Neuroradiology in sub-Saharan Africa

– what can, should, must be done

In Neurodegenerative Diseases, Dementias and Movement Disorders

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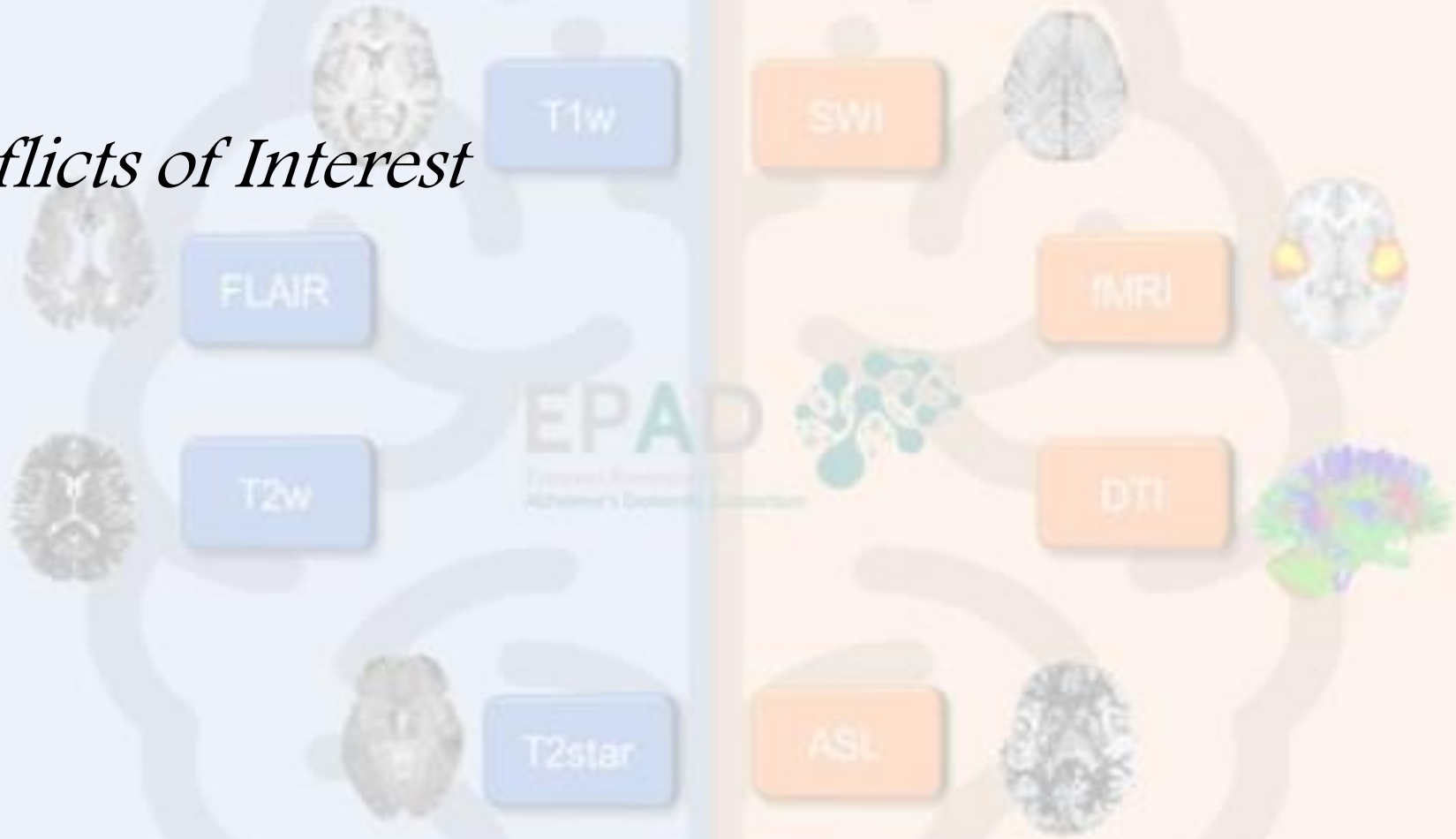
Declaration

- *No conflicts of Interest*



Prerequisite

- Before completing this Teaching Course, participants should have a background on:

1. **Clinical aspects** of main neurodegenerative diseases, dementia and movement disorders
2. **Neuroanatomical** basics
3. **Neuroimaging basics** (structural imaging (CT scan, MRI (sections/ sequences/ indications), functional imaging, molecular imaging)

Objectives

- After completing this Teaching Course, participants will be able:

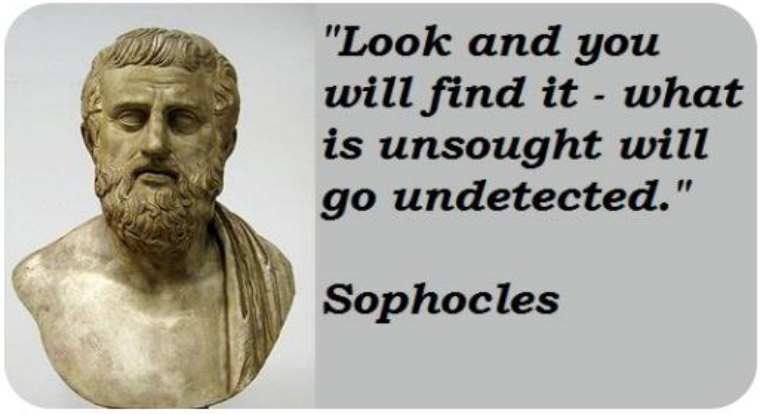
1. To determine the **adapted imaging protocol** for main neurodegenerative diseases, dementias and movement disorders

2. To describe **abnormal imaging findings** in main neurodegenerative diseases, dementias and movement disorders

Introduction

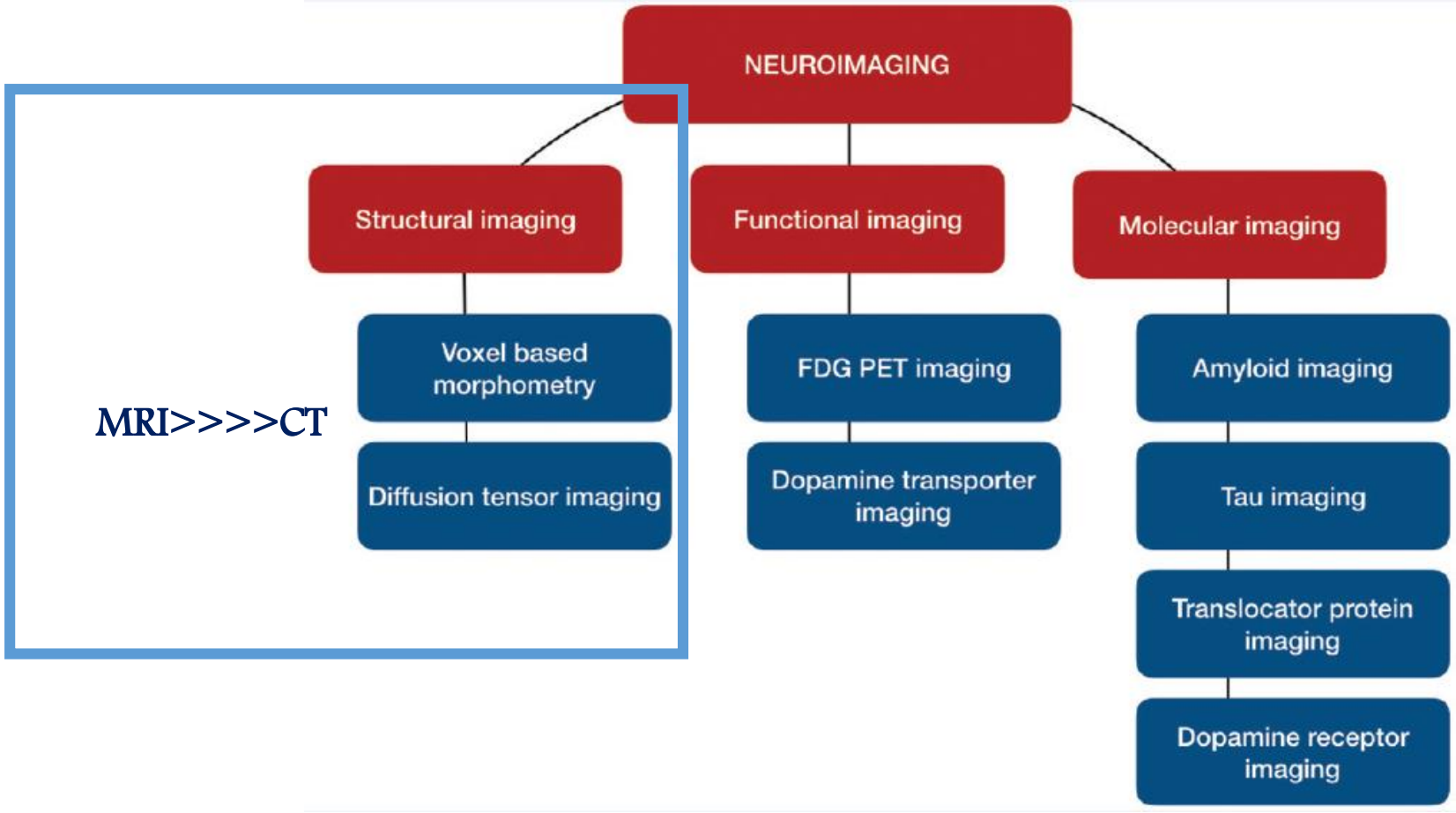
- Role of Neuroimaging in **dementia and movement disorders** nowadays:
  - Extends beyond its traditional role of ***excluding neurosurgical lesions or other acquired/ treatable causes*** ***(exclusionary role)***
  - ***Supports/confirms diagnosis*** of specific neurodegenerative disorders (NDD) ***(inclusionary role)***
  - Contributes to the ***early diagnosis*** of NDD (in MCI➔ early biomarkers)
  - Assesses disease ***progression***

- Need for **standardized, adapted protocol**
  - For each type of NDD (dementias, parkinsonian syndromes, movement disorders)
  - Exclusion of acquired conditions



What can, should, must be done?

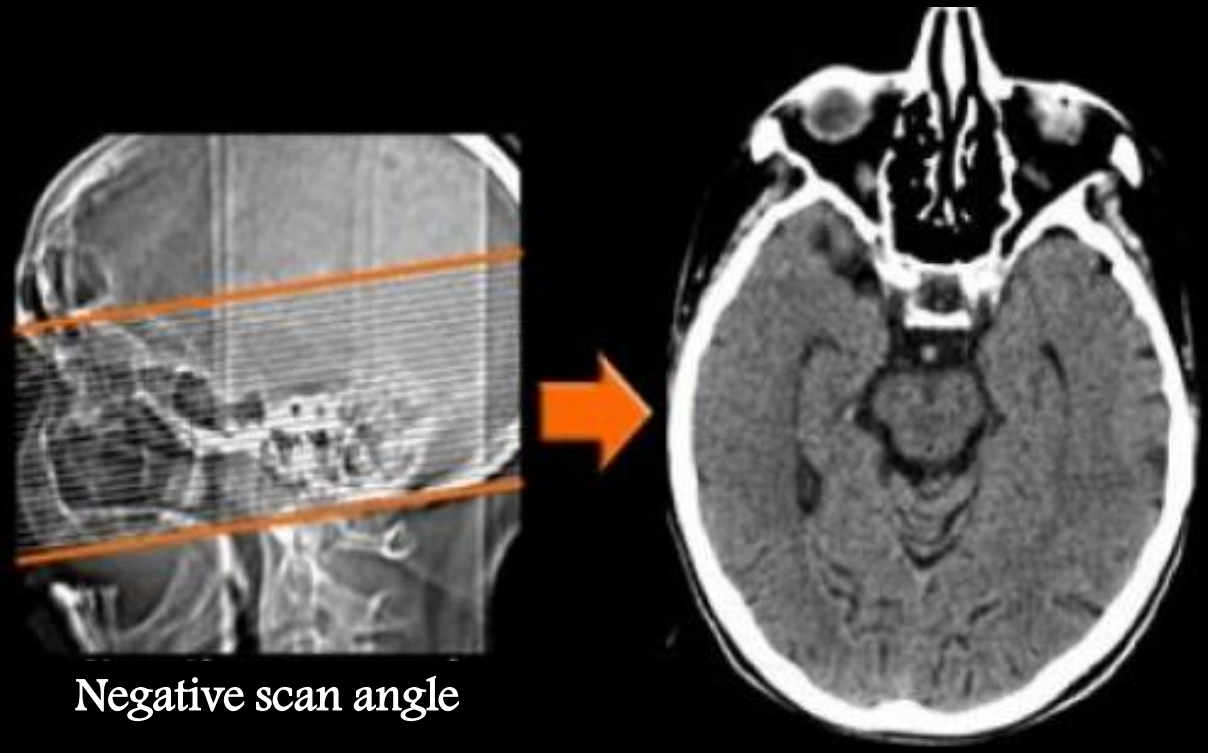
- **Combination** of imaging techniques: often needed for complete evaluation of the patient ➔ help establish the most likely diagnosis



Ranganathan et al, Changing landscapes in the neuroimaging of dementia, Ann Indian Acad Neurol,, 2018

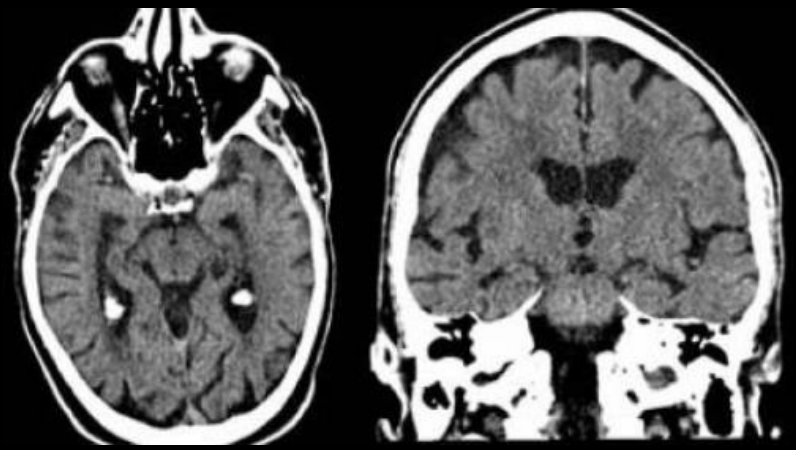
CT Protocol

when contraindications prevent MRI (claustrophobia, pacemaker, very old age)
when the only reason for imaging is to rule out surgically treatable causes

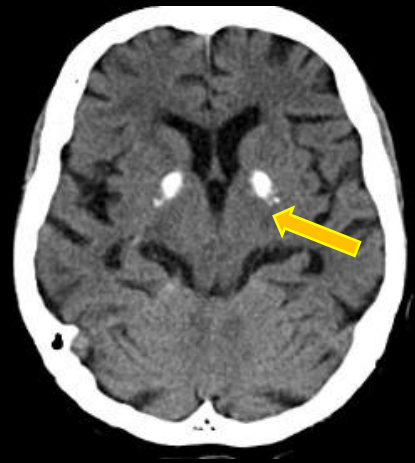


Negative scan angle

CT with negative scan angle for optimal vizualisation of the hippocampus in the transverse plane



Spiral CT of the brain with coronal reconstructions

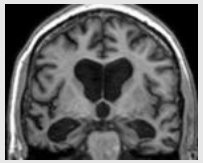
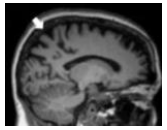
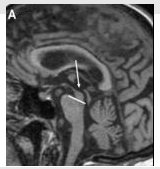
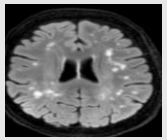
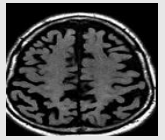
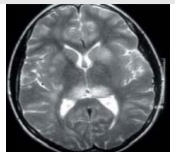
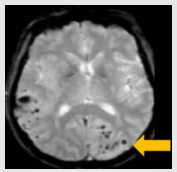
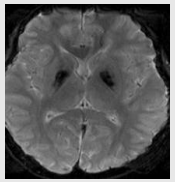
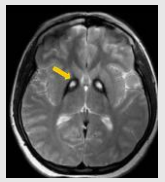
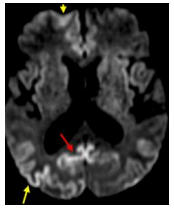


Calcifications

MRI : What for?

- Determine degree and pattern of general cortical atrophy (**GCA**)
- Assess **focal atrophy**
- Assess **microbleeds**
- Determine degree of **vascular** damage and occurrence of **strategic infarct**
- **Differentiate** between various etiologies
- **Exclude** structural lesions

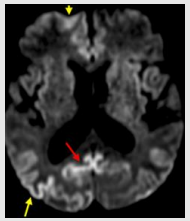
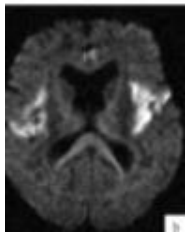
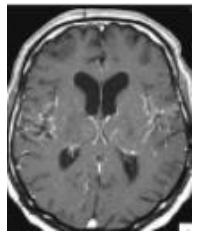
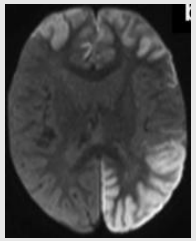
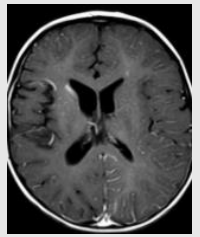
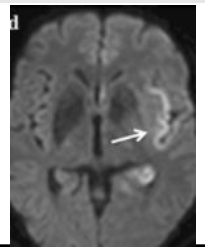
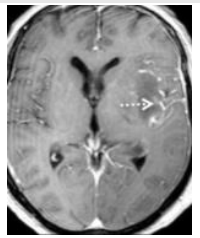
MRI Protocol in Dementia/NDD

MRI section/Sequence	Indication	Peculiar features
Coronal-oblique T1 	Medial temporal lobe and **hippocampal atrophy**	• In a plane orthogonal to long axis of hippocampus (perpendicular to hippocampus); parallel to brainstem • 3D MPRAGAE isotropic voxels (reformatting a sagittal 3D T1 sequence through the entire brain) • Thin-section images
Sagittal reconstructions 	**Midline** structures and **parietal atrophy** 	-
Transversal FLAIR 	**Global** cortical atrophy (GCA) **Vascular** white matter hyperintensities **Infarctions** 	3 mm slices, 1mm istropic voxels
Transversse T2W 	**Infarctions** (in particular lacunar infarctions in the **thalamus and basal ganglia**)	3 mm slices, 1mm istropic voxels
*Transverse T2** 	**Microbleeds** in amyloid angiopathy **Calcification** **Iron** deposition  	Gradient-echo, 3 mm slices, TE> 30ms, small flip angle
DWI 	**Young** patients **Rapidly progressive** NDD (DD - vasculitis, CJD)	Supplemental sequence

Protocol that is used in the Alzheimer Centre in Amsterdam

Indications for DWI or contrast imaging

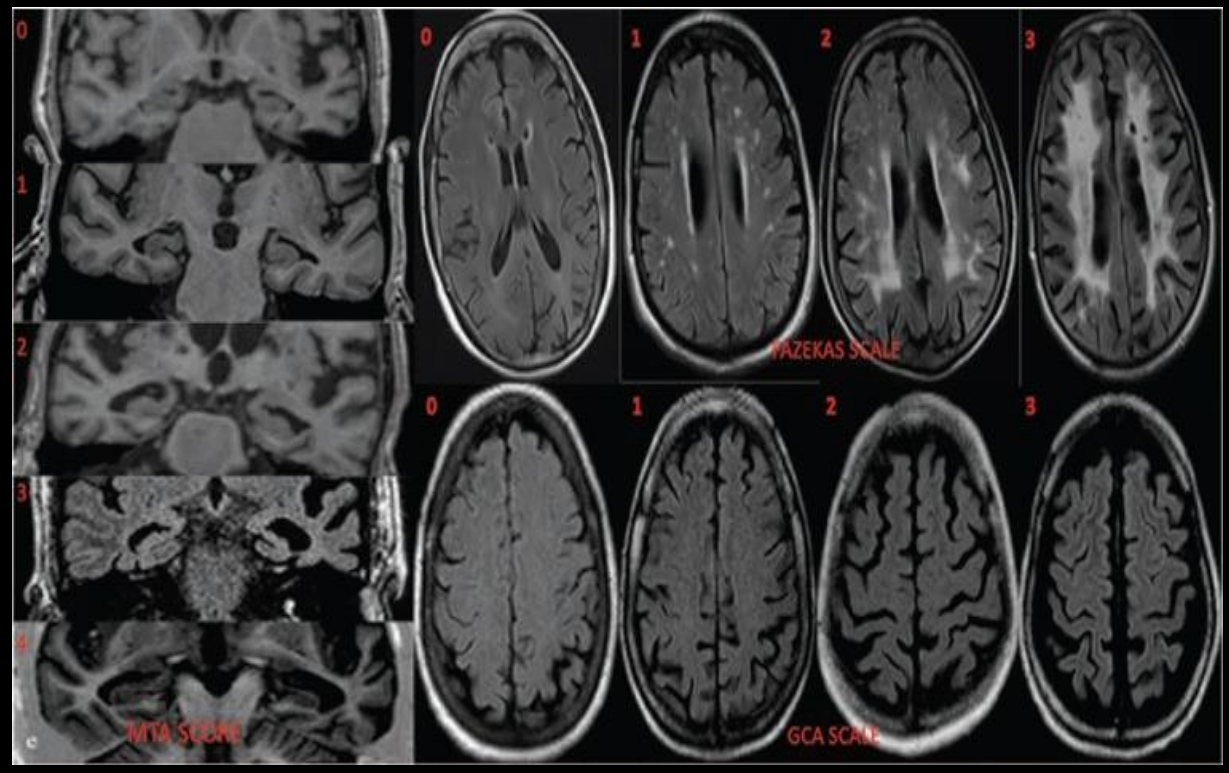
Rapidly progressive dementia/ Young patient

Indications	DWI	Contrast imaging
CJD 	Restricted diffusion (basal ganglia or cortex)	No enhancement with contrast
Infection 	Restricted diffusion (e,g, HSV)	Enhancement of inflamed areas 
Vasculitis 	Areas of infarction	Vascular and leptomeningeal enhancement 
Recent ischemia 	Restricted diffusion	Cave luxury perfusion with enhancement in subacute 

Visual Rating Scales in Dementia

- Global cortical atrophy (GCA)
  - *Pasquier scale (0-3)*
- Medial temporal lobe atrophy (MTA)
  - *Scheltens scale (0-4)*
- Posterior cortical atrophy
  - *Koedam scale (0-3)*
- Fronto-temporal atrophy
  - *Kipps scale (0-4)*

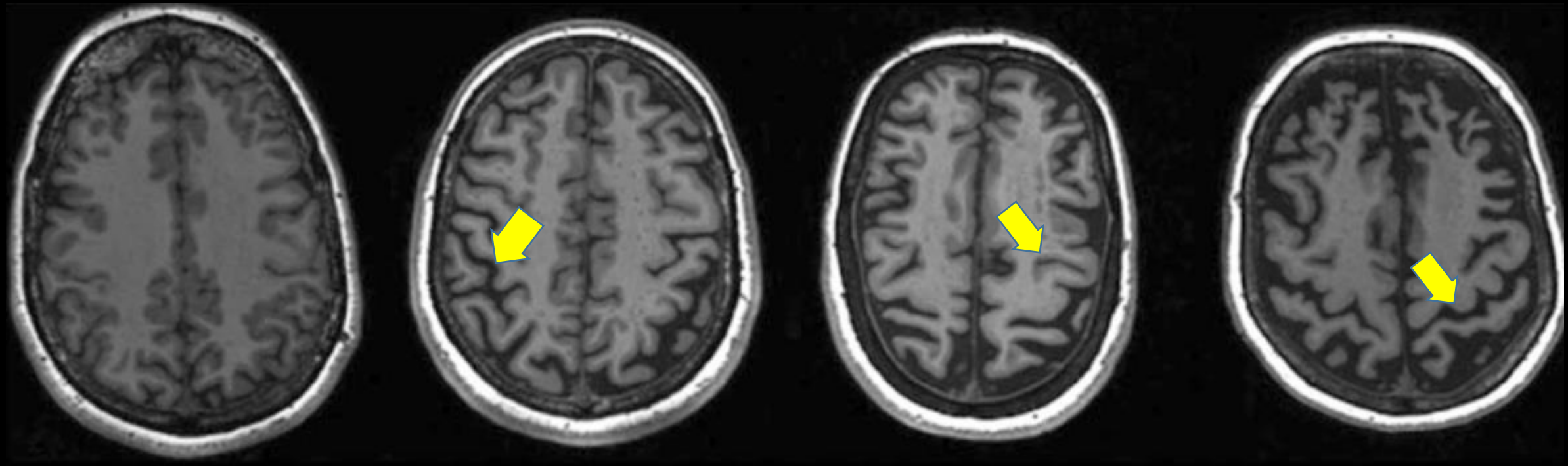
- White matter hyperintensities (WMH)
  - *global Fazekas (0-3)*
  - *regional ARWMC (0-24)*
  - *Visual rating of WMHs according to Scheltens (0-84)*
- Microbleeds
  - *BOMBS*
  - *MARS*
- Enlarged perivascular spaces (EPVS)



Kaushik et al, J Neurosci Rural Pract. 2021

Global Cortical Atrophy (GCA)scale
(Pasquier scale: 0–3)

- Best assessed on FLAIR and 3D T1 images (Cortical atrophy is best scored on FLAIR images)



Score 0
No cortical atrophy
(Normal)

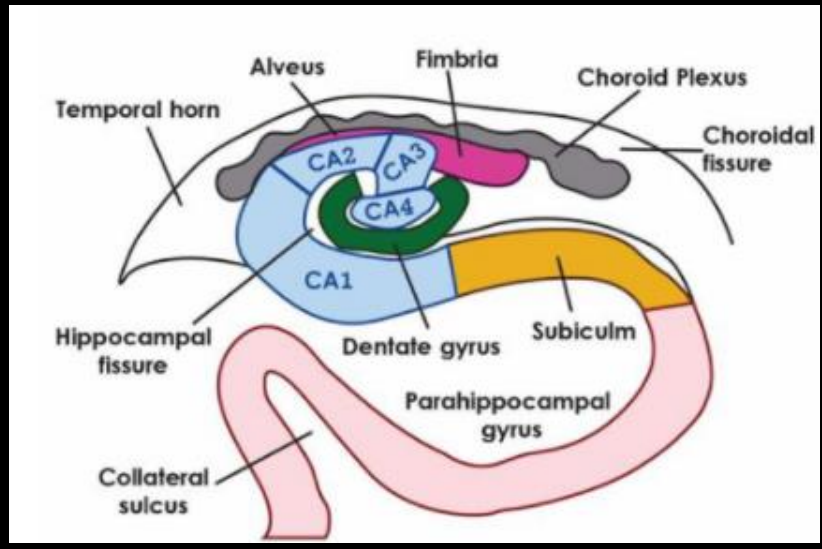
Score 1
Mild atrophy
(opening of sulci
= Open sulci)

Score 2
Moderate atrophy
(volume loss of gyri
=Gyral atrophy)

Score 3
Severe (end-stage) atrophy
(knife blade' atrophy)

J Korean Neuropsychiatr Assoc. 2018
Harper L et al. J Neurol Neurosurg Psychiatry 2015

Medial temporal lobe atrophy (MTA) scale (Scheltens scale: 0–4)

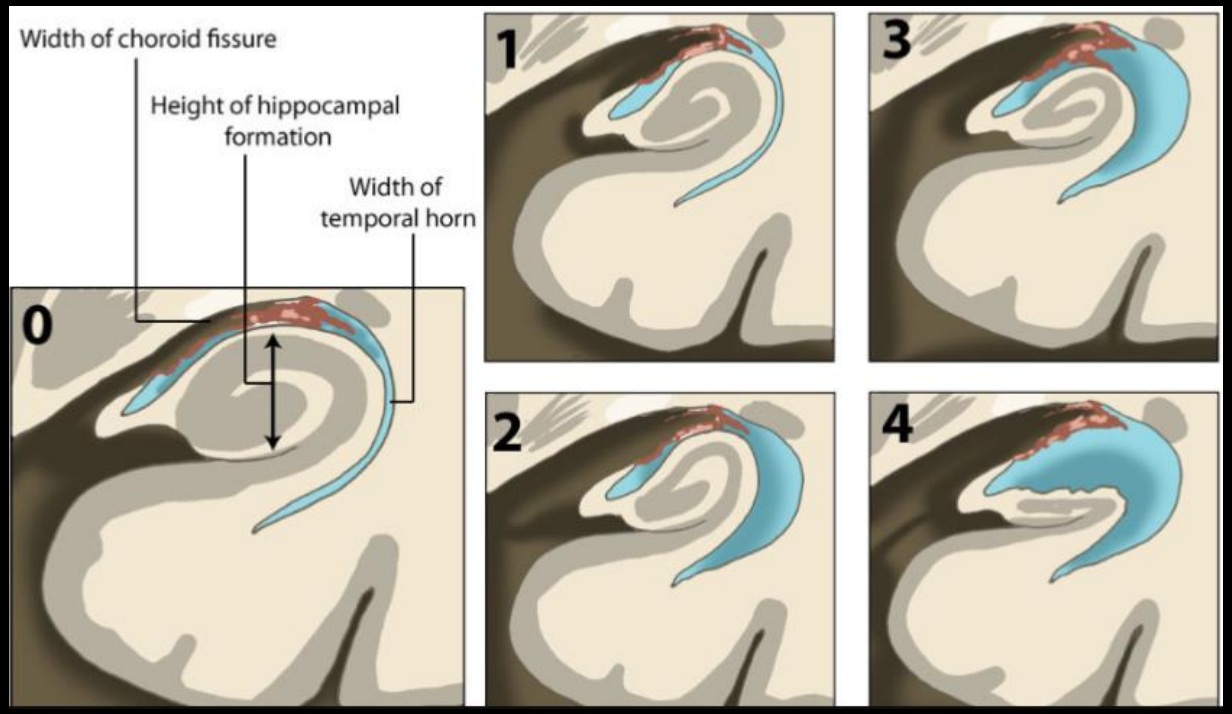


Score	Width of choroid fissure	Width of temporal horn	Height of hippocampal formation
0	N	N	N
1	↑	N	N
2	↑↑	↑	↓
3	↑↑↑	↑↑	↓↓
4	↑↑↑	↑↑↑	↓↓↓

score 0: no atrophy
score 1: only widening of choroid fissure
score 2: also widening of temporal horn of lateral ventricle
score 3: moderate loss of hippocampal volume (decrease in height)
score 4: severe volume loss of hippocampus

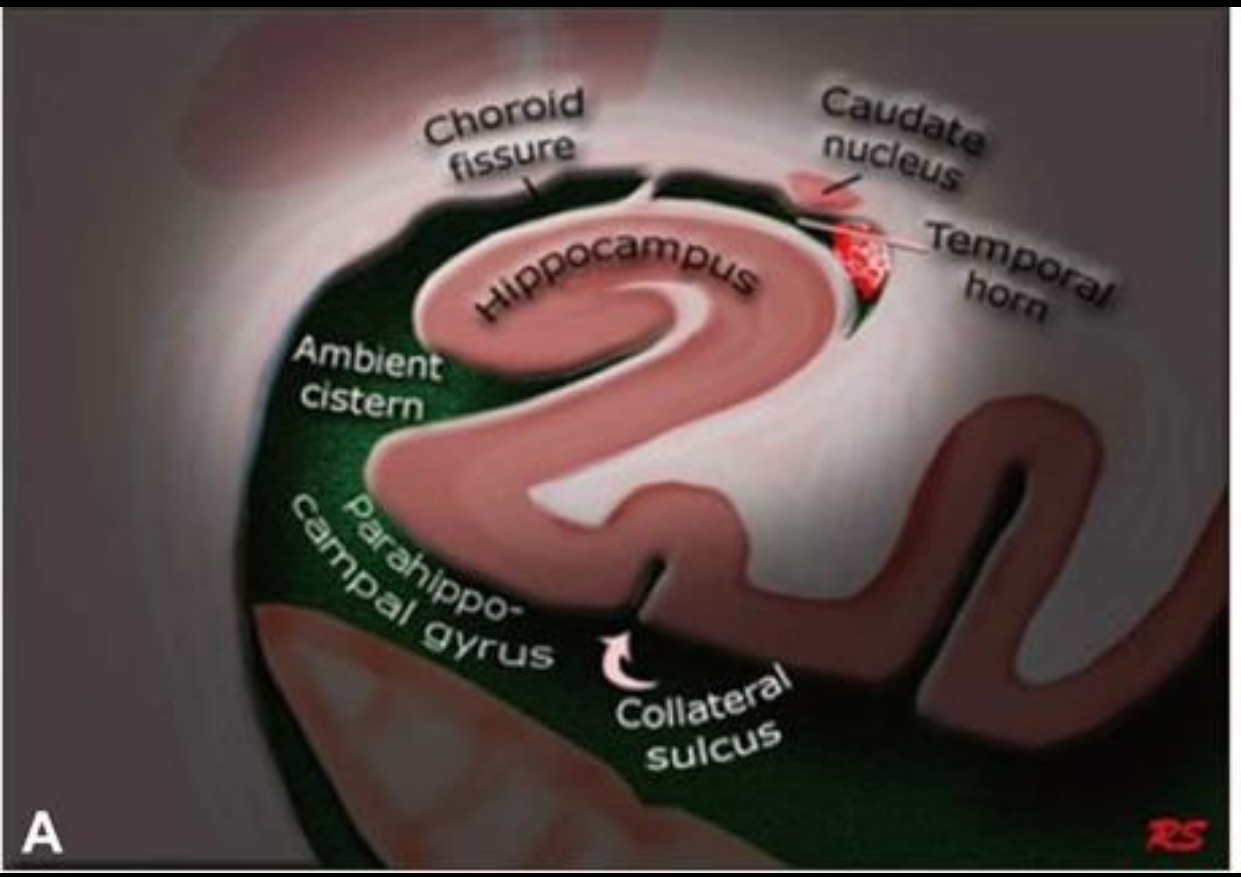
< 75 years: score 2 or more is abnormal.

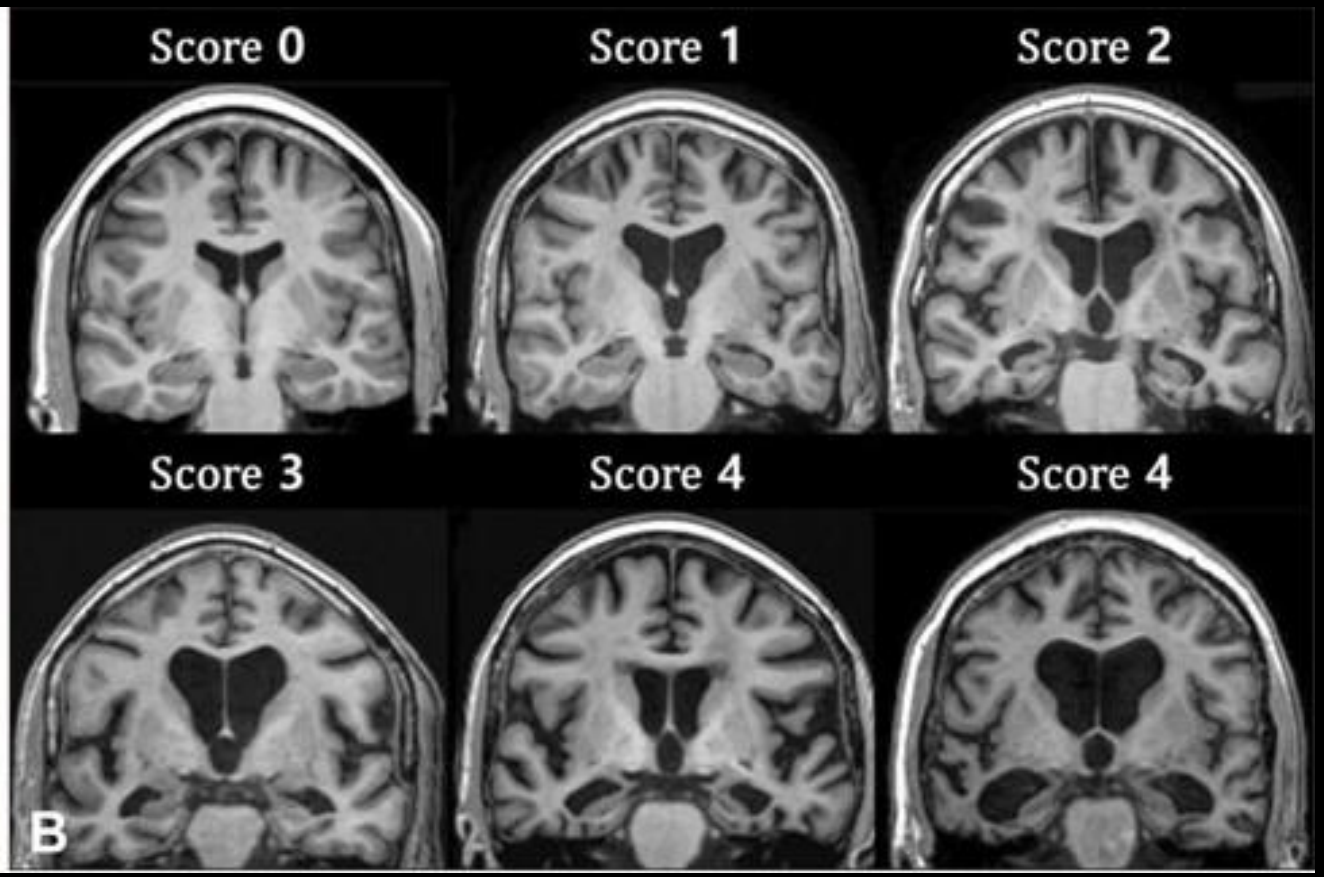
> 75 years: score 3 or more is abnormal



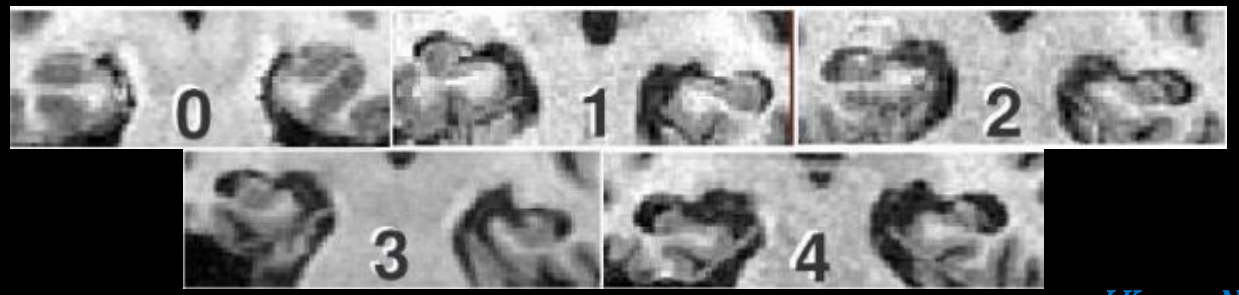
Alahmariet al, International Journal of Radiology 2020

MTA/Scheltens scale





- *rated on coronal T1*
- *slice through corpus of hippocampus (level of anterior pons)*



J Korean Neuropsychiatr Assoc. 2018

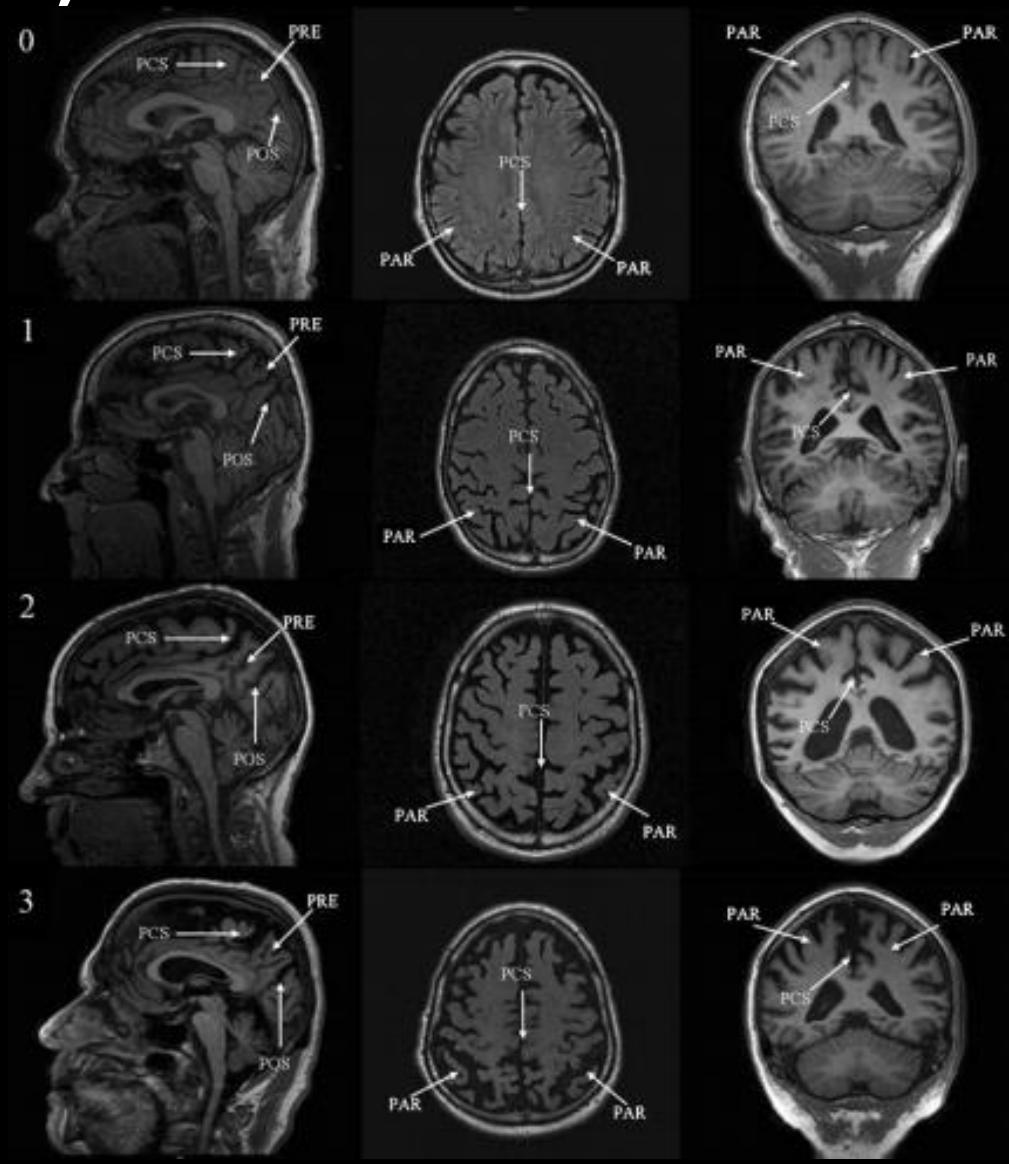
Posterior cortical atrophy
(Koedam scale : 0–3)

- Scale rated on:
  - Sagittal and coronal T1
  - Axial FLAIR

- Evaluates:
  - Sulci:
    - Posterior cingulate
    - Parieto-occipital
  - Parietal Cortex (including the precuneus)

Highest score obtained for an area

Koedam score	Parietal cortical atrophy	Sulci
Grade 0	No cortical atrophy	Closed sulci of parietal lobes and cuneus
Grade 1	Mild parietal cortical atrophy	Opening of sulci (mild widening of posterior cingulate and parieto-occipital sulci)
Grade 2	Moderate/substantial parietal atrophy	Volume loss of gyri (substantial widening of the sulci)
Grade 3	Severe atrophy = end-stage « knife-blade » atrophy	Extreme widening of the posterior cingulate and parieto-occipital sulci

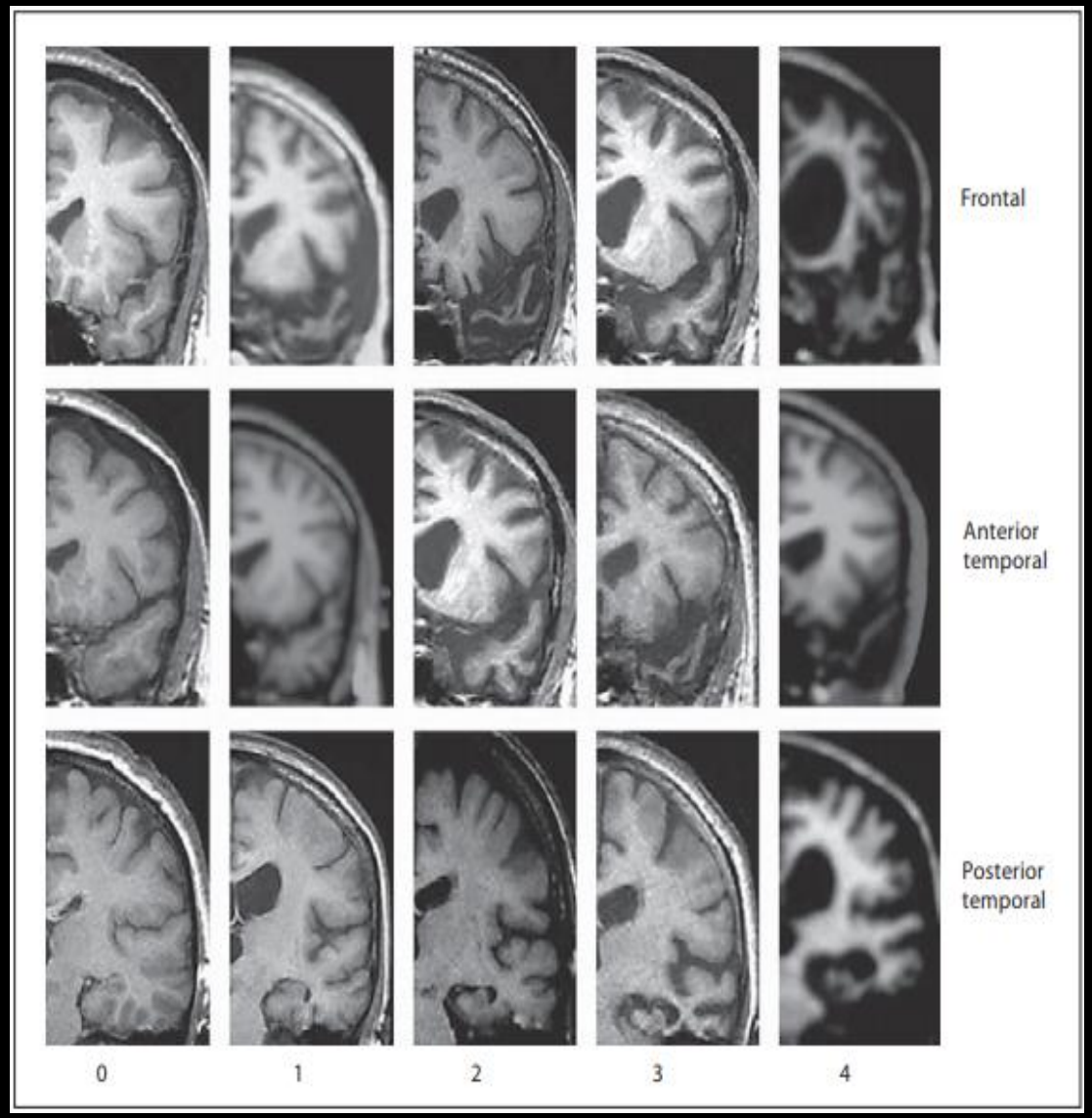


Koedam et al., Eur Radiol, 2011

Fronto-temporal atrophy
(Kipps scale : 0-4)

Scale rated on T1-weighted coronal

Stage	Frontal lobe	Anterior temporal lobe	Posterior temporal lobe
0	Normal appearances	Normal appearances	= normal appearances
1	mild atrophy of orbital or supero-medial frontal cortex – contour of the basal ganglia in the lateral ventricle is convex, as in controls, but with some prominence of the lateral ventricle	slight prominence of anterior temporal sulci	slight increased prominence of the lateral ventricle to form a rim around the anterior hippocampus – temporal sulci show mild prominence
2	definite sulcal widening in any cortical subregion or flattened profile to basal ganglia	temporal sulci definitely widened	lateral ventricle unarguably dilated with subtle reduction in hippocampal size – the medial temporal gyri may be atrophic, and there may be prominence of the temporal sulci
3	severer cortical atrophy with clear reduction in white matter and reduced white-grey matter differentiation – stage 3 basal ganglia have concave profile	gyri severely atrophic and ribbonlike – white and grey matter cannot be distinguished (normal temporal lobe at this level is less substantial than the frontal lobe, and so the ribbon-like gyri of the stage 3 temporal lobe are similar to stage 4 frontal gyri)	the hippocampus is small and sits at the medial tip of a greatly expanded temporal horn – sulci are definitely widened
4	cortex reduced to a ribbon and the basal ganglia virtually indiscernible	temporal pole has a simple linear profile or is not seen at all	hippocampus is extremely small – temporal cortex and white matter show almost complete atrophy

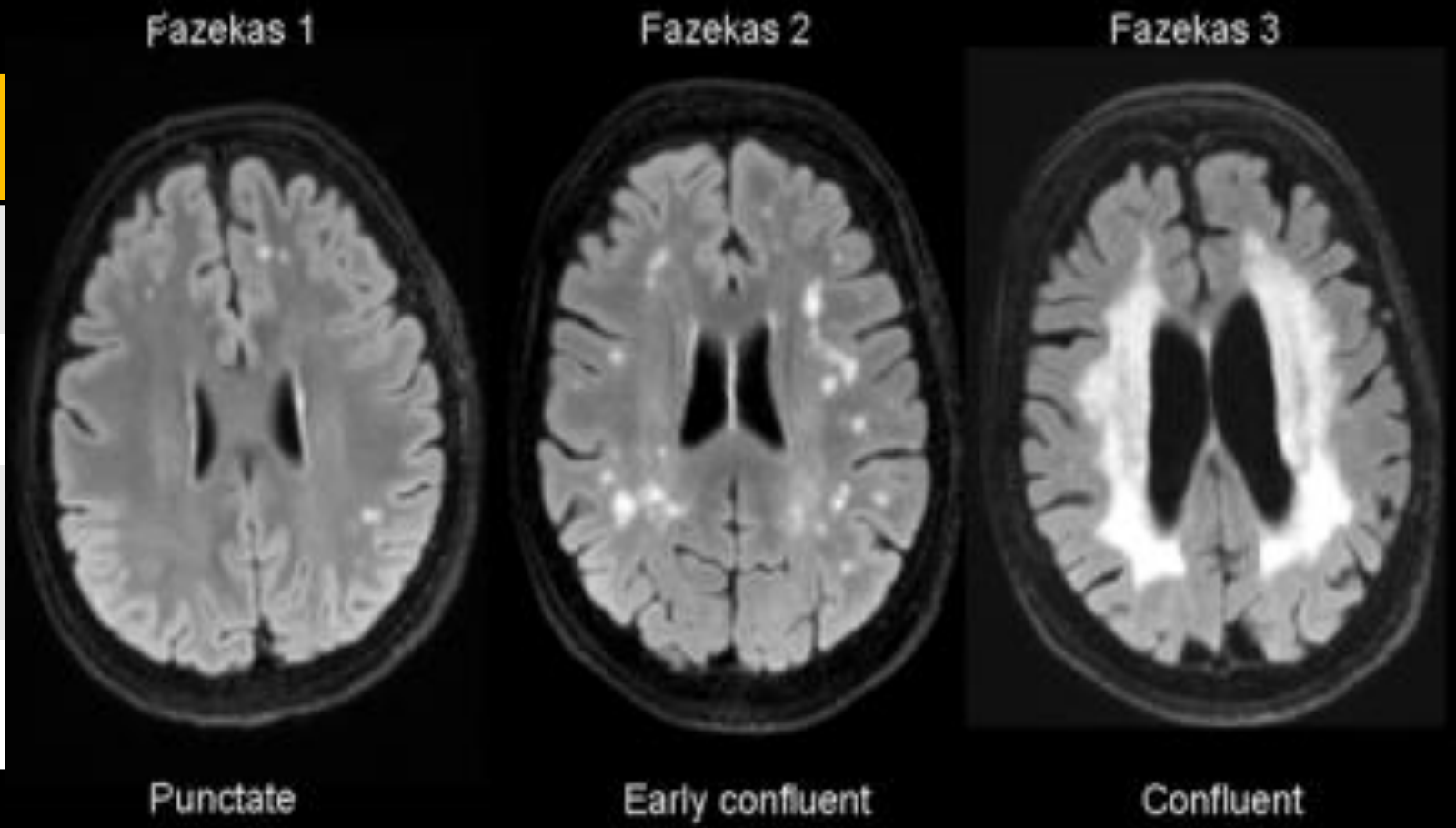


Kipps et al,, Dement Geriatr Cogn Disord 2007

White Matter Hyperintensities: Global Fazekas scale (0-3)

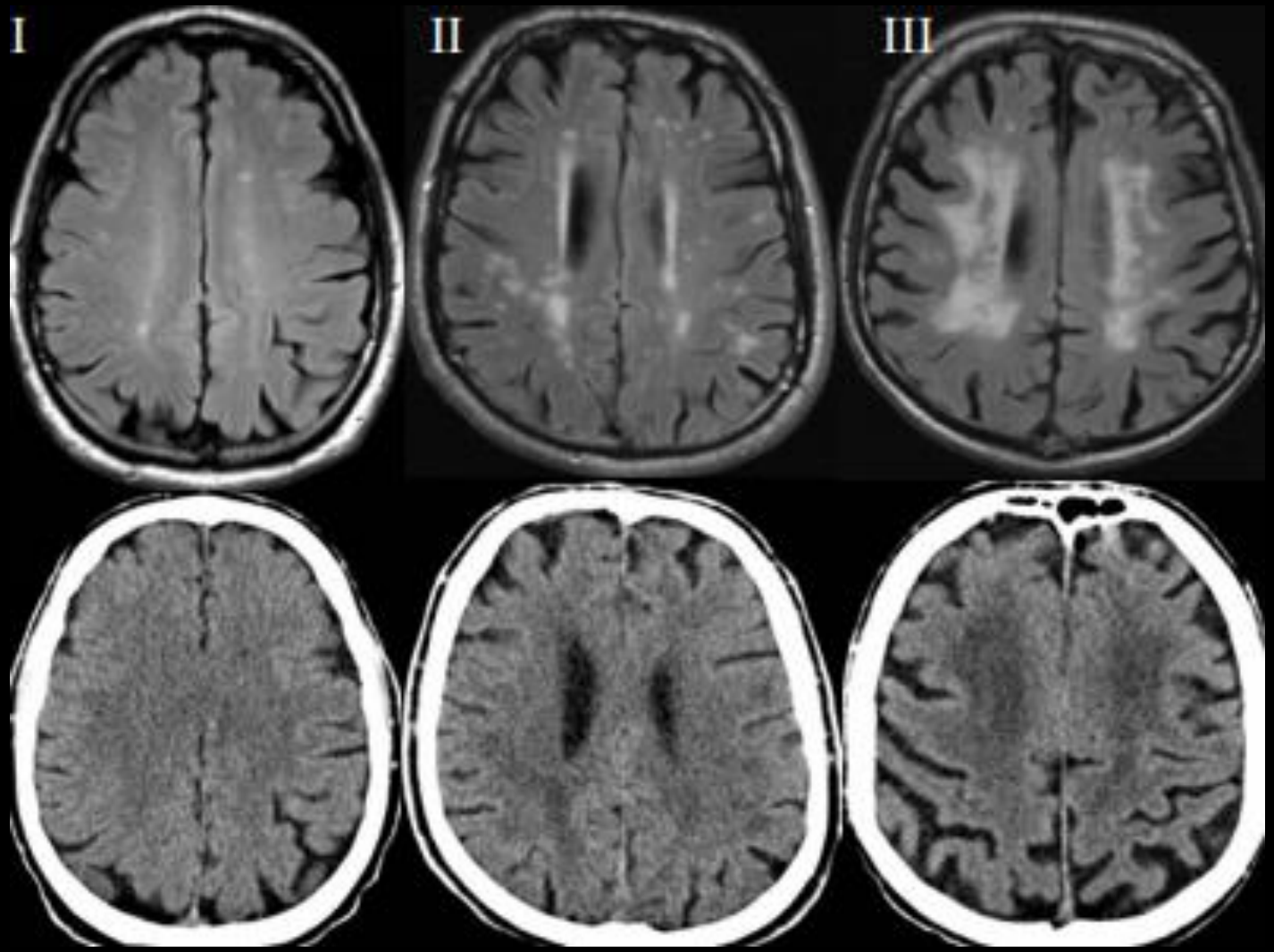
best scored on transverse FLAIR or T2-weighted images

Fazekas score	White Matter Hyperintensities (WMH)
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



Kaushik et al, J Neurosci Rural Pract. 2021

Fazekas: CT vs MRI



Box 1 | Visual rating of WMHs according to Fazekas[19]

Fazekas 0

No WMHs

Fazekas 1

Focal or punctate lesions:

- Single lesions ≤9 mm
- Grouped lesions <20 mm

Fazekas 2

Beginning confluent lesions:

- Single lesions 10–20 mm
- Grouped lesions >20 mm in any diameter
- No more than connecting bridges between individual lesions

Fazekas 3

Confluent lesion:

- Single lesions or confluent areas of hyperintensity ≥20 mm in any diameter

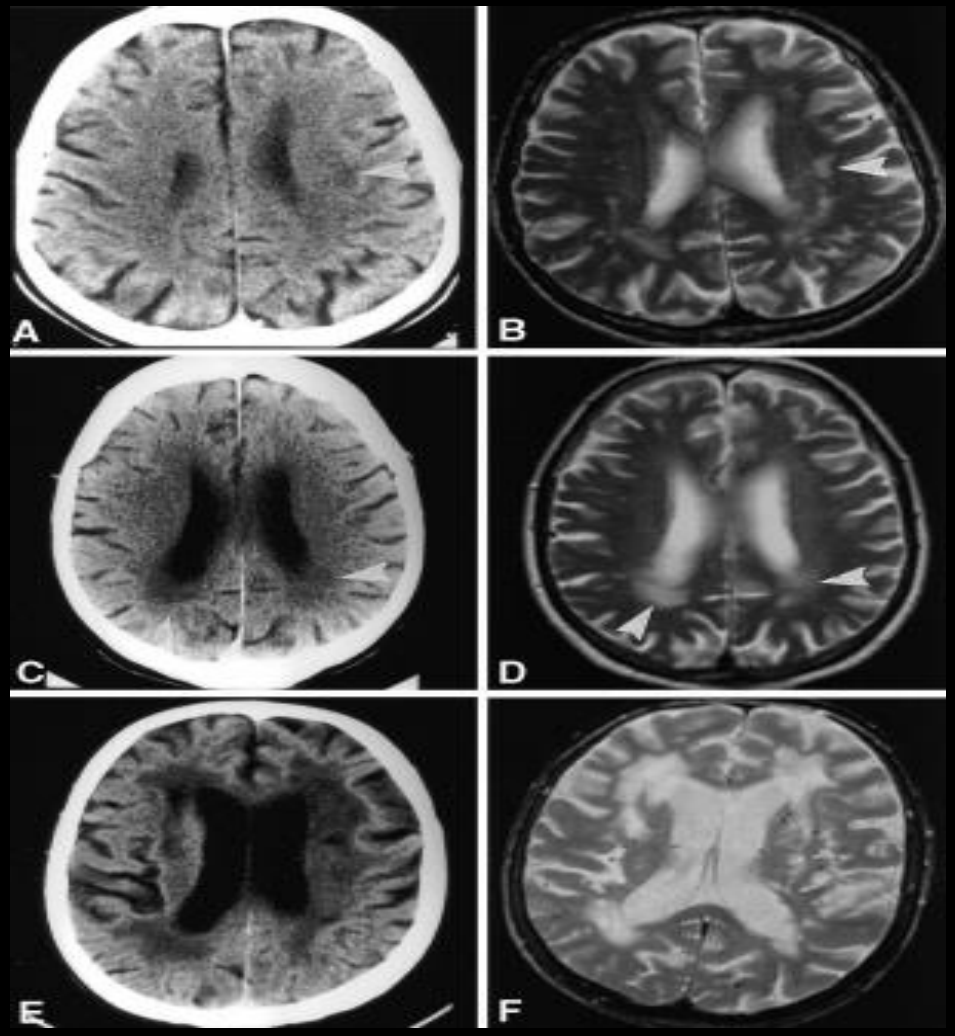
Abbreviation: WMHs, white matter hyperintensities.

Kaushik et al, J Neurosci Rural Pract. 2021

Age-Related White Matter Changes (ARWMC) scale

Applicable to both CT and MRI that has almost equal sensitivity

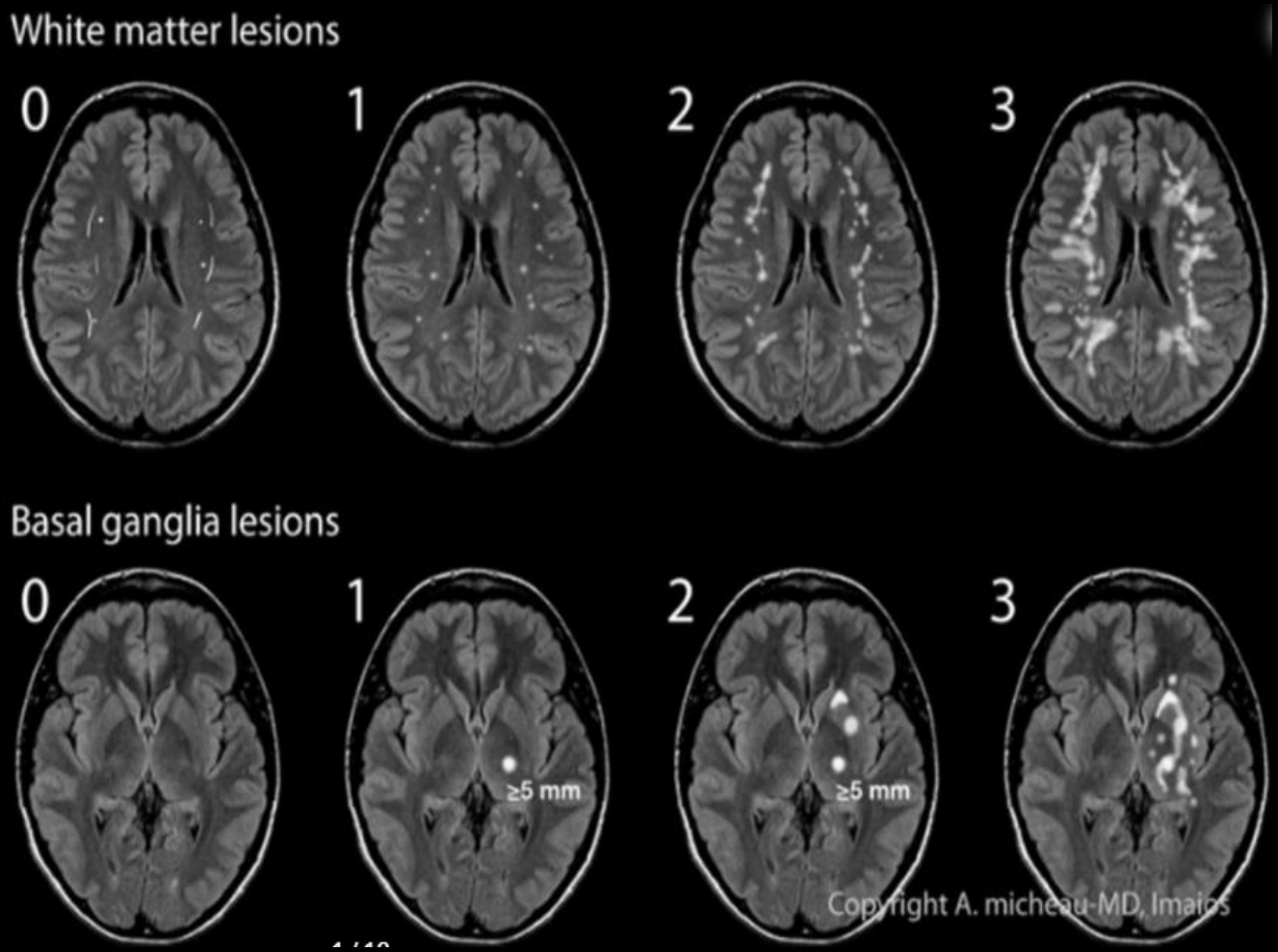
(except for certain regions (MRI>CT: parieto-occipital and infratentorial areas; FLAIR frontal and parieto-occipital)



Wahlund et al,, Stroke, 2001

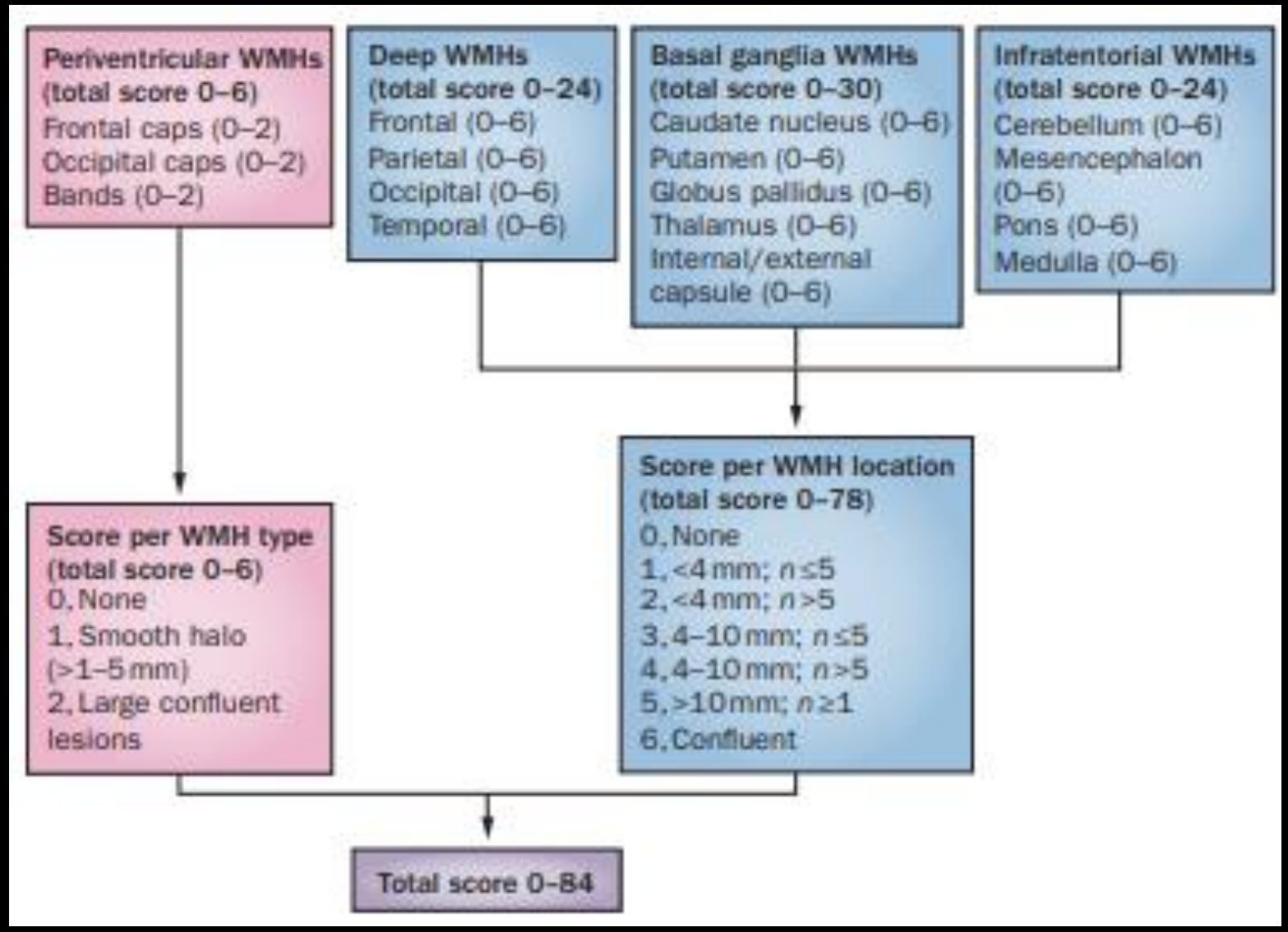
Age-Related White Matter Changes (ARWMC) scale

ARWMC Score	White matter lesions	Basal ganglia lesions
0	No lesions	No lesions
1	Focal lesions	1 focal lesion (>5 mm)
2	Beginning confluence of lesions	>1 focal lesion
3	Diffuse involvement of entire region, with or without involvement of U fibers	Confluent lesions



Wahlund et al., Stroke, 2001

Visual rating of WMHs according to Scheltens (0–84)



Scheltens, P. et al. A semiquantative rating scale for the assessment of signal hyperintensities on magnetic resonance imaging. J. Neurol. Sci. 1993
Prins, & Scheltens,. White matter hyperintensities, cognitive impairment and dementia: an update .Nat. Rev. Neurol, 2015

Microbleeds

best scored on T2*-weighted (SWI) images

The Microbleed Anatomical Rating Scale (MARS)

Reliability of a tool to map brain microbleeds

MARS

Gregoire et al,, Neurology, 2009

Improving Interrater Agreement About Brain Microbleeds

Development of the Brain Observer MicroBleed Scale (BOMBS)

Charlotte Cordonnier, PhD; Gillian M. Potter, FRCR; Caroline A. Jackson, MSc;
Fergus Doubal, MRCP; Sarah Keir, MD; Cathie L.M. Sudlow, DPhil;
Joanna M. Wardlaw, FMedSci; Rustam Al-Shahi Salman, PhD

BOMBS

Cordonnieret al,, Stroke, 2009

Figure Microbleed Anatomical Rating Scale

Patient ID: Date of Birth _ _/_ _/_ _ _ _ Date of MRI _ _/_ _/_ _ _ _

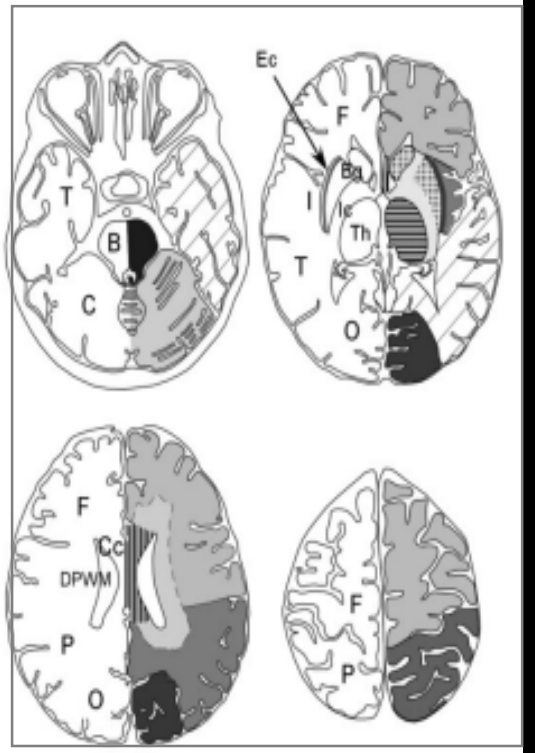
DEFINITE MICROBLEEDS: Small, round, well-defined, hypointense on GRE T2*; 2-10 mm; not well seen on T2

MICROBLEED MIMICS

- Vessels: linear / curvilinear lesions in subarachnoid space, usually cortical or juxta-cortical (visible on T2)
- Mineralization in globi pallidi or dentate nuclei: symmetrical hypointensities (may be bright flecks on CT)
- Haemorrhages within area of infarction (look at the T2, FLAIR or DWI sequences to identify infarction)
- Air-bone interfaces: frontal / temporal lobes (check adjacent GRE T2* slices to clarify)
- Partial volume artifact at the edges of the cerebellum (check adjacent GRE T2* to clarify)
- Small haemorrhages close to a large ICH (visible on GRE T2*) or to an infarct (visible on T2, FLAIR or DWI)

Right Left

		DEFINITE R	DEFINITE L	POSSIBLE R	POSSIBLE L
Infratentorial TOTAL	Brainstem (B)				
	Cerebellum (C)				
Deep TOTAL	Basal Ganglia (Bg)*				
	Thalamus (Th)				
	Internal Capsule (Ic)				
	External Capsule (Ec)				
	Corpus Callosum (Cc)				
	Deep and periventricular WM (DPWM)				
Lobar** TOTAL	Frontal (F)				
	Parietal (P)				
	Temporal (T)				
	Occipital (O)				
	Insula (I)				
TOTALS					



* (Caudate, Lentiform), **Lobar regions include cortex and subcortical white matter

The rating form is available on the Neurology® Web site at www.neurology.org. GRE = gradient-recalled echo; FLAIR = fluid-attenuated inversion recovery; DWI = diffusion-weighted imaging; ICH = intracerebral hemorrhage.

Gregoire et al., Neurology, 2009

The BOMBS rating scale

Brain Observer Micro Bleed Scale (BOMBS)

Date of MRI ___ / ___ / ___ Date of birth ___ / ___ / ___ Study ID_____

Are there any BMBs* ? No → Stop

Yes

Are there 1-2 BMBs? Yes →

- Flow voids in small cortical vessels [check T2/FLAIR]
- Hypointensity at site of deep perforators from proximal MCA
- Symmetrical hypointensity in globi pallidi [check CT: calcium?]
- Rate as 'uncertain' if pale or in a position susceptible to partial volume effects [adjacent to petrous temporal bone or orbit]
- Beware rating only 1 or 2 BMBs <5mm ['uncertain' if in doubt]

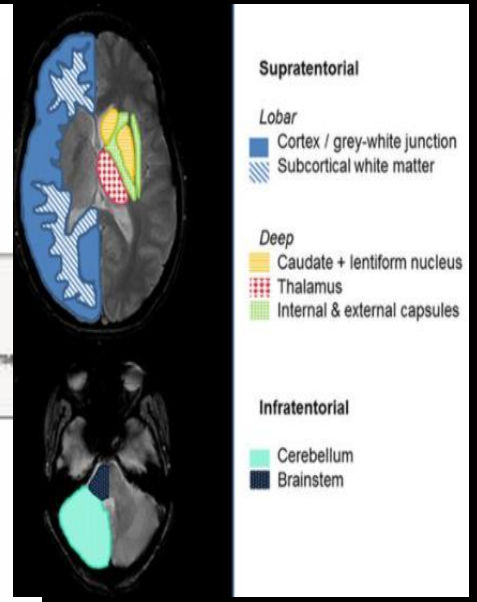
No

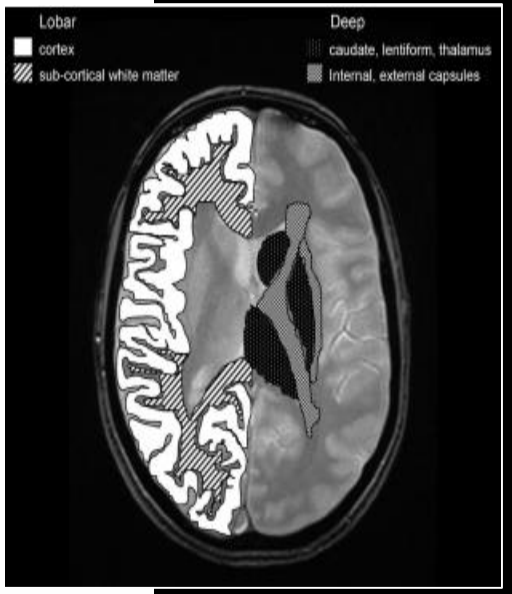
Uncertain about any BMBs? Yes →

No

Rate Rate

	Right Certain	Right Uncertain	Left Certain	Left Uncertain
▶ **Cortex / grey-white junction**[1]				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Subcortical white matter**[2]				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Basal ganglia grey matter**[3]				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Internal and external capsule**				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Thalamus**				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Brainstem**				
Number of BMBs <5mm				
Number of BMBs 5-10mm				
▶ **Cerebellum**				
Number of BMBs <5mm				
Number of BMBs 5-10mm				

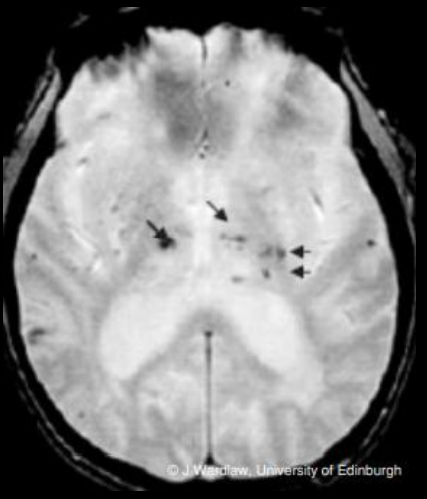


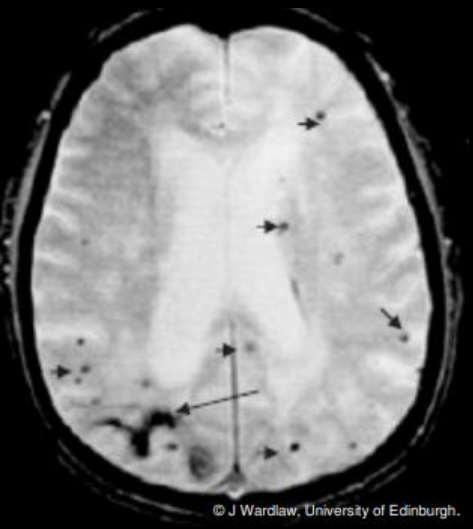


Cordonnieret al., Stroke, 2009

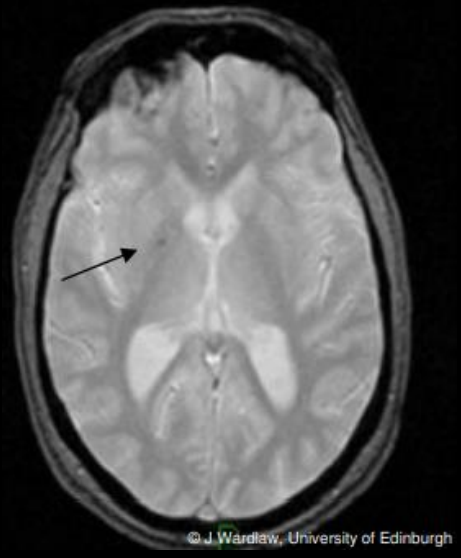
Microbleeds: BOMBS scale

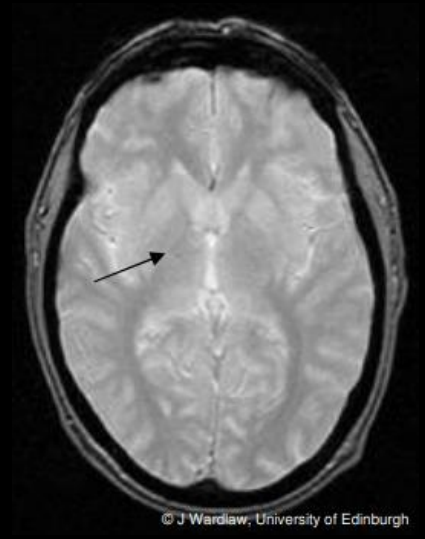
‘Certain’ BMBs





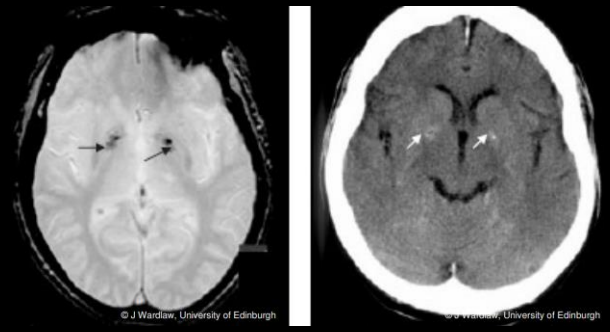
‘Uncertain’ BMBs



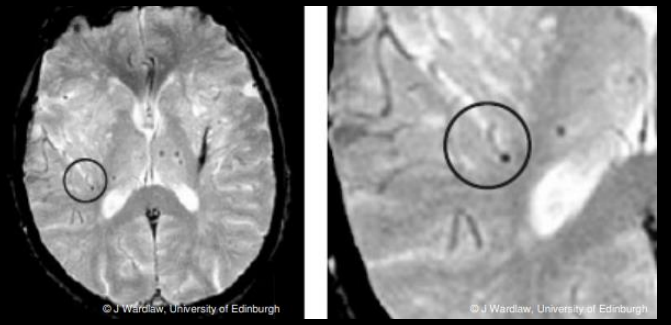


Examples of common ‘BMB mimics’

1. Basal ganglia calcification

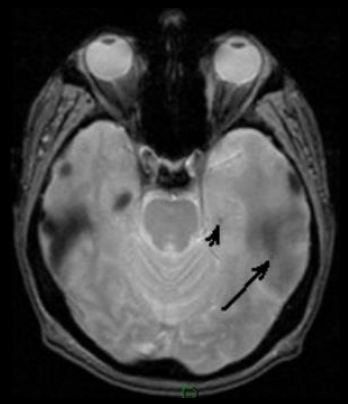


2. Cortical vessels

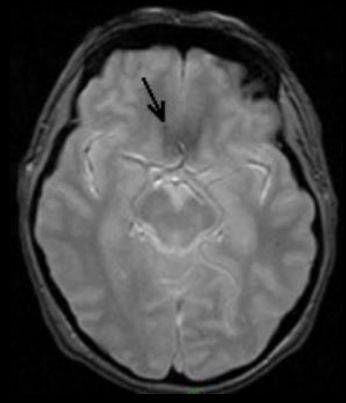


3. Partial volume artefact

From petrous temporal bone



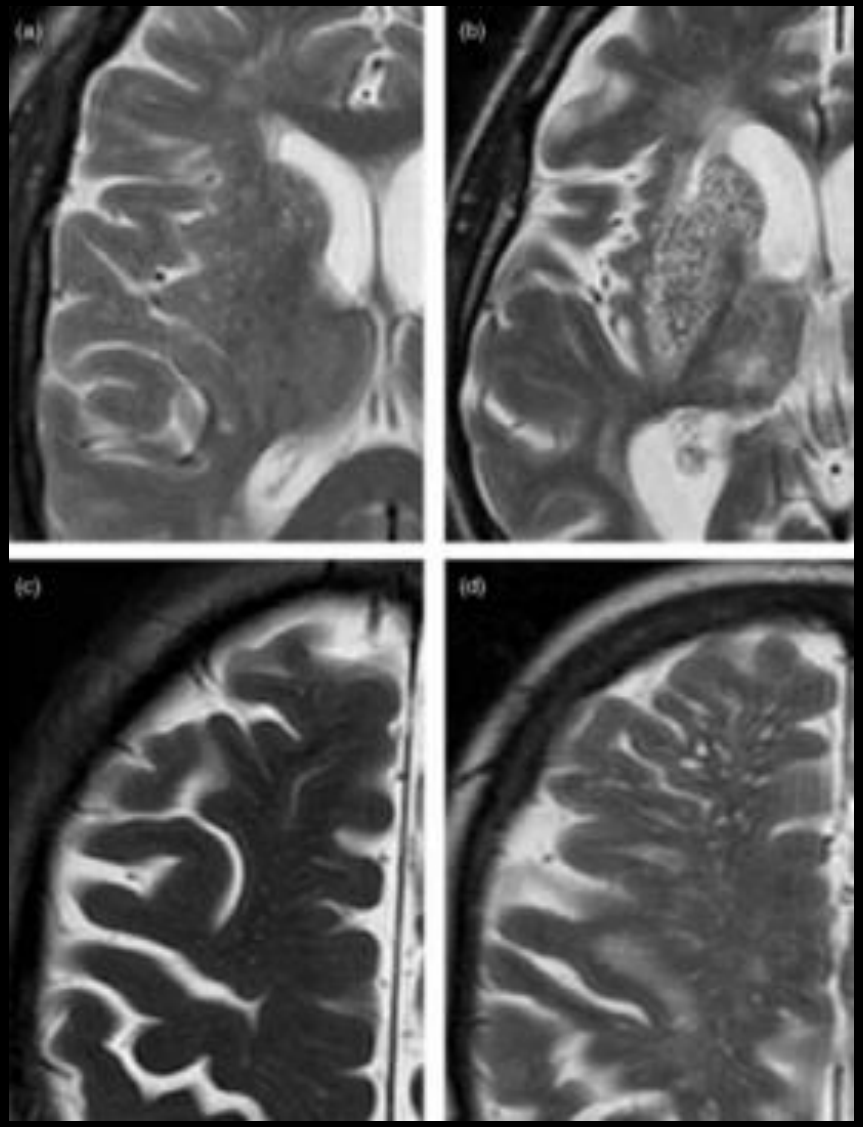
From orbit



Cordonnieret al,, Stroke, 2009

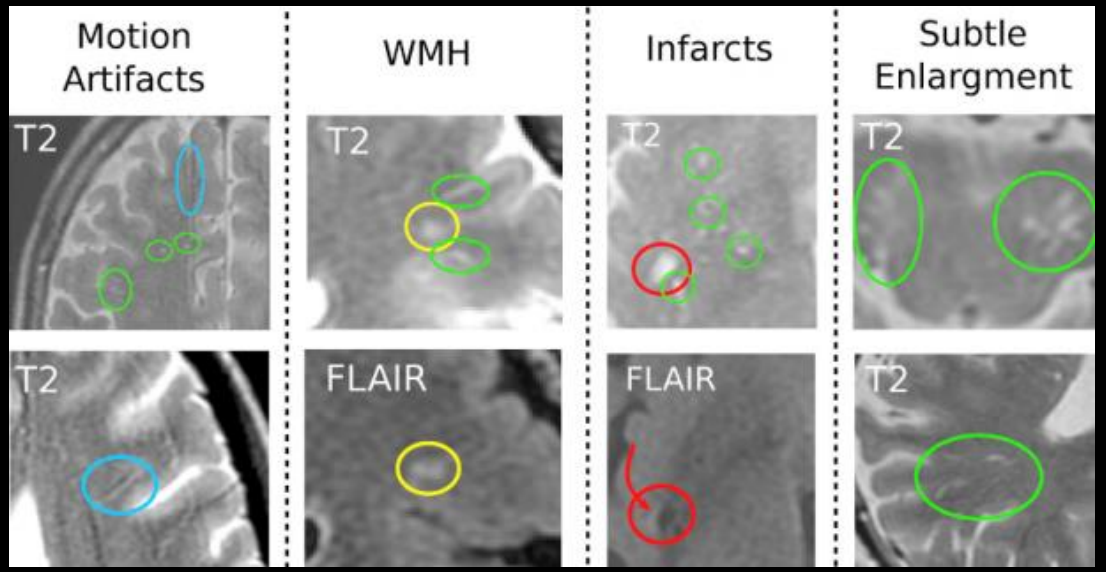
Enlarged perivascular spaces (EPVS) scale

best scored on T1/T2/FLAIR images, regions: centrum semiovale (CSO), basal ganglia (BG), hippocampus, in most affected hemisphere



- 0- no EPVS
- 1- <10 EPVS
- 2- 10-20 EPVS
- 3- 21-40 EPVS
- 4- > 40 EPVS

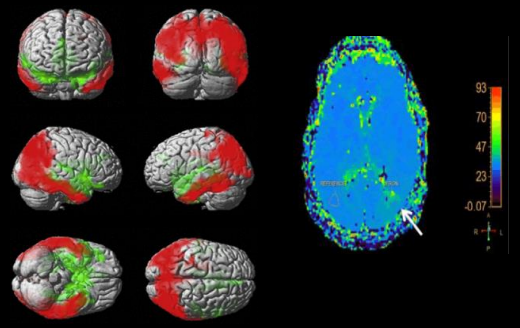
EPVS: Differential Diagnosis



Maclullich et al., J Neurol Neurosurg Psychiatry. 2004
Dubost et al. NeuroImage 2018

Advanced MR techniques

- **Perfusion Weighted imaging (PWI)**

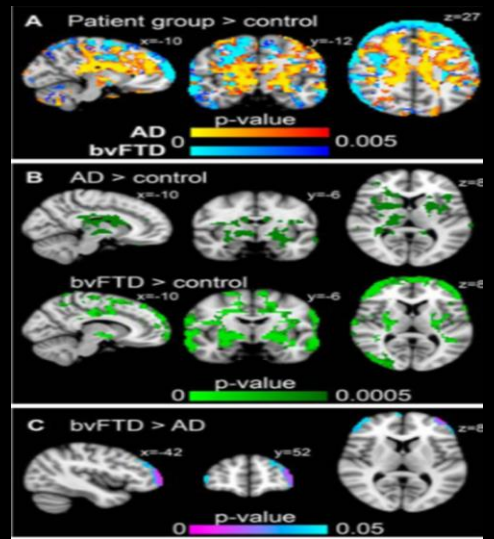


Type of information obtained comparable to nuclear medicine

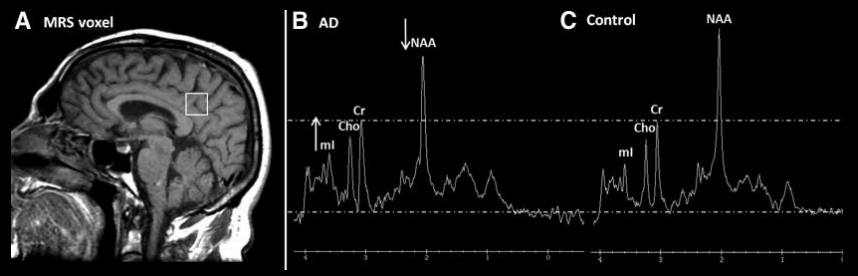
- **BOLD fMRI**

fMRI typically refers to images obtained by using the blood oxygen level dependent (BOLD) contrast

Diffrences in magnetic susceptibility between oxygenated and deoxygenated blood serves as an intrinsic contrast medium



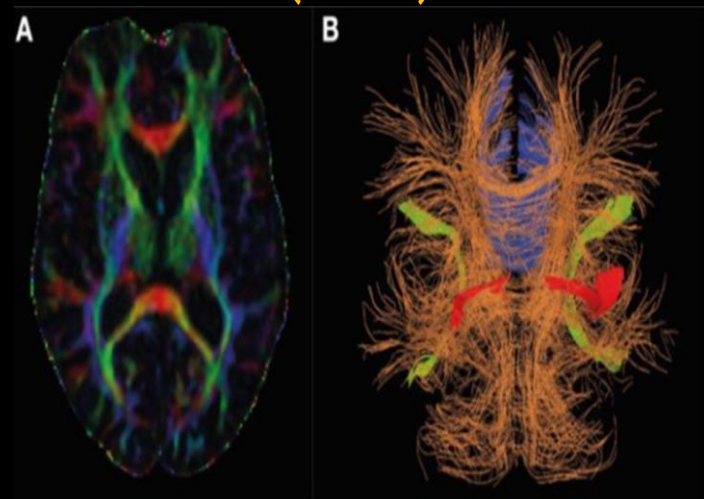
- **MR spectroscopy**

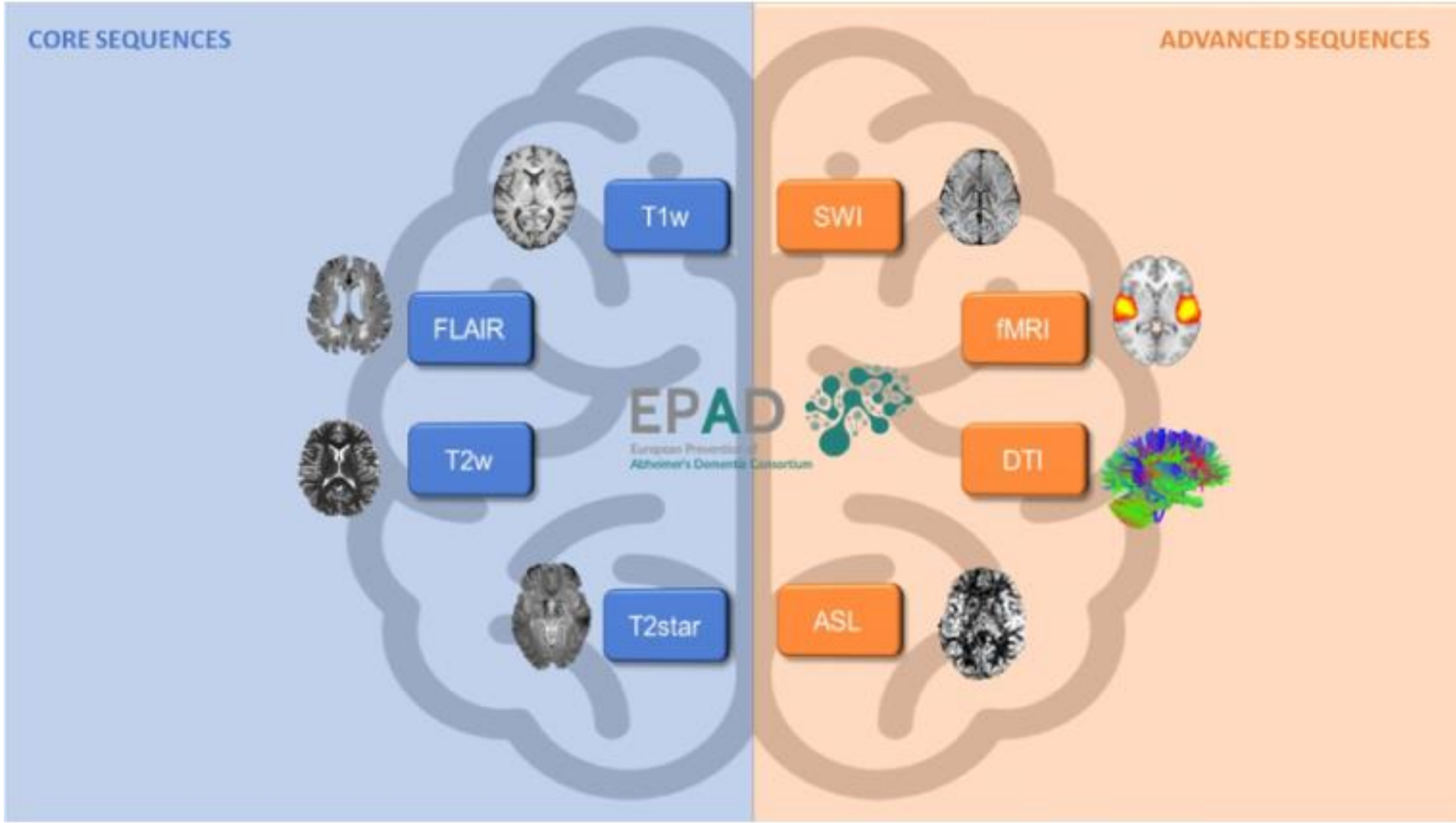


In patients with NDD: usual finding= change in the ratio between metabolites or a general decrease in metabolites

- **Diffusion Tensor Imaging (DTI)**

DTI in dementia have consistently shown alterd diffusion (tract) properties in accordance with the pattern of neurodegenrative pathology





The EPAD core and advanced sequences

What should be done

A radiological report should describe:

- Medial temporal lobe atrophy (MTA) (Scheltens score with explanation)
- General or local widening of sulci (Global Cortical Atrophy (GCA) stage with explanation)
- Width of ventricles
- White matter hyperintensities (WMH) (score according to Fazekas scale with explanation)
- Size and position of infarcts
- Other changes (tumour, normal pressure hydrocephalus, subdural hematoma etc.)
- Comparison with previous examinations (progression of atrophy or white matter changes etc.)
- CONCLUSION: assessment of findings in relationship to clinical suspicion and other examinations such as CSF, PET or SPECT.

Wahlundet al, Insights Imaging , 2017

Normal ageing or pathological conditions?

- « Successful » ageing:
  - minimal morphological (physiological) loss
  - Brain imaging abnormalities without overt clinical deficits or symptoms

Global cortical atrophy:-

- Brain weight peaked by the mid-to-late teens.
- 0.2% / year:- 30-50 years
- 0.3 to 0.5%/ year:- 50-70 years
- Shrinkage of cortical grey matter predominates over white matter loss
- The parietal and frontal lobes are equally affected.

Medial temporal atrophy:-

- MTA score 2 is normal in nondemented pt over 75 year age.
- 0.2% per year:- 30-50 yr
- 0.8% per year:-50-70yr
- 1.5 to 2% per year:- above 80 yr

Microbleeds:-

- Usually found in the basal ganglia or thalamus and posterior fossa in hypertensive patients

Enlarged Virchow robin space:-

- Most enlarged VRS <2 mm in diameter
- Usually found in striatum, ant perforated substance and ant commissure
- Diffuse widening of VRS in basal ganglia is suggestive of focal atrophy

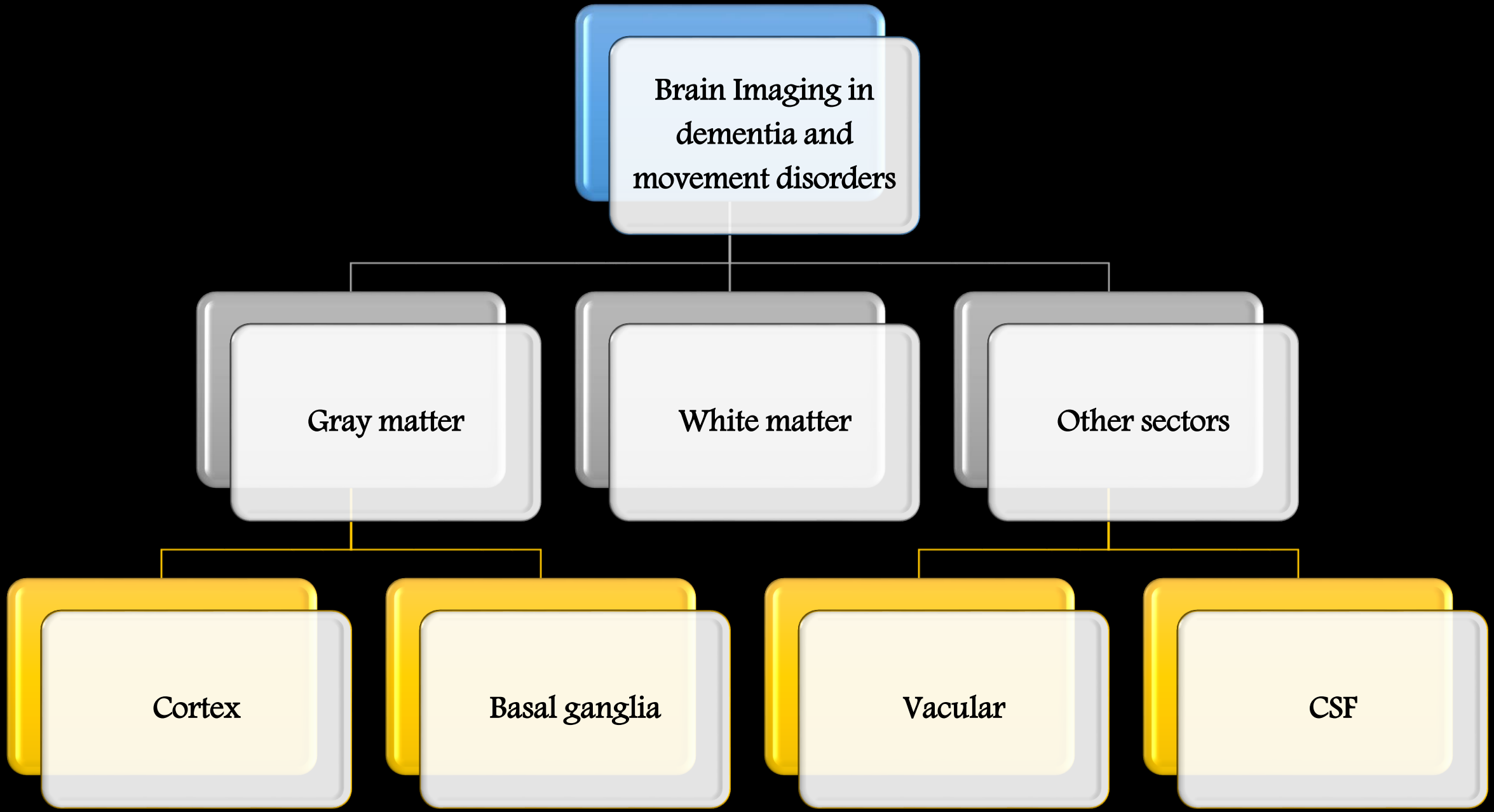
White matter hyper intensities:-

- Periventricular hyperintensities suggestive of increase extracellular fluid and sub ependymal gliosis.
- Represent usual aging phenomenon.
- Panctiform and early confluent deep WMH often have little clinical consequences.

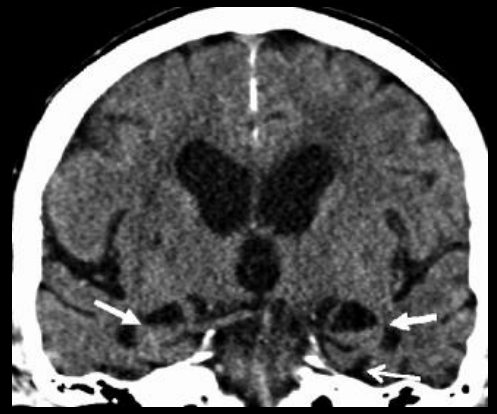
Iron accumulation:-

- Usually involves globus pallidus , striatum, substantia niagra and dentate nucleus
- Hypointensity on T2 images
- Started appearing around third decade

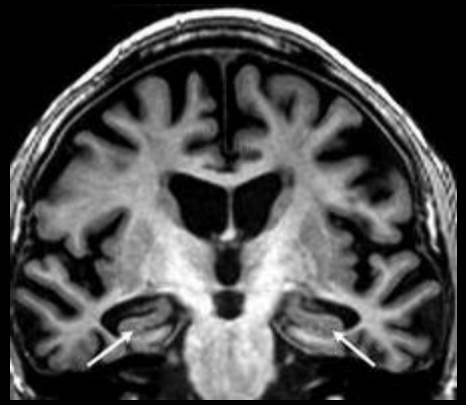
- Reduced resting-state fMRI activity (anterior frontal, precuneus, and posterior cingulate cortices) in ageing.
- Grey matter perfusion decreases by 0.45% per year in healthy adult subjects, predominantly in the frontal cortex
- Hypometabolism in frontal and post cingulate cortex on FDG-PET.
- Abnormal uptake in amyloid-PET is seen in 30% normal eldery subjects.


Brain Imaging in dementia and movement disorders
Gray matter
White matter
Other sectors
Cortex
Basal ganglia
Vacular
CSF

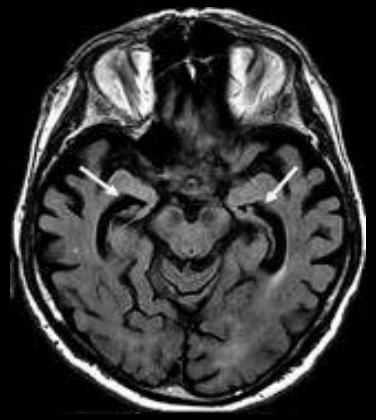
♂, 75 years old,
Progressive memory deficits of hippocampal profile, slow worsening (since 70 y.o.)



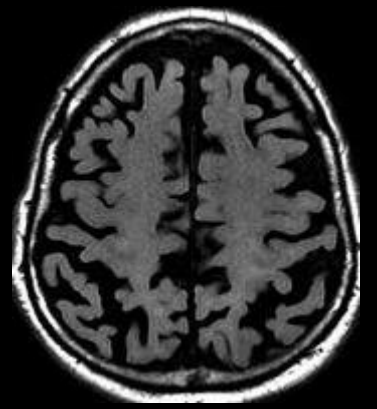
Oblique coronal CT



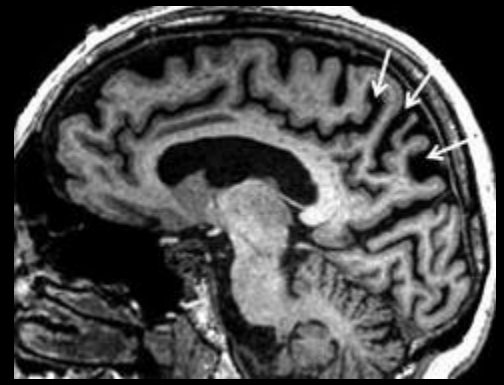
Oblique coronal T1



Axial FLAIR



Axial FLAIR



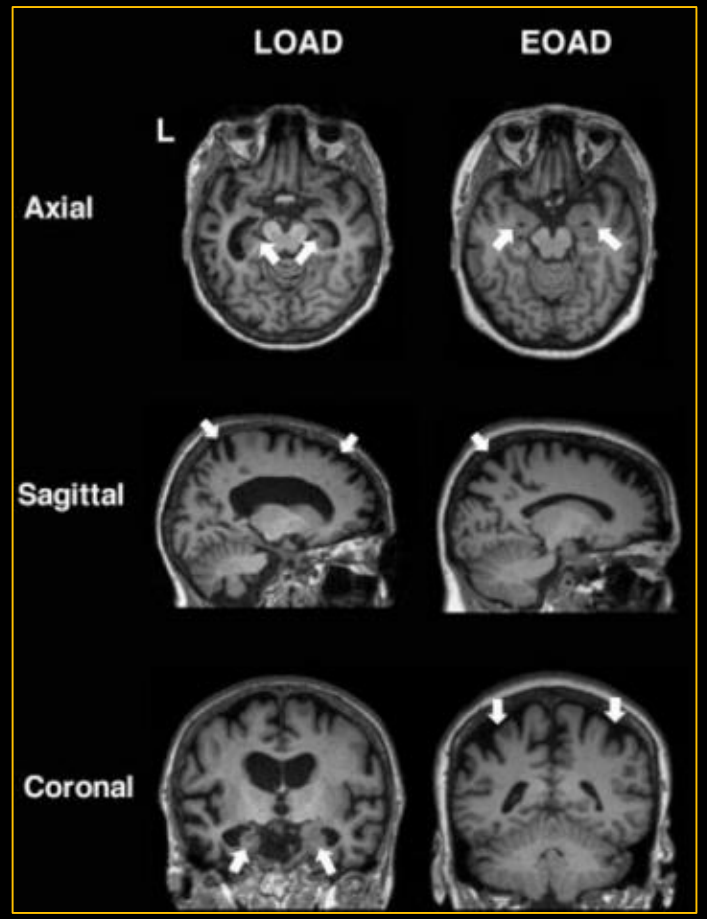
Sagittal T1

GCA (Pasquier) score: 3
MTA (Scheltens) score: 4
Posterior cortical atrophy (Koedam) score: 3

Alzheimer's disease (AD) (Late onset, typical amnestic form, advanced stage)

Imaging patterns of AD

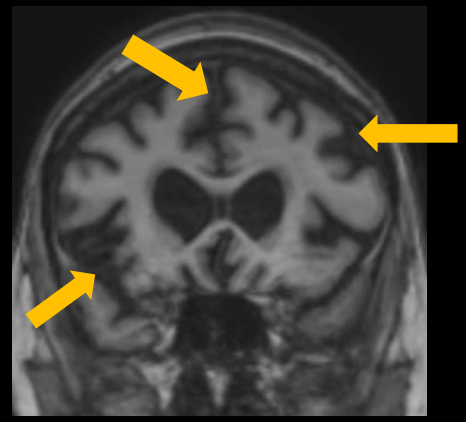
- *Typical amnestic form: Hippocampal and precuneus* atrophy
- *Late AD (>65 years) + APOEε4:* Predominant *hippocampal* atrophy
- *Early AD (<65 years)* : More *posterior* cortical atrophy



Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017

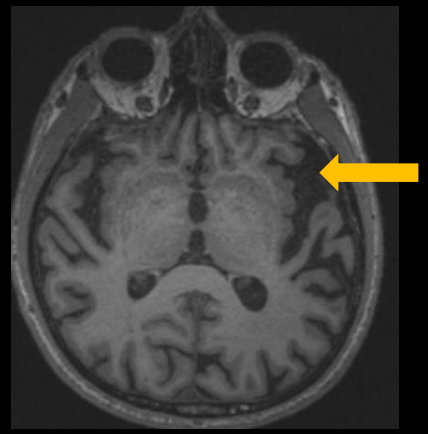
Atypical Forms of AD

Behavioral (Frontal) variant



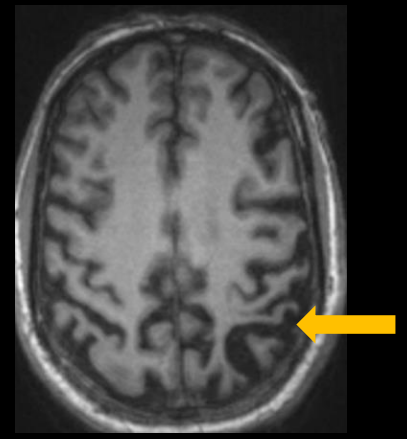
dorsolateral, ventrolateral, and ventromedial prefrontal and insular cortical atrophy

Logopenic progressive primary aphasia (PPA) variant



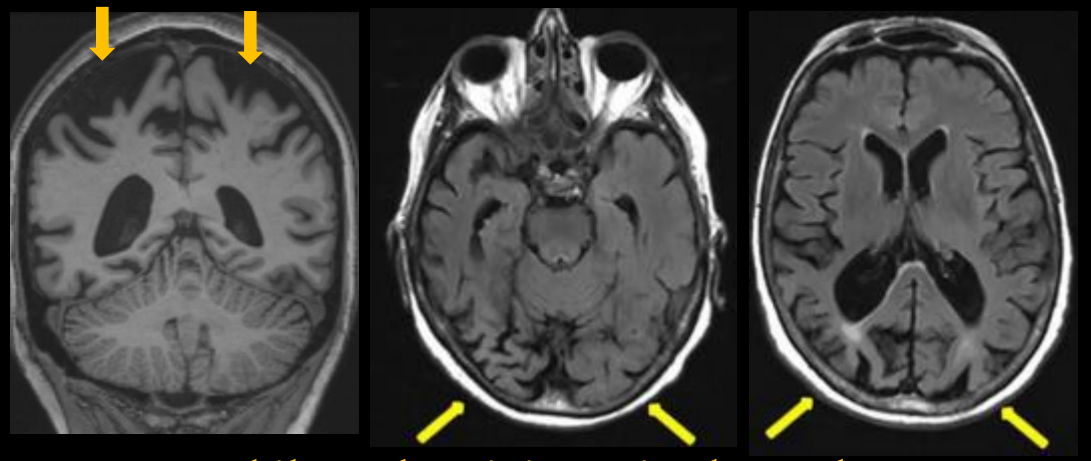
left-lateralized temporal cortical atrophy

Corticobasal syndrome (CBS) variant



left-lateralized peri-Rolandic and parietal cortical atrophy

Posterior Cortical Atrophy (PCA) variant

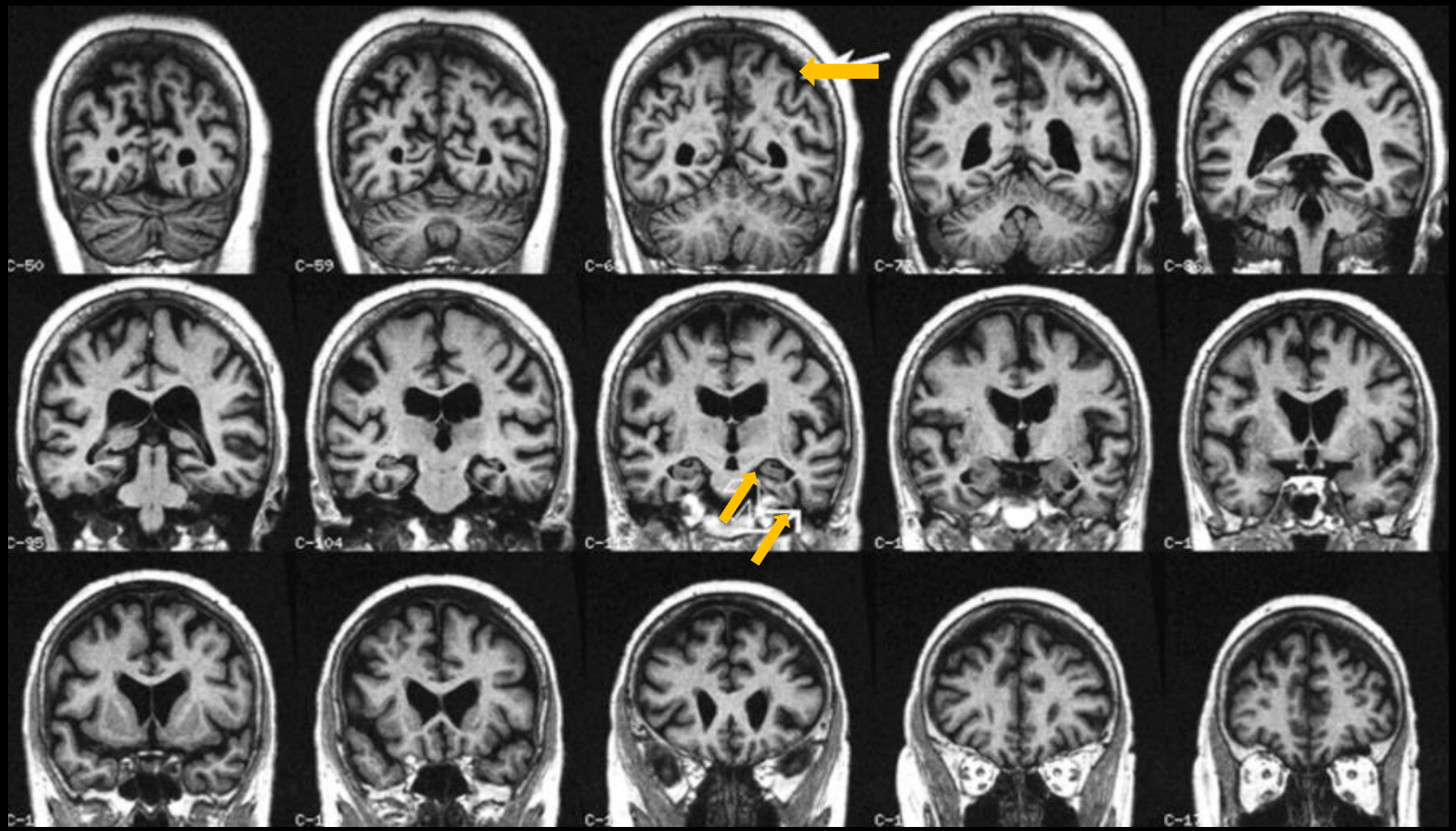


bilateral occipitoparietal atrophy

Camsari et al,, JNeurol Clin. 2016
Dickerson et al,, CNS Spectr. 2017

From Mild cognitive Impairment (MCI) to AD?

- **hippocampal** atrophy + concomitant widening of the collateral **sulcus**= both signs of progressive **MTA**
- Slight **parietal** atrophy: independent predictive value for conversion from MCI to AD

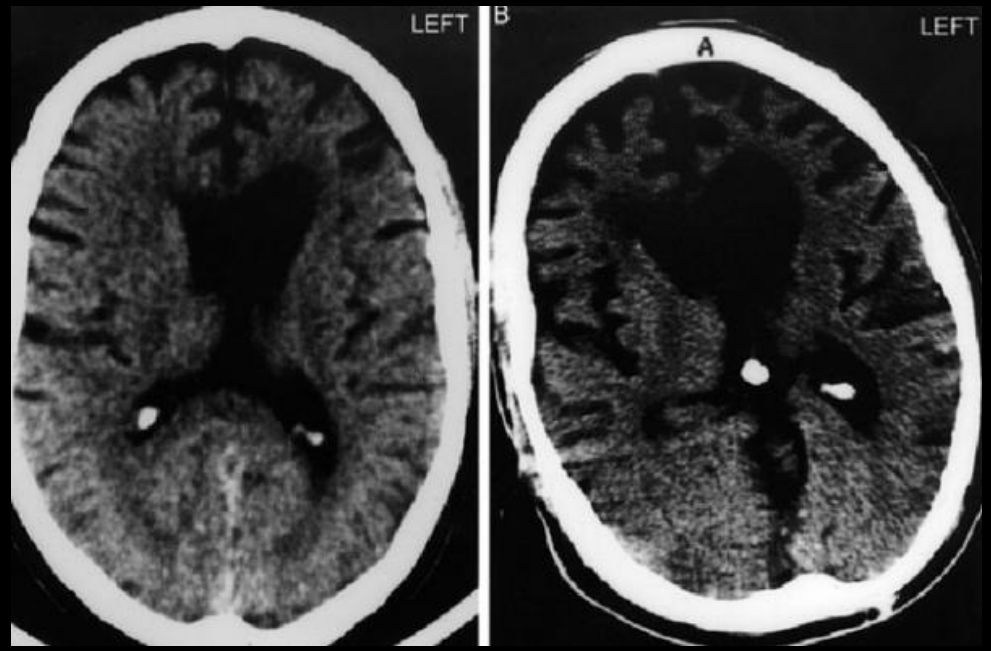


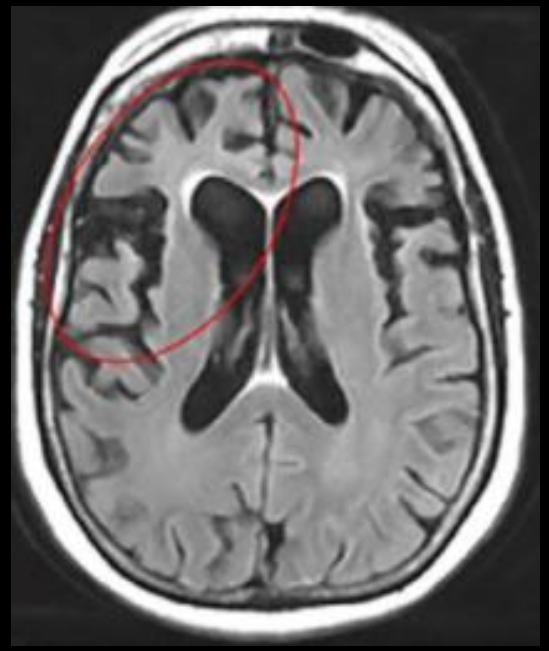
MTA in AD vs other dementias

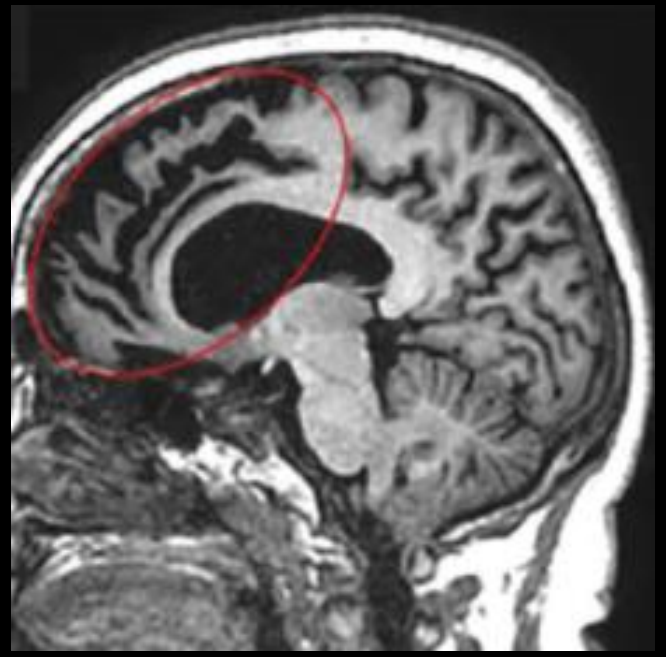
	Present	Absent
AD	100%	-
VaD	87%	13%
DLB	62%	38%
Controls	4%	96%

Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017

♂, 65 years old, similar cases in family
Since age 61, personality changes, apathy, then behavioral disorders (hyper orality, disinhibition, aggressiveness),no overt memory deficits

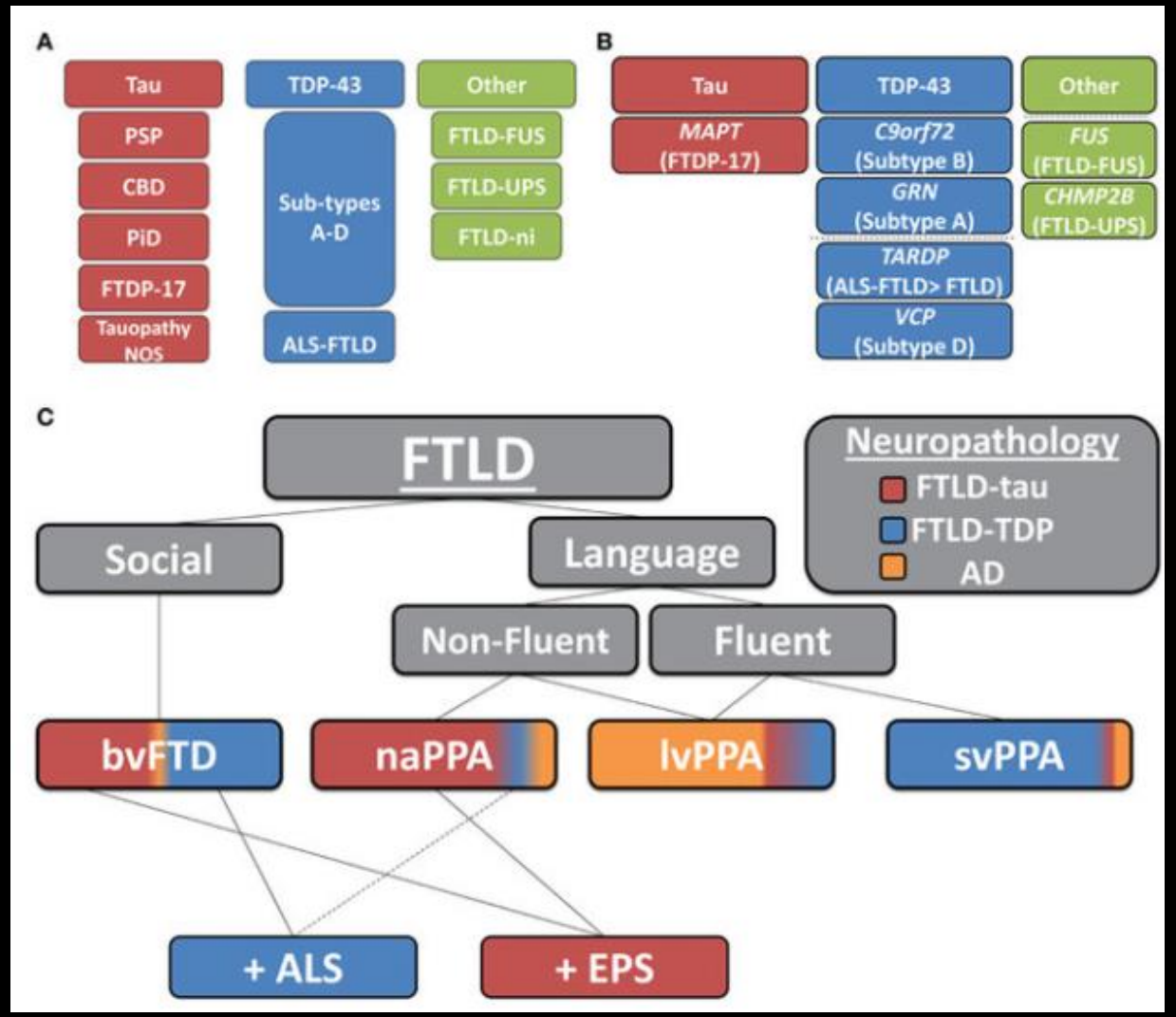


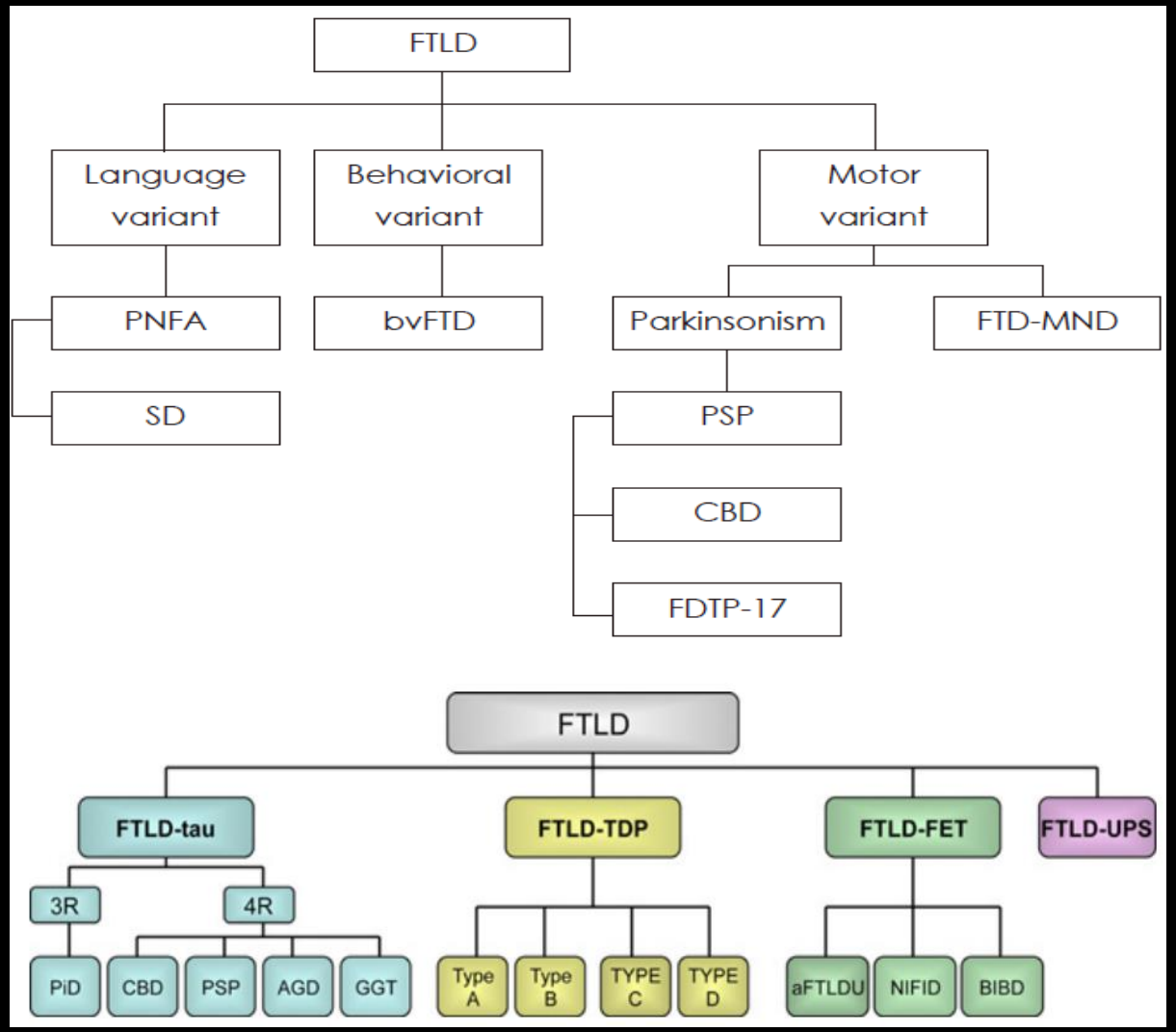




Fronto-temporal lobar degeneration(FTLD): behavioral variant (BvFTD)

FTLD spectrum

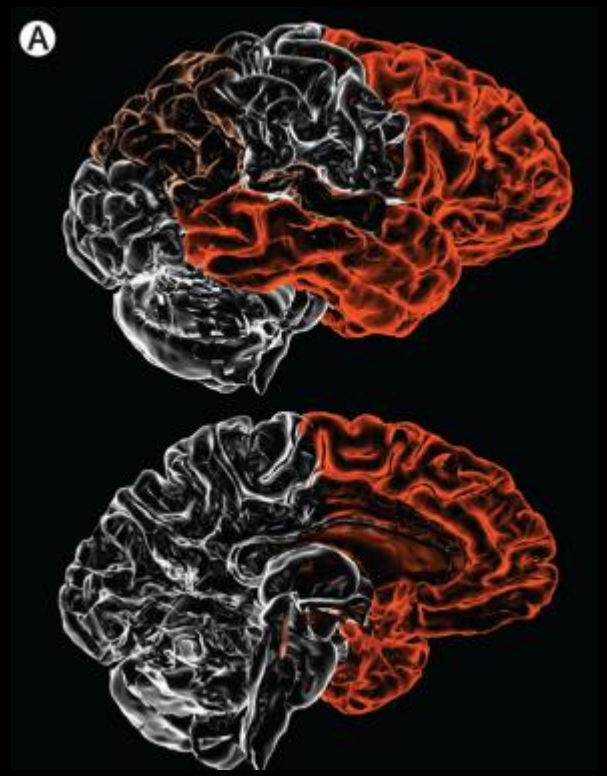


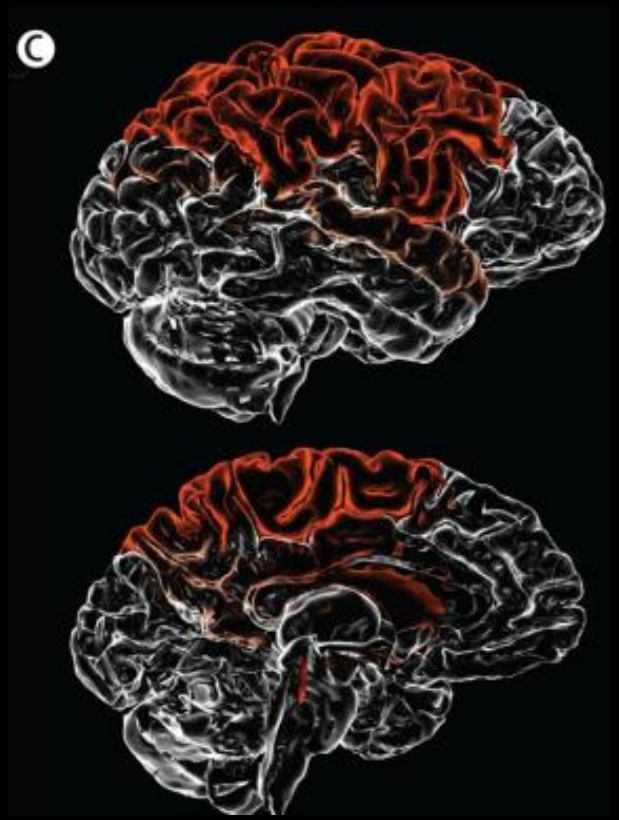


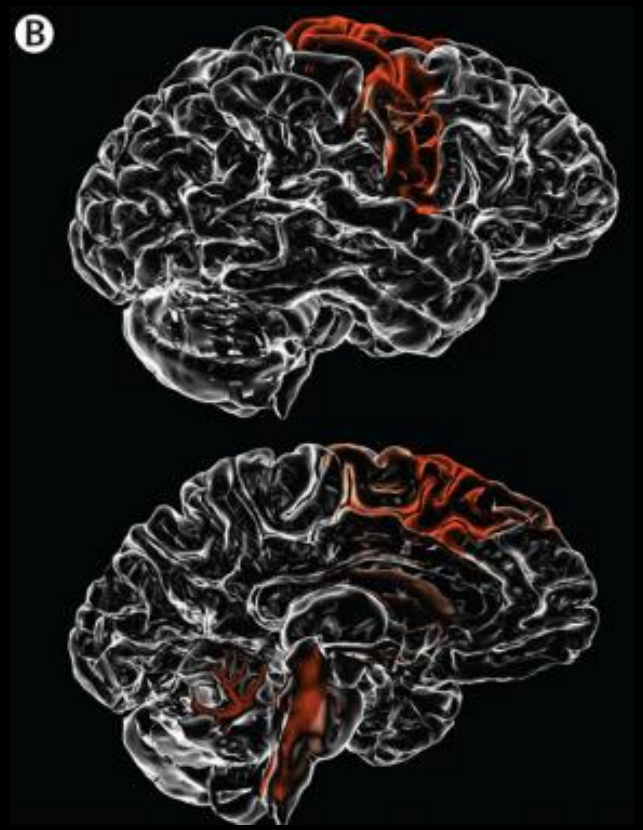
Mackenzie et al,, J. Neurochem., 2016
Irwin et al,, Frontiers in Aging Neuroscience , 2013
Kiyung et al,, JMD Journal of Movement Disorders 2005

FTLD-Tau

Pick's disease (3R)	CBD (4R)	PSP (4R)
Asymmetric fronto-insular atrophy entended to anterior temporal	More Posterior atrophy Preserved frontoinsular area	Specific MRI patterns







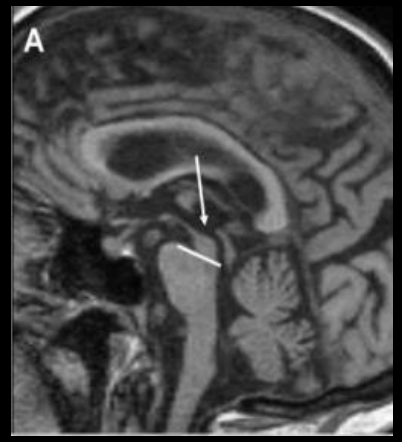
Bang et al., Lancet. 2015

FTLD–Tau

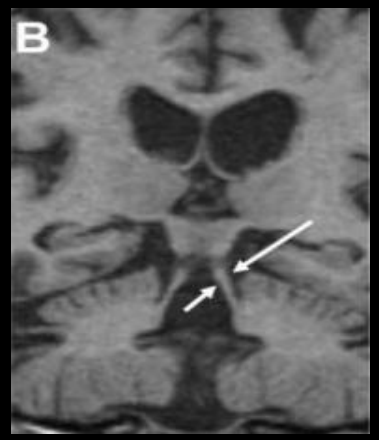
Progressive supranuclear palsyPSP (4R)

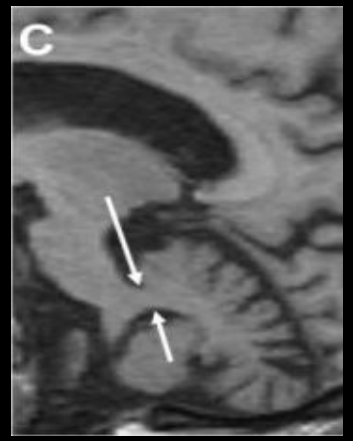
- Marked dilation of third ventricule
- Dorsal mesencephalic atrophy
- Thinning of superior cerebellar penduncules
- Atrophy of thalamus, basal ganglia and frontal cortex

- Mickey mouse sign
- Hummingbird/penguin sign

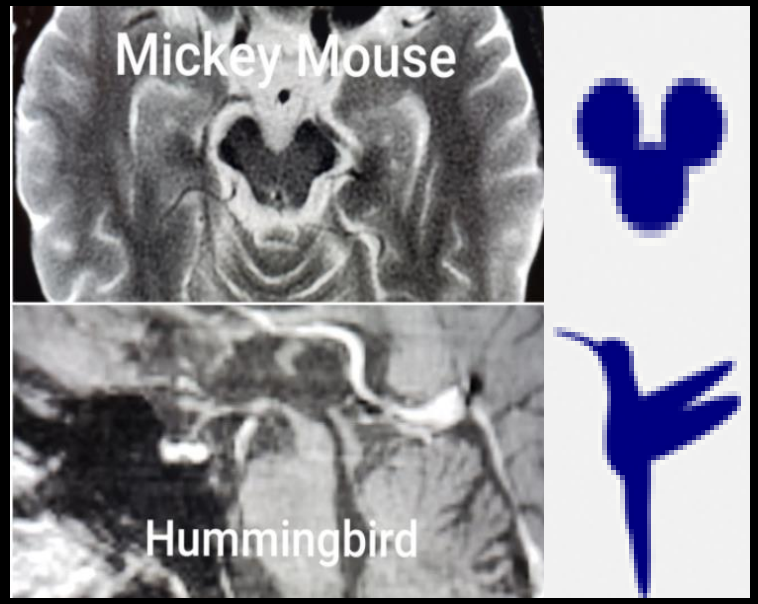


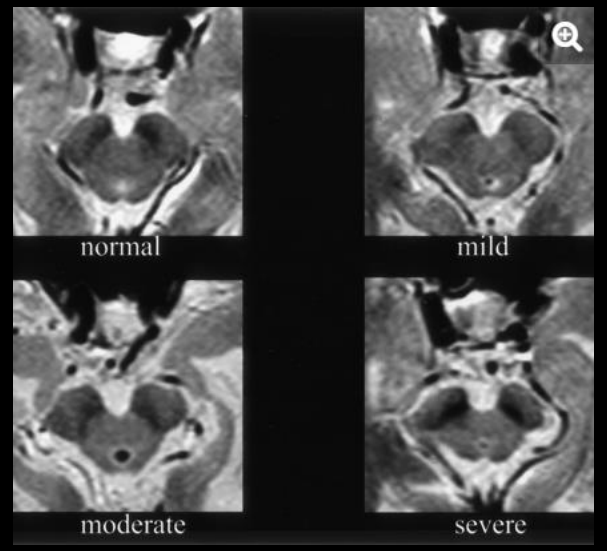
Reduced midbrain area compared with the pons

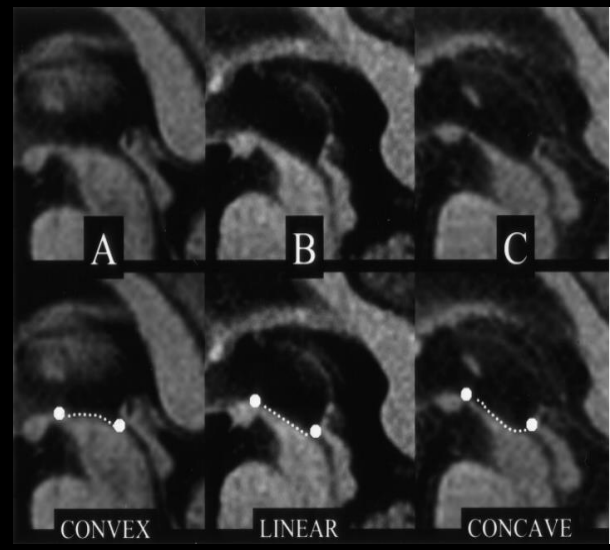


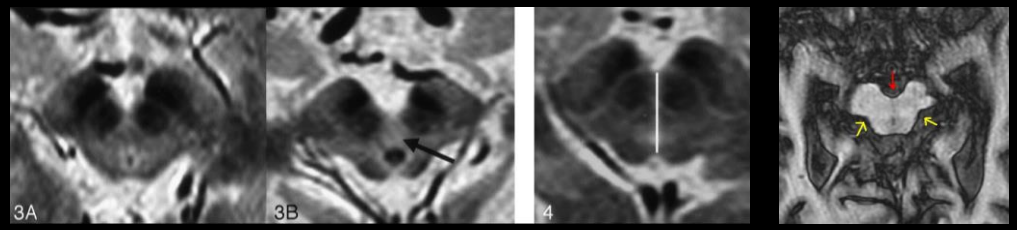


Thinned superior cerebellar peduncles on coronal section (B; arrows) compared with the middle cerebral peduncles (C; arrows)









Ipoemea nil

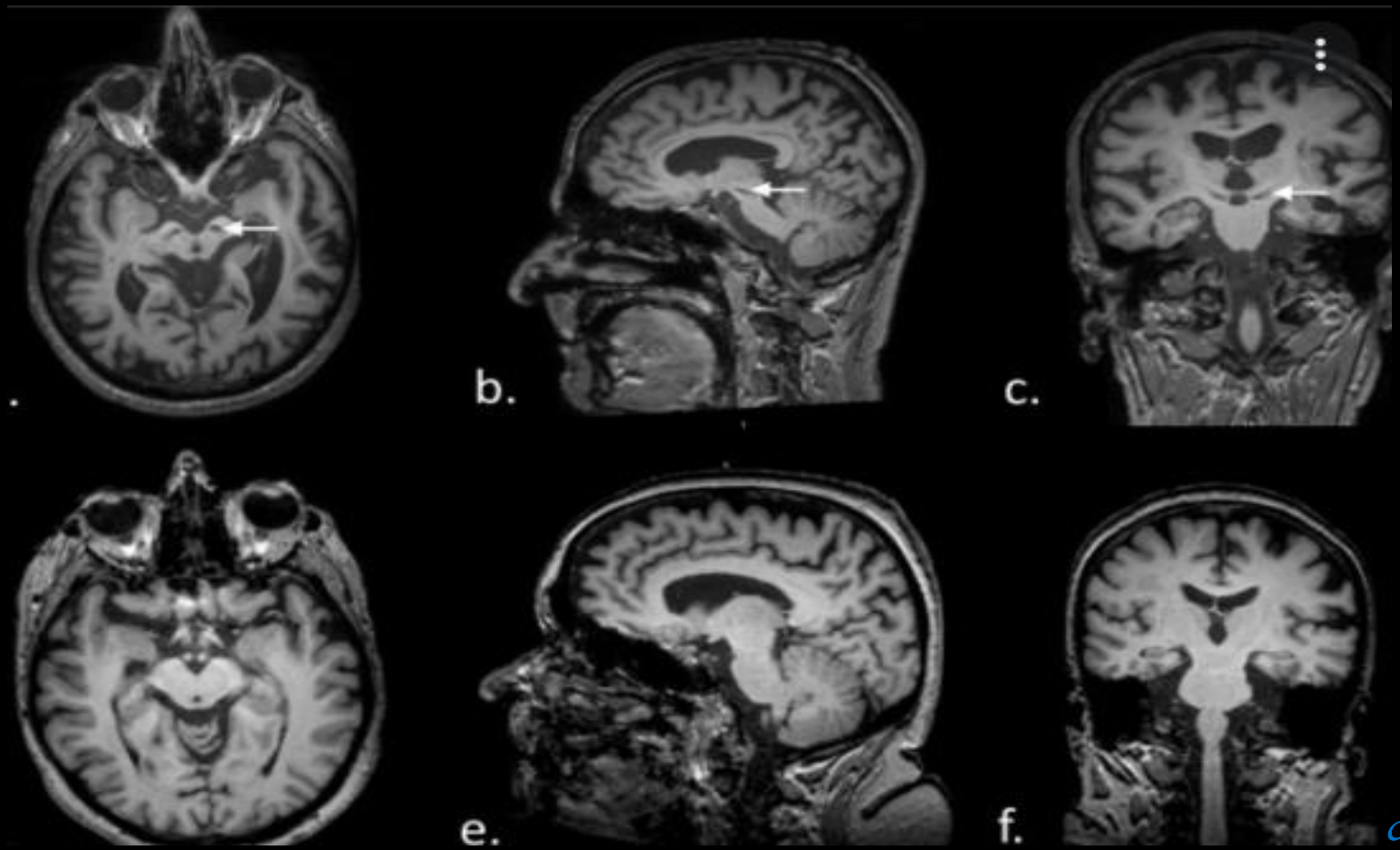
Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017

FTLD–Tau

Progressive supranuclear palsyPSP (4R)

The “hypointense substantia nigra” sign. A novel MRI marker of progressive supranuclear palsy

=Hypointense area at the medial substantia nigra in T1

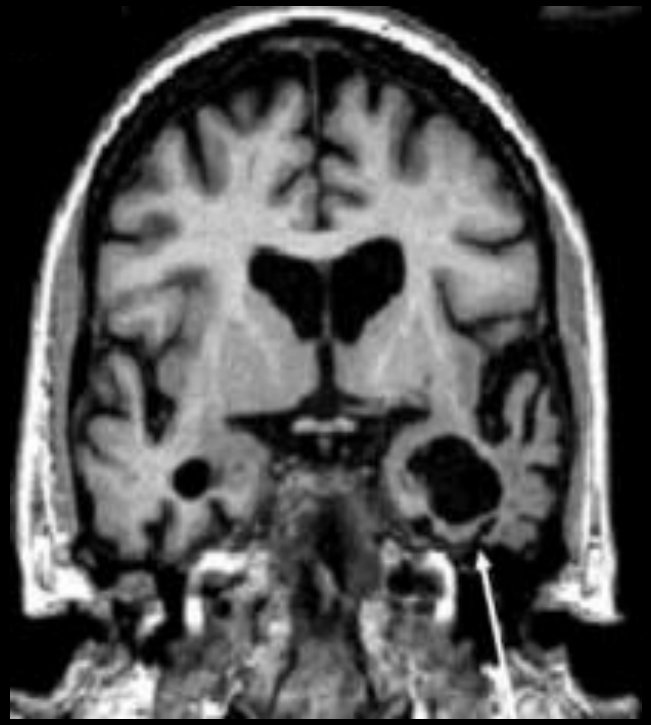


Constantinides et al,, J Neurol Sci, 2021

Primary Progressive Aphasia (PPA)

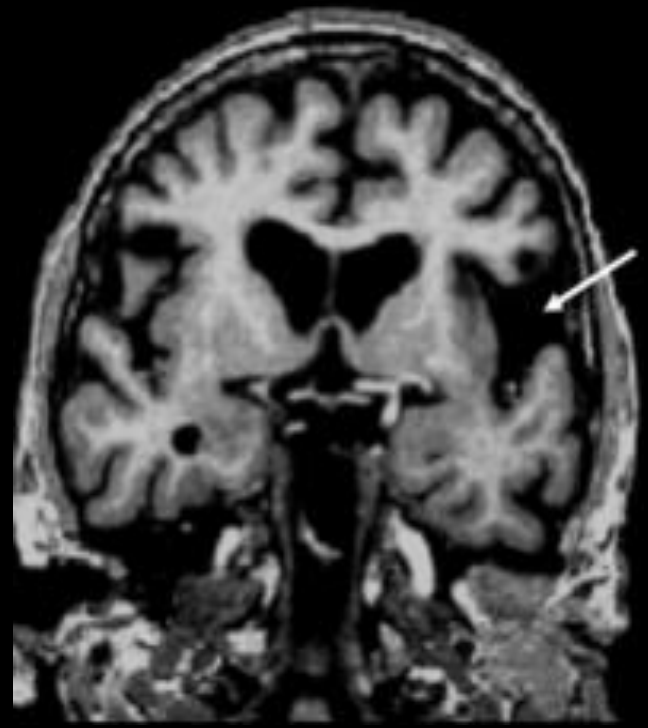
Semantic variant (svPPA)

Substratum: TDP-43C
Anterior and inferior temporal atrophy
Asymmetric-Left Hemisphere



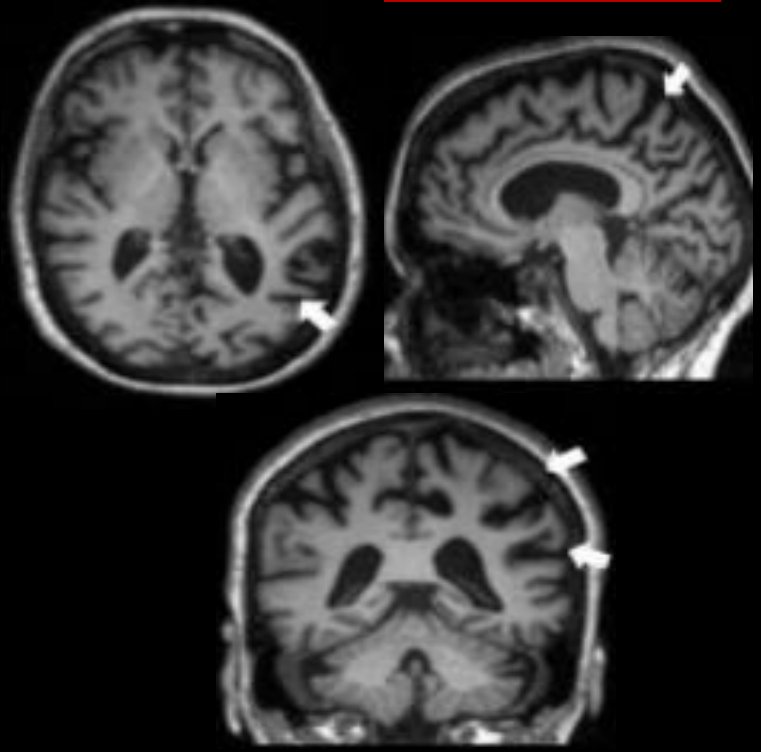
Agrammatic/non fluent variant (naPPA)

Substratum: Tau (4R)
Atrophy: Inferior frontal, insular, premotor cortex
Asymmetric-Left Hemisphere



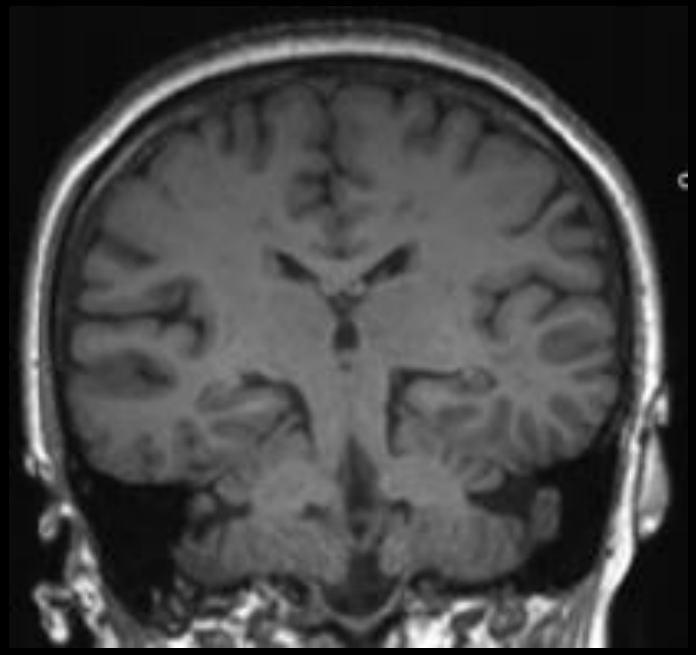
Logopenic variant (lvPPA)

Substratum: AD
Marked temporoparietal atrophy
Asymmetric-Left Hemisphere



Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017

♀, 85 years old, Personal history of RBD
Since the age of 80 , complex visual hallucinations, delirium, fluctuations, then parkinsonism, frequent upward falls , camptocormia



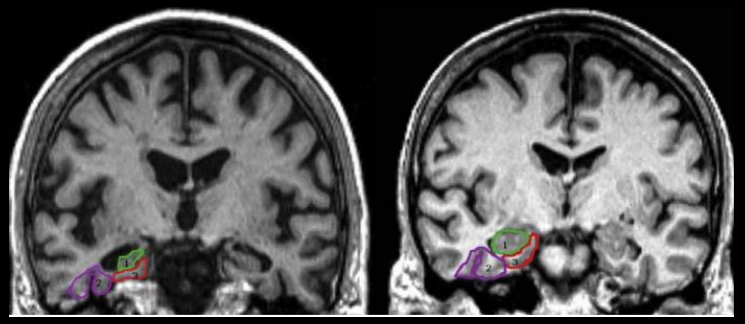
GCA (Pasquier) score: 1
MTA (Scheltens) score: 0
Posterior cortical atrophy (Koedam) score: 1

Dementia with Lewy Bodies (DLB)

Synucleinopathies: PD, DLB, MSA

Dementia with Lewy bodies

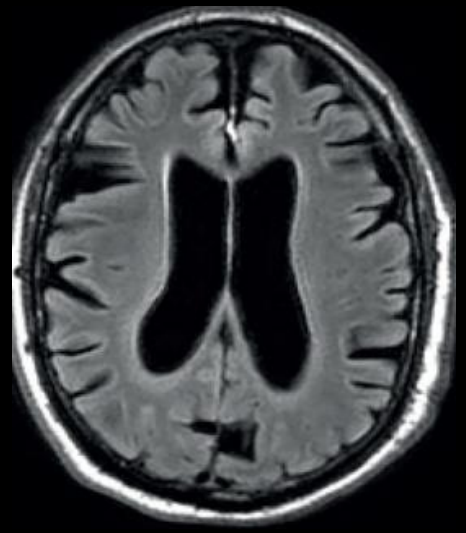
Generalized atrophy
Less medial temporal atrophy than AD
Possible parieto-occipital WM lesions



If medial temporal lobe preserved ➔ supports DLB diagnosis
If medial temporal lobe atrophied➔ Not diagnostically helpful

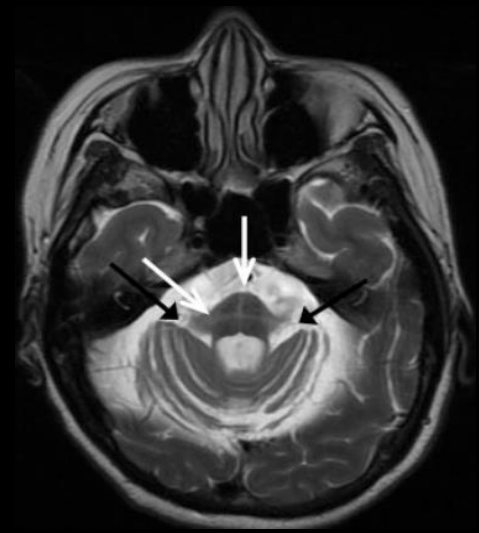
Parkinson's disease (PD)

Vs healthy controls:
-Medial temporal and frontal atrophy
-Severe dementia (PDD) with temporal atrophy
-Frontal, temporal and occipital WM lesions



Multiple system atrophy (MSA)

*Vs PD and PSP:
-greater striatum, brainstem, and cerebellar atrophy
*Specific features:
-Hot-cross bun sign (cruciform sign)
-Putaminal rim sign

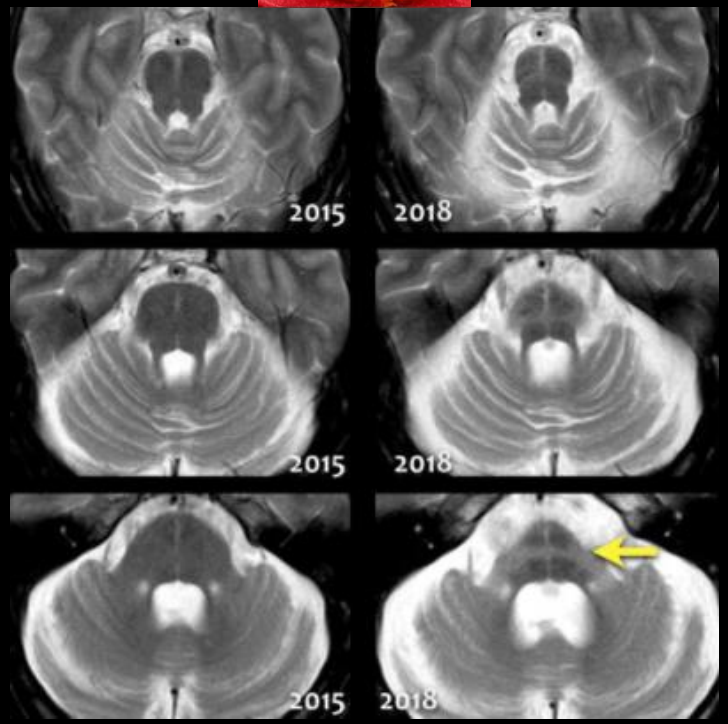


Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017
Rodriguez et al. , Alzheimer's & Dementia , 2012
Petrou et al,. Imaging Med. 2012

Synucleinopathies

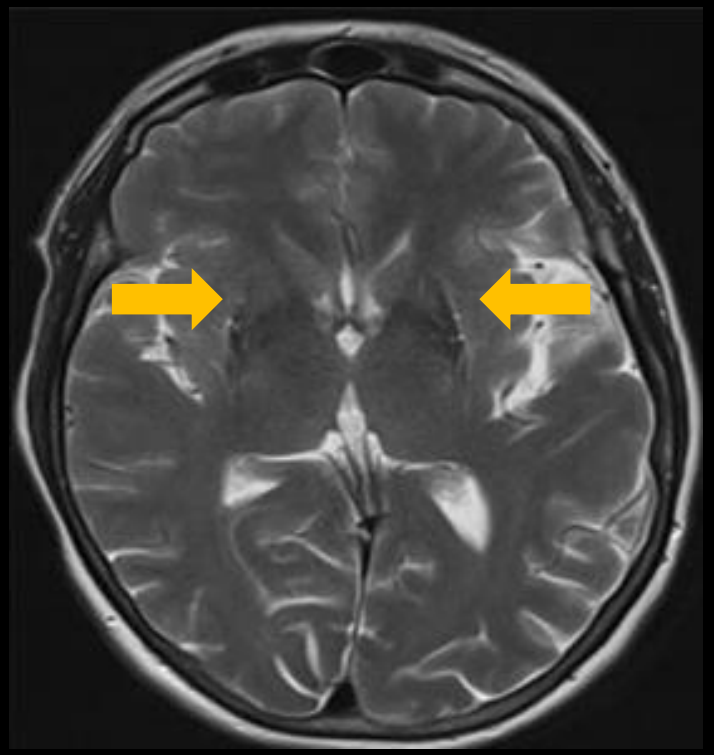
Multiple system atrophy (MSA): MSA-c and MSA-p

Hot-cross Bun sign (HCB) or "cruciform T2" sign
(MSA-c>>MSA-p)



Putaminal rim sign
MSA-p>>MSA-c

Putaminal hypointensity with a hyperintense "putaminal rim" sign on an axial T2-weighted MRI



Chelban et al., Journal of Neurology (2019)
Staffaroni et al., Neuroimaging in dementia , Semin Neurol. 2017

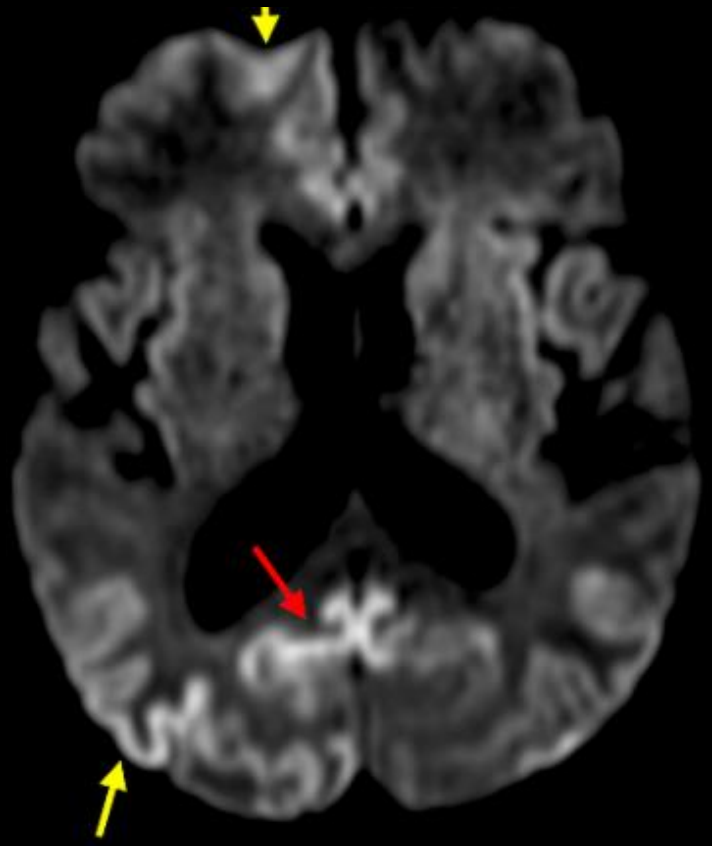
Most Common Imaging Patterns of Idiopathic Parkinson Disease and APS

Disease Entity	Imaging Modality			
	MR Imaging	FDG PET	Amyloid PET	^{123}I Ioflupane SPECT
Parkinson disease	Often normal, occasional diffuse atrophy	Usually normal, preserved putaminal activity, occasional decreased uptake in the parieto-occipital cortex	Normal	Decreased striatal activity (usually asymmetric)
MSA	Putaminal atrophy and marginally increased T2 signal, "hot cross bun sign"	Decreased putaminal or cerebellar uptake, subtype dependent	Normal	Symmetric or asymmetric decreased striatal activity
PSP	"Hummingbird sign," "Mickey Mouse sign"	Decreased uptake in the posterior frontal lobes, midbrain, and basal ganglia	Normal	Symmetric or asymmetric decreased striatal activity
DLB	Diffuse atrophy	Generalized decreased uptake (more prominent in the occipital lobes)	Positive in most cases	Symmetric or asymmetric decreased striatal activity
CBD	Asymmetric parietal and/or frontal cortical atrophy	Asymmetric decreased uptake in the parietal and/or frontal lobes	Normal	Decreased striatal activity (usually asymmetric)

Note.—APS = atypical parkinsonian syndromes, CBD = corticobasal degeneration, DLB = dementia with Lewy bodies, MSA = multiple system atrophy, PSP = progressive supranuclear palsy.

Broski et al, radiographics.rsna.org, 2014

♂, 62 years old,
rapidly progressive cognitive decline, myoclonus, dystonia, chorea
(within few months)



Creutzfeldt Jakob disease (CJD)

Greutzfeldt Jakob disease (CJD): Sporadic and variant CJD

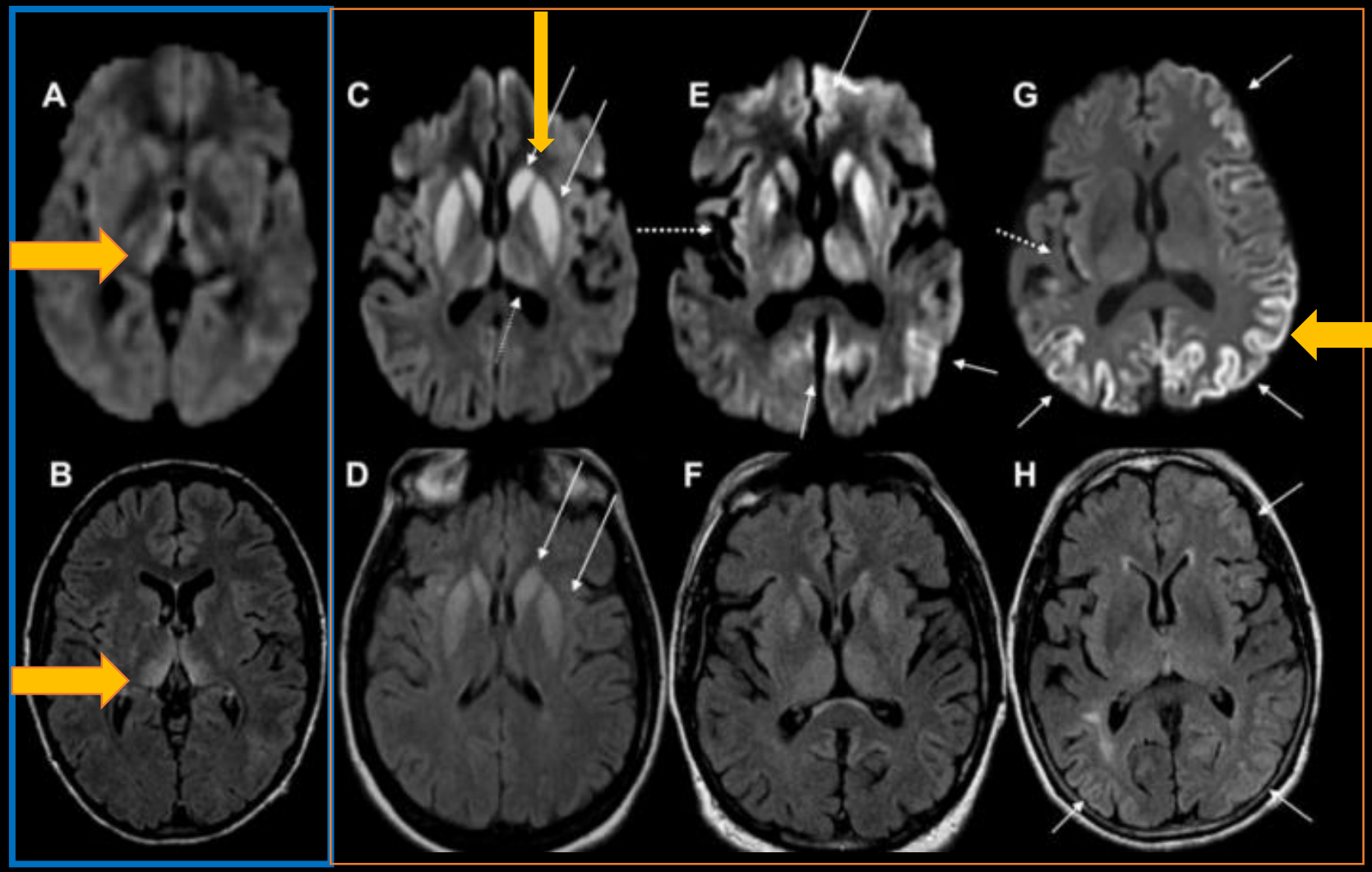
vCJD

Striatal hyperintensity

sCJD

Double hockey stick sign

Pulvinar sign



Cortical ribonning hyperintensity

Staffaroni et al,, Neuroimaging in dementia , Semin Neurol. 2017

Greutzfeldt Jakob disease (CJD): Sporadic and variant CJD

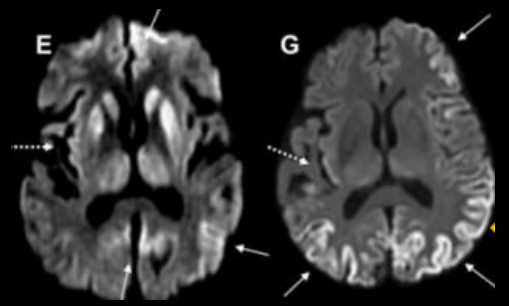
UCSF 2017 Proposal of MRI Criteria for JCD Diagnosis

Diagnosis	UCSF 2017 Modified JCD MRI criteria[a]
MRI definitely JCD	DWI[b] > FLAIR cortical ribboning[c] hyperintensity in:
	1. Classic pathognomonic cingulate,[d] striatum, and > 1 neocortical gyrus (often precuneus, angular, superior parietal, superior frontal, middle frontal, or lateral temporal gyrus)
	a. Supportive for subcortical[e] involvement:
	i. Striatum with decreasing anterior–posterior gradient
	ii. Corresponding ADC hypointensity
	b. Supportive for cortical involvement:
	i. Asymmetric involvement of midline neocortex or cingulate[d]
	ii. Sparing of precentral gyrus[f]
	iii. Corresponding ADC cortical ribboning hypointensity
	2. Cortex only (> 3 gyri); see supportive for cortex (above)
MRI probably JCD	1. Unilateral striatum or cortex (≤ 3 gyri); see supportive for subcortical and cortex (above)
	2. Bilateral striatum (see supportive for subcortical) or posteromedial thalamus; see supportive for subcortical (above)
	3. DWI > FLAIR hyperintensities only in limbic areas, with corresponding ADC hypointensity[g]
MRI probably not JCD	1. Only FLAIR/DWI abnormalities only in limbic areas, where hyperintensity can be normal (e.g., insula, anterior cingulate, and hippocampi), and ADC map does not show corresponding restricted diffusion (hypointensity)
	2. DWI hyperintensities due to artifact (signal distortion); see other MRI issues (below)
	3. FLAIR > DWI hyperintensities[h], see other MRI issues (below)
MRI definitely not JCD	1. Normal
	2. Abnormalities not consistent with JCD
Other MRI issues	In prolonged courses of sJCD (~ >1 year), brain MRI might show significant atrophy with loss of DWI hyperintensity, particularly in areas previously with restricted diffusion.
	To help distinguish abnormality from artifact, obtain b2000 diffusion sequences in multiple directions (e.g., axial and coronal).

TABLE 2. Findings in different types of CJD

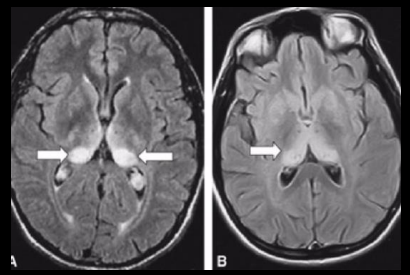
Features	CJD Type				
	sCJD	vCJD	fCJD	GSS	FFI
Mean age at onset	60–70 yrs	28 yrs	60 yrs	60 yrs	50 yrs
Duration of illness	5 mos	14 mos	6 mos	5 yrs	14 mos
Predominant clinical features	Rapid cognitive decline, myoclonus	Early psychiatric symptoms, then cognitive decline	Similar to sCJD	Cerebellar signs	Insomnia
MRI findings	60%–70% have hyperintesity in basal ganglia or cortex	Pulvinar sign in 90%	Basal ganglia & cortical hyperintensity	Rarely abnormal	Nonspecific atrophy
EEG findings	PSWCs in 60%–70%	PSWCs negative	PSWCs in 75%	Rarely positive	Rarely positive
14–3-3 status	Positive in 90%	Positive in 50%	Similar to sCJD	Negative	Rarely positive
Genetics	MM1 most common (70%)	MM in 100%	PRNP mutation	P102L is most common mutation	D178N mutation

sCJD



Hyperintensity in basal ganglia and cortex

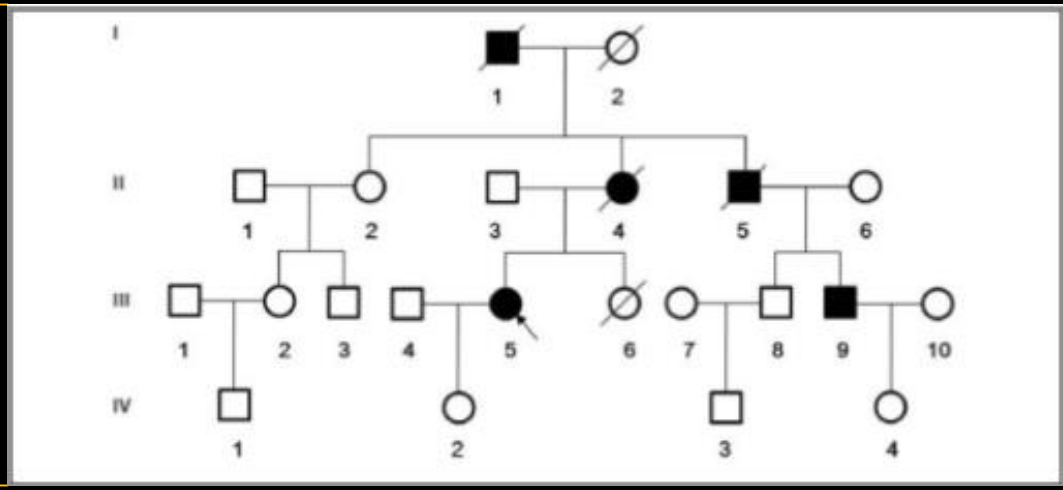
vCJD

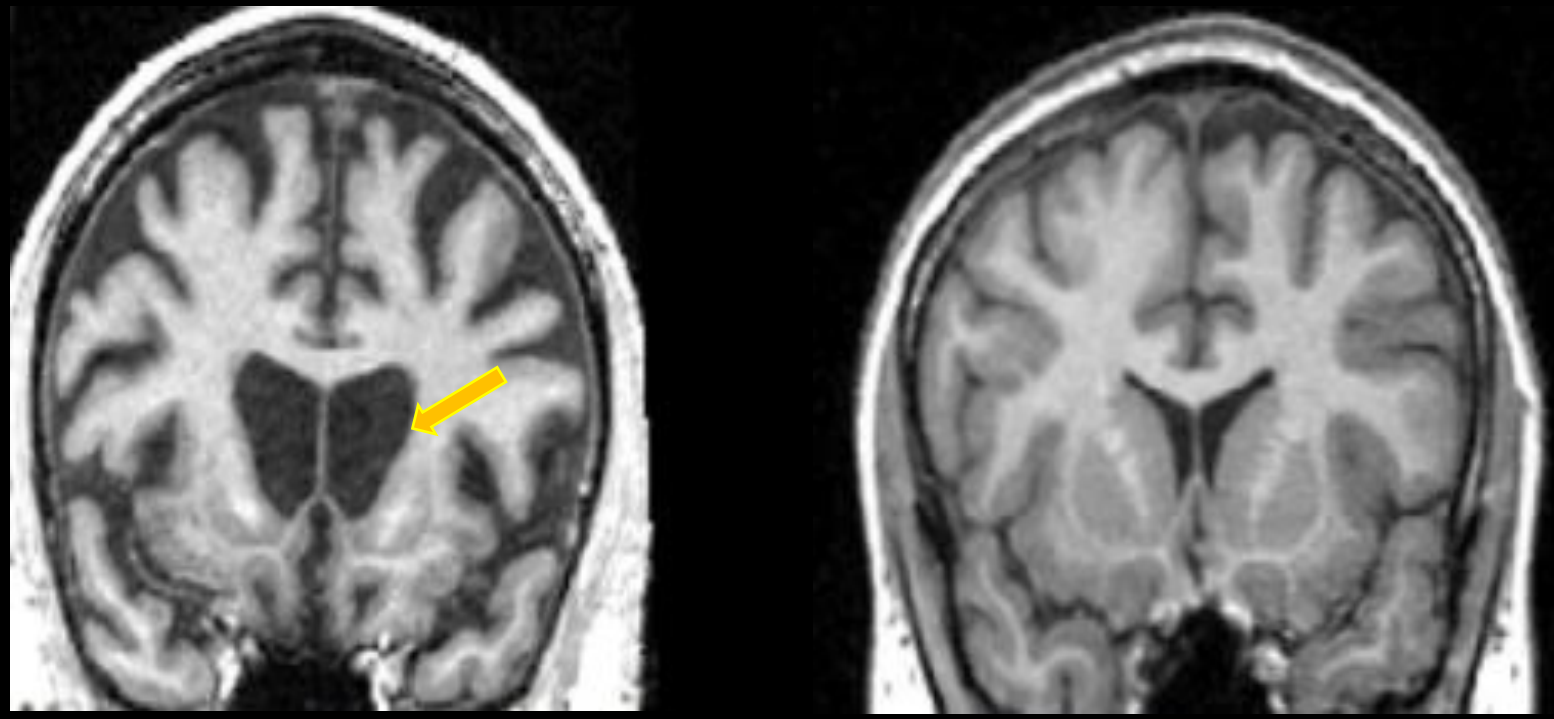


A. Pulvinar sign. Hyperintensity in pulvinar
B. Double Hockey stick sign. Hyperintensity in pulvinar + dorsomedial thalamus

Staffaroni et al., Neuroimaging in dementia , Semin Neurol. 2017
Engleberg et al., 2013

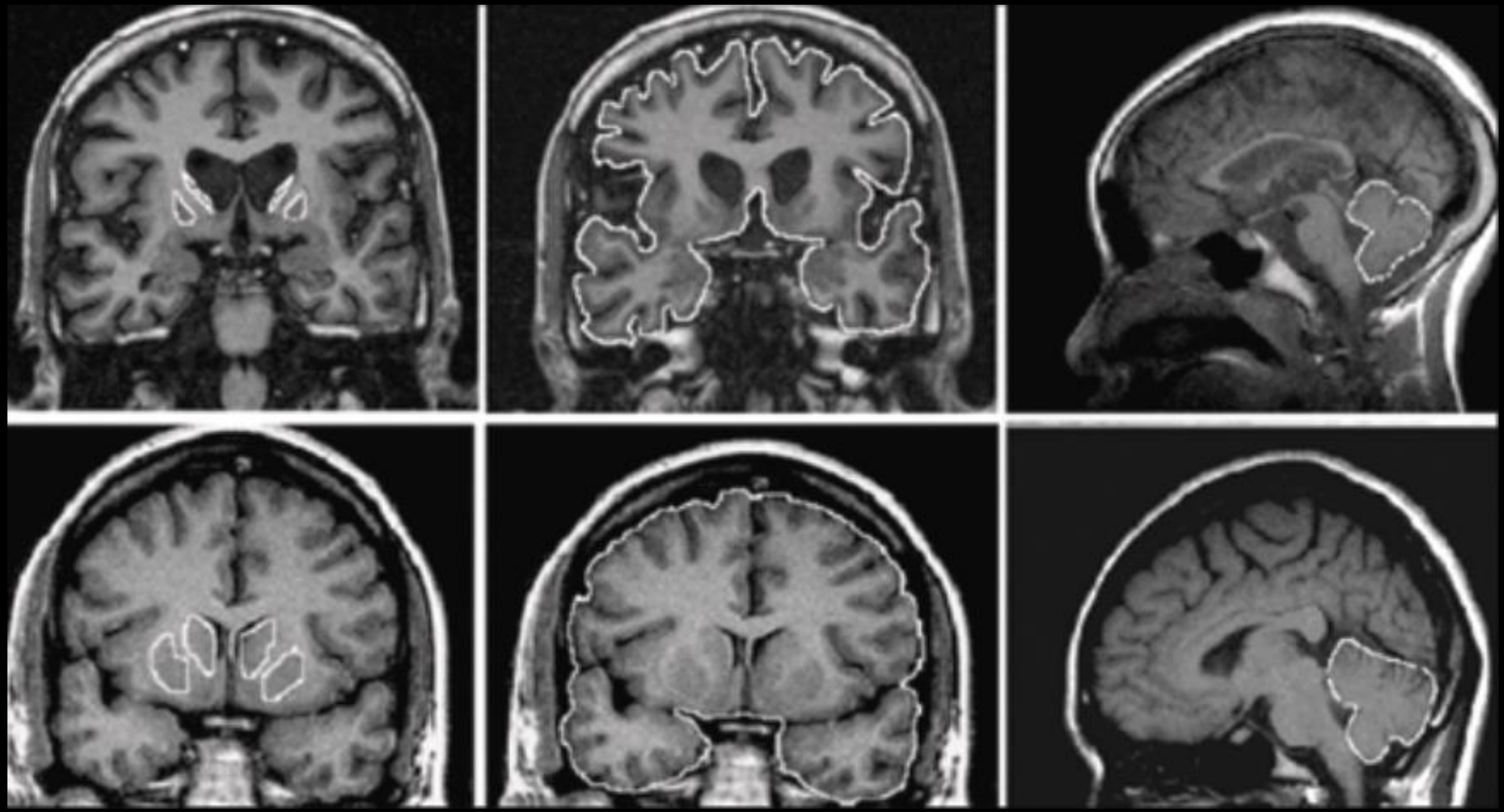
♀, 50 years old, non consanguineous mariage
Chorea (45 y.o.) then psychiatric disorders and cognitive deficits (48 y.o.)





Huntington disease (chorea)

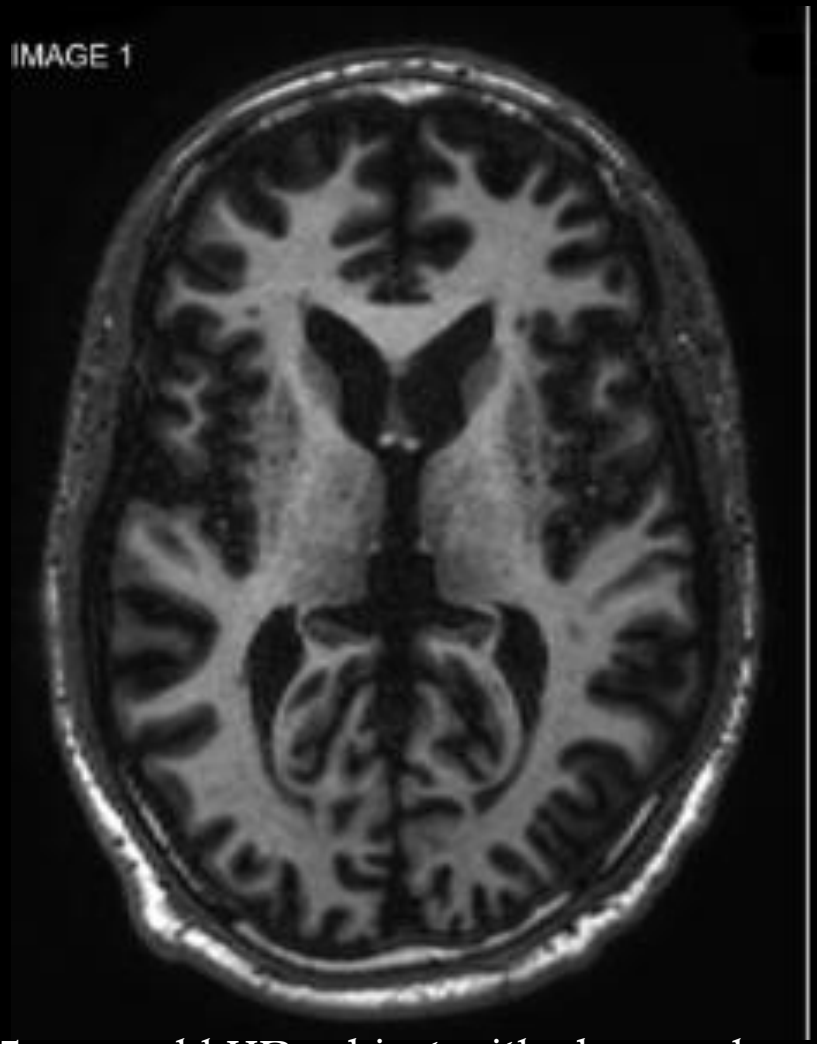
Huntington disease: MRI findings



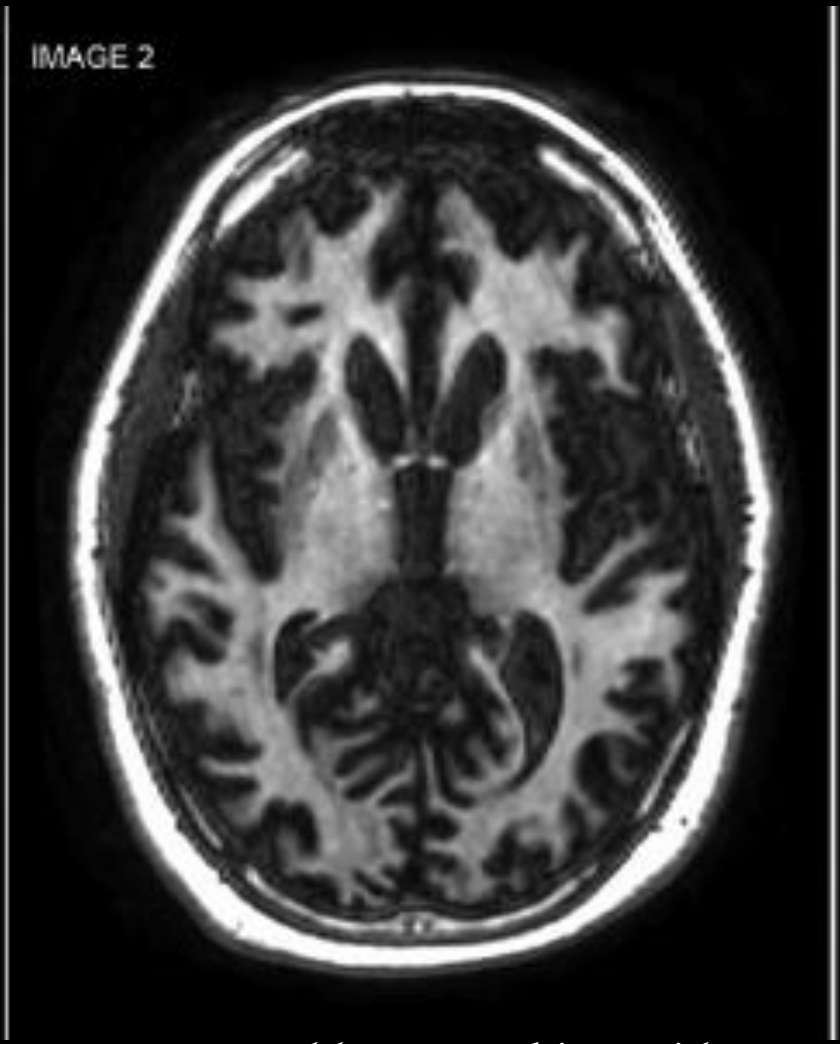
Ruocco et al,, CLINICAL PRESENTATION OF JUVENILE HUNTINGTON DISEASE, Arq Neuropsiquiatr 2006

Huntington disease like (HDL–2): same findings

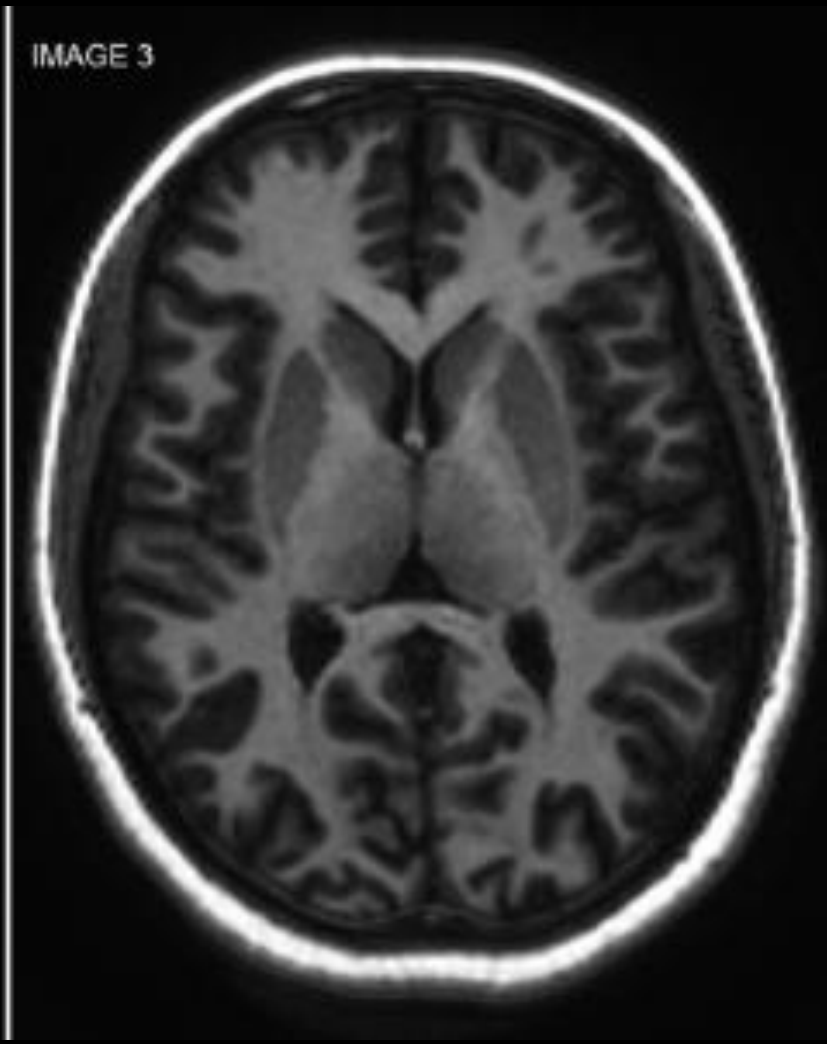
HDL-2: most common Huntington's disease (HD) phenocopy in populations with an African ancestry



35-year-old HD subject with abnormal HTT allele = 49 triplet repeats



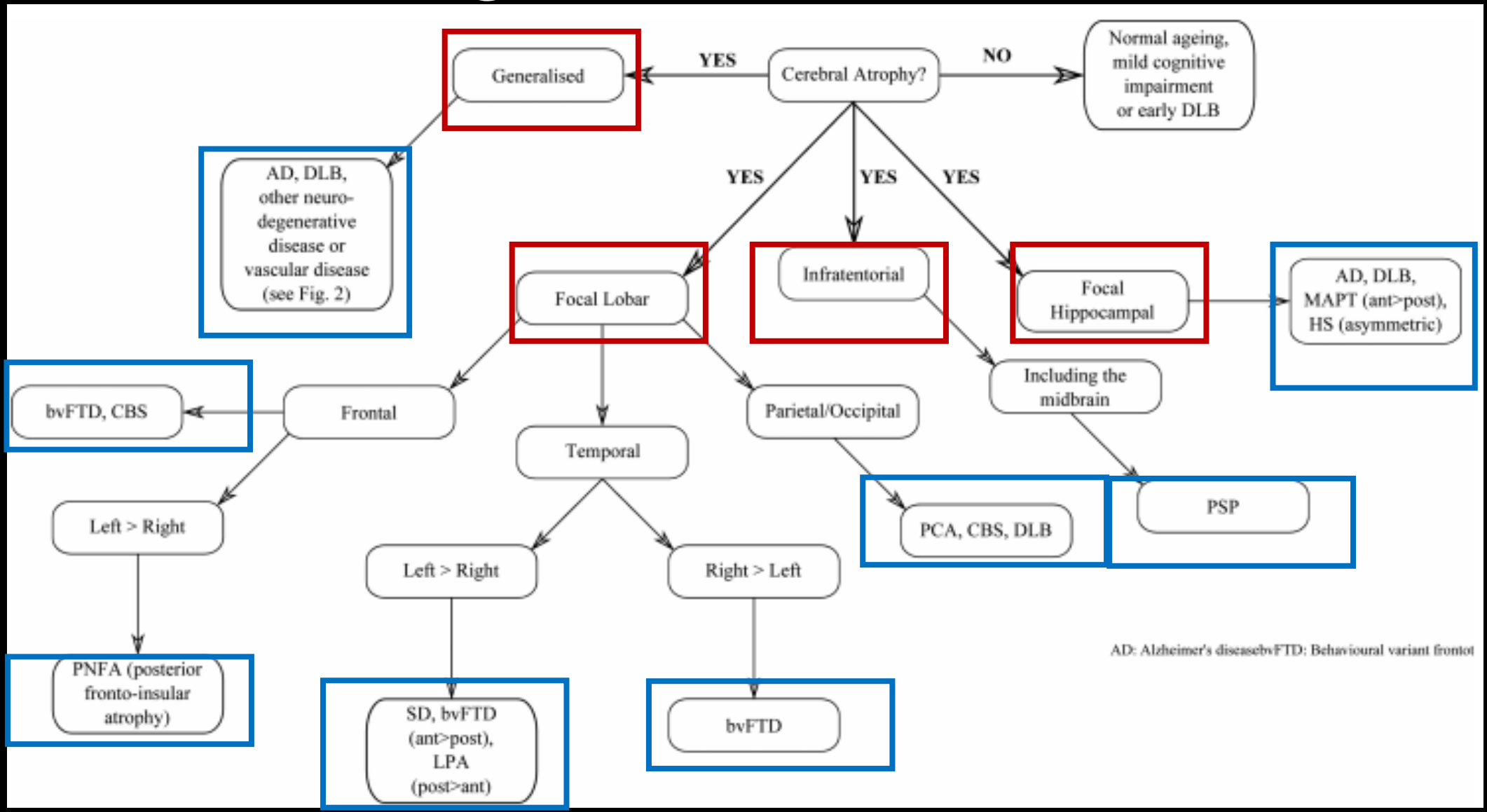
32-year-old HDL2 subject with abnormal JPH3 = 53 triplet repeats



32-year-old normal control subject

Yu et al,, Neural regeneration research , 2014

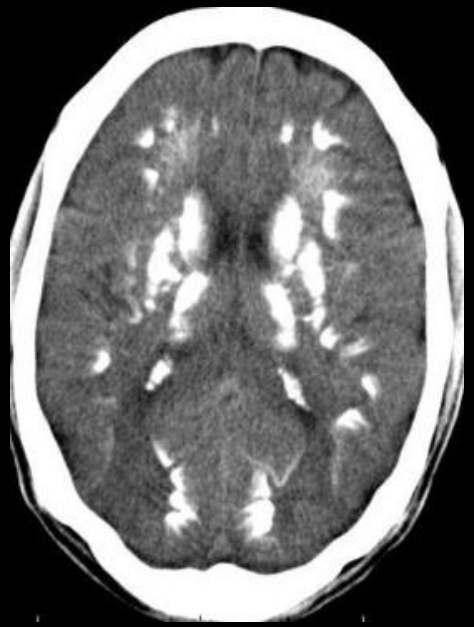
Approach to cerebral atrophy assessment in cognitive impairment

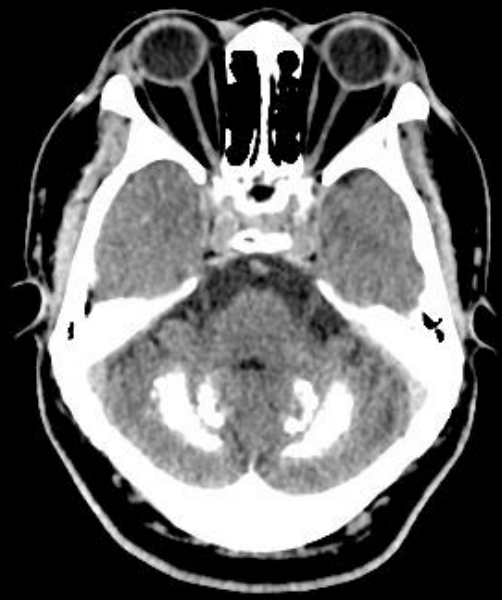


Harper L, et al. J Neurol Neurosurg Psychiatry 2014

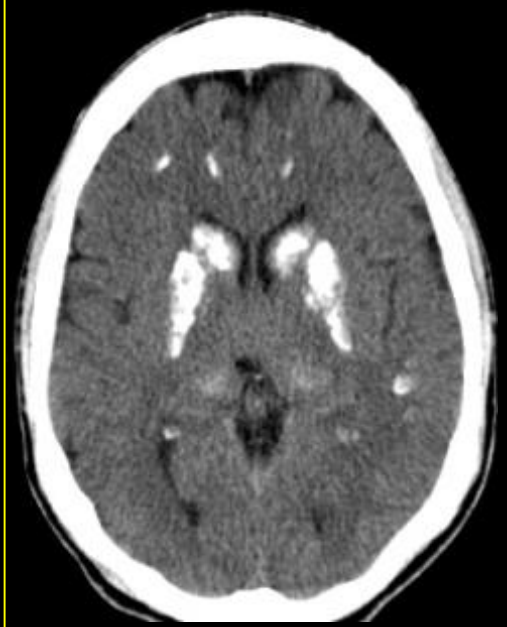
♂, 54 years old,
Progressive cognitive decline , cerebellar ataxia, dystonia since the age of 48
Family history: Mixed movement disorders (dystonia+chorea) in his son /Dystonia in his daughter

Patient

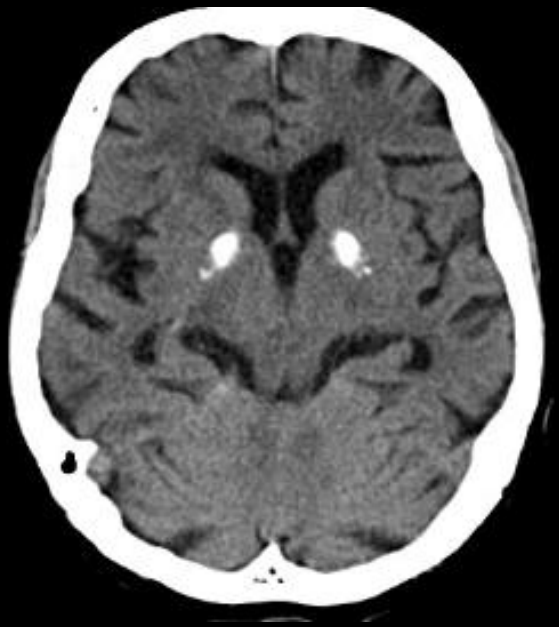




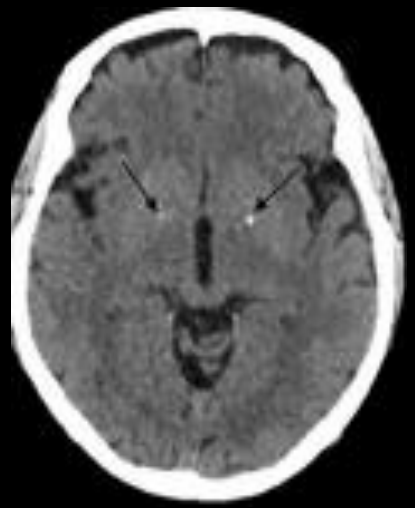
Son



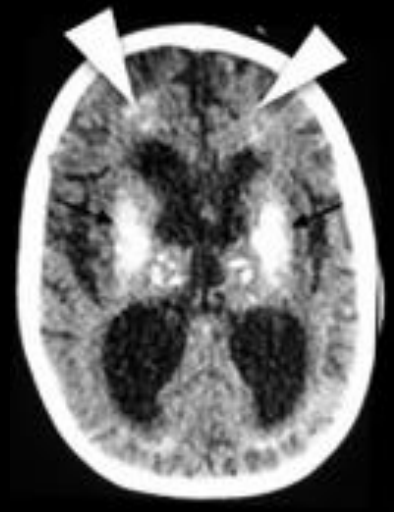
Daughter



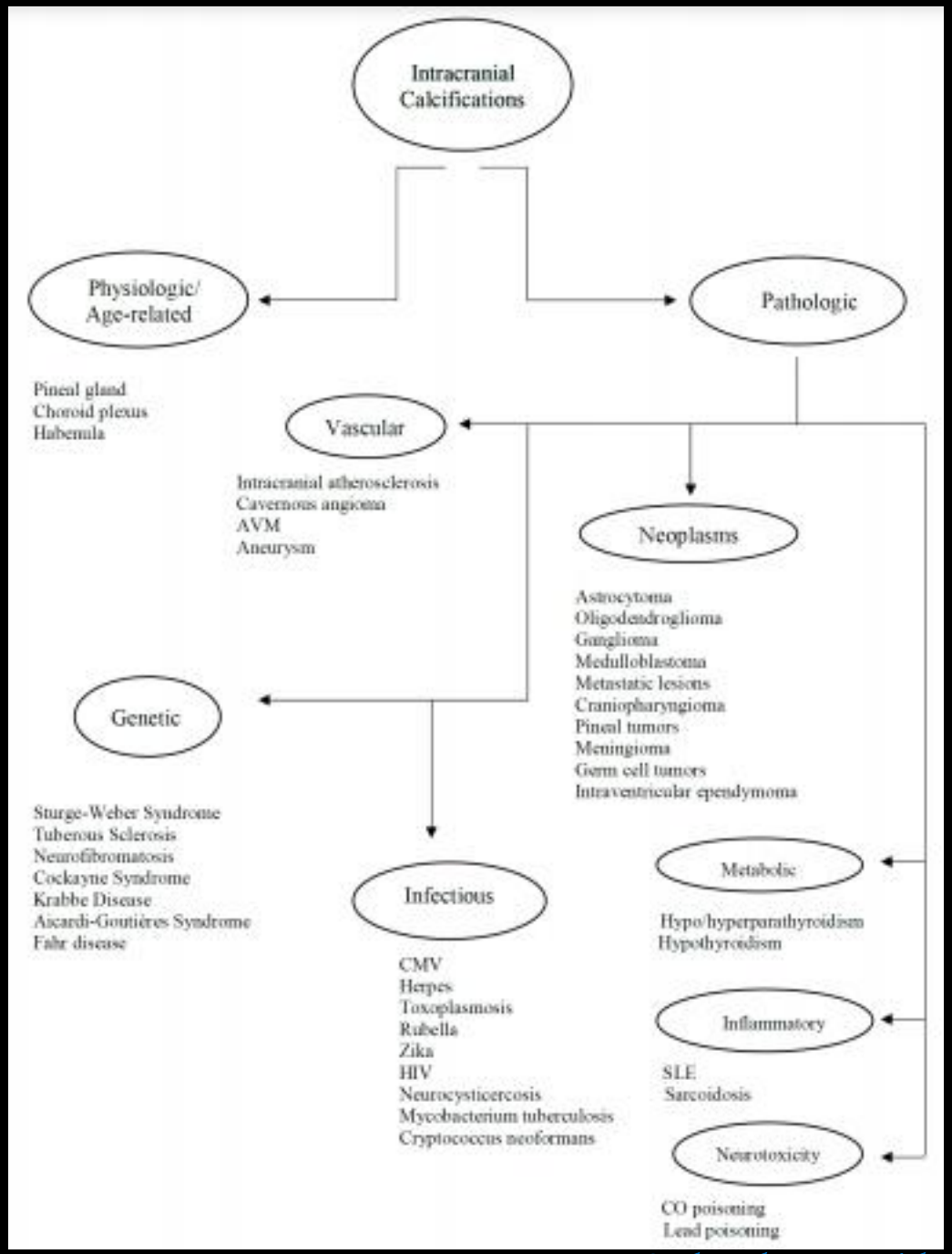
Basal ganglia calcification is also known as Fahr's disease or Fahr's syndrome

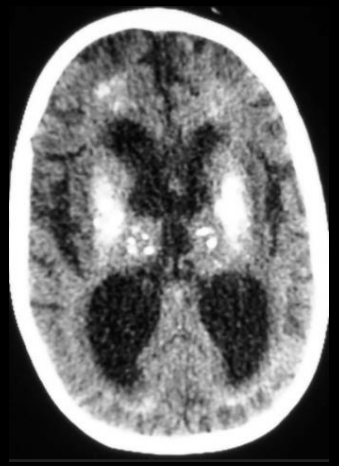


Incidental

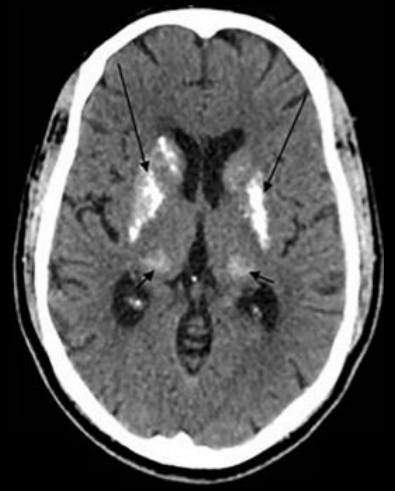


Cockayne disease





Aicardi-Goutières syndrome



Hyperparathyroidism

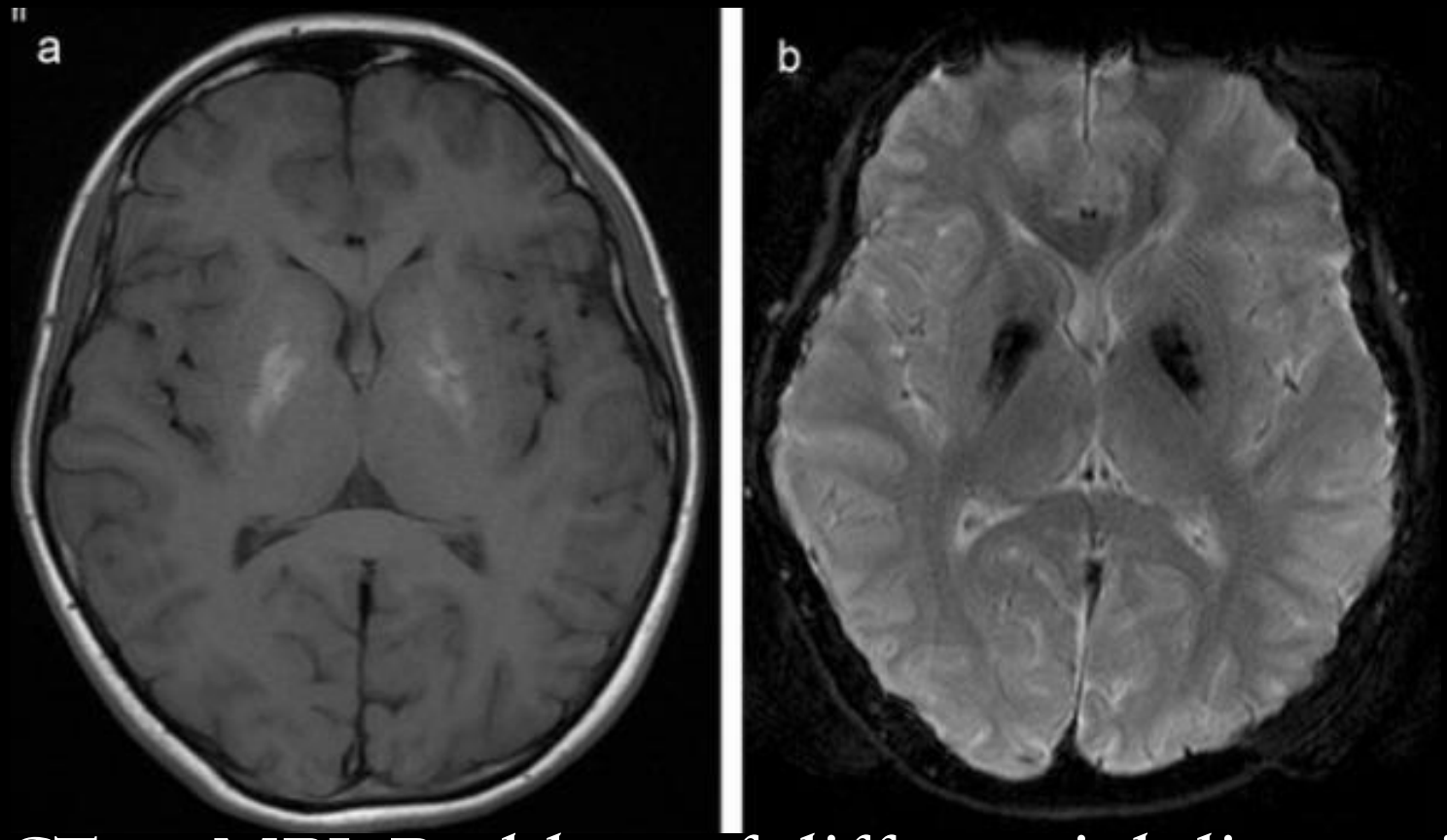
Saade et al., Intracranial calcifications on CT: an updated review, Radiology Case. 2019

Fahr's syndrome

On MRI: best appreciated on GRE/T2* or SWI , may be paradoxically hyperintense on T1

Hyperintensity on T1WI

Hypointensity on SWI

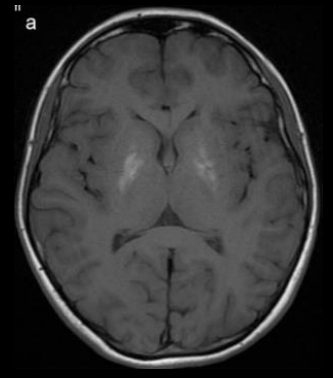


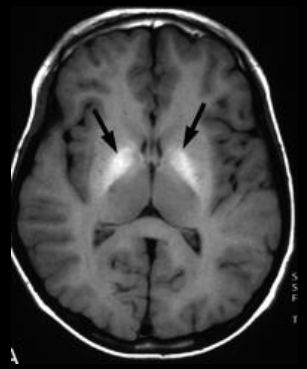
CT>>MRI: Problem of differential diagnosis

Bekiesinska-Figatowska et al., Basal ganglia lesions in children and adults, European Journal of Radiology, 2013

T1 Hyperintensities

(in basal ganglia+++)

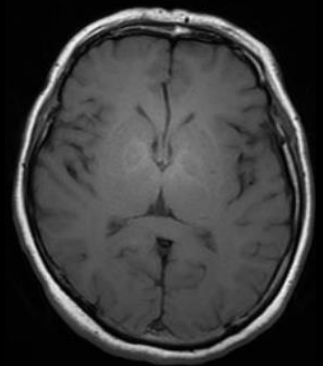




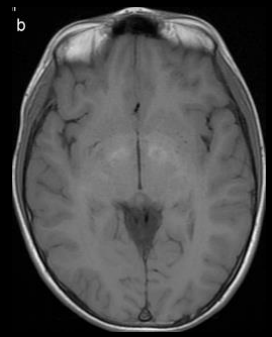
Calcifications

Wilson disease

T1-hyper- OR hypointensity

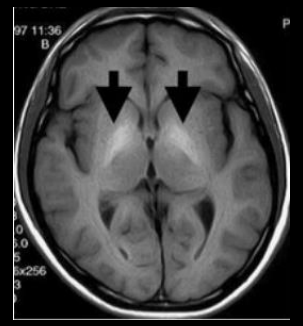


Carbon monoxide
(delayed)

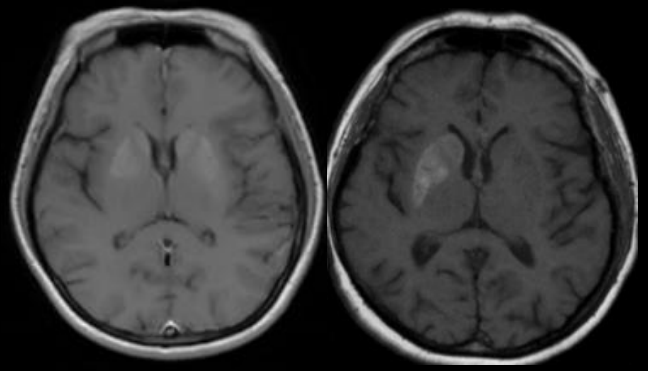


Neurofibromatosis
type 1

Hamartoma

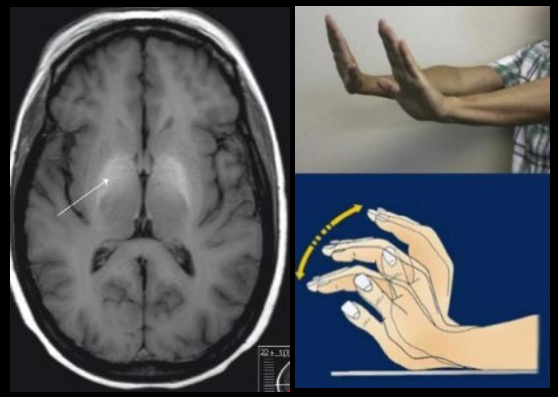


Manganese
Intoxication



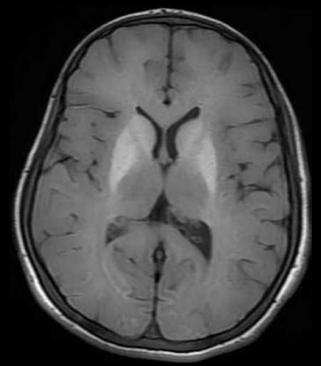
(Hemi)chorea-
(hemi)ballismus

Non ketotic
hyperglycemic chorea



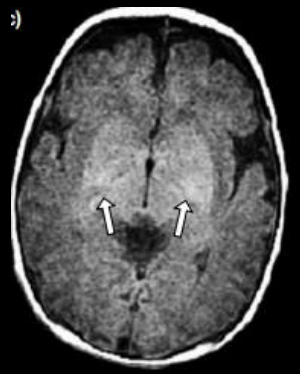
Hepatic
encephalopathy

Confusion
+ Flapping tremor (Asterexis)



Methemoglobinemia

cyanosis, microcephaly,
encephalopathy, axial hypotonia,
dystonia with hyperkinetic movements



Hypoxia–ischemia,
newborns

Bekiesinska-Figatowska et al., Basal ganglia lesions in children and adults, European Journal of Radiology, 2013

T2 or SWI Hypointensities*

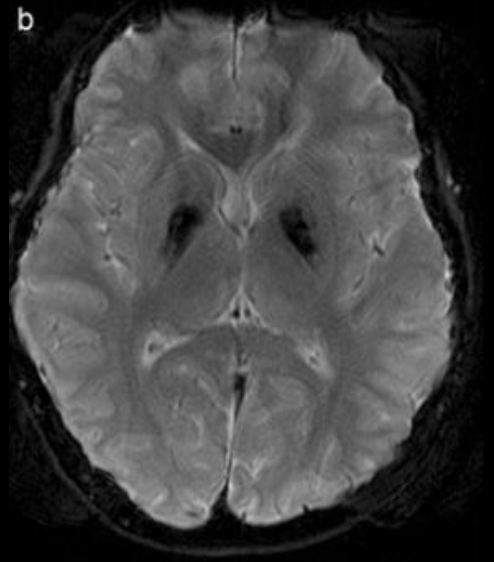
Calcifications

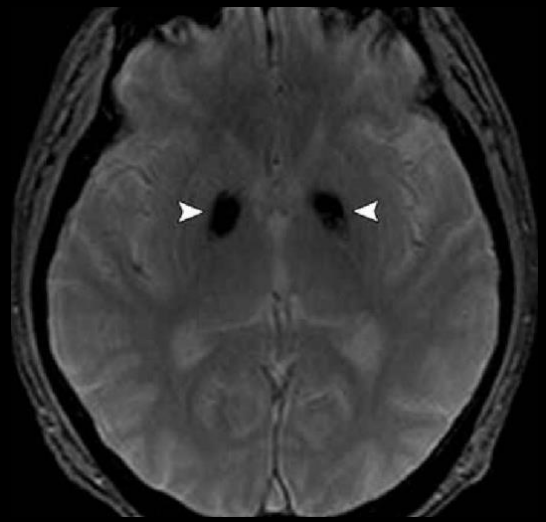
Iron

Physiological

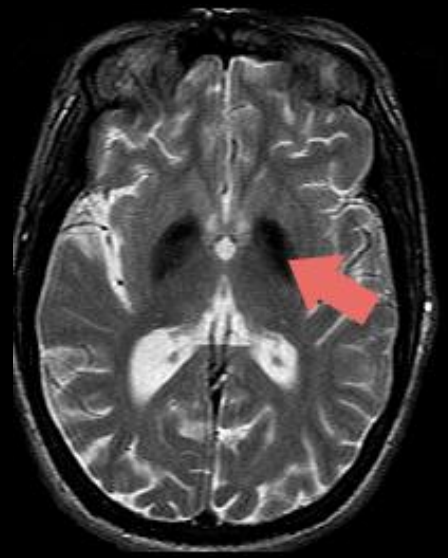
Pathological

Hemosiderin (hemorrhage)

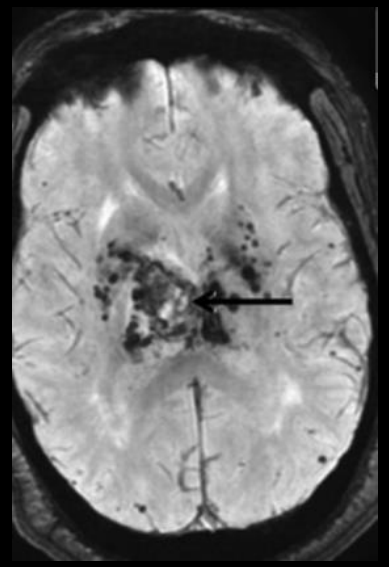




Ageing



NBIA

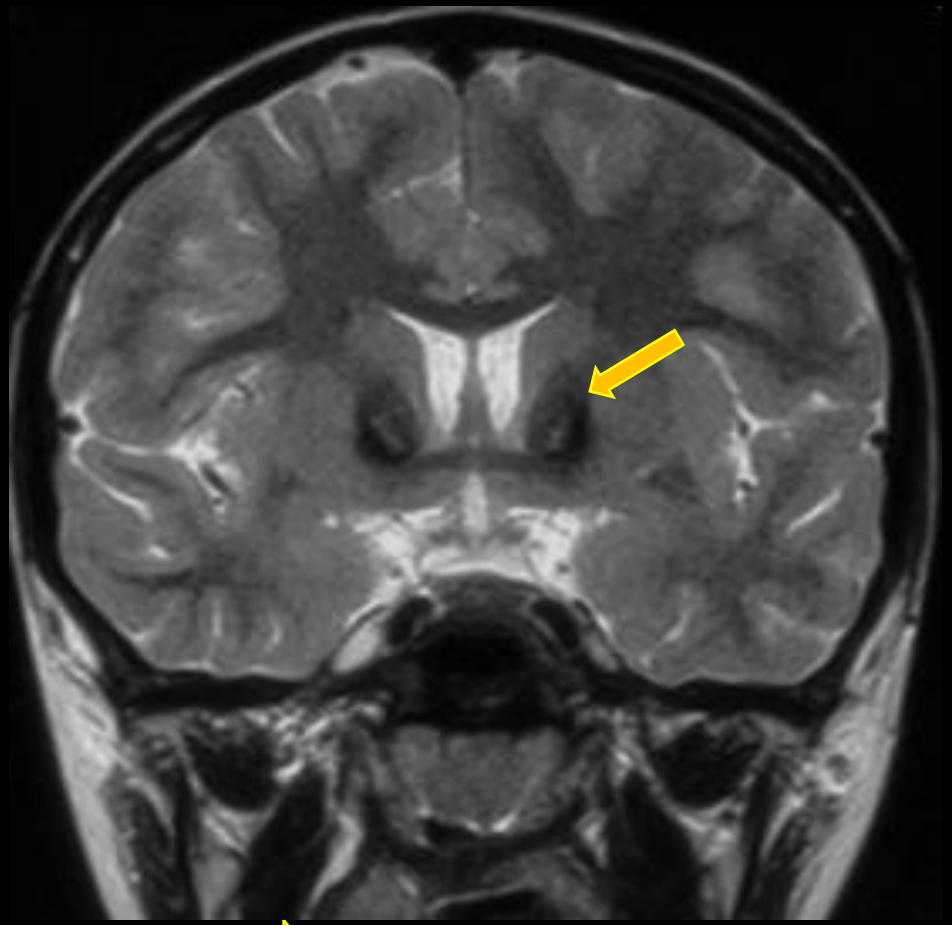


T2-hypointensity	Old age Parkinson's disease (globus pallidus) Calcifications Hemosiderin (old hemorrhage) or deoxyhemoglobin
T2-hyper- **AND** hypointensity	Panthotenate kinase-associated neurodegeneration – "eye-of-the-tiger" Parkinson variant of multiple system atrophy

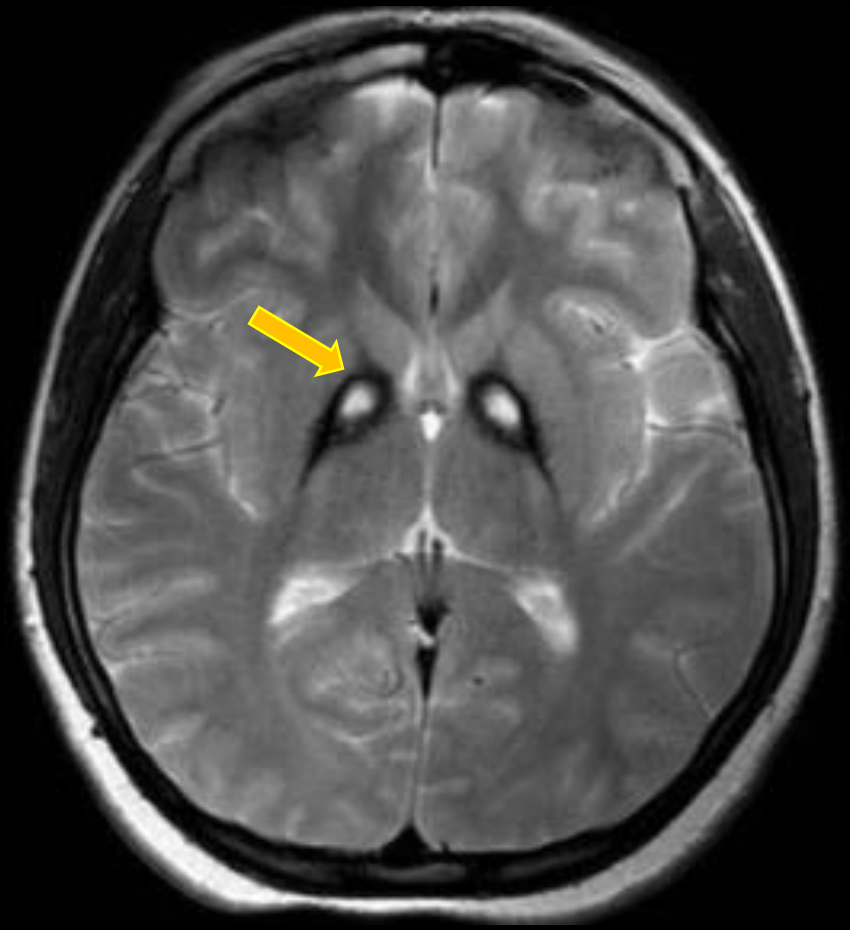
Bekiesinska-Figatowska et al., Basal ganglia lesions in children and adults, European Journal of Radiology, 2013

Hegde et al, Radiographics, 2011

♂, 30 years old, consanguineous mariage
Since the age of 24, difficulties with walking, speech, and writing, followed by dystonia and emotional and behavioral symptoms

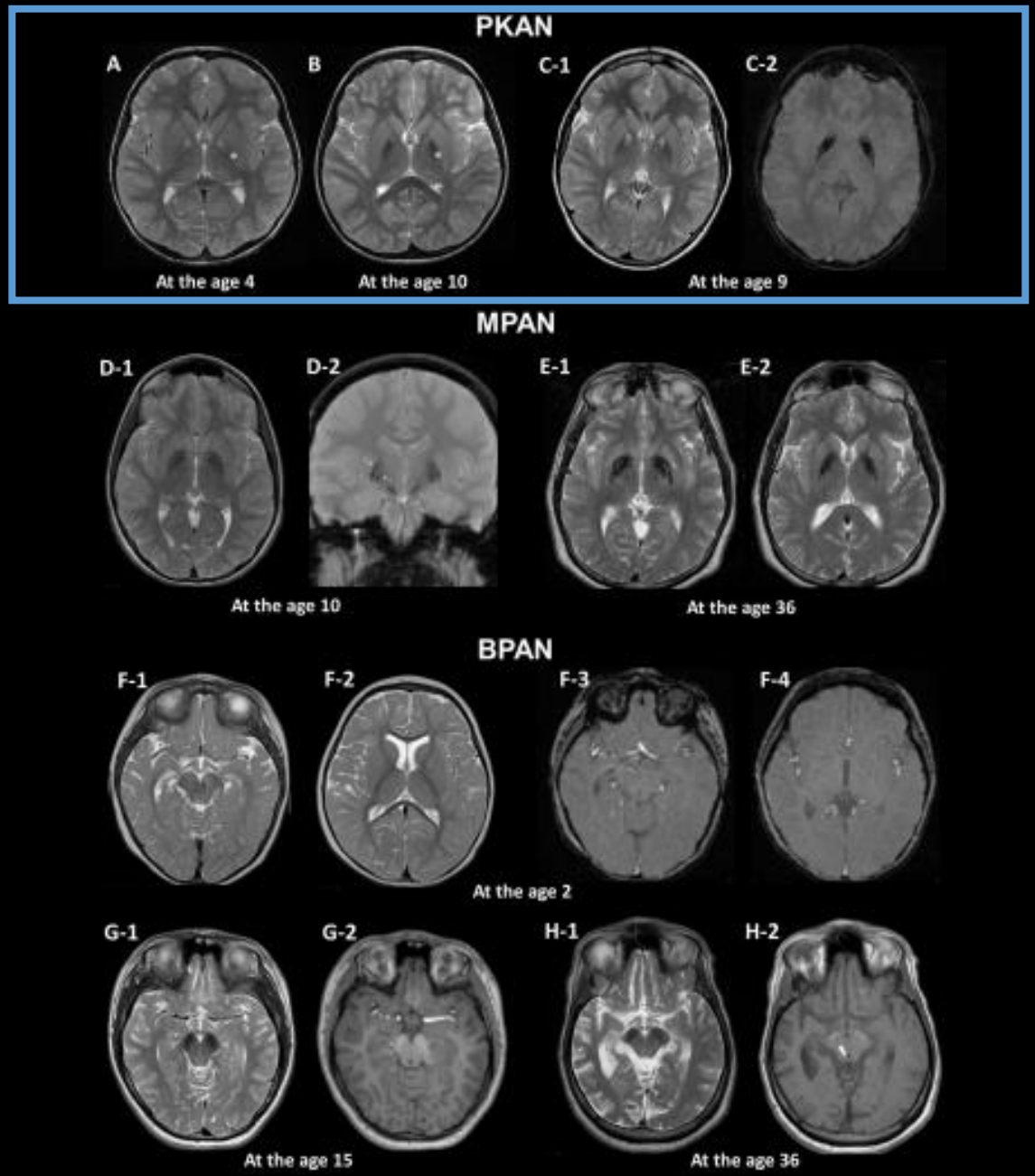


Eye of the Tiger



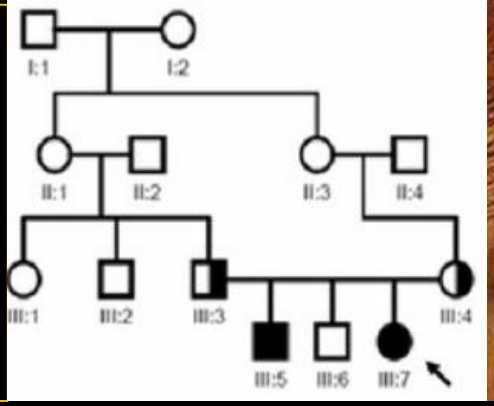
PKAN: Pantothenate Kinase Associated Neurodegeneration

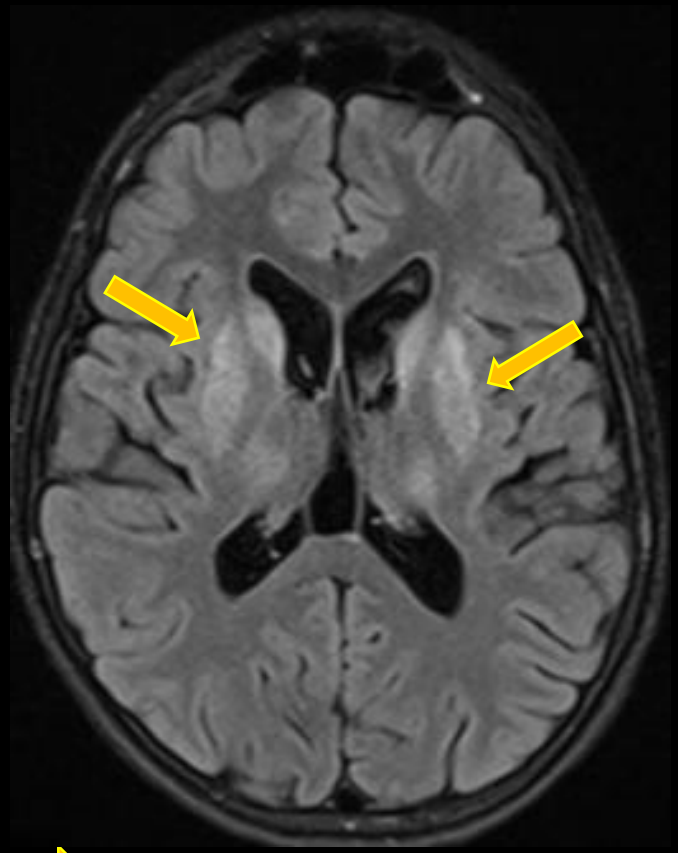
Neurodegeneration With Brain Iron Accumulation



Lee et al,, Brain MRI Pattern Recognition in Neurodegeneration With Brain Iron Accumulation, Frontiers in Neurology, 2020

♀, 25 years old, consanguineous mariage, similar cases, Movement disorders (hyperkinetic (chorea+ dystonia)+ hypokinetic (since 22 y.o.) then cognitive deficits (23 y.o.) Altererd liver /copper tests



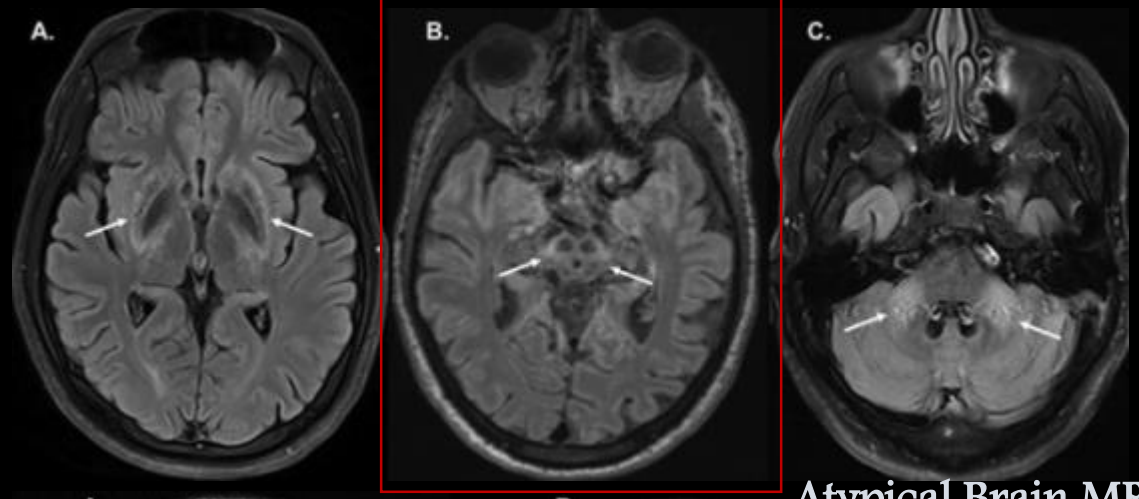


➡ Wilson's disease

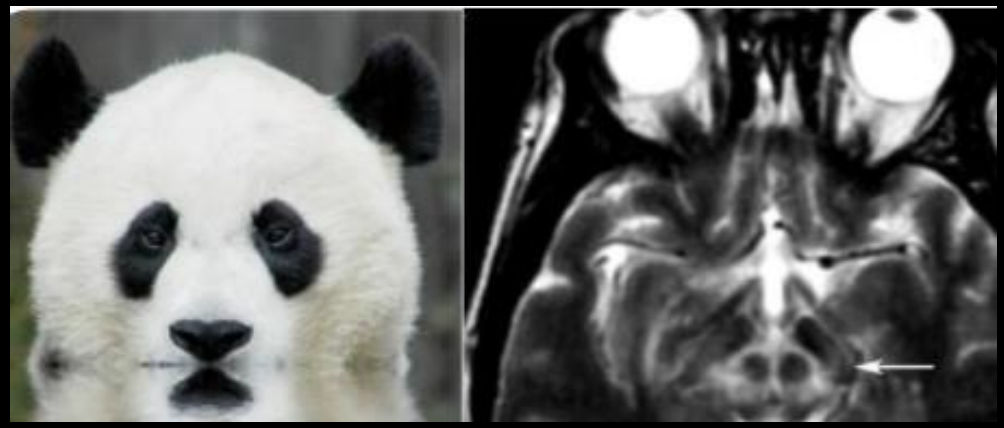
Wilson's disease: MRI findings

• MRI abnormal in all patients, • Putamen most involved (85.3%), • Sensitivity of T2 and FLAIR was highest 97.1% each.
• MRI load correlated with age, tremor, psychiatric disorder, choreoathetosis, and severity

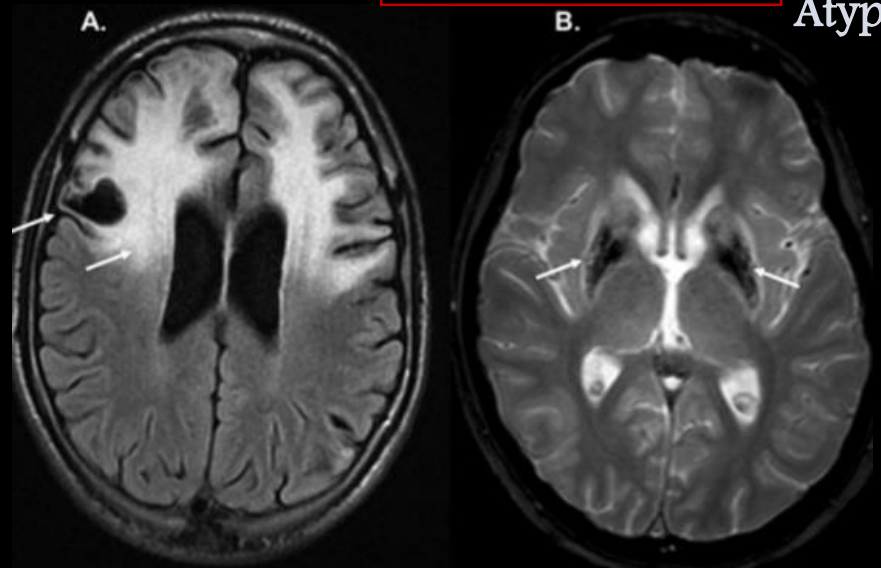
Classical Brain MRI findings

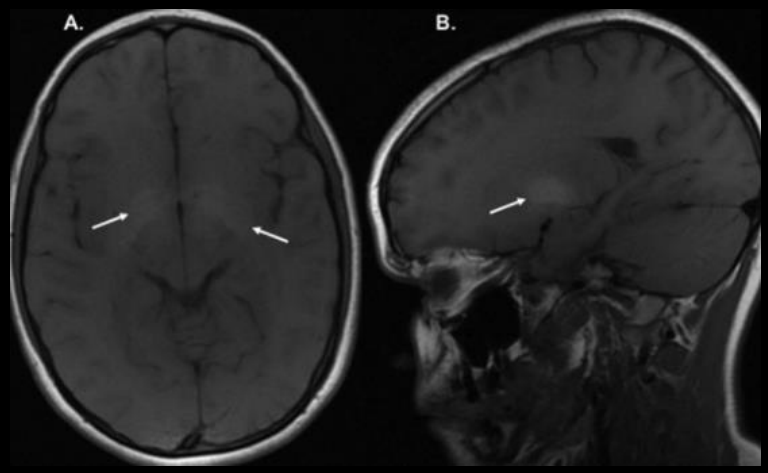


sign of the "giant Panda face"



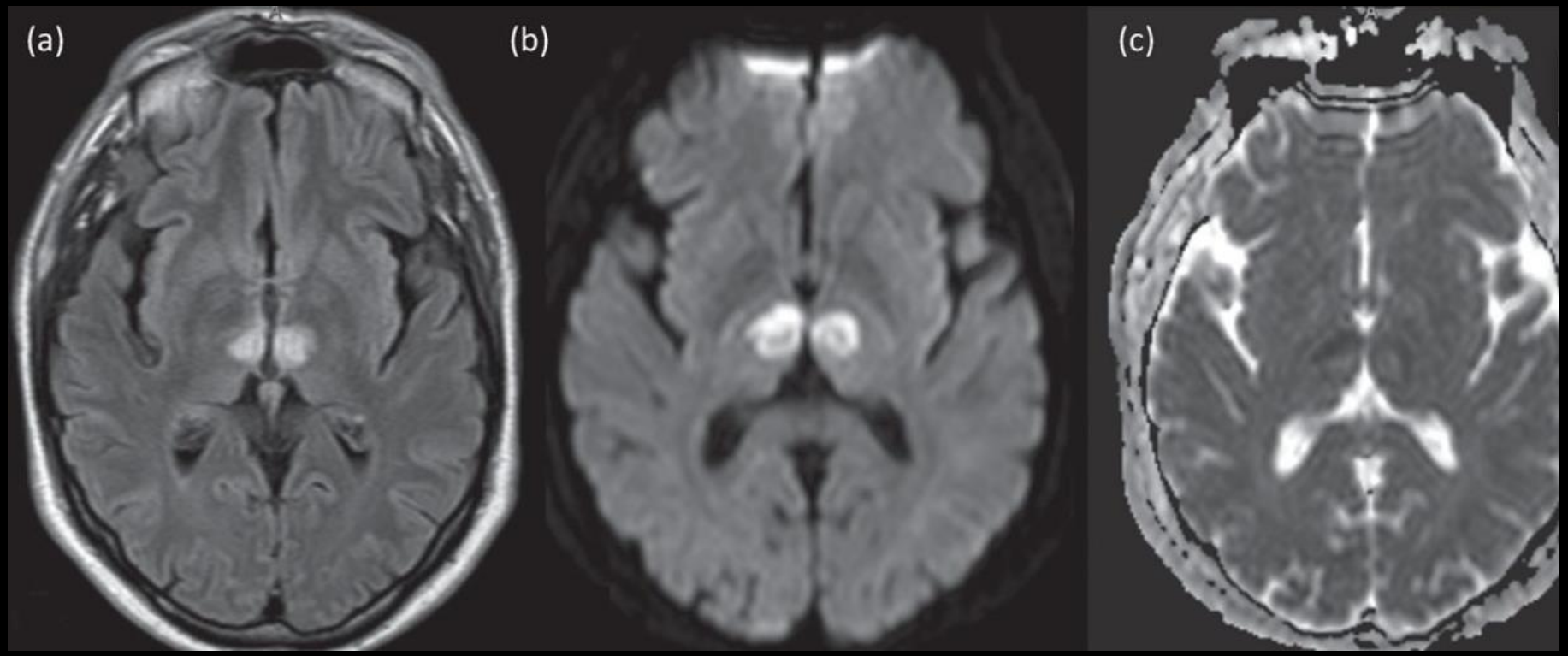
Atypical Brain MRI findings





Poujois et al,, Wilson's disease. A 2017 update, astroentérologie Clinique et Biologique , 2018

♂, 71 years old, presented with decreased consciousness (fluctuating Glasgow Coma Scale score of 5–7). He had a background of atrial fibrillation and was anticoagulated with dabigatran, a novel oral anticoagulant Computed tomography (CT) scan showed a mildly reduced attenuation in the region of the left thalamus. He later kept cognitive deficits with progressive decline (memory, language)

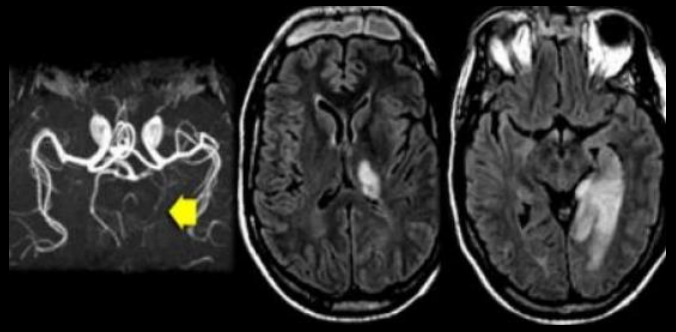


Bilateral thalamic infarction (artery of Percheron): Strategic Infarct

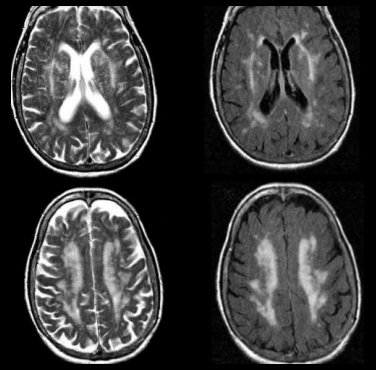
Vascular dementia (VaD)

Cognitive dysfunction in VaD can be the result of :

- ***Large vessel infarctions***:
  - Bilateral in the anterior cerebral artery territory.
  - Parietotemporal- and temporo-occipital association areas of the dominant hemisphere (angular gyrus included)
  - 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



strategic PCA infarction involving the hippocampus

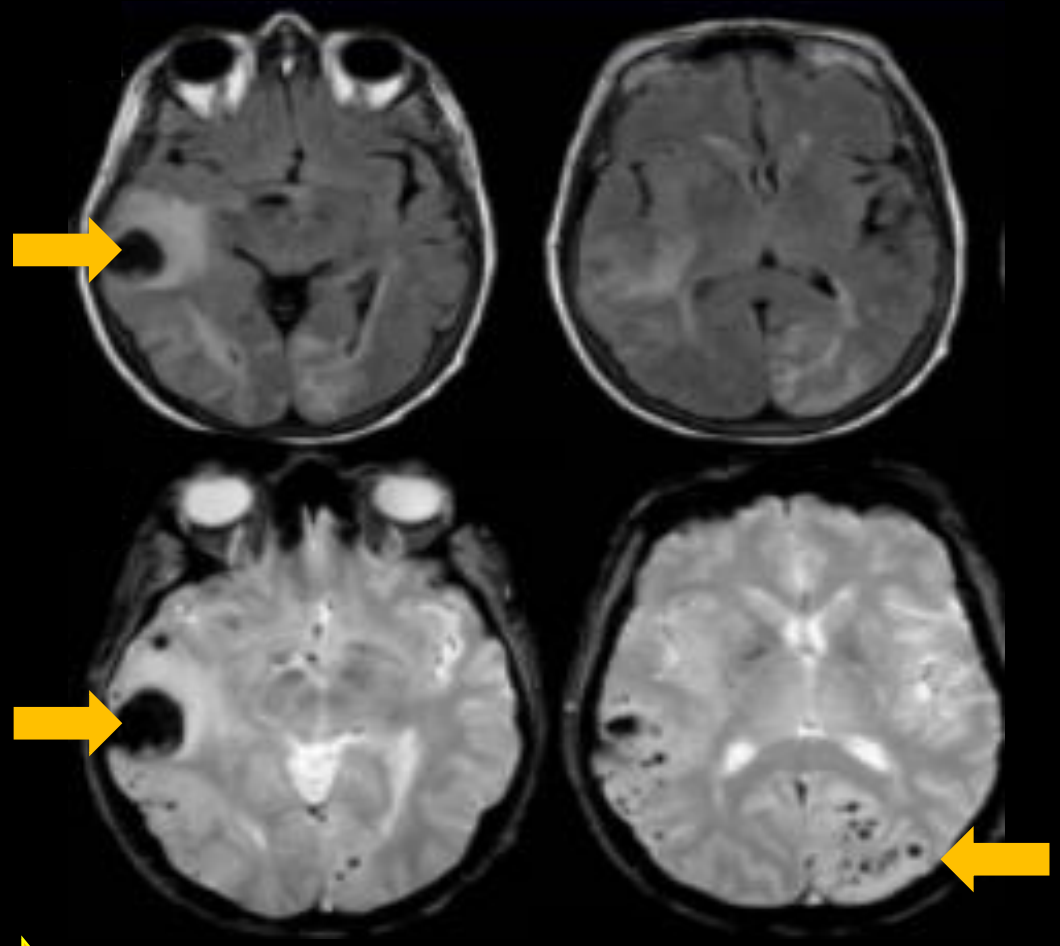


WMI (Fazekas 3) (Leukoaraiosis)

Strategic infactions	Site
Med Cerebral artery	Parieto-temporal or temporo-occipital association areas Angular gyrus
Post Cerebral artery	
Watershed infarctions	Superior frontal or parietal
Lacunar infarctions	Bilateral thalamic

Poujois et al,, Wilson's disease: A 2017 update, astroentérologie Clinique et Biologique , 2018

♂, 65 years old, Family history: Stroke (hemorrhagic and ischemic), dementia
Personal history of cerebral hemorrhage and Infarcts
Progressive cognitive decline since the age of 62



Cerebral Amyloid Angiopathy (CAA)

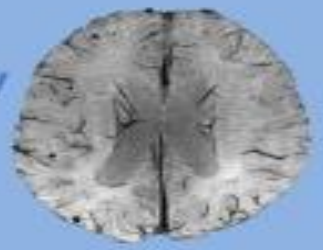
Lobar CMBs

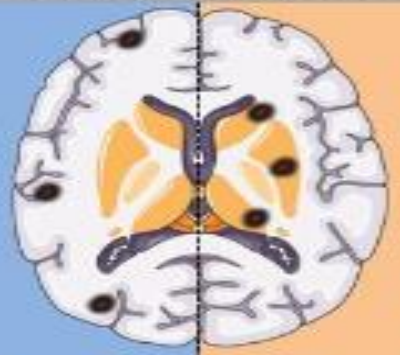
Deep CMBs

Main underlying causes

Cerebral Amyloid Angiopathy

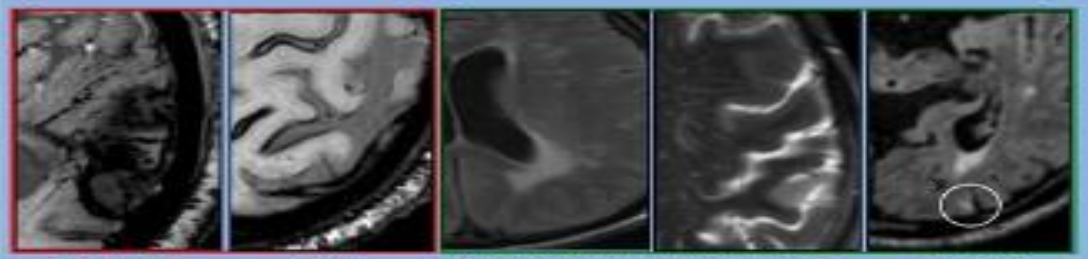
Search for other biomarkers





Haemorrhagic biomarkers

Non-haemorrhagic biomarkers



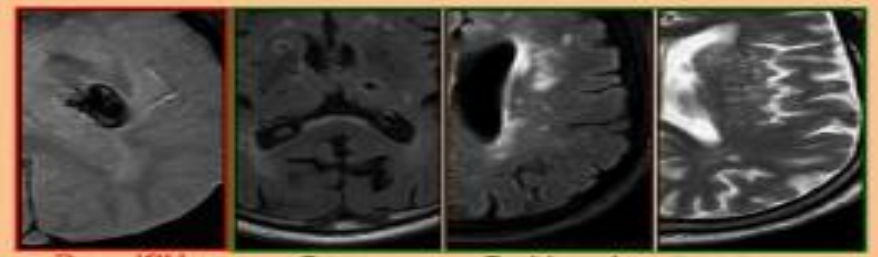
Lobar ICH sequelae | cSS | Posterior WMH with multiple spots | CSO EPVS | Cortical Micro-infarcts

Arteriolosclerosis

Search for other biomarkers

Haemorrhagic biomarkers

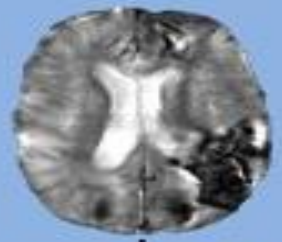
Non-haemorrhagic biomarkers



Deep ICH sequelae | Deep Lacunes | Peri-basal ganglia WMH | Basal ganglia EPVS

Vascular prognostic value in general population and stroke cohorts

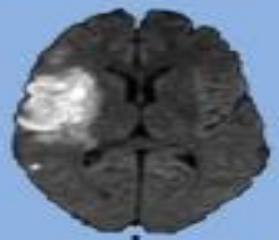
ICH risk



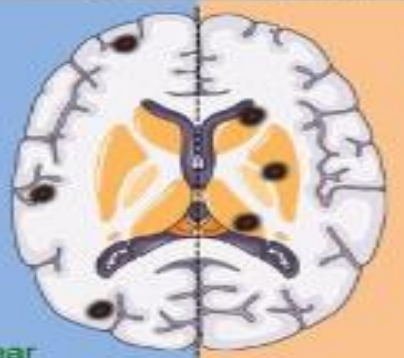
First ever event* — *0.13%* per year

Reccurent event** — *10% per year*

Ischaemic stroke risk

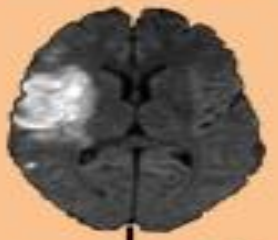


0.25% per year



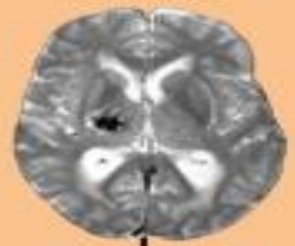
Presence of CMBs whatever the location:
ICH risk = *1.6%* per year
IS risk = *3.8%* per year

Ischaemic stroke risk



0.9% per year

ICH risk



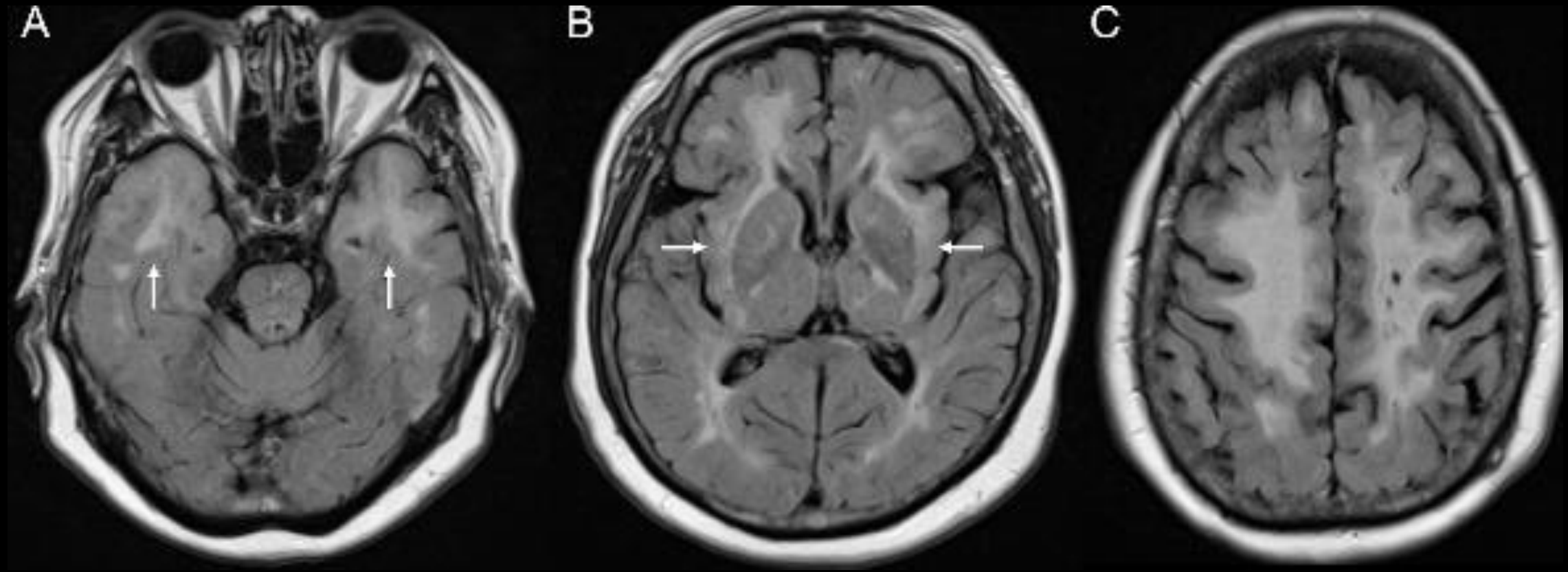
0.16% per year

2% per year

*data from general population ; ** data from stroke cohorts

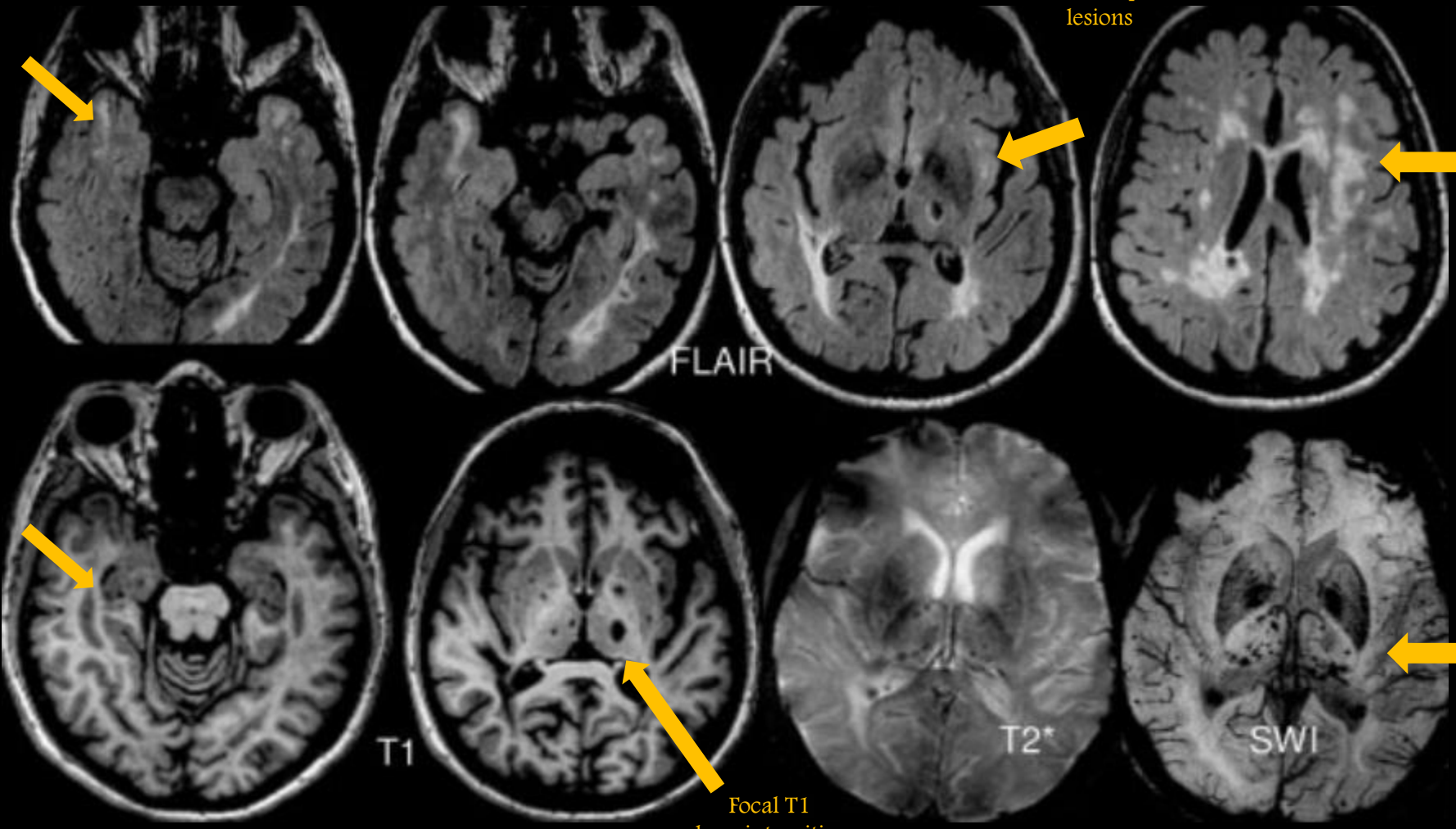
Puy L, et al. J Neurol Neurosurg Psychiatry 2021

♀, 45 years old, Family history: Migraine, Stroke,Dementia, Personal history: Migraine with aura
Progressive cognitive impairment, mood disturbances, apathy, parkinsonism, seizures and stroke-like episodes



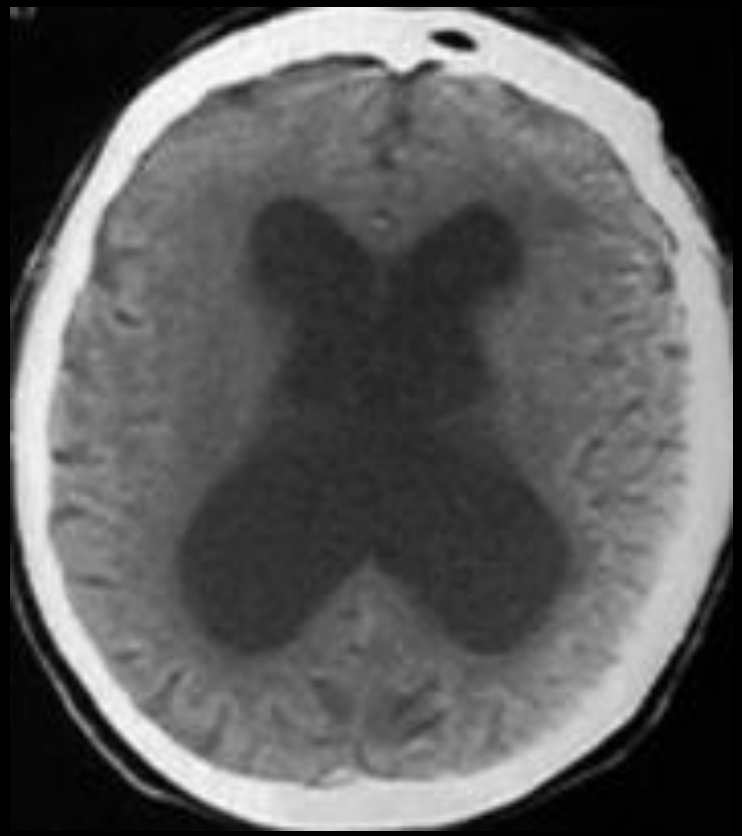
CADASIL (cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy)

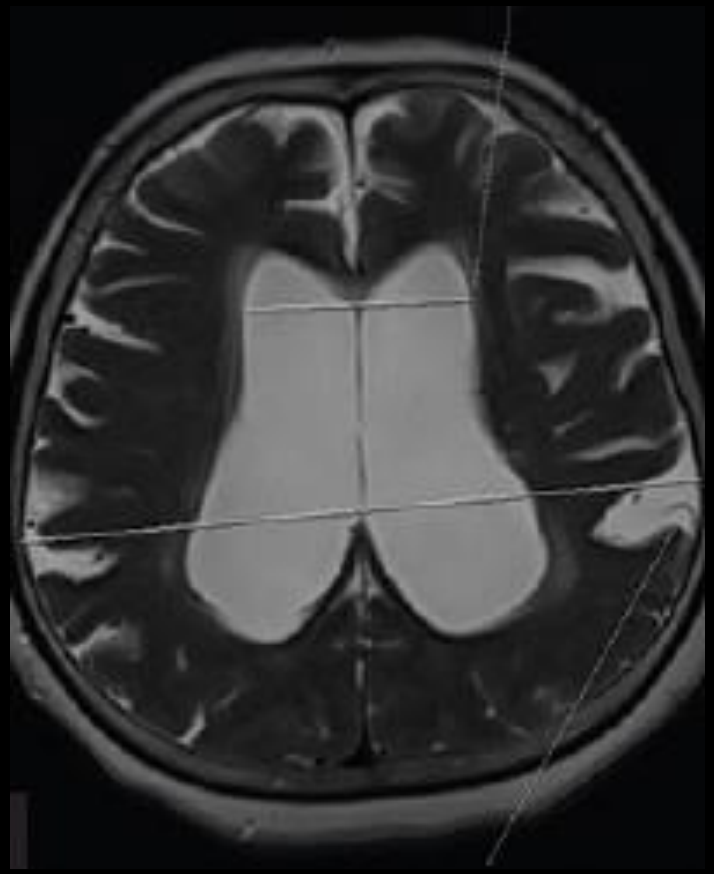
CADASIL: Typical imaging findings

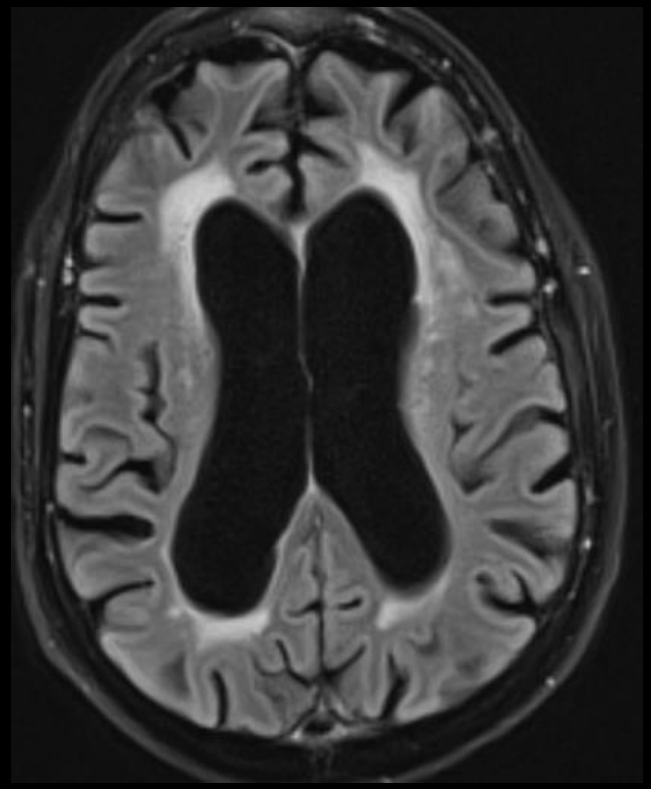


André et al., Arq Neuropsiquiatr 2010

♂, 72 years old, progressive cogntive decline, gait disorders, impairment of bladder control
On examination: major cognitive impaiment, parkinsonian syndrome prevailing in lower limbs



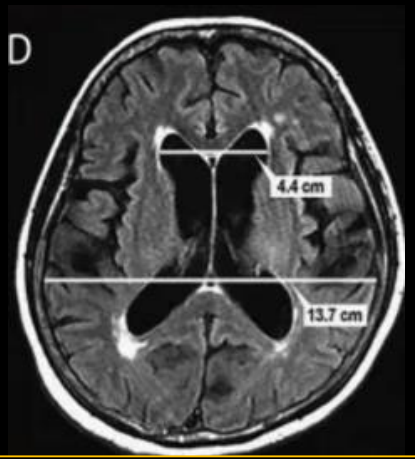




NPH (Normal pressure hydrocephalus)

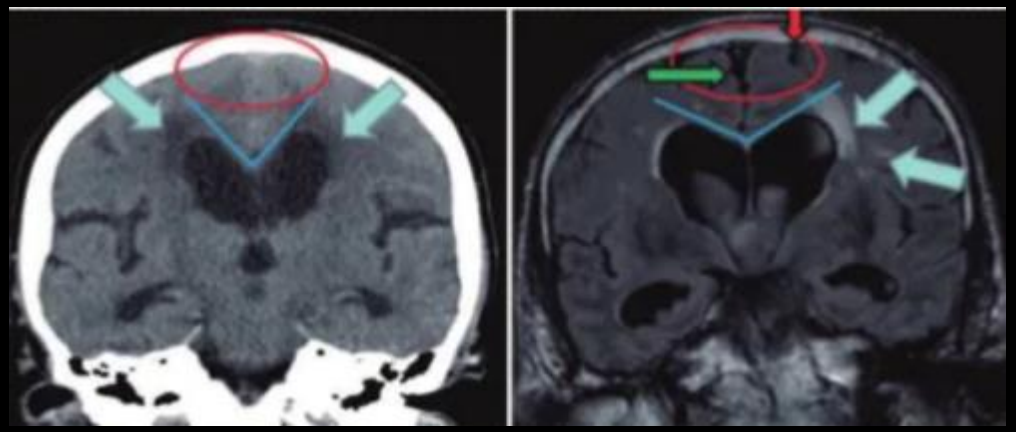
NPH (Normal pressure hydrocephalus)

EVANS Index> 0.30 to 0.33
- Variable for localisation and angle of section
- Not specific

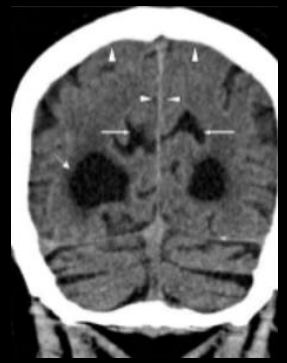


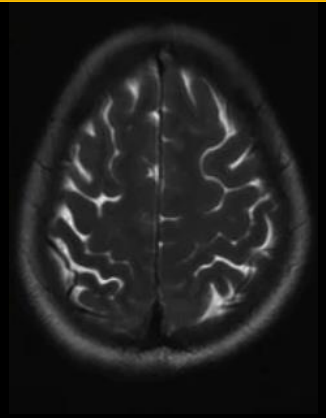
Corpus callosum angle

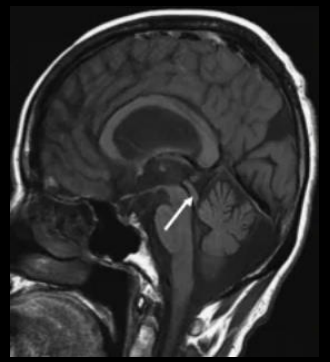
- 50-80° vs hydrocephalus exvacuo ((100-120°)



DESH, the combination of high-convexity tightness, Sylvian fissure dilation, and ventriculomegaly : increasingly recognized as a neuroimaging hallmark of iNPH

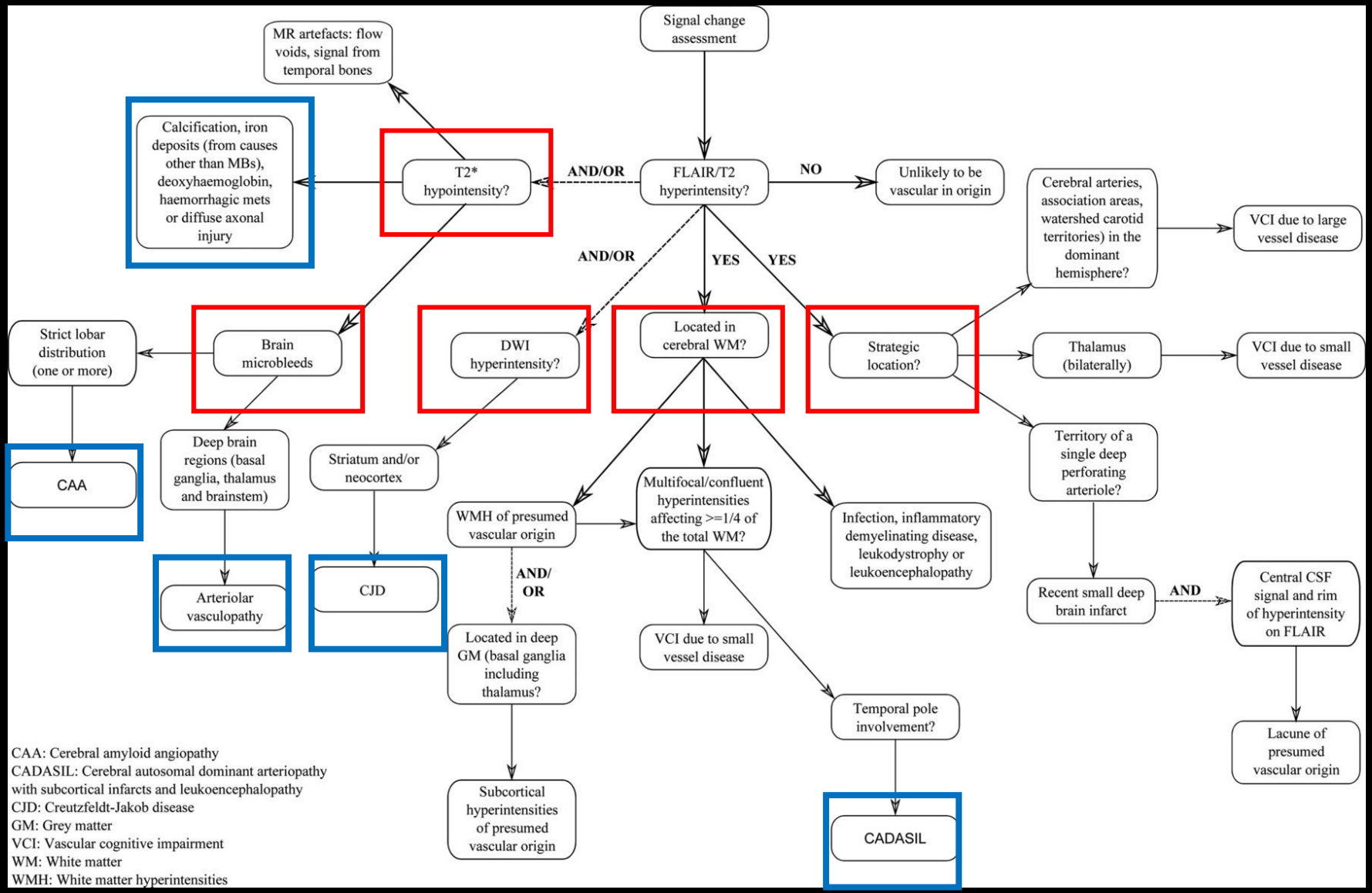




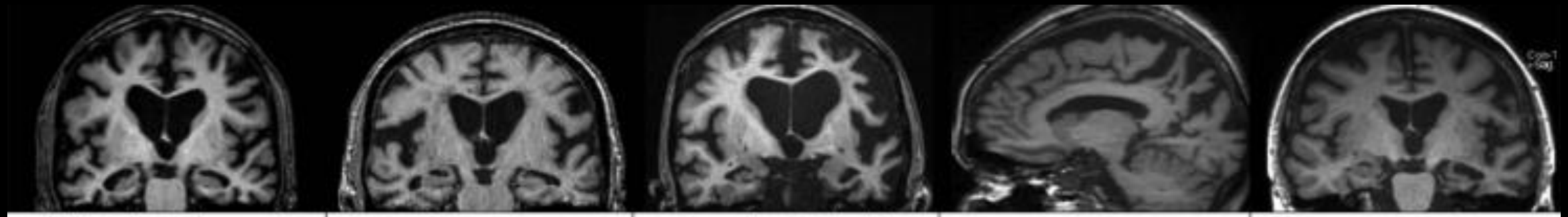


Continuum, 2016
Dement Neuropsychol, 2015

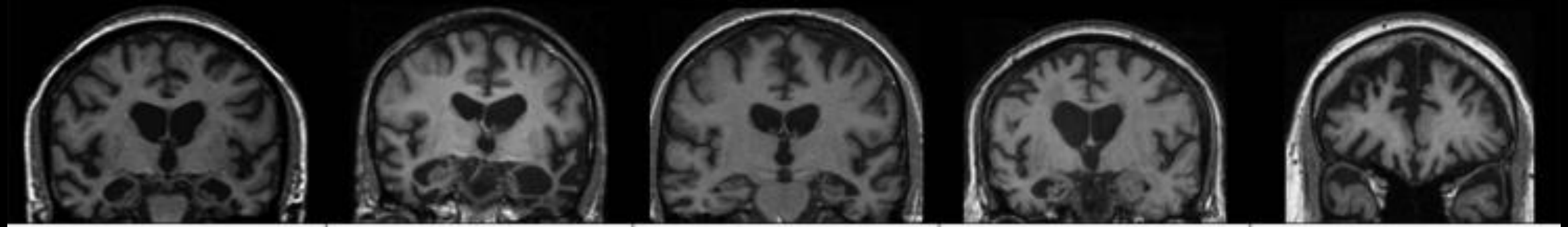
Approach to signal change assessment in cognitive impairment



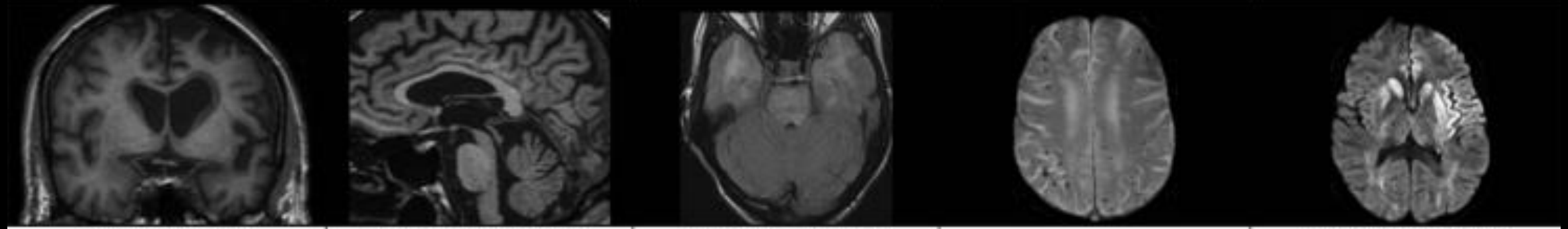
Harper L, et al. J Neurol Neurosurg Psychiatry 2014



Global atrophy with hippocampal atrophy AD – Braak stage VI	Global atrophy with relatively preserved hippocampi DLB – diffuse neocortical	Asymmetric atrophy involving whole hemisphere bvFTD (PGRN) – TDP43A	Parietal/occipital atrophy PCA – AD Braak stage VI	Temporo-parietal atrophy, L>R LPA – AD Braak stage VI



Severe and focal anterior medial temporal atrophy bvFTD – Tau MAPT	L>R temporal lobe atrophy Semantic FTD - TDP43C	Asymmetric (L>R) frontal and temporal atrophy bvFTD – FUS aFTLDU	Asymmetric (R>L) MTL atrophy bvFTD – Tau Pick's	Frontal lobe atrophy bvFTD – Tau Pick's



Atrophy of the frontal gyrus/insula, L>R PNFA – Tau Pick's	"Hummingbird" appearance of sagittal midbrain PSP – Tau PSP	Confluent hyperintensities in temporal poles CADASIL	Cortical-subcortical CMBs on T2* *CAA	Hyperintensity in cortex and basal ganglia on DWI CJD – Iatrogenic CJD

Harper L, et al. J Neurol Neurosurg Psychiatry 2014

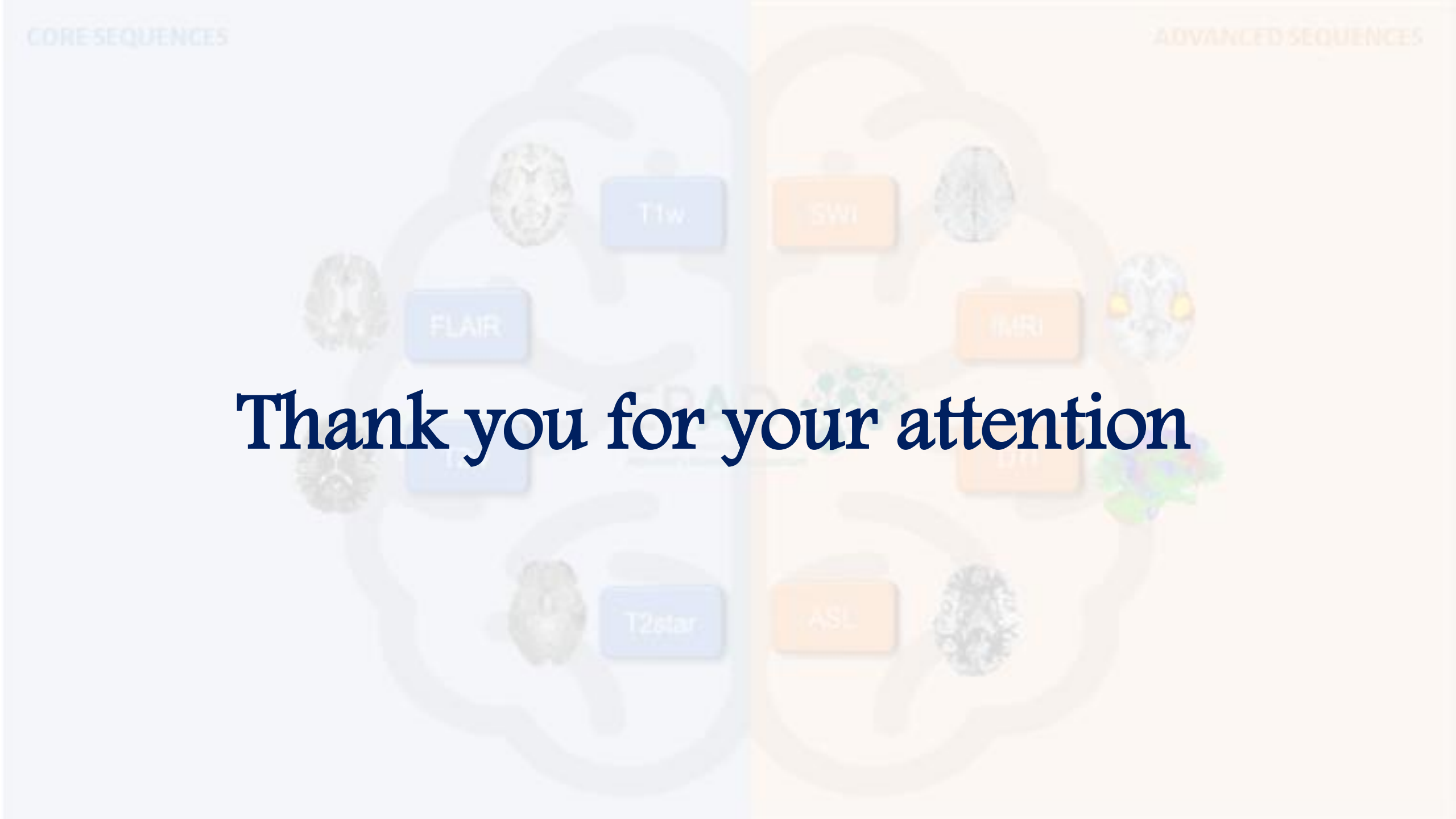
Conclusion

- Large ***panel of imaging assessments*** for a large spectrum of diseases

- Need for a **systematic** (Gray matter, White matter, vascular, CSF) vs **adapted** strategy (use of visual scales, use of sequences,,,,) for both **Clinicians and Radiologists**

- Expending imaging findings and imaging techniques

➔ Need to keep « informed » (**updates and basics**)



Thank you for your attention