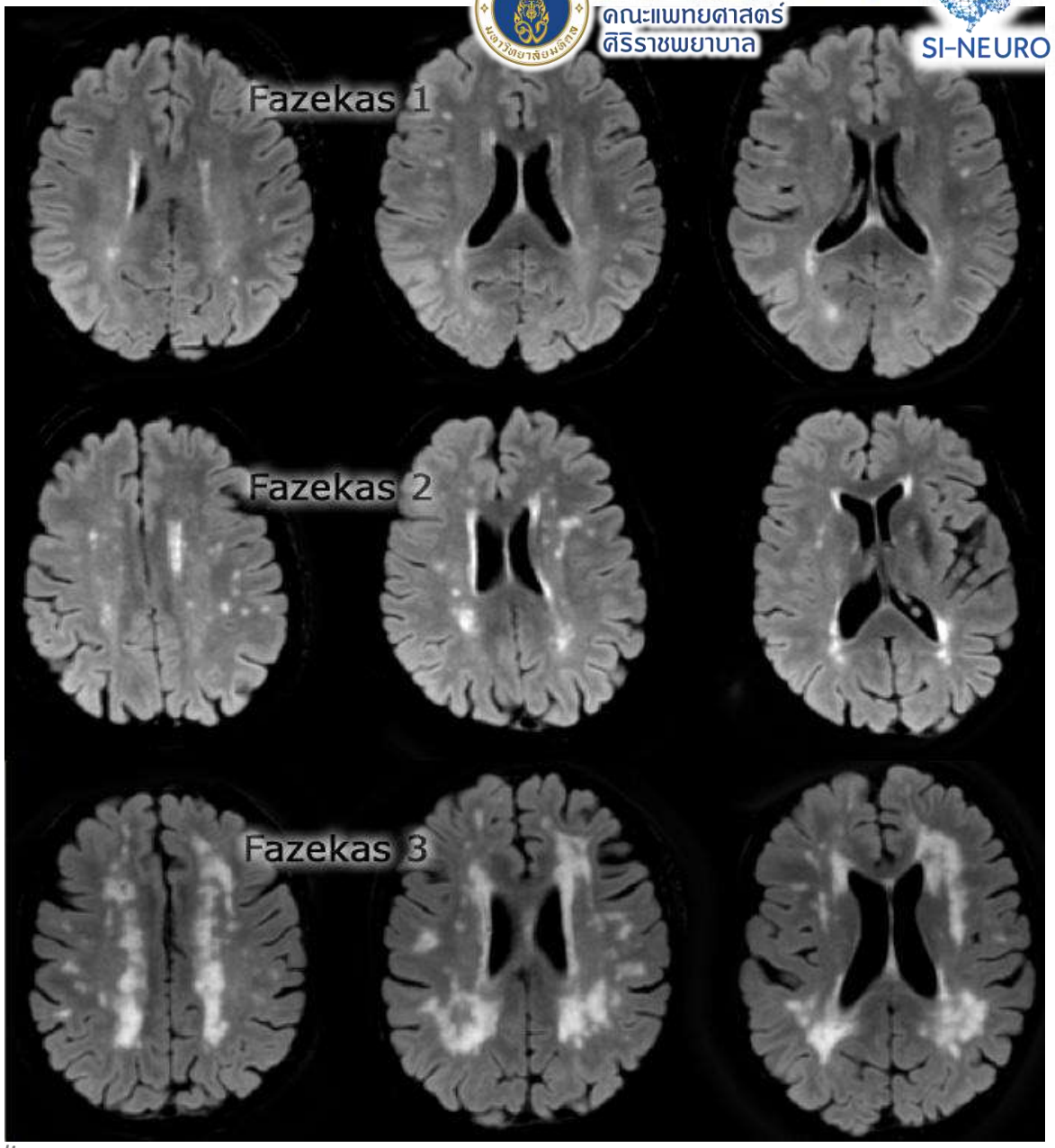


https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease

Vascular Dementia

Score:

- Fazekas 0: None or a single punctate WMH lesion
- Fazekas 1: Multiple punctate lesions
- Fazekas 2: Beginning confluency of lesions (bridging)
- Fazekas 3: Large confluent lesions



https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease

Vascular Dementia

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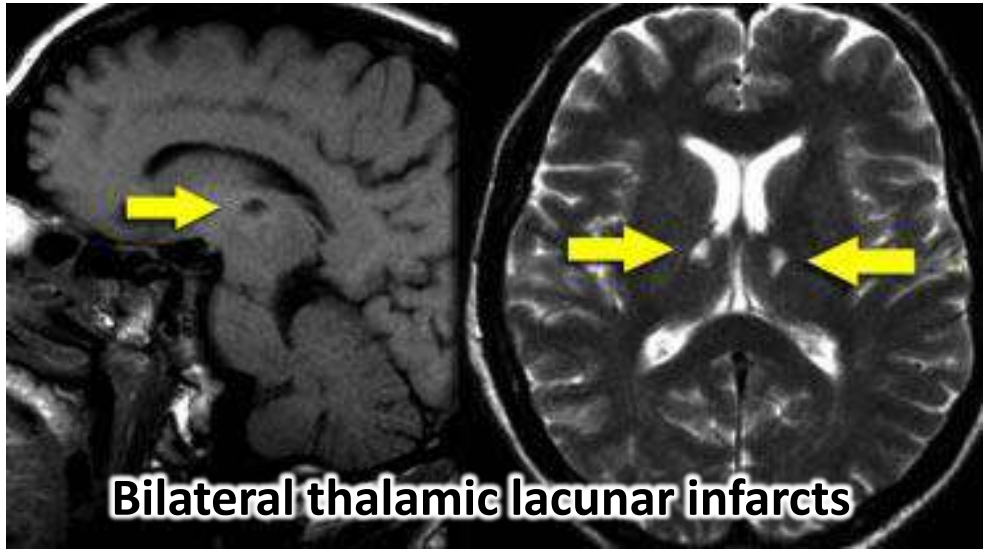
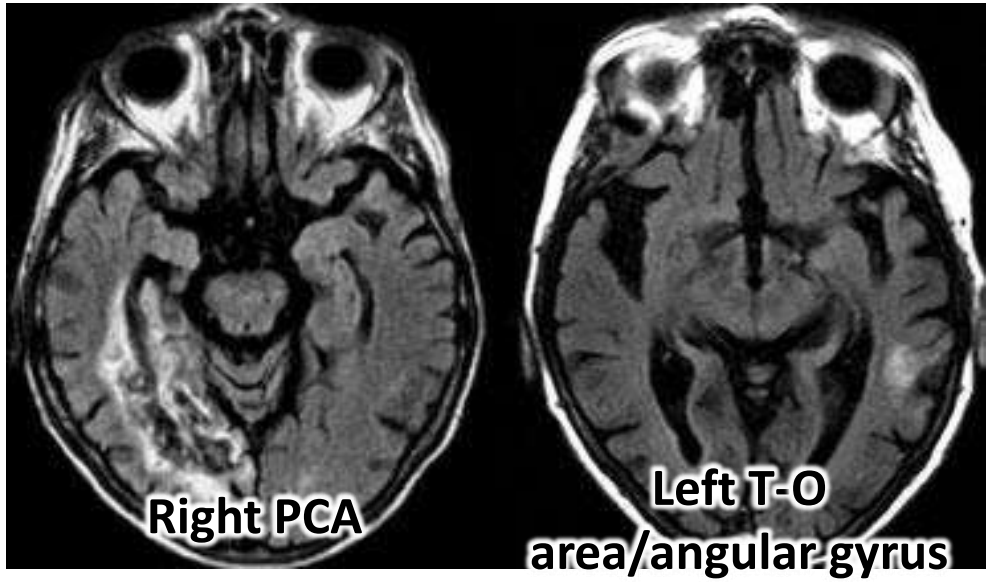
Strategic Infarctions	
Medial Cerebral Artery	Parieto-temporal or Temporo-occipital associatoion areas Angular gyrus
Posterior Cerebral Artery	Paramedian thalamic Inferior medial temporal lobe
Watershed infarctions	Superior frontal or parietal
Lacunar infarctions	Bilateral thalamic

Cognitive dysfunction in VaD can be the result of (2):

- Large vessel infarctions:
  - Bilateral in the anterior cerebral artery territory.
  - Parietotemporal- and temporo-occipital association areas of the dominant hemisphere (angular gyrus included)
  - o Posterior cerebral artery territory infarction of the paramedian thalamic region and inferior medial temporal lobe of the dominant hemisphere
- Watershed infarctions in the dominant hemisphere (superior frontal and parietal)
- Small vessel disease:
  - Multiple lacunar infactions in frontal white matter (≥2) and basal ganglia (≥2)
  - WMLs (at least more than 25% of WM)
  - Bilateral thalamic lesions





https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease

Dementia with Lewy Bodies (DLB)

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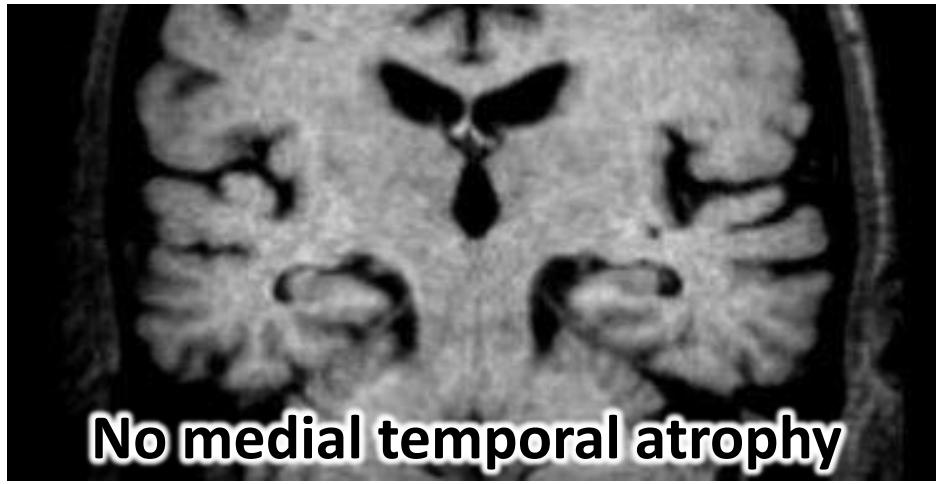
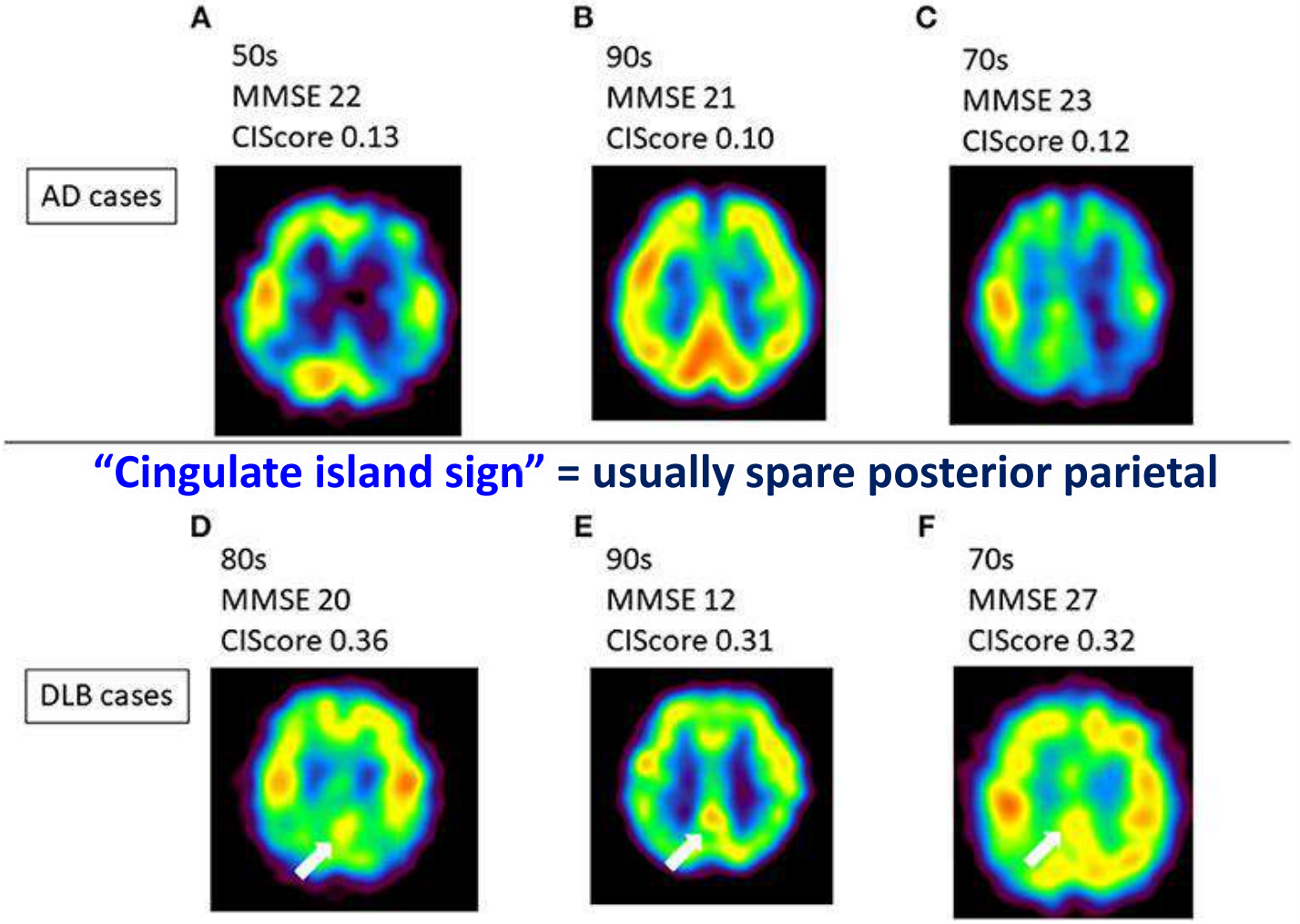
Mainly clinical diagnosis!!

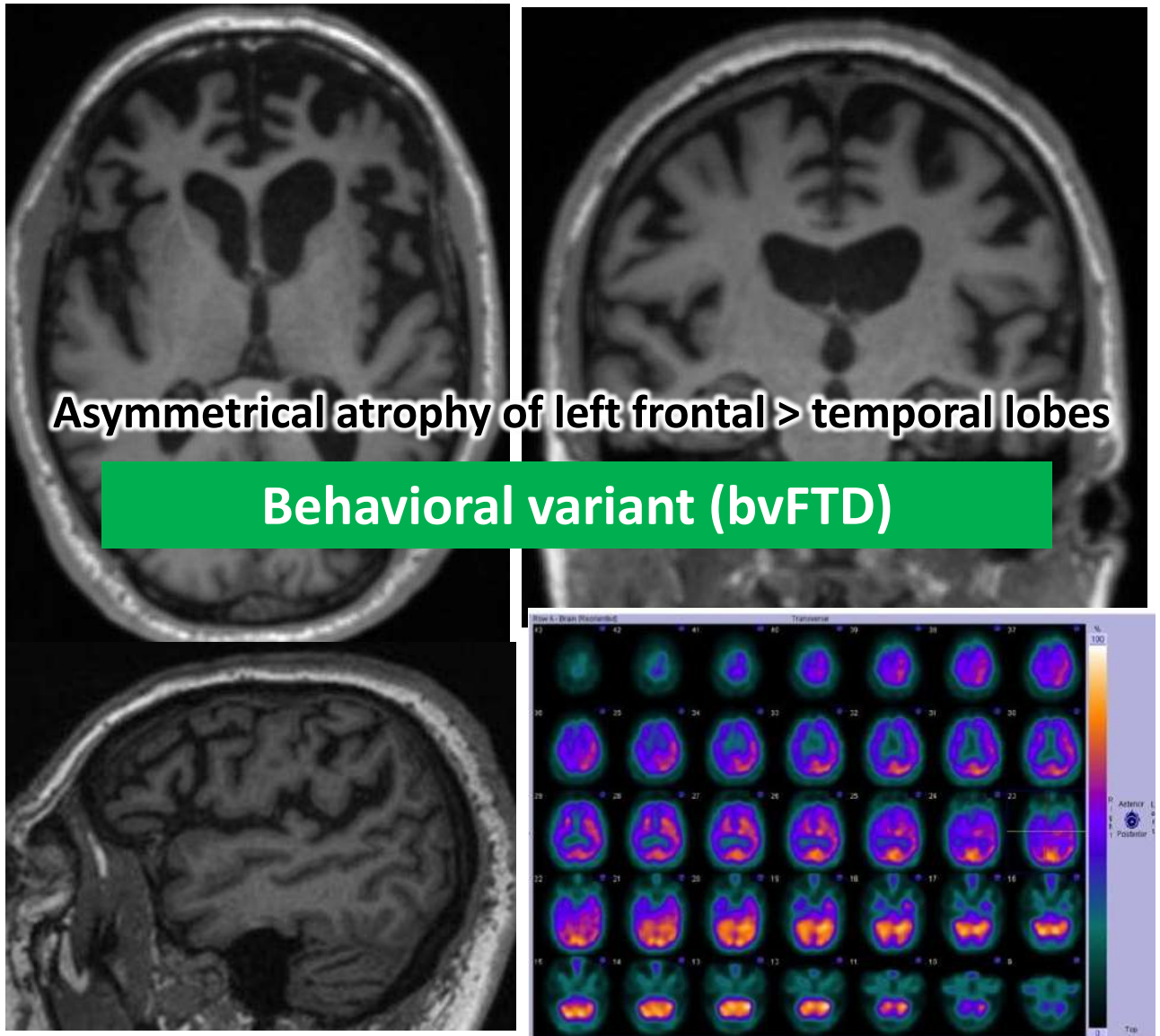


FDG-PET scan



https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease
Kanetaka H, et al. Front Neurol 2020; doi: 10.3389/fneur.2020.568438

Frontotemporal Dementia (FTD)



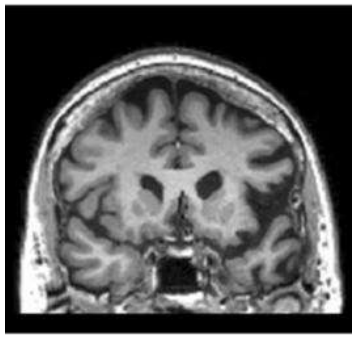
Asymmetrical atrophy of left frontal > temporal lobes

Behavioral variant (bvFTD)

https://radiologyassistant.nl/neuroradiology/dementia/role-of-mri#specific-diseases-alzheimers-disease
Ruksenaite J, et al. Curr Neurol Neurosci Rep 2021; 21(3)

Primary progressive aphasia (PPA)

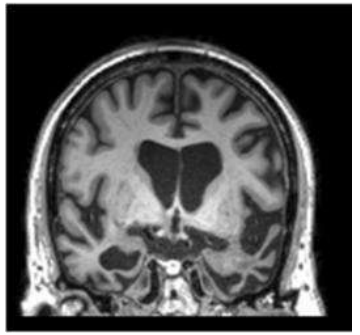
nfvPPA



Nonfluent variant

- Left inferior frontal, insular, ant-sup temporal

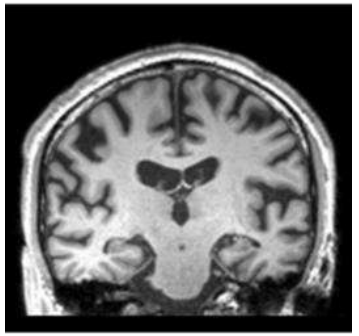
svPPA



Semantic variant

- Left anterior inferior & mesial temporal lobe

lvPPA



Logopenic variant

- Left T-P junction

Parkinson vs. Parkinsonism-Plus

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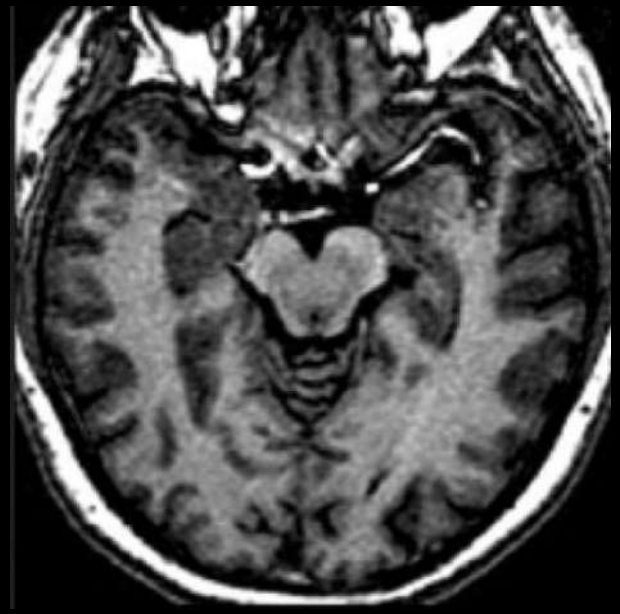
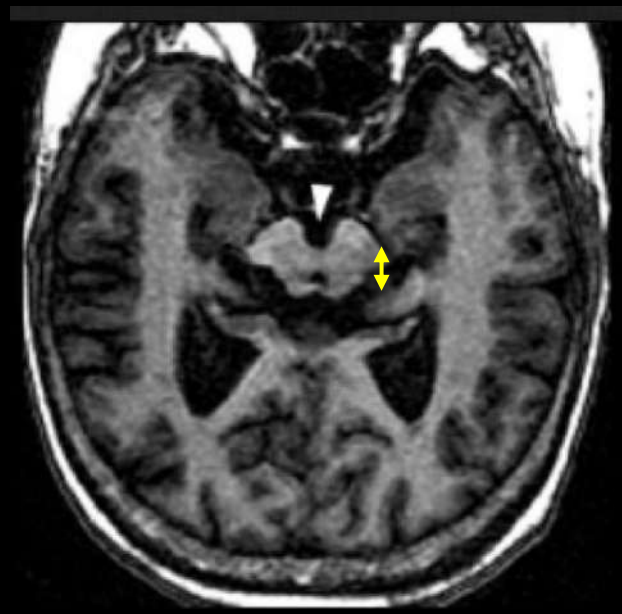
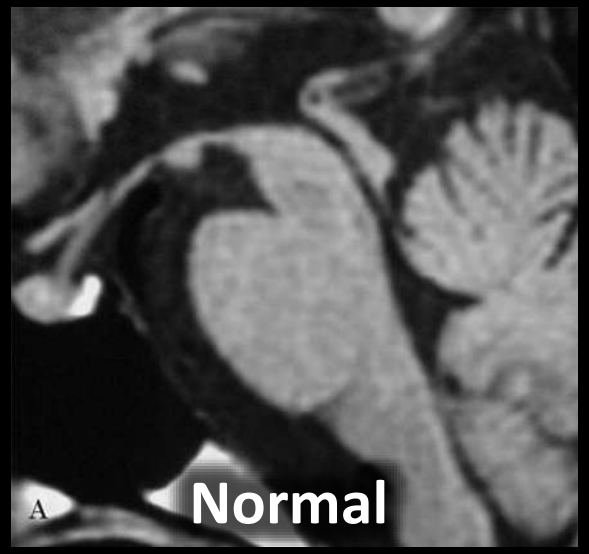
Features	PD	PSP	MSA	CBS	DLB
Motor symmetry	+	+++	+++	+	++
Axial rigidity	++	+++	++	++	++
Tremor	+++	-	-	+	+
Limb dystonia	+	+	+	+++	-
Pyramidal signs	-	+	++	+++	-
Apraxia	-	+	-	+++	-
Postural instability	++	+++	++	+	++
Vertical supranuclear gaze restriction	+	+++	++	++	-
Frontal behavior	+	+++	+	++	++
Visual hallucination	+	-	-	+	+++
Dysautonomia	+	-	++	-	+
Levodopa response early in course	+++	+	+	-	+
Levodopa response late in course	++	-	+	-	+

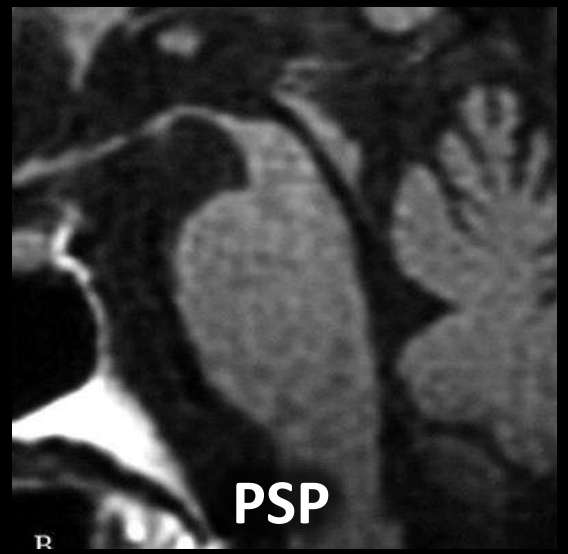
CBS corticobasal syndrome; DLB dementia with Lewy body; MSA multiple system atrophy; PD Parkinson disease; PSP progressive supranuclear palsy

Progressive Supranuclear Palsy (PSP)









Midbrain :
- **Short A-P diameter**
- **Dilation of 3rd vent**

“Hummingbird sign”
“Mickey mouse sign”
“Morning glory sign”

Multiple System Atrophy (MSA)

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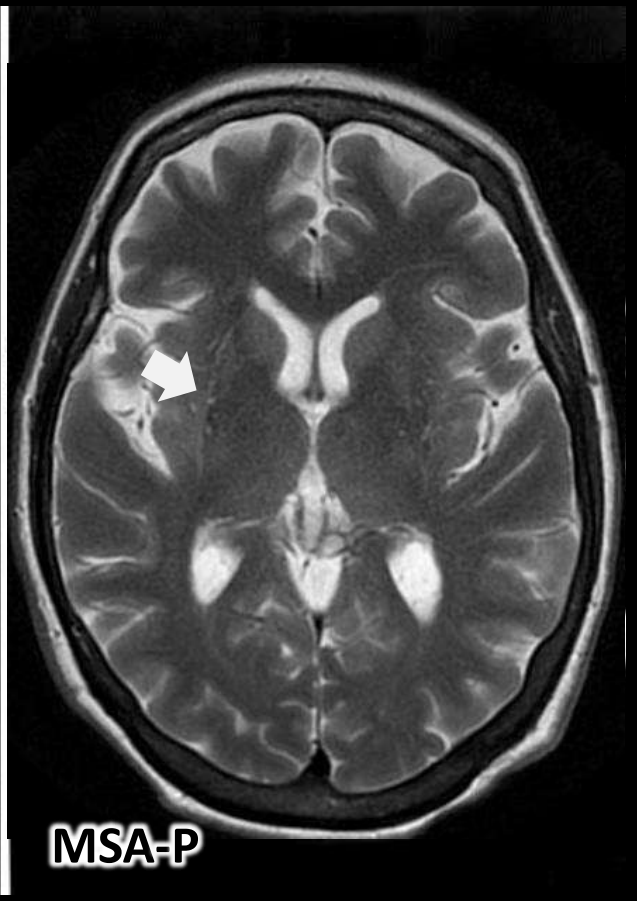
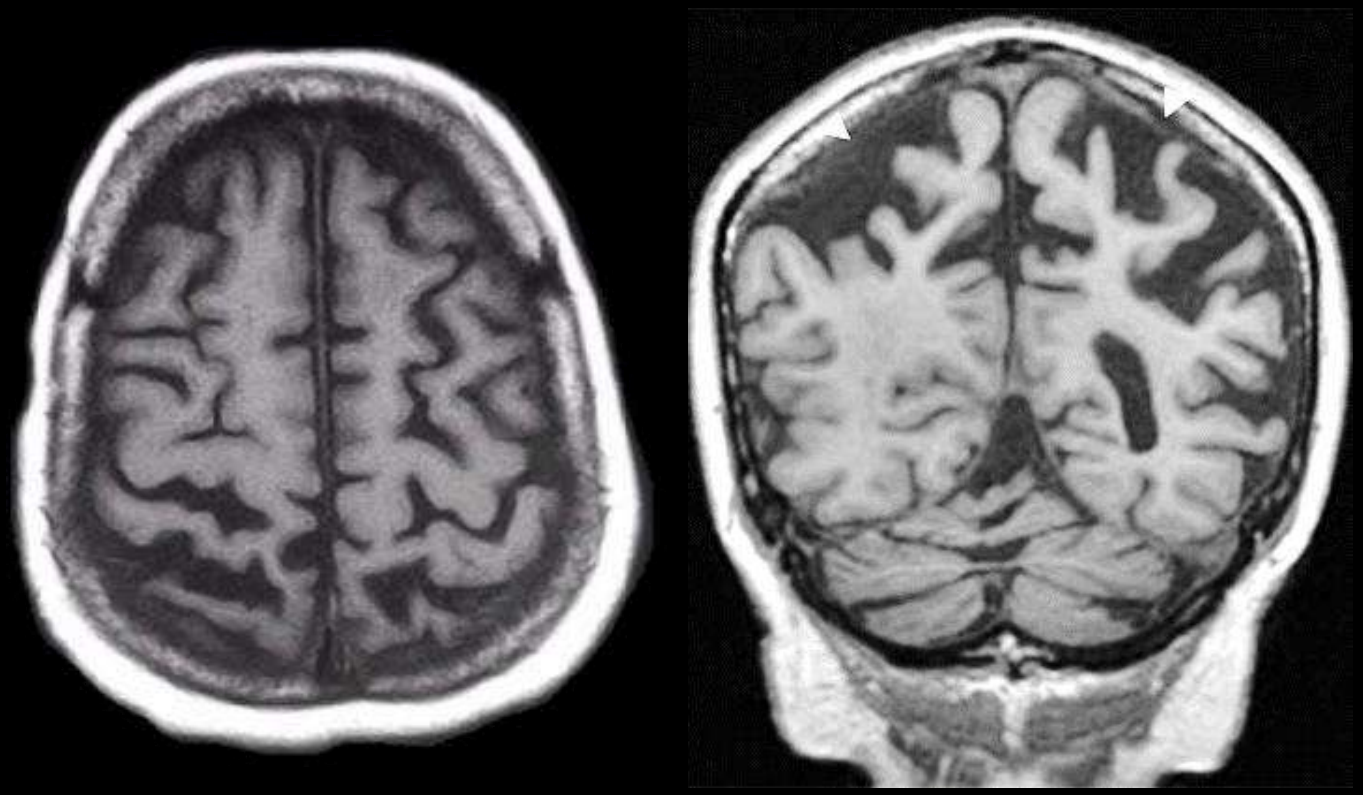


Pons : Hot cross bun sign

Cerebellar peduncle : Hypersignal in T2W

Putamen : Lateral slit-like hyperintensity

Cortico-Basal Syndrome (CBS)



MRI :

- **Asymmetric posterior cortical atrophy**
- **Esp. parietal lobe**

Wilson's Disease

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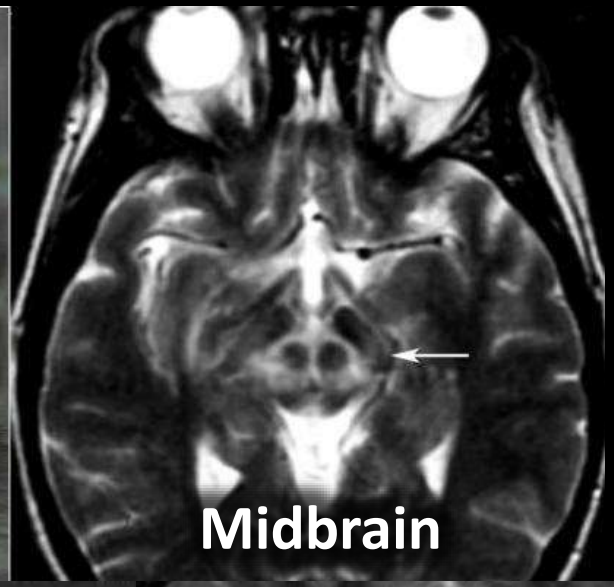

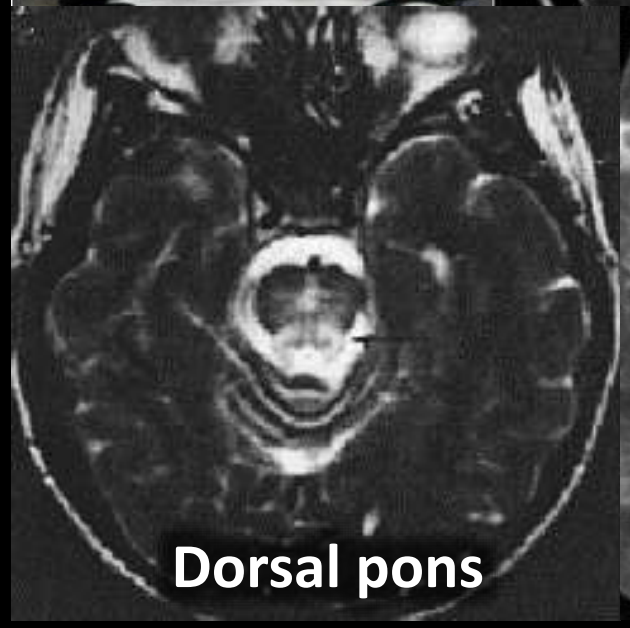

Midbrain :

Face of the giant panda

Dorsal pons :

Face of the miniature panda

Basal ganglion :

Bright claustrum

Pantothenate Kinase Associated Neurodegeneration (PKAN)

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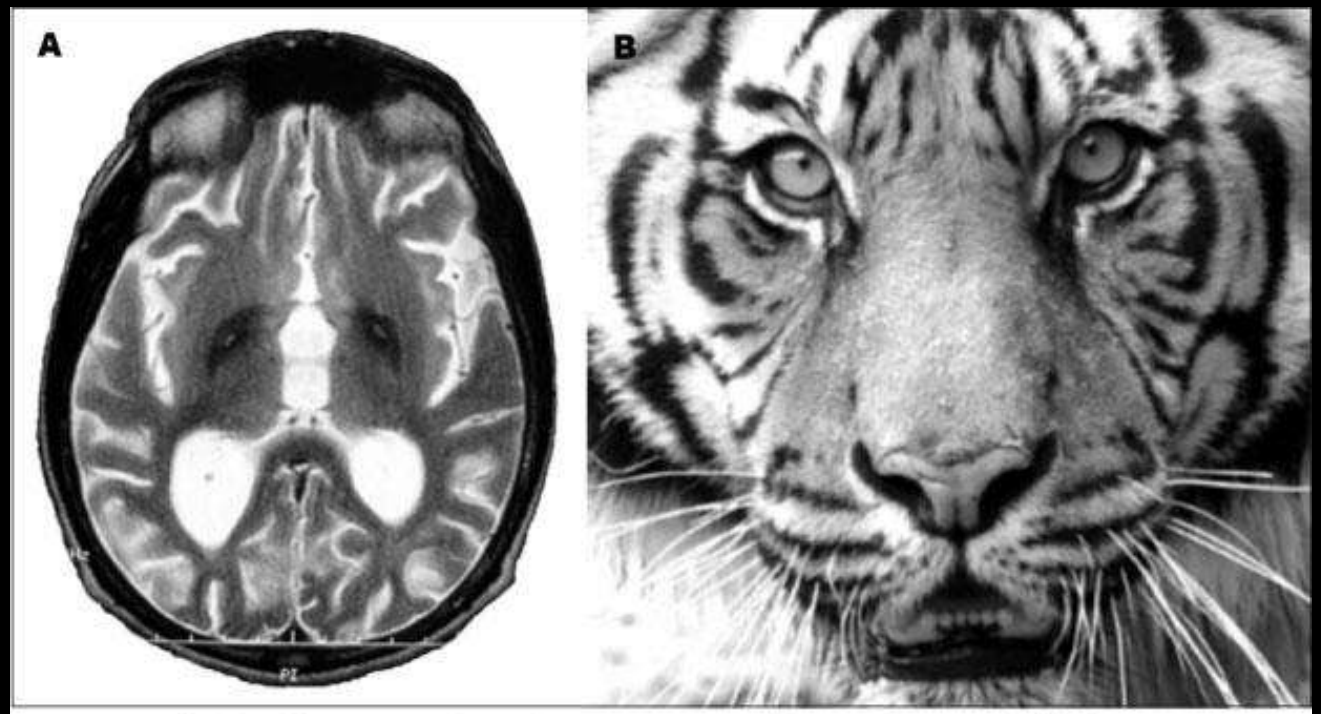
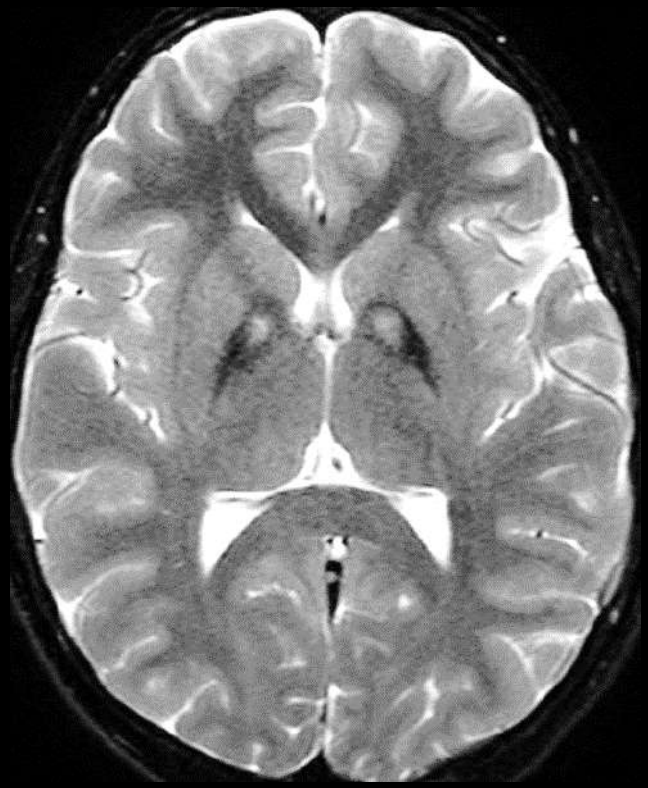


Fig 7. T2-weigthed axial brain RMI showing hyperintense signal (necrosis) surrounded by hyperintense (iron accumulation) at the medial aspects of the globus pallidus [A]. The image resembles tiger eyes - "Eye-of-the-tiger-sign" [B].

Basal ganglia :

Eyes of the tiger



Huntington's Disease (Chorea)

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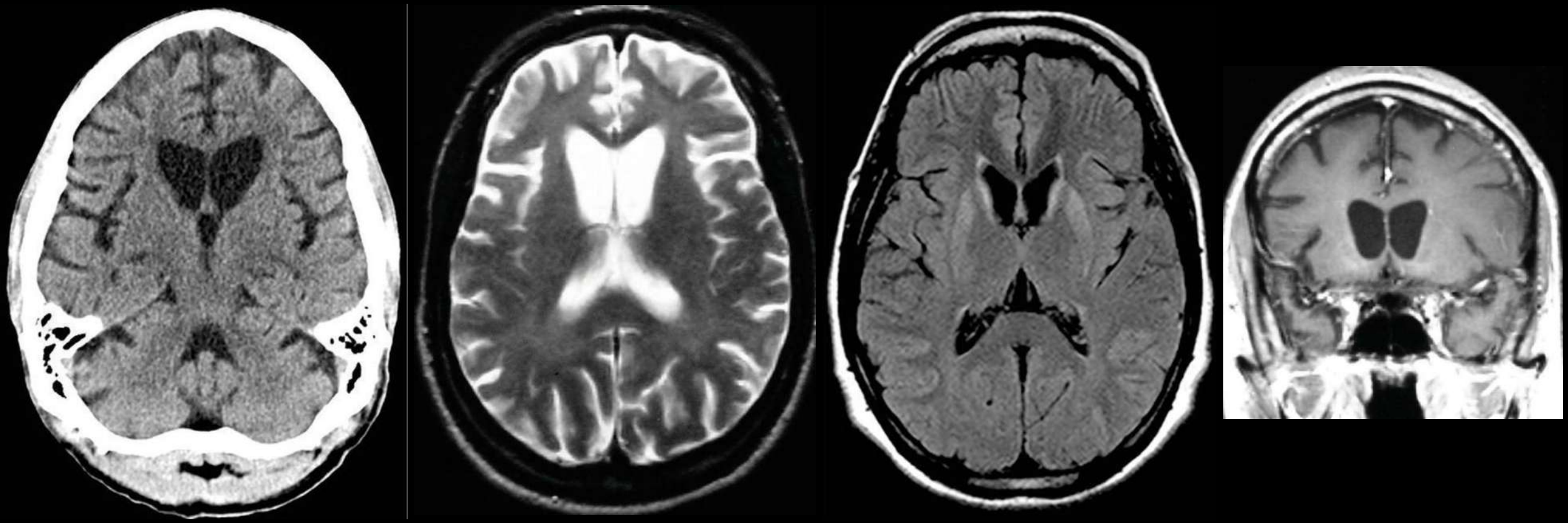
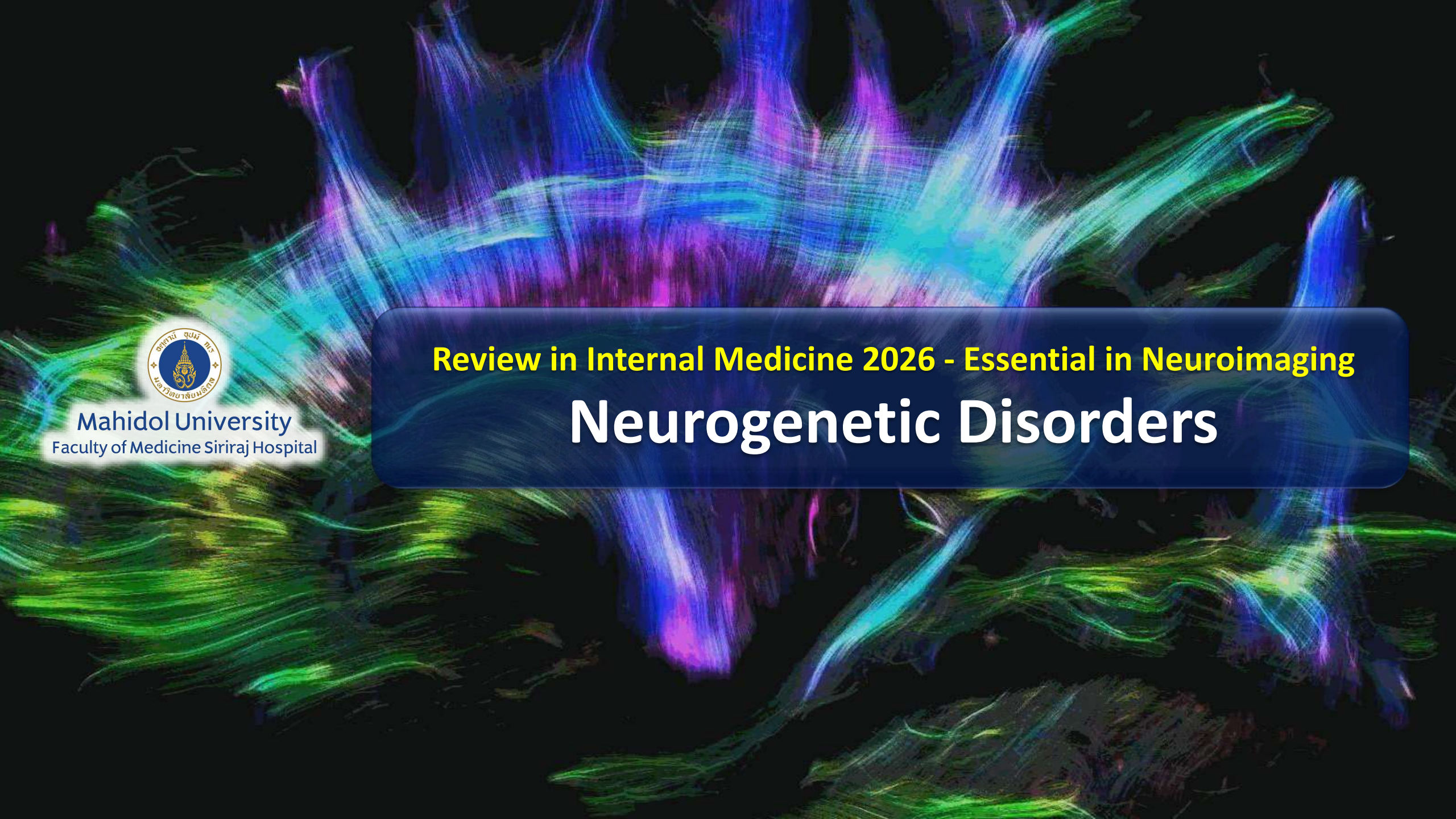


Caudate head atrophy with straightening of walls of lateral ventricles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Neurogenetic Disorders

Selected Neurogenetic Syndromes

- Neurofibromatosis type 1 (NF1)
- Neurofibromatosis type 2 (NF2)
- Tuberous sclerosis complex
- Sturge-Weber syndrome
- Von Hippel Lindau syndrome

Neurofibromatosis Type 1 (NF1)

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A diagnosis of NF1 can be made in an individual with 2 or more of the following:

Skin 3	*	≥6 café au lait macules (>5 mm in greatest dimension for prepubertal persons and >15 mm in greatest dimension for postpubertal persons)
	*	Axillary or inguinal freckles
	*	≥2 neurofibromas (any type) or 1 plexiform neurofibroma
Eye 2	*	Optic glioma
	*	≥2 Lisch nodules
Bone	*	Sphenoid dysplasia, tibial pseudoarthrosis, or other distinctive bone lesion
FamHx	*	First-degree relative with a diagnosis of NF1

Abbreviation: NF1, Neurofibromatosis type 1.

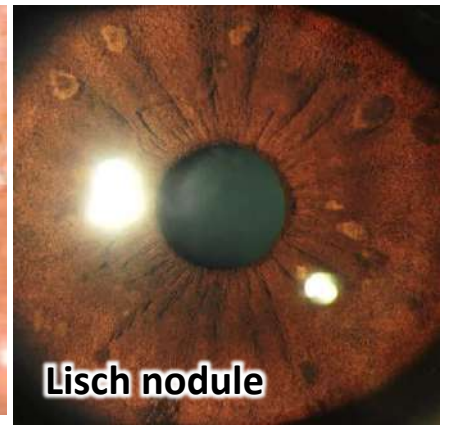

Café au lait macules


Axillary frecklings


Cutaneous neurofibroma


Plexiform neurofibroma


Eyelid neurofibroma


Lisch nodule

Neurofibromatosis Type 1 (NF1)

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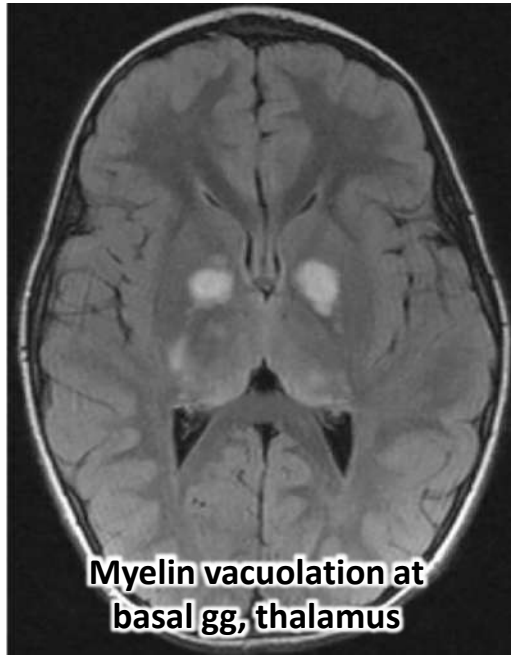
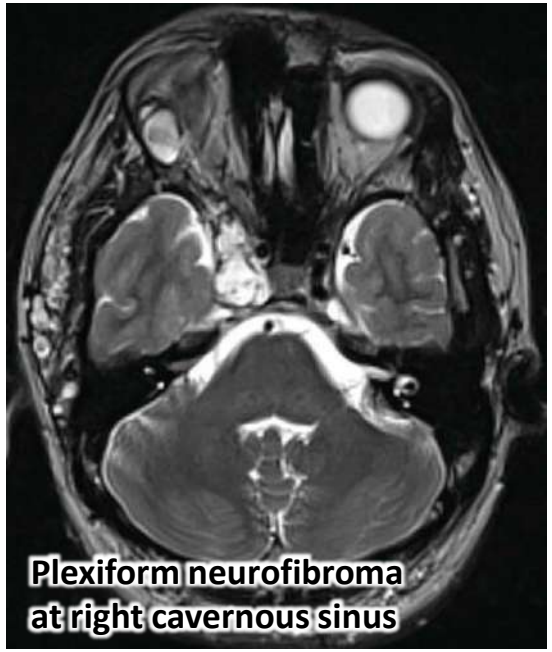
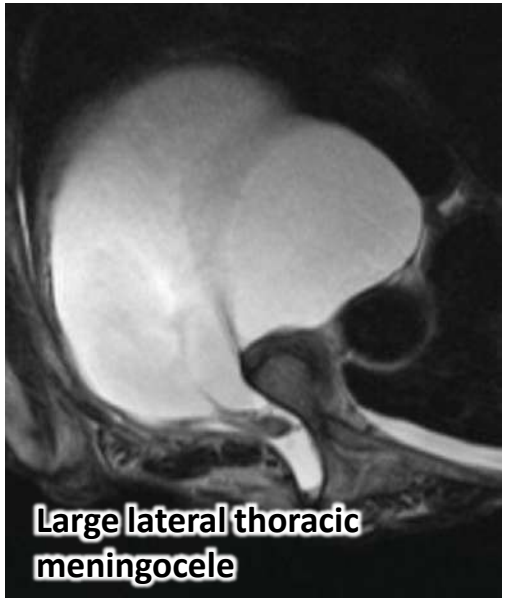
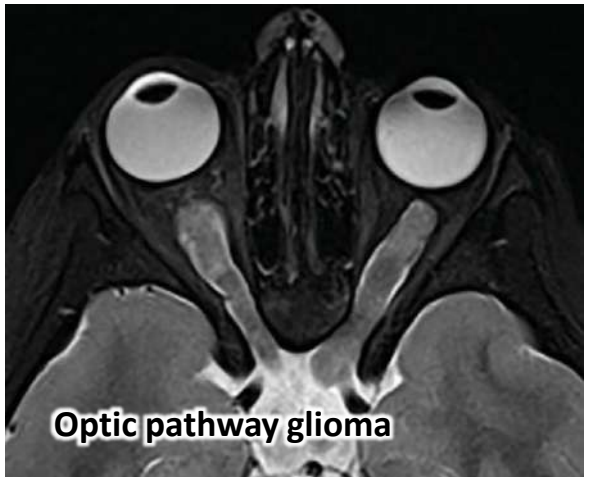
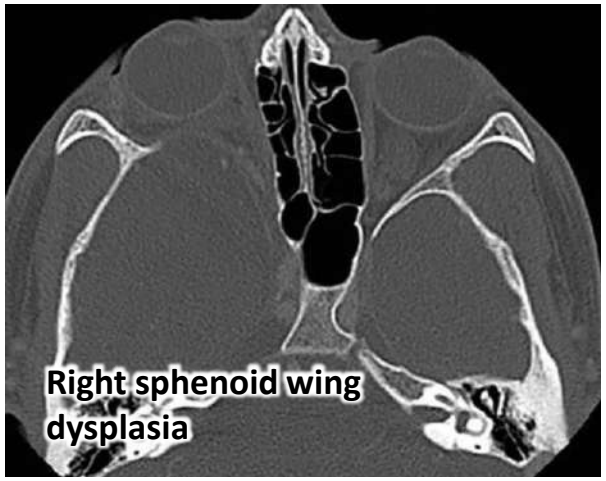
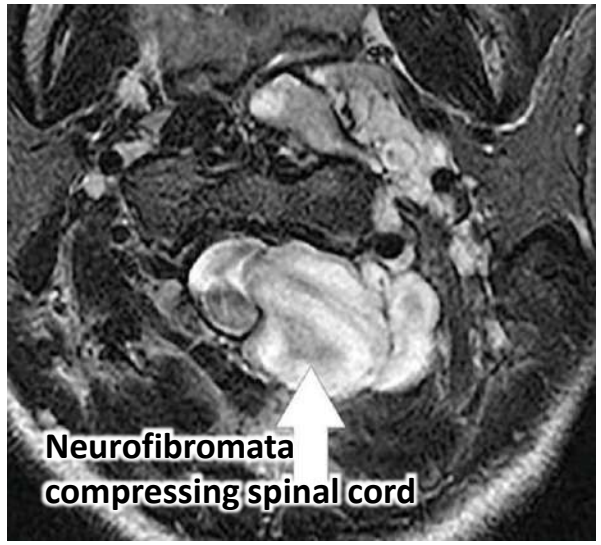

Myelin vacuolation at basal gg, thalamus


Plexiform neurofibroma at right cavernous sinus


Large lateral thoracic meningocele


Optic pathway glioma


Right sphenoid wing dysplasia


Neurofibromata compressing spinal cord

NF2-Related Schwannomatosis (2022 Dx)

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Bilateral vestibular schwannomas (VS)

OR

Identical *NF2* pathogenic variant in ≥2 anatomically distinct NF2-related tumors (schwannoma and/or ependymoma)

OR

Either [2 Major] or [1 Major + 2 Minor] of the following:

Major
Unilateral VS
Multiple meningiomas
1st degree relative other than sibling with NF2-related schwannomatosis
NF2 pathogenic variant in unaffected tissue (e.g. blood)

Minor (can count >1 of type)
Ependymoma
Single meningioma
Schwannoma

Minor (can count only once)	
Juvenile (age<40 y)	Subcapsular/ cortical cataract
	Retinal hamartoma
	Epiretinal membrane

Neurofibromatosis Type 2 (NF2)

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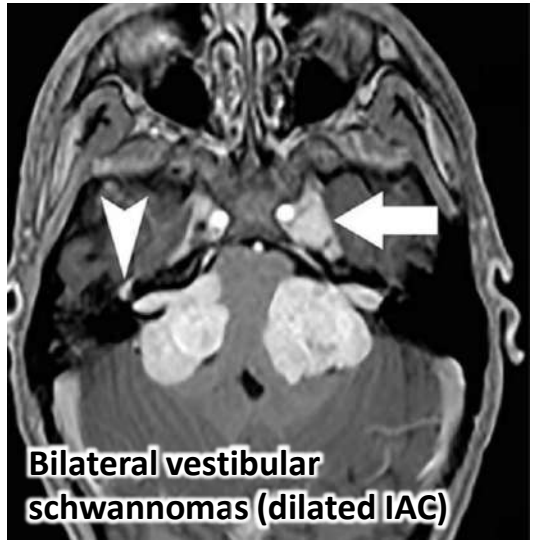
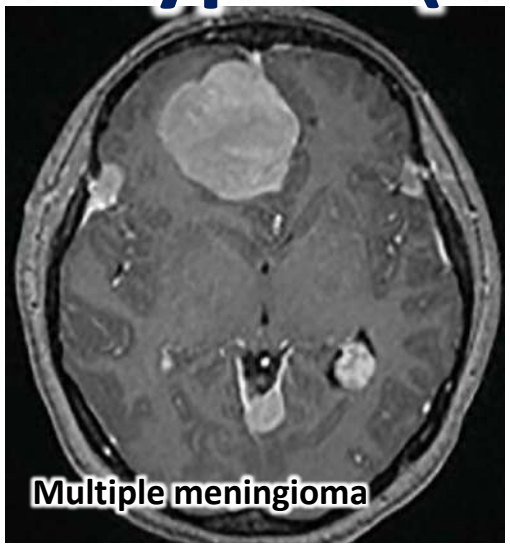
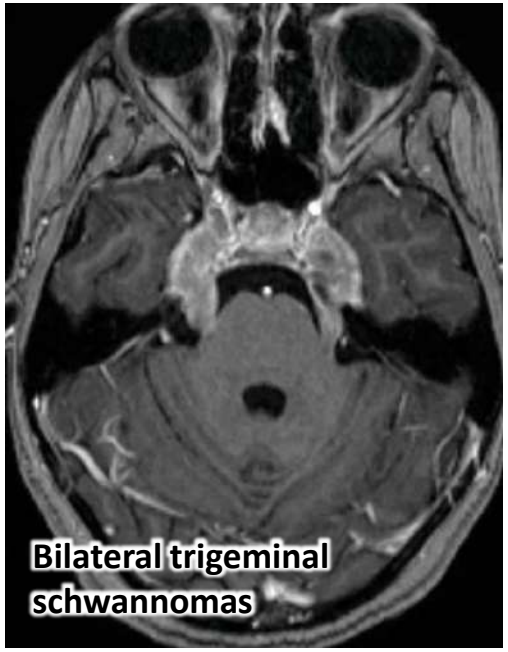

Bilateral vestibular schwannomas (dilated IAC)


Multiple meningioma


Schwannoma at left parapharyngeal space


Bilateral trigeminal schwannomas


Schwannoma of cauda equina


Intramedullary ependymoma

Cerebellopontine Angle Mass

Enhancing mass

- Vestibular schwannoma (80%)
- Meningioma (10%)
- Trigeminal schwannoma
- Facial nerve schwannoma
- Ependymoma
- Metastasis

Mass with high T1

- Hemorrhagic vestibular schwannoma
- Neurenteric cyst
- Thrombosed berry aneurysm
- CPA lipoma
- Ruptured intracranial dermoid cyst

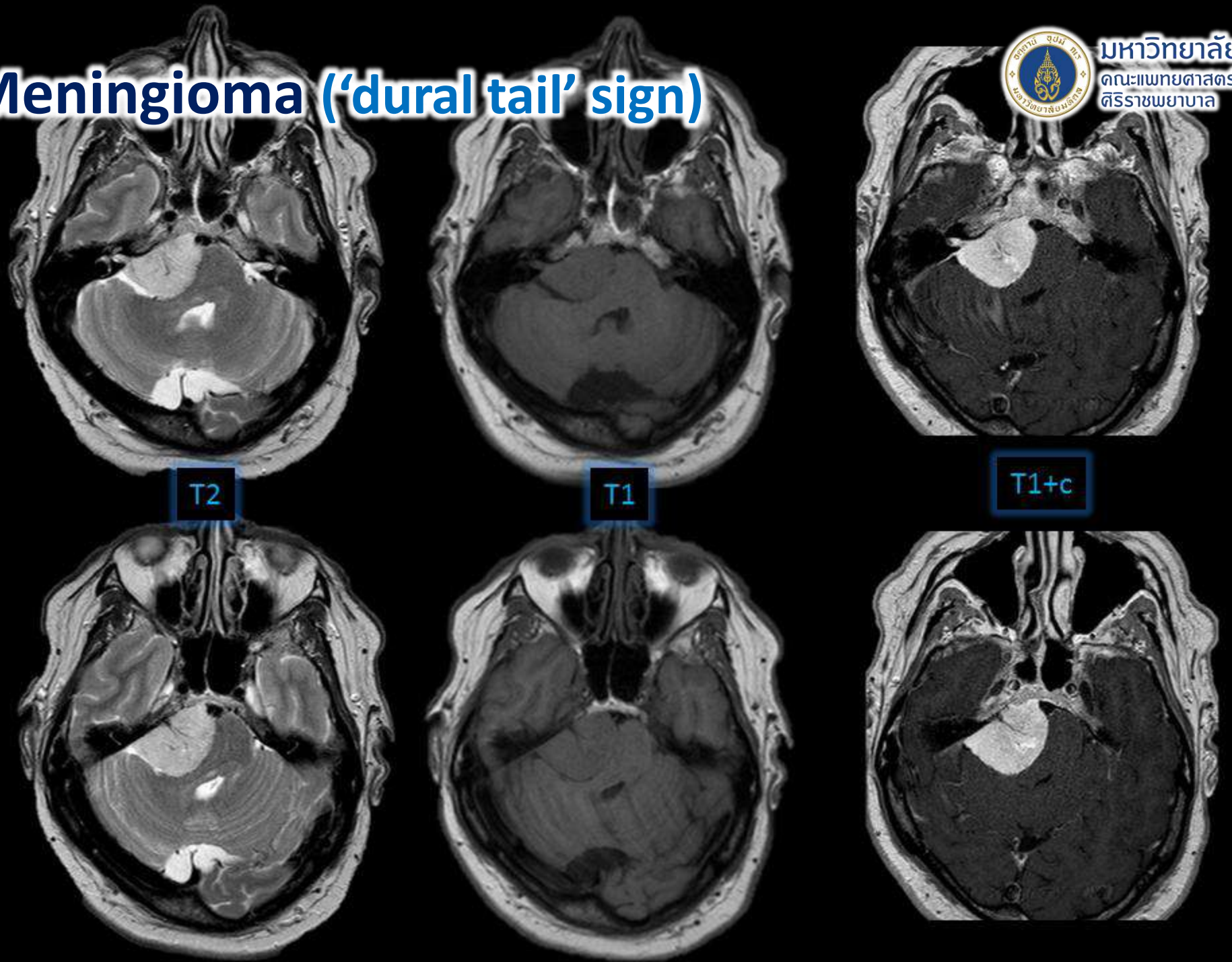
Mass with CSF density

- Epidermoid cyst (5%)
- Arachnoid cyst

Other masses

- Neurosarcoidosis
- Cholesterol granuloma
- Paraganglioma, chrondrosarcoma
- Chordoma, endolymphatic sac tumor
- Brainstem glioma, choroid plexus papilloma, lymphoma, hemangioblastoma, medulloblastoma

CPA Meningioma (‘dural tail’ sign)



Tuberous Sclerosis Complex (TSC)

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2 Major criteria OR 1 Major + 2 Minor


Facial angiofibroma (adenoma sebaceum)

Diagnostic criteria for tuberous sclerosis

Major features	Minor features
Facial angiofibromas or forehead plaque	Multiple, randomly distributed pits in dental enamel
Nontraumatic ungual or periungual fibroma	Hamartomatous rectal polyps
Hypomelanotic macules (three or more)	Bone cysts
Shagreen patch (connective tissue nevus)	Cerebral white matter migration lines
Multiple retinal nodular hamartomas	Gingival fibromas
Cortical tubers	Nonrenal hamartoma
Subependymal nodule	Retinal achromic patch
Subependymal giant-cell astrocytoma	Confetti-like skin lesions
Cardiac rhabdomyoma, single or multiple	Multiple renal cysts
Lymphangiomyomatosis, renal angiomyolipoma, or both	


Periungual fibroma


Hypomelanotic macule (Ash leaf)


Shagreen patch

Tuberous Sclerosis Complex (TSC)

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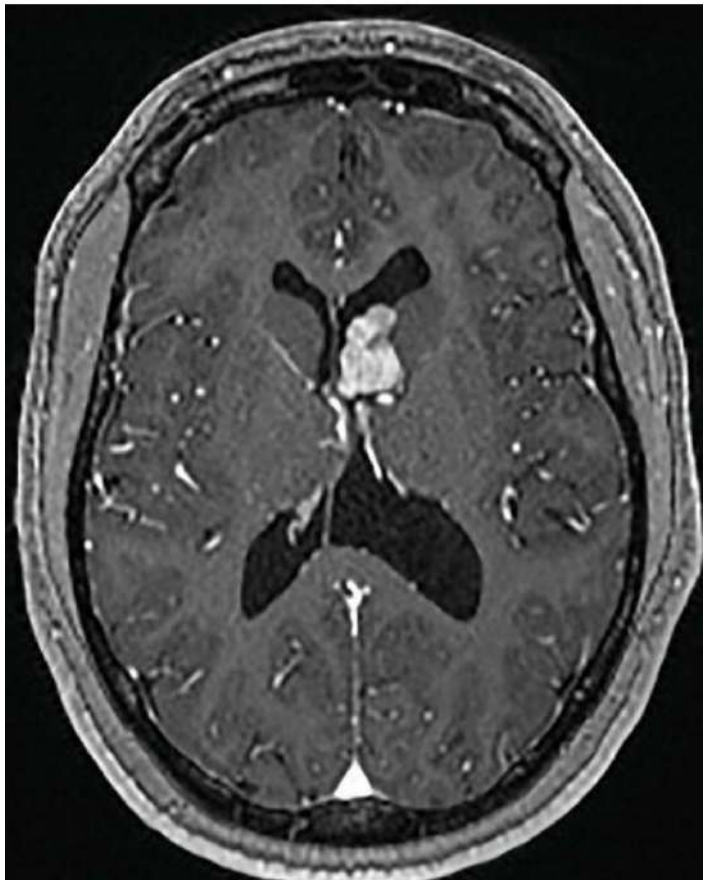
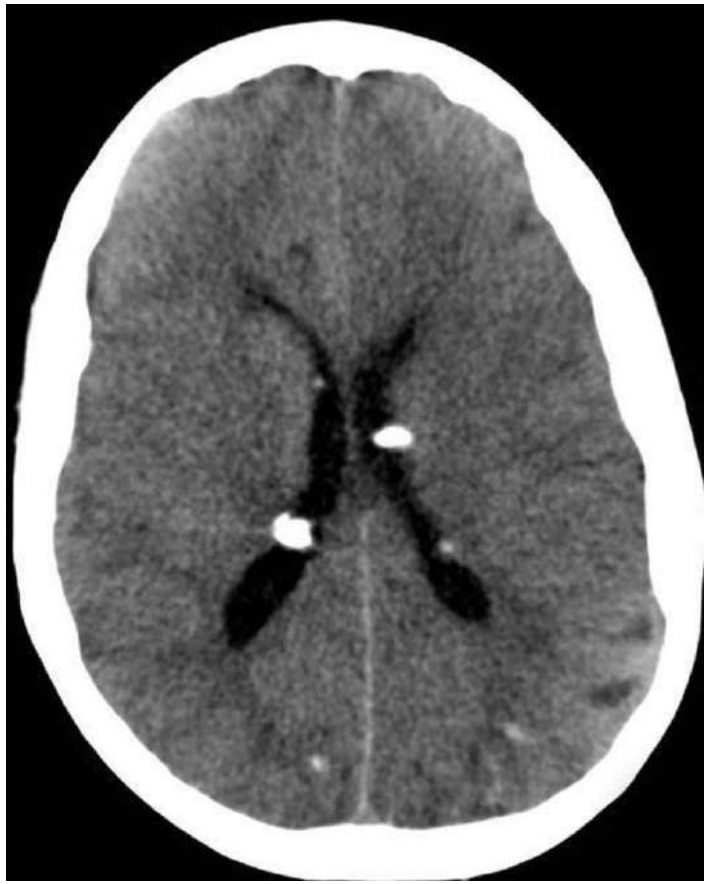
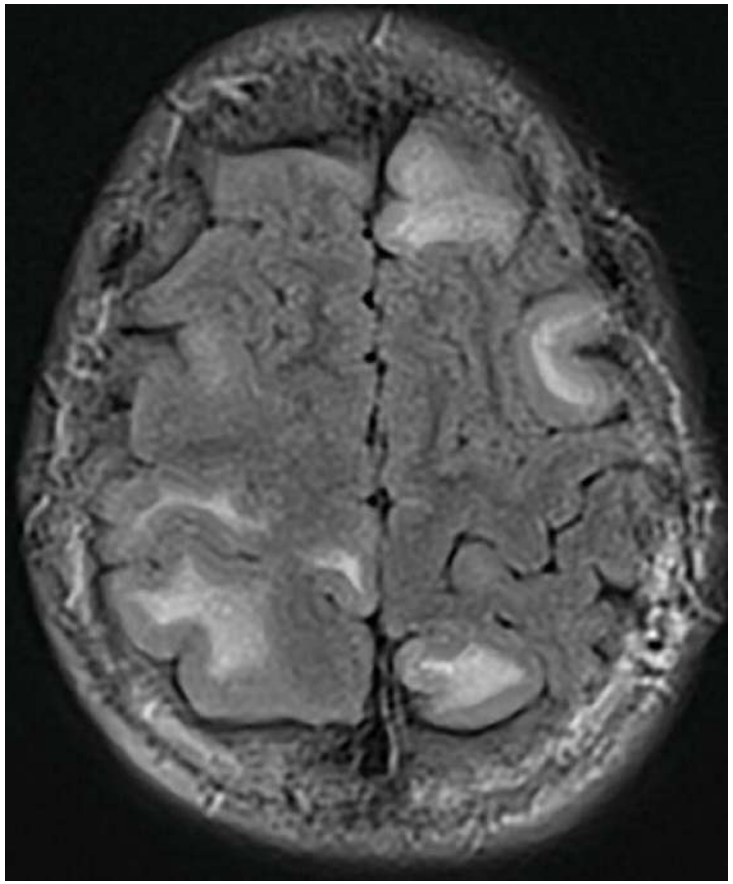


Subependymal giant cell astrocytoma (SEGA)**

Near Foramen of Monro



Multiple calcified subependymal nodules & subcortical hamartoma



Numerous cortical tubers (expansile)

Sturge-Weber Syndrome (SWS)

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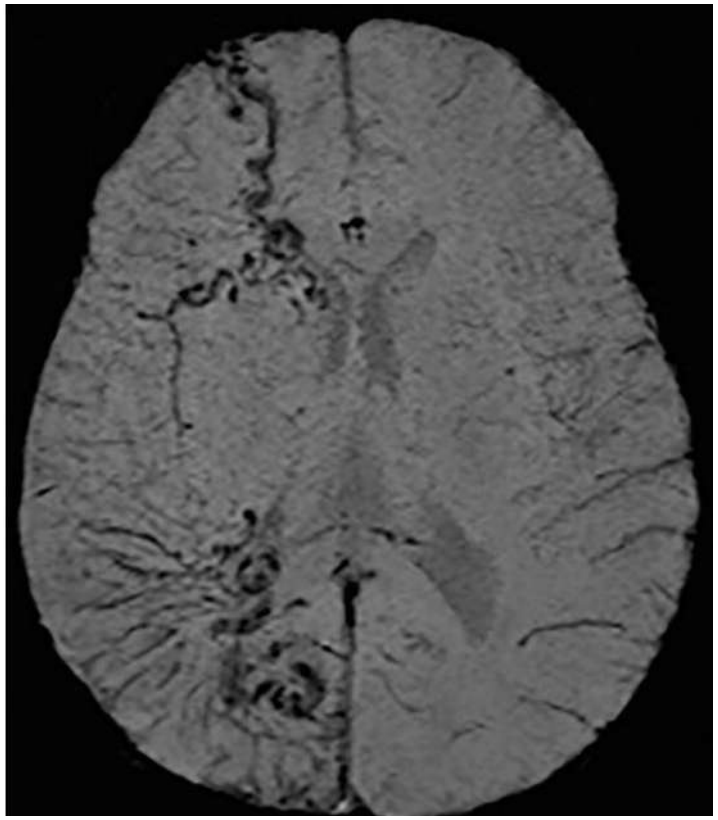
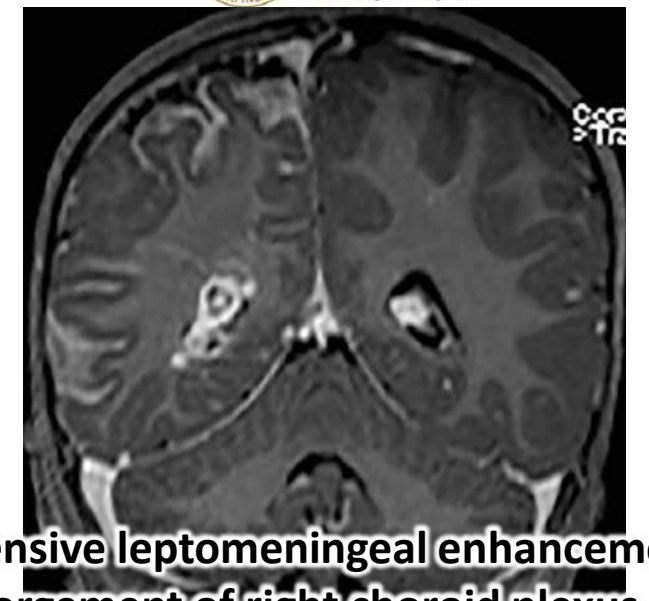
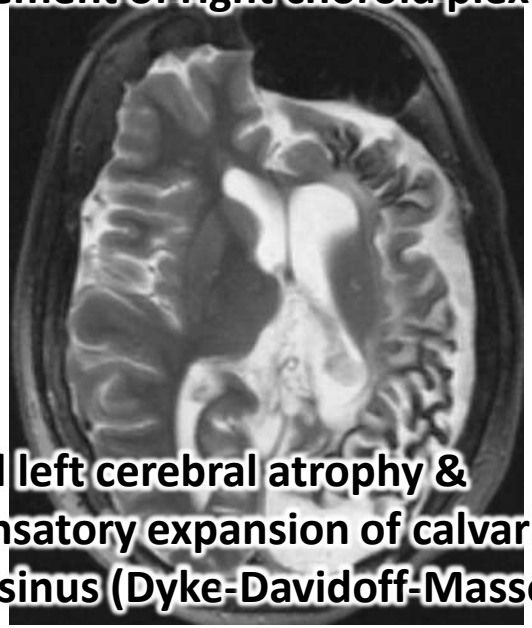
Cortical calcification & engorged choroid plexus



Deep medullary & ventricular/ choroidal venous collaterals



Extensive leptomeningeal enhancement & engorgement of right choroid plexus



Marked left cerebral atrophy & compensatory expansion of calvarium & frontal sinus (Dyke-Davidoff-Masson)

von Hippel-Lindau Disease (vHL)

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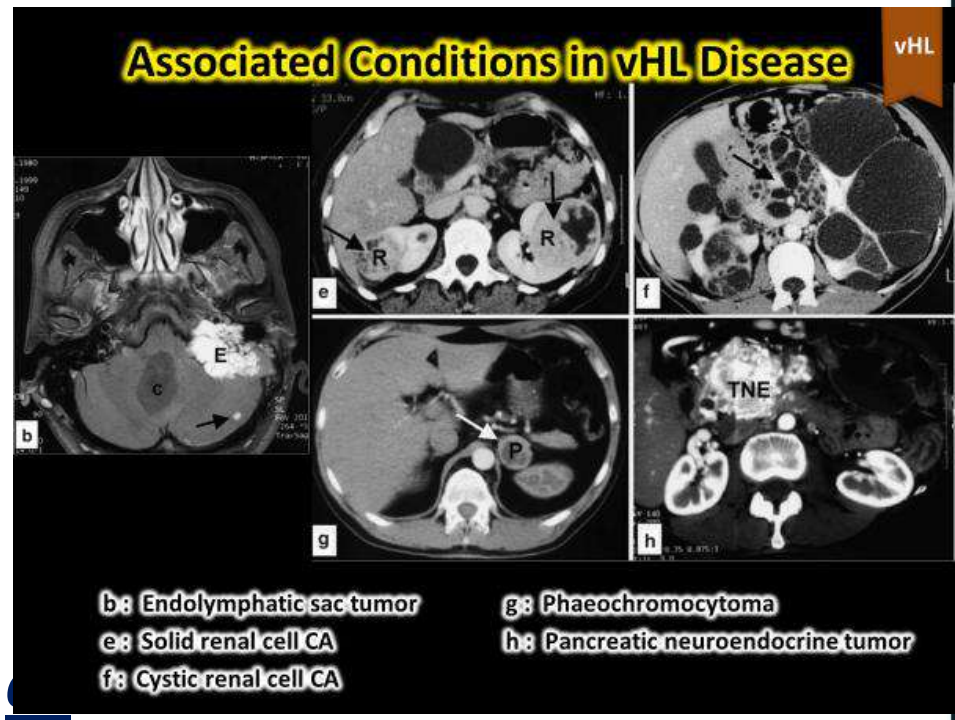
If +ve family Hx of retinal/CNS hemangioblastoma :

- One hemangioblastoma *or*
- One visceral lesion

e.g. renal tumor, pancreatic cyst/tumor, pheochromocytoma or papillary cystadenoma of the epididymis



If no definite family Hx :

- Two retinal or cerebellar hemangioblastomas *or*
- One hemangioblastoma plus one visceral tumor

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Cystic hemangioblastoma with enhancing mural nodule that abuts the pial surface

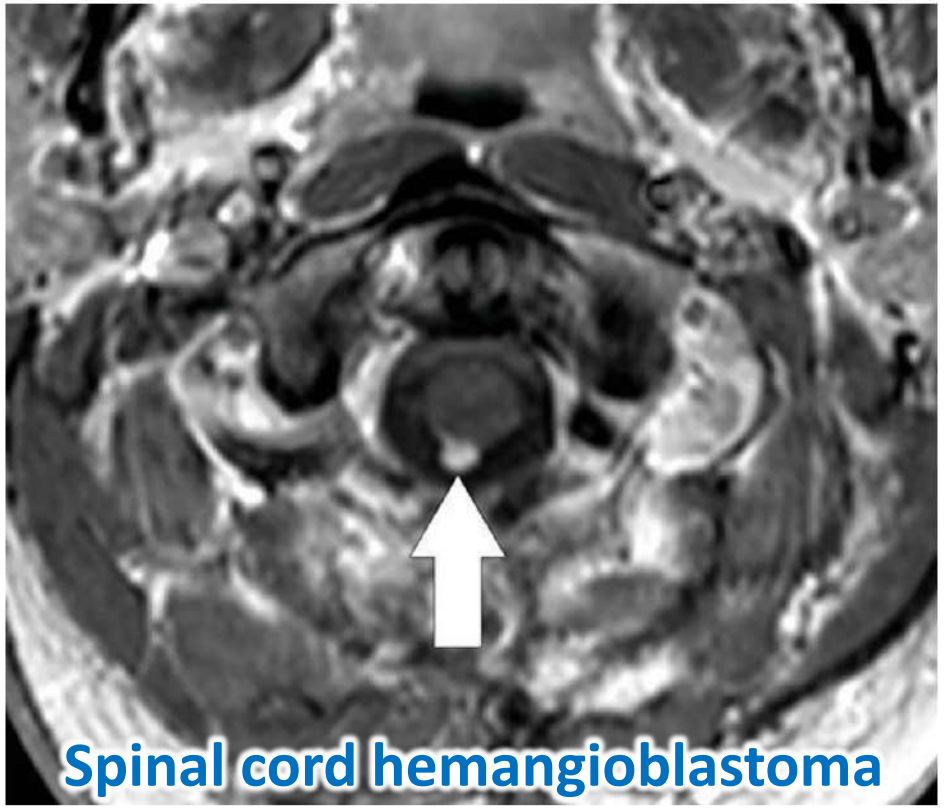

FIGURE 19-36. Axial postcontrast T1, in the same patient, shows a pial-based hemangioblastoma in the upper cervical spine (*arrow*).


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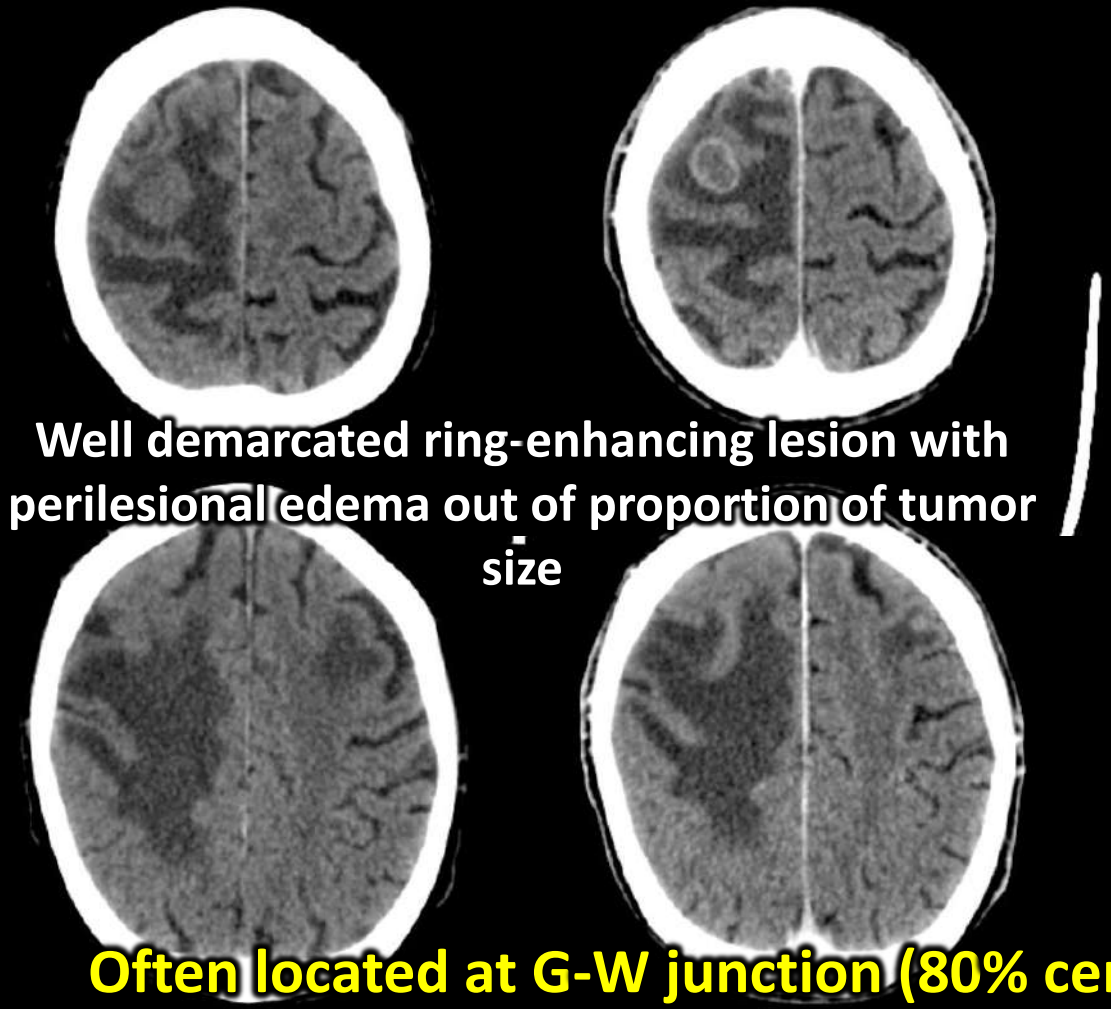
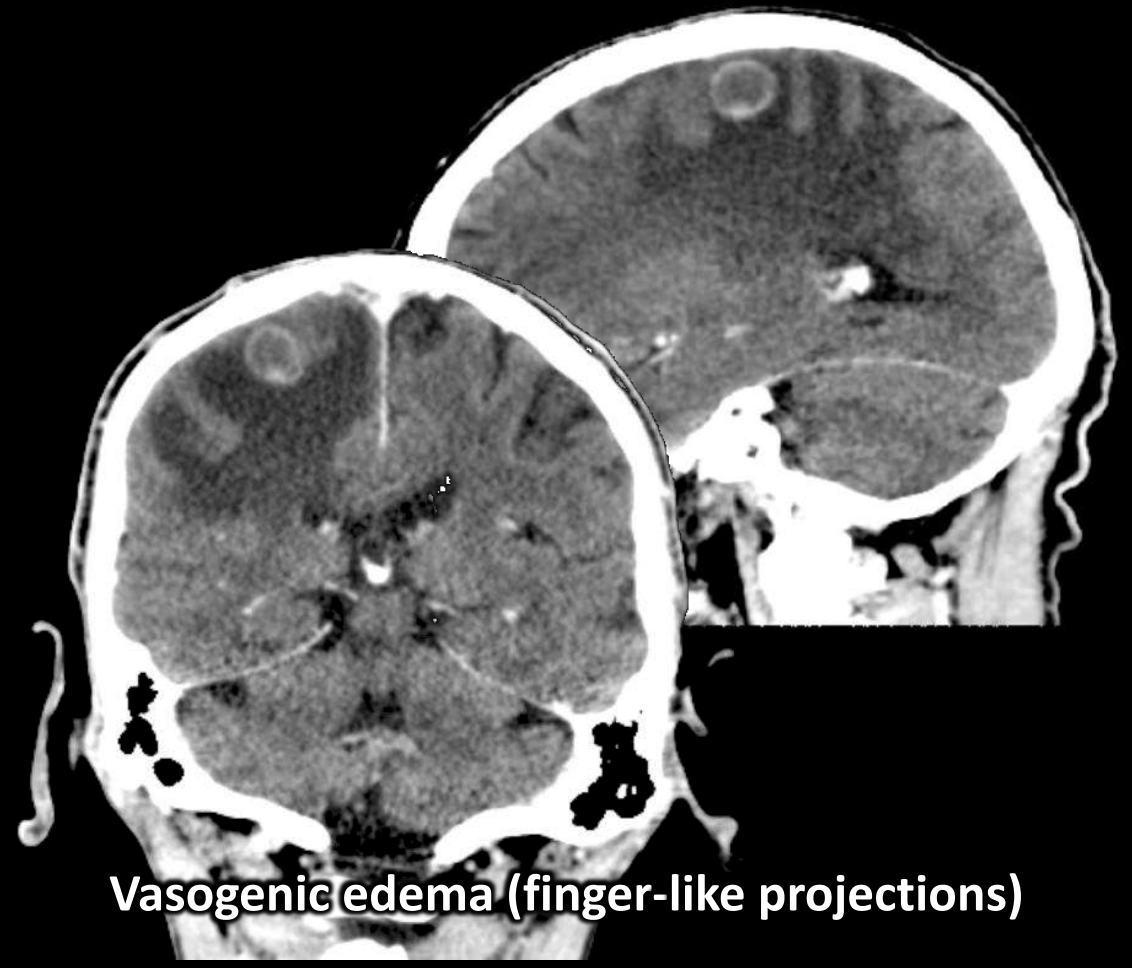
Miscellaneous Conditions

Brain Metastasis

80% from lung, RCC, breast, melanoma, colorectal



Well demarcated ring-enhancing lesion with perilesional edema out of proportion of tumor size



Vasogenic edema (finger-like projections)

Often located at G-W junction (80% cerebral hemispheres, 15% cerebellum)

50% solitary lesion

Hemorrhagic Metastasis

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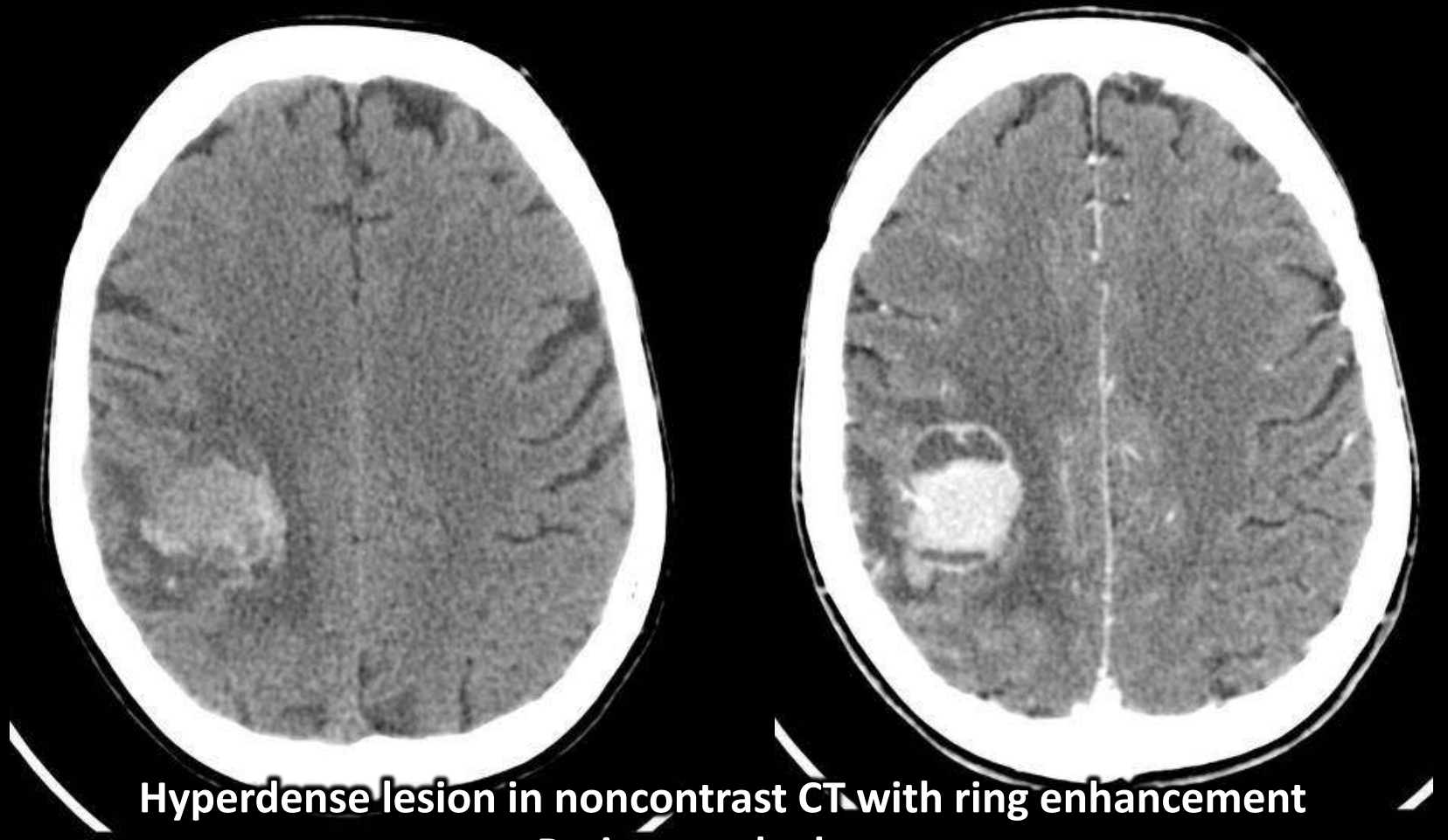
Hemorrhagic metastasis – melanoma, RCC, chorioCA, thyroid CA



Hyperdense lesion in noncontrast CT with ring enhancement
Peritumoral edema

Sellar-Suprasellar Massses

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Intrasellar masses

- Pituitary adenoma
- Pituitary carcinoma
- Pituitary metastasis
- Pituitary lymphoma

Supra/parasellar masses

- Meningioma
- Craniopharyngioma
- Germ cell tumors
- Astrocytoma / glioma
- Hamartoma
- Dermoid / epidermoid / teratoma

Pituitary Macroadenoma

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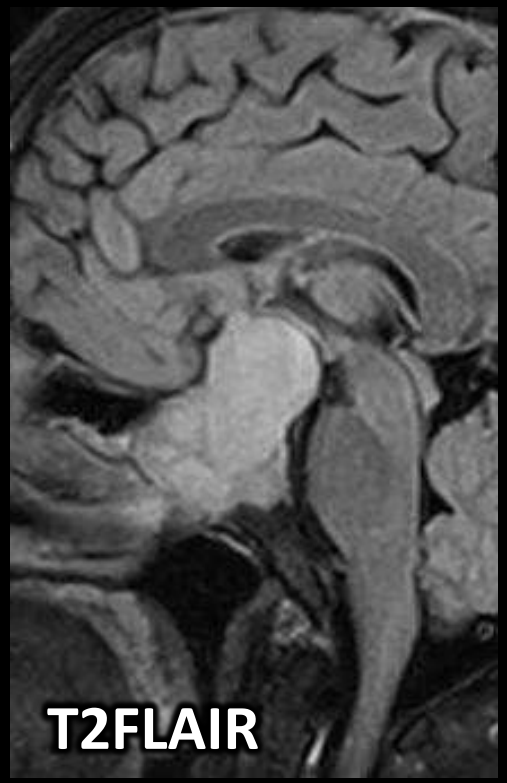
≥10 mm in size; isointense to gray matter, moderate contrast enhancement
Optic chiasm compression, +/- cavernous sinus invasion



Large lesion are often heterogeneous (due to area of cystic change/necrosis)
Bilateral identation by diaphragma sellae “snowman” or “figure-of-8” appearance

Craniopharyngioma

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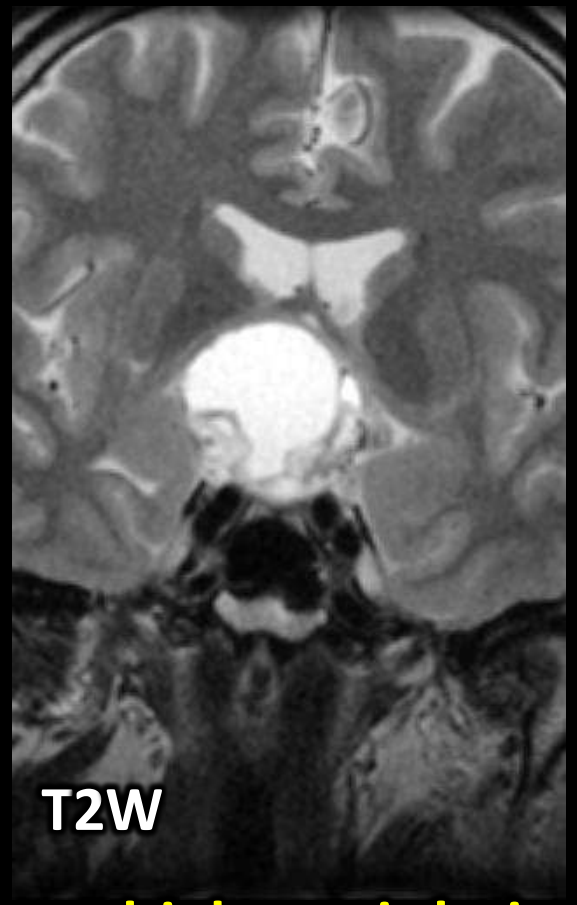
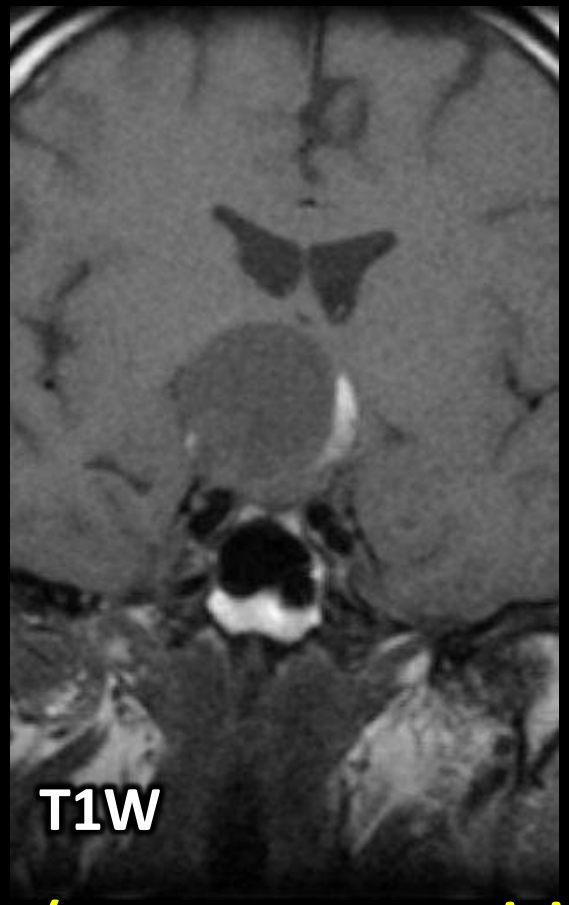
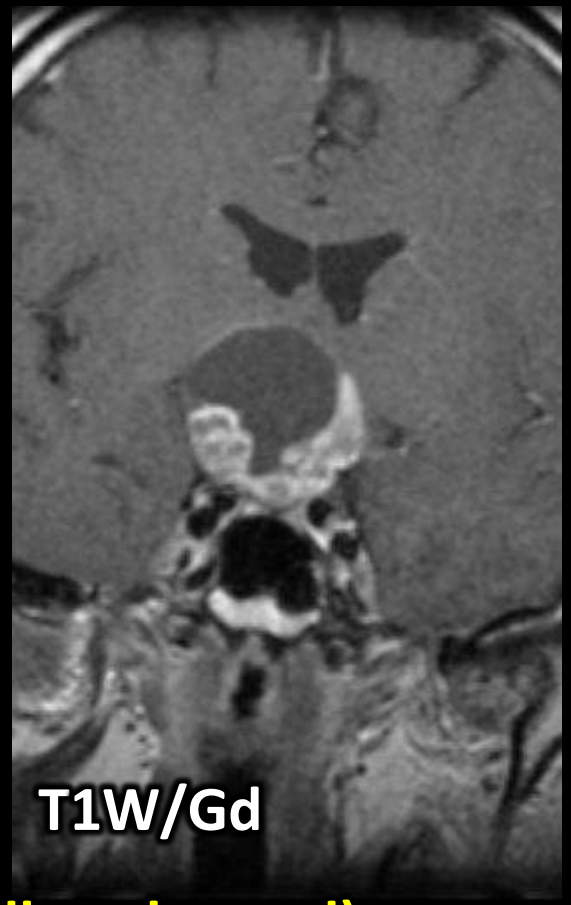
Suprasellar 75%, large tumor compressing optic chiasm/midbrain, +/-obstructive hydrocephalus







Lobulated contour, multiple cystic lesions (some parts are vividly enhanced)
Calcification is very common (90%)

Germ Cell Tumors

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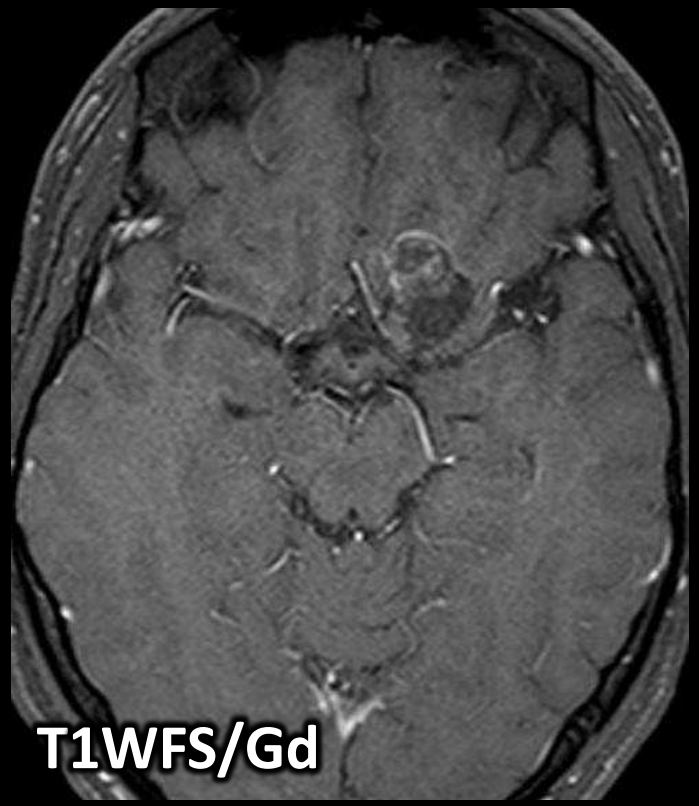
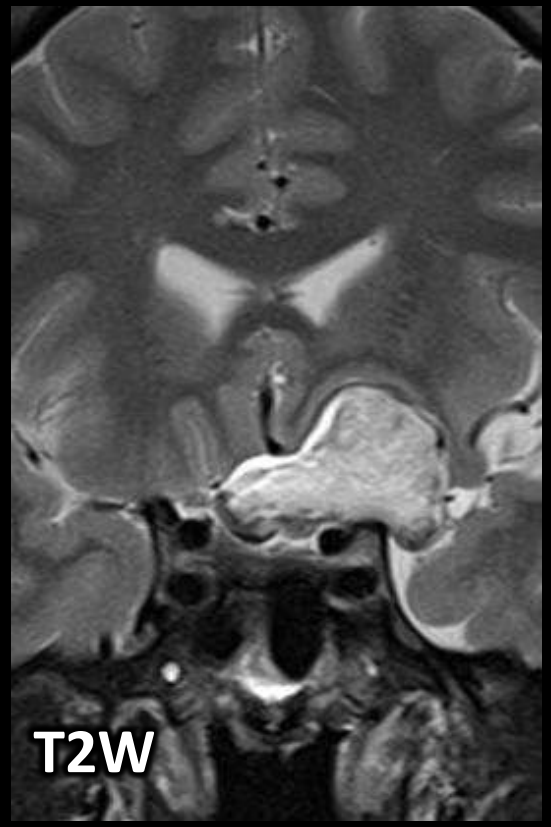
Large heterogeneous lobulated tumors with solid/cystic/calcified/fatty components





T1W – Hyper (fat, proteinaceous), hypo (calcification, blood products) with enhancement
T2W – mixed signal

Idiopathic Intracranial Hypertension (IIH)

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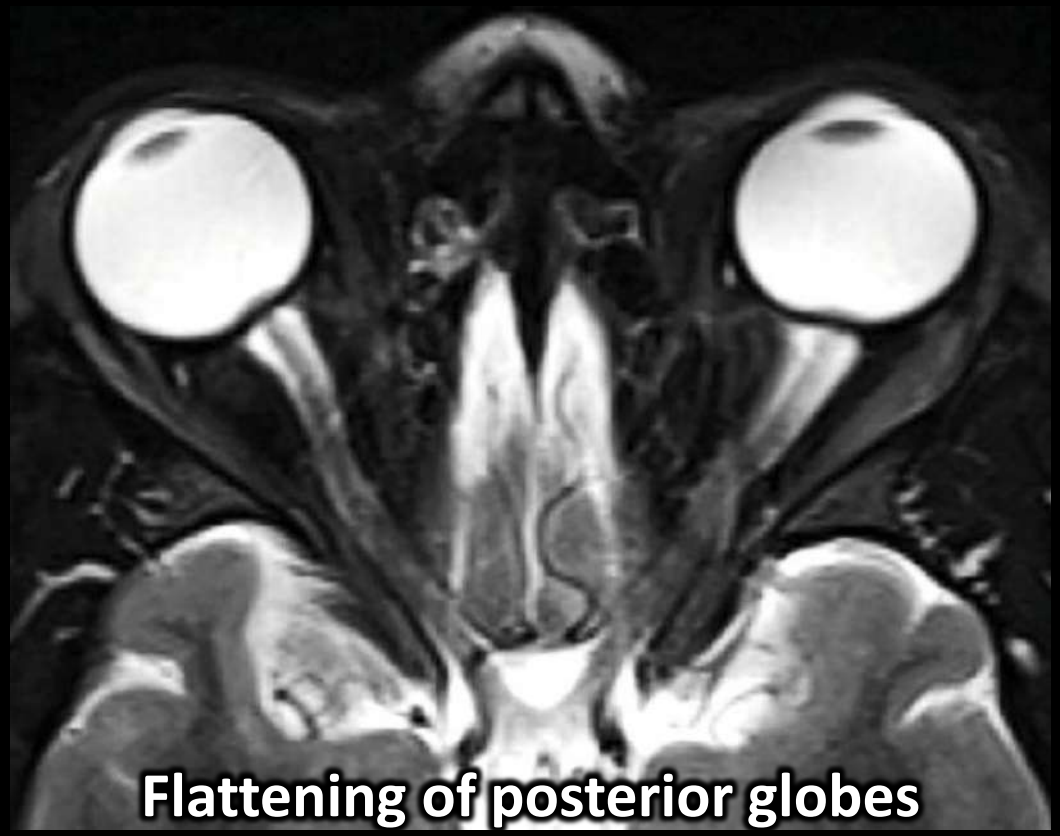
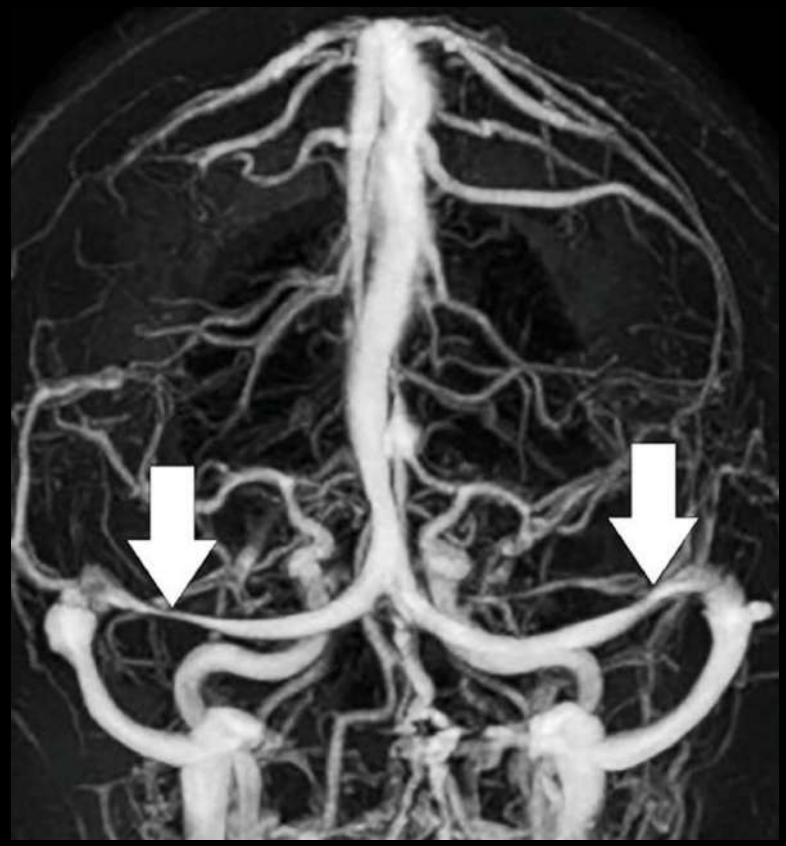


Flattening of posterior globes
Protrusion of optic discs
Dilated perioptic subarachnoid space
Tortuosity of optic nerves

Partial empty sella



Transverse sinus stenosis

Spontaneous Intracranial Hypotension (SIH)

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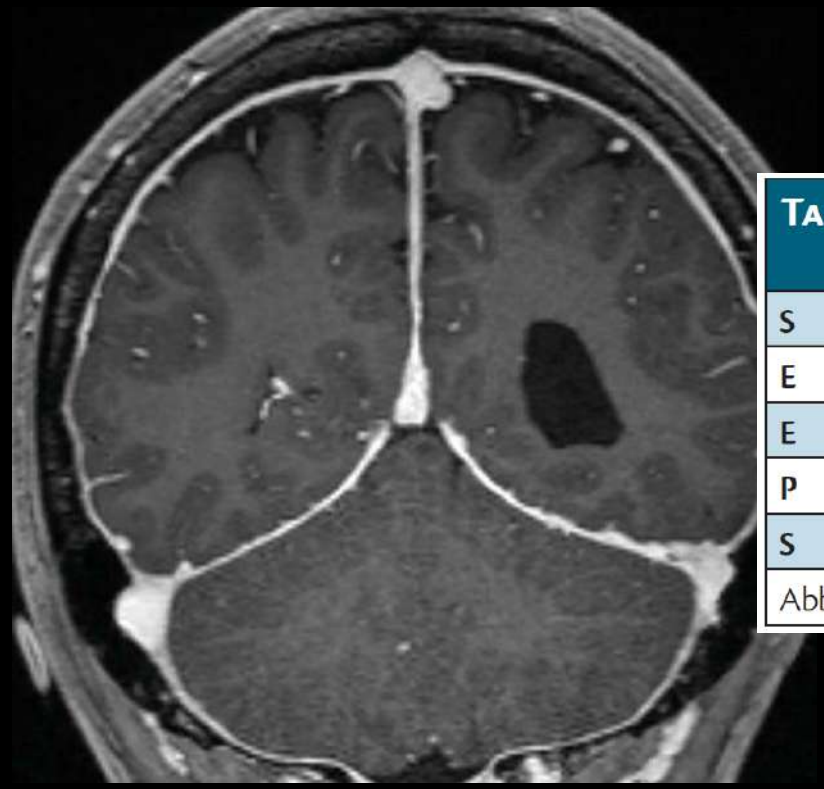
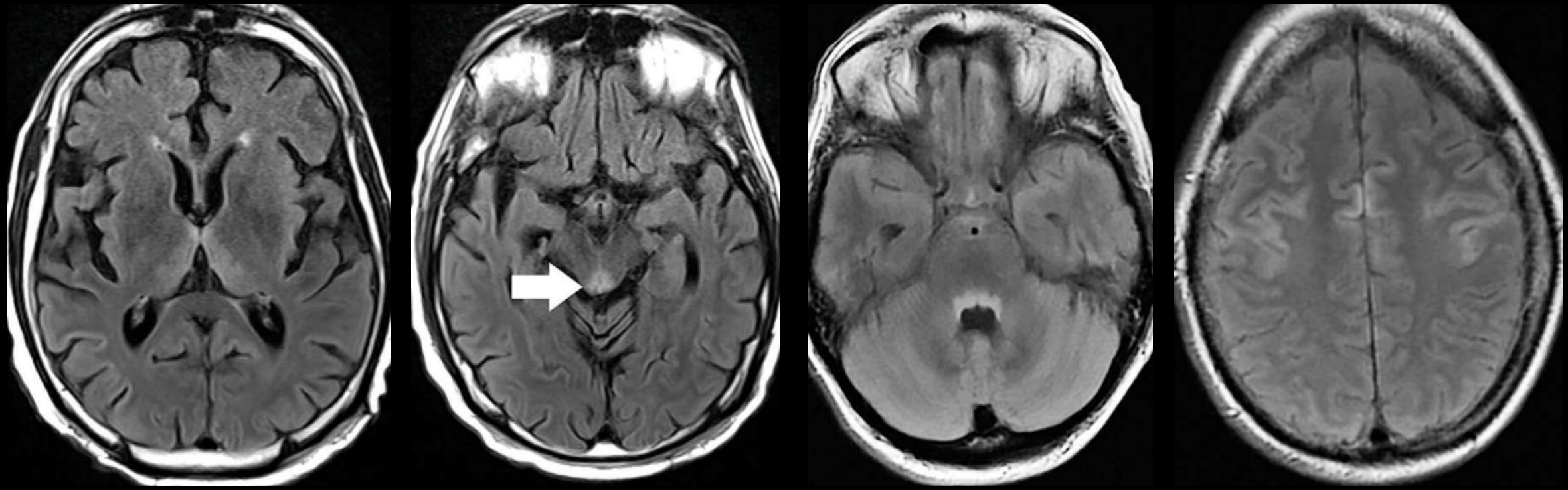


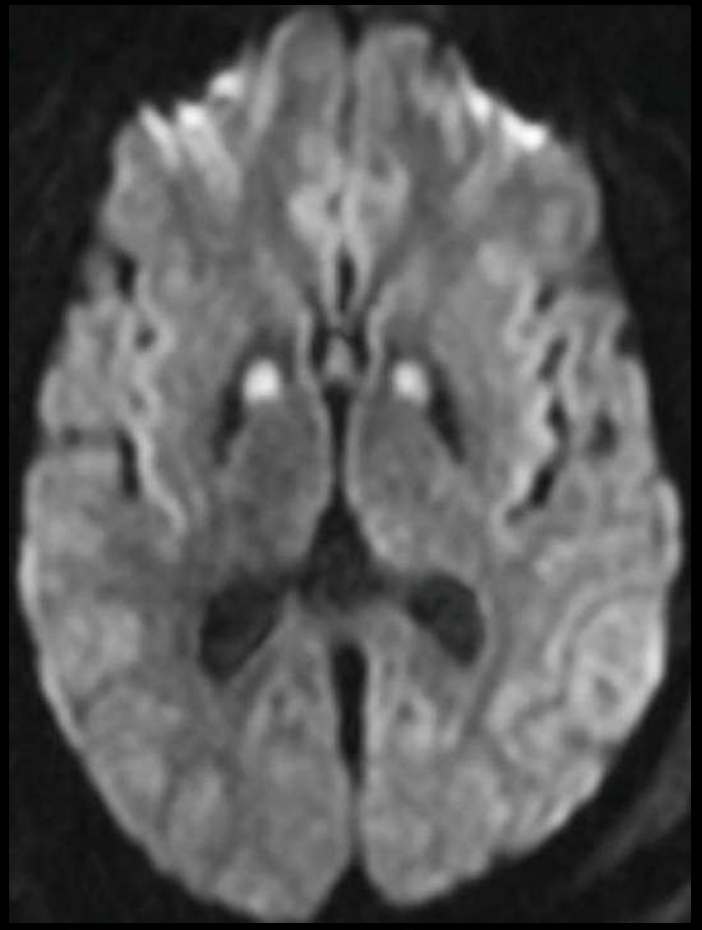
Table 3. The SEEPs Mnemonic for Qualitative Features of CSF Leak on MRI	
S	Subdural fluid collection
E	Enhancement of the pachymeninges
E	Engorgement of venous structures
P	Pituitary hyperemia
S	Sagging of the brain
Abbreviations: CSF, cerebrospinal fluid	

Wernicke Encephalopathy



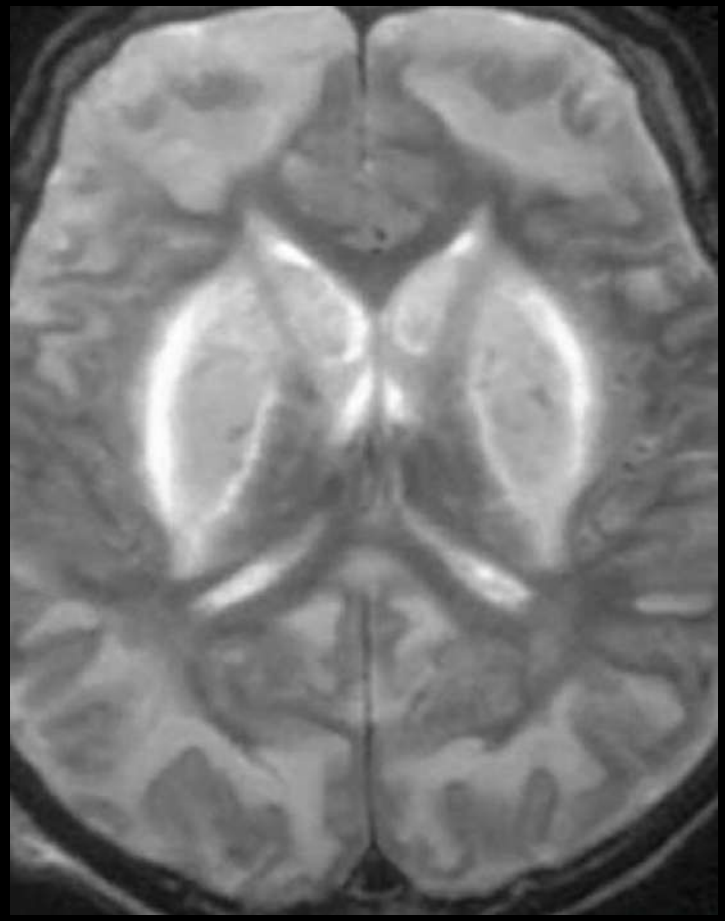
- Hyperintense T2 signal in:
  - Medial thalamus, mammillary body, periaqueductal gray, dorsal pons/medulla, around central fissure (cerebral cortex)
- DDx: NMOSD, CJD

Carbon Monoxide vs. Methanol Poisoning



Carbon monoxide poisoning

HyperT2 in globus pallidus



Methanol poisoning

Caudate + putamen

Nonketotic Hyperglycemia

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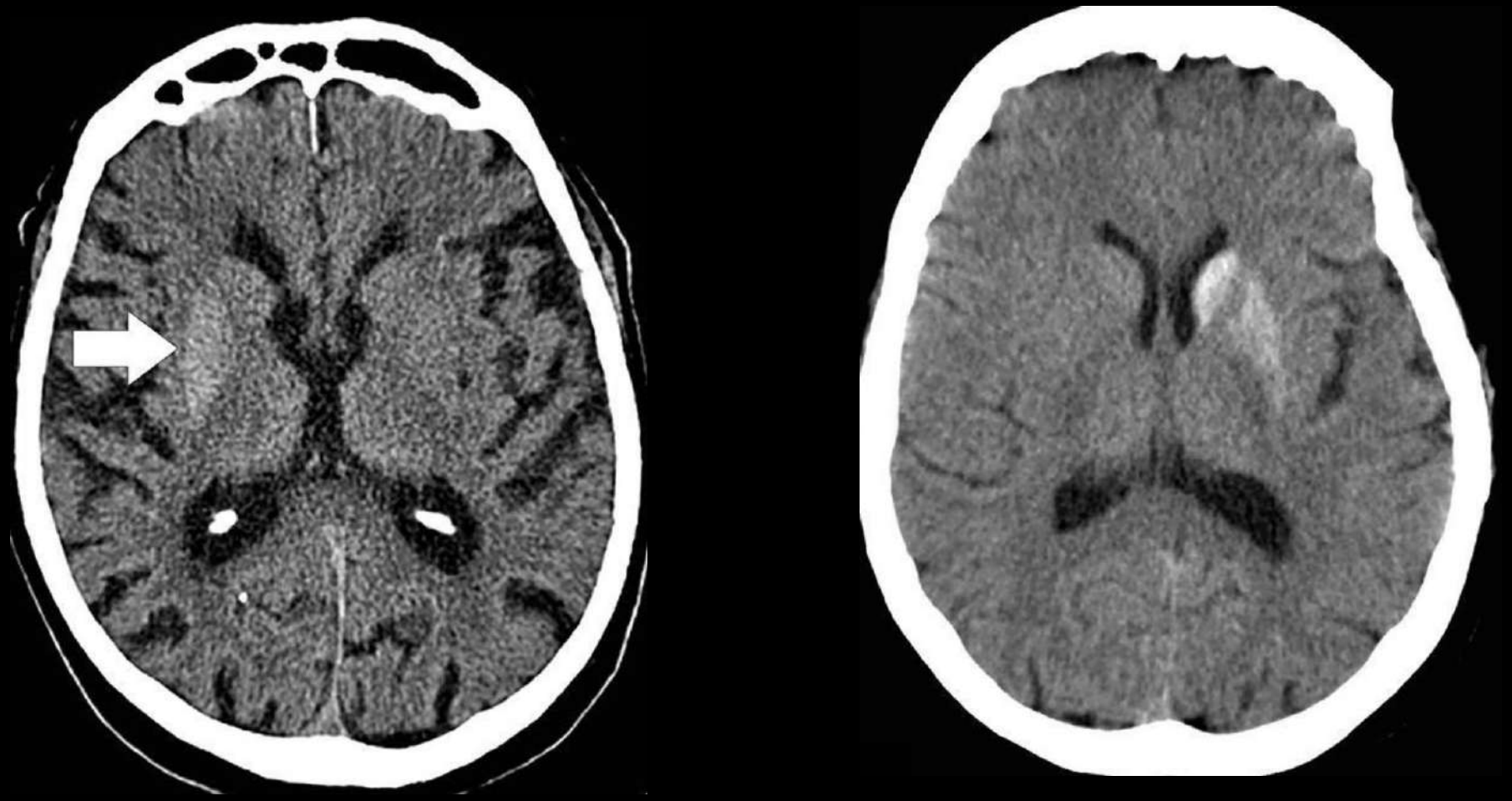
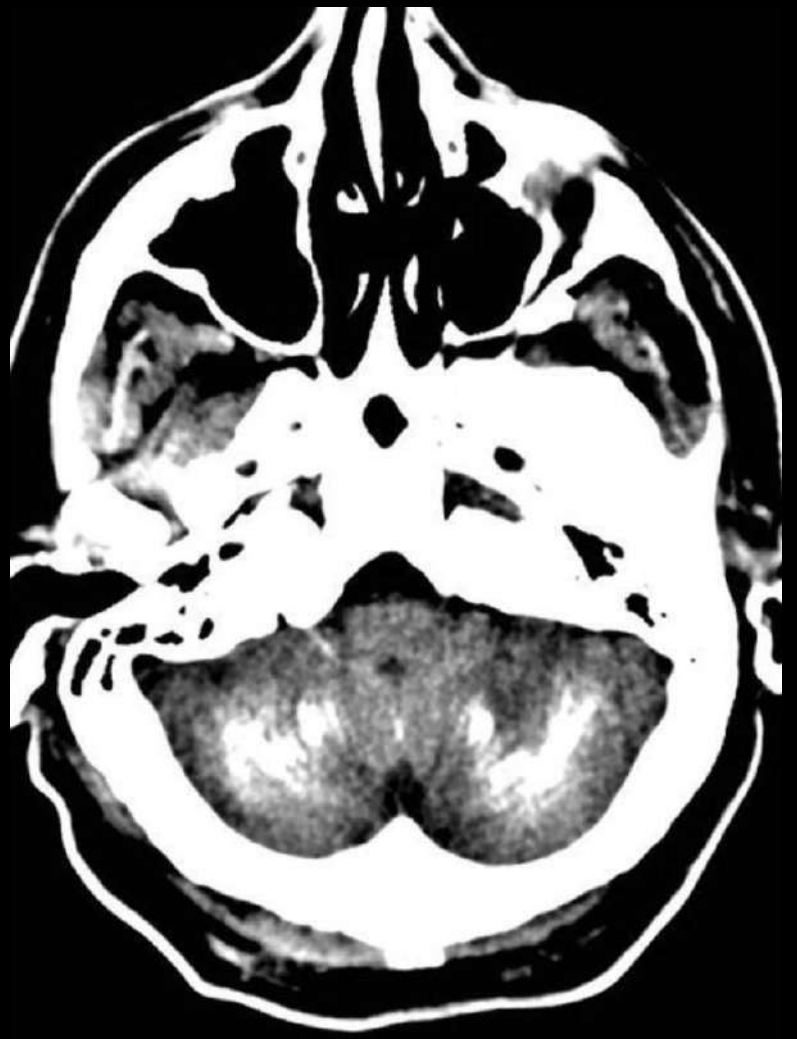
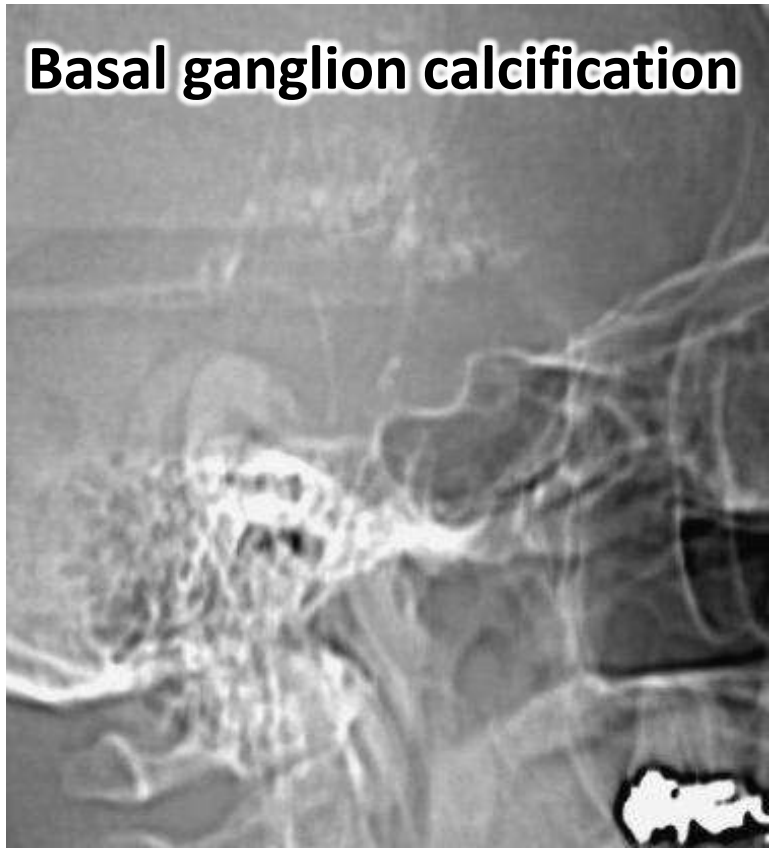


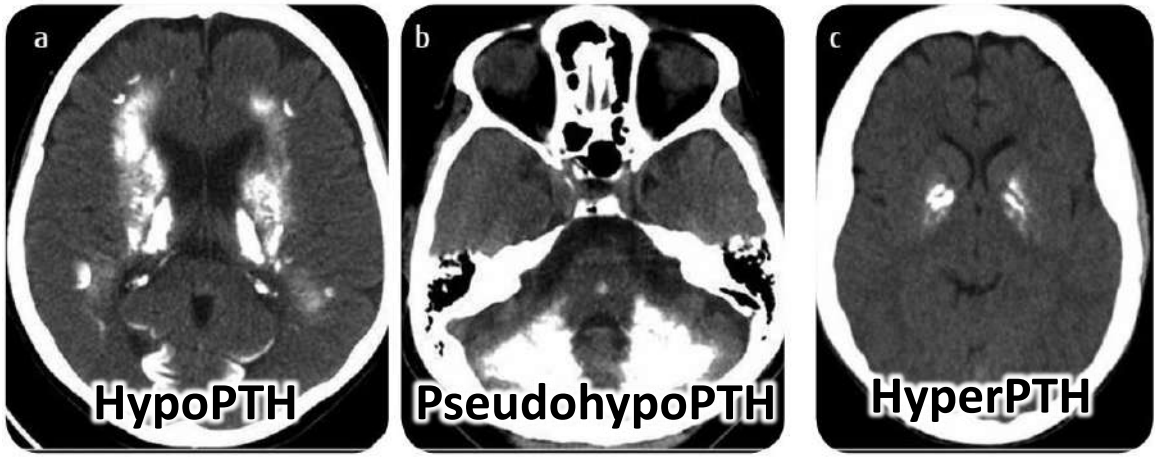
Hyperdense at caudate and putamen in noncontrast CT

Cerebral Calcifications



Plain Film Used in Selected Conditions



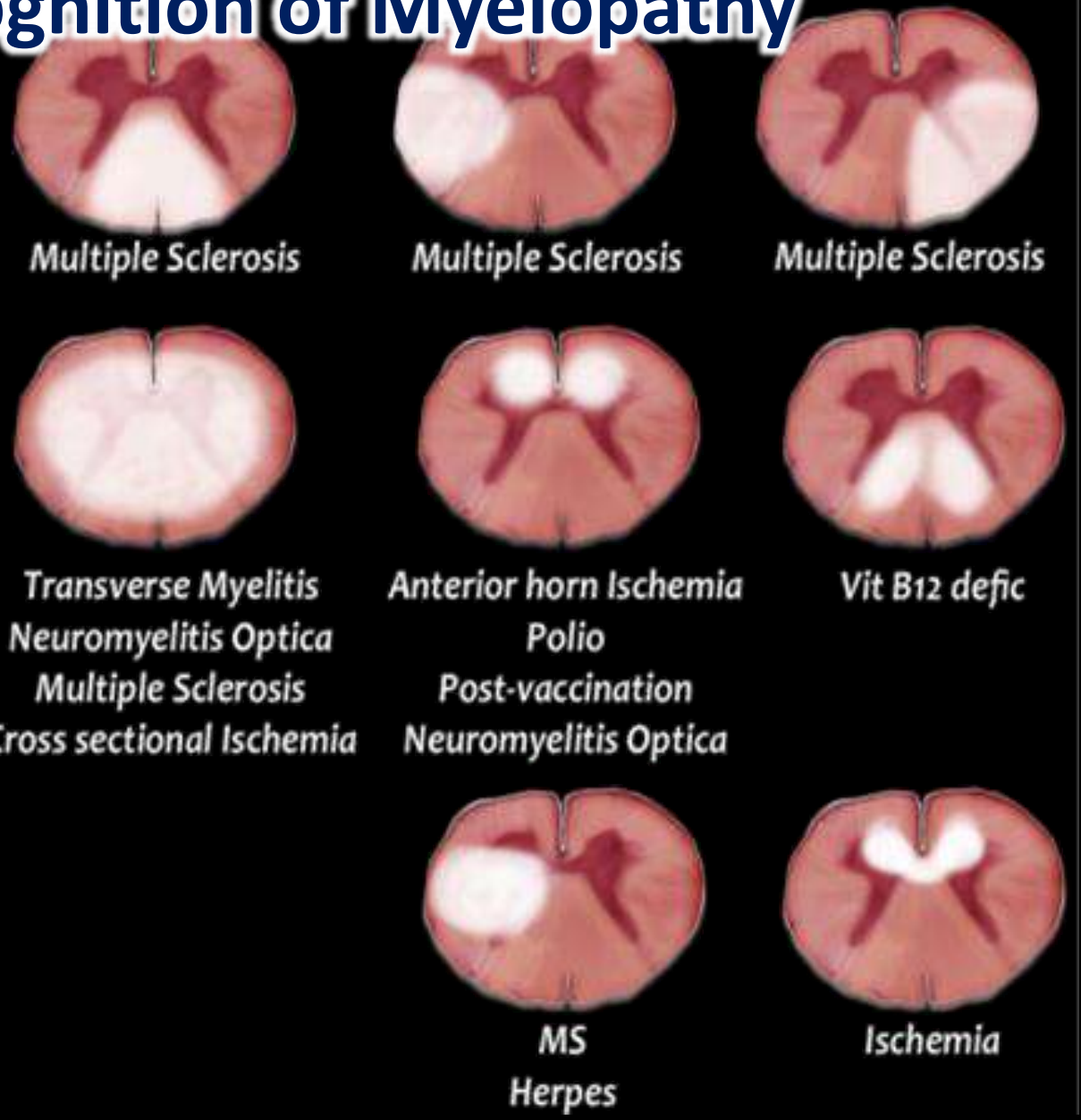


Classification of Pathological Calcifications

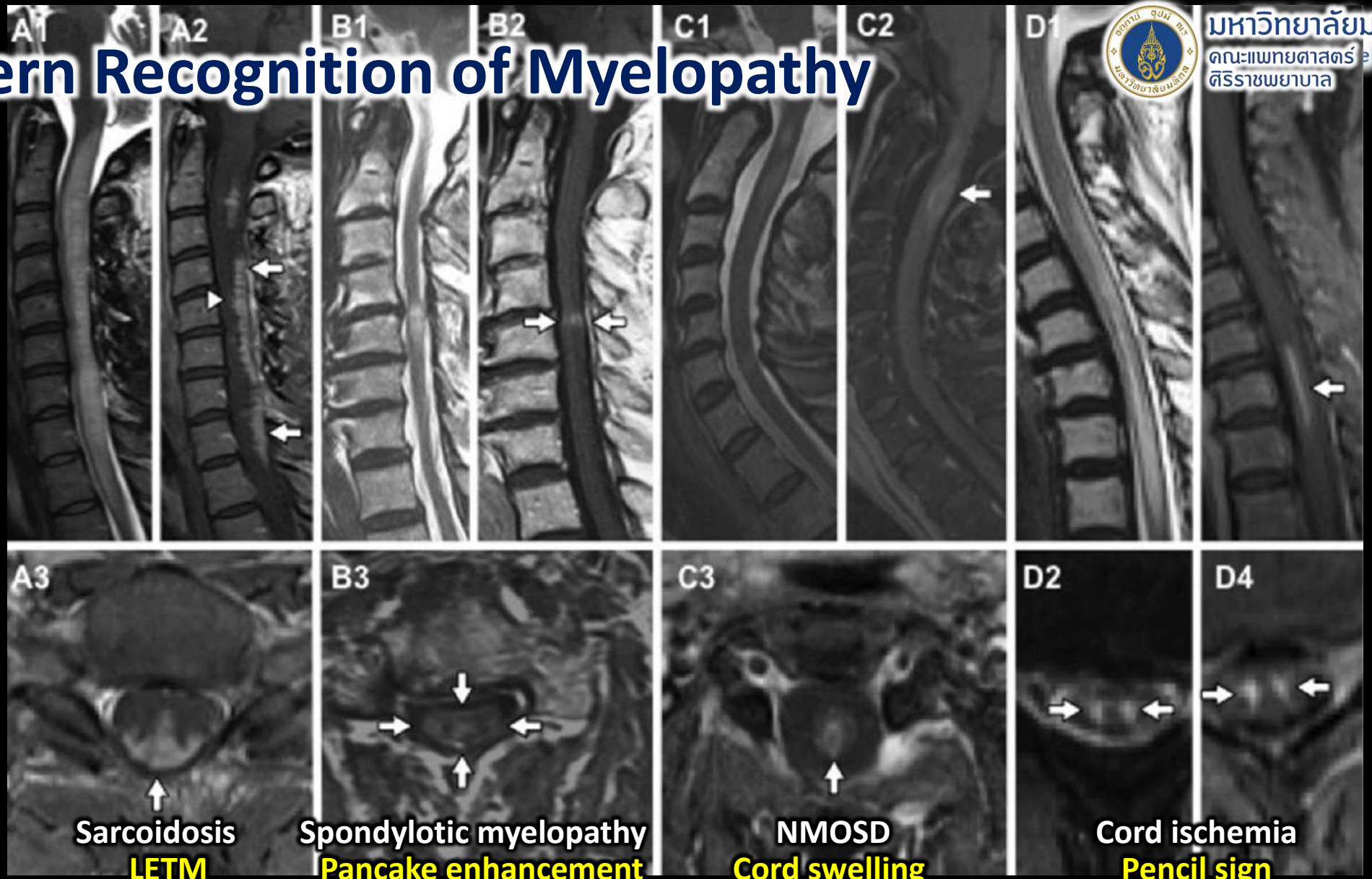
Congenital	Sturge-Weber syndrome Tuberous sclerosis Neurofibromatosis Lipoma Cockayne syndrome Gorlin syndrome TORCH infection, Zika
Non-congenital infections	Chronic viral encephalitis Granulomatous infections HIV infections
Vascular	1º atherosclerosis Cavernous malformation AVM, aneurysm Chronic infarction/ vasculitis
Metabolic	Fahr's disease Hypothyroidism Hypoparathyroidism Hyperparathyroidism Pseudohyperparathyroidism
Neoplasms	Oligodendroglioma Craniopharyngioma Germ cell tumors Neurocytoma Neuroectodermal primitive tumor Ependymoma Ganglioma Meningioma Medulloblastoma Pliocytic astrocytoma

https://rad.washington.edu/about-us/academic-sections/neuroradiology/teaching-cases/69-year-old-progressive-dysarthria-extrapyramidal-signs-ataxia/
http://contenido.acronline.org/Publicaciones/RCR/RCR28-3/04-RCR-28-3-Algoritmos_Ingles%20(para%20publicacion).pdf

Pattern Recognition of Myelopathy



Pattern Recognition of Myelopathy



Sarcoidosis
LETM
Dorsal subpial enhancement

Spondylotic myelopathy
Pancake enhancement

NMOSD
Cord swelling
Ring enhancement

Cord ischemia
Pencil sign
Owl's eyes

Spinal Cord Infarction

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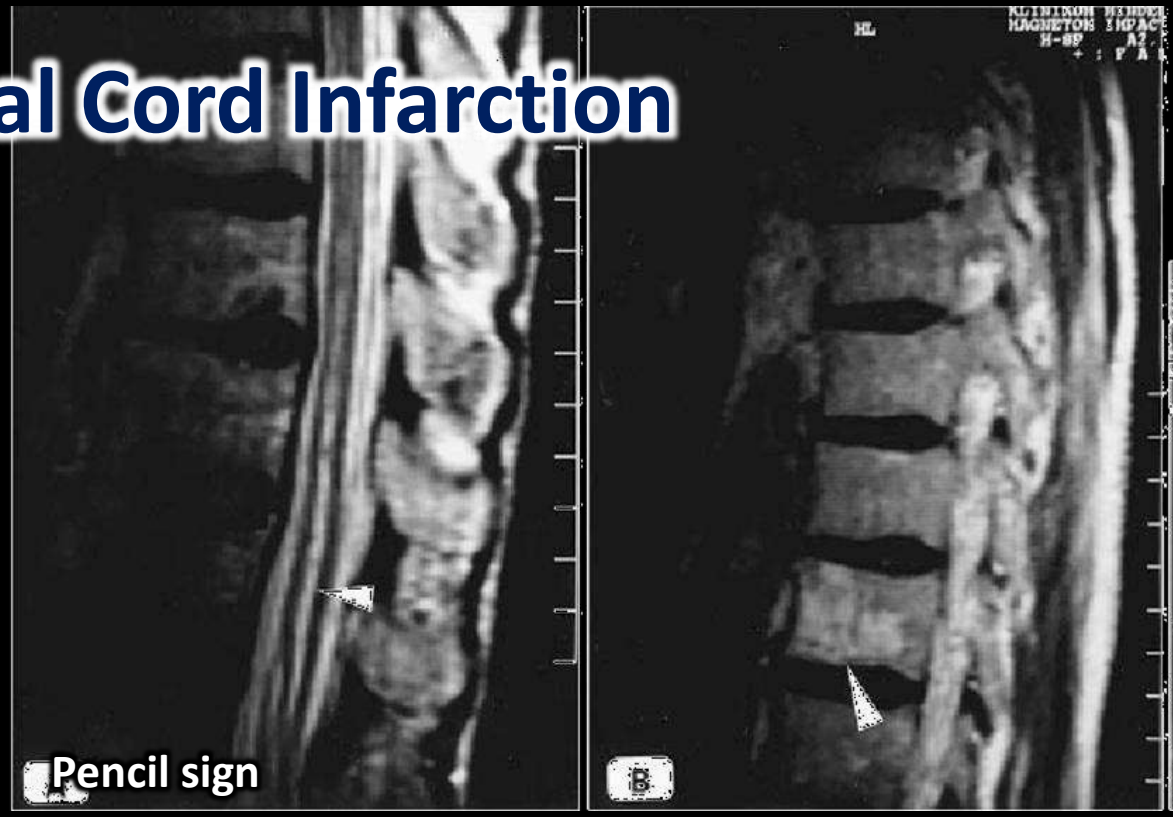
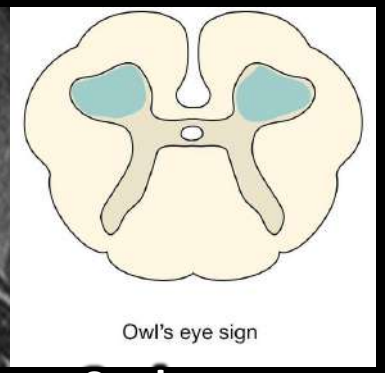


Pencil sign

Abnormal bone signal
Thrombotic plaque on aorta



Snake-eye

Restricted diffusion (↑DWI, ↓ADC)

Spinal Dural Arteriovenous Fistula

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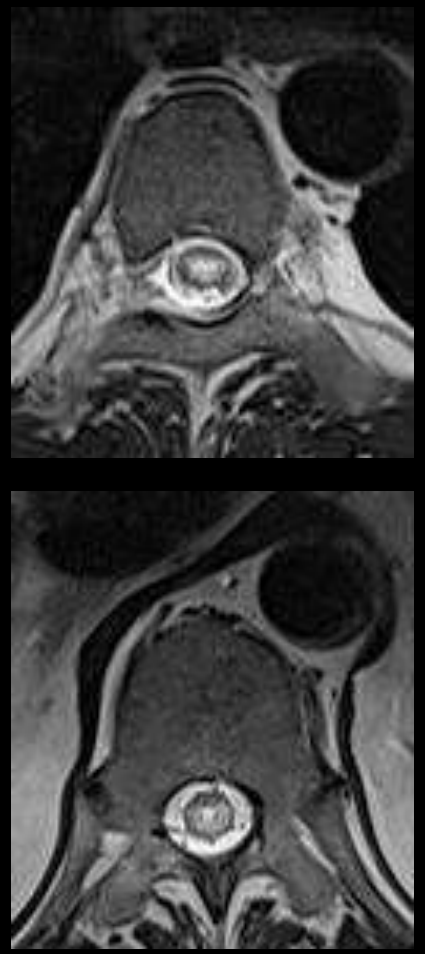

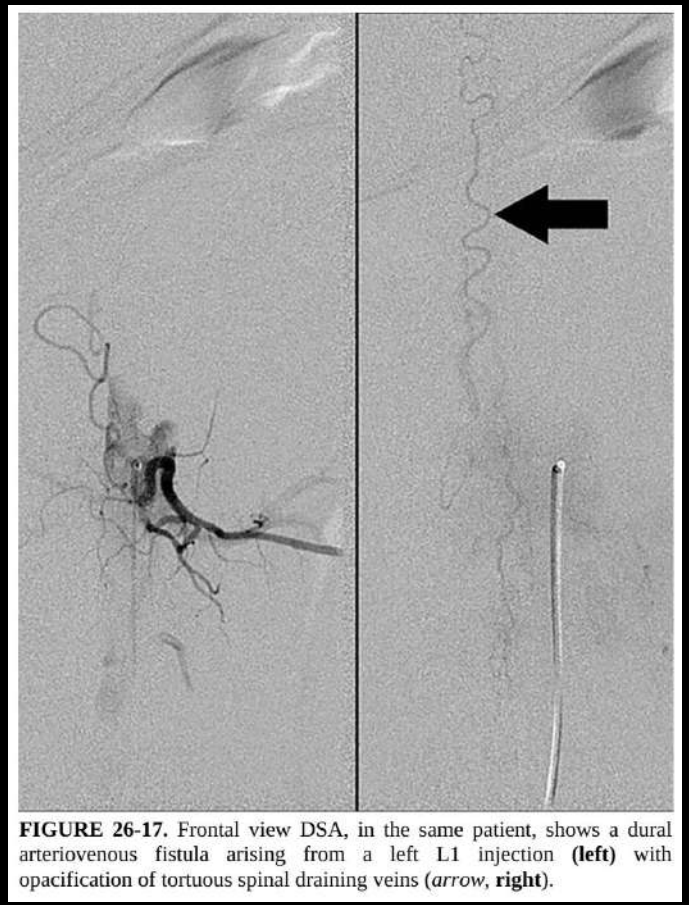

FIGURE 26-17. Frontal view DSA, in the same patient, shows a dural arteriovenous fistula arising from a left L1 injection **(left)** with opacification of tortuous spinal draining veins (*arrow*, **right**).

Intramedullary hyperT2 (due to edema), can reach the level of longitudinal extensive lesion

Prominent serpiginous intradural extramedullary flow-void structures

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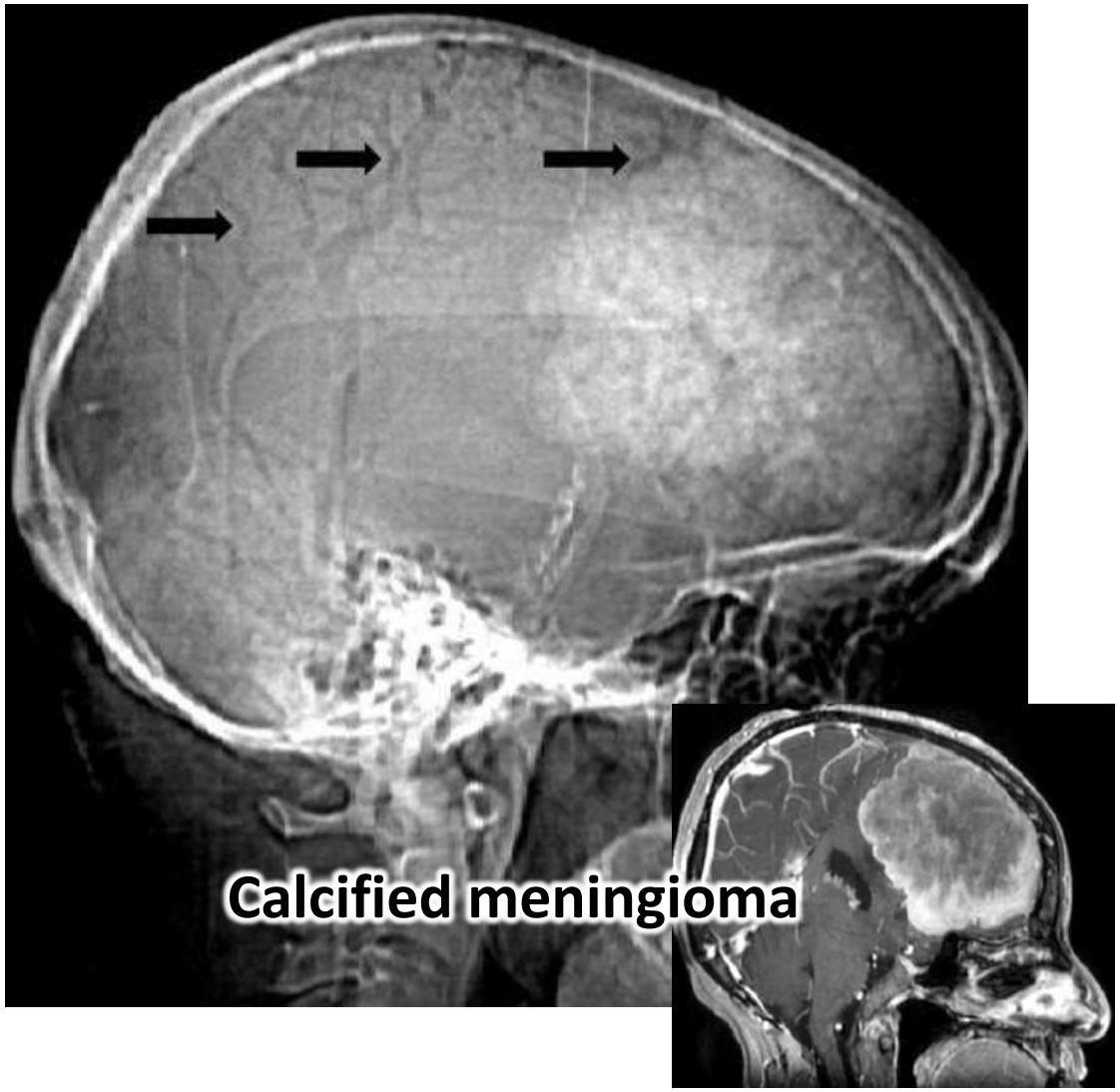
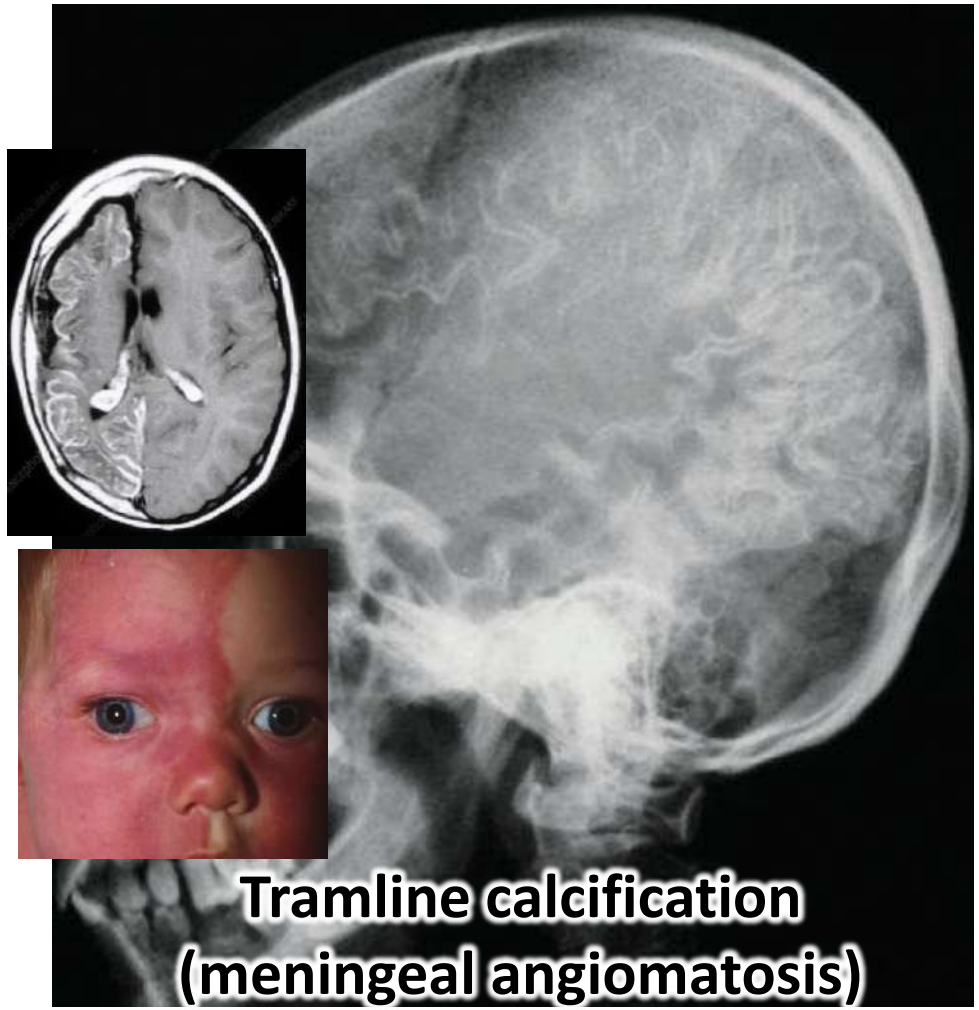
Review in Internal Medicine 2026 - Essential in Neuroimaging

Plain X-Ray Film

Plain Film Used in Selected Conditions



Calcified meningioma

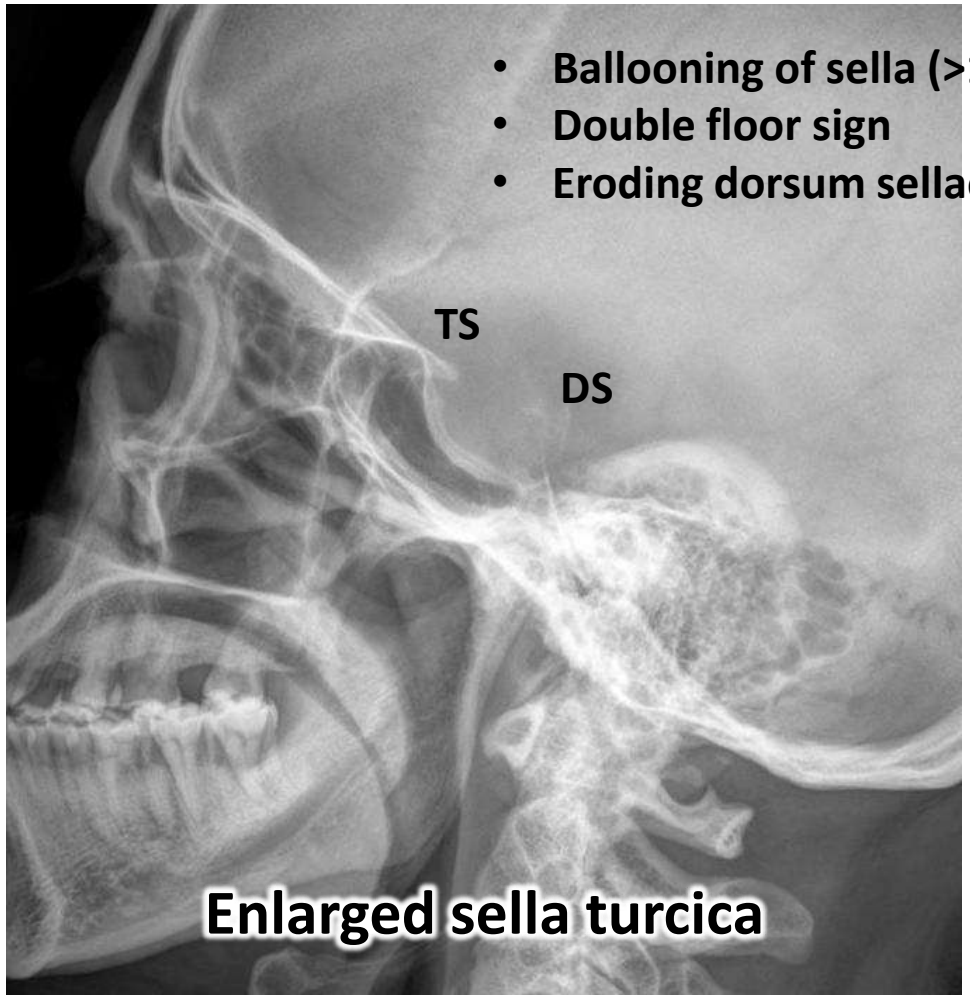


Tramline calcification
(meningeal angiomatosis)

Khaiary S, Orz Y. BMJ Case Rep 2017.
Sattur AP, Goyal M. Lancet 2011; 378: 1580.
https://www.sciencephoto.com/media/262710/view/sturge-weber-syndrome
Wolf SM. Pediatric Ann 2006; 35(5): 332-44

Plain Film Used in Selected Conditions

Skull metastases



Enlarged sella turcica

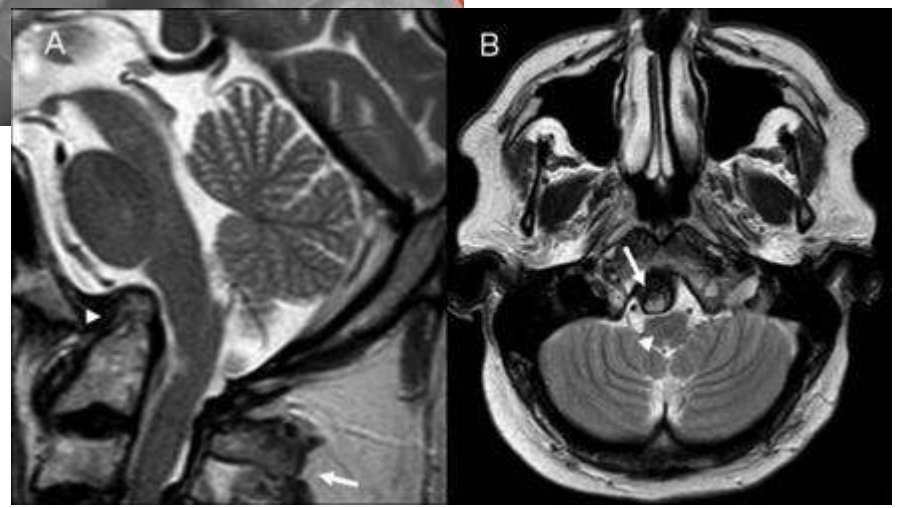
https://radiopaedia.org/cases/osteolytic-skull-metastasis-of-lung-cancer
https://radiopaedia.org/cases/pituitary-macroadenoma-2

TS tuberculum sellae, DS dorsum sellae

Plain Film Used in Selected Conditions

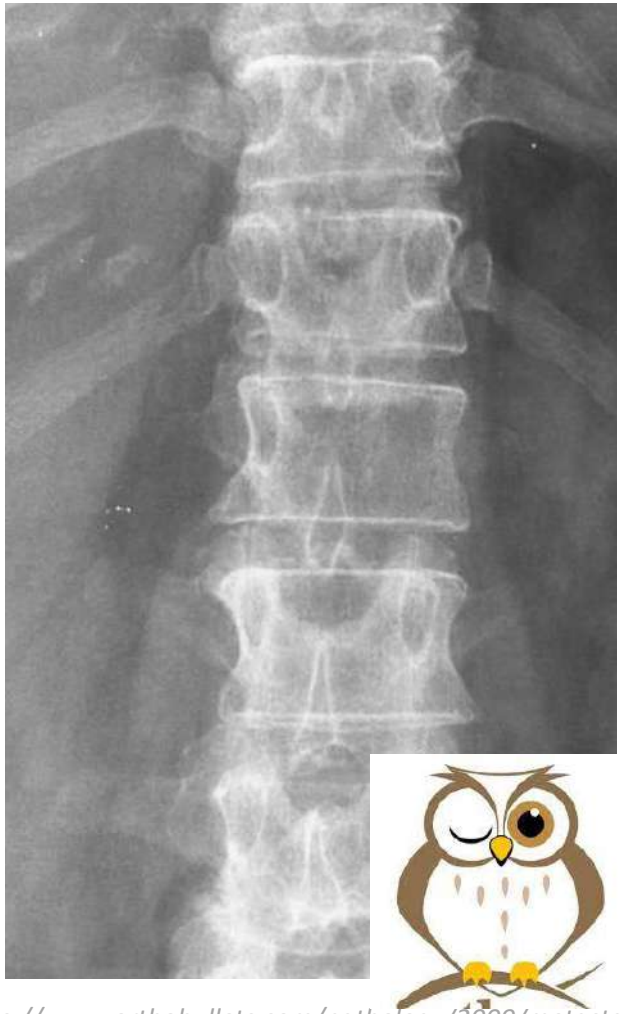
Atlanto-axial subluxation

- Rheumatoid arthritis
- Psoriatic arthritis
- Ankylosing spondylitis
- SLE
- Down syndrome
- Marfan syndrome
- Neurofibromatosis type 1
- Etc.



http://learningradiology.com/archives05/COW%20177-RA-CSpine/racspinecorrect.htm
https://radiopaedia.org/cases/atlantoaxial-subluxation-in-rheumatoid-arthritis?lang=us
Renna R, et al. J Rheumatol 2013; 40(11): 1925

Plain Film Used in Selected Conditions



Vertebral metastases

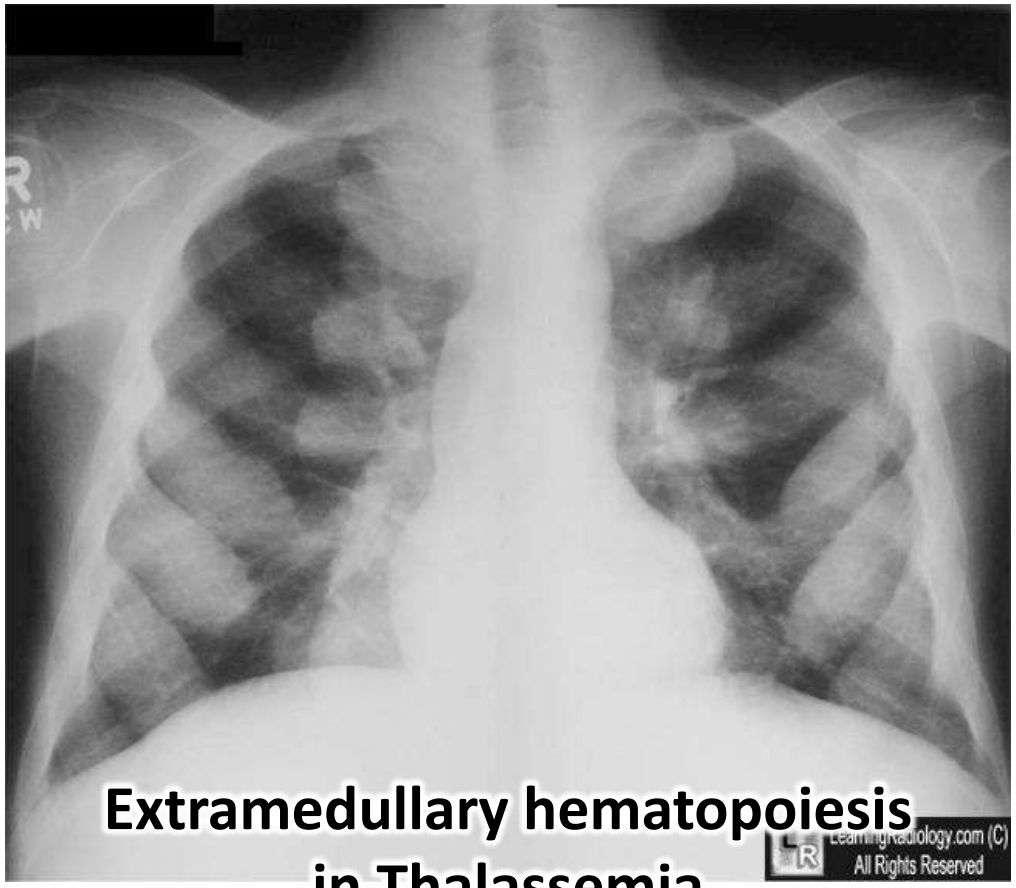
- Absent pedicle sign
- 'Winking owl' sign
- Breast, thyroid, renal, lung, prostate cancers

Osteoblastic bone lesions

- Ivory vertebra
- Prostate > breast/lung/carcinoid
- Paget's disease, lymphoma, renal osteodystrophy, etc.

https://www.orthobullets.com/pathology/2009/metastatic-disease-of-spine
https://www.facebook.com/TheWinkingOwlAviemore/
http://www.meddean.luc.edu/lumen/meded/radio/curriculum/surgery/met_bone_list1.htm
https://www.rama.mahidol.ac.th/radiology/sites/default/files/public/meet17/ISSROP/60-06-10-handout_Multiple_bone_lesions.pdf

Plain Film Used in Selected Conditions



Extramedullary hematopoiesis in Thalassemia

Hashmi MA, et al. Asian J Neurosurg 2014; 9(2): 102-4
https://learningradiology.com/notes/bonenotes/extramedullarycorrect.html

Outline: Essential in Neuroimaging

- Basic principles of imaging
- Neuroimaging in selected conditions

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34th Review in Internal Medicine 2026

Essential in Neuroimaging

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April 6th, 2026