Evaluating the Infarct : MRI diffusion and CT ASPECTS scores

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Disclosure Statement

- There is no actual or potential conflict of interest in regards to this presentation

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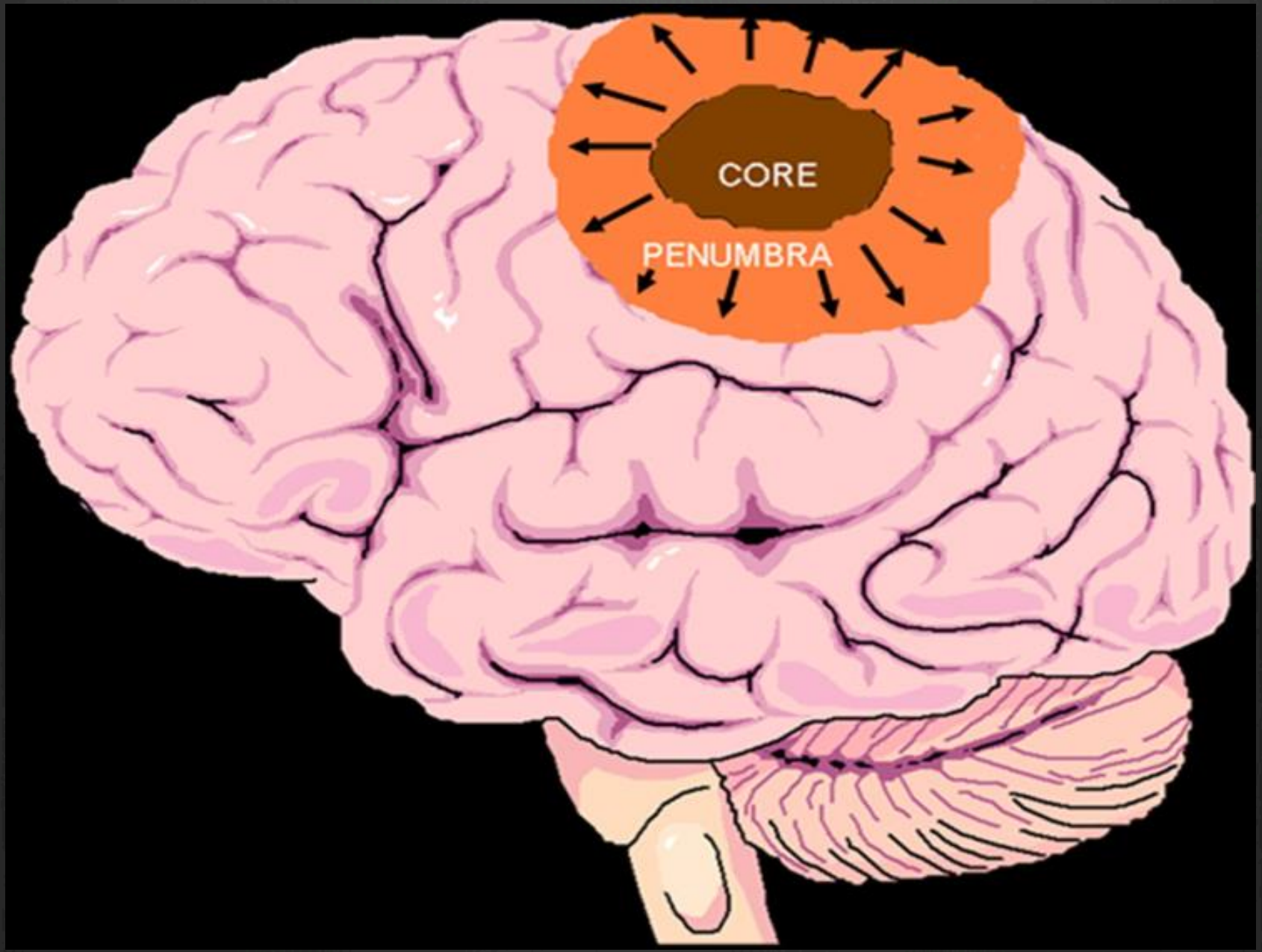
Learning Objectives

At the conclusion of this course participants will be able to

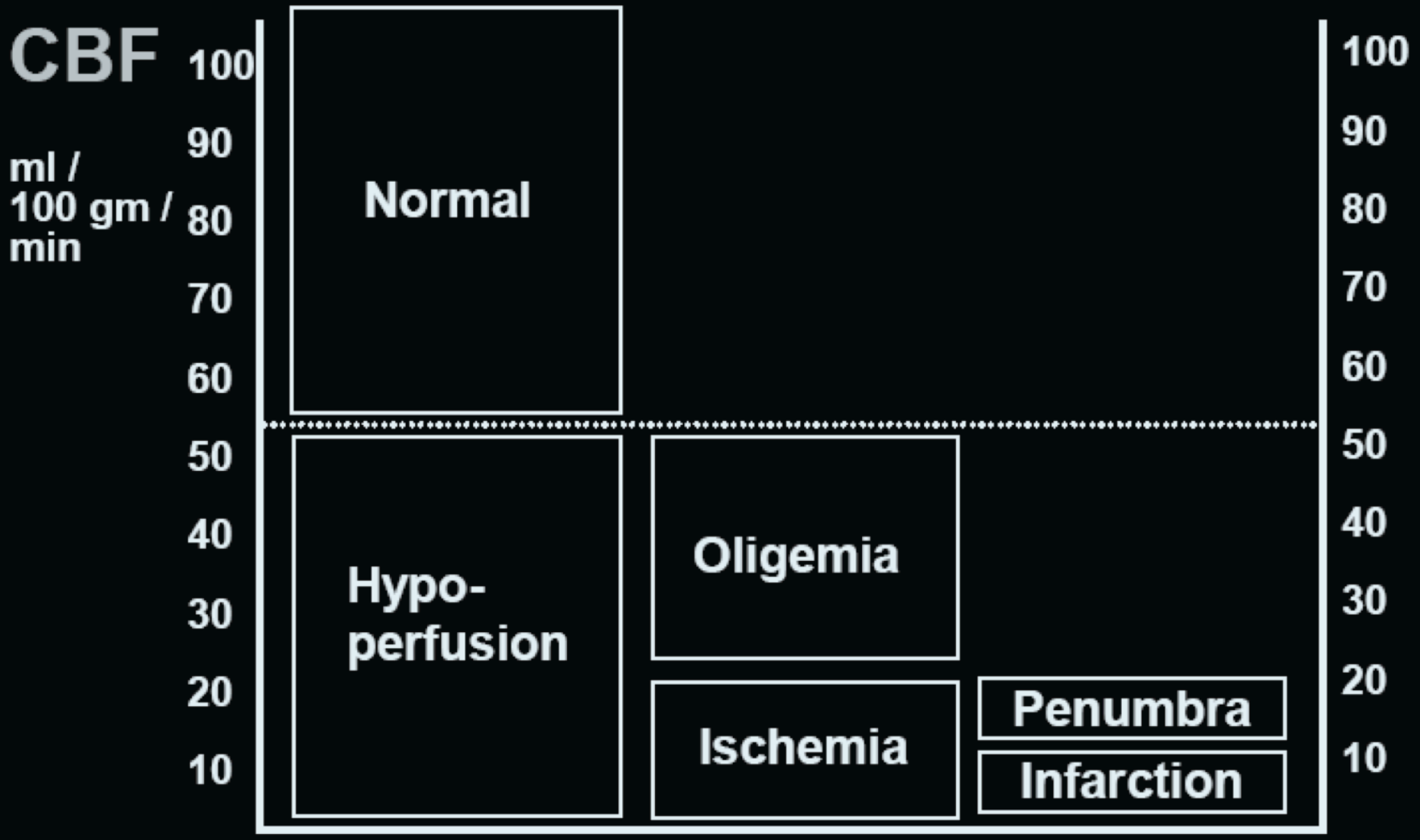
- **Identify imaging signs of early ischemic changes (EIC) on a non-contrast CT.**
- **Apply APSECTS score on a non-contrast CT**
- **Analyze diffusion MR imaging in stroke.**

Organization

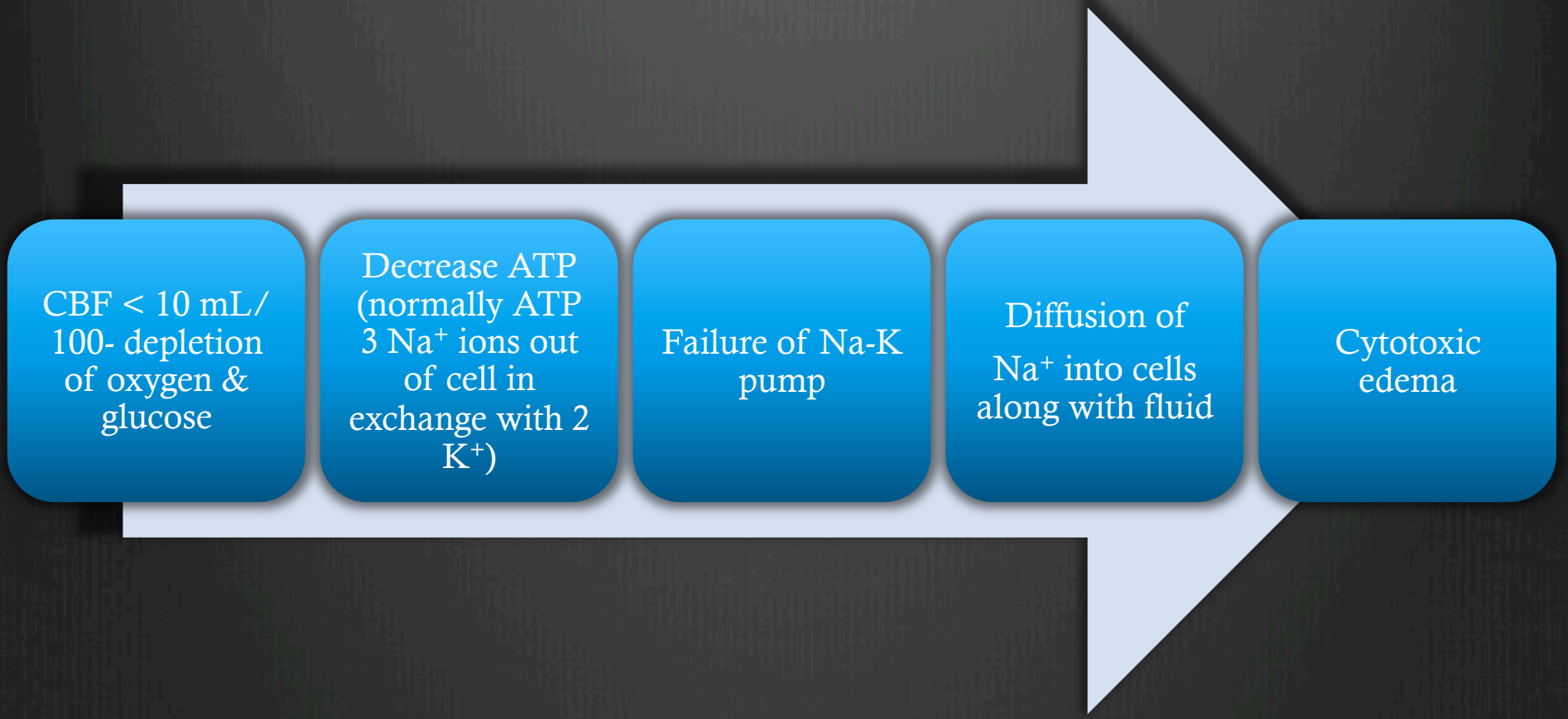
- Pathophysiology of acute ischemic stroke
- CT signs of acute ischemic stroke
- What is ASPECTS ?
- Why and how do we use ASPECTS ?
- Limitations of ASPECTS
- Basics of Diffusion MRI
- Role of diffusion MRI in acute ischemic stroke
- Collateral circulation


CORE
PENUMBRA

Cerebral Blood Flow Thresholds



Sodium-Potassium Pump

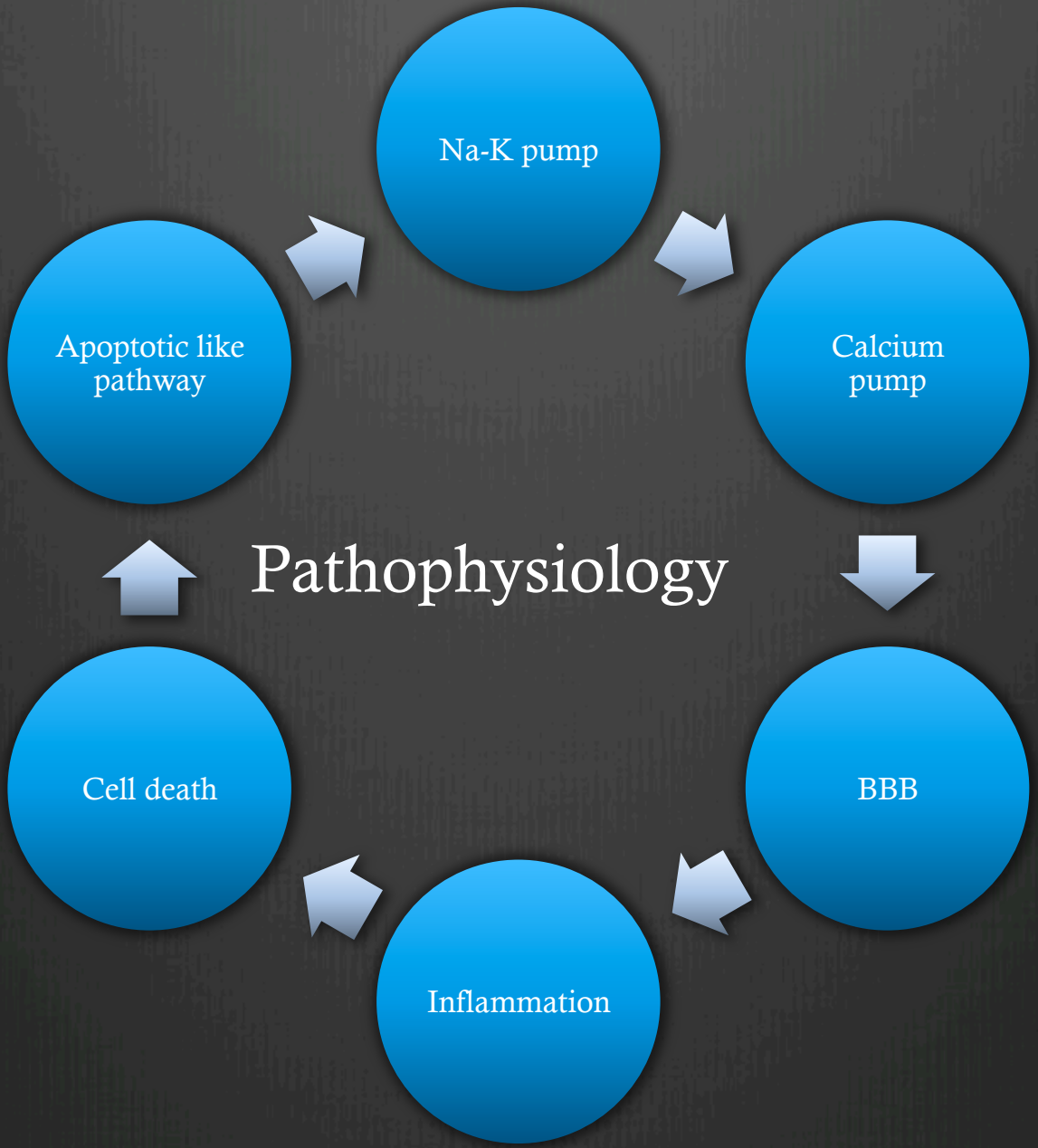


Calcium Pump

Cell depolarization- release of excitotoxic amino acids- glutamate

Large influx of Ca^{+2} into cells

Higher levels of intracellular Ca^{+2} cause mitochondrial damage and cellular rupture


Na-K pump
Calcium pump
BBB
Inflammation
Cell death
Apoptotic like pathway
Pathophysiology

Current mainstay of acute stroke neuroimaging

- **Core**
- **Clot**
- **Collateral**

“Time is brain”

- **Strong evidence supporting use of IV tPA as a recanalization therapy to improve clinical outcomes 0 hour- 4.5 hour time window**
- **Acute ischemic stroke caused by proximal intracranial occlusion of anterior circulation, intra-arterial treatment administered within 6 hours after stroke onset was effective and safe (MR CLEAN)**
- **IA tPA upto 8 hrs**
- **Evidence from numerous studies suggest that early ischemic change (EIC) on NCCT before the administration of acute stroke therapies can predict both functional outcome and the risk of ICH**

CT in Acute Stroke Evaluation

- **Non contrast CT (NCCT)**
- **CT angiogram (head & neck)**
- **CT perfusion +/-**

NCCT

- **CT brain Stroke Protocol – Axial 5 mm. Sagittal, Coronal, True axial reformats**

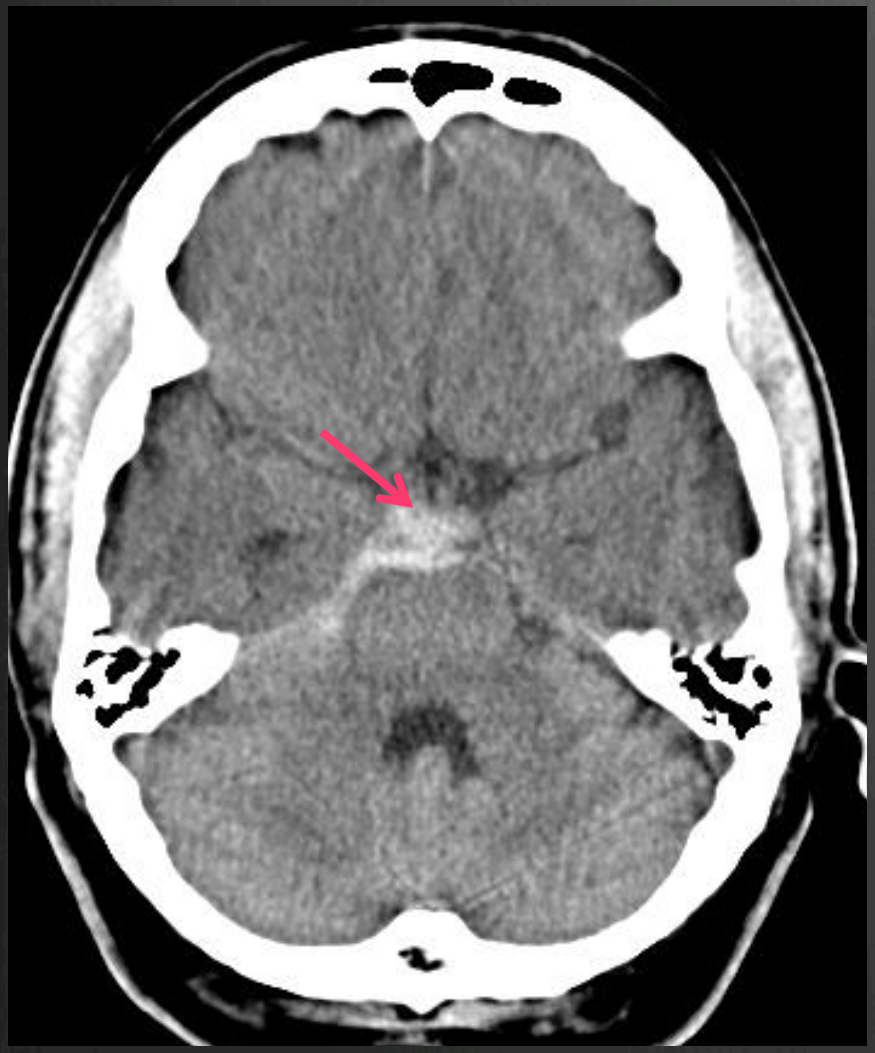
NCCT – What you need to know for stroke evaluation

- History ?
- Is there hemorrhage ?
- Exclude structural lesions which can mimic stroke
- Importance of window setting
- Recognize CT signs of early ischemic change (EIC)
- How extensive is the edema (>1/3 MCA territory Vs ASPECTS)

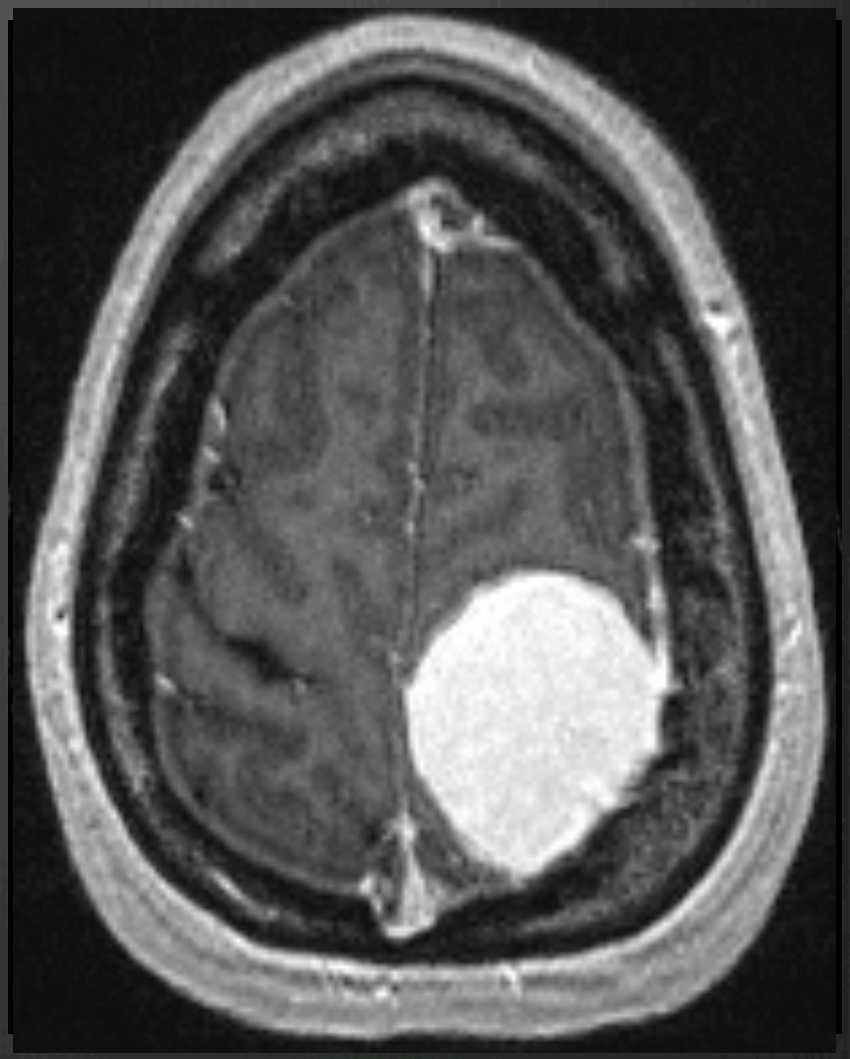
Importance of history

- **Onset time**
- **Motor**
- **Sensory**
- **Aphasia**
- **Visual**
- **Dizziness, vertigo, ataxia**

Is there hemorrhage ?



Exclude structural lesions which can mimic stroke

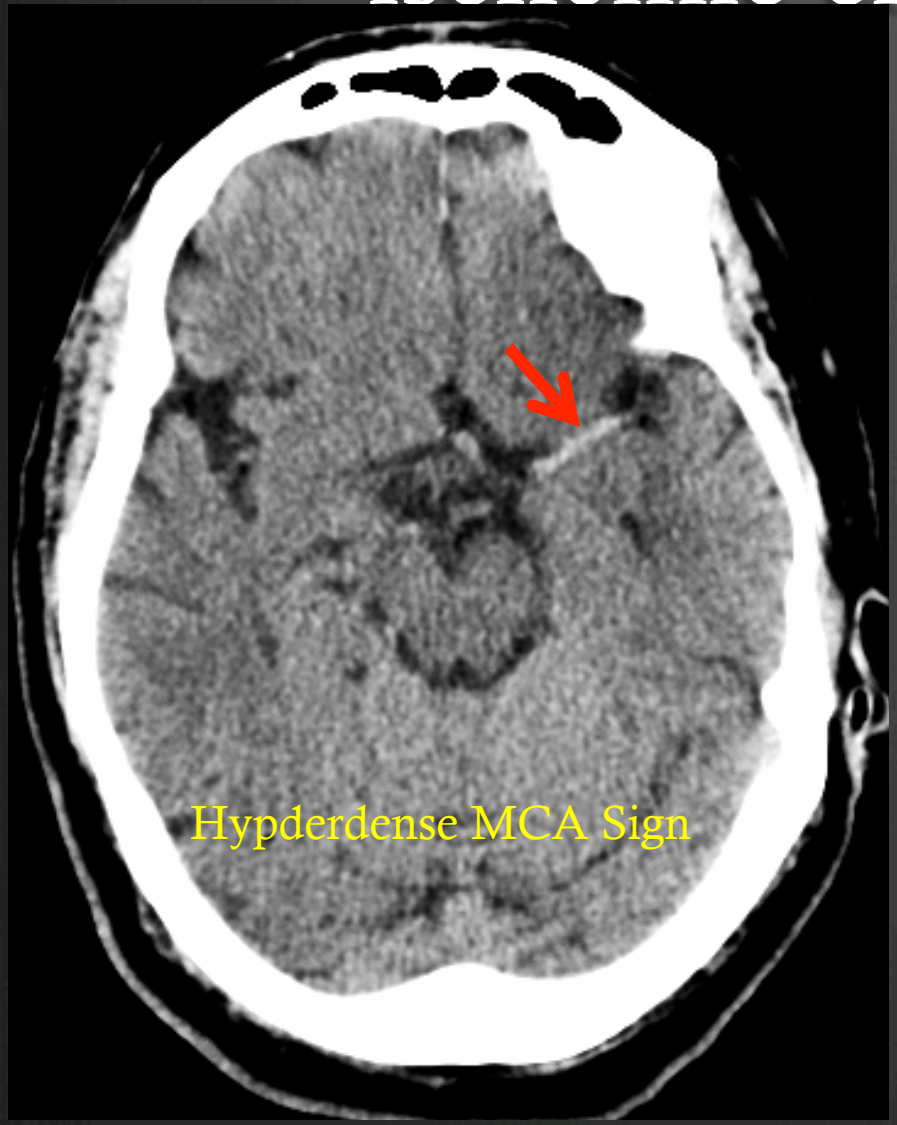


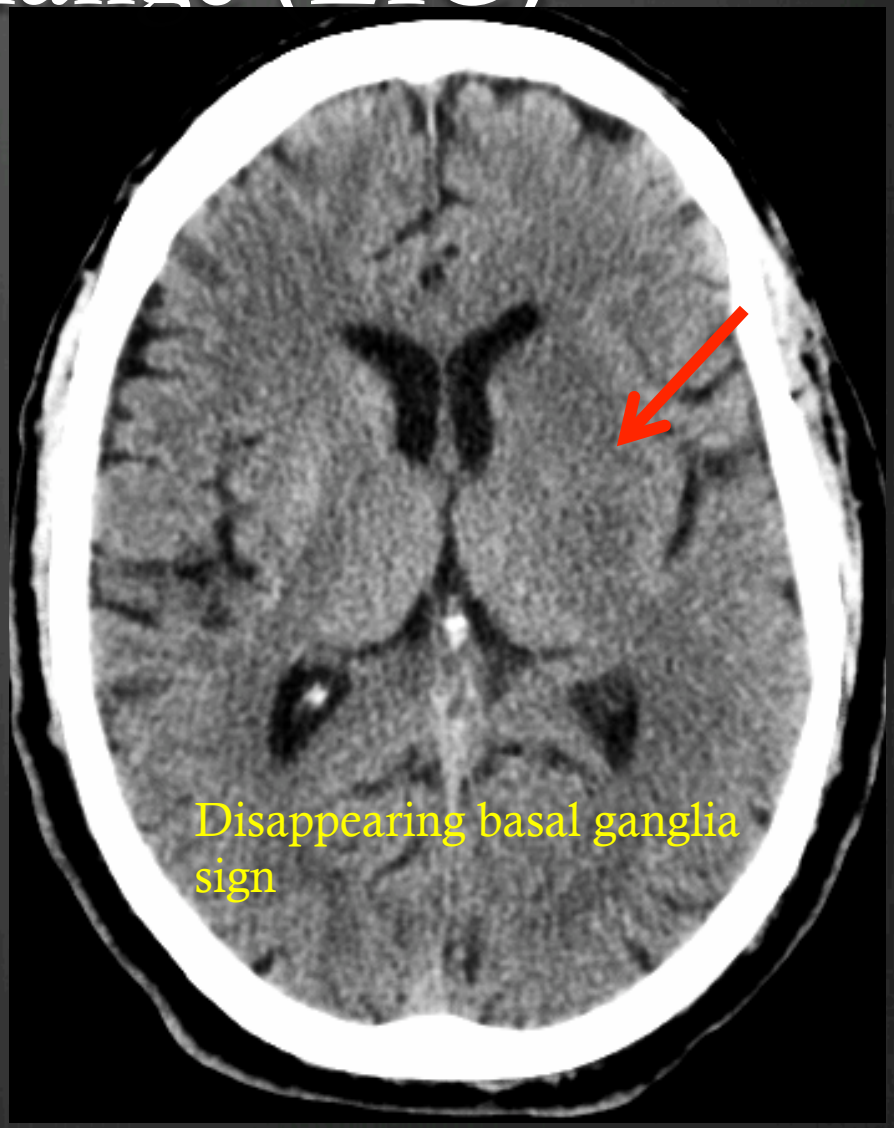
Importance of window setting

WW-80 WL-40

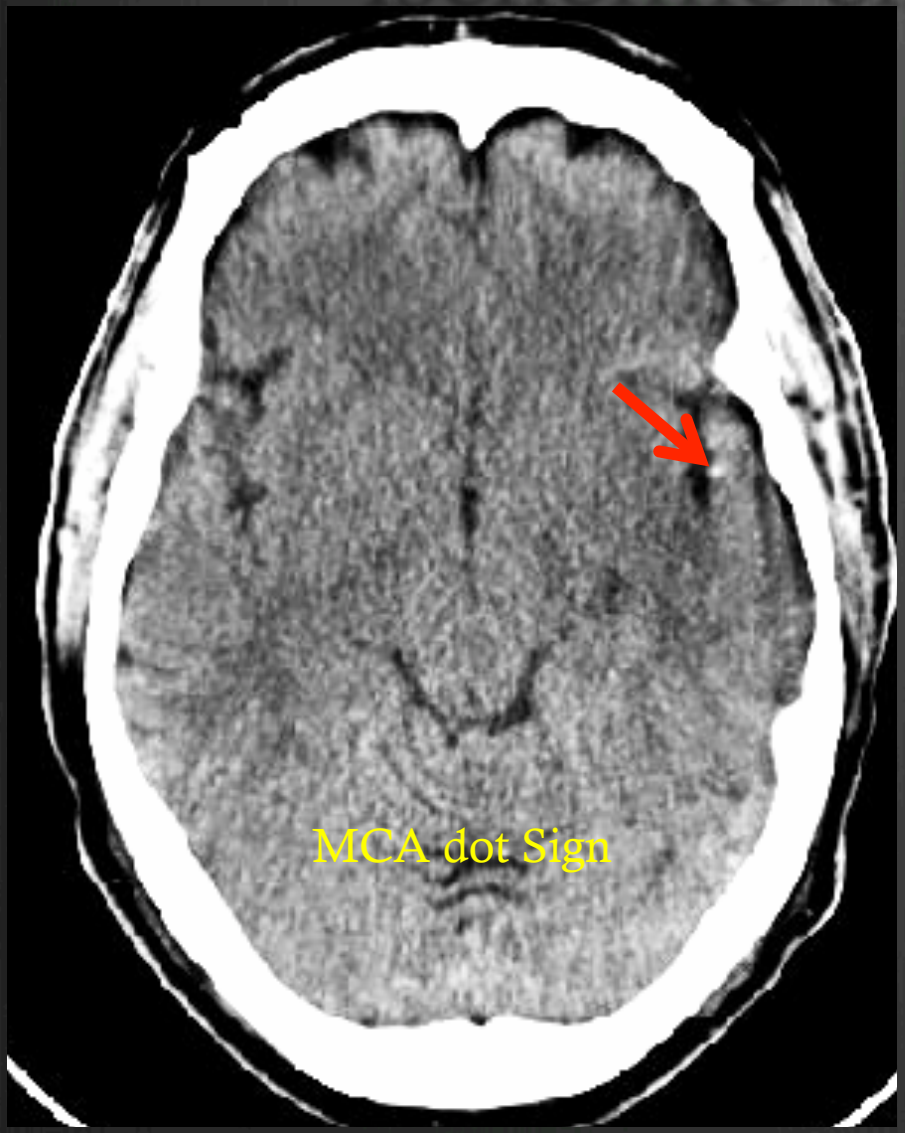
WW-35 WL-35

Recognize CT signs of early ischemic change (EIC)

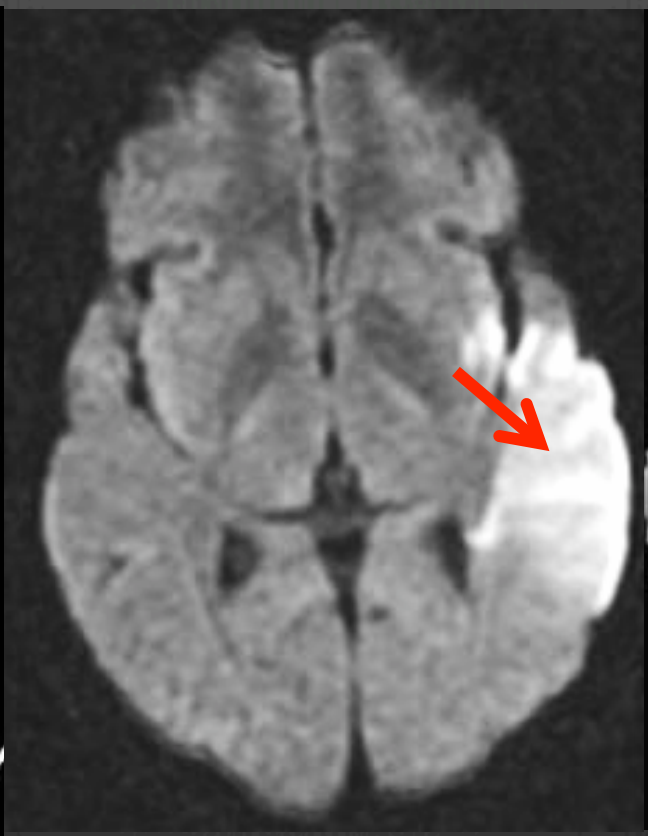




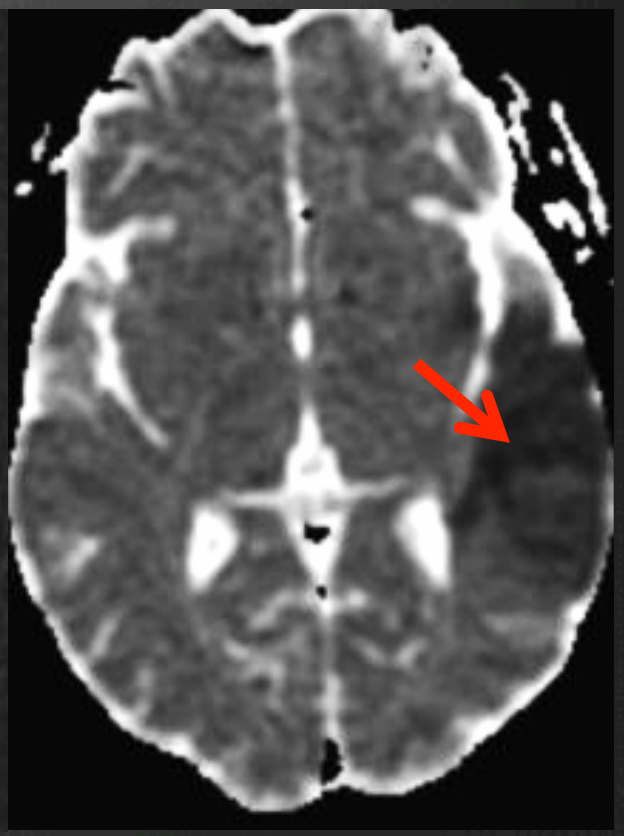
Recognize CT signs of early ischemic change (EIC)



Recognize CT signs of early ischemic change (EIC)

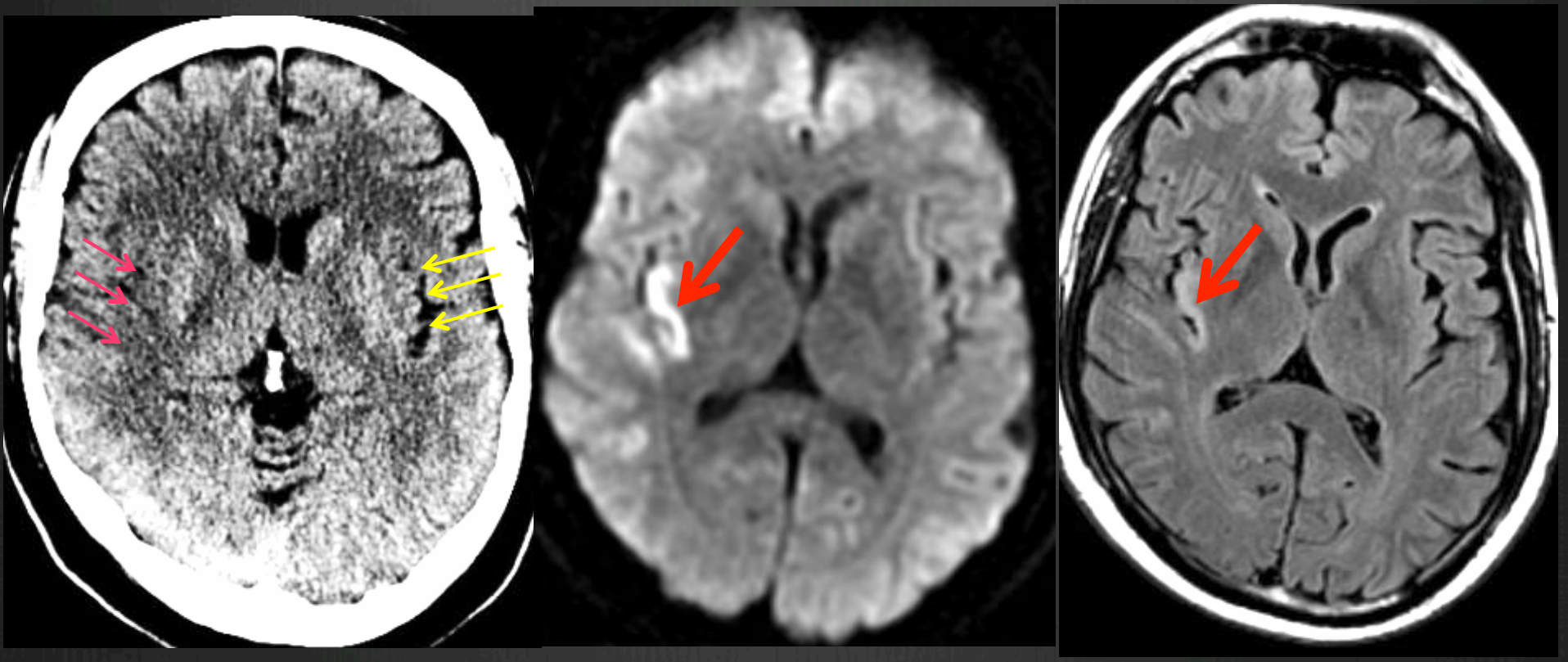


Diffusion



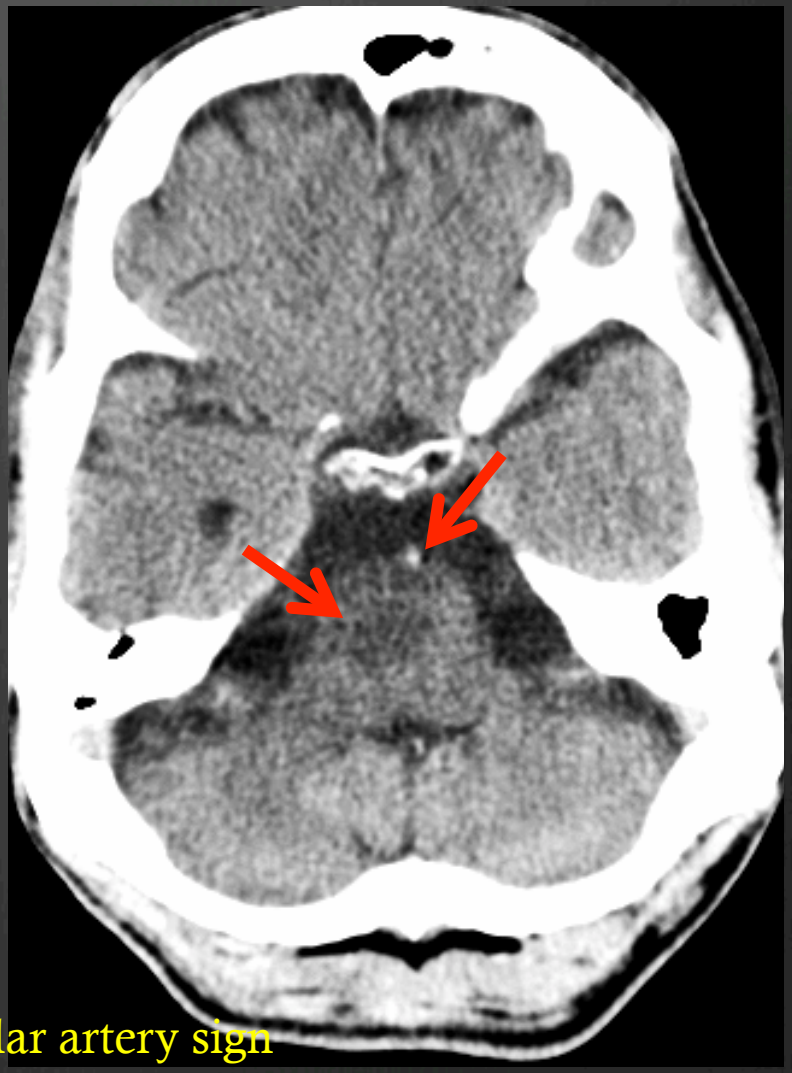
ADC Map

Recognize CT signs of early ischemic change (EIC)



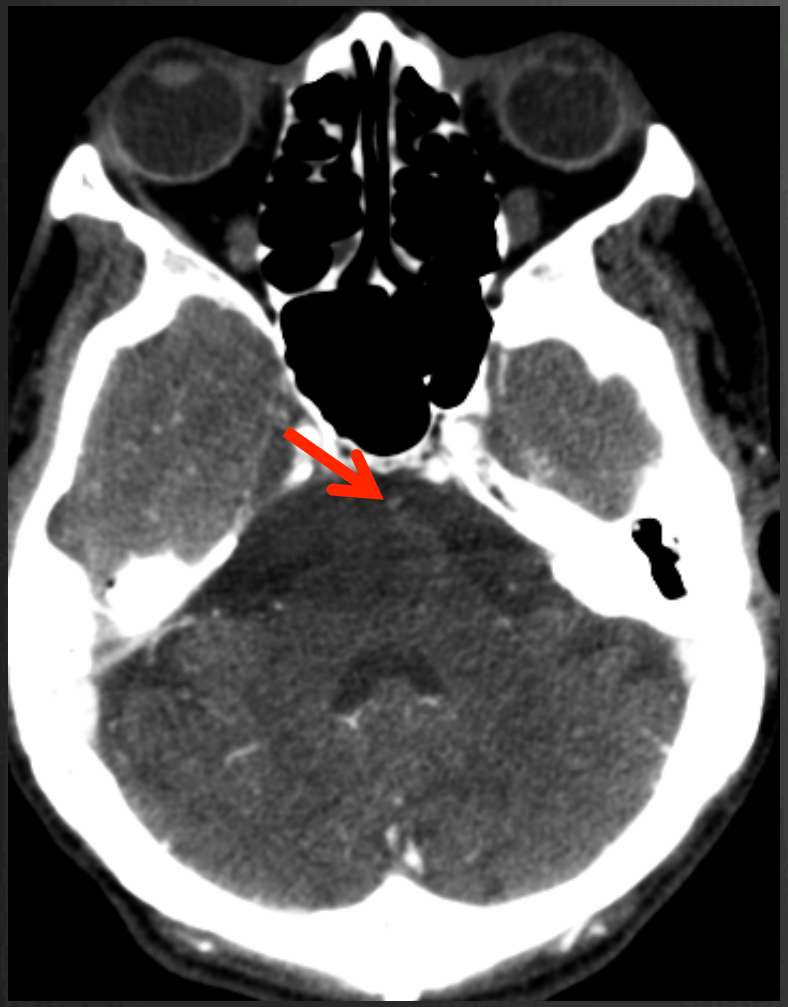
Insular ribbon sign

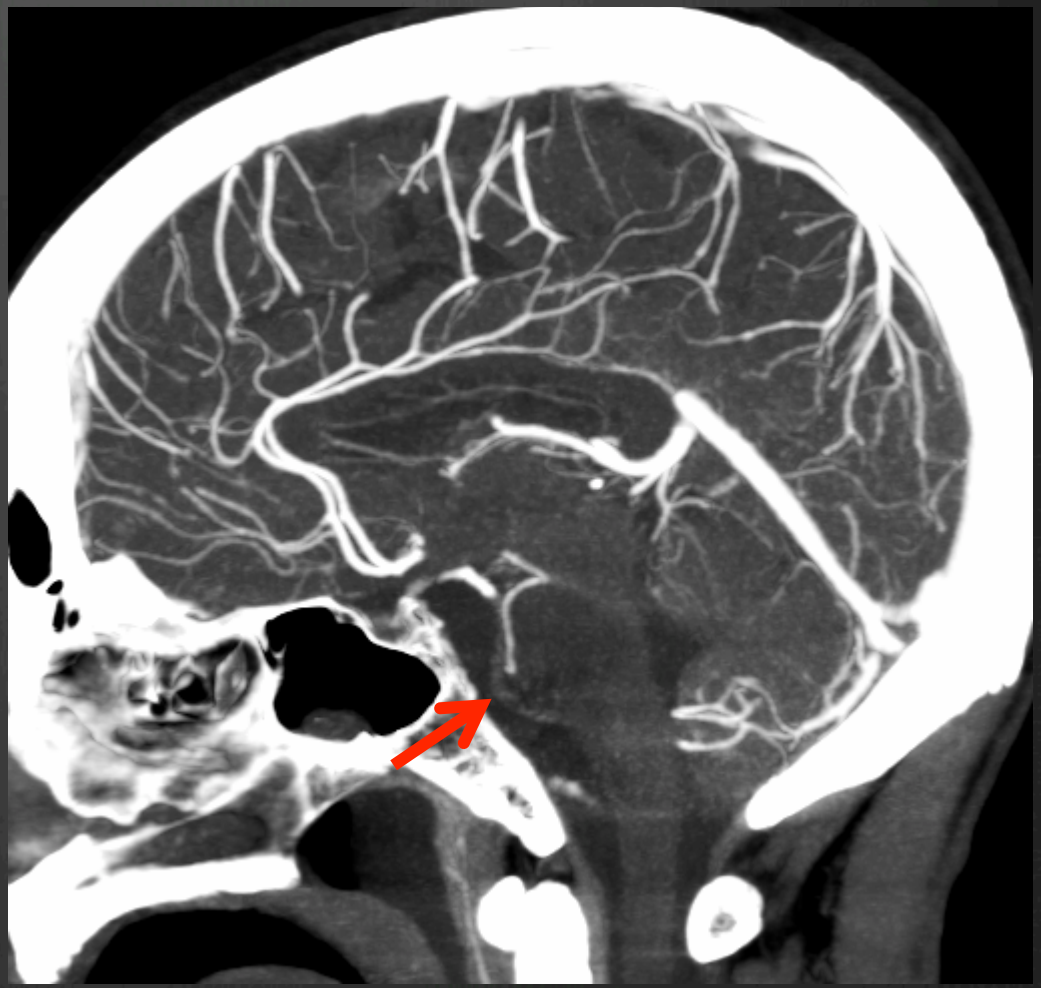
Recognize CT signs of early ischemic change (EIC)



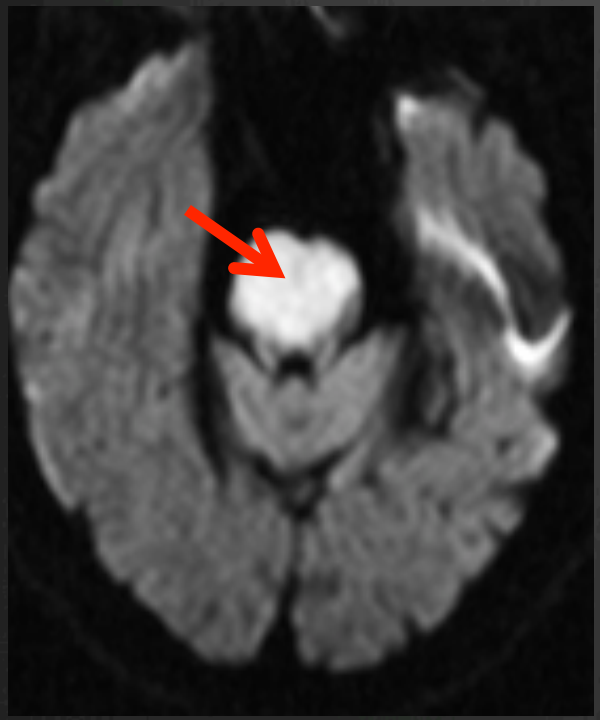
Hyperdense Basilar artery sign

Recognize CT signs of early ischemic change (EIC)

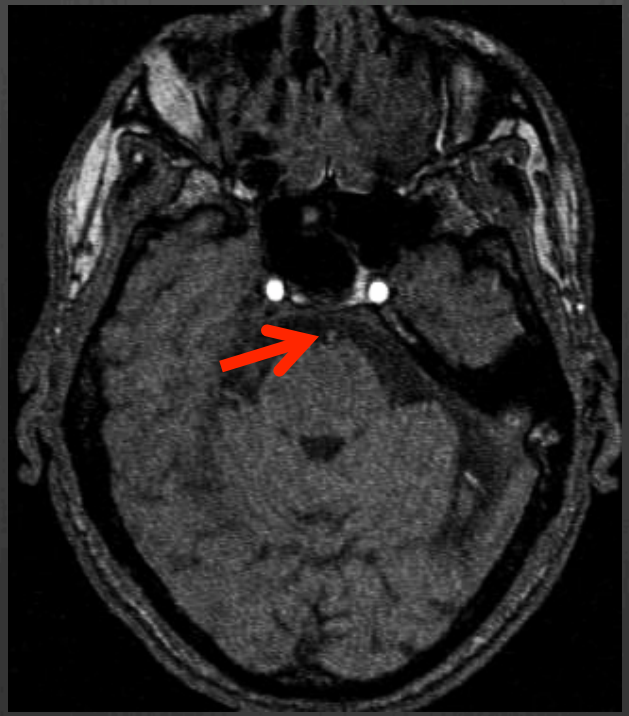




Recognize CT signs of early ischemic change (EIC)



Diffusion



MRA- Source image

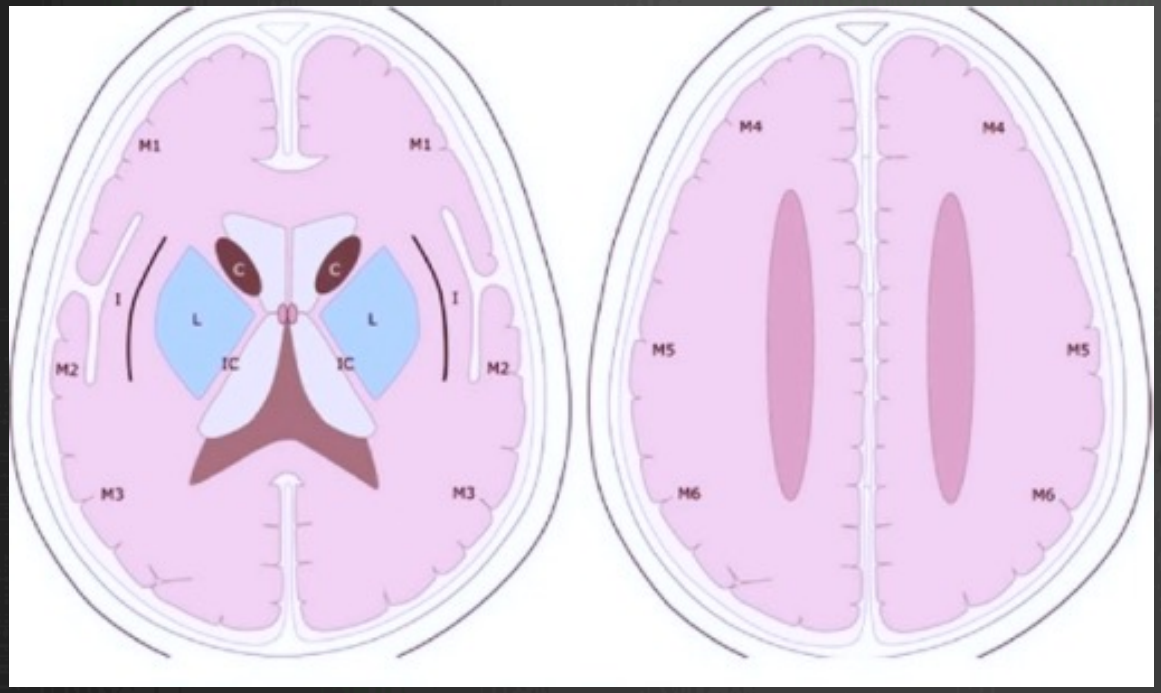
MRA- MIP

How extensive is the edema ?
> 1/3 MCA territory

Need for ASPECTS

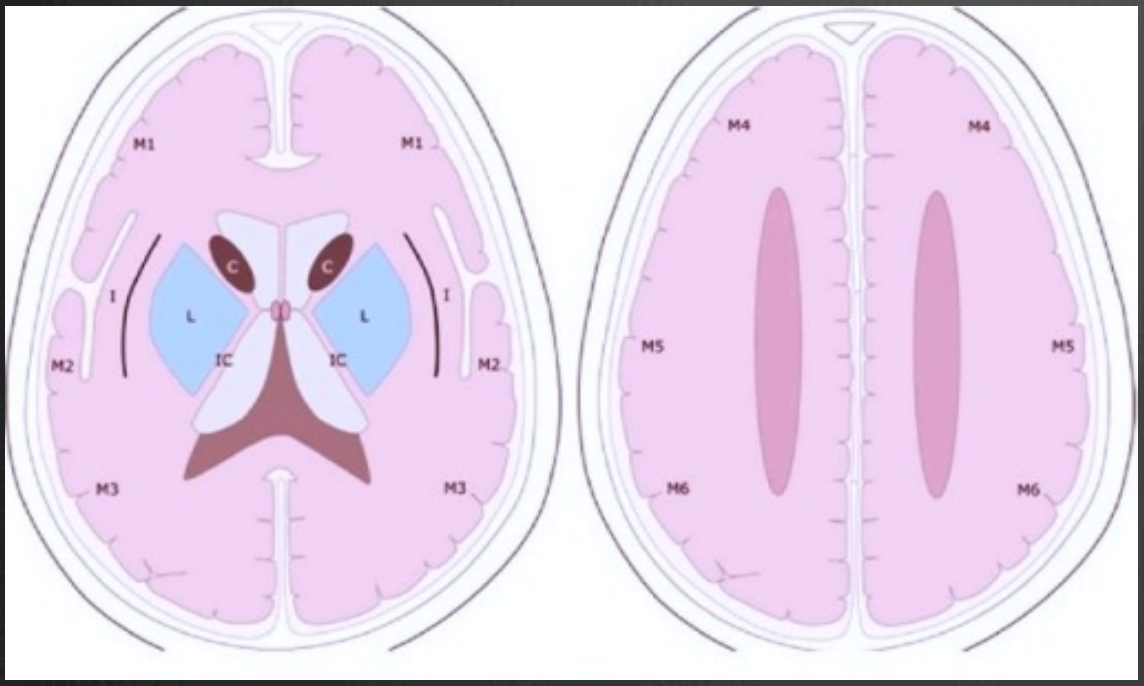
- Extent of early ischemic changes (EIC) is an important predictor of the response to thrombolysis
- Thrombolysis increases the chance of good functional outcome in patients with a small (less than 1/3 of the MCA territory) hypoattenuating area on NCCT scan
- Volume estimation with the one-third rule is difficult in routine practice
- ASPECTS was developed to standardize detection and reporting of the extent of ischemic hypodensity.

How to compute ASPECTS

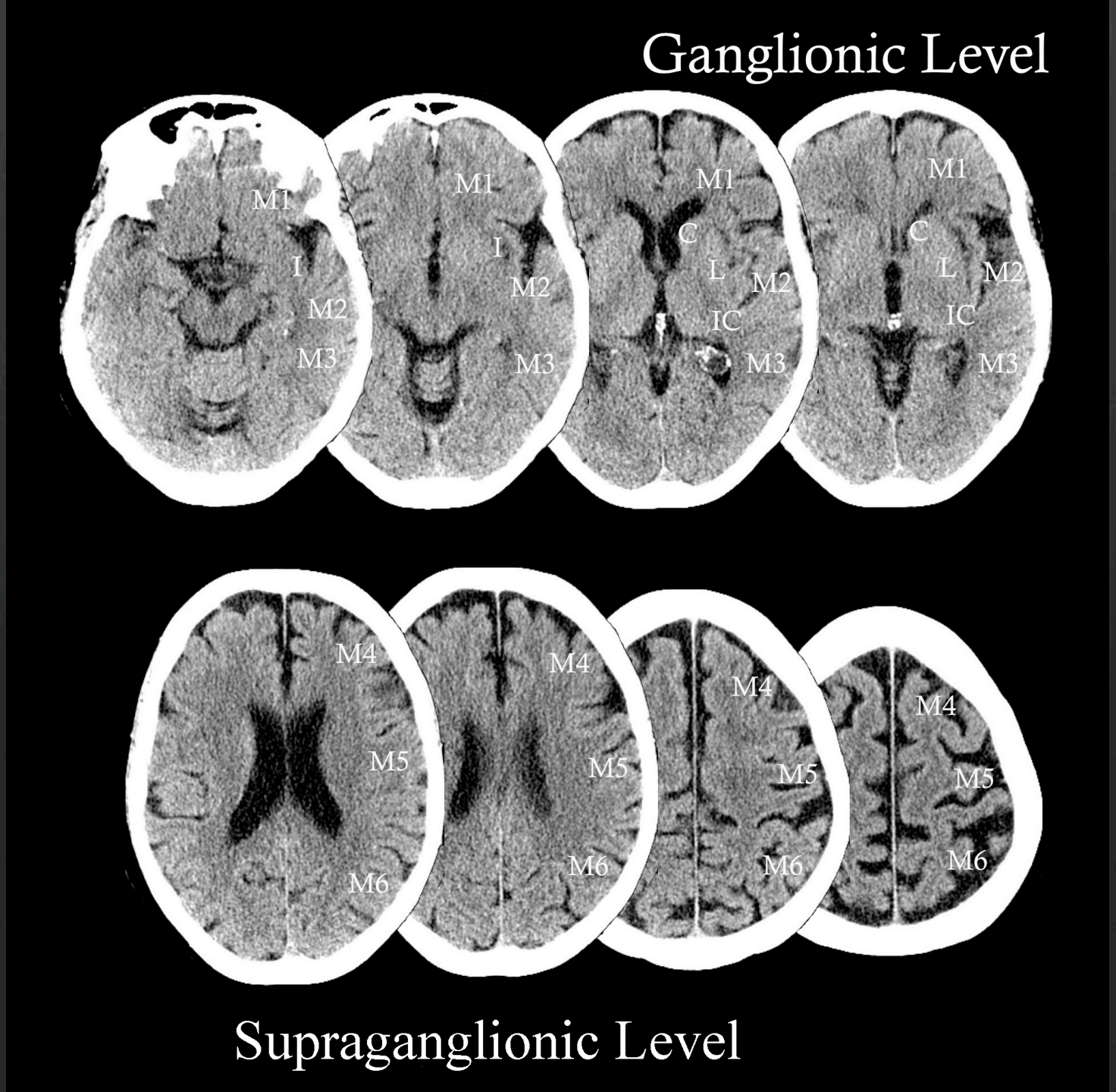


- Two standardized regions of the MCA territory: the basal ganglia level and the supraganglionic level.
- Abnormality should be visible on at least two consecutive cuts to ensure that it is truly abnormal rather than a volume averaging effect

How to compute ASPECTS



- 1 point is subtracted from 10 for any evidence of early ischemic change (EIC) for each of the defined regions.
- Normal CT scan - ASPECTS of 10 points.
- Score of 0 - diffuse involvement throughout the MCA territory


Ganglionic Level
M1
I
M2
M3
M1
I
M2
M3
M1
C
L
M2
IC
M3
M1
C
L
M2
IC
M3
M4
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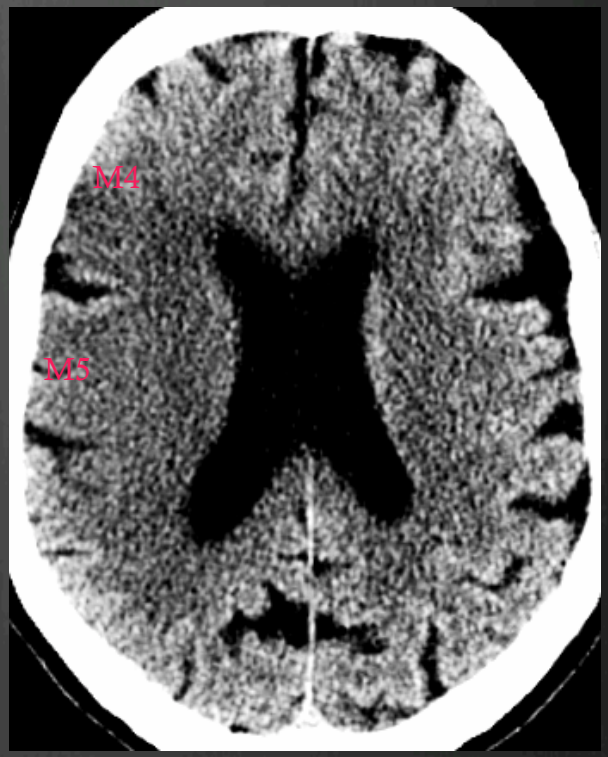
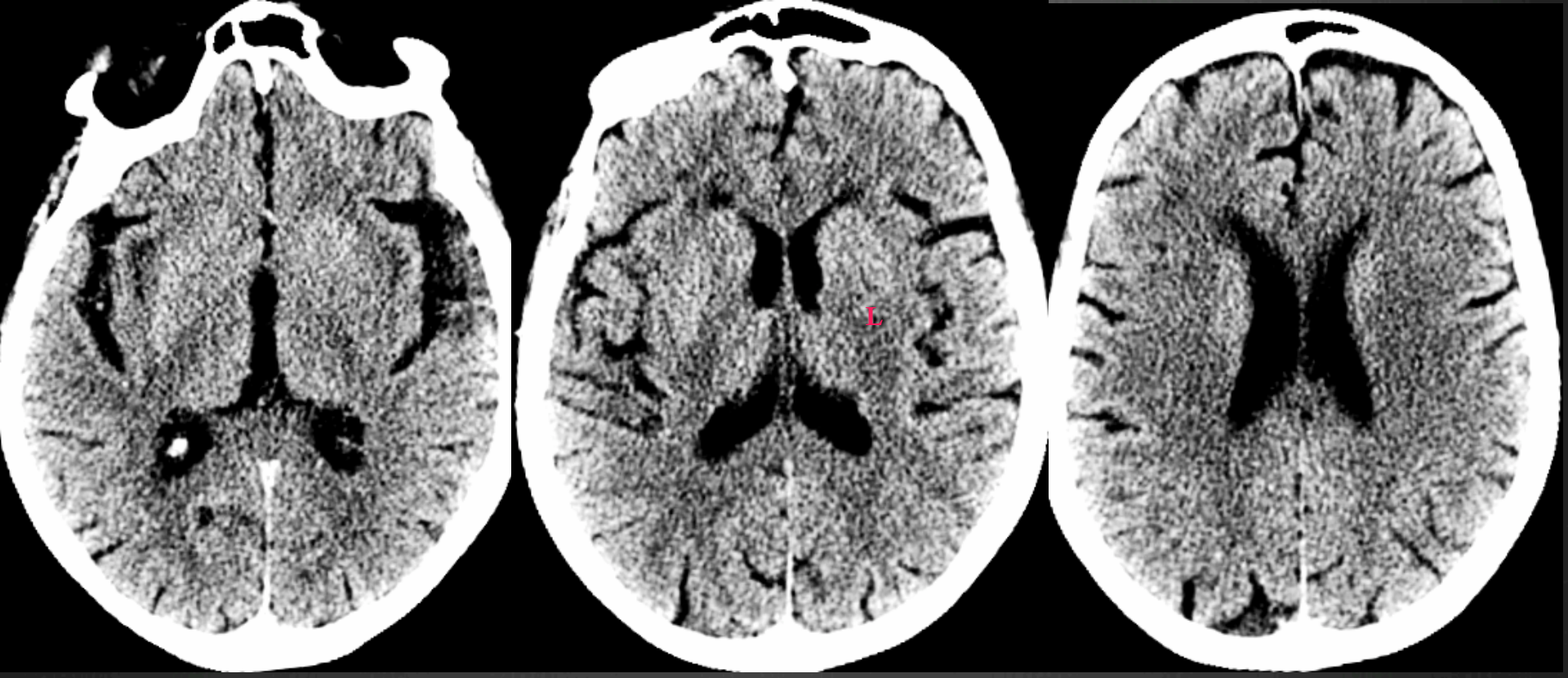
M6
M4
M5
M6
M4
M5
M6
M4
M5
M6
Supraganglionic Level



- 72 yr old female presented with acute onset of left side weakness and aphasia
- Regions involved right lentiform, insula, M1, M2, M4 & M5
- Score 10-6 = 4



- 65 yr old male presented with acute onset of right side weakness
- Region involved left lentiform nucleus
- Score 10-1 = 9

Use of ASPECTS in acute ischemic stroke

- Within the first 3 h of MCA stroke onset

Baseline ASPECTS $\propto$ 1/severity of NIHSS & functional outcome

- Scores of 7 or less correlated with poor functional outcome and symptomatic intracerebral hemorrhage
- Scores of 8-10 associated with a greater extent of benefit from i.v. thrombolysis

How we use ASPECTS in acute ischemic stroke

2015 AHA/ASA Update on guidelines for early management of patients with acute ischemic stroke regarding endovascular therapy.

Patients should receive endovascular therapy with a stent retriever if they meet all the following criteria

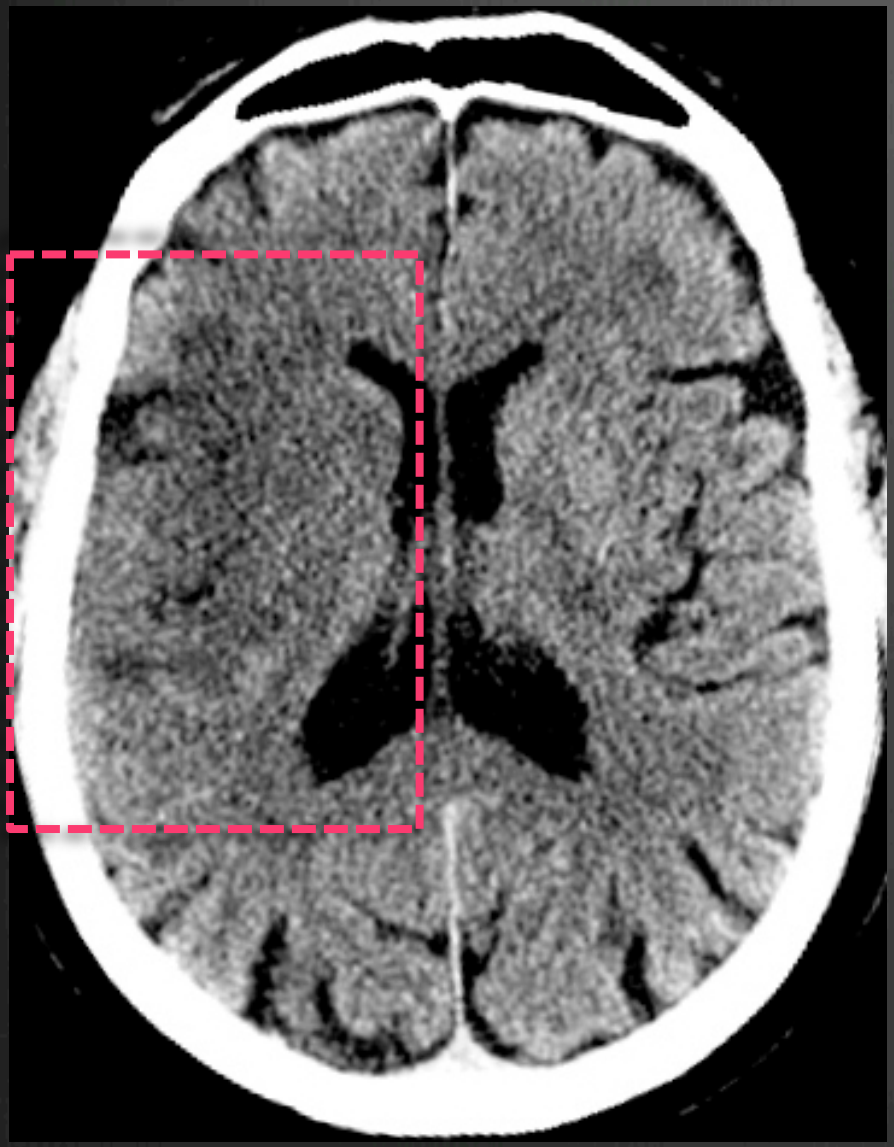
- A) Prestroke mRS score 0 to 1
- B) Acute ischemic stroke receiving r-TPA within 4.5 hrs of onset according to guidelines
- C) Occlusion of ICA or proximal MCA
- D) Age ≥ 18 years
- E) NIHSS score of ≥ 6
- F) ASPECTS of ≥ 6
- G) Treatment can be initiated within 6 hrs of symptom onset

Factors affecting scan quality

- Vendor and age of the CT scanner
- Spiral/conventional scanning (conventional scanning better than spiral)
- kV and mAs ,Slice thickness and collimation
- Patient movements during scan
- Optimal window setting – CT stoke windows

Limitations of ASPECTS

- Acute-on-chronic infarct
- Acute infarcts with periventricular white matter changes
- Difficult to score ASPECTS in patients having extensive age-related periventricular changes
- ASPECTS scoring - MCA territory infarcts only. Look for ACA and PCA territory.
- Poor scan quality like motion artifacts or tilt can lead to incorrect ASPECTS scoring



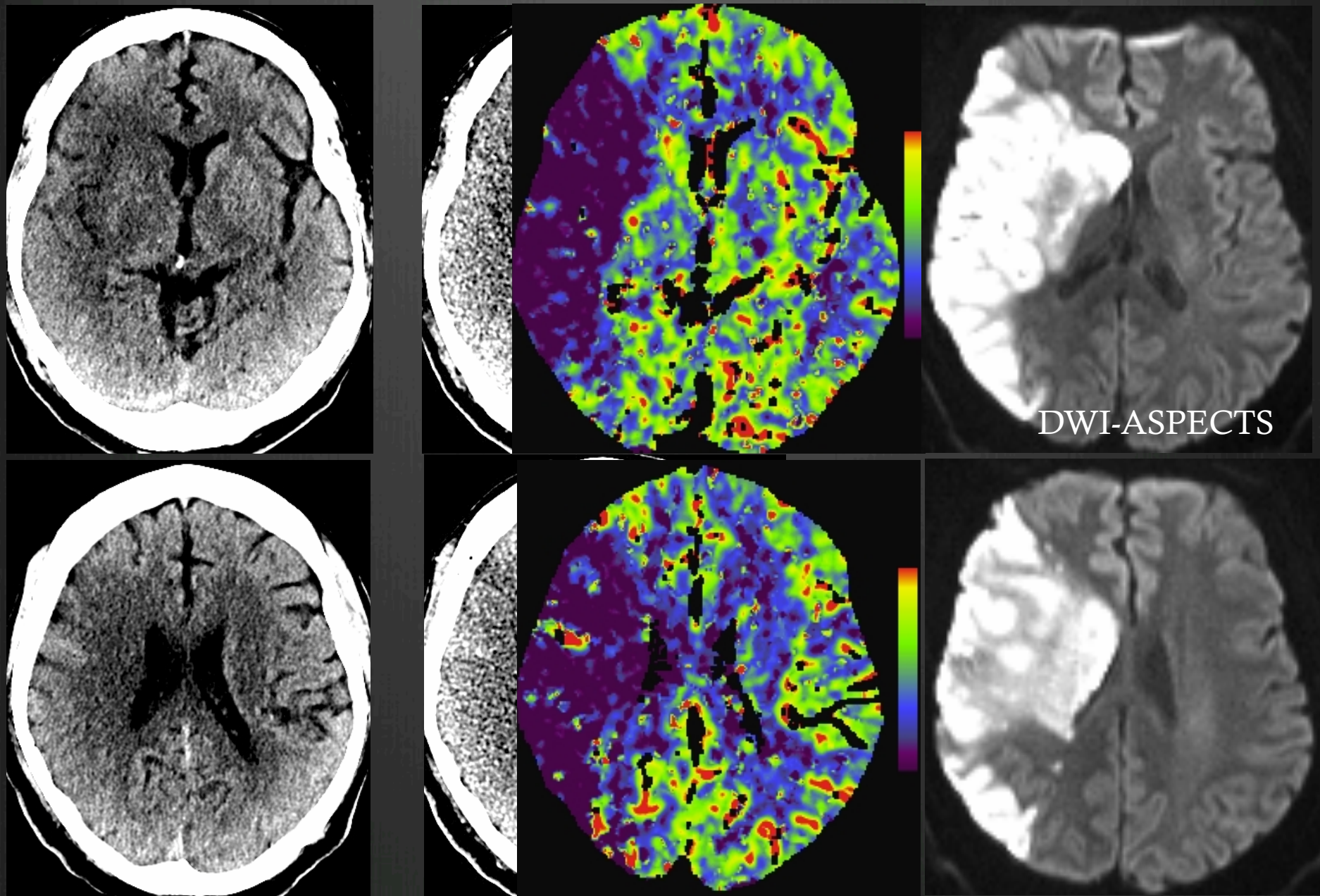

512

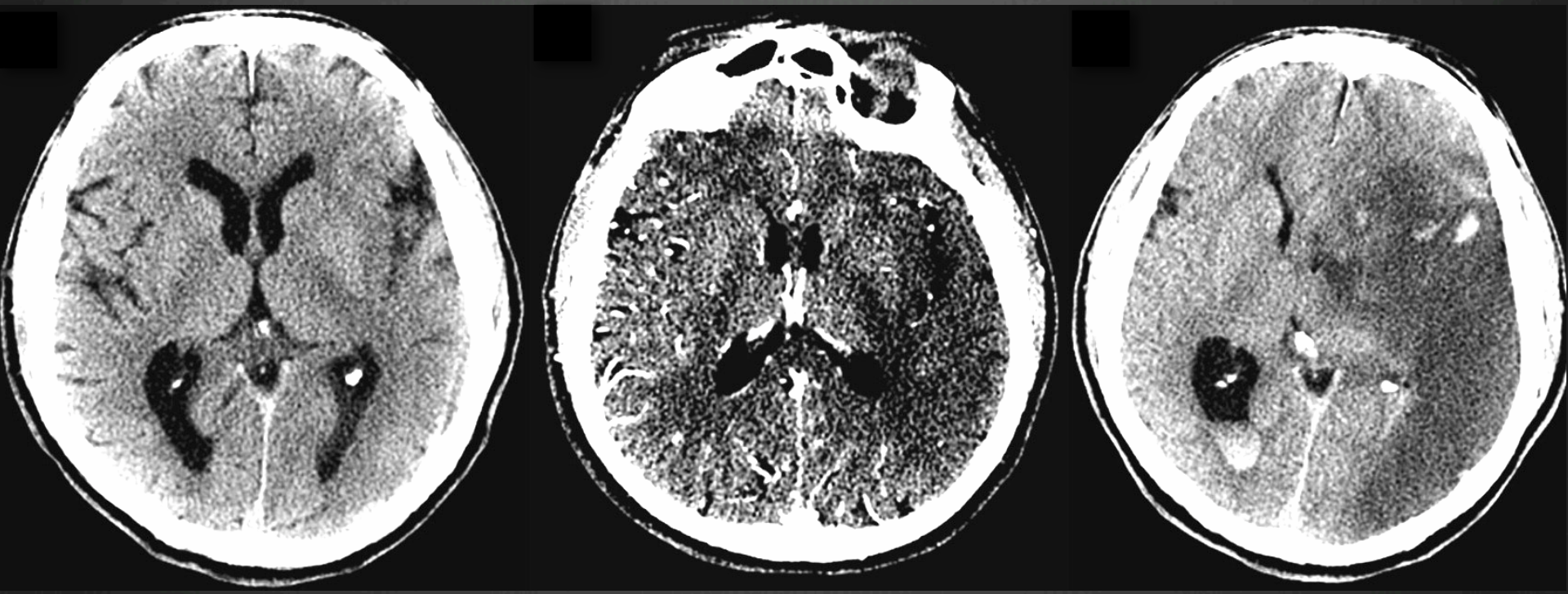

Extension of ASPECTS

- CTA-SI ASPECTS
- CT/MR Perfusion ASPECTS
- DWI ASPECTS
- Posterior circulation Pc-ASPECTS

CTA-SI ASPECTS

CTP ASPECTS





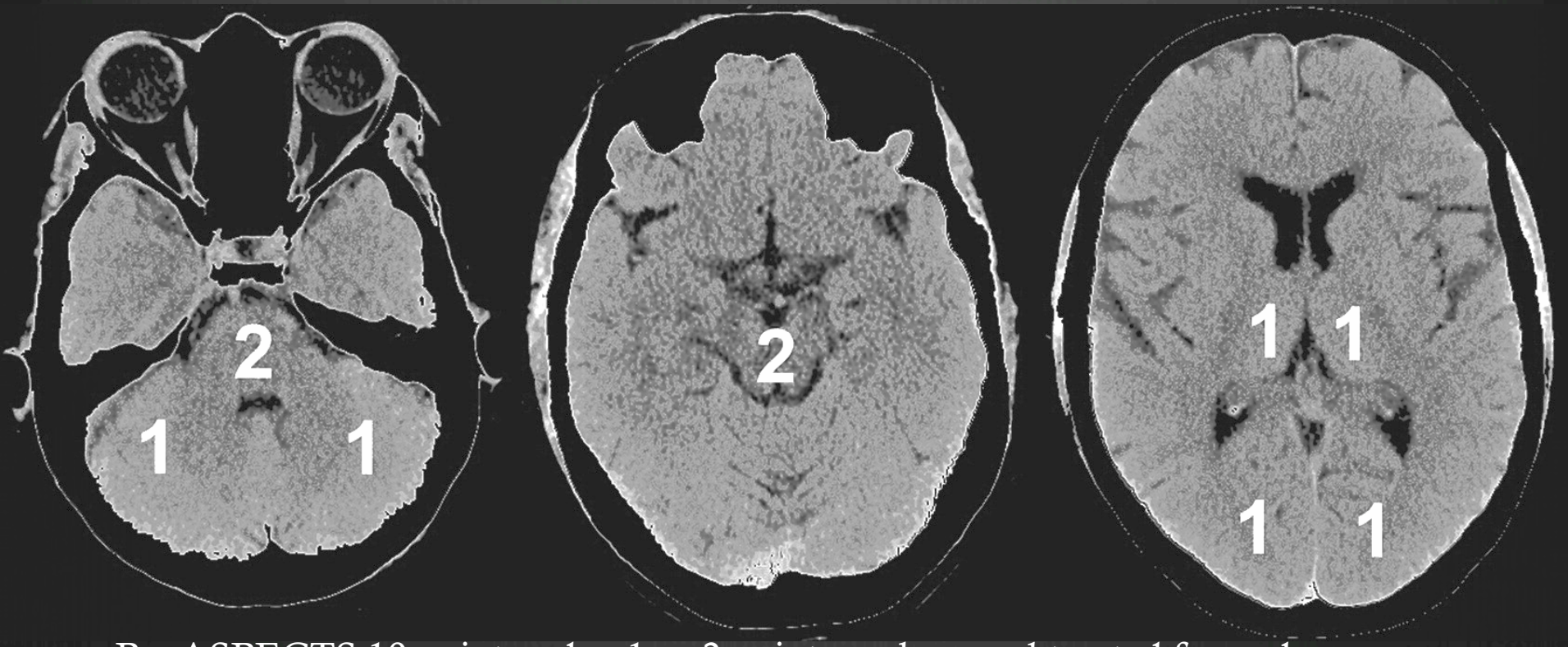
Patient with carotid T-occlusion.

NCCT – EIC left basal ganglia & insula NCCT ASPECTS 7

CTA-SI ASPECTS 3

Follow up NCCT – malignant MCA infarction

Pc- ASPECTS

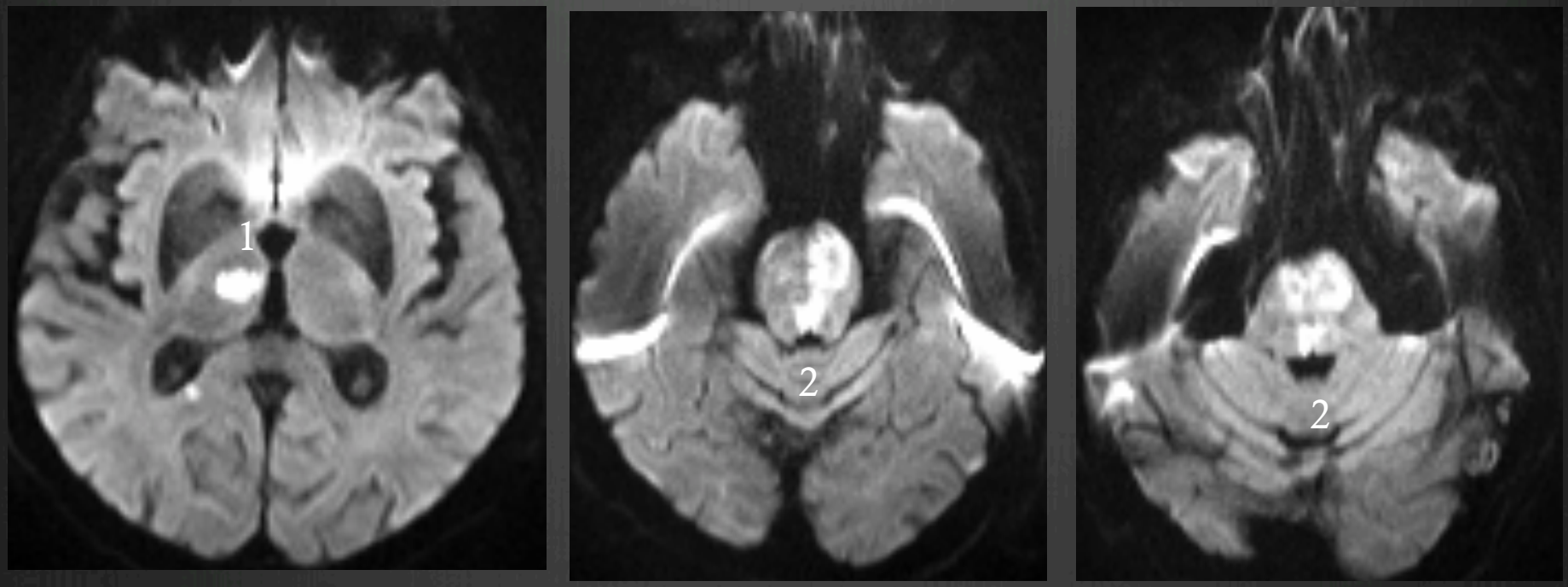


Pc- ASPECTS 10 point scale , 1 or 2 points each are subtracted for early ischemic changes. NCCT, CTA-SI, DWI MR

Pc-ASPECTS 10 – indicates normal scan

Pc-ASPECTS 0 - extensive posterior circulation infarction.

Pc- ASPECTS



Pc-ASPECTS 10 – 5 = 5

Pc-ASPECTS on diffusion MR can be a powerful marker for predicting functional outcome.

J Neurol. 2010 May;257(5):767-73

Diffusion MRI

MRI-Ultrafast Stroke Protocol

- Diffusion – 00.56 min
- Axial GRE – 2.11 min
- Axial FLAIR – 00.50 min
- 3D-TOF MRA – 3.25 min
- MR perfusion – DSC (CBV,CBF,TTP,MTT) 1.53 min
- MRA neck + contrast – 00.50 min

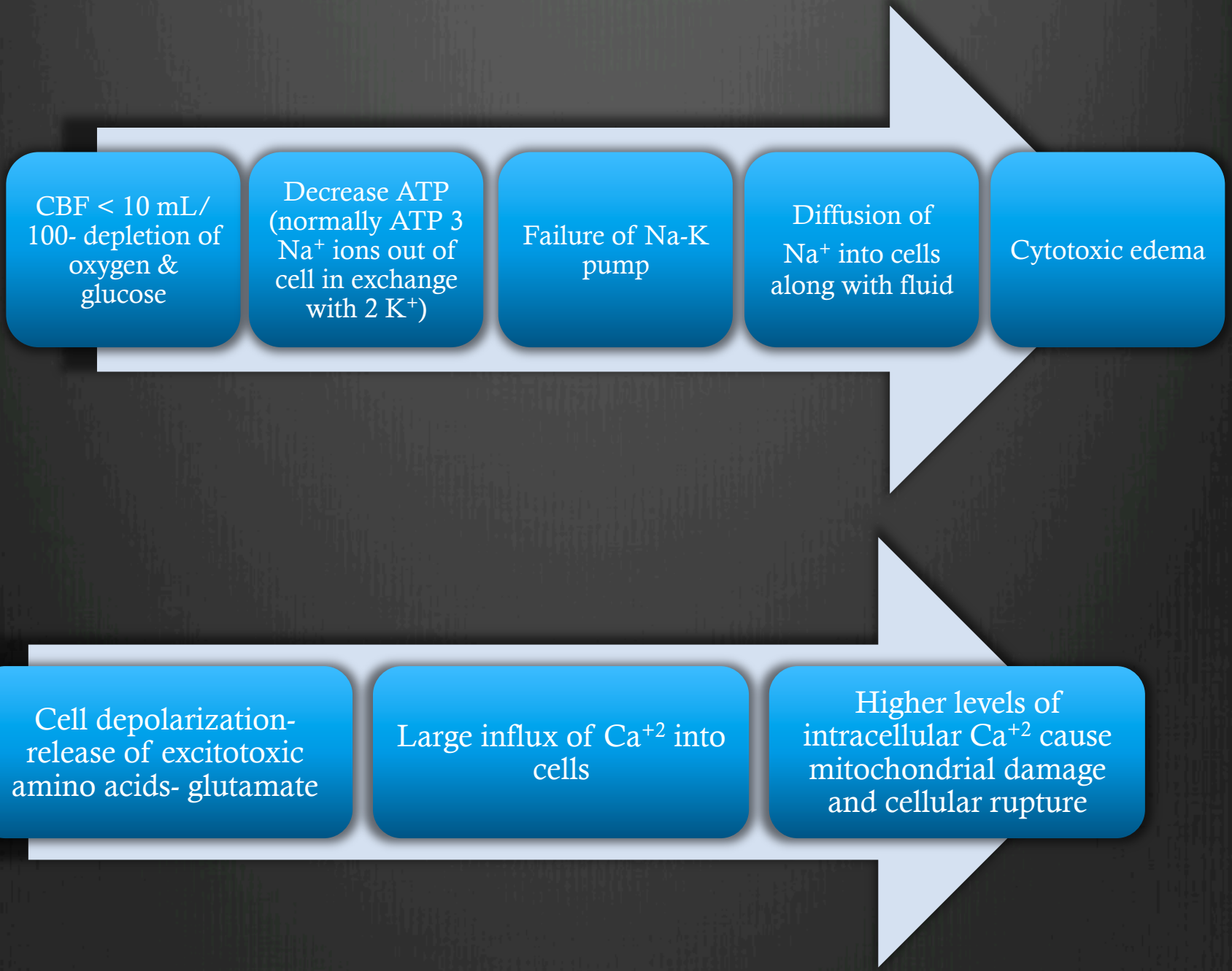
- Total time 10-12 minutes

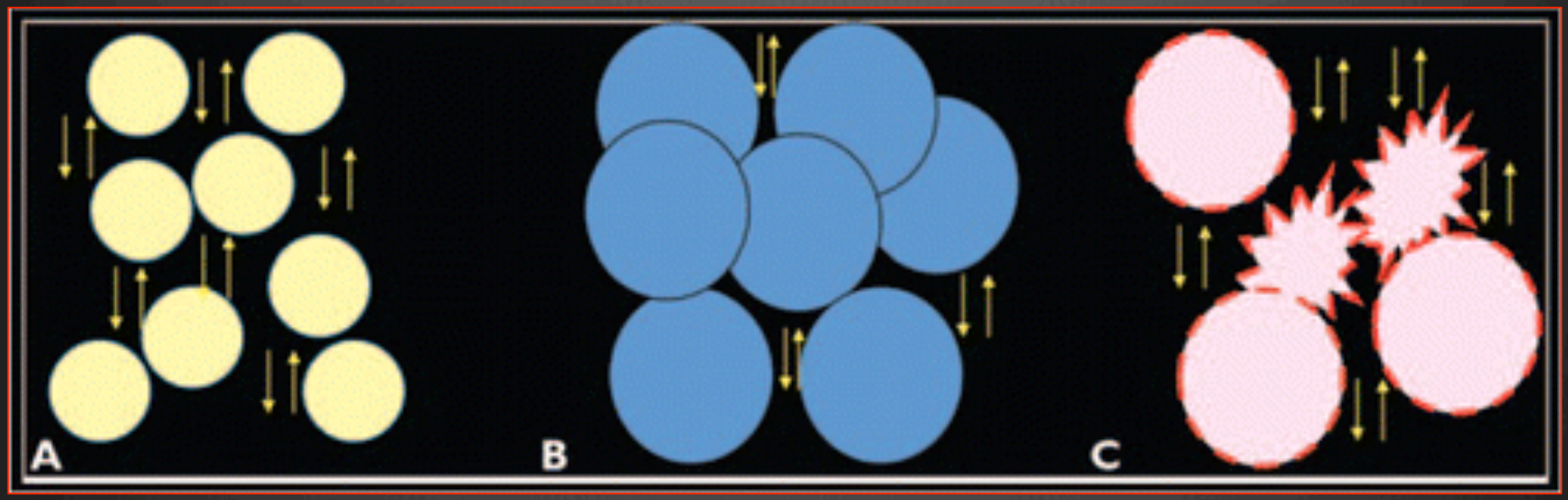
Acute Infarct

- Early cortical swelling, FLAIR parenchymal hyperintensity approx 6 hrs post ictus.
- T2 hyperintensity develops by 12-24 hrs.
- Gradient echo T2*/SWI - detection of acute blood products, ‘blooming’ artifact from thrombosed vessel due to clot susceptibility .

Diffusion

- Diffusion MRI is the best available method for the early detection of the infarct core
- DWI abnormalities sometimes reverse, but this is rare, and when it occurs, it usually involves only a small part of the lesion
- DWI abnormality volume of >70 mL is highly specific for a poor outcome

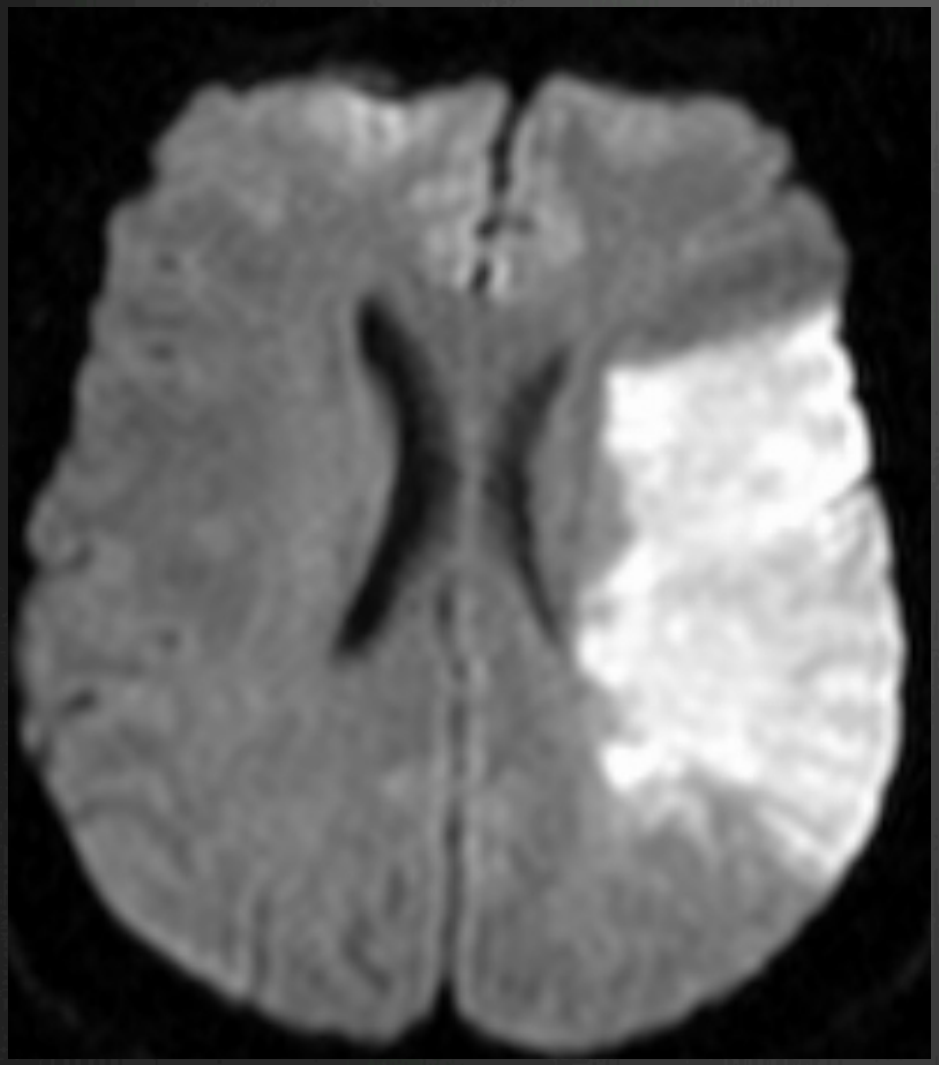

CBF < 10 mL/ 100- depletion of oxygen & glucose
Decrease ATP (normally ATP 3 Na^+ ions out of cell in exchange with 2 K^+)
Failure of Na-K pump
Diffusion of Na^+ into cells along with fluid
Cytotoxic edema
Cell depolarization- release of excitotoxic amino acids- glutamate
Large influx of Ca^{+2} into cells
Higher levels of intracellular Ca^{+2} cause mitochondrial damage and cellular rupture



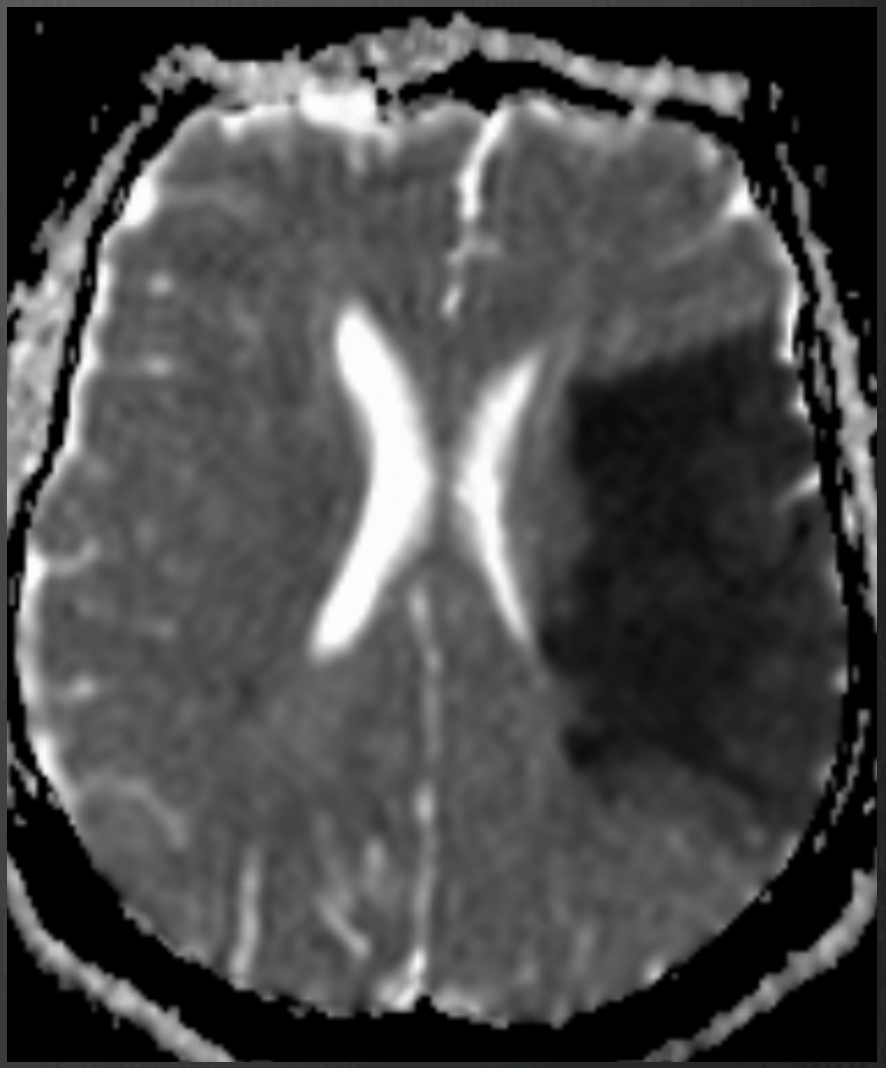
A, Arrows show normal brownian motion in extracellular space with normal-size cells.

B, Failure of sodium-potassium-ATP pump leads to intracellular edema, swelling of cells (cytotoxic edema), decreased extracellular fluid, and hence decrease in brownian motion.

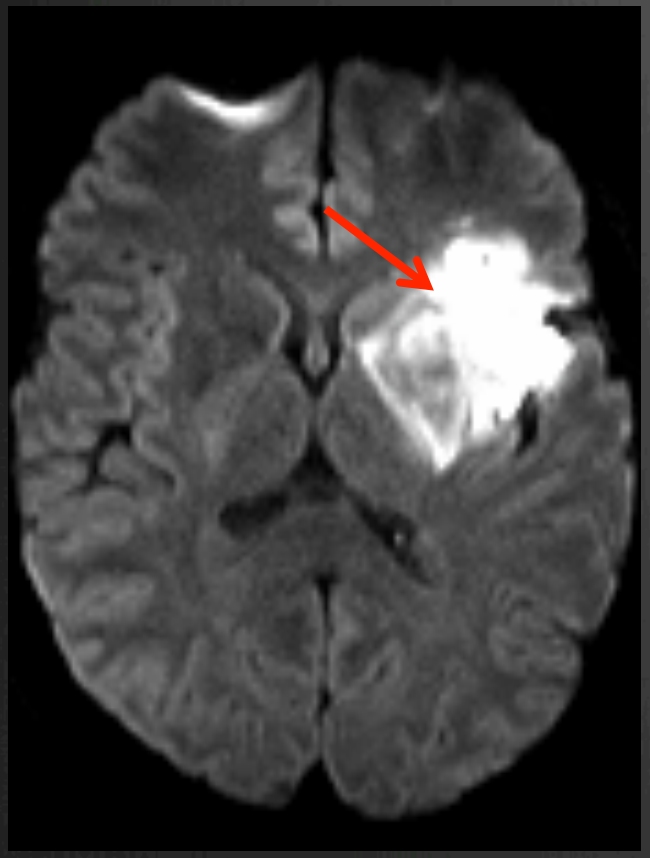
C, Large influx of Ca2+ inside cells leads to mitochondrial damage and cellular wall disruption, which in turn leads to cell rupture and increase in extracellular fluid (vasogenic edema).



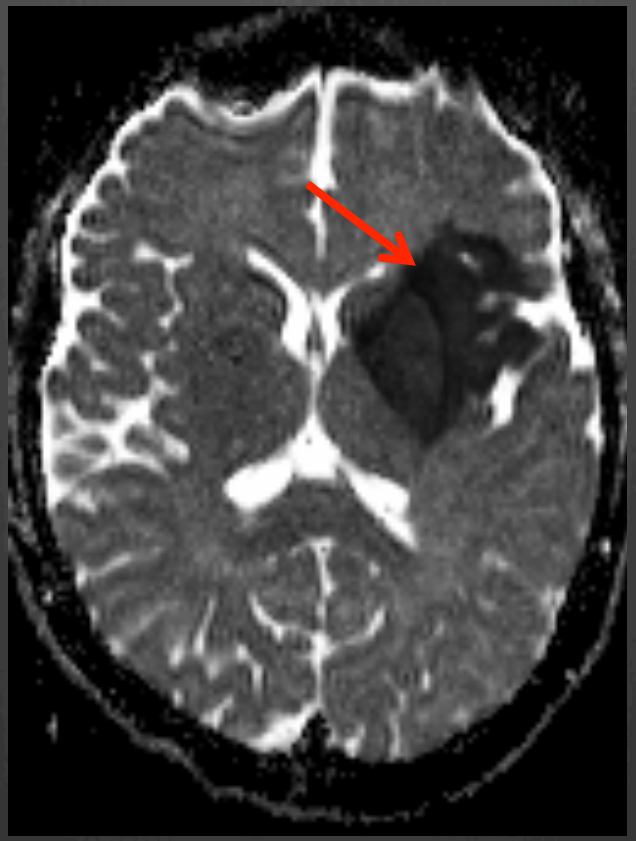
DWI Image



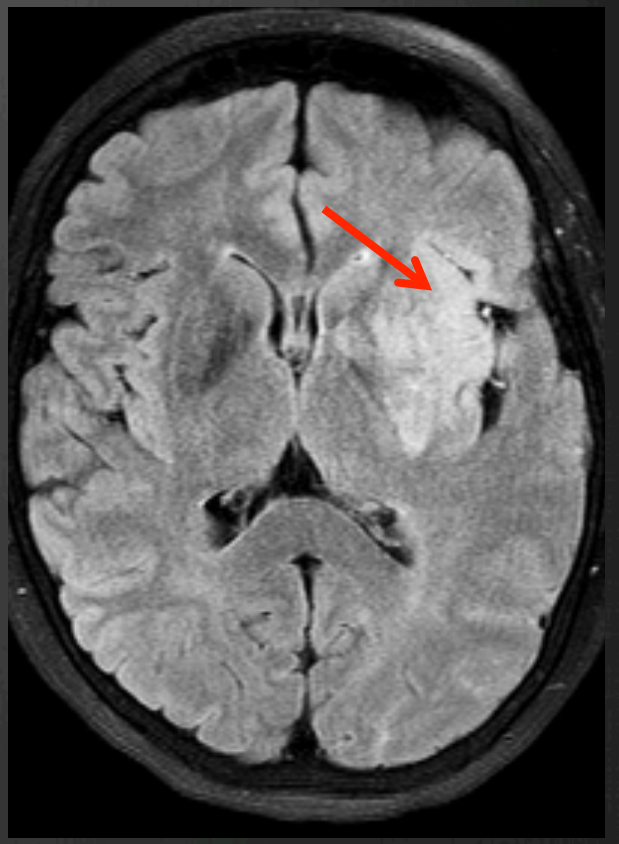
ADC Map



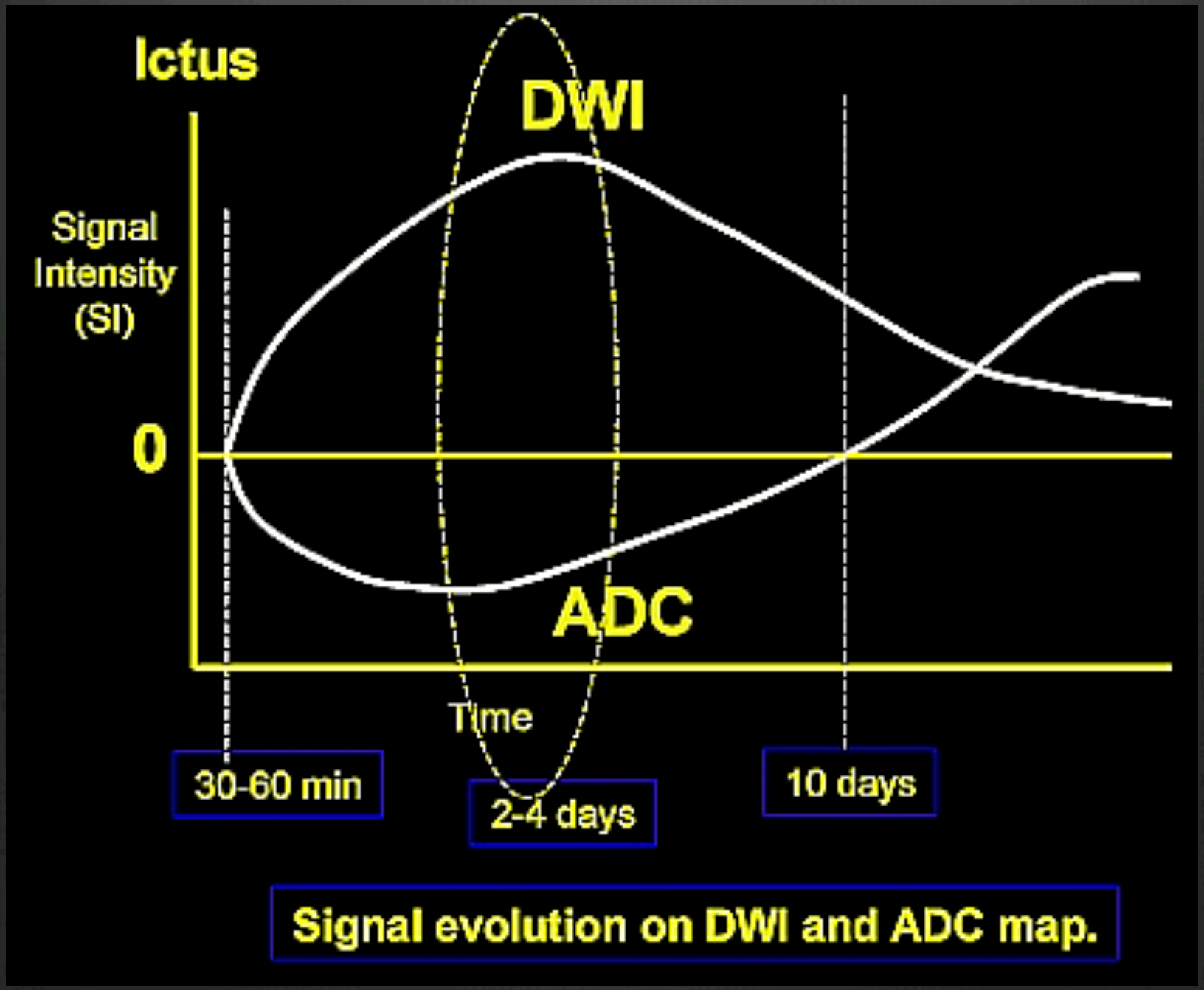
DWI



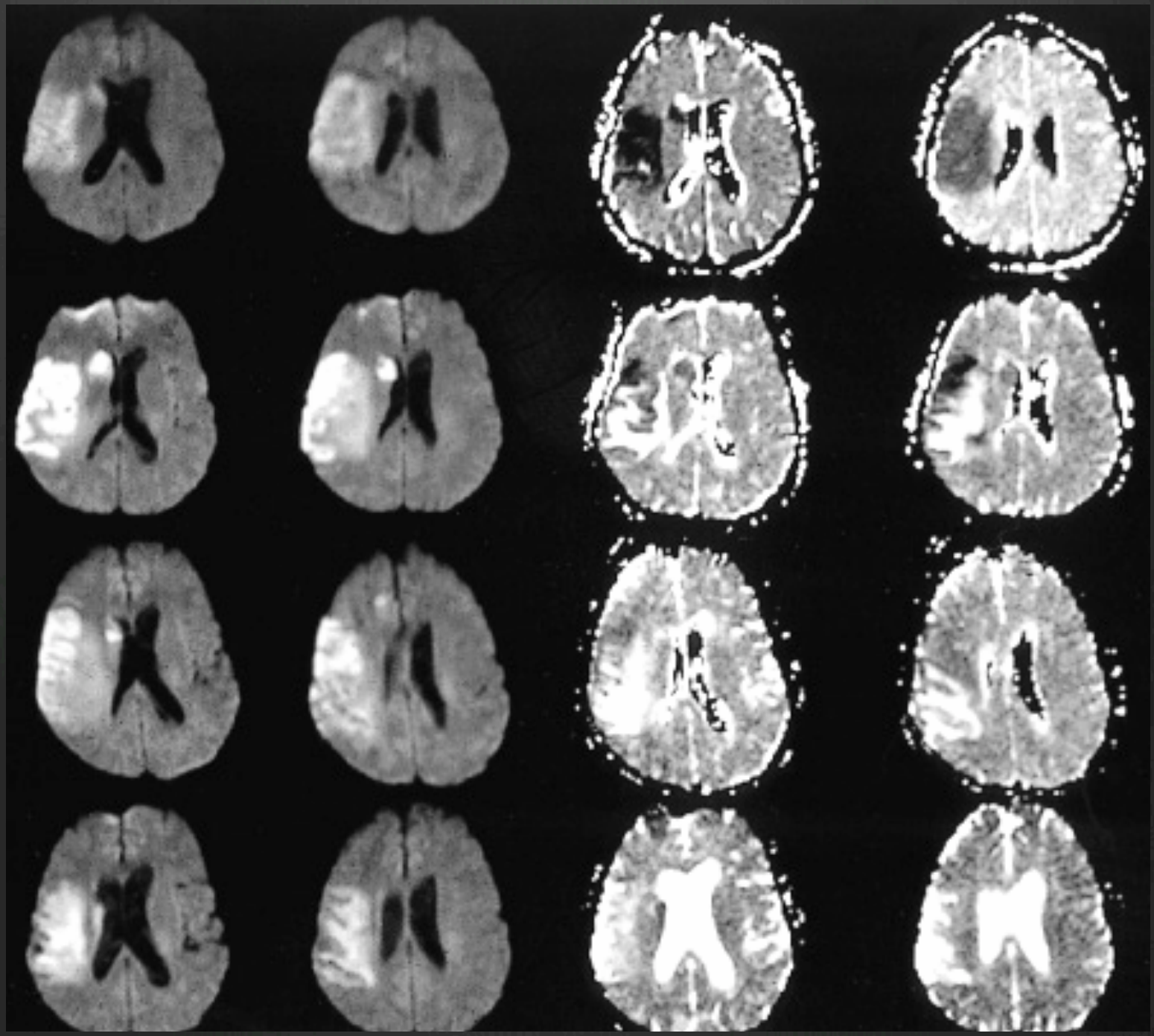
ADC



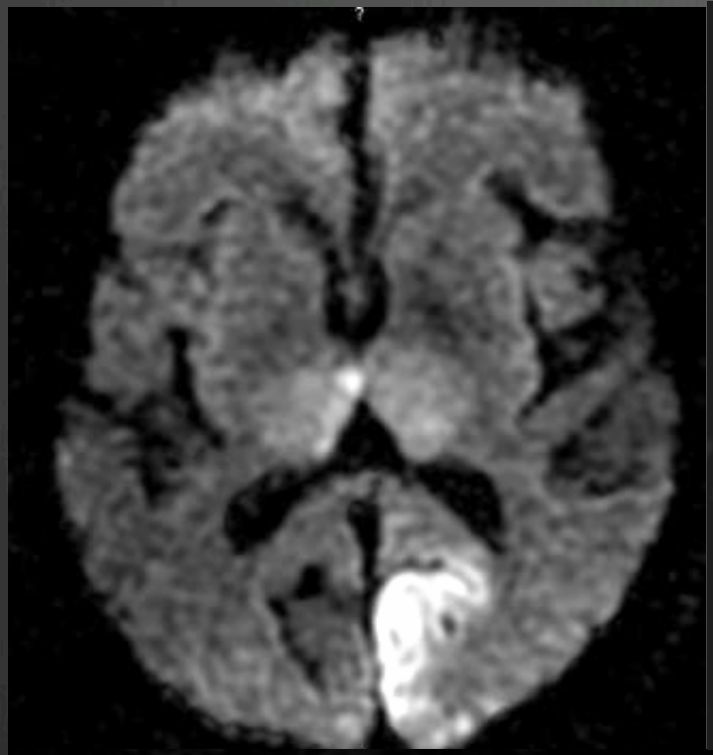
FLAIR

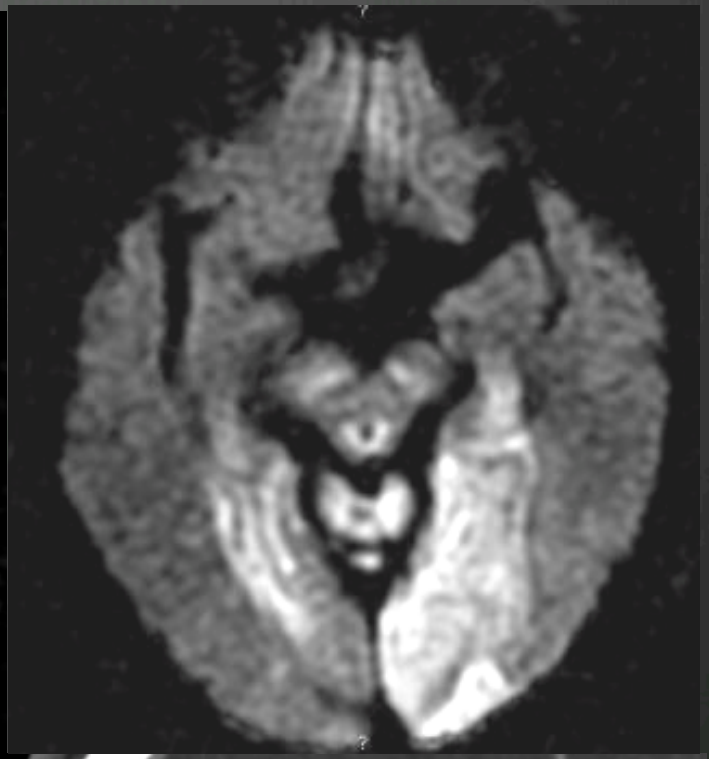


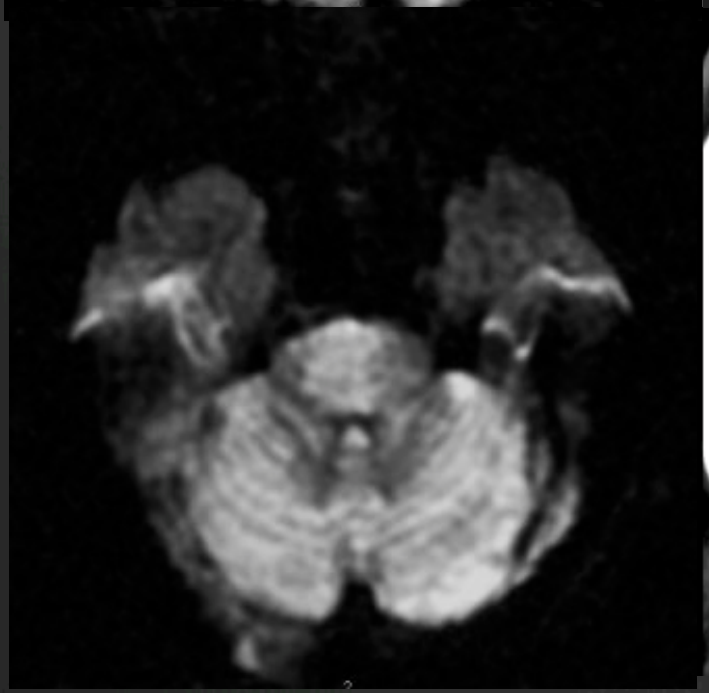
Signal evolution on DWI and ADC map.

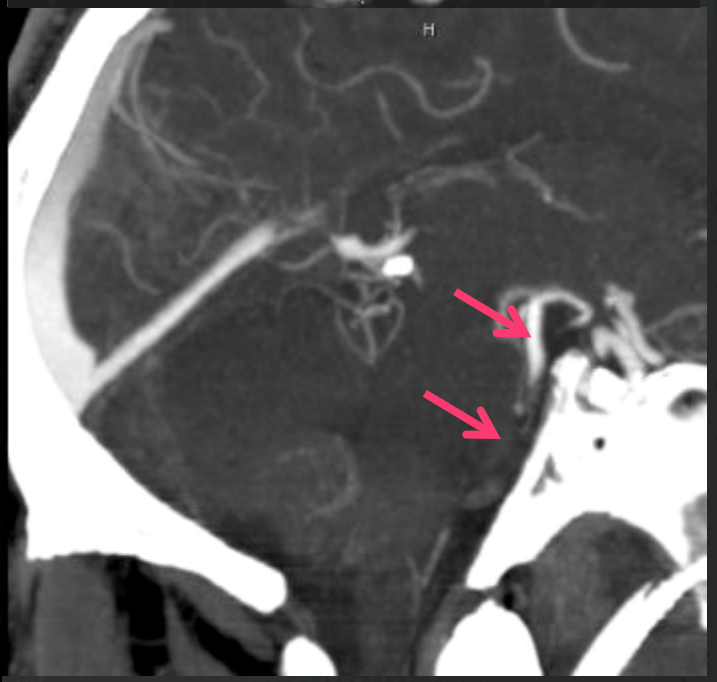

3 hrs
1.5 days
6 days
21 days

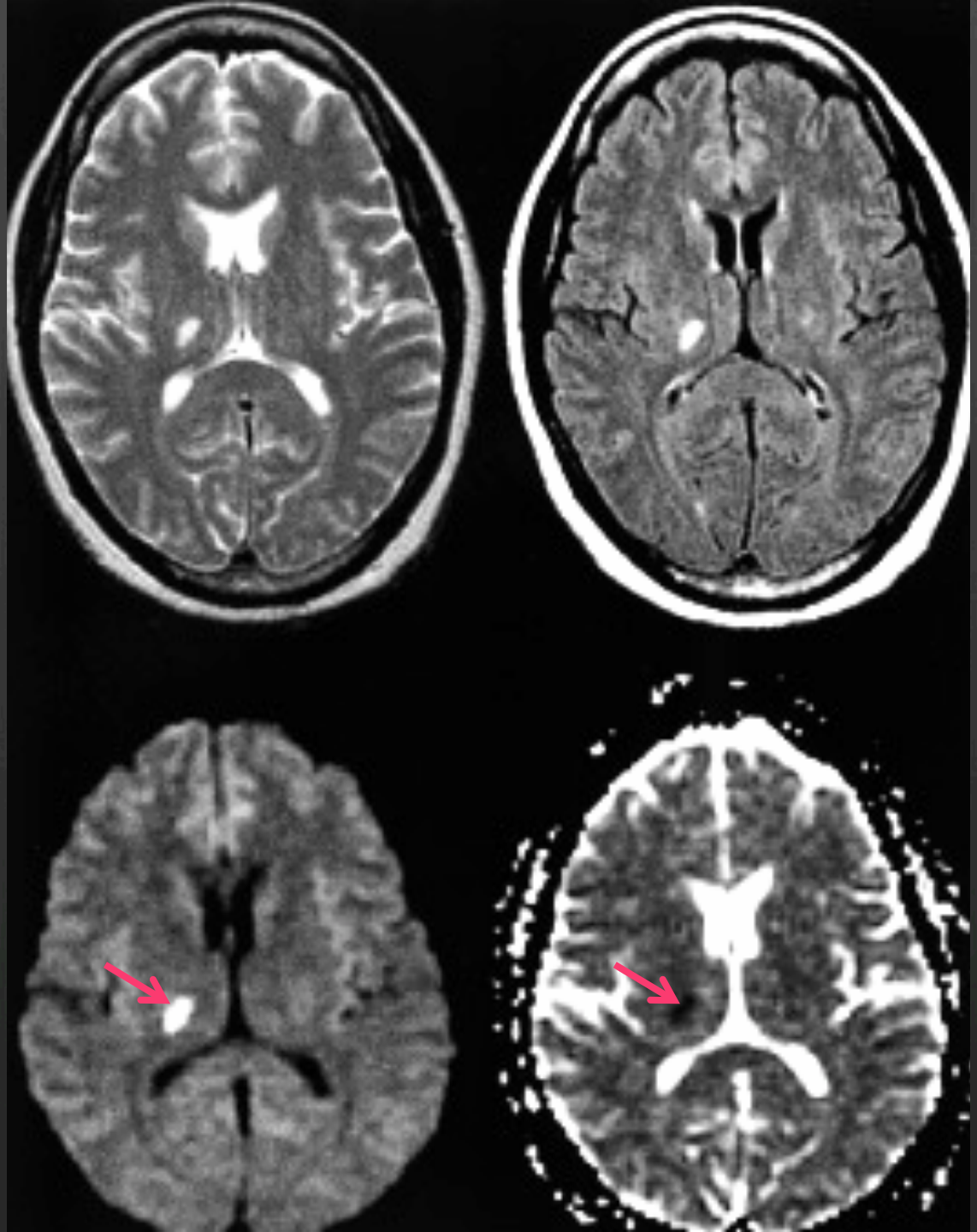
Posterior circulation infarction – Basilar artery thrombosis



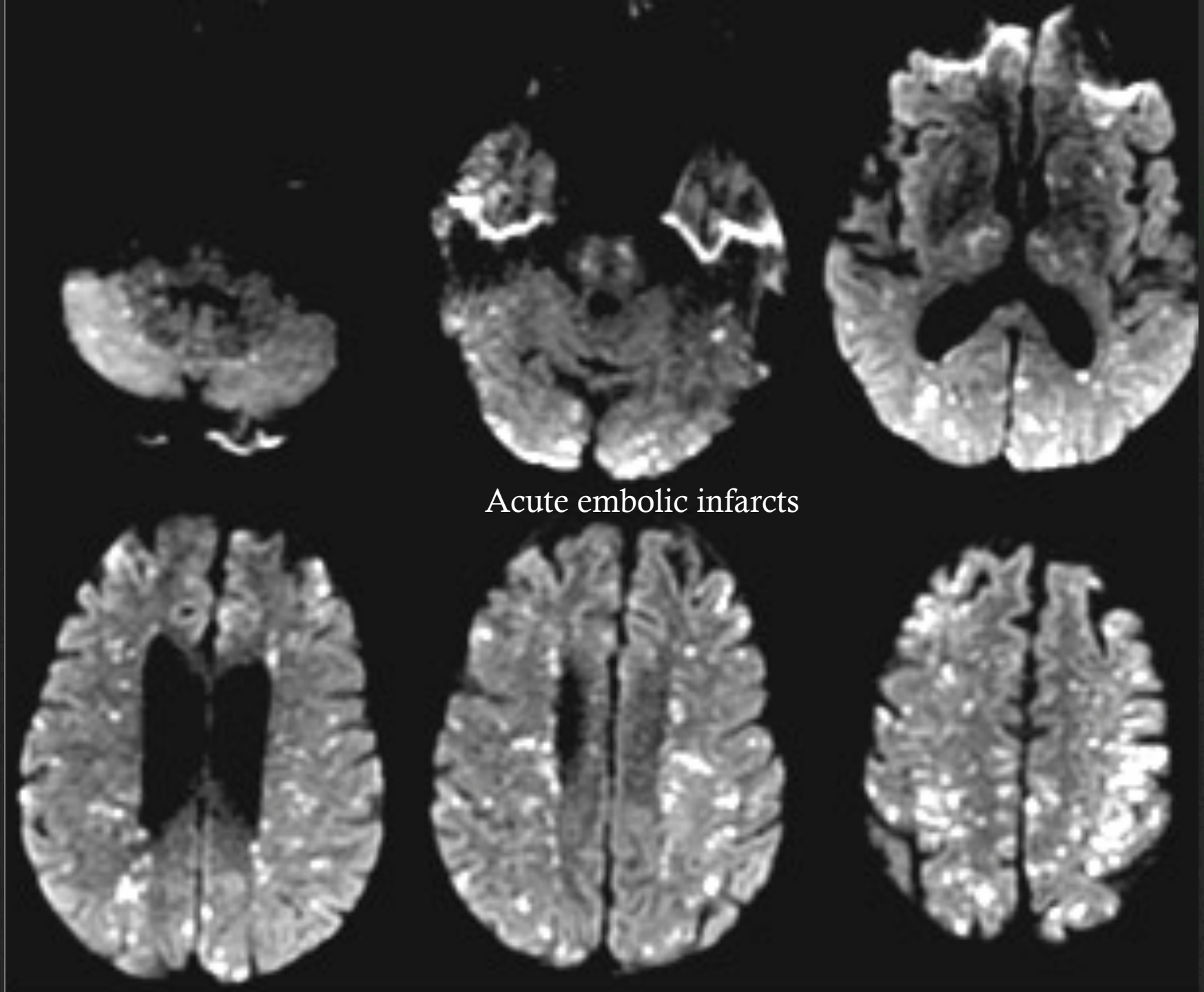




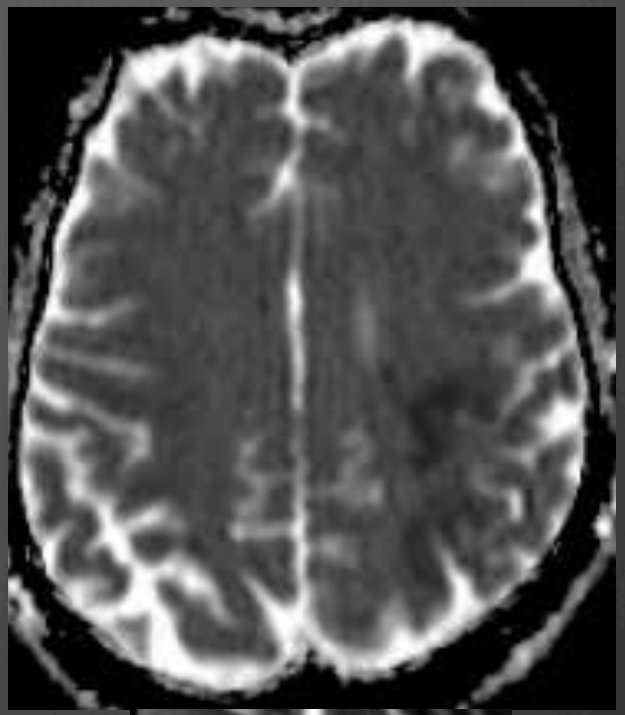


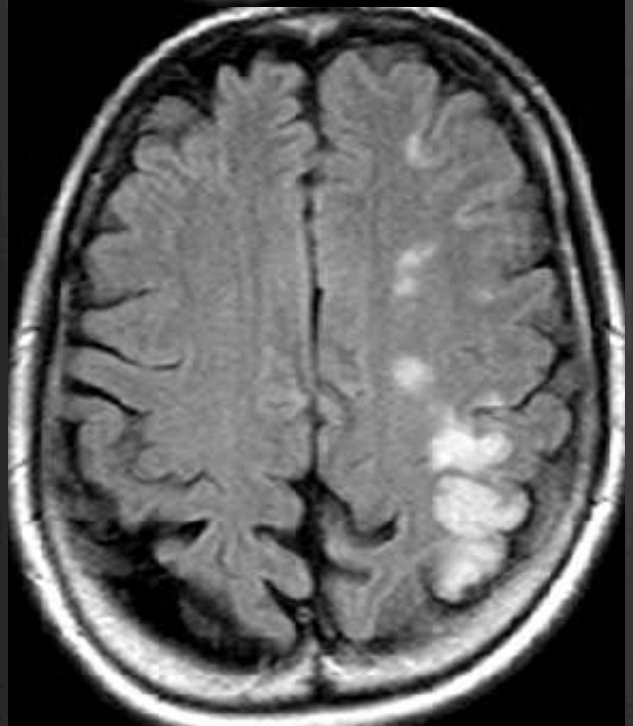


Acute Lacunar infarct



Acute embolic infarcts





Watershed infarcts
ICA high grade stenosis

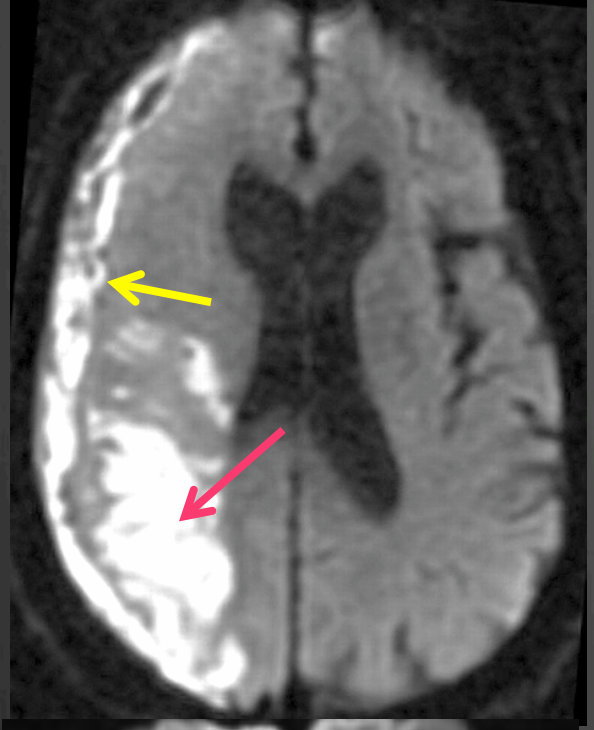
DWI keys points

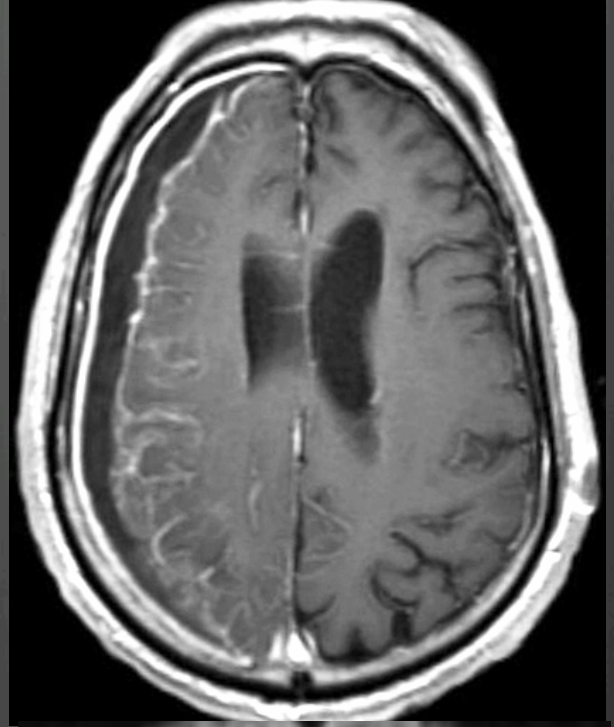
DWI is sensitive for acute stroke

- Most sensitive way to detect ischemic parenchyma
- Use DWI, ADC and T2/FLAIR to characterize lesions

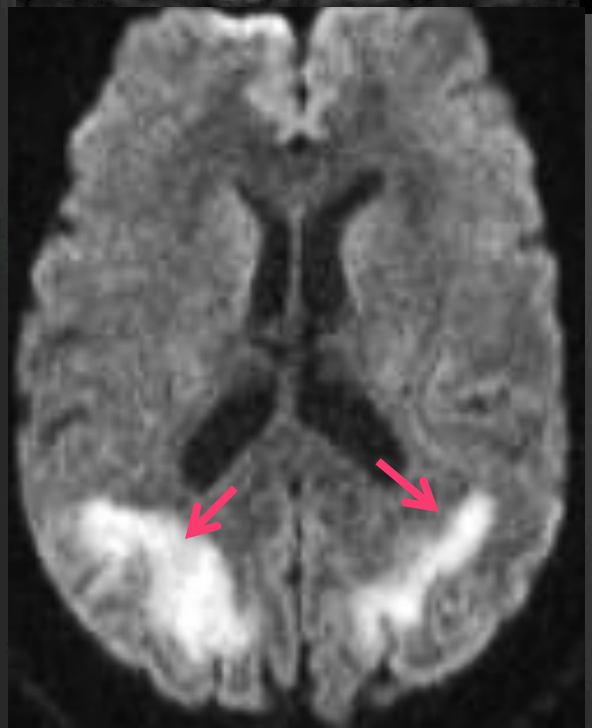
DWI is not specific for Stroke

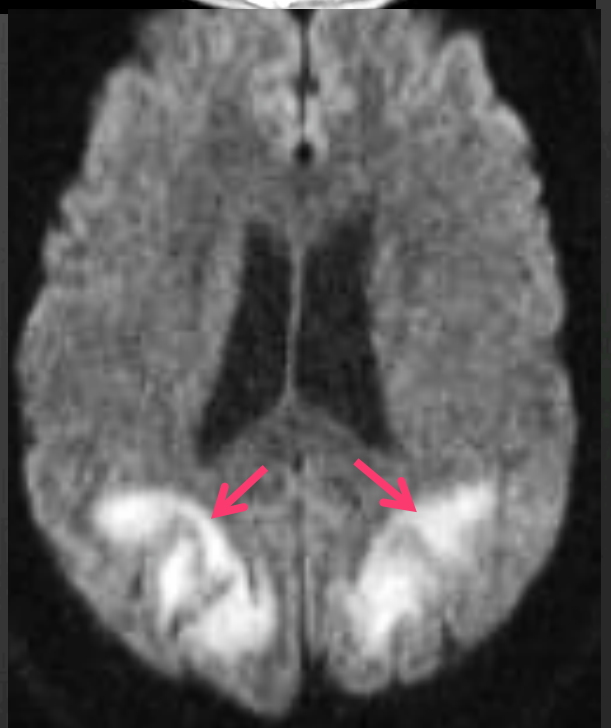
- Prolonged seizures, toxins, metabolic, cerebritis
- Restricted fluid – abscess, hemorrhage
- Highly cellular tissue – tumors



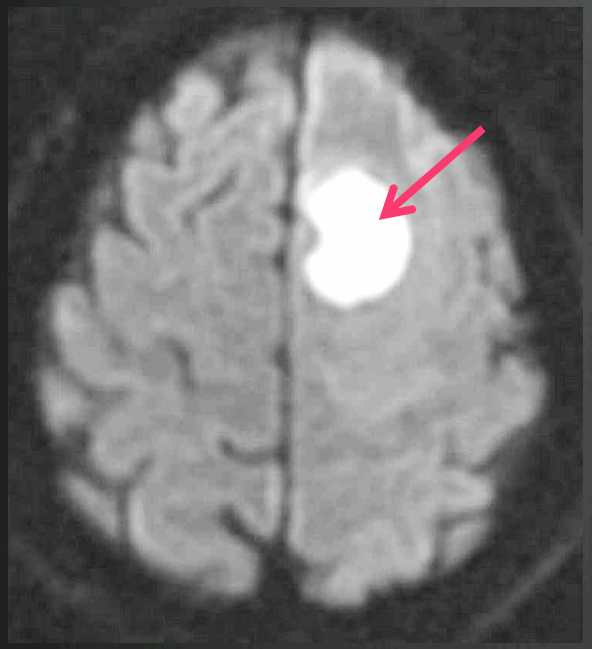


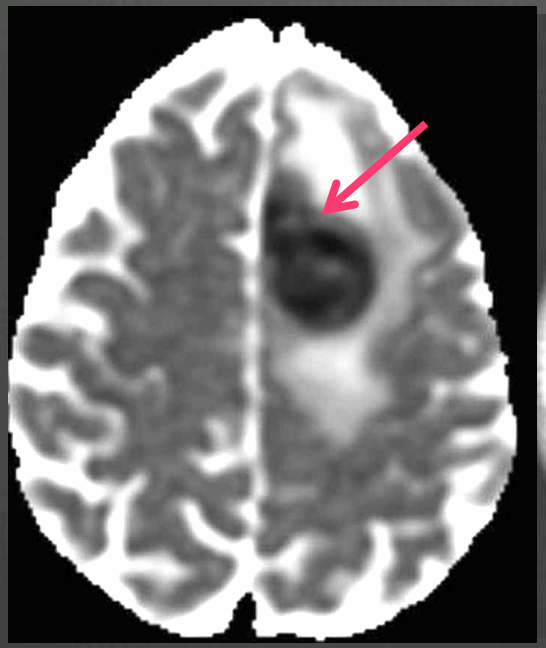
MCA infarct with subdural empyema

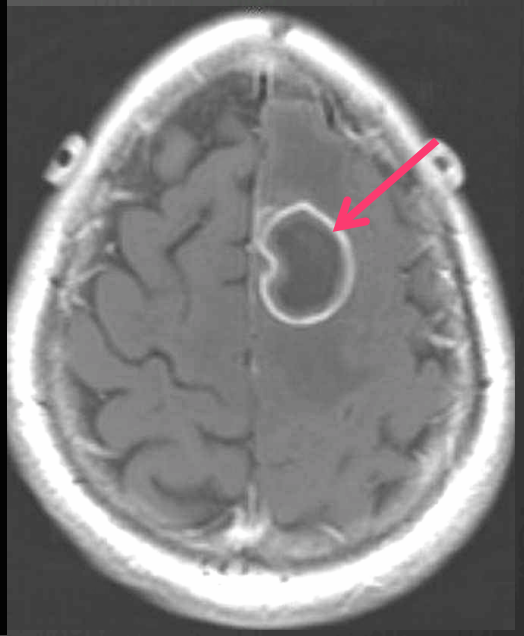




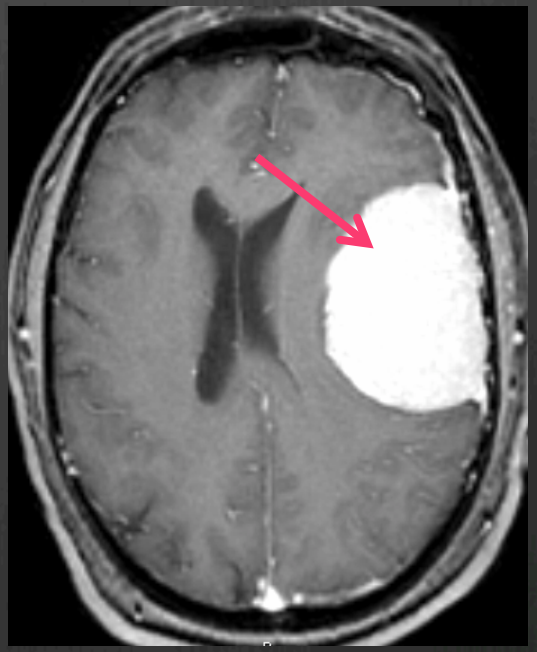
Transient seizure related DWI changes







Abscess

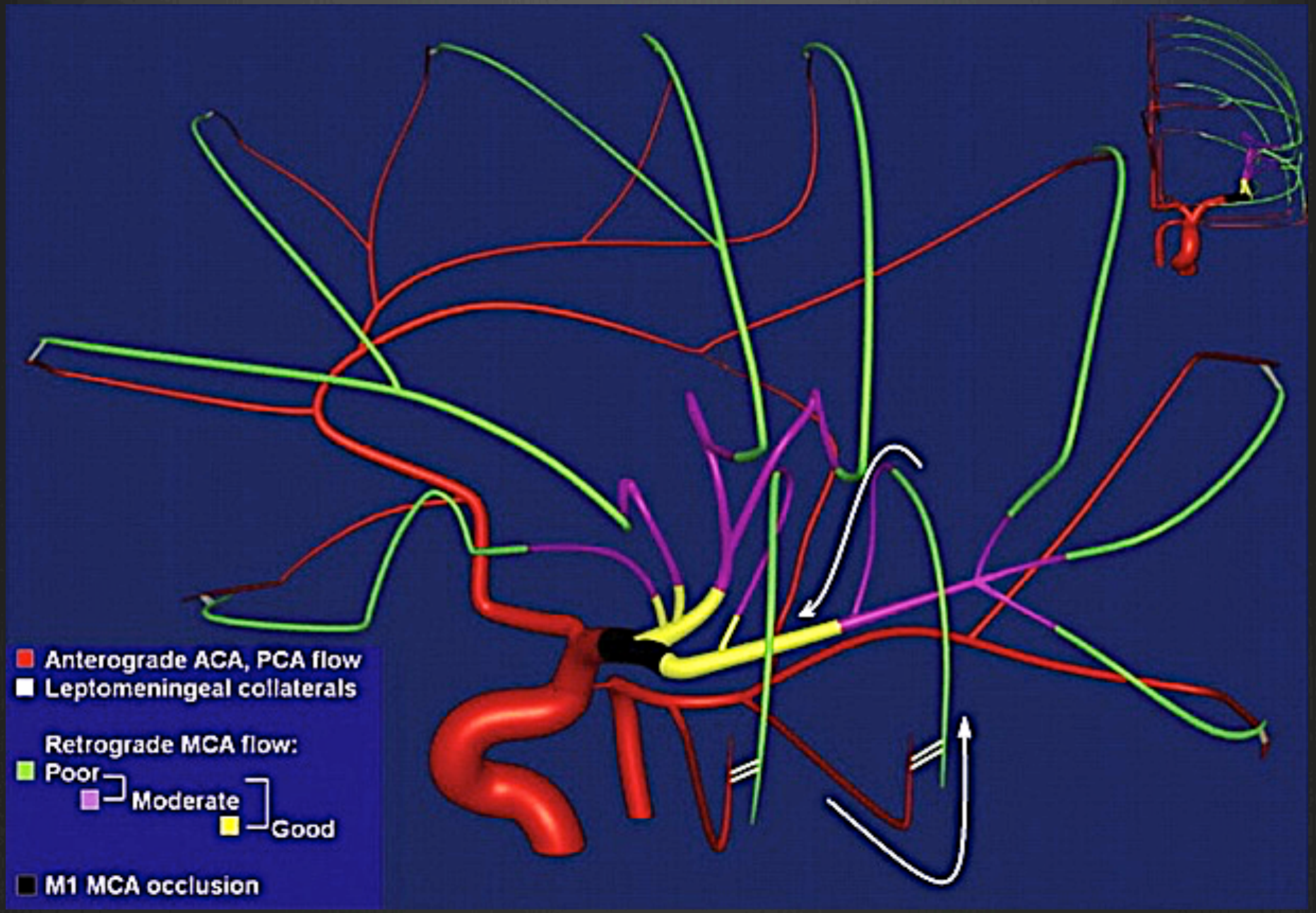


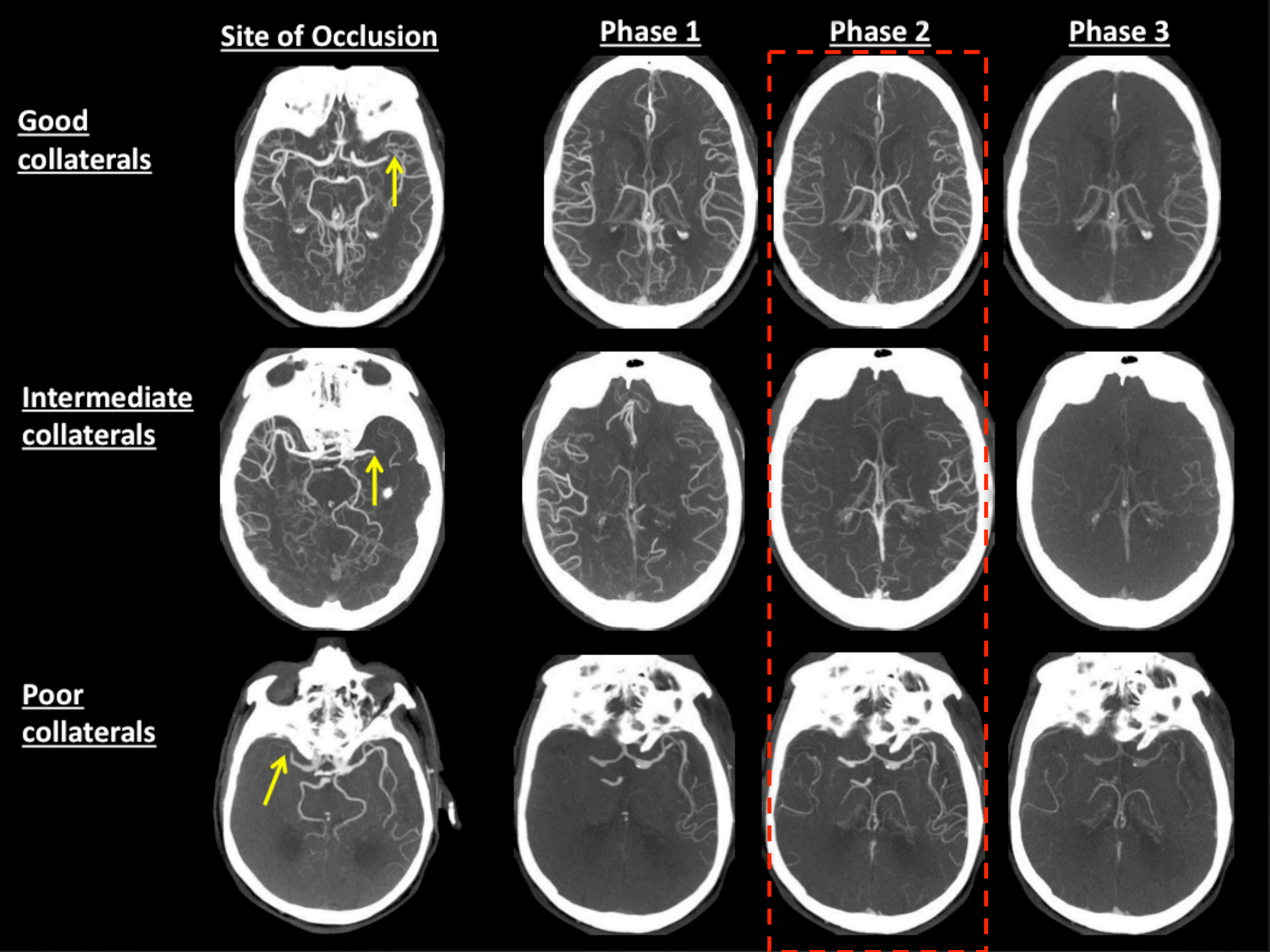
Meningioma

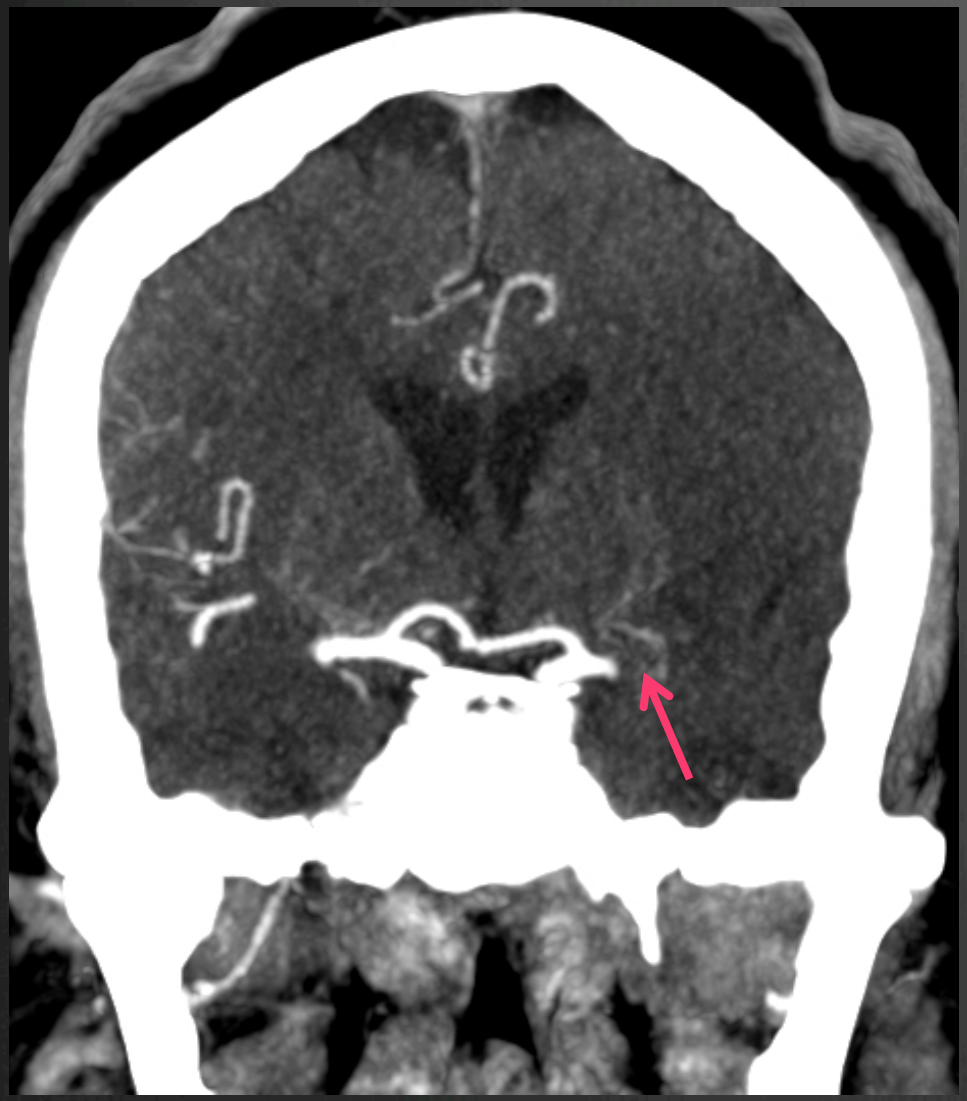
Collateral Scoring on CTA

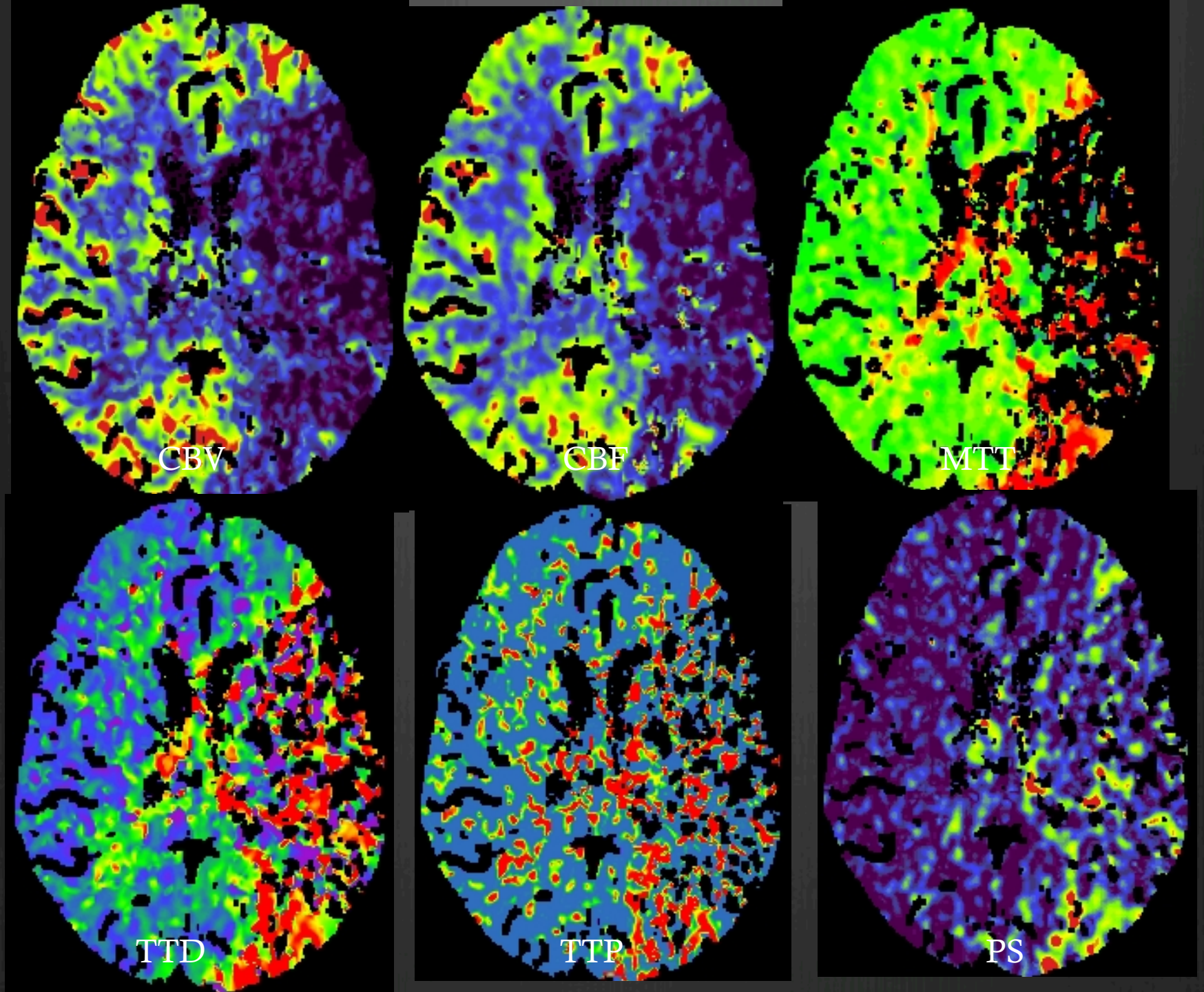
- Collaterals are measured on muli-phase CTA by comparing backfilling arteries beyond the blocked artery to similar arteries in the opposite unaffected hemisphere.
- **On a single phase (venous phase), multiphase or dynamic CTA, no or minimal collaterals in a region greater than 50% of the MCA territory when compared to pial filling on the contralateral side considered as poor collaterals**

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

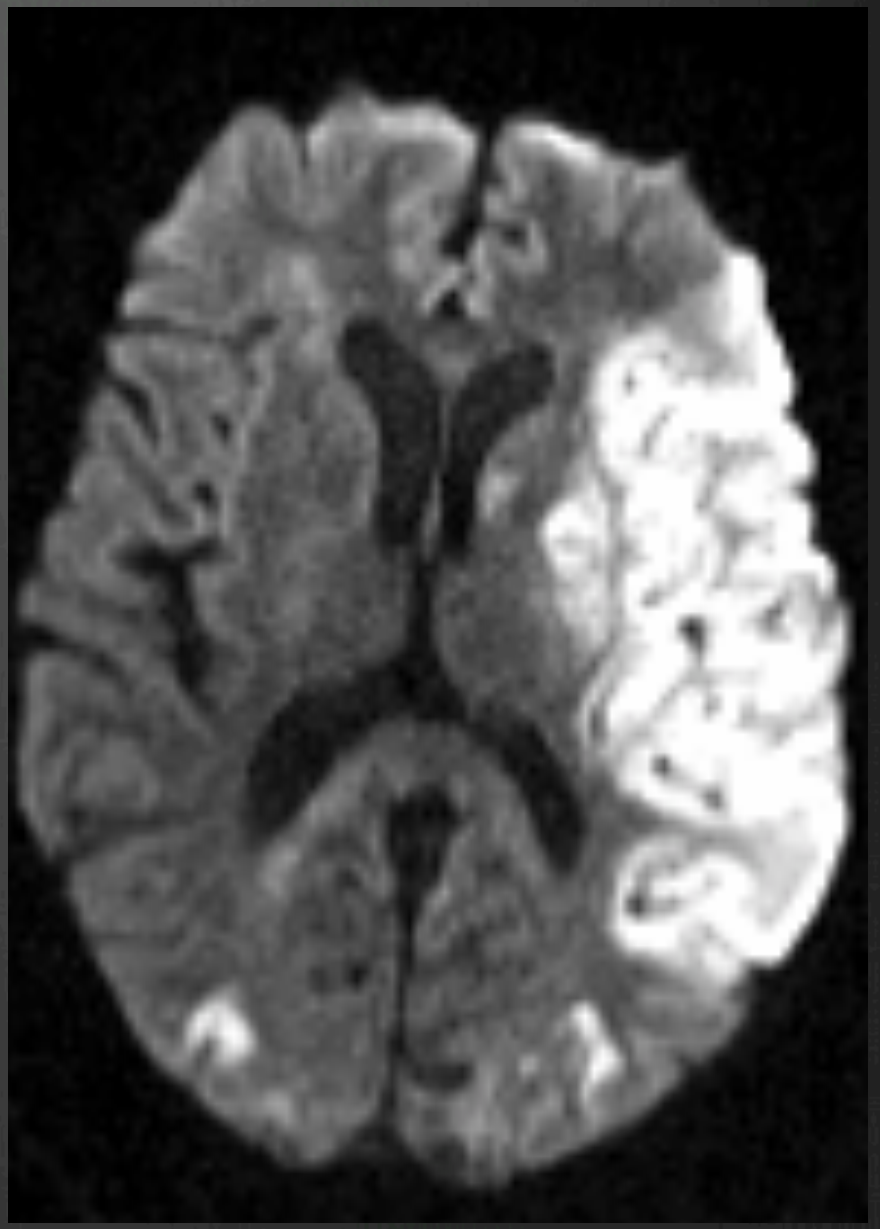

Anterograde ACA, PCA flow
Leptomeningeal collaterals
Retrograde MCA flow:
Poor
Moderate
Good
M1 MCA occlusion


Site of Occlusion
Phase 1
Phase 2
Phase 3
Good collaterals
Intermediate collaterals
Poor collaterals

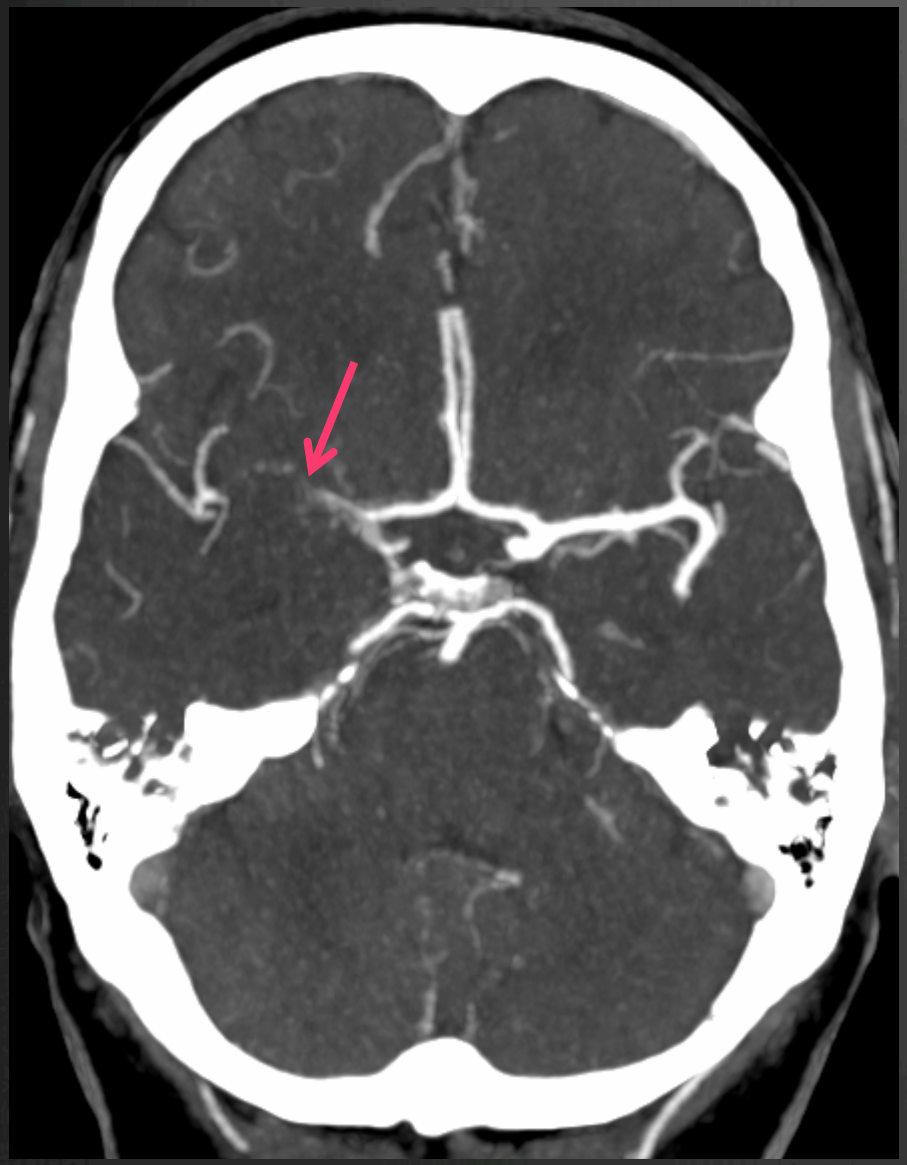



CBV
CBF
MTT
TTD
TTP
PS

MRA

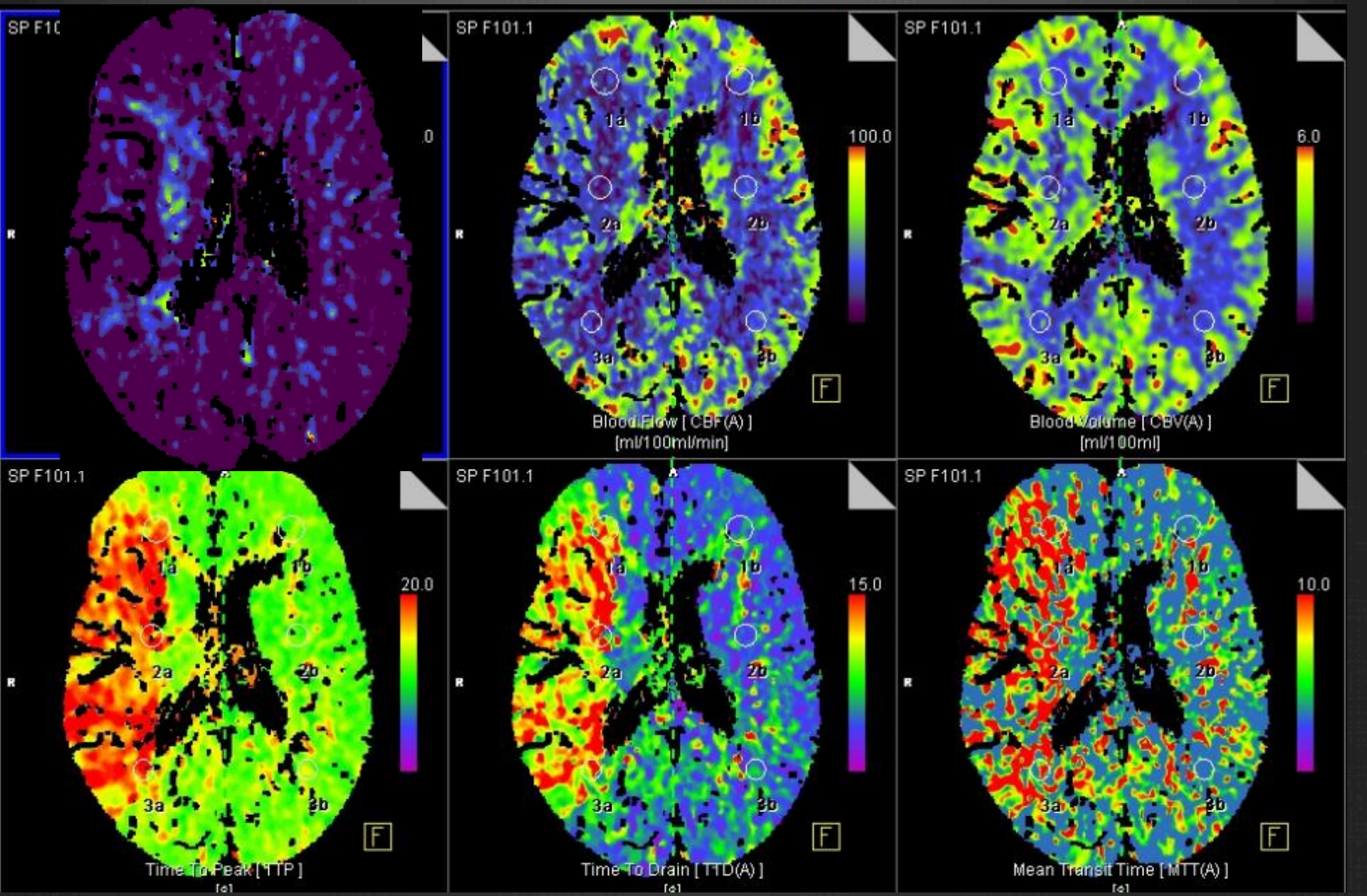


Diffusion



Dual energy CTA MIP Plaque On

CTA MIP Plaque off


SP F101.1
1a
1b
2a
2b
3a
3b
100.0
Blood Flow [CBF (A)]
[ml/100ml/min]
SP F101.1
6.0
Blood Volume [CBV(A)]
[ml/100ml]
SP F101.1
20.0
Time To Peak [TTP]
SP F101.1
15.0
Time To Drain [TTD(A)]
SP F101.1
10.0
Mean Transit Time [MTT(A)]

MRA

Diffusion

Conclusion

- Pathophysiology of acute ischemic stroke
- CT signs of acute ischemic stroke
- What is ASPECTS ?
- Why and how do we use ASPECTS ?
- Limitations of ASPECTS
- Basics of Diffusion MRI
- Role of diffusion MRI in acute ischemic stroke
- Collateral circulation

http://www.aspectsinstroke.com/

Thank you