Current Concept of Imaging Application in acute ischemic stroke and intra-arterial mechanical thrombectomy

廖漢文

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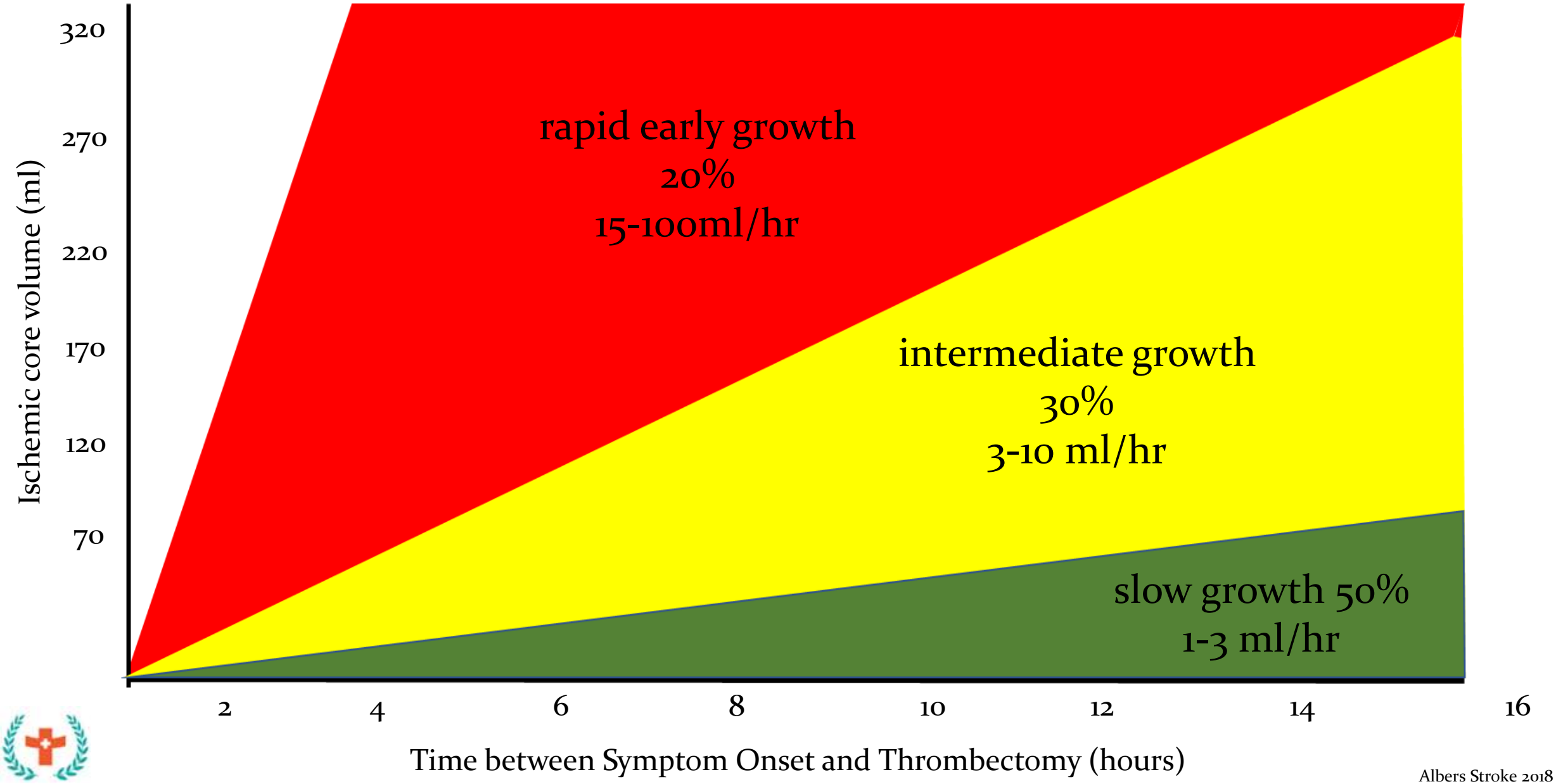

Albers Stroke 2018

Real Concept of Tissue-Based Selection

- Imaging is not a tool for patient selection.
- Imaging is only for suggesting prognosis and preventing futile recanalization.

Imaging used in AIS

- NCCT (or MR)
  - Identify hemorrhage
  - ASPECTS (Alberta stroke program early CT score)
  - Identify stroke-like syndrome

- CT angiography (or MR angiography)
  - Confirm LVO
  - Evaluate location, characteristic and length of clots
  - Evaluate collateral

- CT perfusion (or MR perfusion)
  - Confirm the diagnosis
  - Identify the core
  - Identify penumbra

Table 3. Efficient Workflow and Utility of Acute Ischemic Stroke NCCT/mCTA Protocol/Image Processing Methods

Workflow Sequence	Image Processing Methods	Clinical Utility
NCCT performed	NCCT head standard 5-mm slice thickness	Early ischemic change detection with ASPECTS
		Subacute infarcts/severe leukoaraiosis
		Subtle hemorrhage
IV tPA decision	NCCT head thin section 0.5-mm slice thickness	Hyperdense artery signs and length detection—tPA response
Multiphase CTA performed while IV tPA mixed and prepared if eligible		
	Neck CTA with mCTA head 0.5-mm source images	Quick determination of proximal occlusion
		Residual flow at intracranial occlusion site/ Nonocclusive thrombi
		Extracranial thrombus (donut sign)
IV tPA bolus given and infusion started in CT scanner		
Call endoteam		
Patient removed from CT suite or CTP imaging performed	mCTA 1st phase head axial thick MIPs	Arterial occlusion site
	Peak arterial to equilibrium acquisition	Fast collateral filling (excellent collaterals)
		Circle of Willis variation
	mCTA 2nd phase head axial thick MIPs	Arterial occlusion site with slow cardiac output/mistimed bolus
	Peak venous acquisition	Slow flow versus occlusion (distal ICA occlusion versus near occlusion)
		Clot length
		Delayed collateral filling (good collaterals)
	mCTA 3rd phase head axial thick MIPs	Clot length
	Late venous acquisition	Impaired washout (fair collaterals)
		Region of impaired washout—territory at risk
		No collateral filling by 3rd phase (no or poor collaterals/large core)
	NCCT head only standard 5-mm slice thickness	Reevaluate ASPECTS in light of collateral information especially if ultraearly scan/significant motion artifact/old infarcts
Discussion with endo team on suitability for EVT	CTA neck 0.5mm source images	Evaluate access
		Cervical ICA stenosis severity
		Circle of Willis variation
	CTA neck with mCTA coronal/sagittal neck/head axial thin MIPs	Arch anatomy/atheroma
		Great vessel thrombi
		Neck tortuosity
		Variations of anatomy (fetal PCA etc)
	mCTA head coronal thick MIPs	Terminal ICA occlusion type
		M1 versus M2 occlusion
	mCTA head sagittal thick MIPs	Distal M2 and beyond occlusions; ACA occlusions
		Distal vasculopathy
Plan endovascular procedure		

ACA indicates anterior cerebral artery; ASPECTS, Alberta stroke program early CT score; CT, computed tomography; CTP, computed tomographic perfusion; EVT, endovascular treatment; ICA, internal carotid artery; IC, intravenous; mCTA, multiphase computed tomographic angiography; MIP, maximum intensity projection; PCA, posterior cerebral artery; and tPA, tissue-type plasminogen activator.

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Stroke. 2016;47:00-00.

Early Signs of Ischemia on NCCT Within 6 Hours of Stroke Onset (61% +/- 21%)

- Hypoattenuation involving one-third or more of the middle cerebral artery (MCA) territory
- Obscuration of the lentiform nucleus
- Cortical sulcal effacement
- Focal parenchymal hypoattenuation
- Loss of the insular ribbon or obscuration of the Sylvian fissure
- Hyperattenuation of large vessel (eg, "hyperdense MCA sign")
- Loss of gray-white matter differentiation in the basal ganglia

Neuroimaging of acute ischemic stroke - UpToDate

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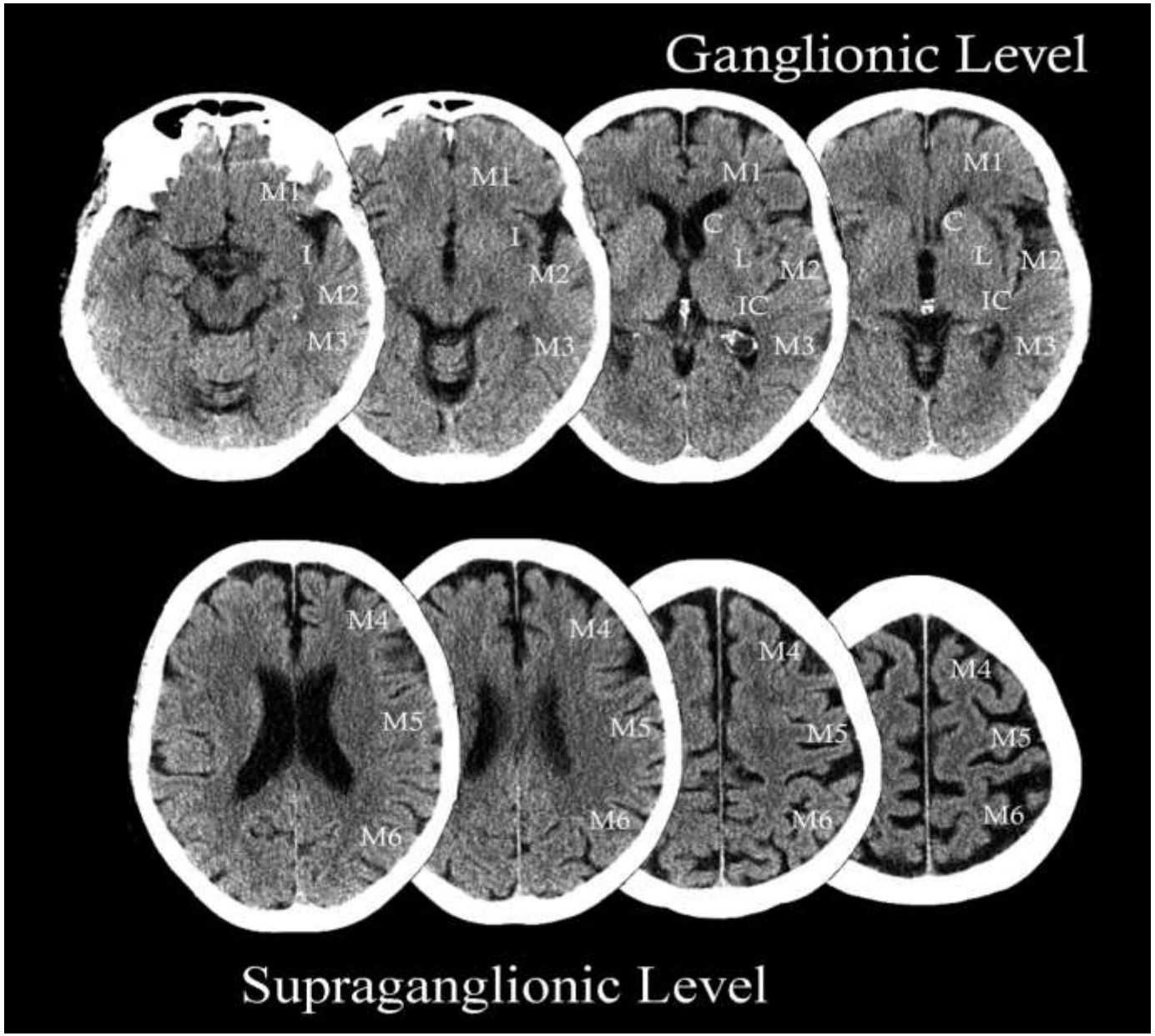
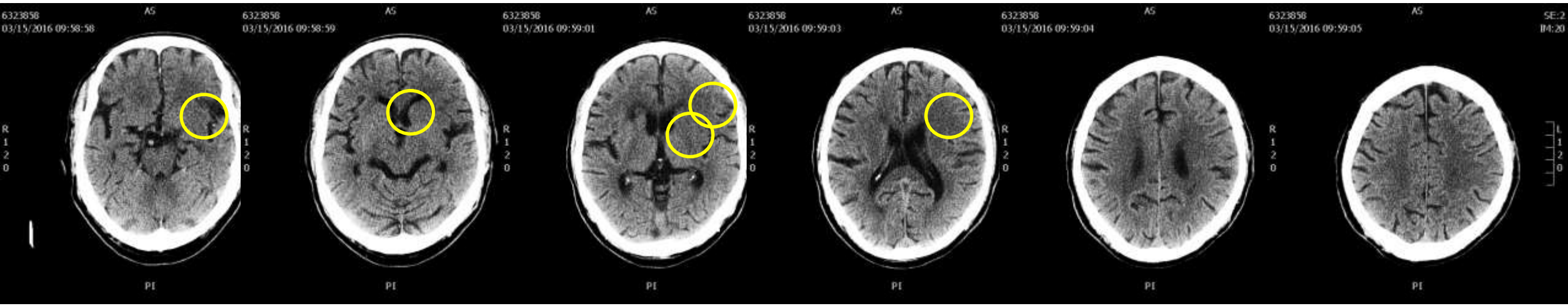
Subcortical structures are allotted 3 points (Caudate, Lentiform, and Internal Capsule).
MCA cortex is allotted 7 points (insular cortex, M1, M2, M3, M4, M5 and M6)

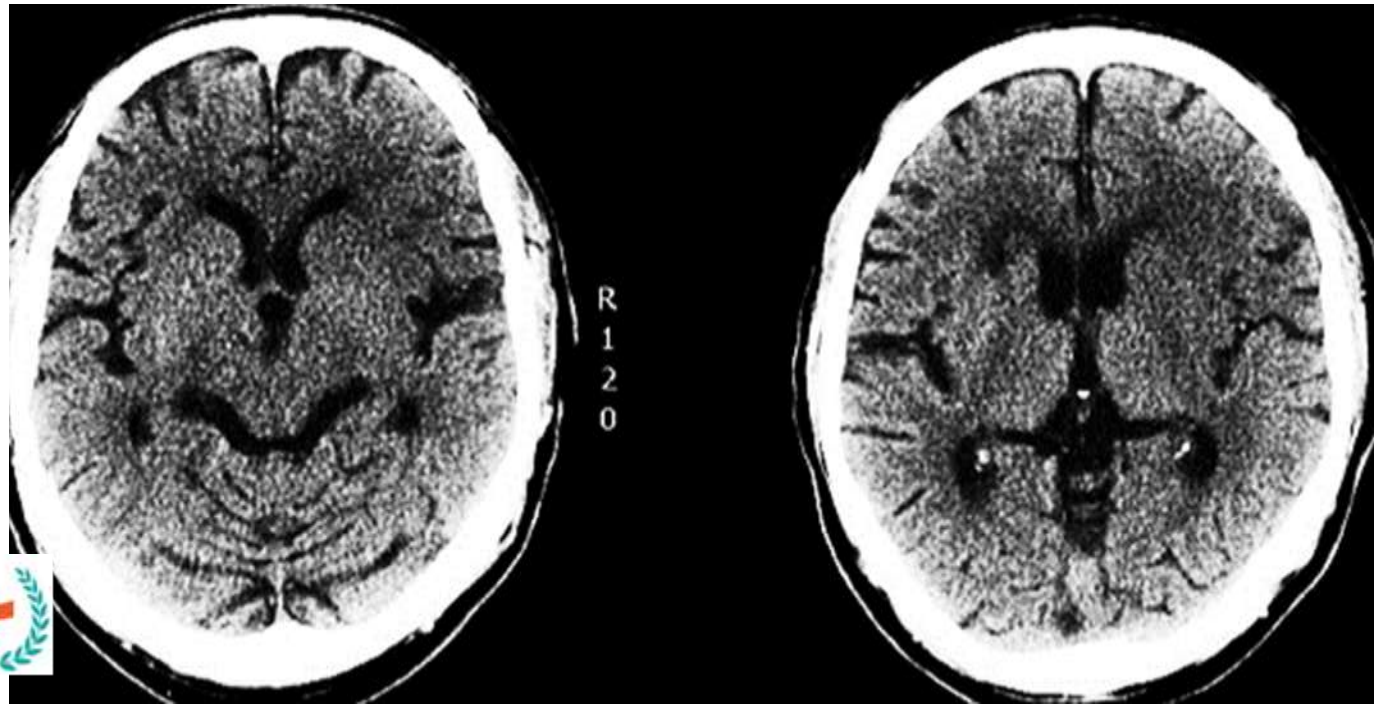
A common misunderstanding of ASPECTS scoring is to assess only two standardized cuts, i.e. one ganglionic cut and one supraganglionic cut.

ASPECTS >/= 6, 7, 8

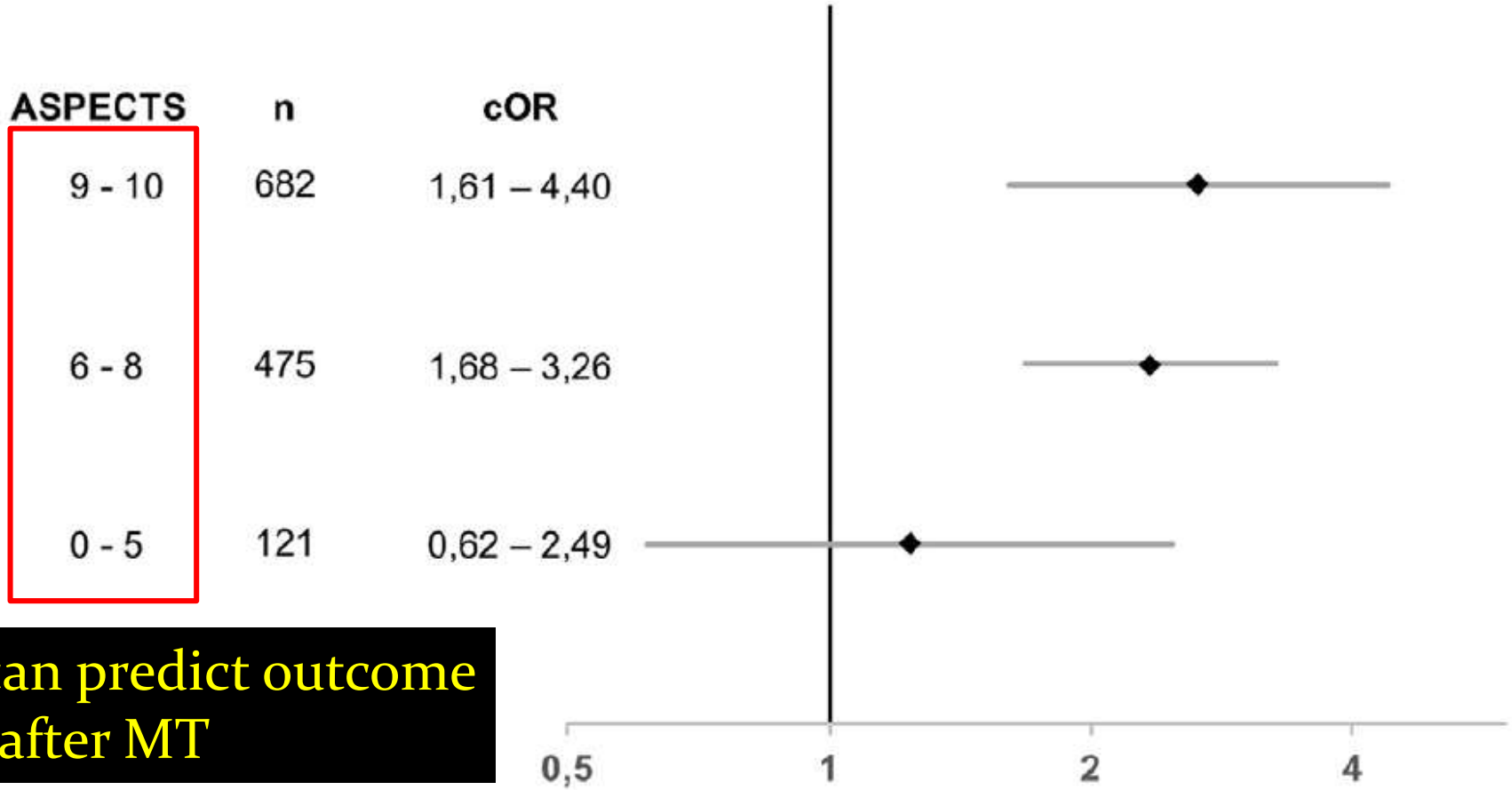


ASPECTS: caudate+ lentiform+ insula+M1+M4 = 10-5= 5





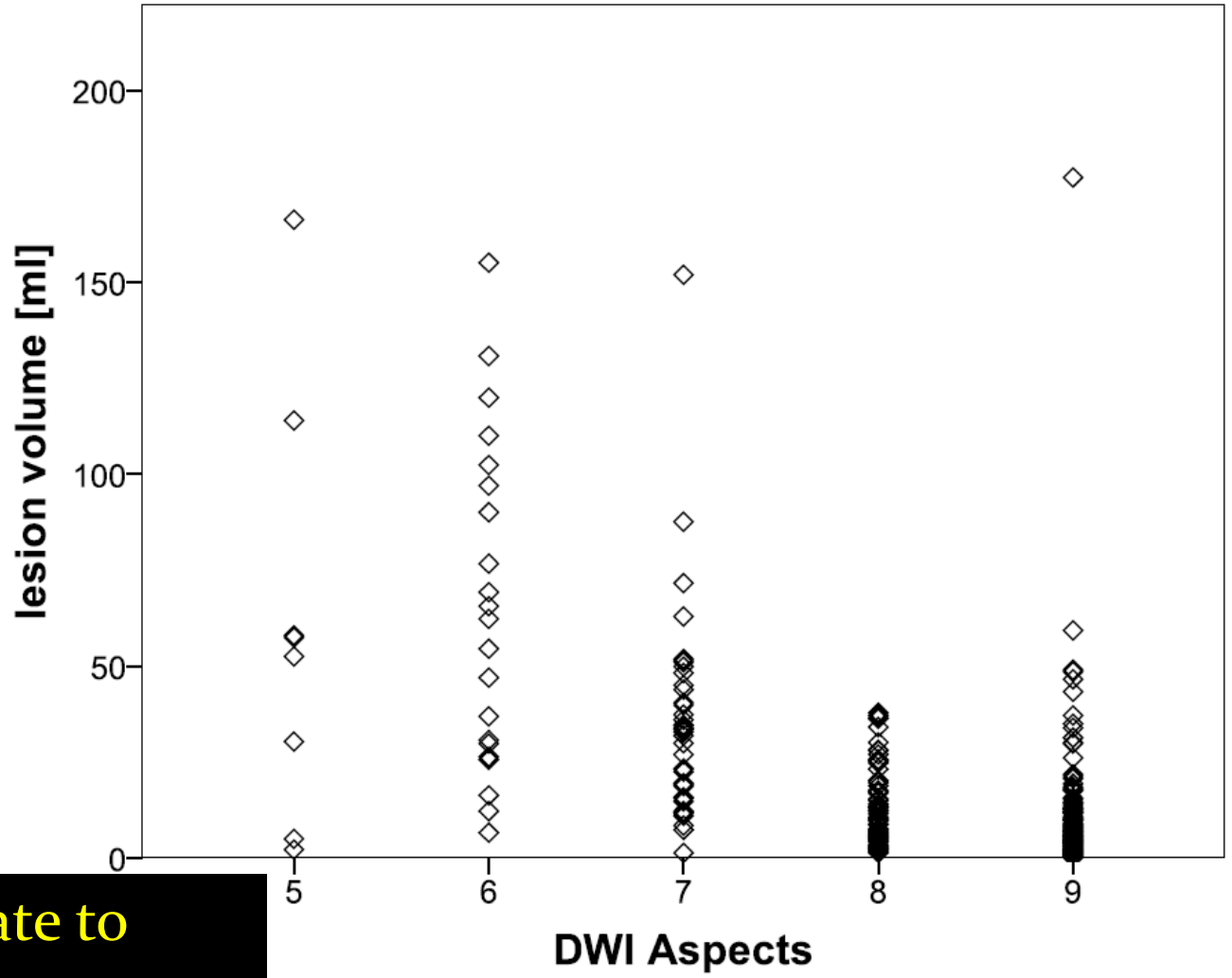
- Better use sequential scan
- 0.5cm slice thickness
- Appropriate narrowed CT window settin
- Comparing to opposite side
- Lesion at least seen on 2 adjacent cuts
- Rule of thumb



ASPECTS can predict outcome after MT

FIGURE 3 | Odds ratios for adjusted treatment effect for MRS 0–2 at 90 days stratified for different Alberta Stroke Program Early Computed Tomography Score subgroups in the HERMES meta-analysis; there was no significant heterogeneity of effect ($p = 0.29$); *n* indicates the number of patients analyzed; cOR, common odds ratio. Based on data from Goyal et al. (49).

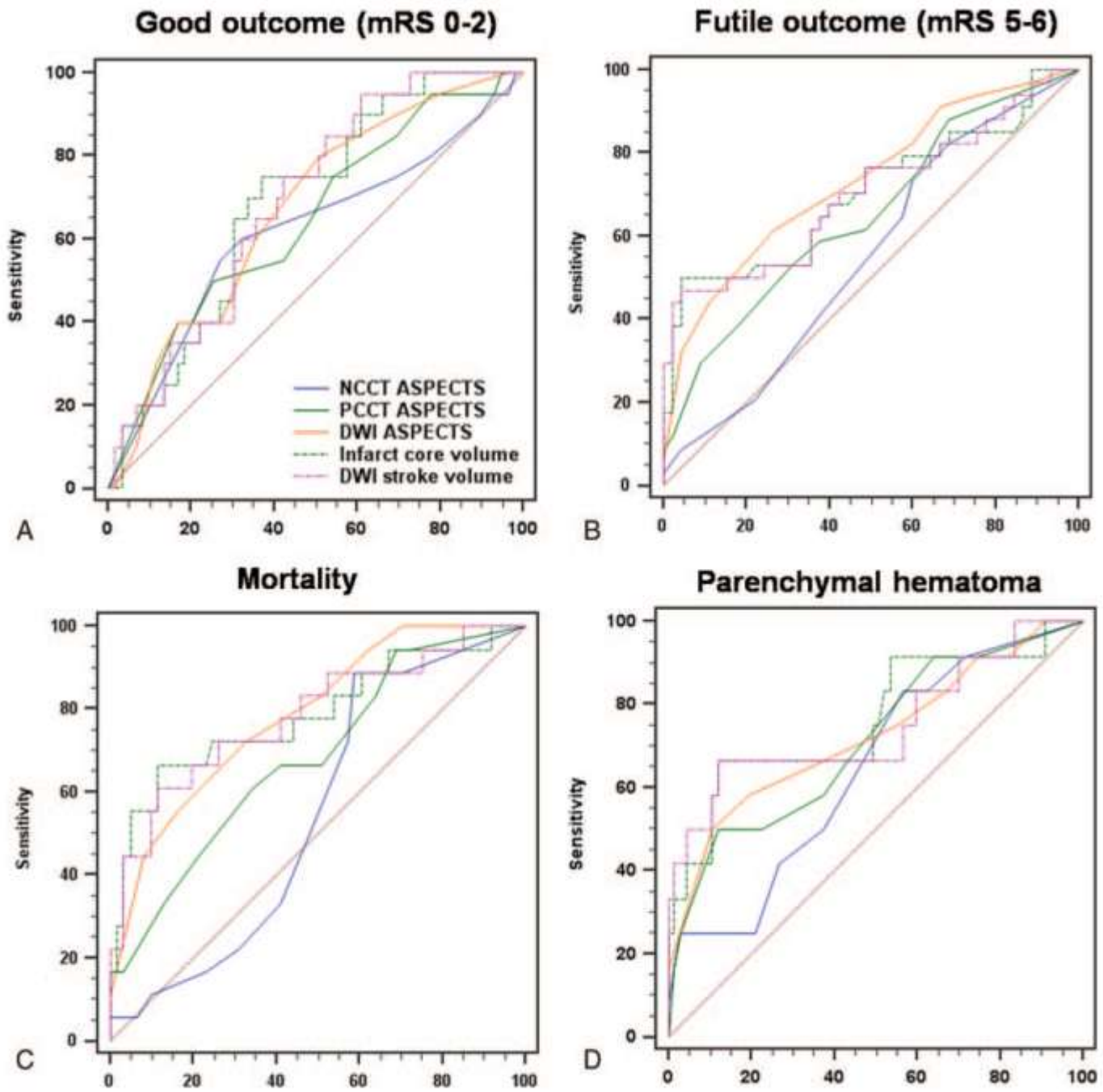
Front. Neurol. 7:245.



ASPECTS correlate to DWI lesion volume

FIGURE 4 | Distribution of lesion volumes in patients with diffusion-weighted MRI (DWI)-Alberta Stroke Program Early Computed Tomography Score (ASPECTS) ≥5, these patients were shown to benefit from mechanical thrombectomy in the recent HERMES meta-analysis (49). Lesion volumes varied considerably in patients with the same DWI ASPECTS. Based on data from Schröder et al. (33).

Front. Neurol. 7:245.



DWI ASPECTS best in predict futile recanalization

Medicine (2016) 95:35

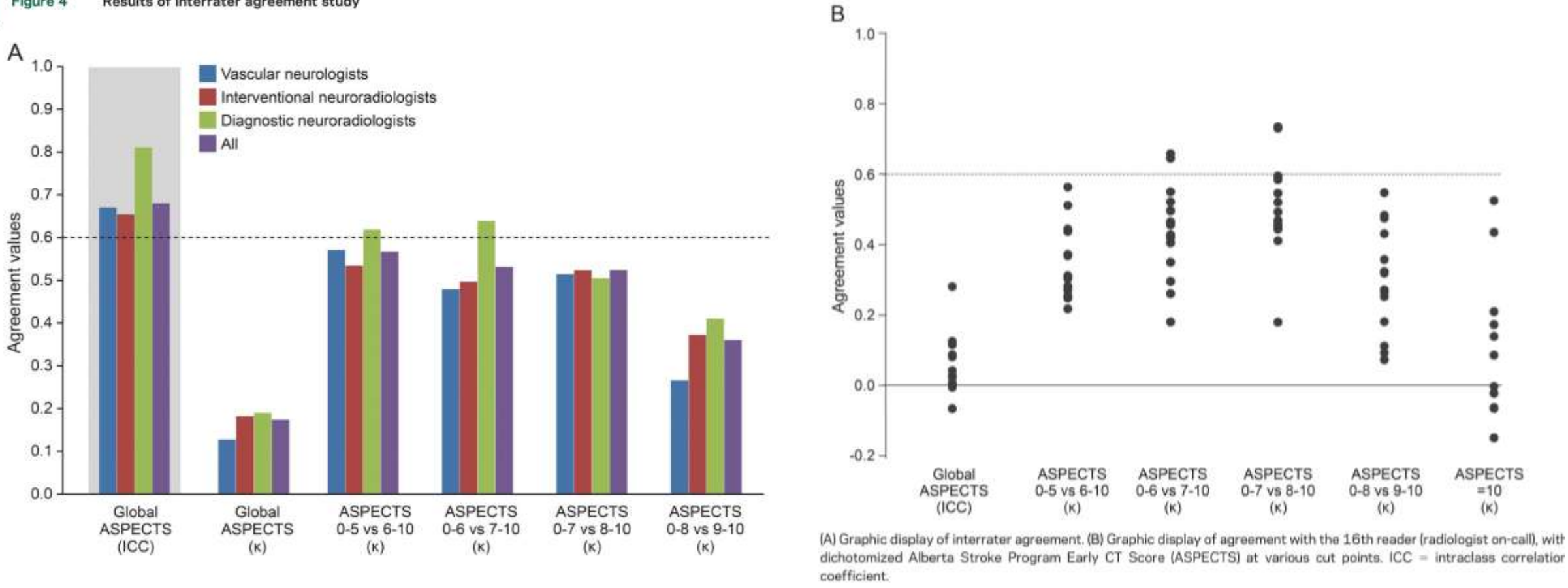
2. ROC curve analysis for predicting outcome of endovascular treatment according to the imaging protocol. A, Good outcome. B, Futile outcome. C, Mortality. D, Parenchymal hematoma. ROC = receiver operating characteristic.

Limitations of ASPECTS

- Limited to only MCA territory region
- ASPECTS scoring is difficult in M2 region (temporal fossa) in presence of streak artifacts in the base of skull
- Watershed infarcts are difficult to score according to ASPECTS on NCCT scans. (lacuna, brainstem…)
- Leukoaraiosis changes can lead to incorrect ASPECTS scoring
- The template is unequally weighed and correlation with lesion volume depends on lesion location.
- Eloquent versus non-eloquent.
- A clear cutoff value to define “low ASPECTS values” cannot be given.

interrater agreement did not reach a substantial level

Figure 4 Results of interrater agreement study

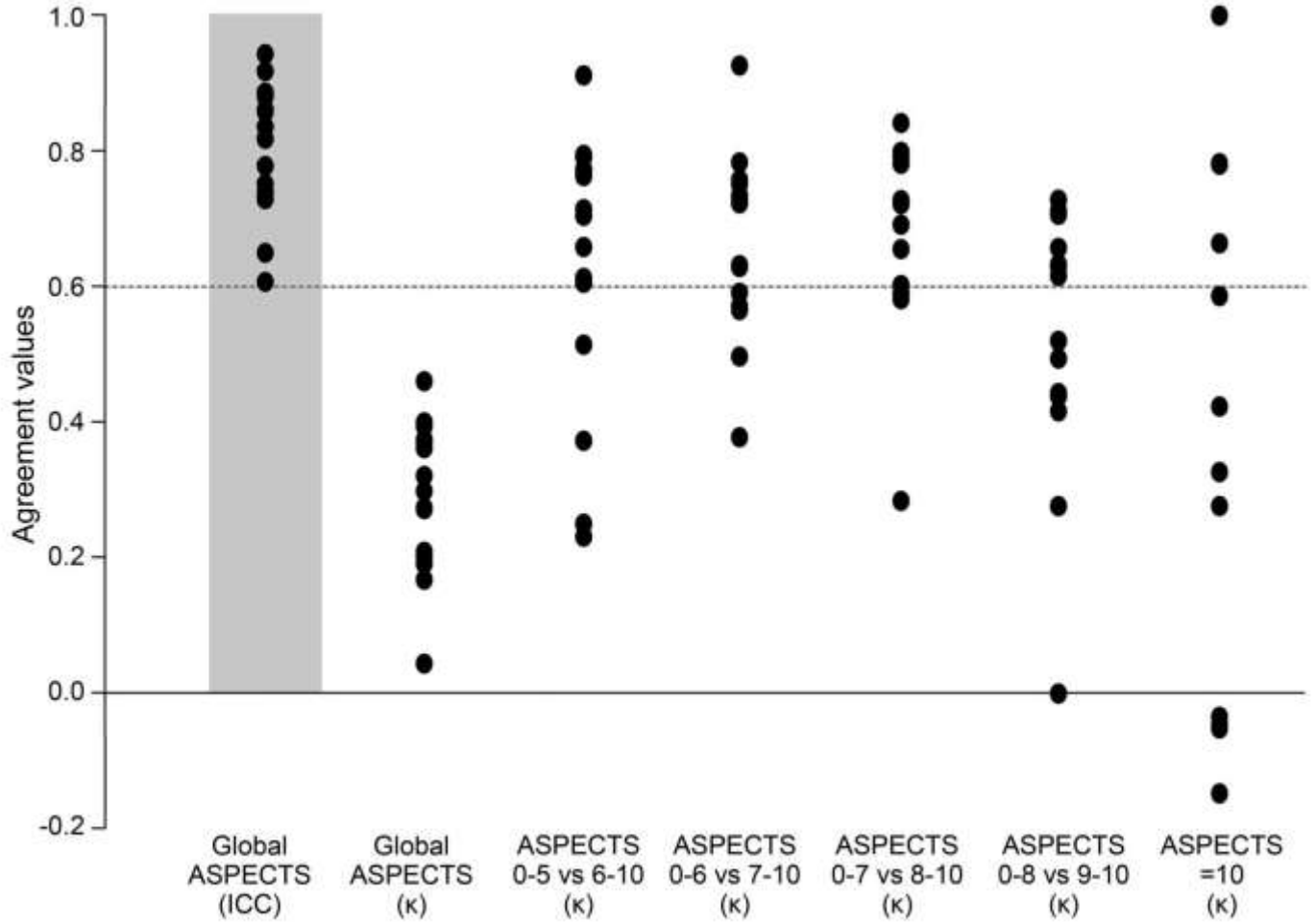


(A) Graphic display of interrater agreement. (B) Graphic display of agreement with the 16th reader (radiologist on-call), with dichotomized Alberta Stroke Program Early CT Score (ASPECTS) at various cut points. ICC = intraclass correlation coefficient.

Even in the best of cases, when ASPECTS was dichotomized as 0–5 vs 6–10, interrater agreement did not reach a substantial level (k =0.561), which translates into at least 5 of 15 raters not giving the same dichotomized verdict in 15% of patients.

Neurology® 2016;87:249–256

Figure 5 Results of intrarater agreement study



Graphic representation of intrarater agreement for each of the 15 readers, expressed as intraclass correlation coefficients (ICCs) or kappa values for the global Alberta Stroke Program Early CT Score (ASPECTS), and kappas obtained for dichotomized scores using various cut points.

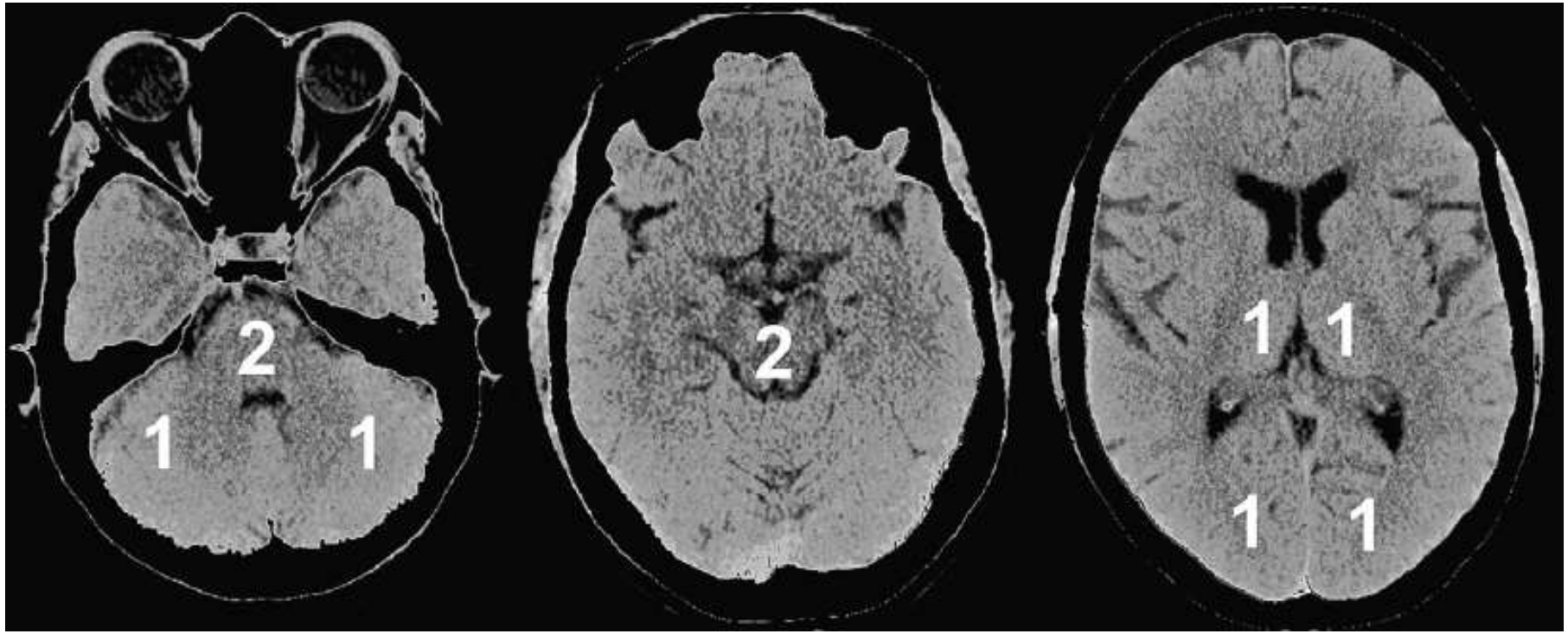
Conclusions: In patients considered for thrombectomy, there may be insufficient agreement between clinicians for ASPECTS to be reliably used as a criterion for treatment decisions.

Neurology® 2016;87:249–256

Posterior Circulation Acute Stroke Prognosis Early CT Score (pc-ASPECTS)

- More sensitive for detection of early ischemic change and prediction of functional outcomes with contrast infusion (as compared to non-contrast CT), and could help identify patients with BA occlusion who are unlikely to have favorable outcomes despite recanalization.
- Infarction size in the PC does not correlate well with stroke severity. Due to the close proximity of vital tracts and nuclei, location site is a more critical functional outcome predictor.
- Applying the pc-ASPECTS score to MRI-DWI has been shown to be a powerful marker for the prediction of functional outcome of PC stroke.

The posterior circulation Acute Stroke Prognosis Early CT score (pc-ASPECTS)



Noncontrast CT which includes thin section CT for hyperdense sign length determination

- NCCT head thin section 0.5-mm slice thickness to identify Hyperdense artery signs and length as well as tPA response.
- Thrombus length was measured as length of arterial hyperdensities in admission nonenhanced CT images with a slice width of 1.25 to 2.5 mm.
- No recanalization was noted in any intravenous tPA patient with a thrombus length >8 mm. – Reconstruction without extra imaging- if no CTA available can may decision on large long clots .5mm is good for this

Clot and Response to therapeutic interventions

- CT : Hyperdense Middle Cerebral Artery Sign (HMCAS) correlating with higher RBC content.
- Clot density predicted recanalization. Successful recanalization was achieved in 79% of patients with the hyperdense vessel sign (33/42), but in only 36% (9/25) of patients without (P = 0·001)
- Thrombus is prone to fragmentation (embolization of new territory, ENT)

AJNR Am J Neuroradiol 2012; 33:90–6.
Stroke 2013; 44:243–5.
J Neurointerv Surg 2013; 5:289–93.

MRI (SWI) of clot

- Susceptibility weighted imaging depicts RBC-rich thrombi as hypointense blooming which extends beyond the actual size of the thrombus.
- Longer and curved susceptibility vessel signs have been associated with reduced effectiveness of reperfusion therapies.
- MRI can differentiate RBC thrombi from fibrin and estimate RBC concentration. TIMPR, SWI, T2GE, and FLAIR showed high correlation between MRI signal and RBC concentration

Neuroradiol 2015; 42: 86–92.
PLoS One 2016; 11: e0154945
Blood 2016; 127: 2337–2345.

Clot Burden Score

clot burden score of 4.

Stroke. 2016;47:2972-2978. DOI: 10.1161/STROKEAHA.116.014565

Multiphase CTA performed while IV tPA mixed and prepared if eligible

↓

IV tPA bolus given and infusion started in CT scanner

↓

Call endoteam

↓

Neck CTA with mCTA head 0.5-mm source images

Quick determination of proximal occlusion

Residual flow at intracranial occlusion site/ Nonocclusive thrombi

Extracranial thrombus (donut sign)

Stroke. 2016;47:00-00.

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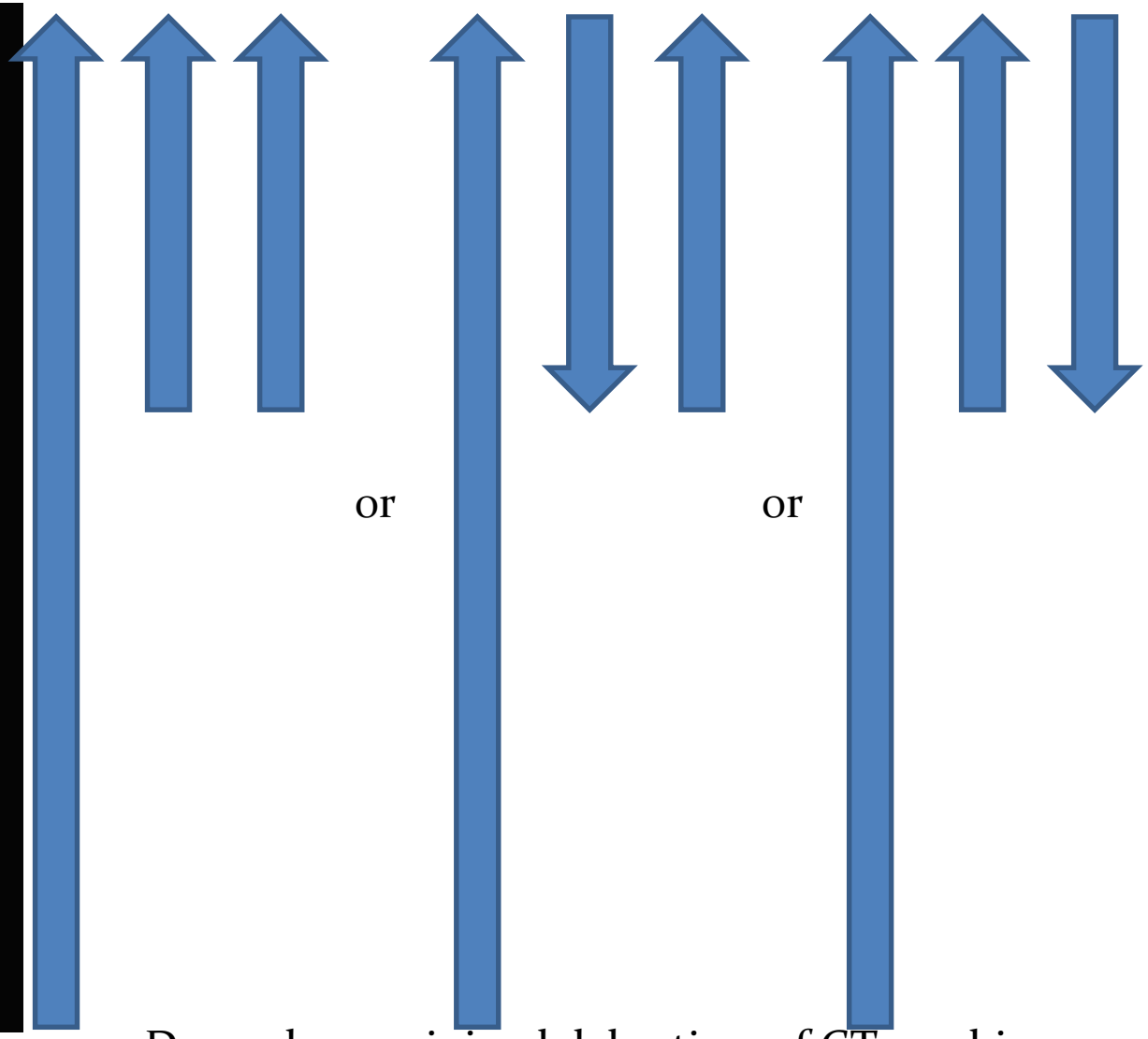
Multiphase CTA -- Scanning



or

or

Depends on minimal delay time of CT machines

1st Phase

2nd Phase

3rd Phase

Patient removed from CT suite or CTP imaging performed

↓

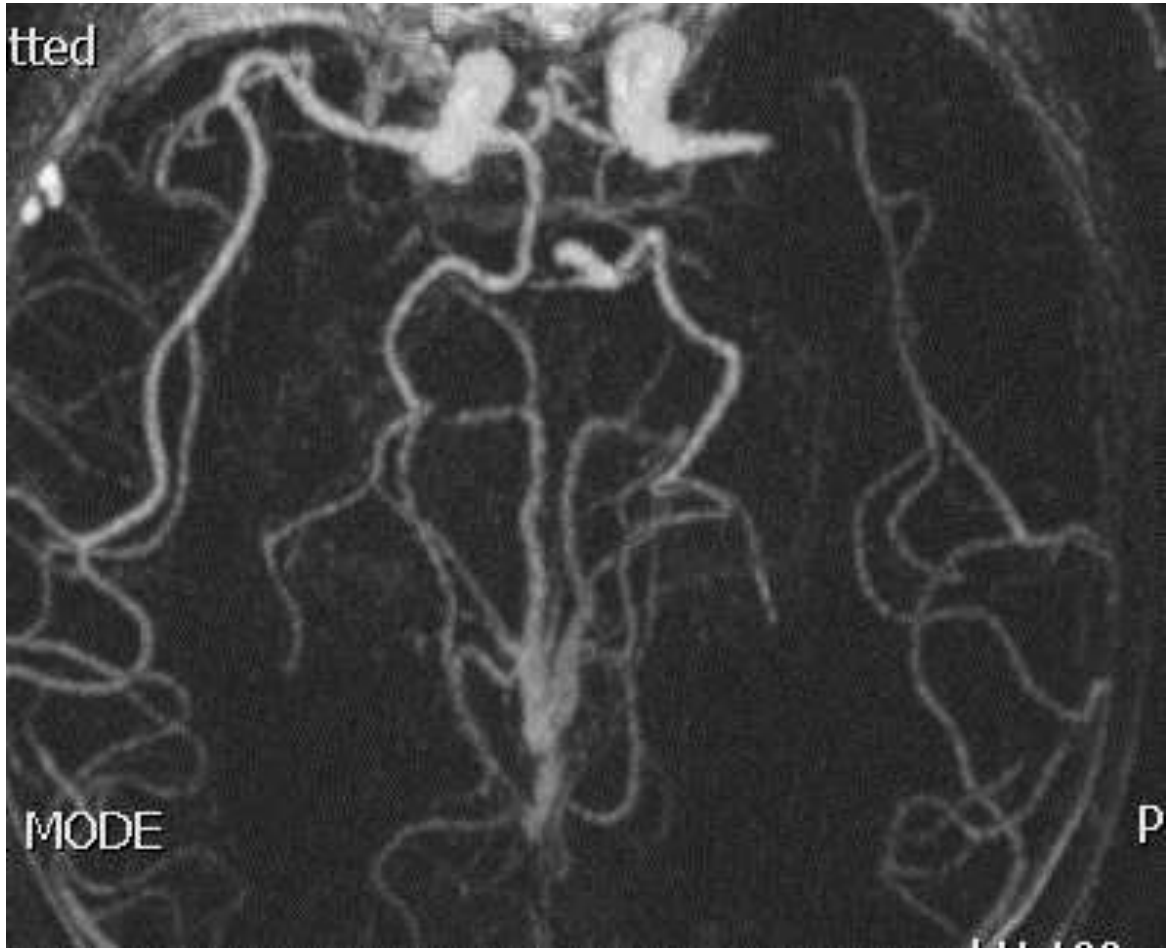
mCTA 1st phase head axial thick MIPs	Arterial occlusion site
Peak arterial to equilibrium acquisition	Fast collateral filling (excellent collaterals)
	Circle of Willis variation
mCTA 2nd phase head axial thick MIPs	Arterial occlusion site with slow cardiac output/mistimed bolus
Peak venous acquisition	Slow flow versus occlusion (distal ICA occlusion versus near occlusion)
	Clot length
	Delayed collateral filling (good collaterals)
mCTA 3rd phase head axial thick MIPs	Clot length
Late venous acquisition	Impaired washout (fair collaterals)
	Region of impaired washout—territory at risk

Stroke. 2016;47:00-00.

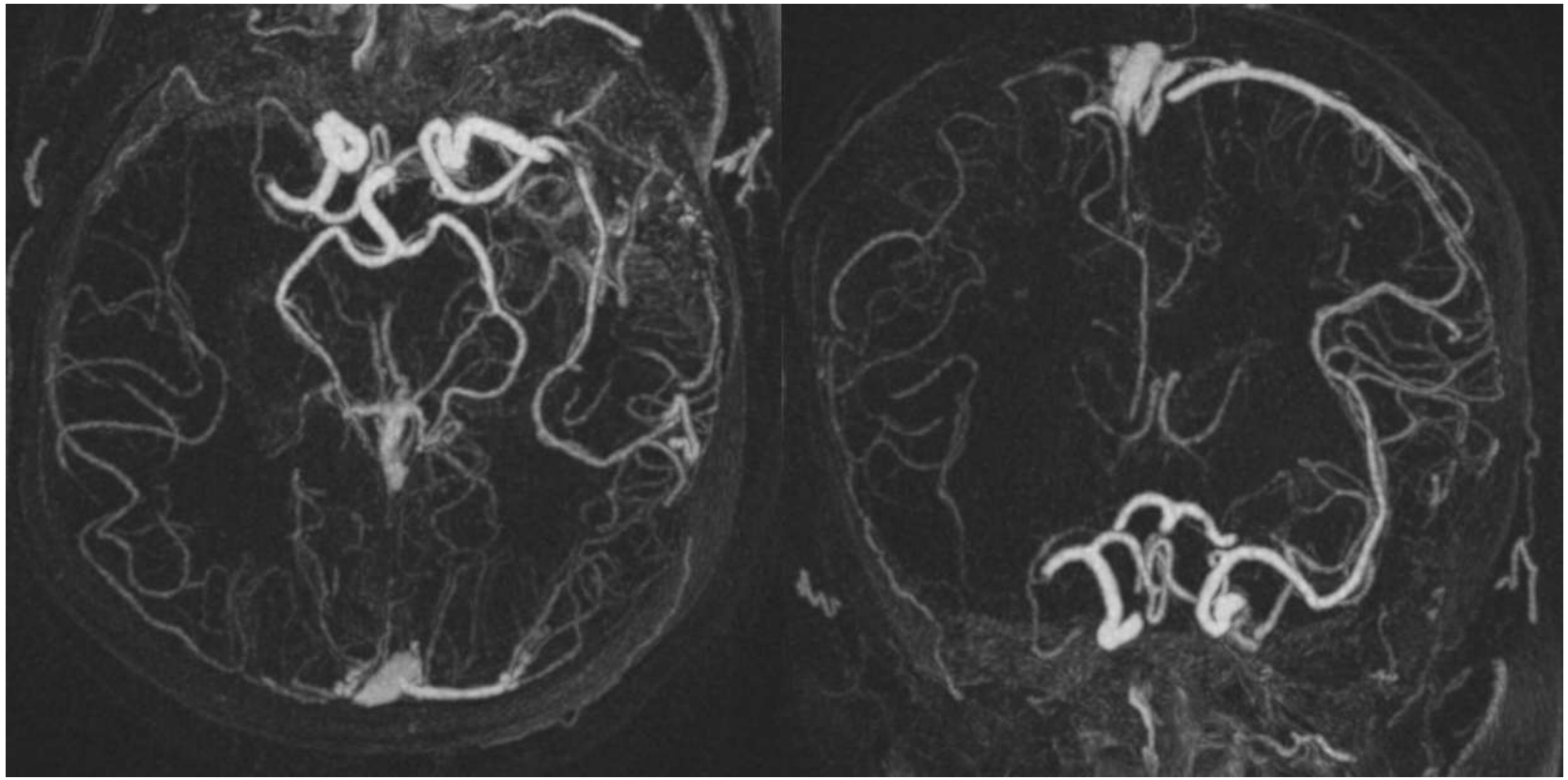
CTA neck and head 0.625 mm source images

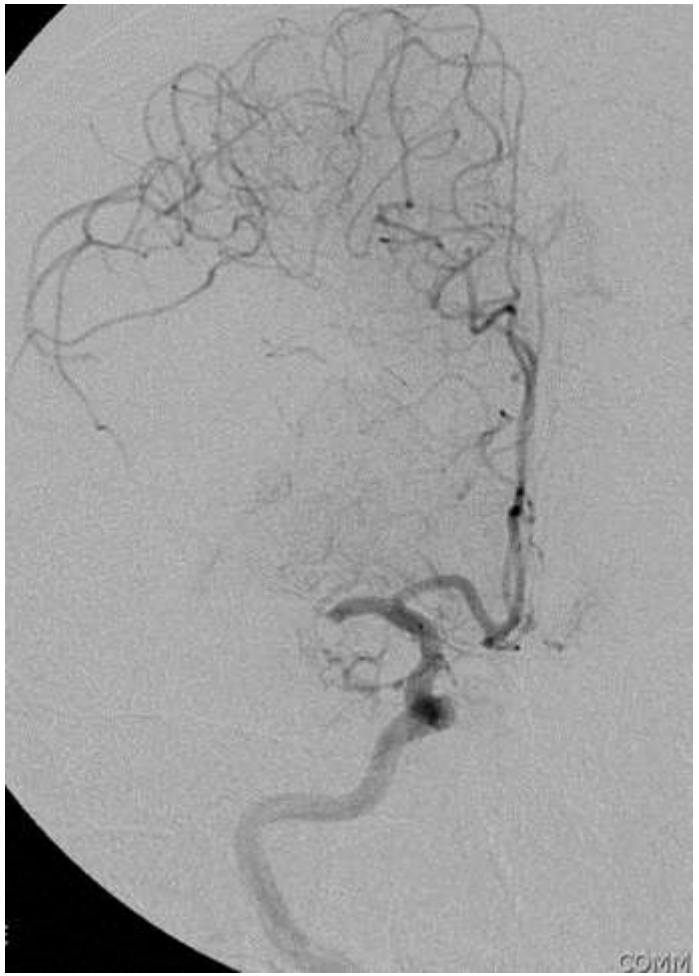
- Neck CTA with mCTA head 0.5-mm source images can be used for quick determination of proximal occlusion Residual flow at intracranial occlusion site/ Nonocclusive thrombi Extracranial thrombus (donut sign).

CTA or MRA (large vessel occlusion; ICA, M1, M2, A1, VA, BA)



CTA or MRA (large vessel occlusion; ICA, M1, M2, A1, VA, BA)



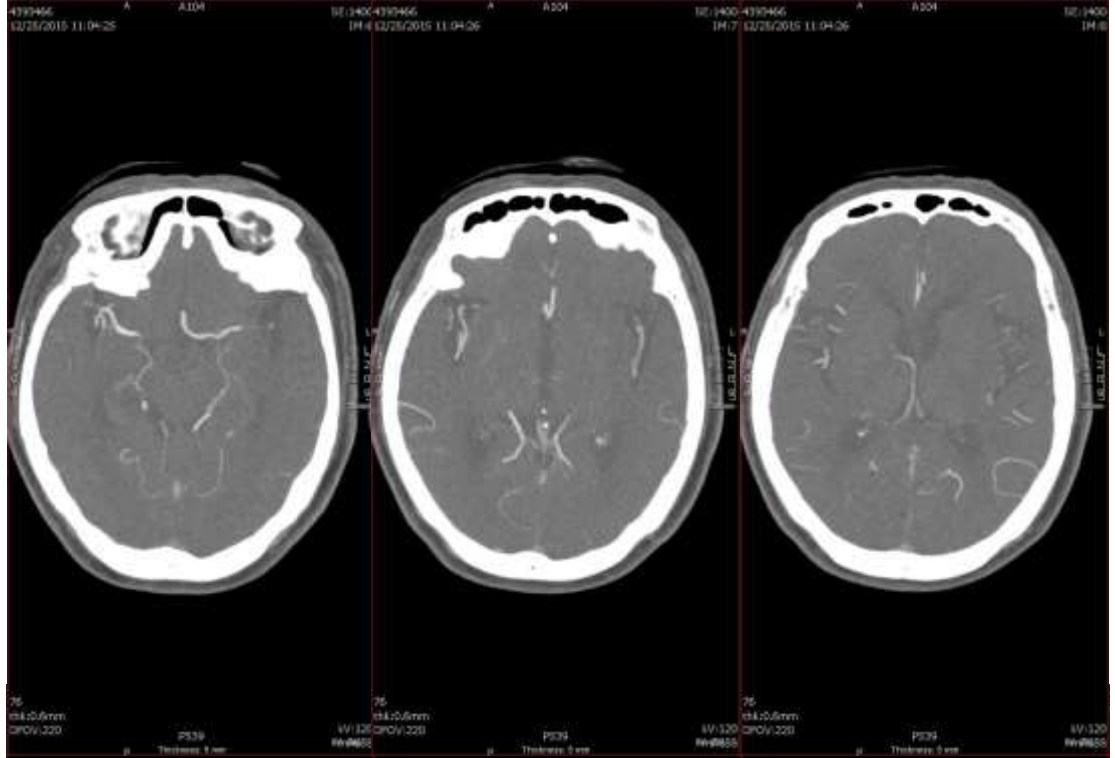


Multiphase CTA (2 additional movements of gantry) 1 mSV additional radiation

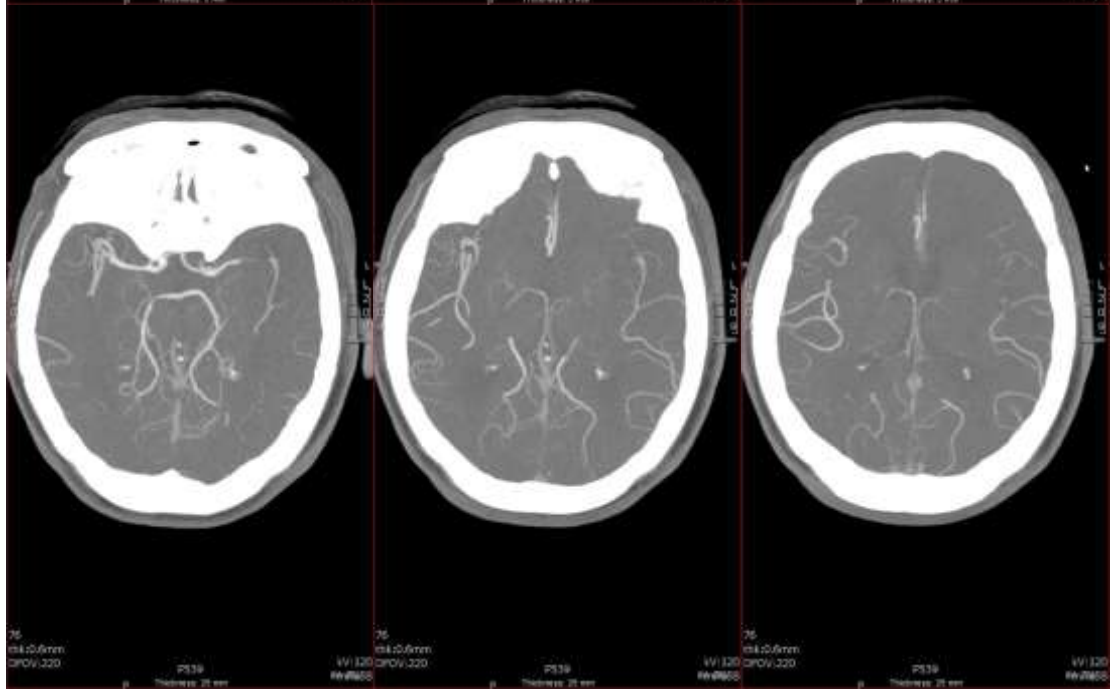
- Aortic arch to vertex CTA is performed with a multidetector CT scanner during the first phase of acquisition timed to capture the peak arterial phase in a healthy brain for 7 s.
- The remaining 2 phases are from the skull base to the vertex in the equilibrium/peak venous and late venous phases by the movement of the CT gantry over the cranium ≈8 s apart.
- Multiphase CTA has advantages, including the speed of acquisition and interpretation, minimal additional radiation, no additional contrast material, whole-brain coverage, and no post processing.

Multiphase CTA thick section (23 mm) MIPs of all three phases

- Allows for collateral grading. Good collaterals have good collateral filling on 1st phase. Fair collaterals have one or two phase delay in collateral filling and poor collaterals have absent filling on any phases in significant portion of MCA territory.



5mm



25 mm

Thick section coronal neck and thick section coronals and sagittal MIPs

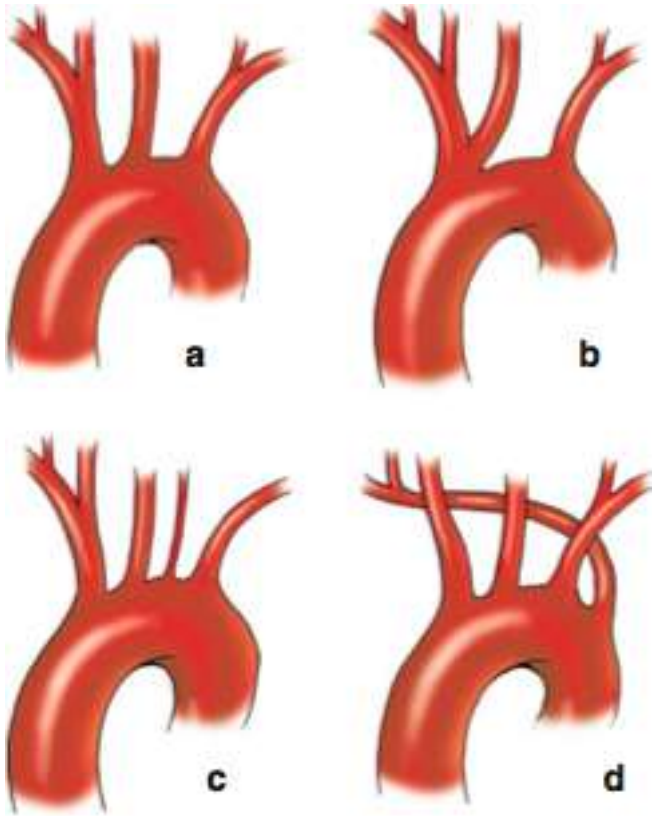
- The mCTA head coronal thick MIPs will help identify terminal ICA occlusion and determine type M1 versus M2 occlusion. The mCTA head sagittal thick MIPs will help identify distal M2 and beyond occlusions; ACA occlusions, and distal vasculopathy.

If you can't place the long guiding/ sheath/BGC at the CCA (or ICA).

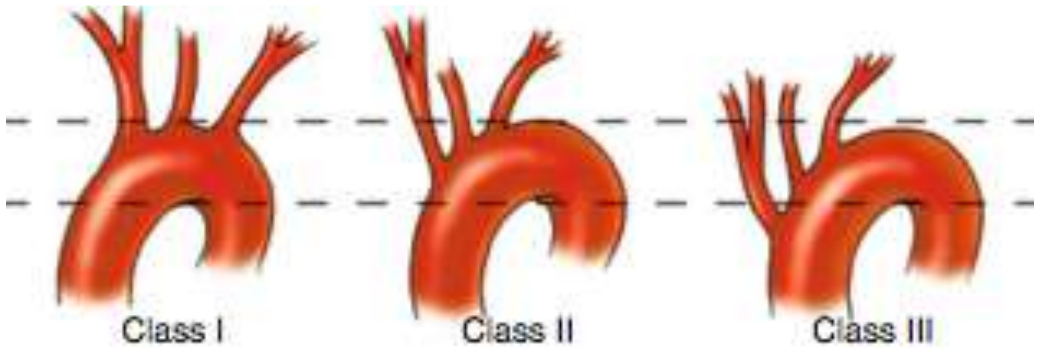
You absolutely fail !!!!!!!!!!

https://www.dornbossign.com/sign-blog/5-interesting-or-funny-signs-found-on-the-web/

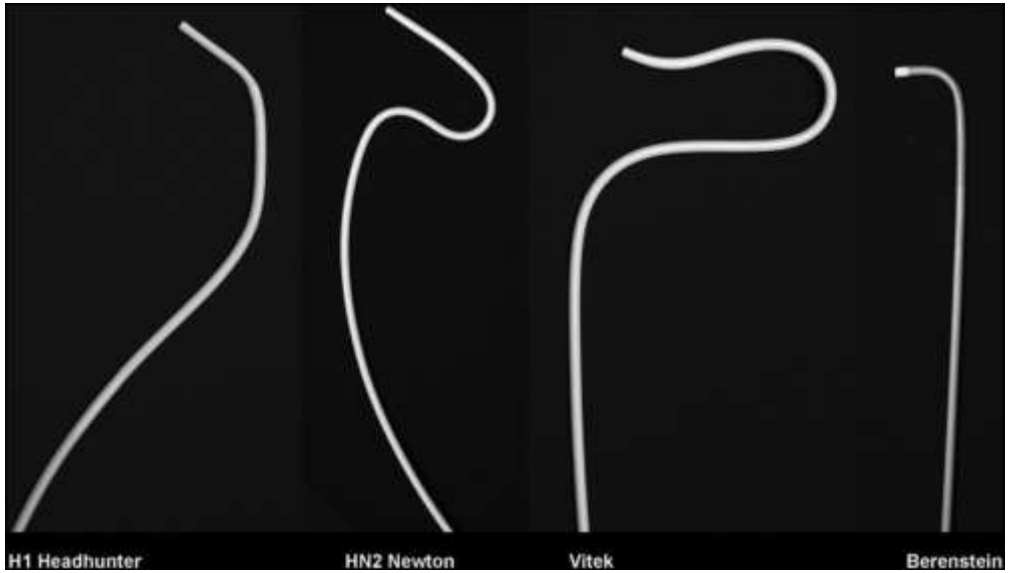
Arch and Supra-aortic Branches Configurations

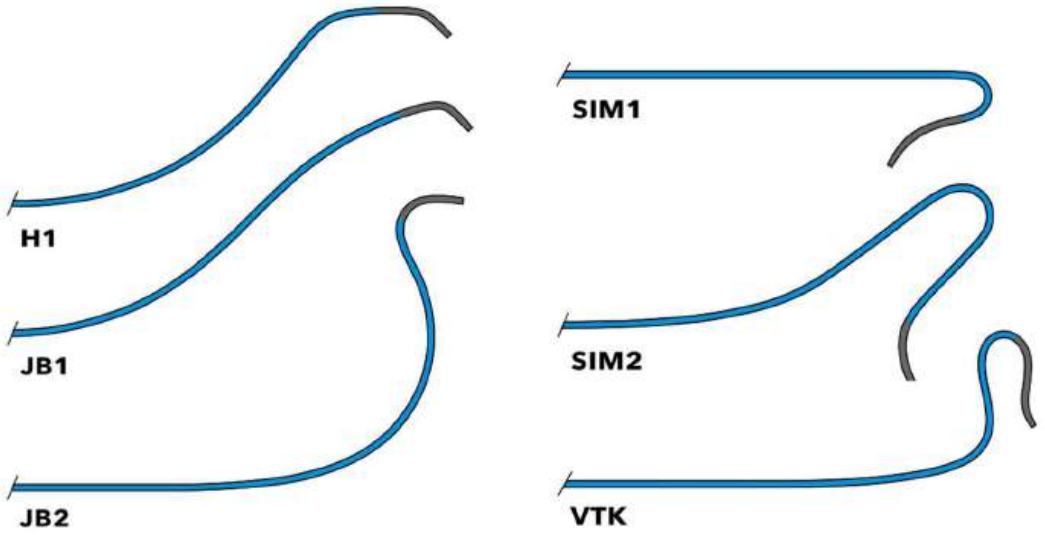


Normal Variants

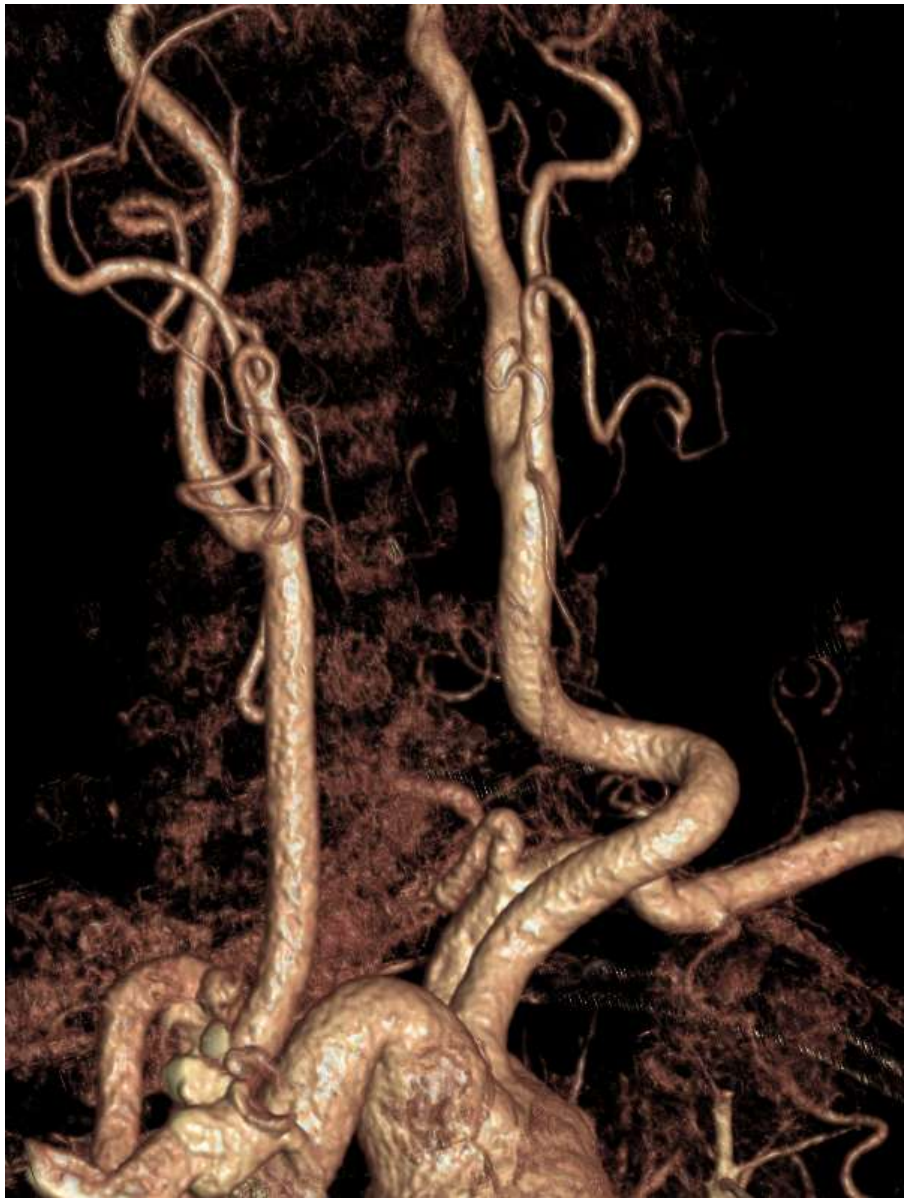


What are their differences??

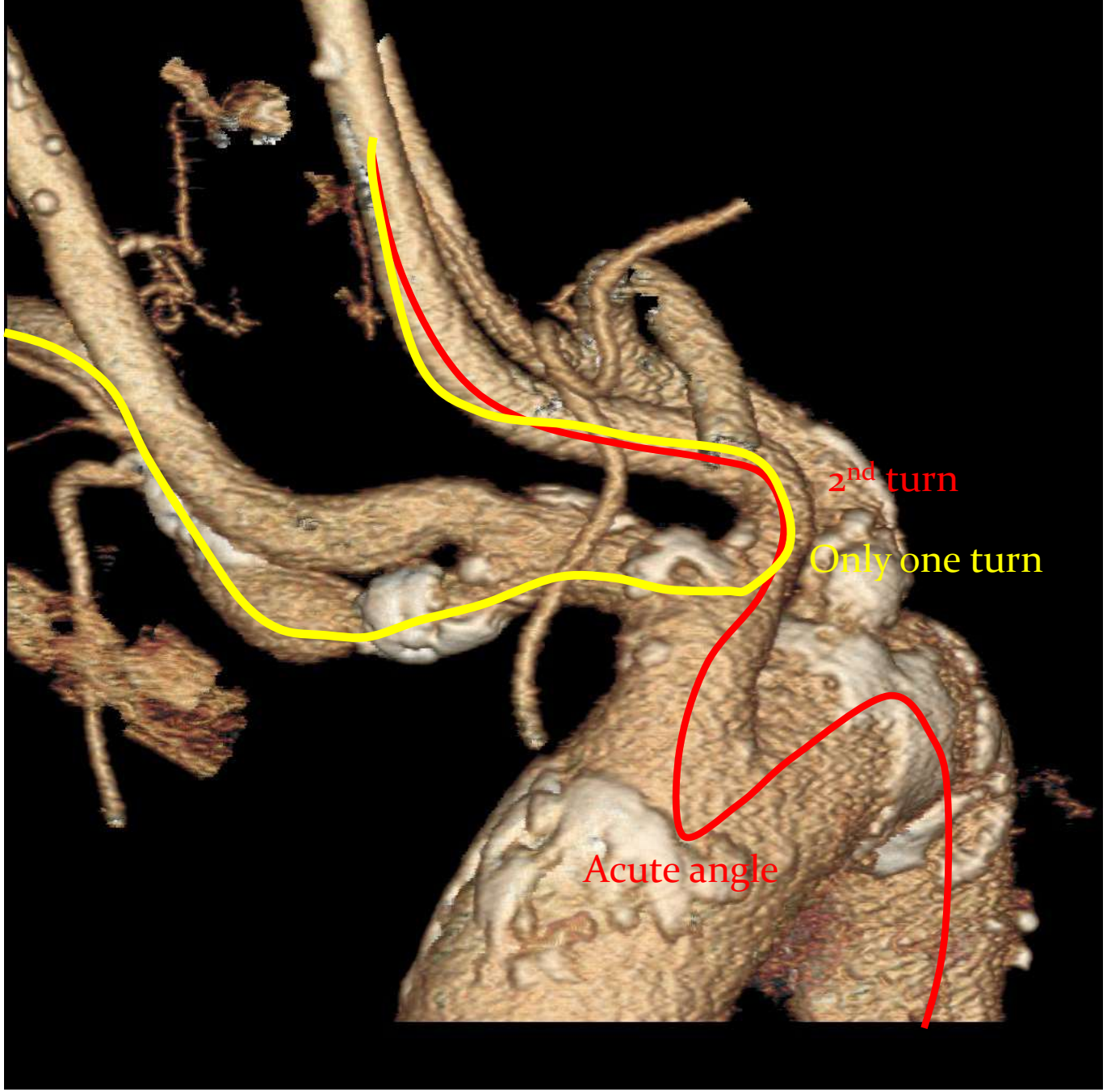


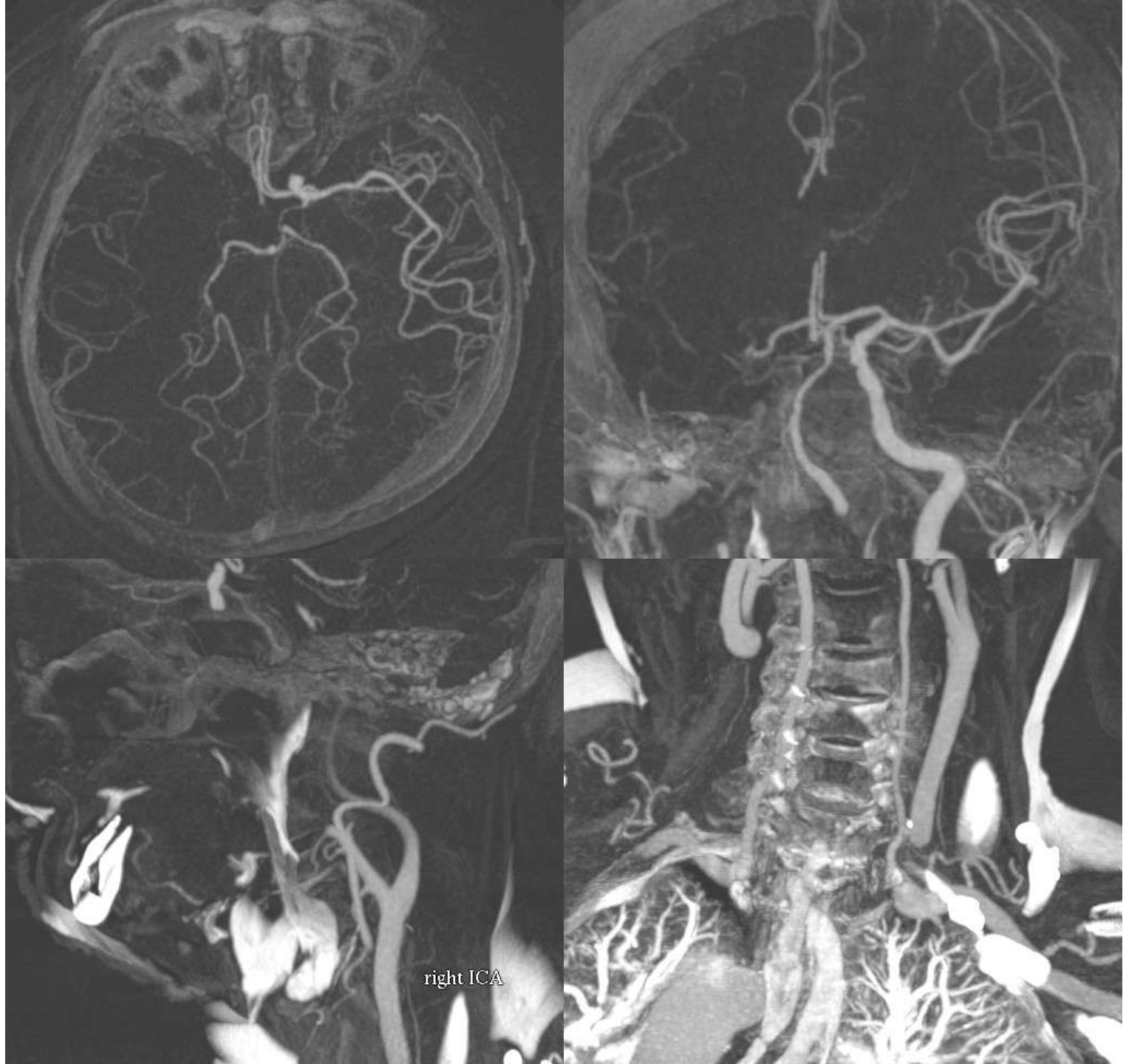


75 y



78M




right ICA

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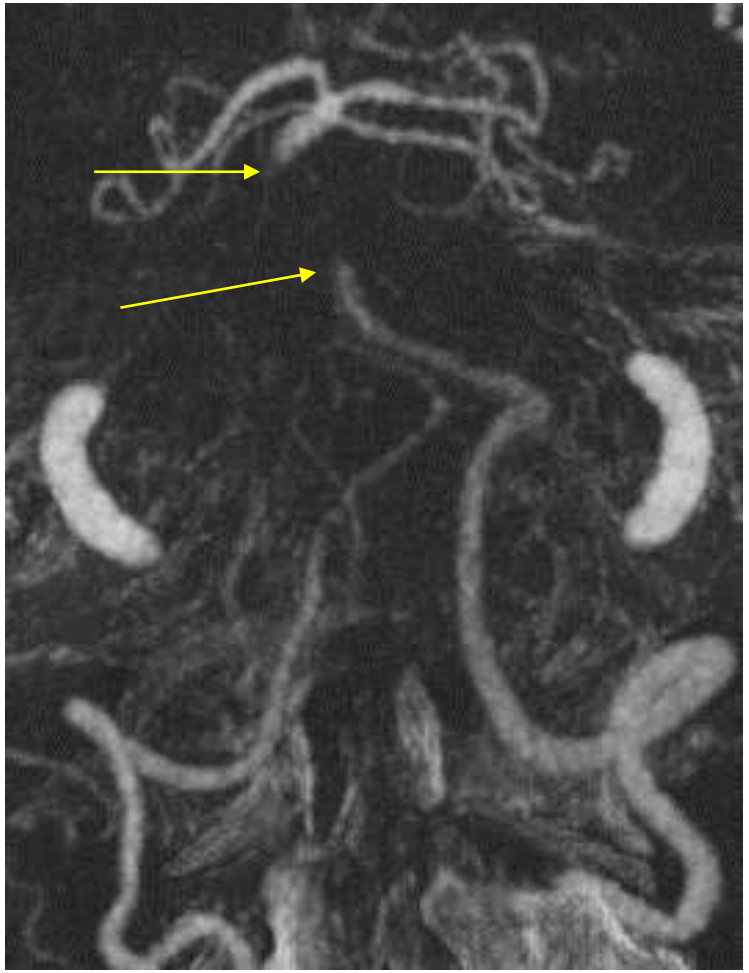
Late Phase of CTA can Determine the Clot Length)



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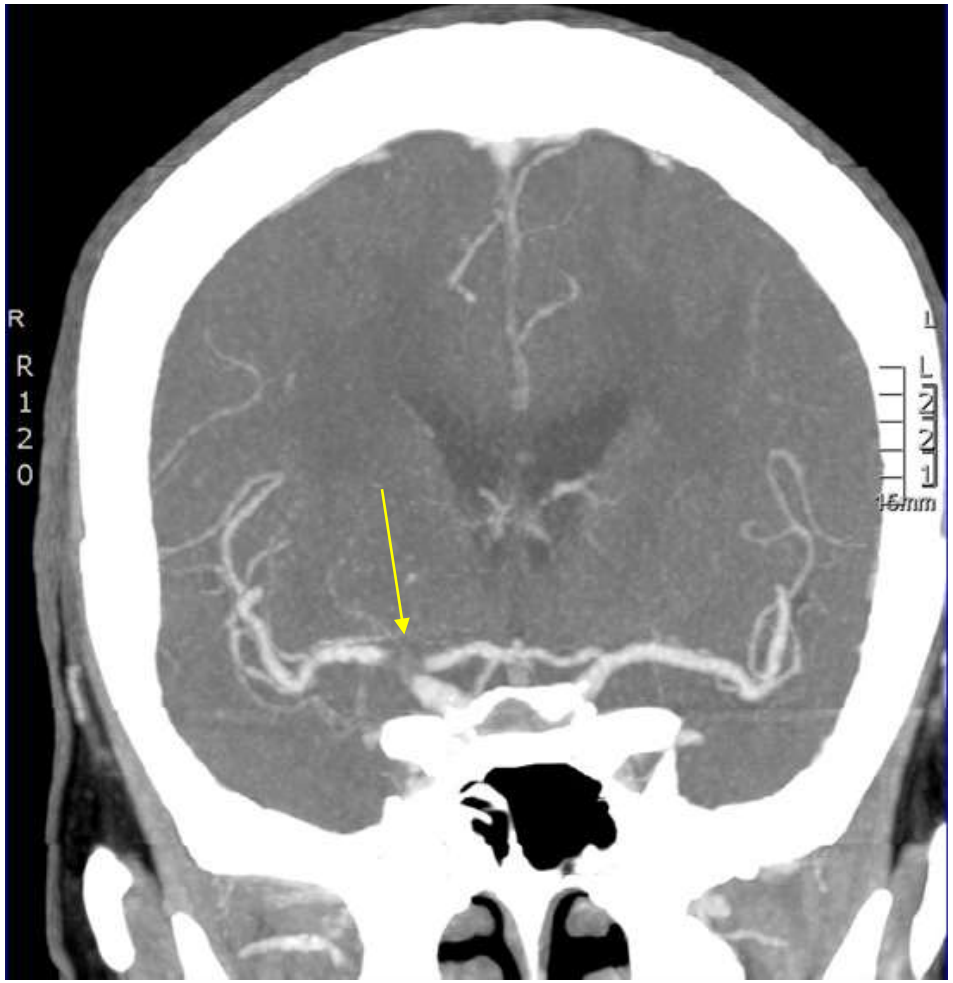
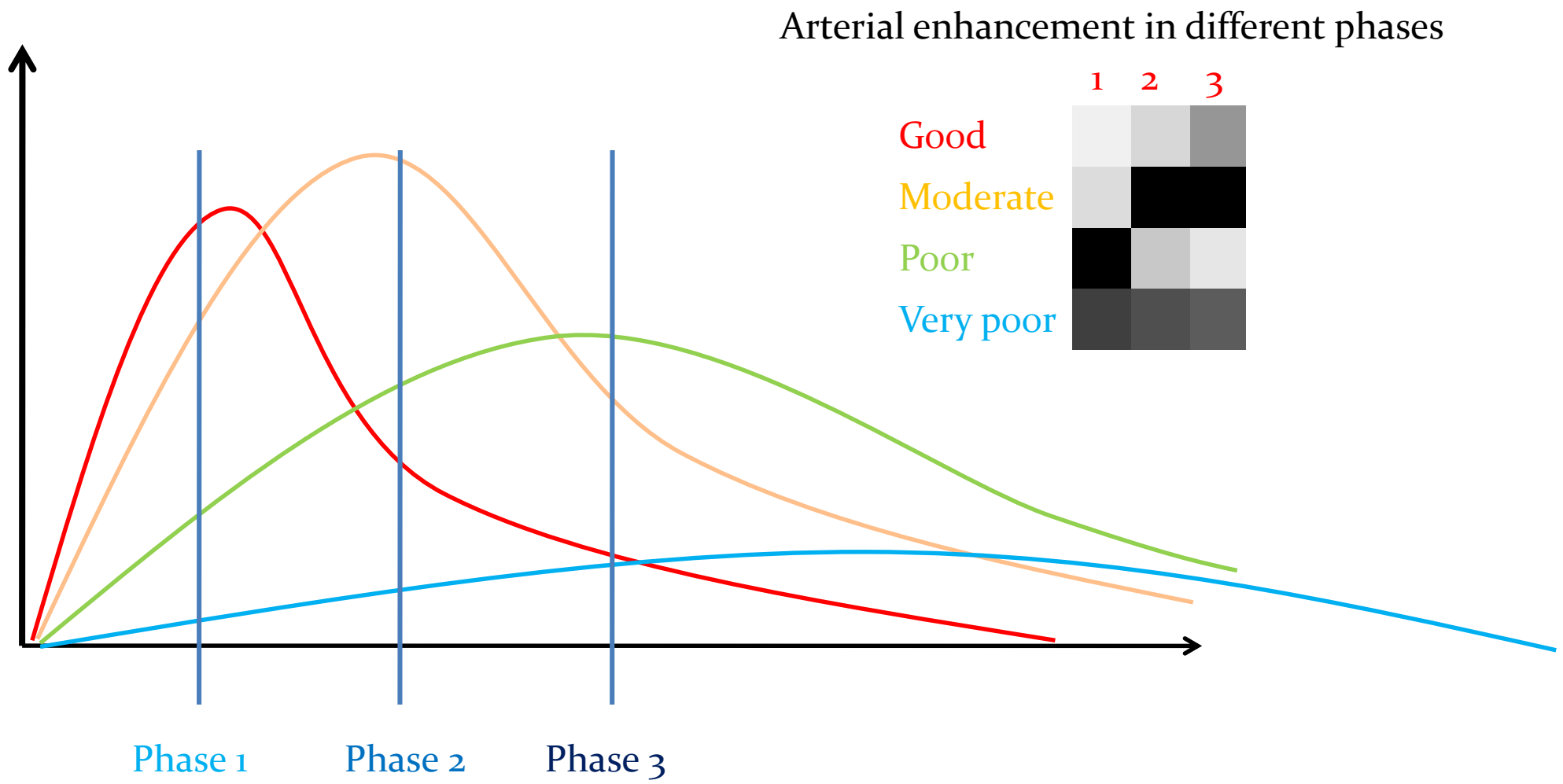


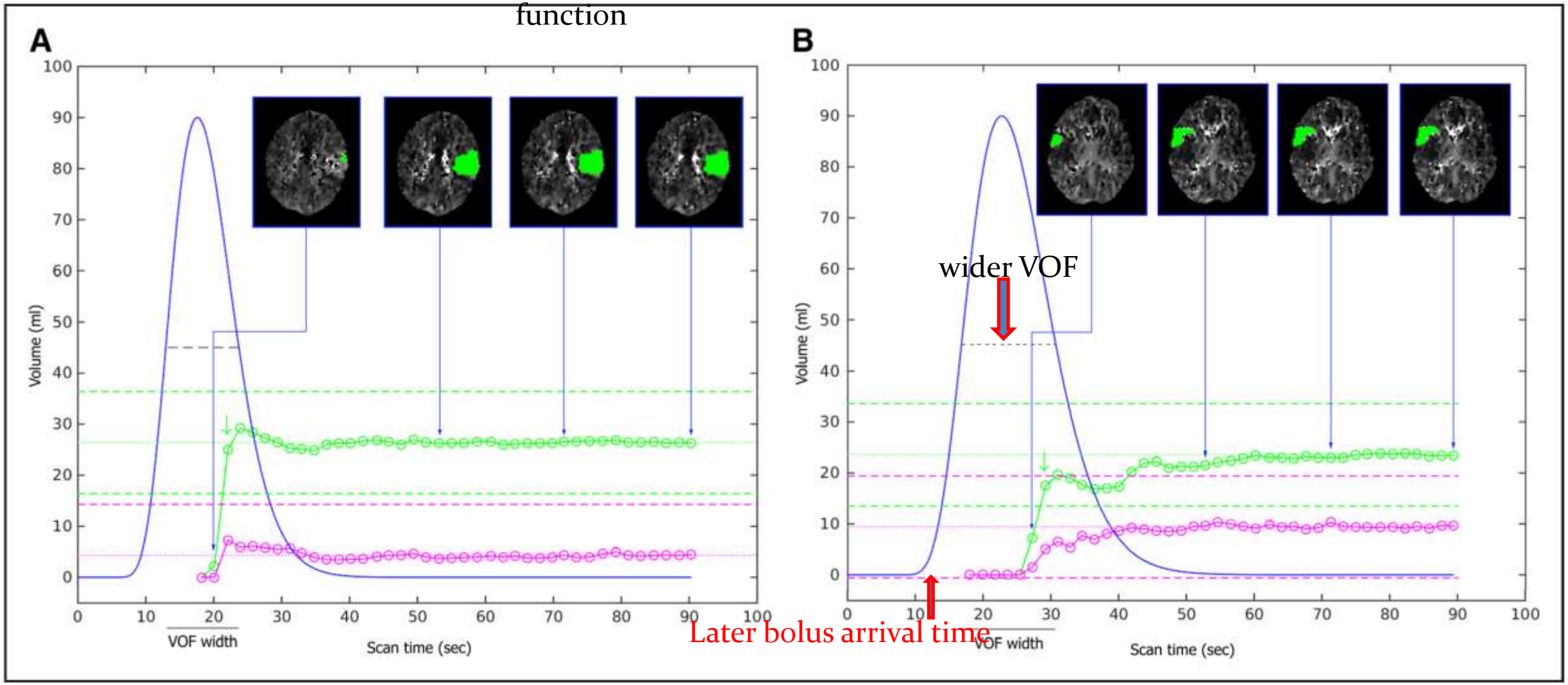
MP-CTA Presentation of Different Perfusion Pattern



Penumbra volume (Tmax >6 s) estimate (green circles) is essentially unaffected by reductions in scan time from 90 s down to 38 s.

Later bolus arrival time (T_0) and a wider VOF, the penumbra volume smaller, and infarct core larger

VOF, defined as the full width at half maximum of the fitted gamma variate function



penumbra volume (Tmax >6 s; green circles); infarct core (relative cerebral blood flow <30%, pink circles)

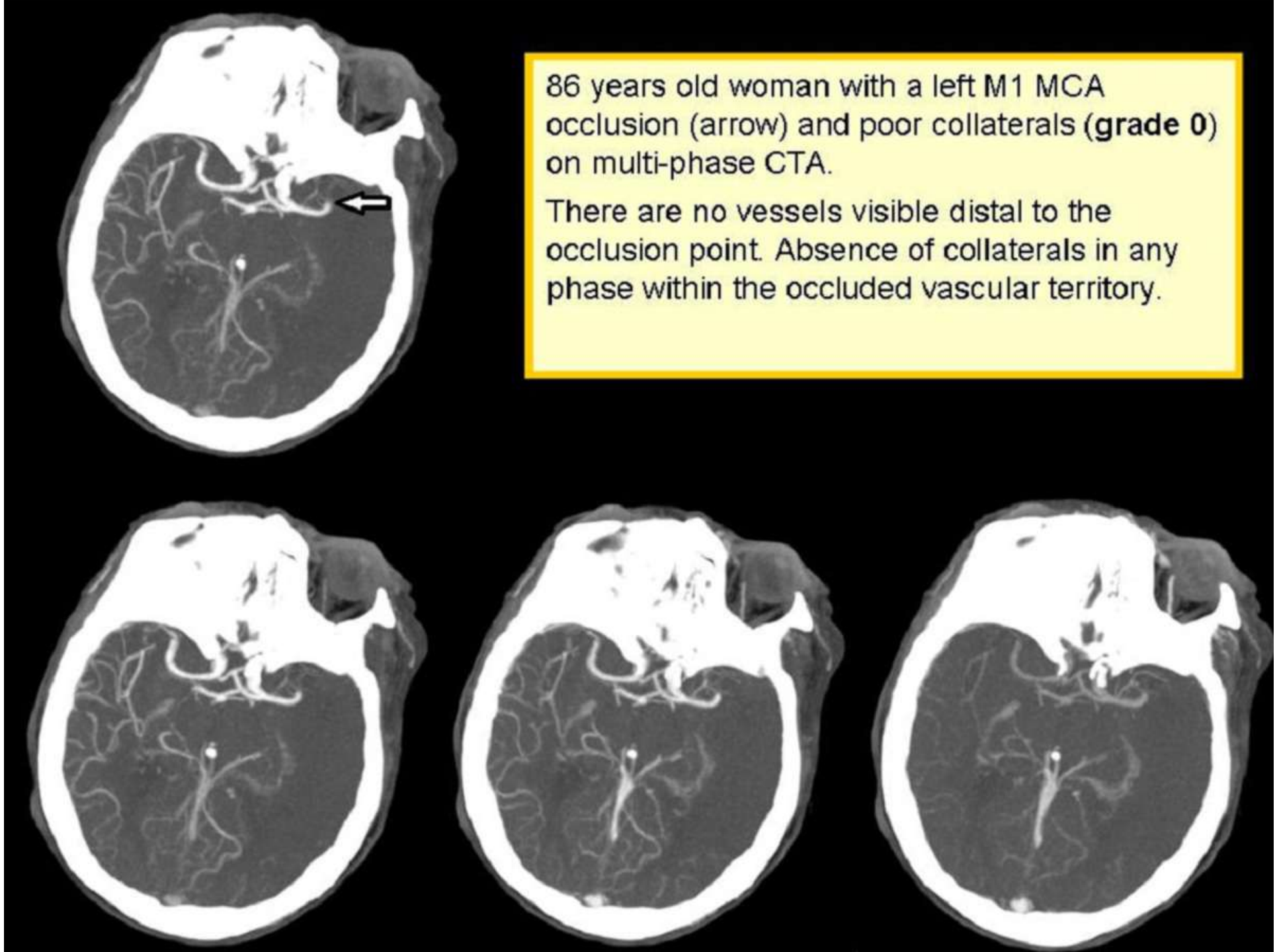
Stroke. 2016;47:2966-2971

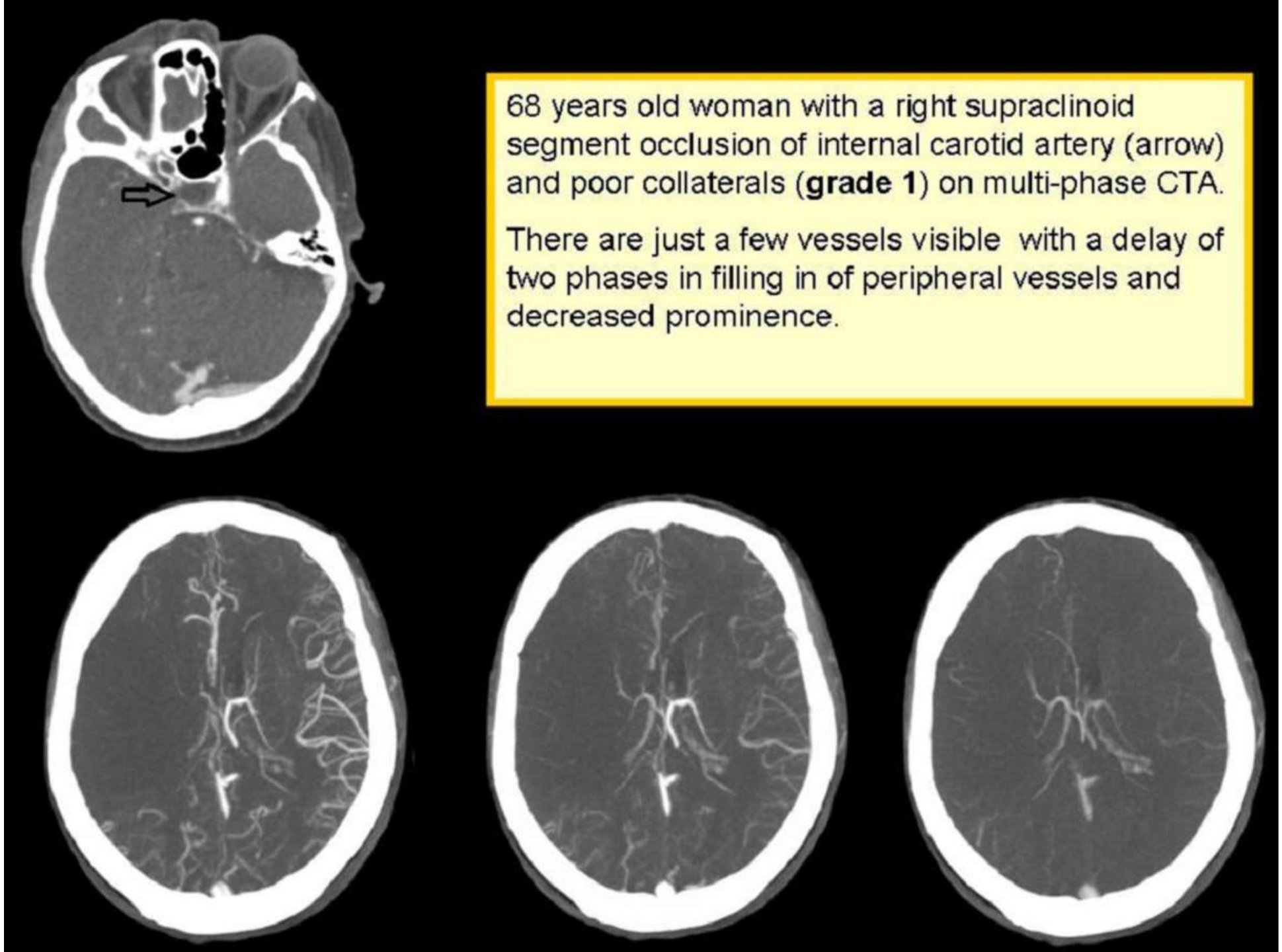
Multiphase CTA: University of Calgary classification

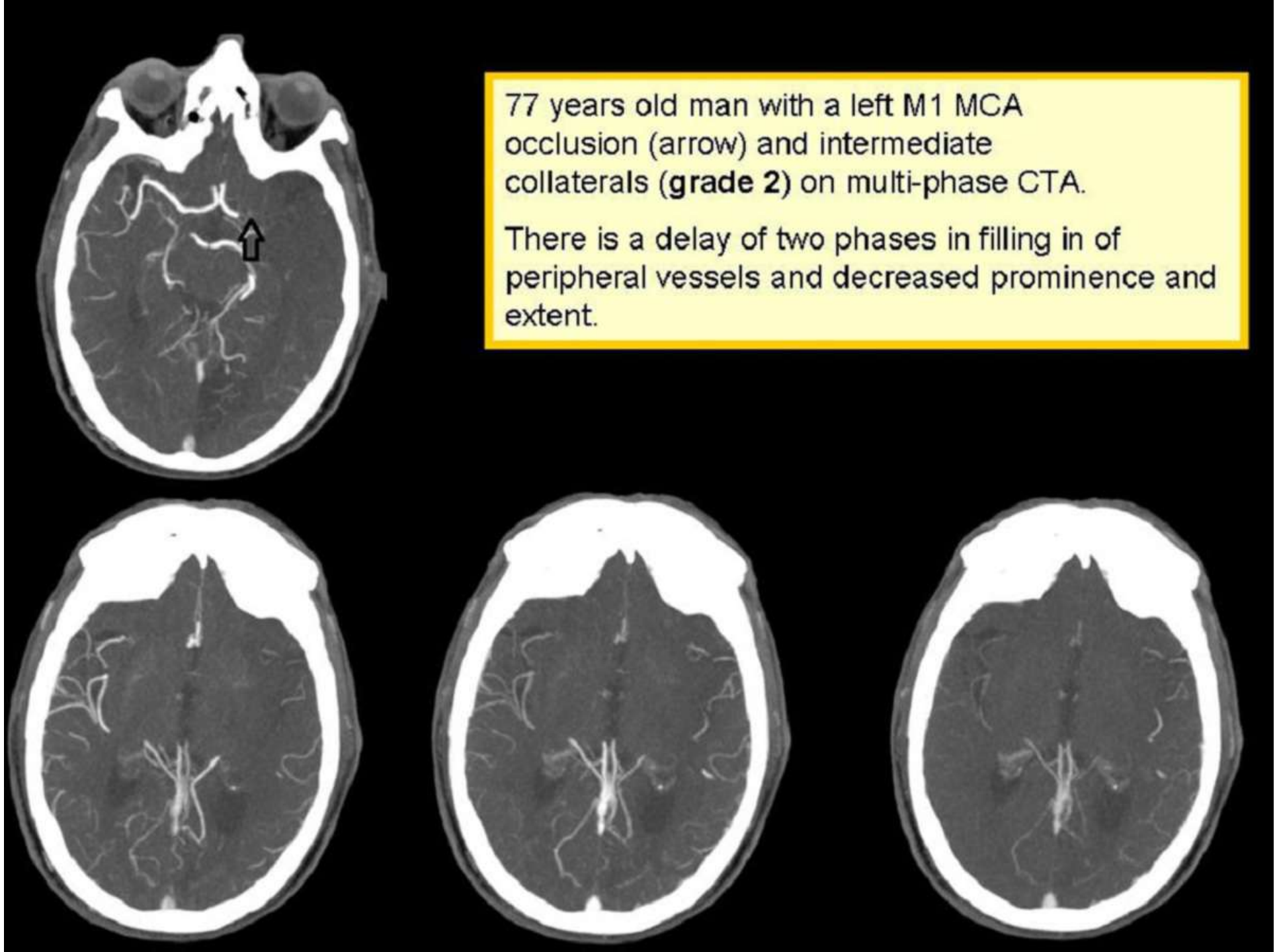
8 seconds delay in each phase

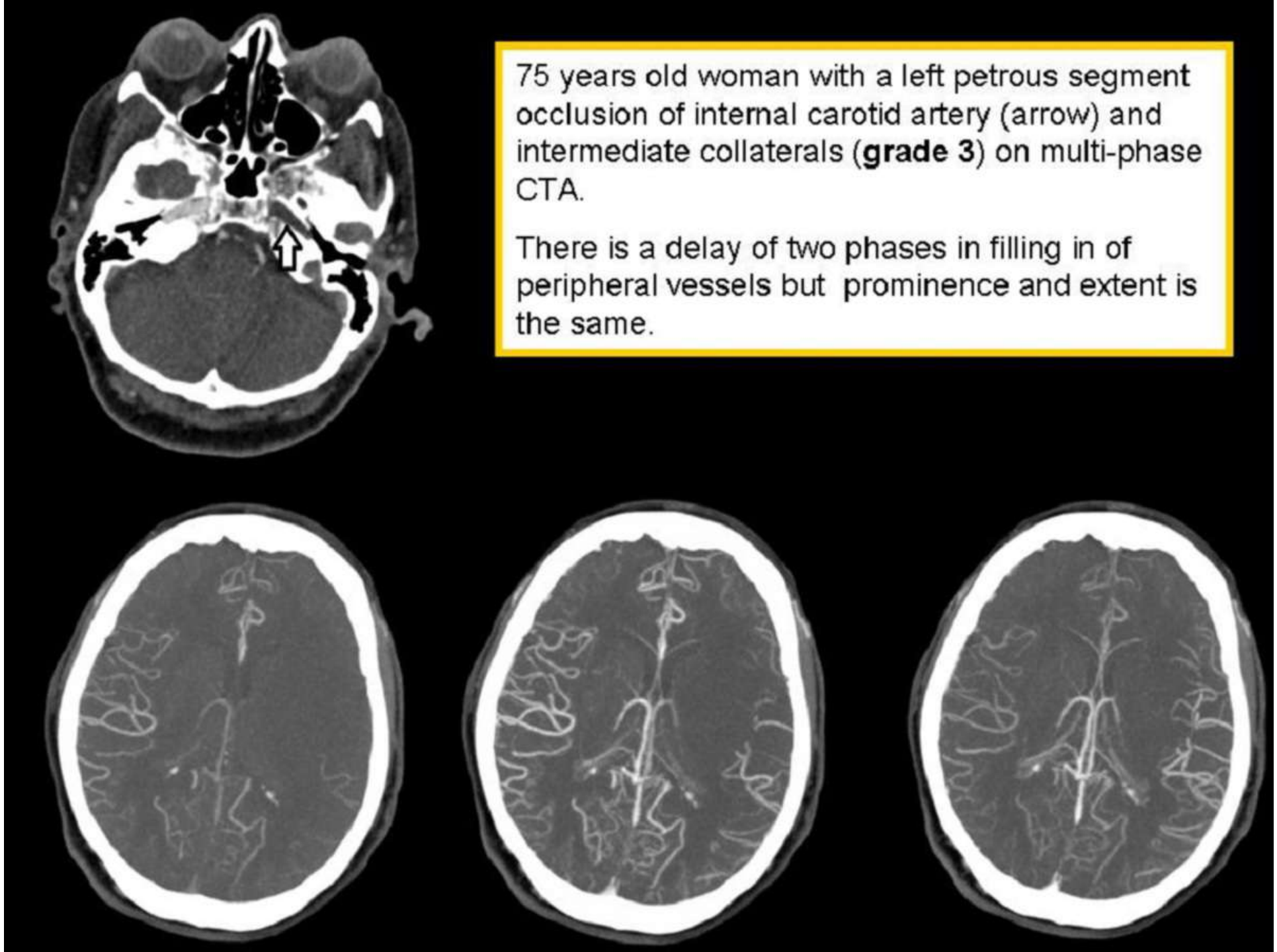
Category	Score	Compare to the asymptomatic contralateral hemisphere:
Poor	0	There are no vessels visible in any phase within the occluded vascular territory
	1	There are just a few vessels visible in any phase within the occluded vascular territory
Intermediate	2	There is a delay of two phases in filling in of peripheral ve4ssels and decreased prominence (thinner vessels) and extent or a one-phase delay and some regions with no vessels in some part of the territory occluded
	3	A delay of two phases in filling in of peripheral vessels but prominence and extent is the same or a one phase delay and decreased prominence and reduced number of vessels in some part of the territory occluded.
Good	4	There is a delay of one phase in filling in of peripheral vessels but prominence and extent are the same
	5	no delay, normal or increased prominence and normal extent of peripheral vessels.

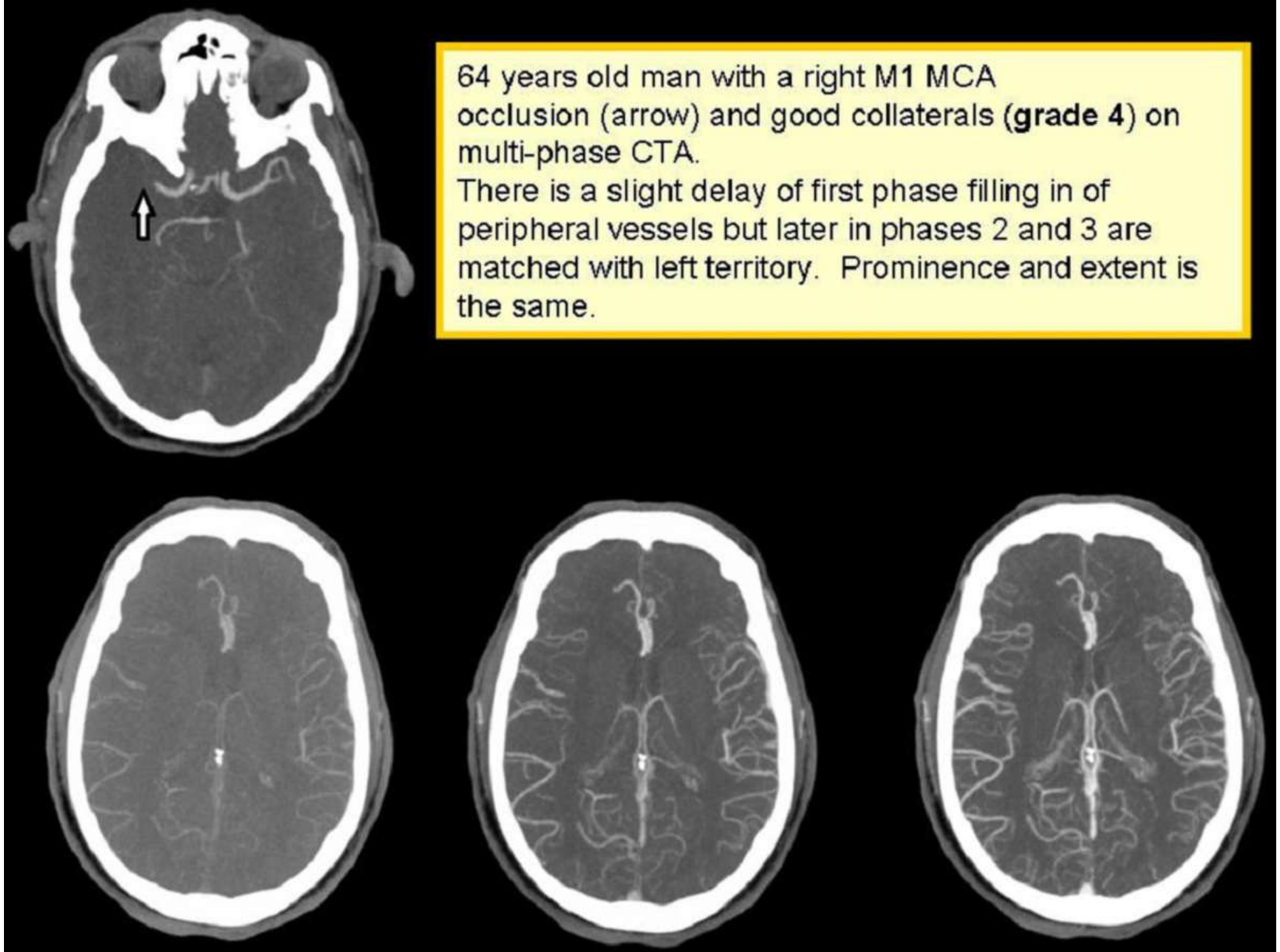
We use tri-phase CTA and perfusion CT if possible

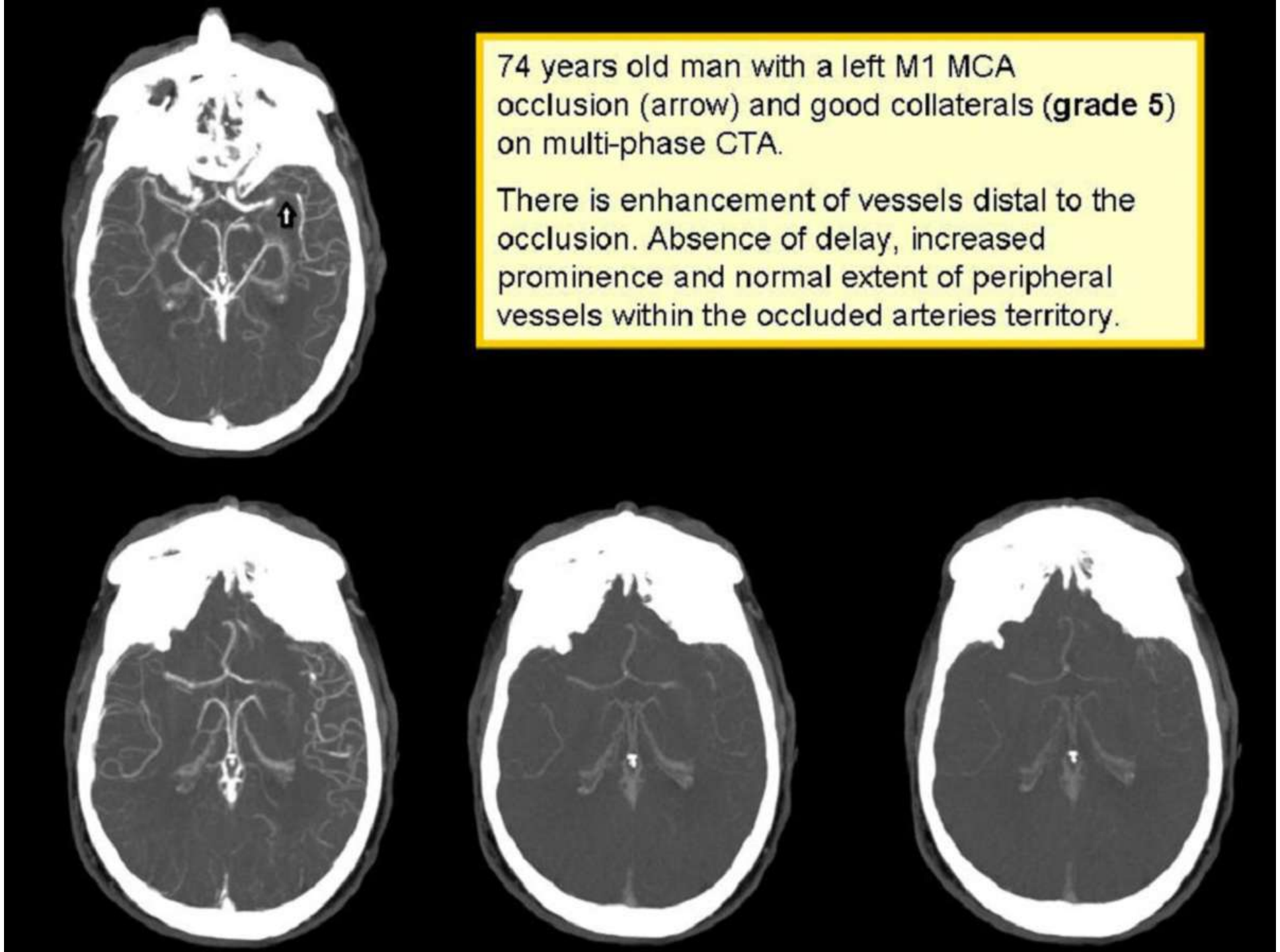

86 years old woman with a left M1 MCA occlusion (arrow) and poor collaterals (**grade 0**) on multi-phase CTA.
There are no vessels visible distal to the occlusion point. Absence of collaterals in any phase within the occluded vascular territory.


68 years old woman with a right supraclinoid segment occlusion of internal carotid artery (arrow) and poor collaterals (**grade 1**) on multi-phase CTA.
There are just a few vessels visible with a delay of two phases in filling in of peripheral vessels and decreased prominence.


77 years old man with a left M1 MCA occlusion (arrow) and intermediate collaterals (**grade 2**) on multi-phase CTA.
There is a delay of two phases in filling in of peripheral vessels and decreased prominence and extent.


75 years old woman with a left petrous segment occlusion of internal carotid artery (arrow) and intermediate collaterals (**grade 3**) on multi-phase CTA.
There is a delay of two phases in filling in of peripheral vessels but prominence and extent is the same.


64 years old man with a right M1 MCA occlusion (arrow) and good collaterals (**grade 4**) on multi-phase CTA.
There is a slight delay of first phase filling in of peripheral vessels but later in phases 2 and 3 are matched with left territory. Prominence and extent is the same.


74 years old man with a left M1 MCA occlusion (arrow) and good collaterals (**grade 5**) on multi-phase CTA.
There is enhancement of vessels distal to the occlusion. Absence of delay, increased prominence and normal extent of peripheral vessels within the occluded arteries territory.

Pons-Midbrain Index

- CTA-SI
- Grade 0: no hypoattentuation
- Grade 1: <50% hypoattenuation
- Grade 2: >50% hypoattentuation

Complete Eclipse of the Sun

Core and penumbra

https://hdwallsource.com/solar-eclipse-wallpaper-background-51351.html

How to Measure the Ischemic Core? (CTA)

- A >66% reduction of CT-CBF from baseline values has a high probability of infarction. (>30% reduction of CBF)

AJNR Am J Neuroradiol 30:885–92 May 2009

- No region with absolute CBV < 2.2 mL/100 g survived. The CBV threshold of <2.0 mL/100 g selected to define core.

AJNR Am J Neuroradiol 2006;27:20–25
Ann Neurol 2002; 51:417–32
Stroke 2006;37:979–85

Measure the Ischemic Core

Modality	Sensitivity 3h	Sensitivity 6h	Sensitivity 24h
CT	12%		57-71%
MRI DWI	73-92%	95-100%	
MRI FLAIR (mismatch)		78-93%	

- Low density on non-contrast CT represents infarction
- Restricted diffusion on MR (DWI or ADC) represents infarction
- MRI is much more sensitive.

European Journal of Radiology (2017), http://dx.doi.org/10.1016/j.ejrad.2017.08.014

How to Measure the Ischemic Penumbra? (CTA)

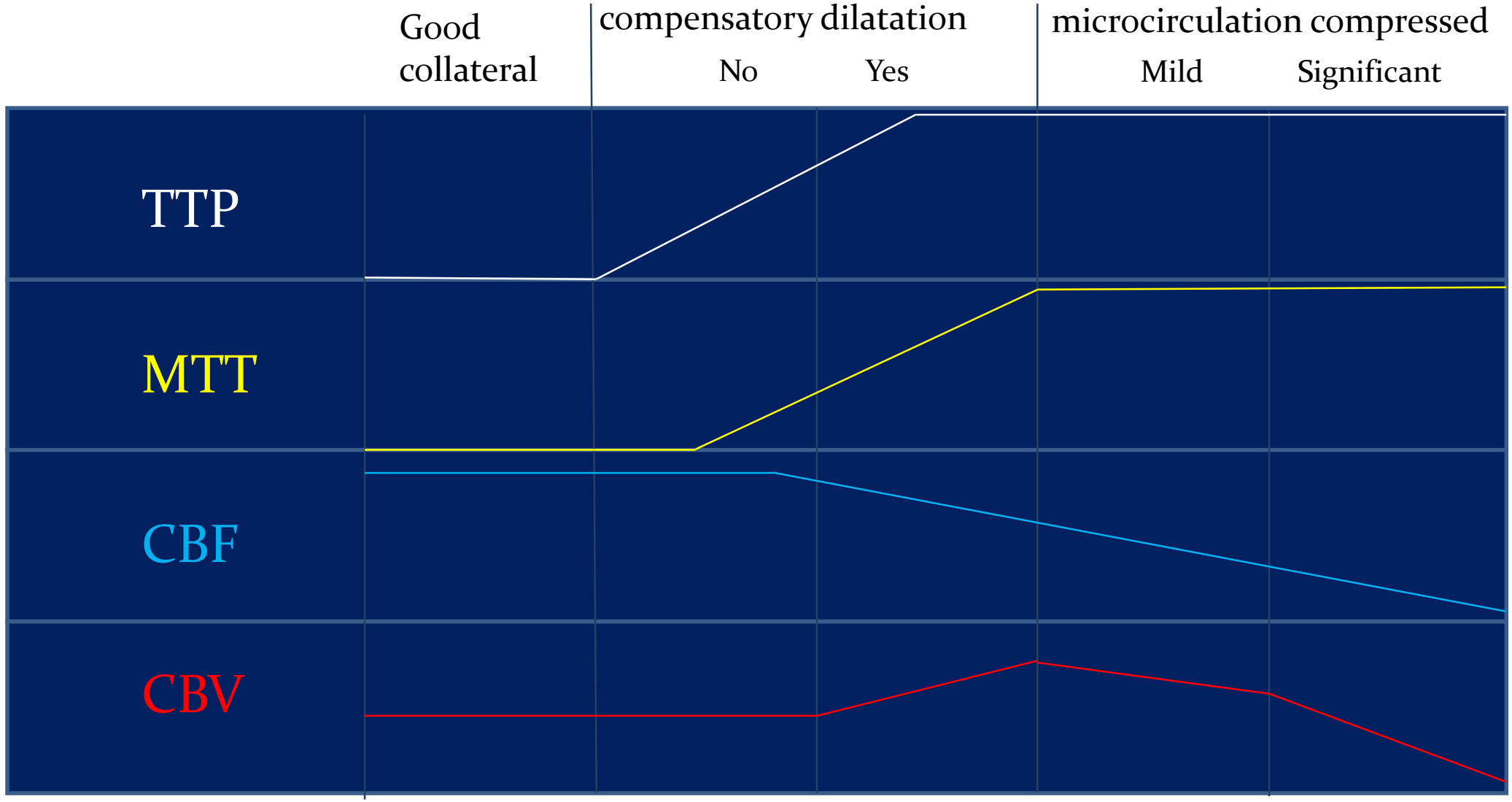
- A threshold of Tmax >6 s is strongly correlated with the final infarct volume in the absence of early (within 12 h) reperfusion.

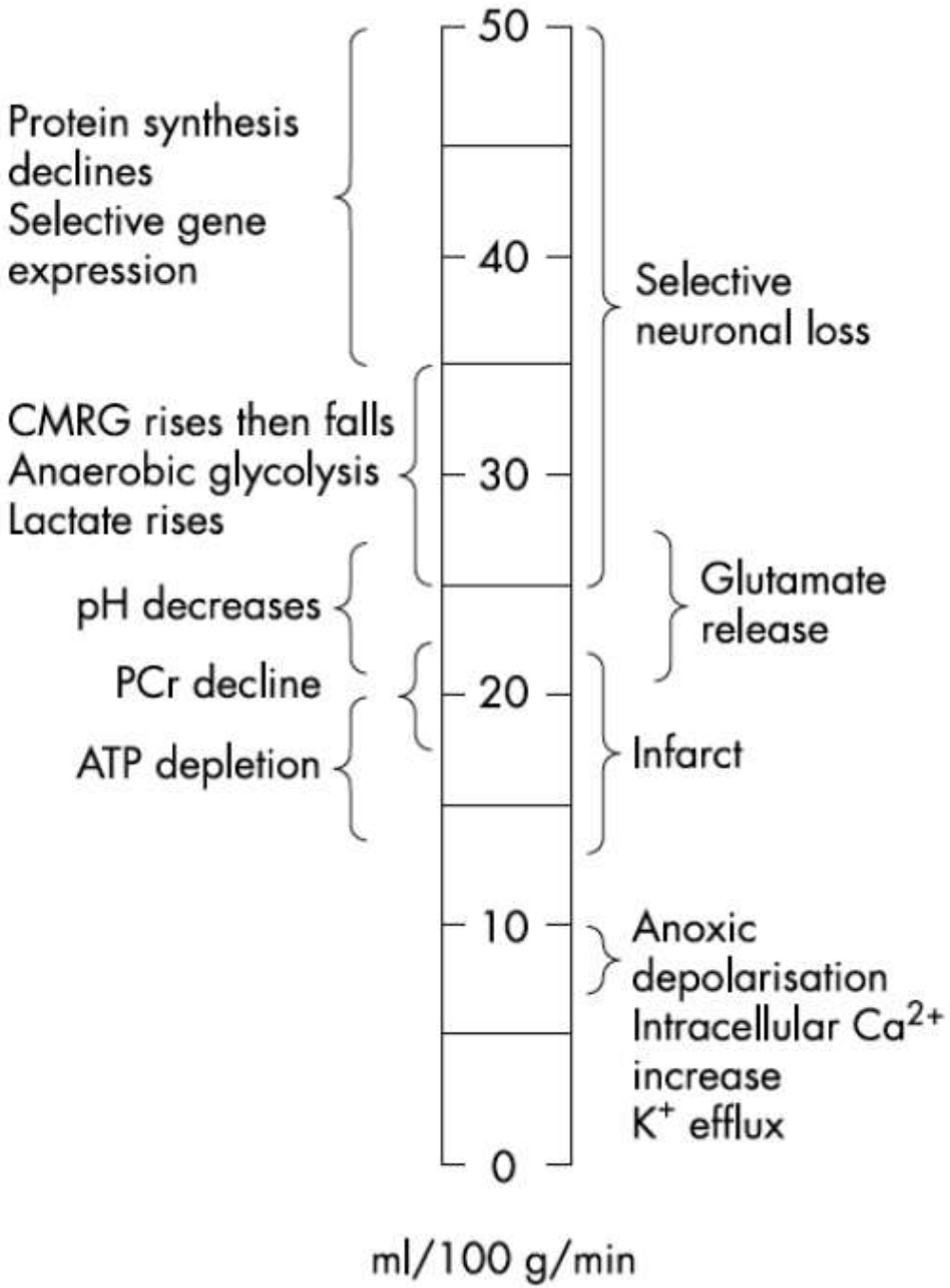
Stroke 2013;44:681–5

- MTT >7 s or 145% of the contralateral healthy area and CBV >2.0ml/100 g)

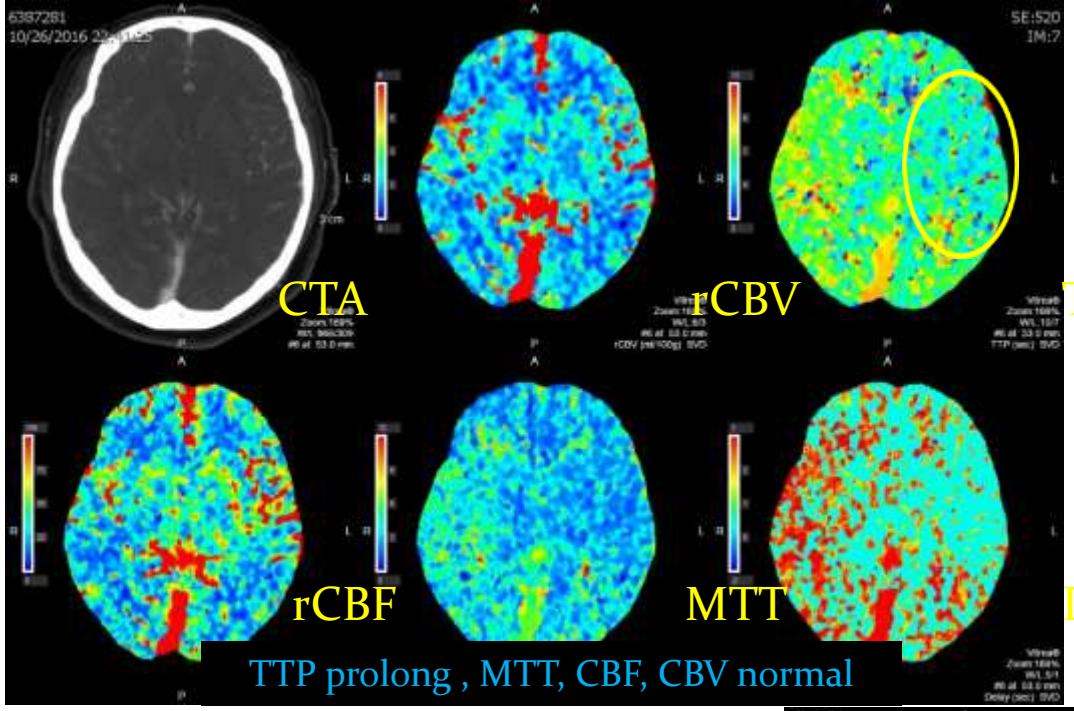
Stroke 2006; 37:979–85

Bayliss effect

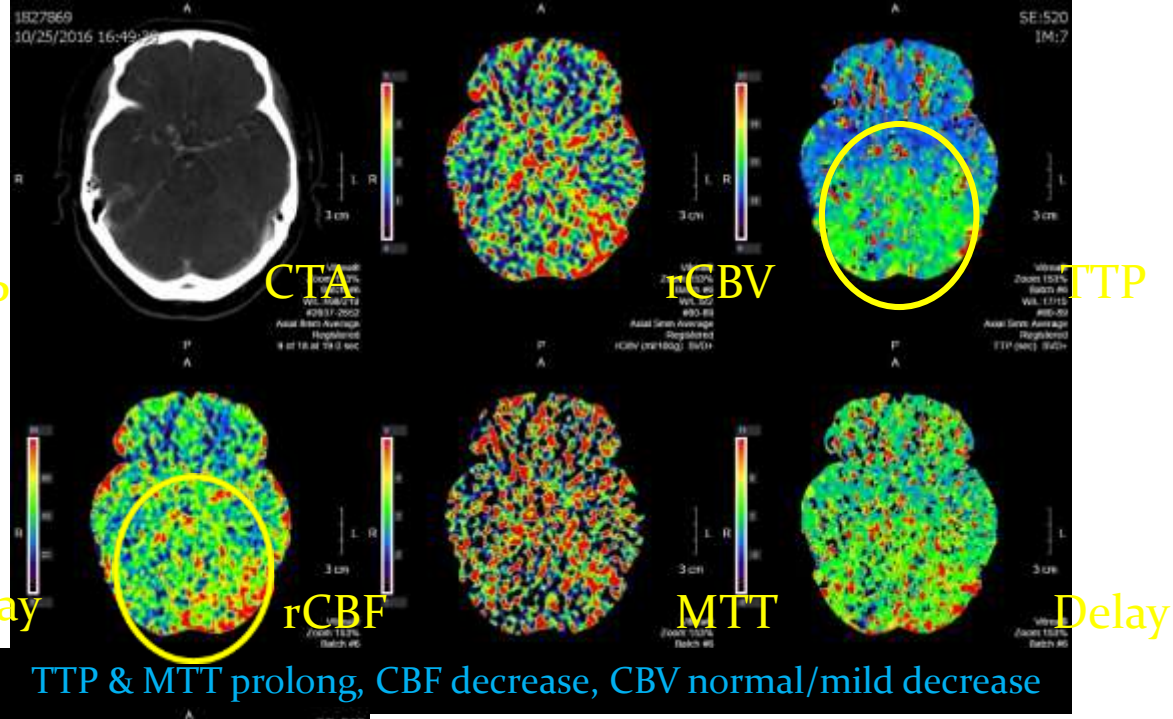




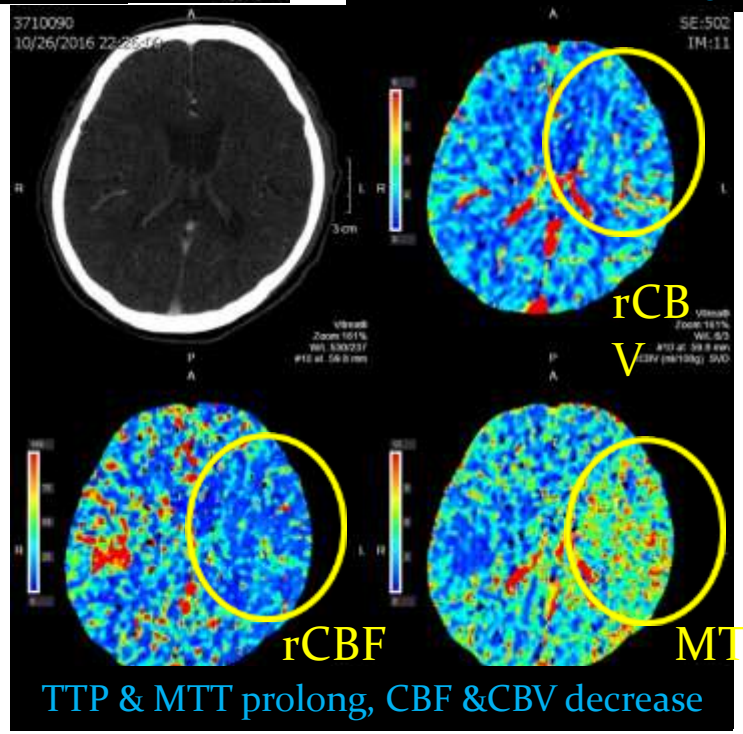
Circ Res. 2017;120:541-558. DOI: 10.1161/CIRCRESAHA.116.309278.
PHYSIOLOGY 24: 257–265, 2009; doi:10.1152/physiol.00015.2009
Trends in Neurosciences, November 2014, Vol. 37, No. 11
J Neurol Neurosurg Psychiatry 2004;75:353–361. doi: 10.1136/jnnp.2003.025825



TTP prolong , MTT, CBF, CBV normal

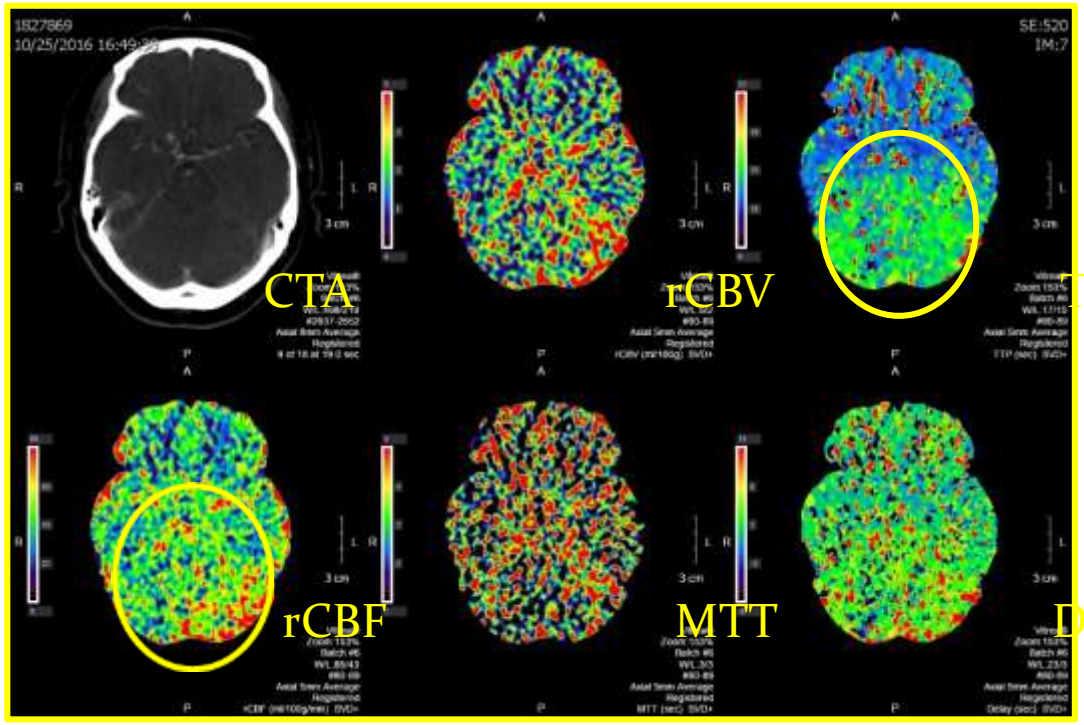


TTP & MTT prolong, CBF decrease, CBV normal/mild decrease

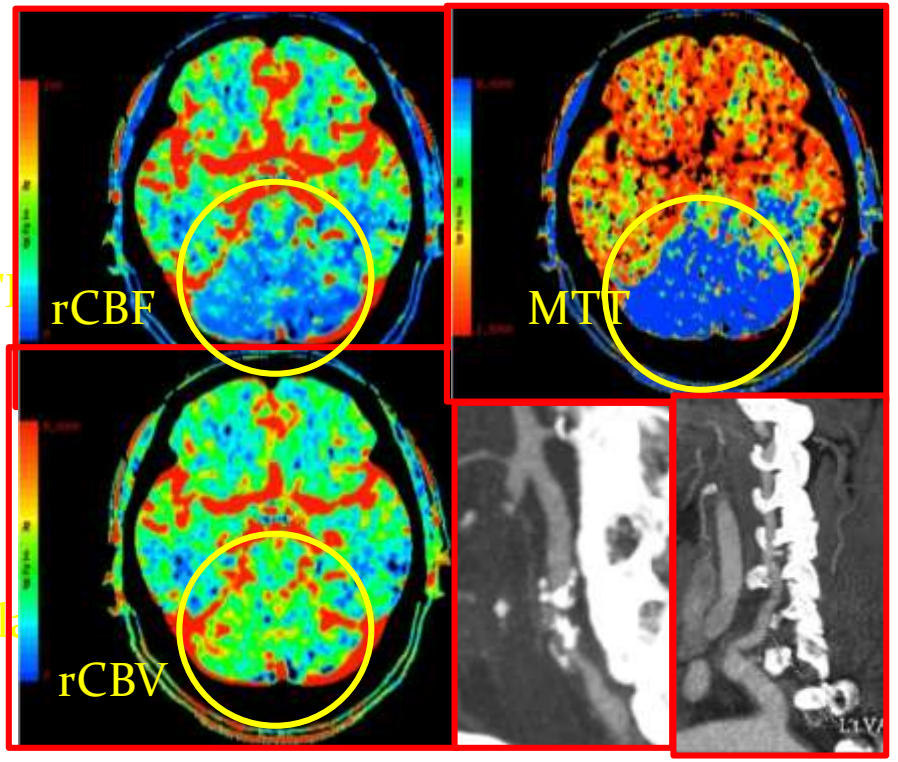


TTP & MTT prolong, CBF &CBV decrease

Mostly, perfusion CT be applied in posterior fossa too



TTP & MTT prolong, CBF decrease, CBV normal/mild decrease

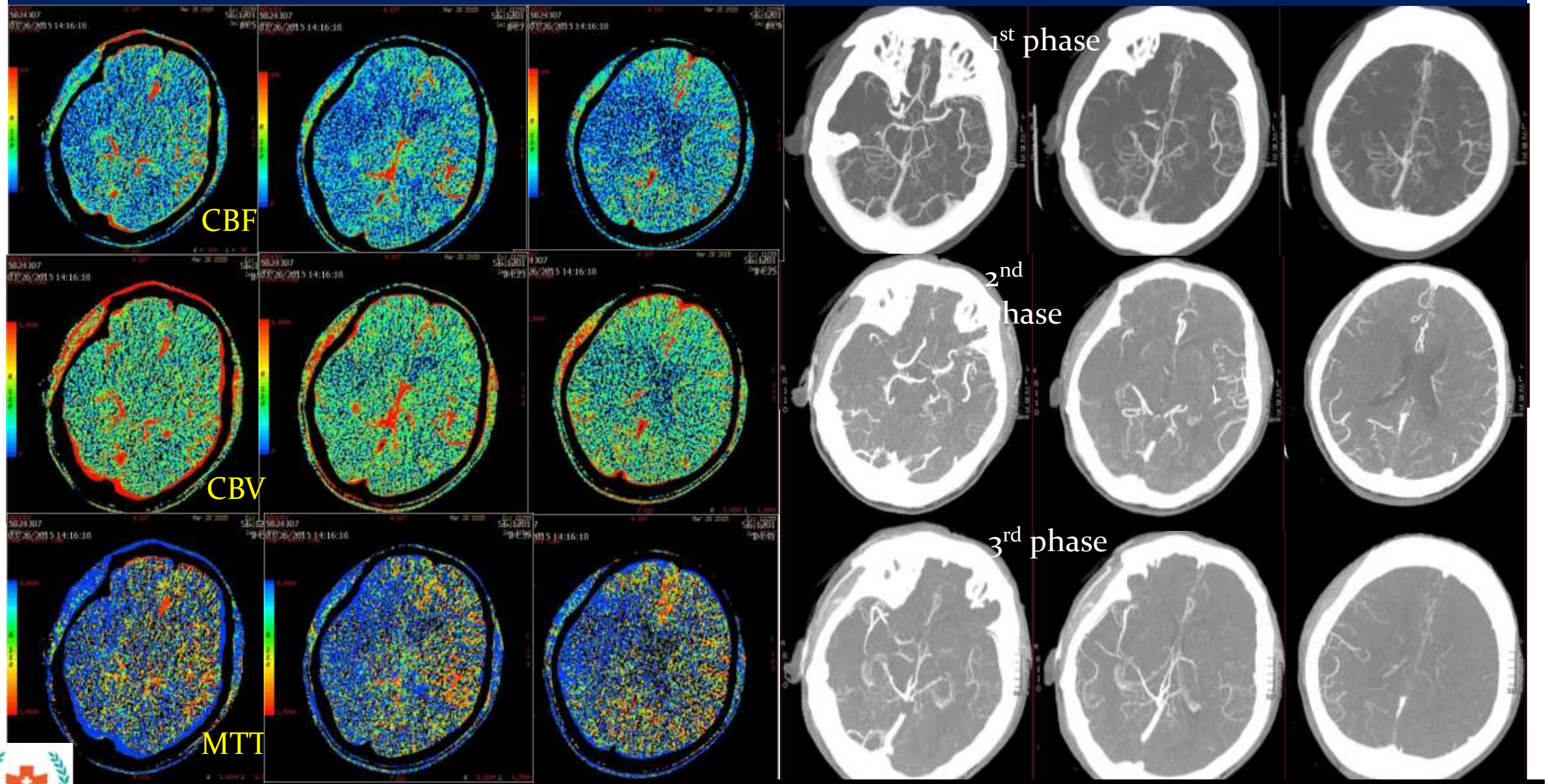


TTP & MTT prolong, CBF &CBV decrease

Fair compensation

Poor compensation

Both PCT and 3- phase CTA showed moderate or poor collateral

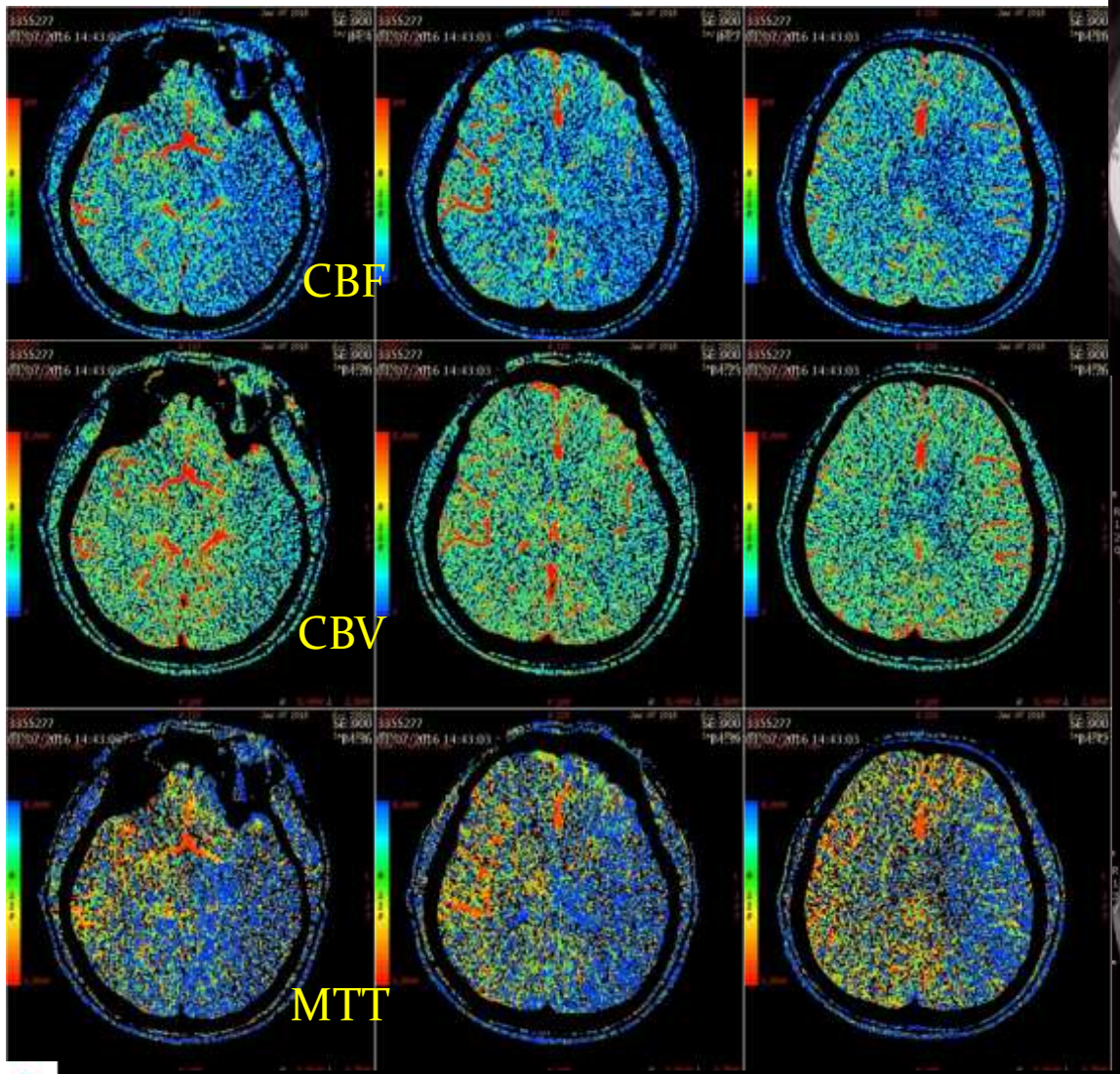


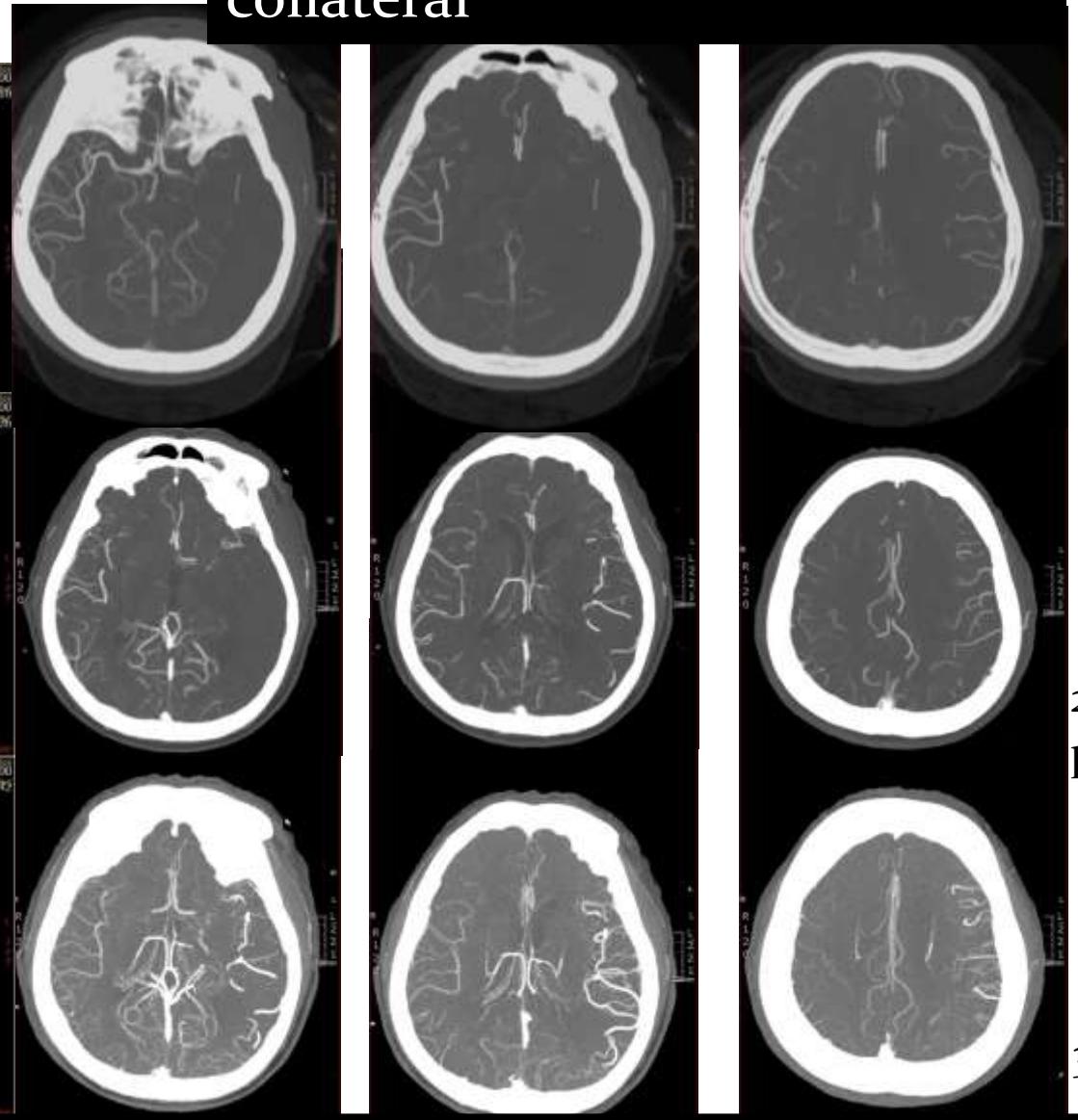
59 male, initial NIHSS 18, iv-tPA , NIHSS 18, CTA, RMCAO, Thrombectomy, NIHSS 2

PCT: MTT prolong
CBF & CBV decrease

Poor collateral

3-Phase CTA moderate to poor collateral





1st phase

2nd phase

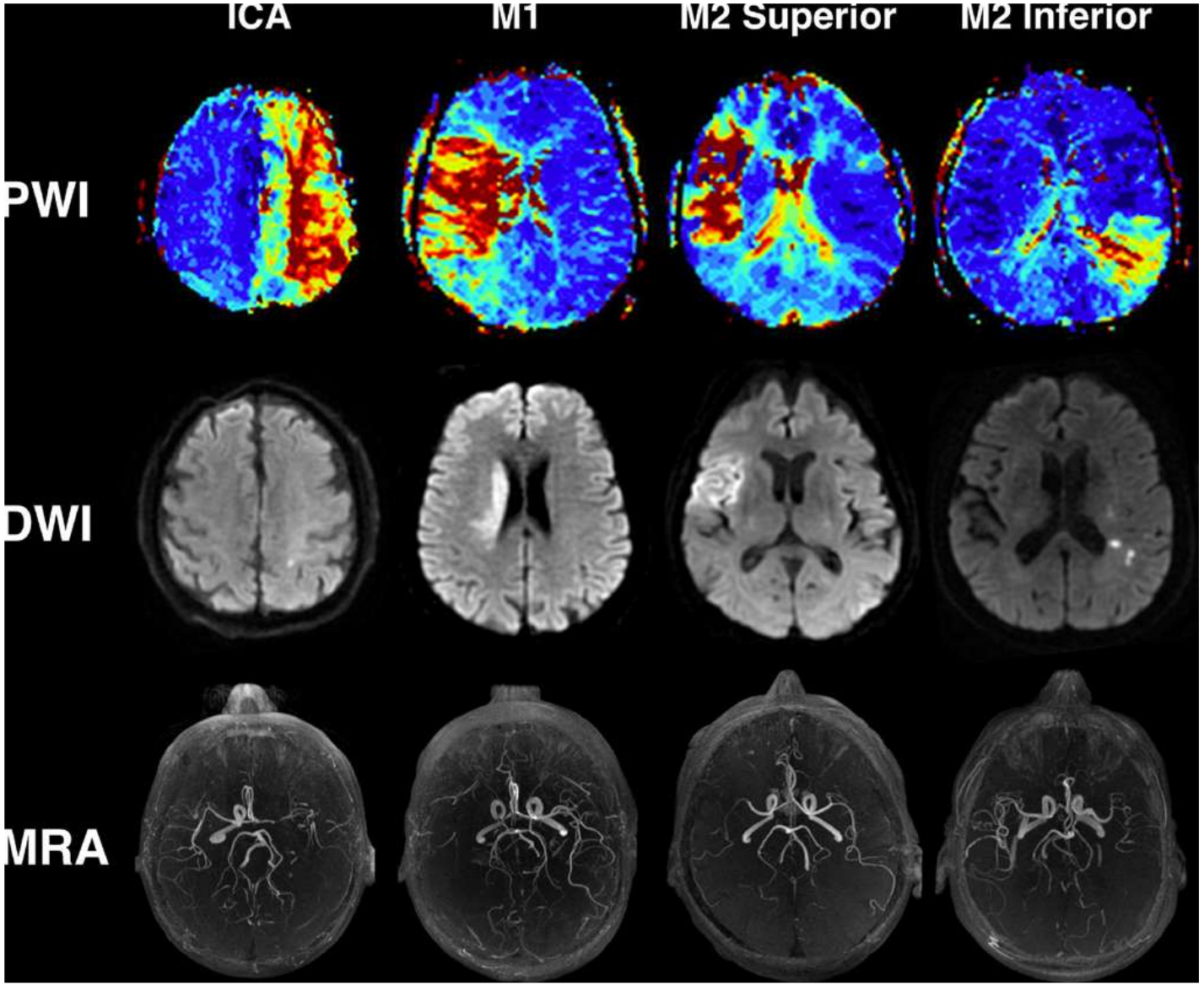
3rd phase

Male, initial NIHSS; 18, CTA/ PCT, then iv-tPA, NIHSS; 30, S/P thrombectomy; 26+x

Factors Influence Outcome of Ischemic Core/ Penumbra Imaging

- No well-validated threshold for any of the tissue states.
- Design of the injection (rate, dosage)
- Imaging protocol
- Arrival time and width of the contrast bolus
- Different post-processing algorithms (delay and dispersion)

.Ann Neurol 2011;70:384–401
Stroke 2011;42:1923–8
AJNR Am J Neuroradiol2012;33:545–9.



Perfusion patterns of large vessel occlusion

J NeuroIntervent Surg 2018;0:1–6.

DWI-FLAIR mismatch

- 4.5 h, negative FLAIR had 62-66% sensitivity and 70-78% specificity to identify wake-up stroke patients. Stroke 47 (4) (2016) 1018–1022.
  Lancet Neurol. 10 (2011) 978–986.
- 6h, negative FLAIR with signal intensity ratio (SIR) ≦1.18 had 86% sensitivity (95% confidence interval,81%–92%) and 79% specificity (95% confidence interval, 73%–85%).
- 8h, negative FLAIR SIR≦1.20 had 89% sensitivity (95% confidence interval,83%–94%) and 76% specificity (95% confidence interval,71%–81%) with the 8-hour window. J. Stroke Cerebrovasc. Dis. 26 (2017) 1582–1587.

Tissue-Based Selection

- Imaging is not a tool for patient selection.
- Imaging is only for suggesting prognosis and preventing futile recanalization.

Include or exclude more patients by imaging ?!?!?!

Current Concept of Imaging Application in acute ischemic stroke and intra-arterial mechanical thrombectomy

廖漢文

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