

STROKE IMAGING

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OVERVIEW

- Imaging appearances of cerebral infarct
- Understanding of CT perfusion: concept of core and penumbra
- Stroke trials and treatment algorithms: latest guidelines
- Advanced imaging

IMAGING GOALS

- Rule out acute intracranial hemorrhage
- Detect early ischemia
- Identify large vessel occlusion(LVO)
- Assess salvageable tissue

INITIAL IMAGING

- CT

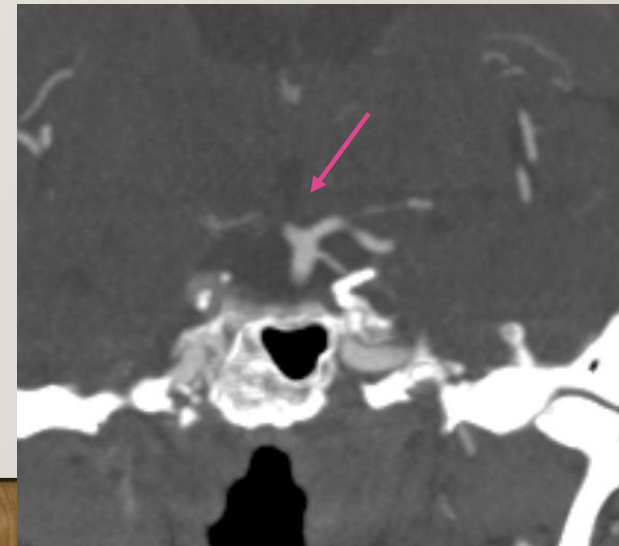
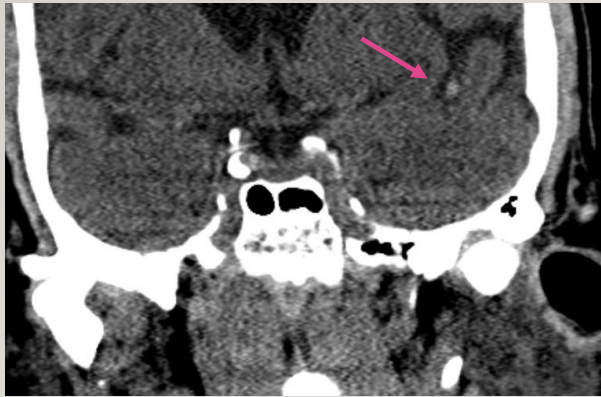
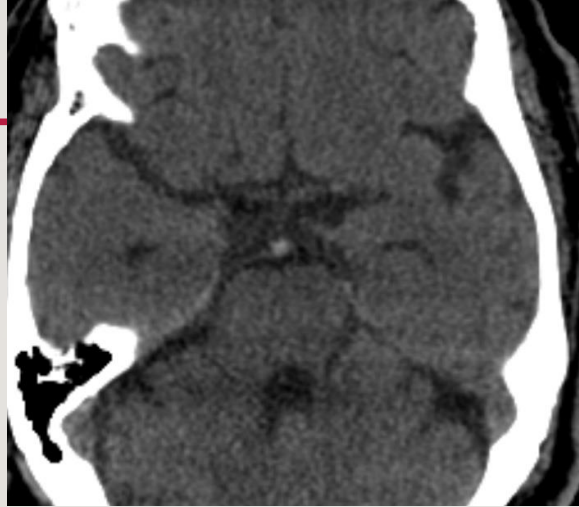
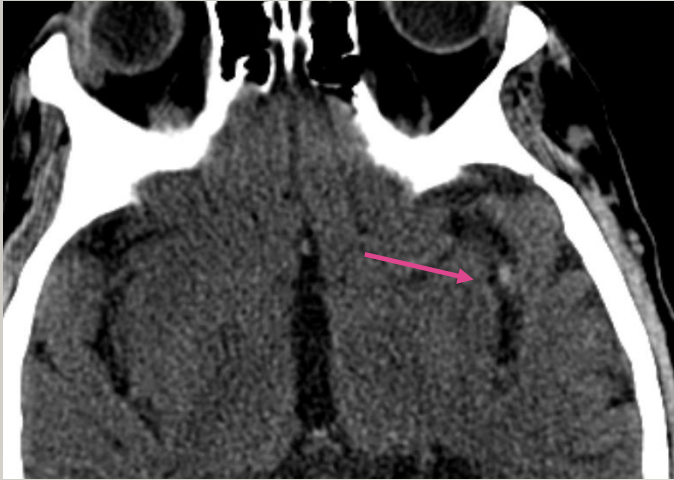
- Windowing : narrow window(8/40 WW/VWL)
- Loss of G-W matter(3 hours)
- Insular ribbon sign
- Hyperdense vessel sign

- CTA

- Detects vessel occlusion
- Evaluate collateral circulation



HYPERDENSE VESSEL



COLLATERAL CIRCULATION

Good vs poor
collaterals

Impacts infarct
progression

Strong predictor of
outcome

COLLATERALS

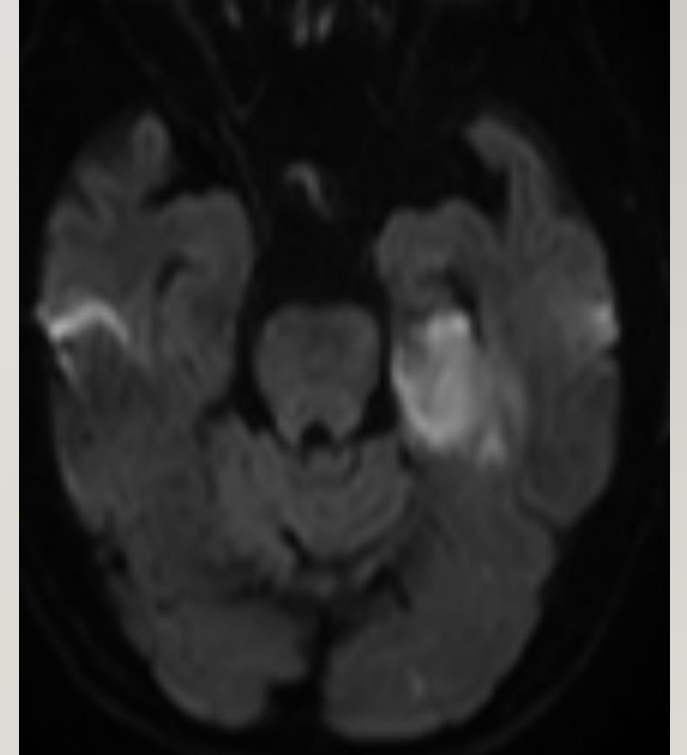
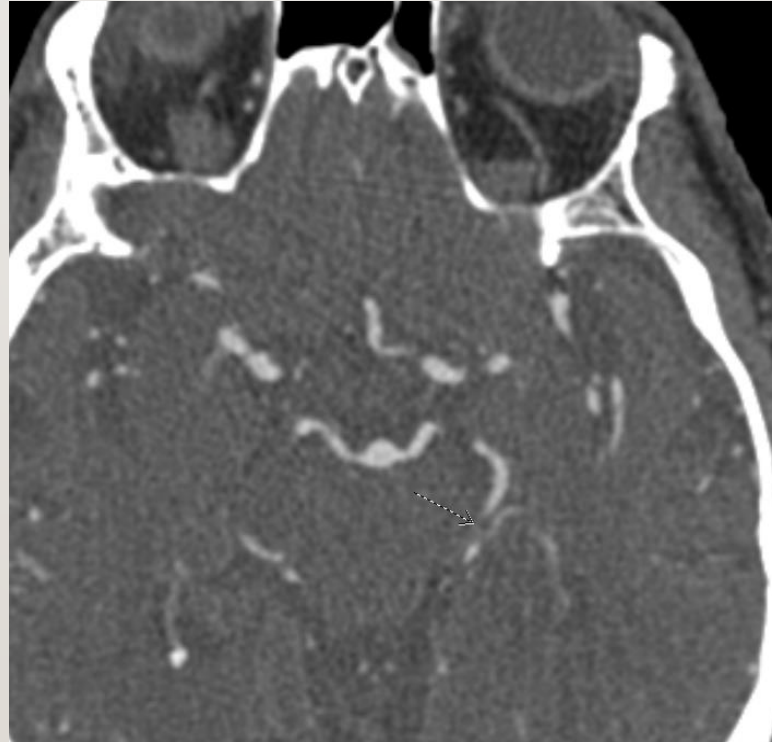
Good

- Distal vessels: Well visualized
- Territory filling: Near complete
- Infarct growth: slow
- Outcome: better

Poor

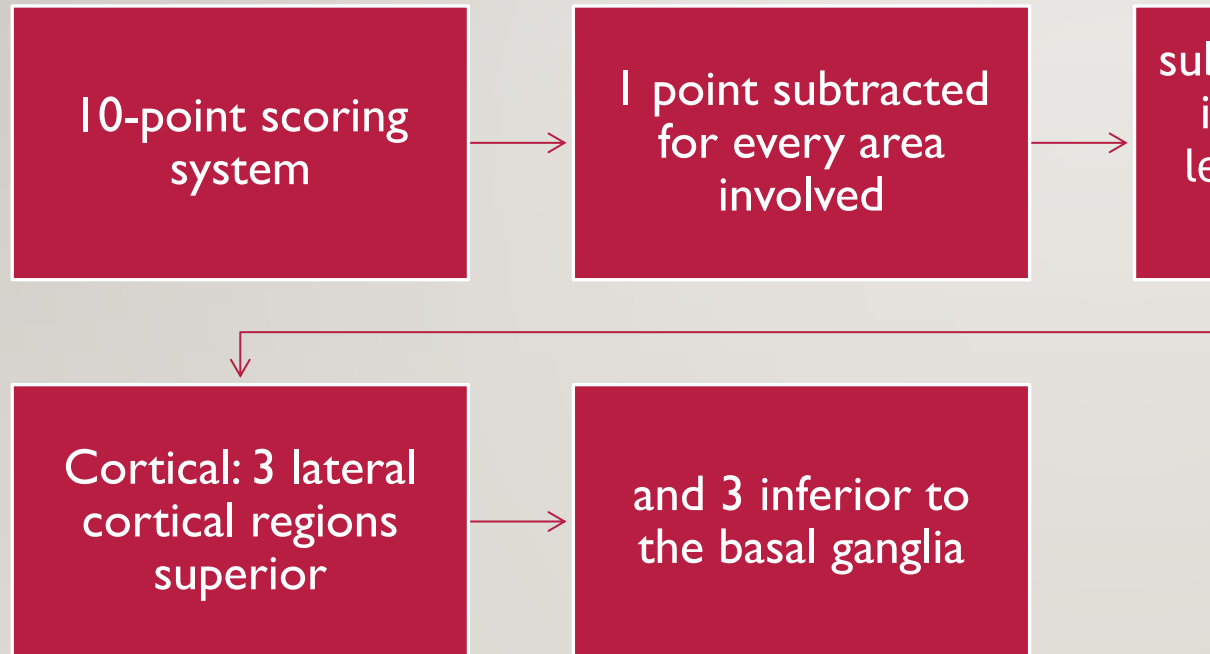
- Sparse/absent
- Limited
- Rapid
- worse

CALCIFIED THROMBUS



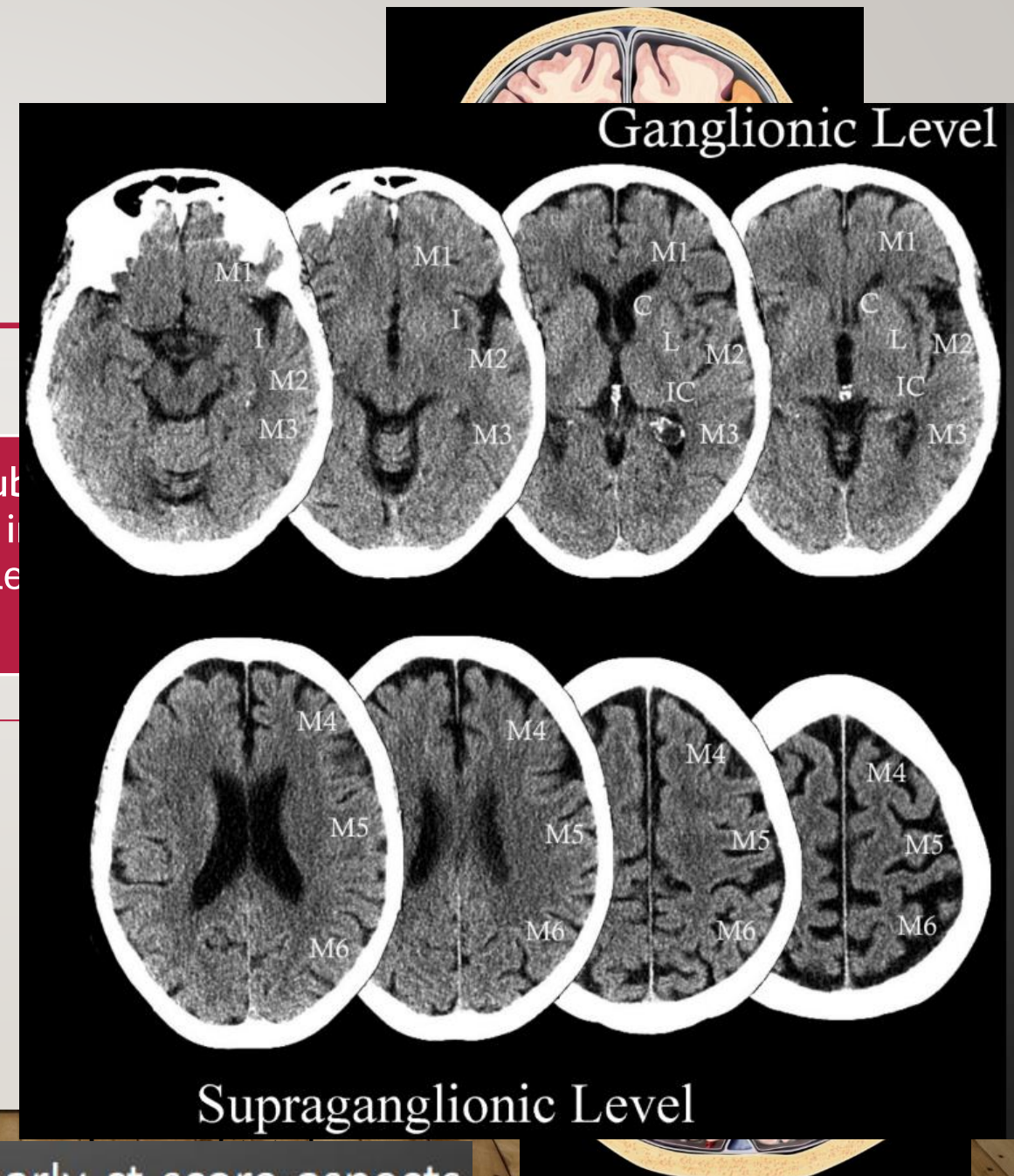
Significant high risk for recurrent embolic stroke
Cardiac valvular disease

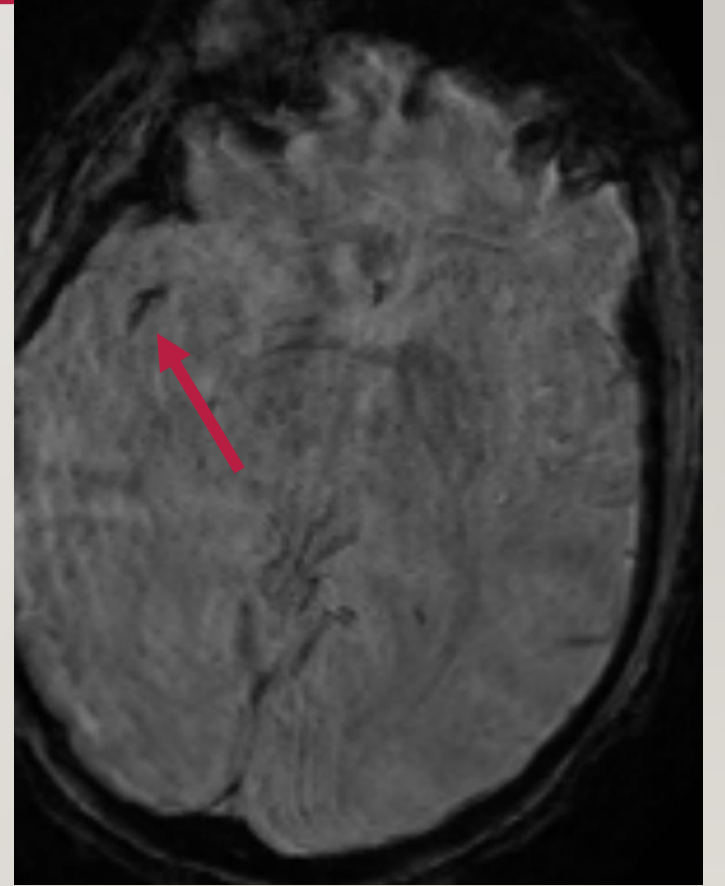
ASPECTS



Lower the scores indicate larger the infarct

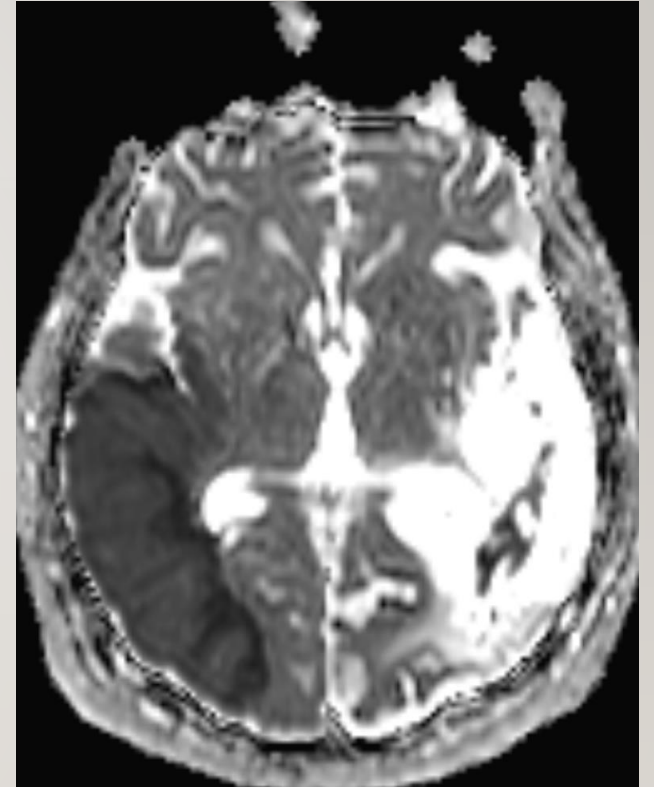
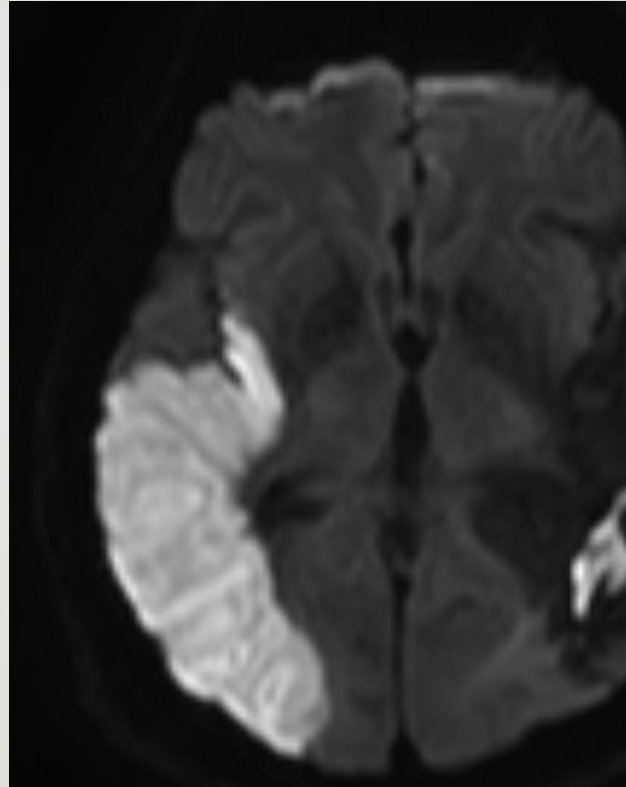
<https://www.mdcalc.com/alberta-stroke-program-early-ct-score-aspects>





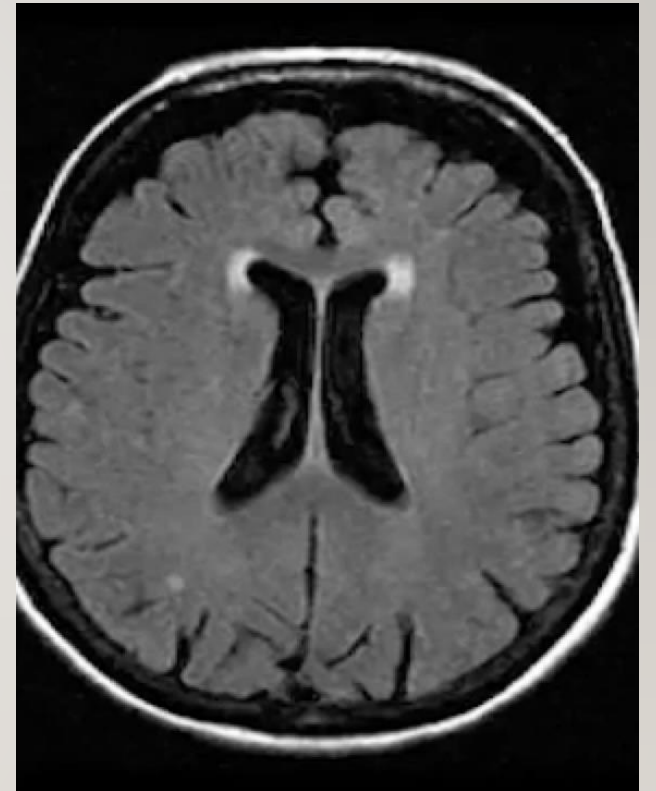
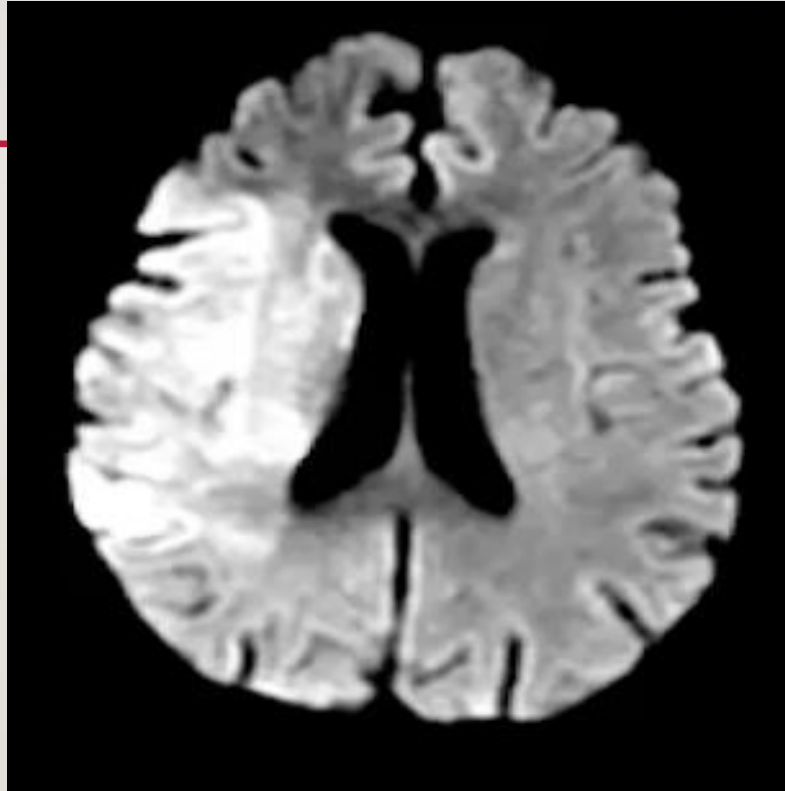
MRI

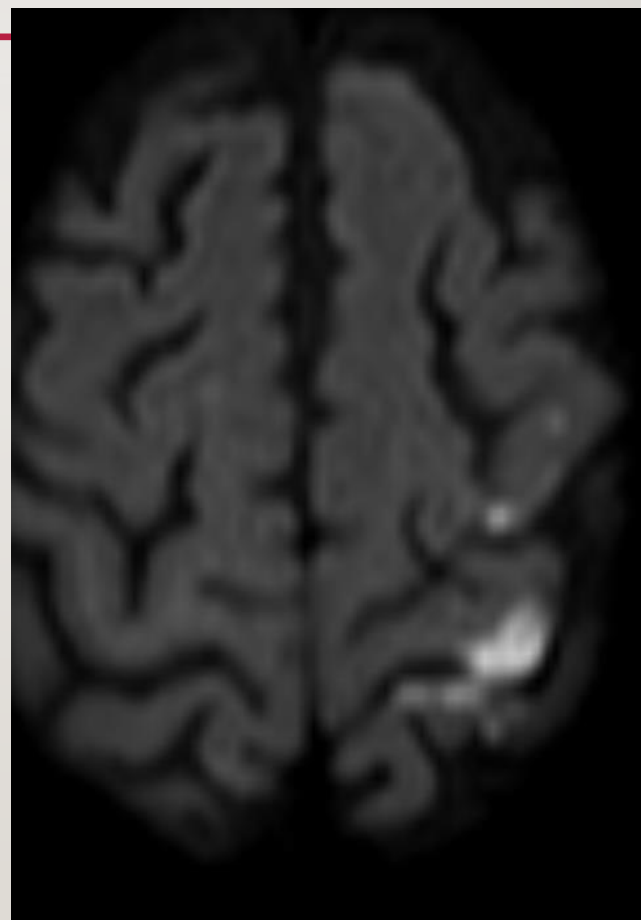
- More sensitive than CT
- Findings:
 - Restricted Diffusion
 - Loss of flow void
- Useful:
 - Lacunar infarcts & posterior fossa stroke
 - Unclear and late presentations

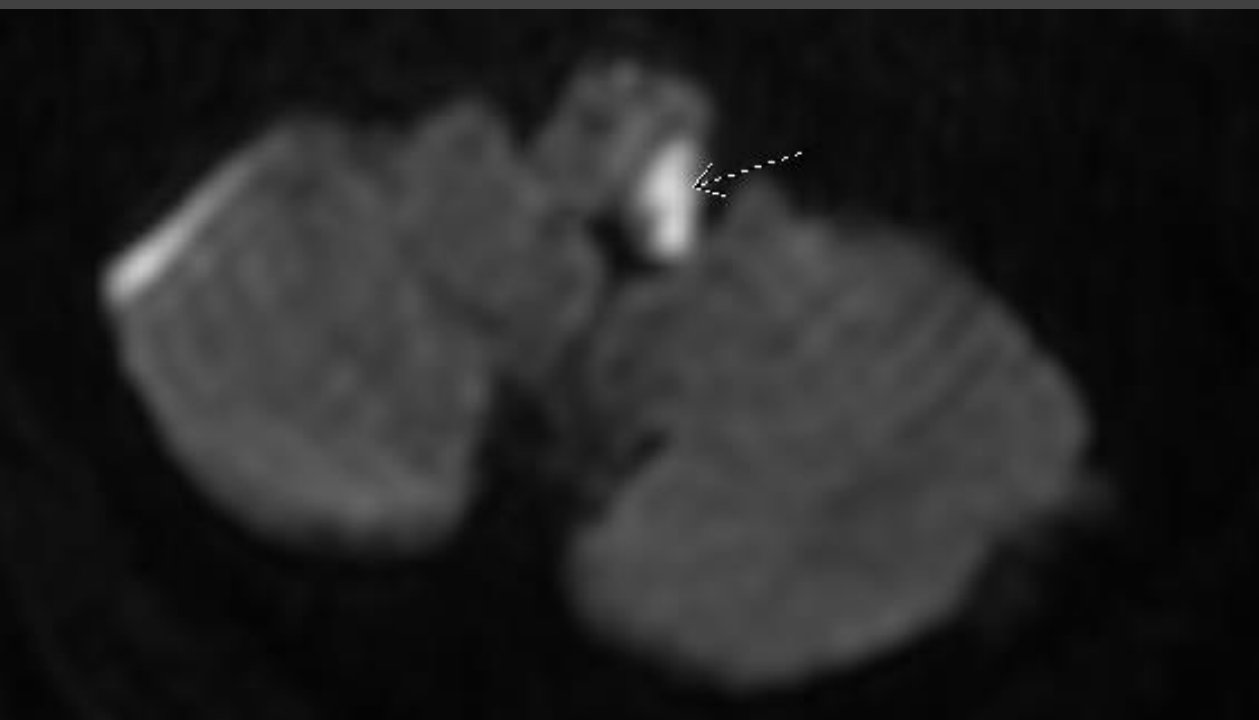
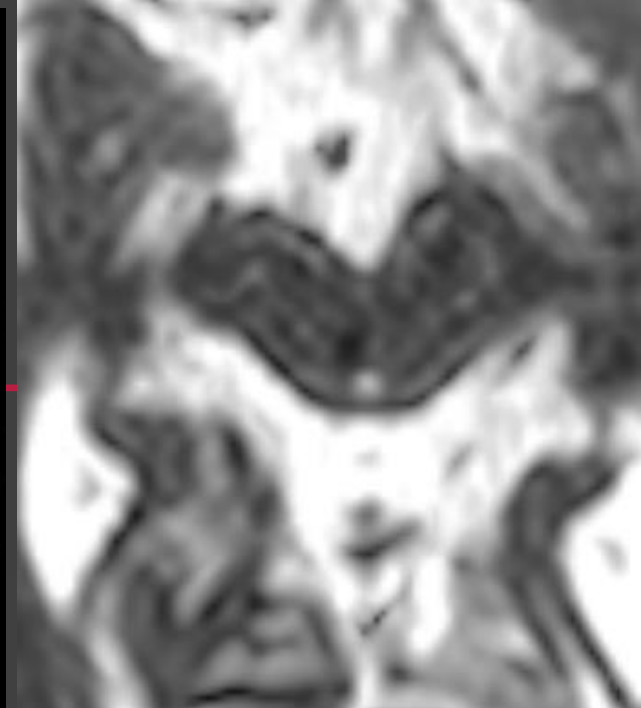
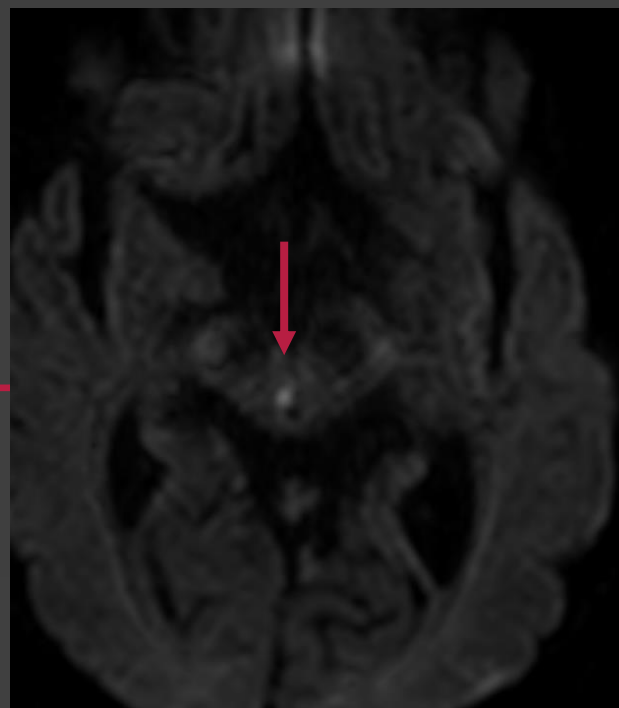
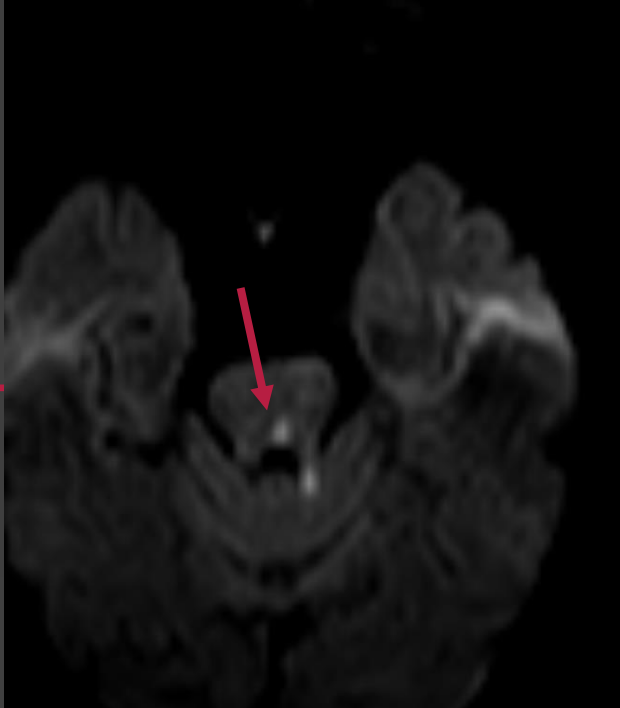


DWI-FLAIR MISMATCH

- Hyperacute stroke
- Used in wake up strokes





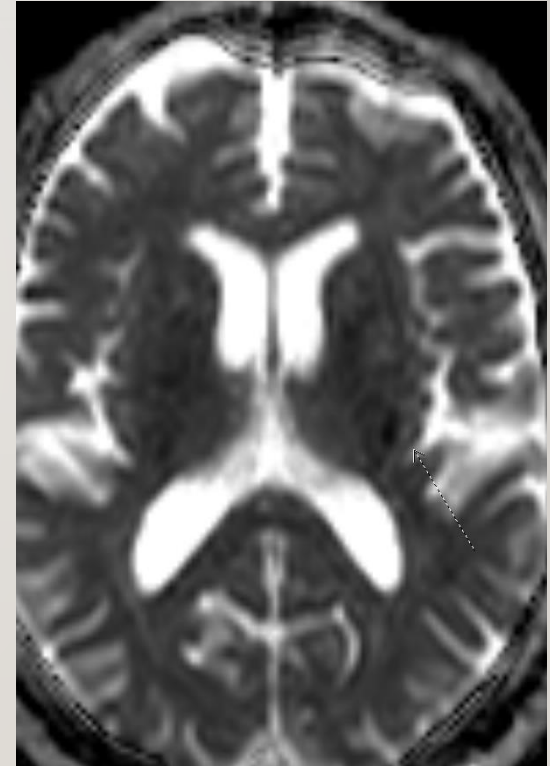
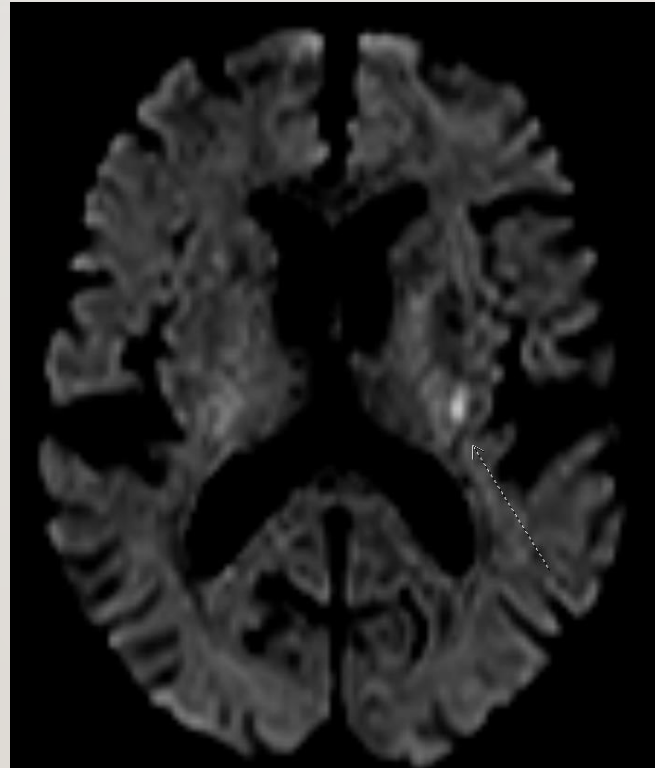
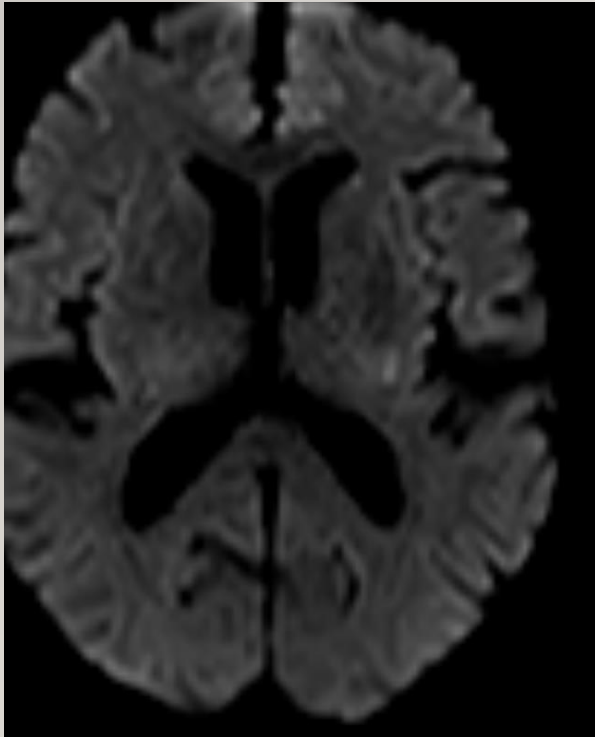


POSTERIOR FOSSA SMALL STROKES

- DWI with B2000: Higher diffusion weighting, more diffusion contrast and lower SNR
- Highly sensitive for small posterior fossa and cortical infarcts.



DWI B1000 VS. B2000



IMAGING WORKFLOW IN ACUTE STROKE

NCCT, CTA
and CTP

MRI (DWI,
FLAIR, MRA+/-
perfusion)

SUBACUTE INFARCT(2DAYS-2WEEKS)

- CT

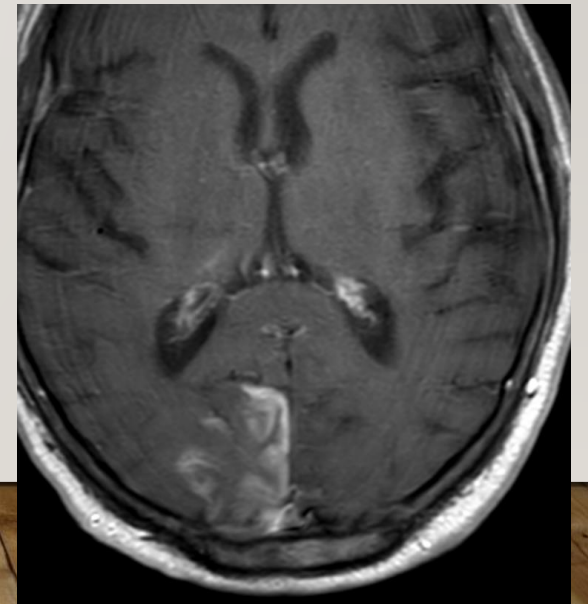
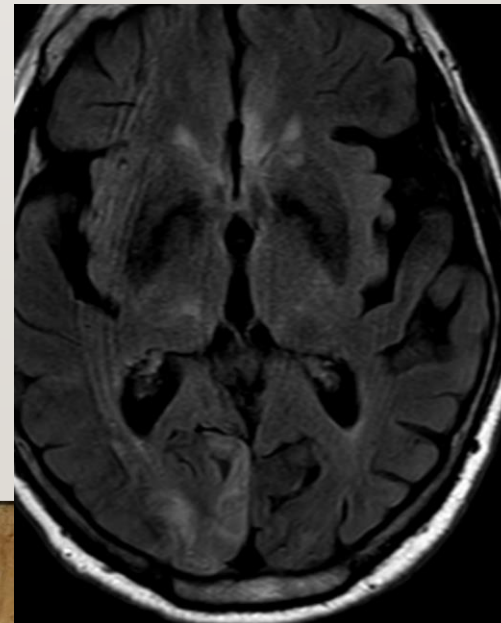
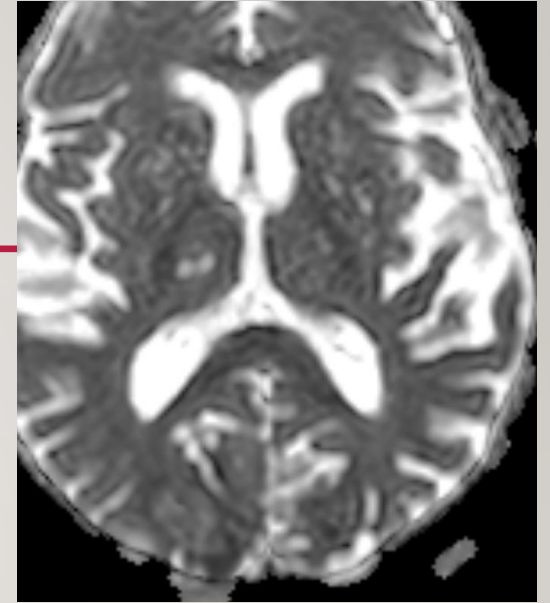
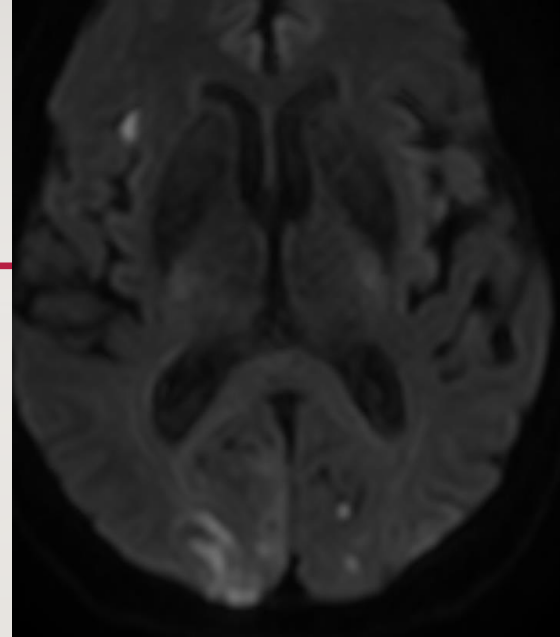
- Increased mass effect/herniation
- Edema
- Sulcal effacement
- Hemorrhagic transformation



SUBACUTE INFARCT

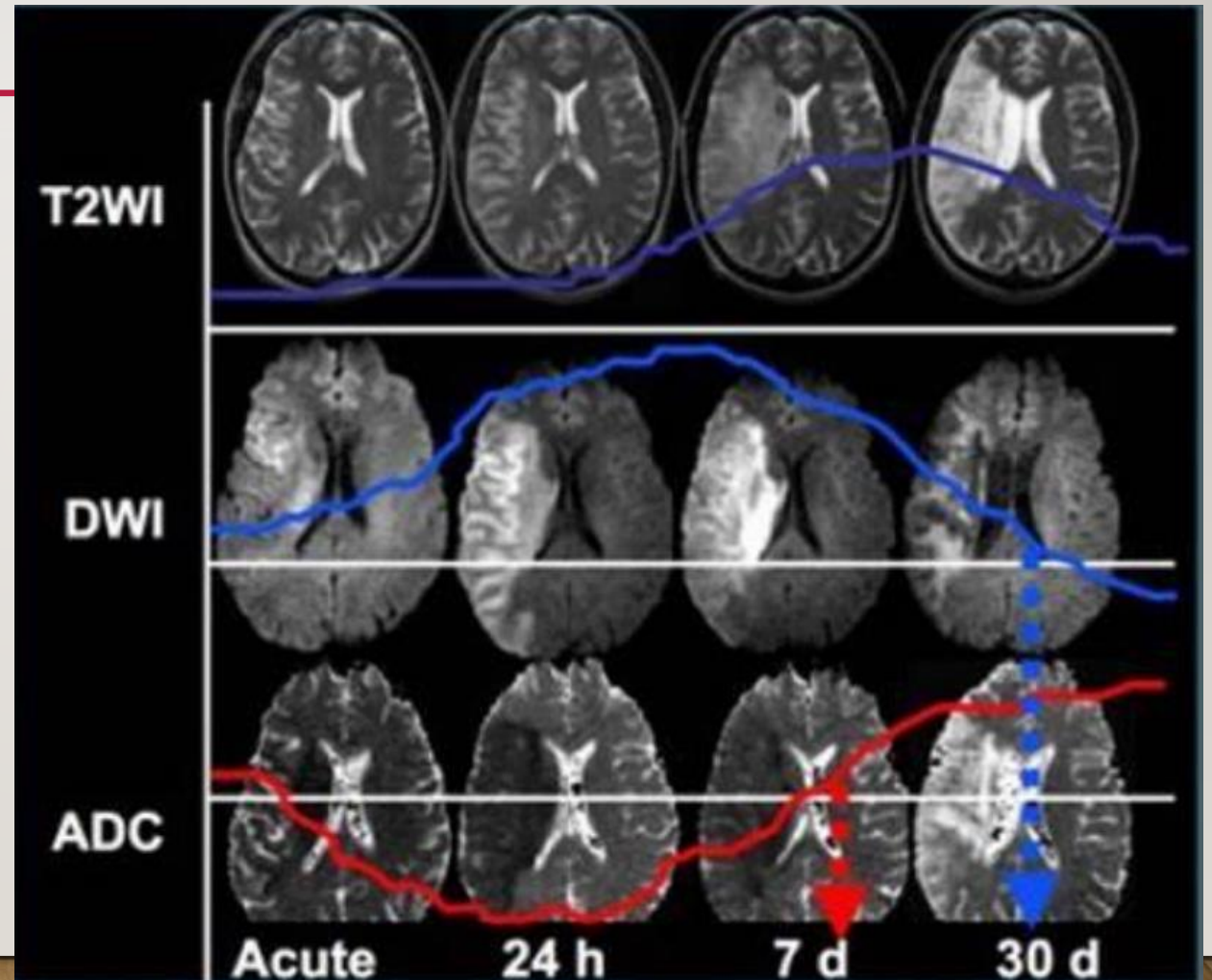
- MRI

- Pseudo-normalization of ADC
- T2/FLAIR signal abn
- T2 fogging effect
- **Gyral enhancement**



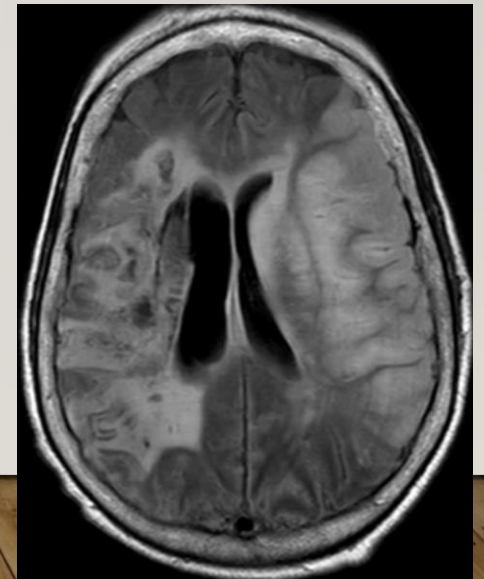
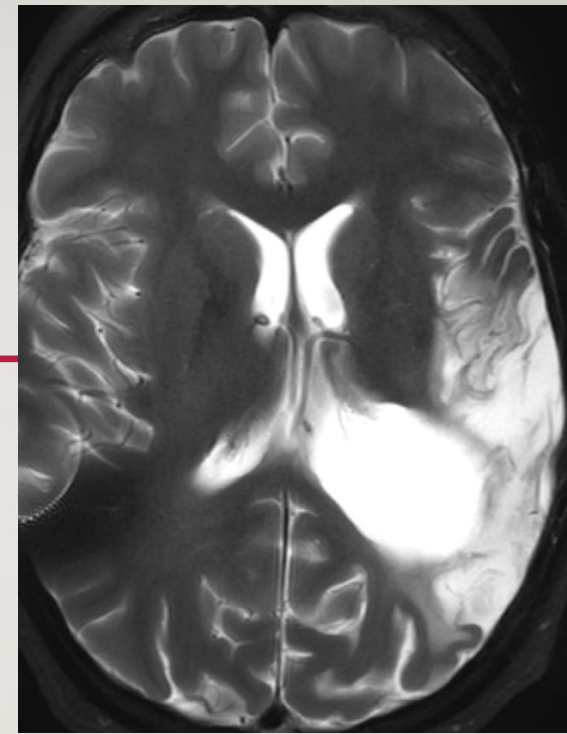
PSEUDO-NORMALIZATION OF ADC

- ADC values falls back to near normal levels in 7-10 days
- Not represent resolution of stroke
- After 10days, ADC values rise(“T2 shine through”)

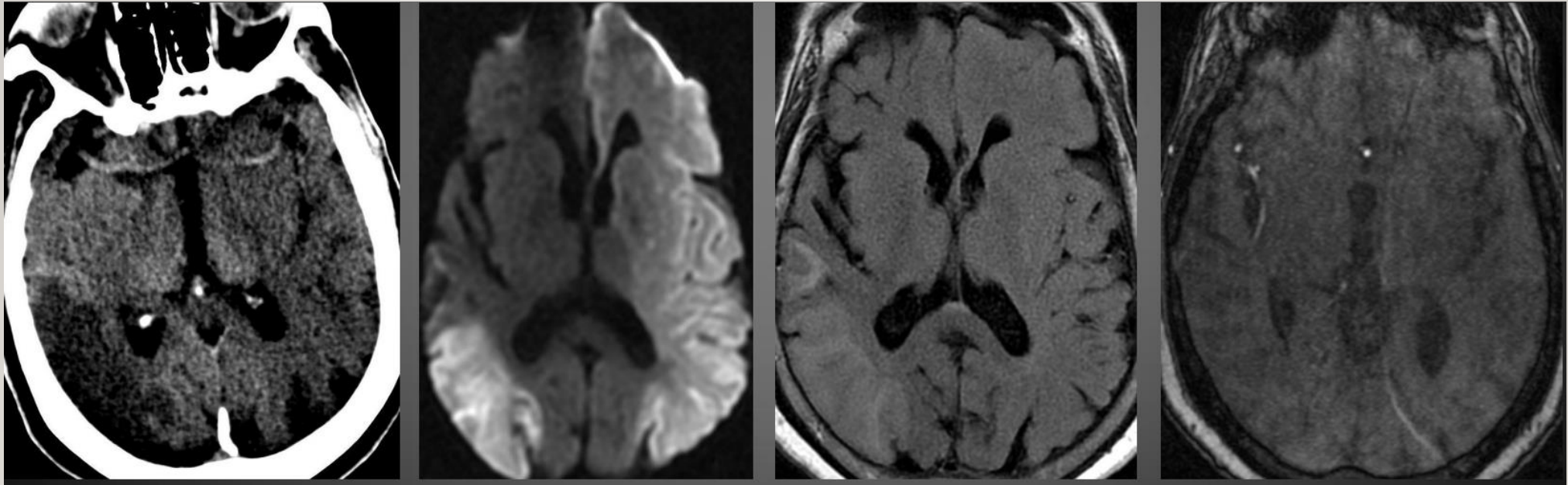


CHRONIC INFARCT

- Volume loss
 - Shrinkage of parenchyma and ventricular enlargement
- Loss of overlying cortex
- Encephalomalacia with surrounding gliosis
- SWI/GRE: hemosiderin deposition

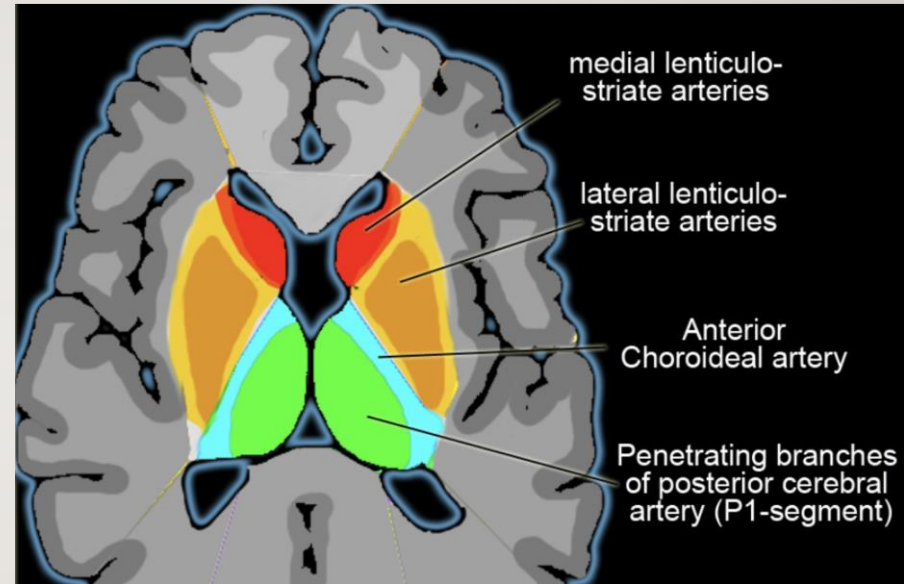
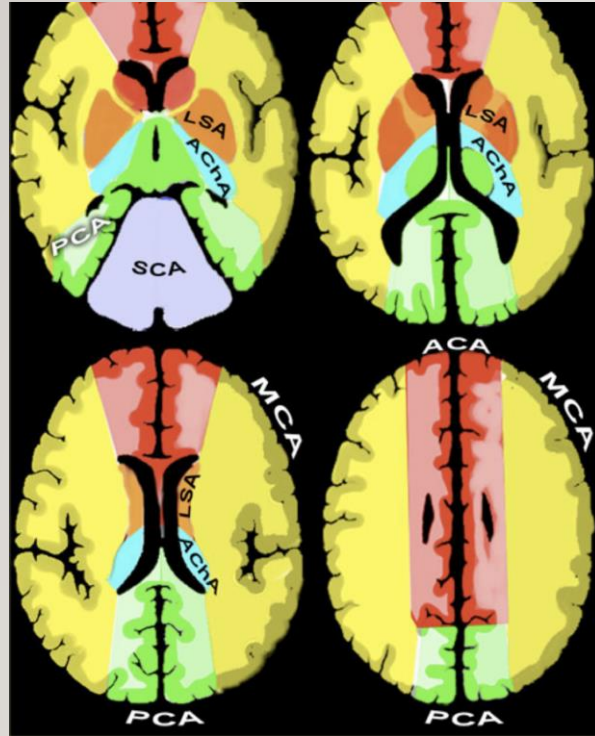


ACUTE VS. SUBACUTE INFARCT





SUBACUTE VS.
CHRONIC INFARCT

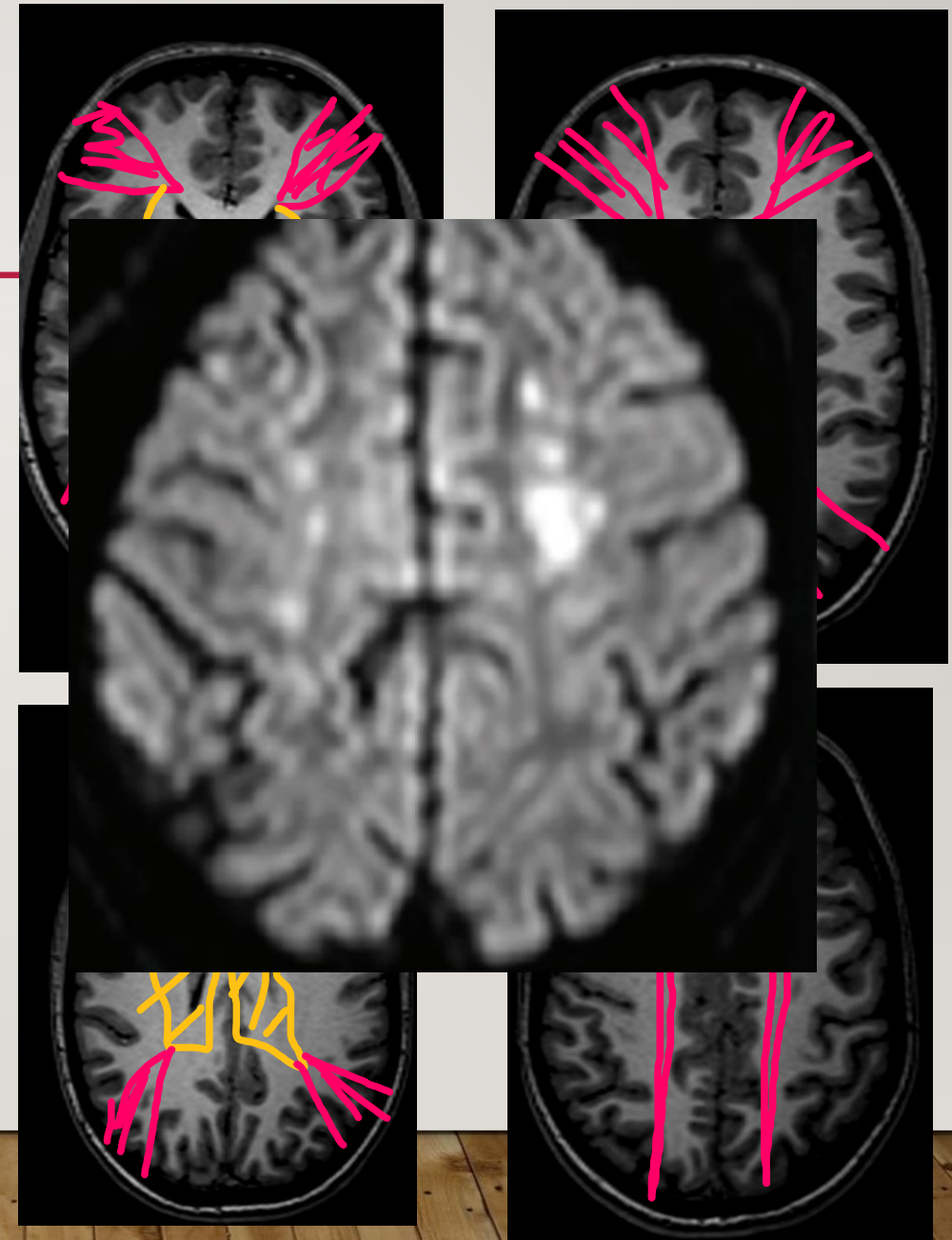


VASCULAR TERRITORIES

Radiology Assistant

WATERSHED ZONES(WSZ)

- Cortical WSZ: between ACA,MCA and PCA territories
- Deep WSZ: between deep and superficial perforators.
- Hypoperfusion and microemboli



CT PERFUSION

- Identifies perfusion deficits early
- Technique:
 - 40 mL of contrast
 - Scan every 1-3 sec for 60-70 sec
 - Captures entire bolus passage: Arteries=>Capillaries=> veins
- Postprocessing:
 - Generates attenuation-time curves for every pixel
 - uses circular deconvolution to estimate contrast concentration
 - Produces perfusion maps: CBF, CBV, MTT/Tmax.
- Differentiates between core and penumbra
- Treatment decisions
 - small core and large penumbra: beneficial to early reperfusion treatments

KEY PARAMETERS OF PERFUSION

- Cerebral blood flow(CBF)
 - Amount of blood reaching capillaries/tissue volume/unit time (mL/100gm/min)
 - GM2X>WM GM: 60mL/100gm/min
WM: 25mL/100gm/min
- Cerebral blood volume(CBV)
 - Volume of blood in given volume
 - GM2X>WM. GM: 4mL/100gm
WM: 2mL/100 gm
 - more frequently applied for tumor imaging
- Either can be used for infarct core

MTT AND TTP

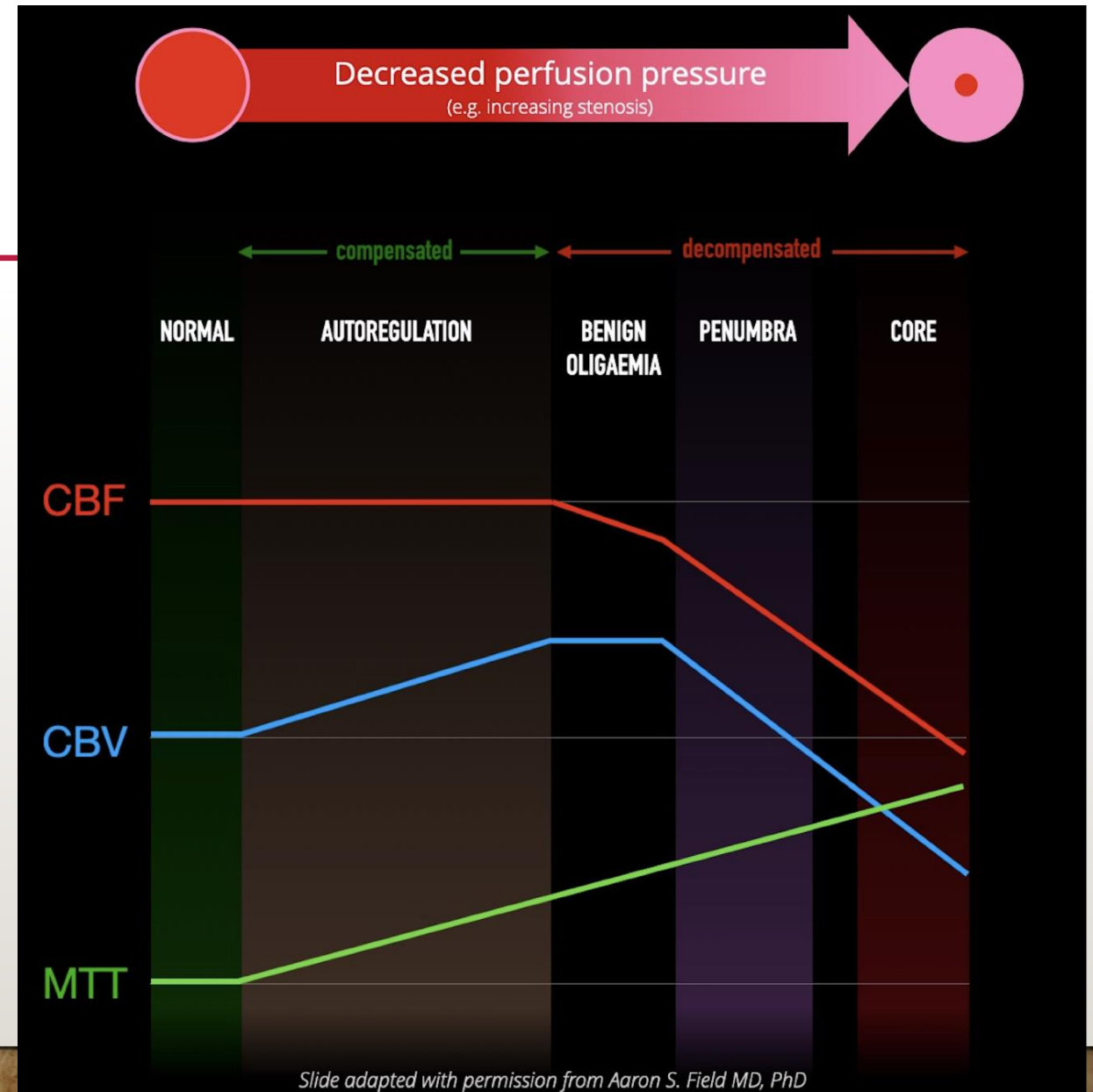
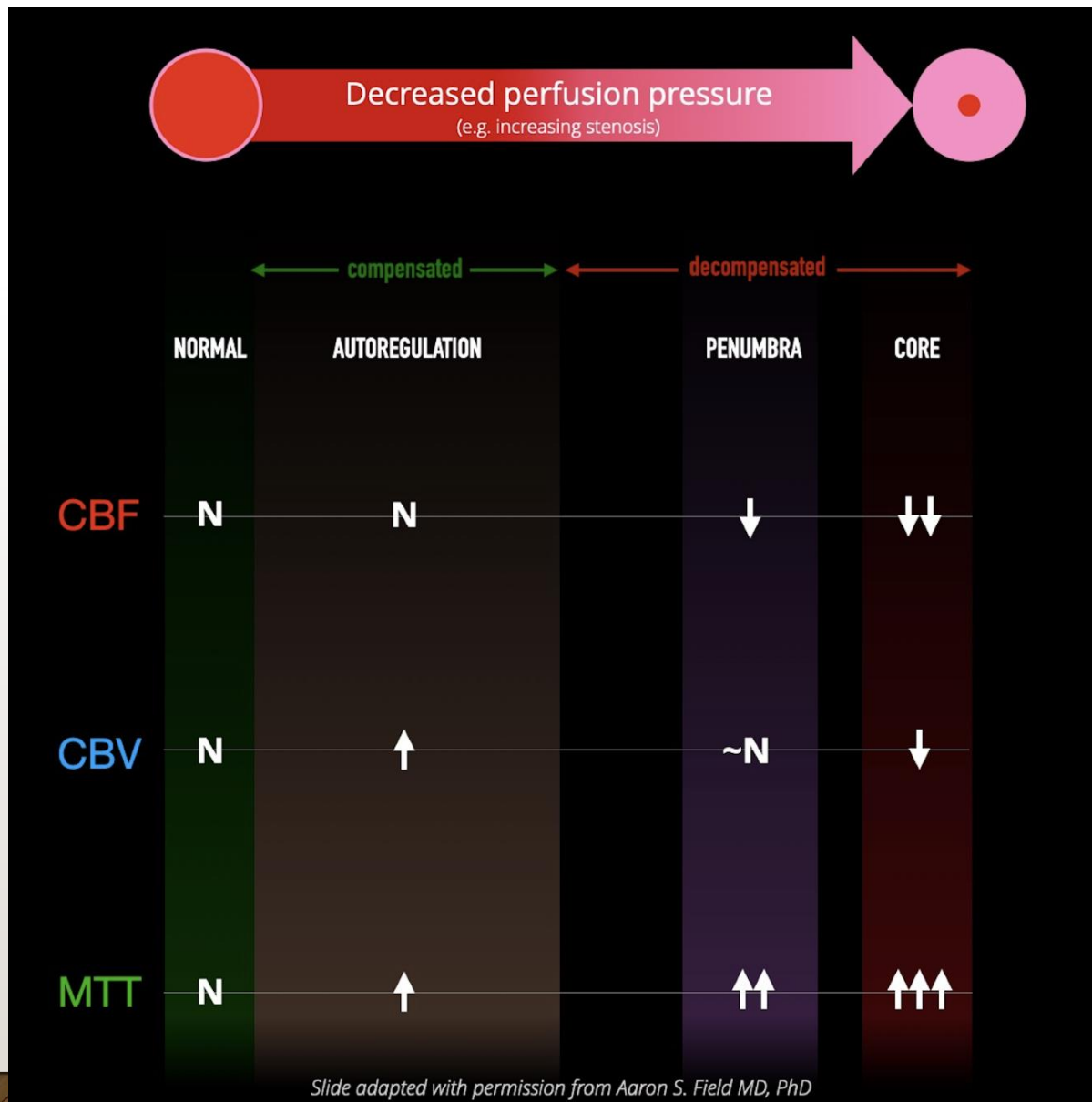
- Mean Transit Time(MTT): Time takes contrast to cross the voxel

$$MTT = \frac{\textit{Volume of distribution}}{\textit{Flow}}$$

GM=WM

normal MTT GM=4sec

WM=4.8sec



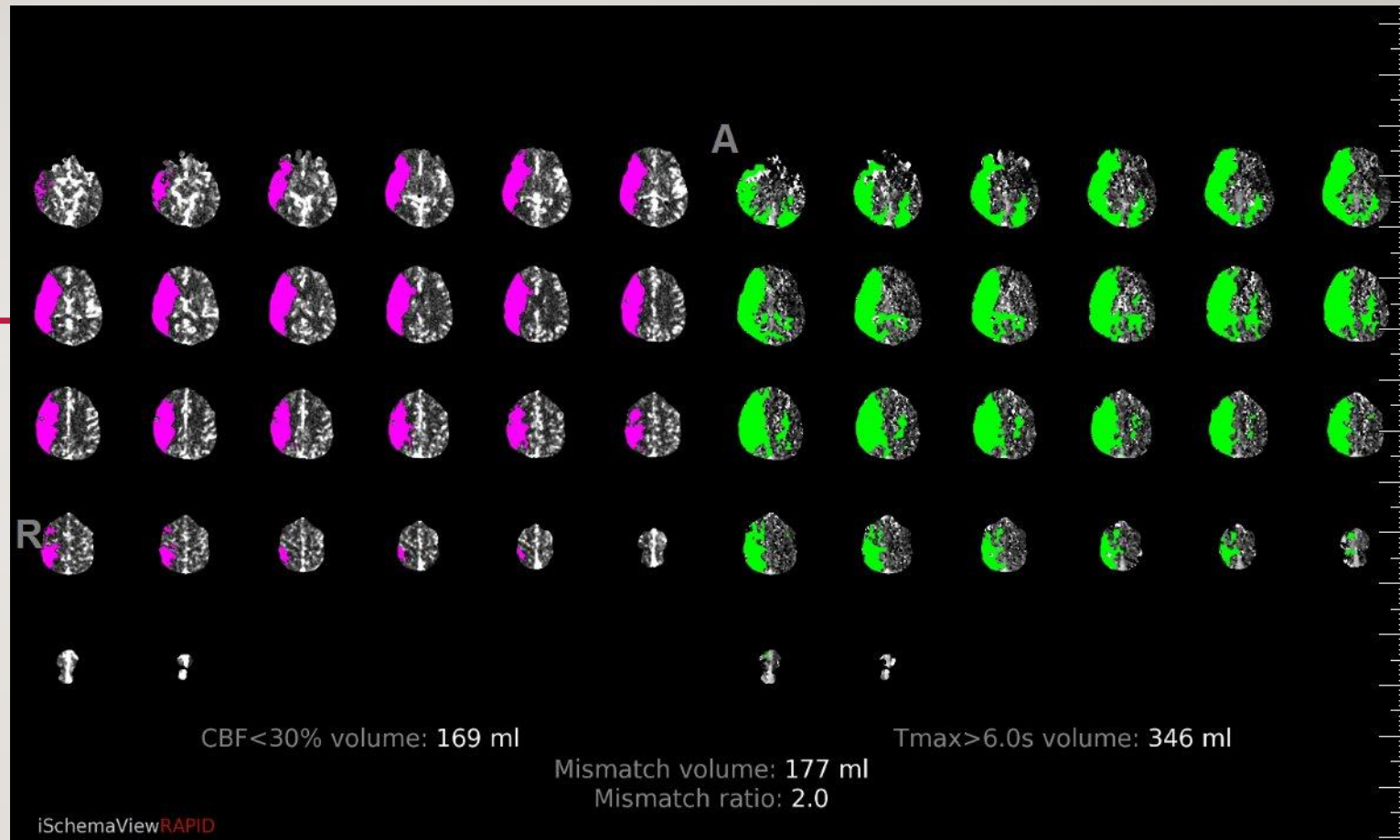
CORE VS PENUMBRA

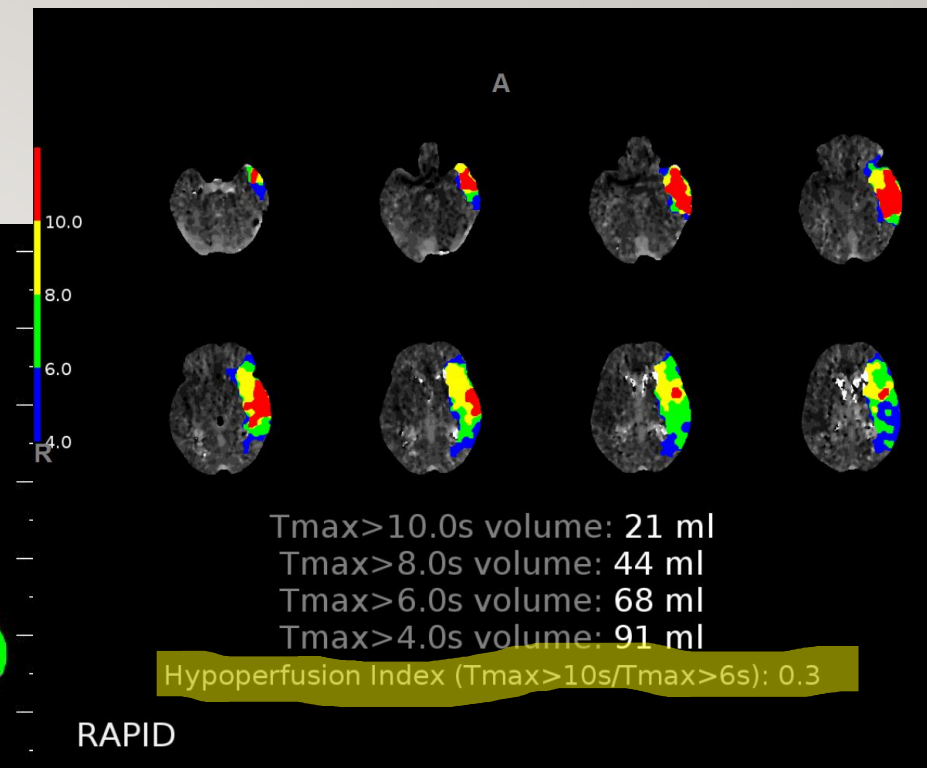
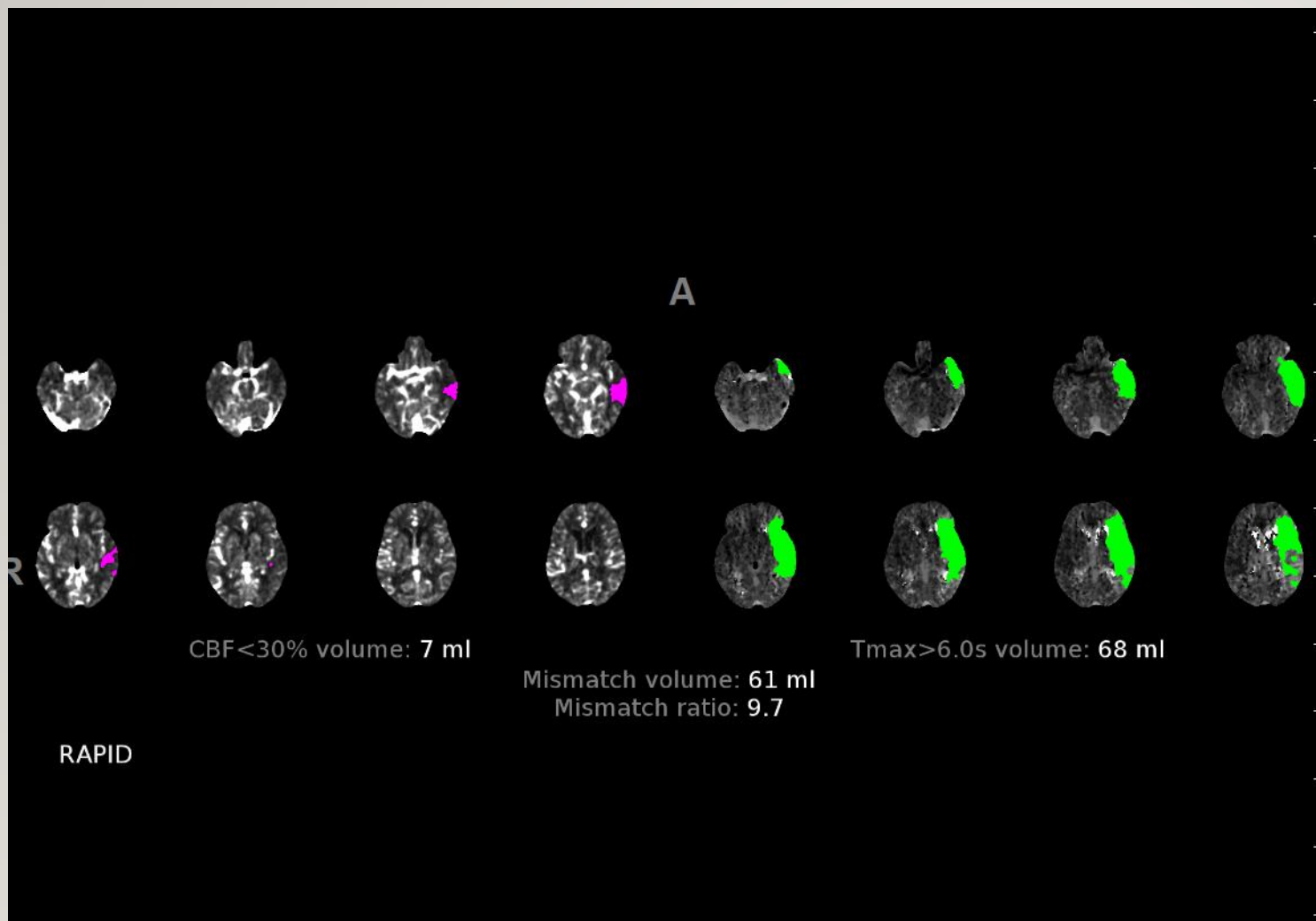
Core infarct: ↓ CBF and
CBV

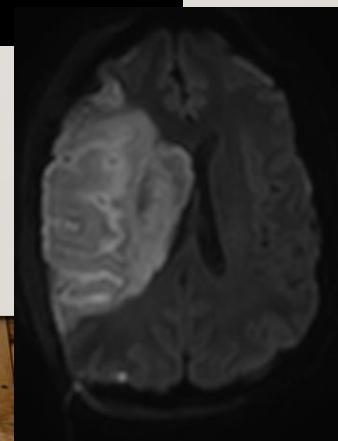
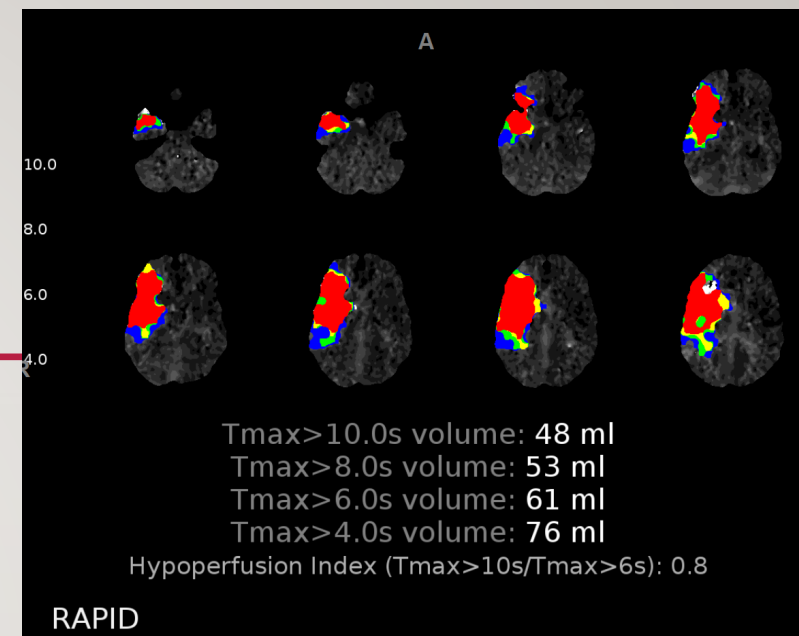
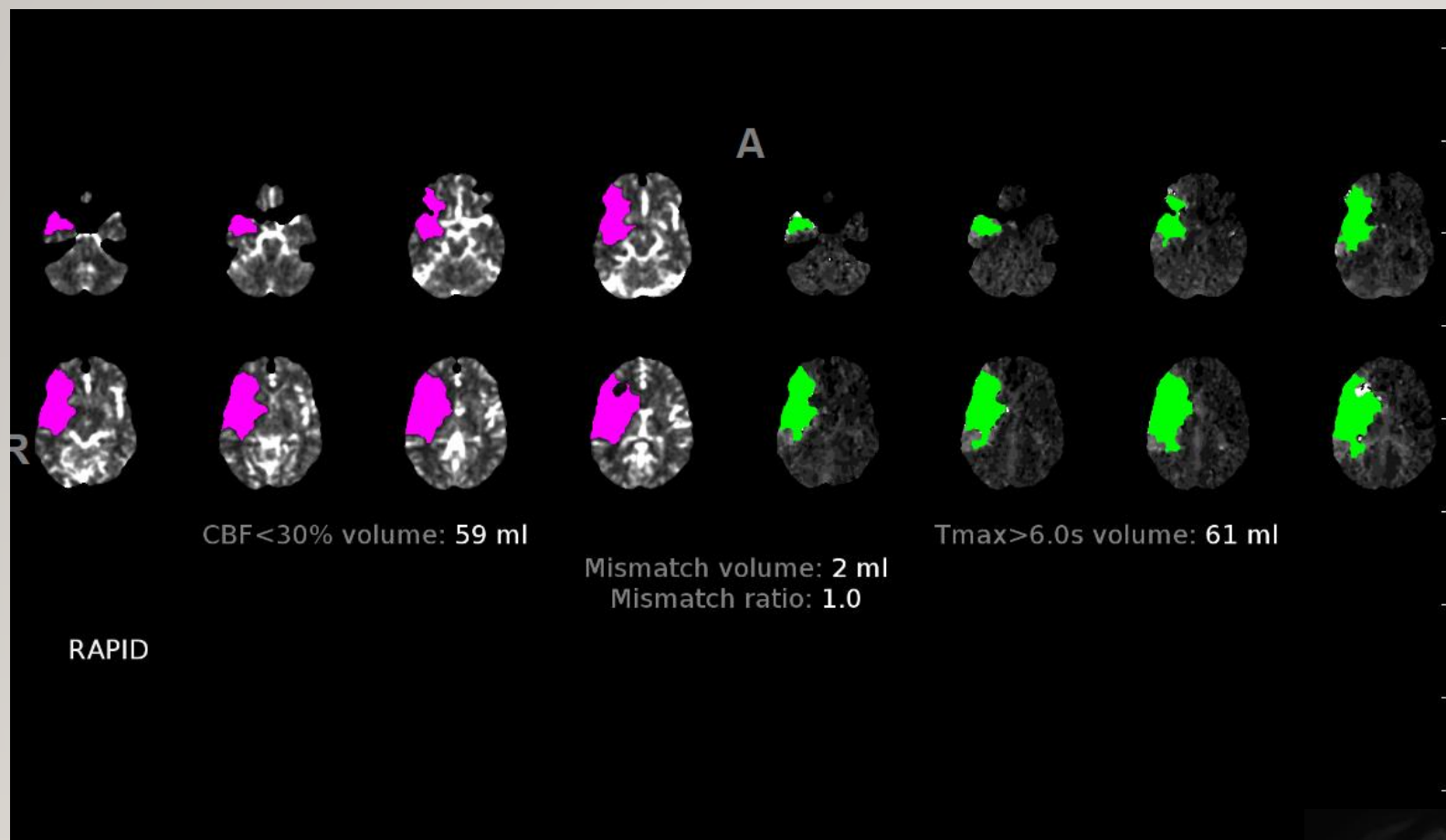
Penumbra: ↓ CBF, CBV
is preserved and ↑
Tmax

PERFUSION MAPS

- Always interpret with non con CT head
- Who would benefit from thrombectomy?
 - Mismatch ratio > 1.8
 - Core volume $< 70\text{mL}$



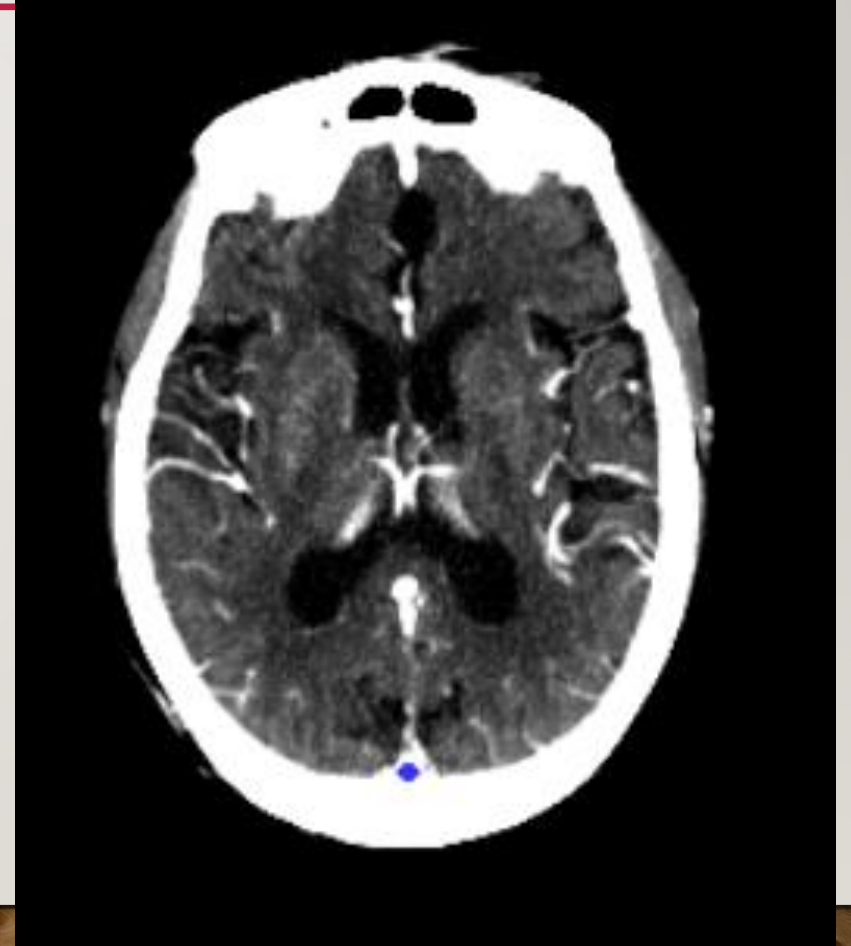




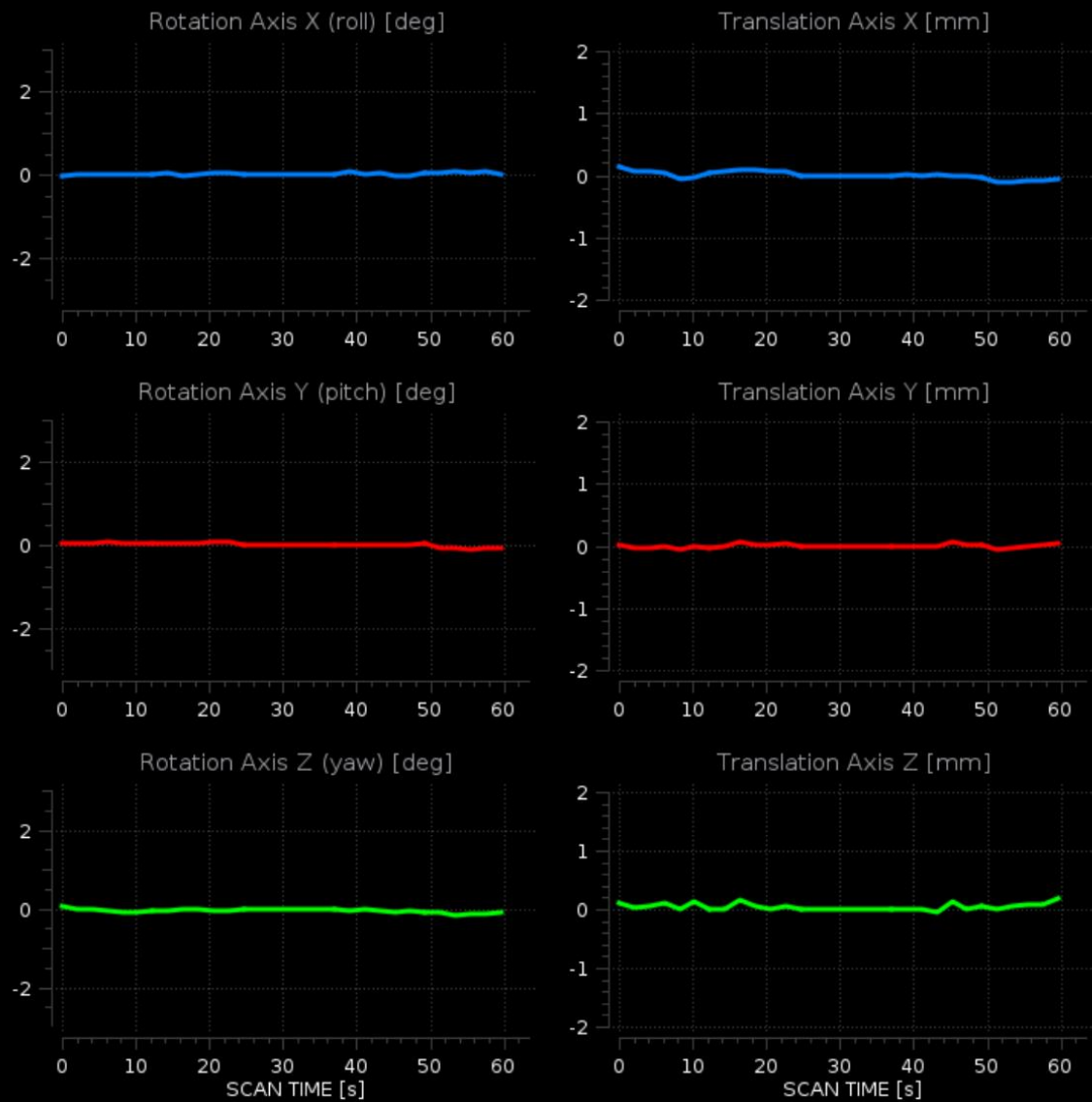
CT PERFUSION QUALITY

- Vascular time attenuation curves(AIF and VOF)
- Verifying the quality and analyzing all available data

AIF AND VOF LOCATIONS

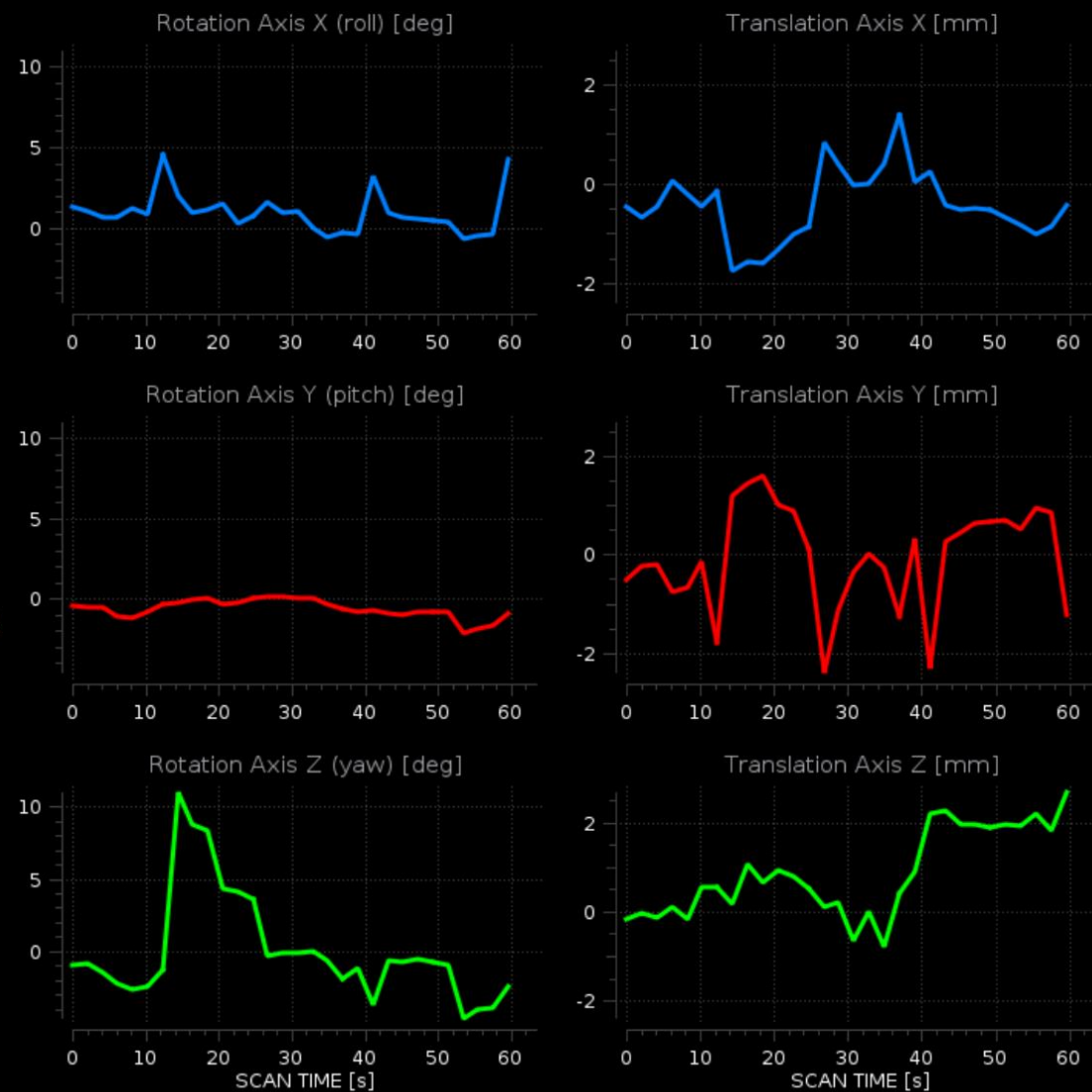


A



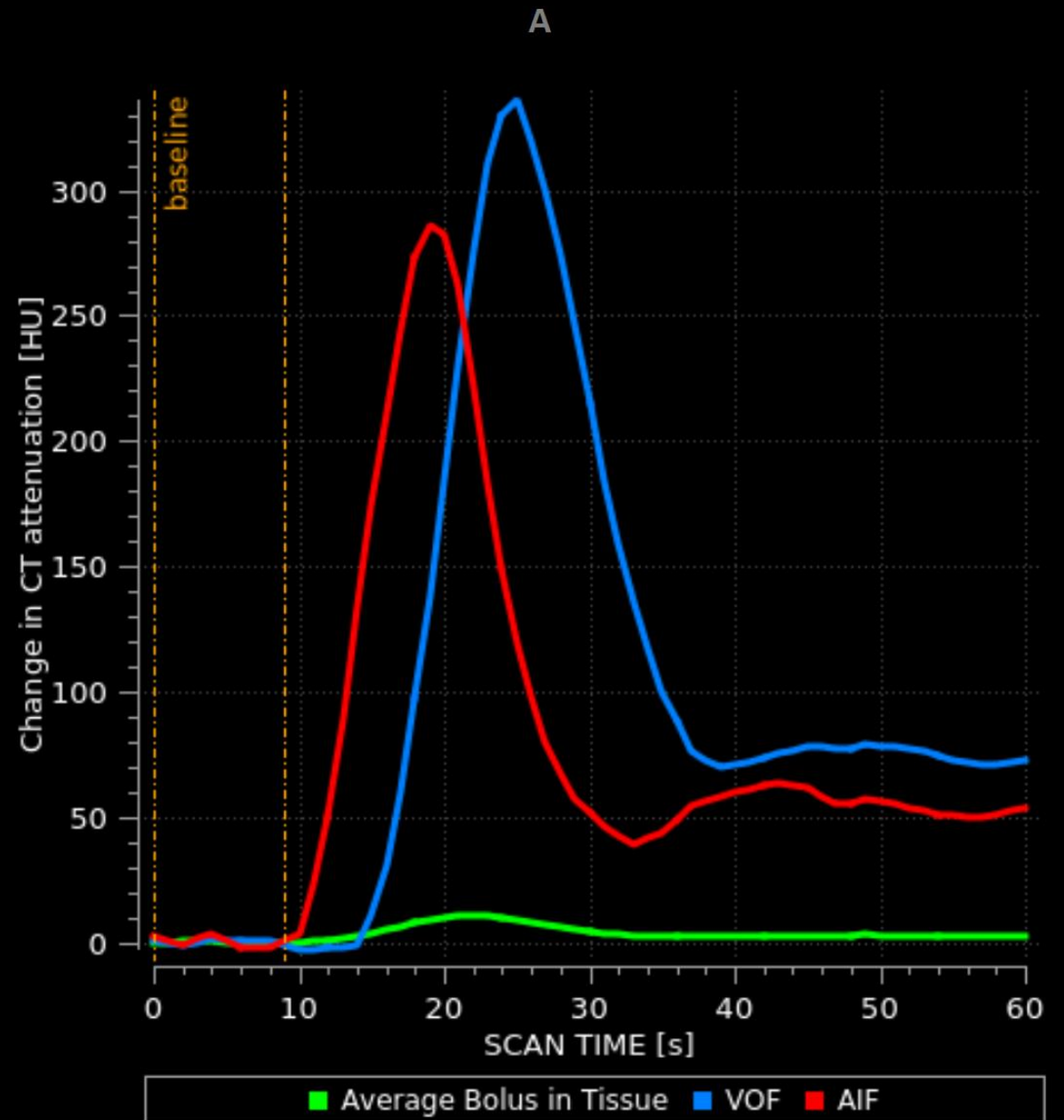
RAPID

A

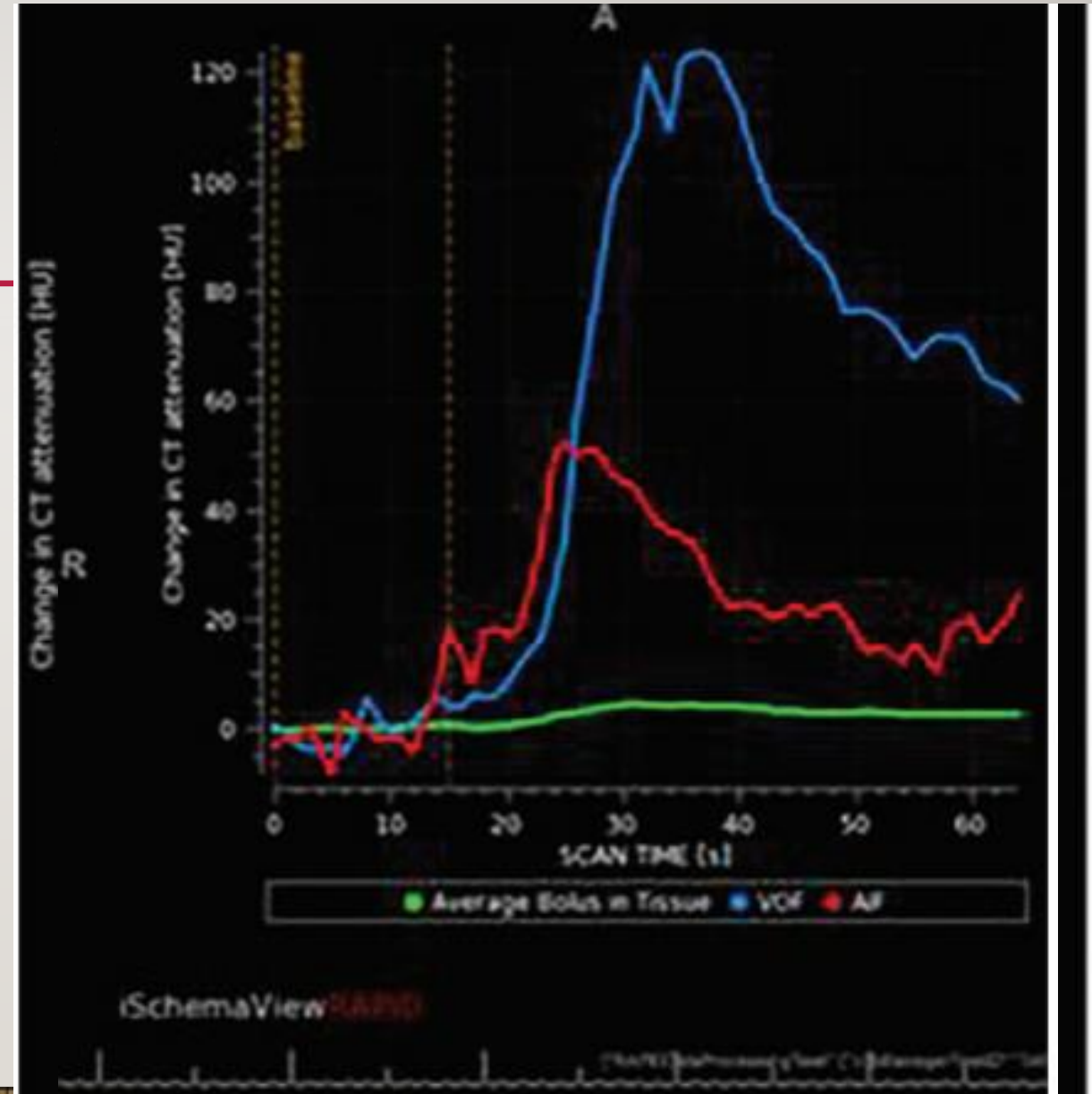


CTP CURVES

- AIF and VOF curves:
 - Sharp, single peak
 - >80 HU

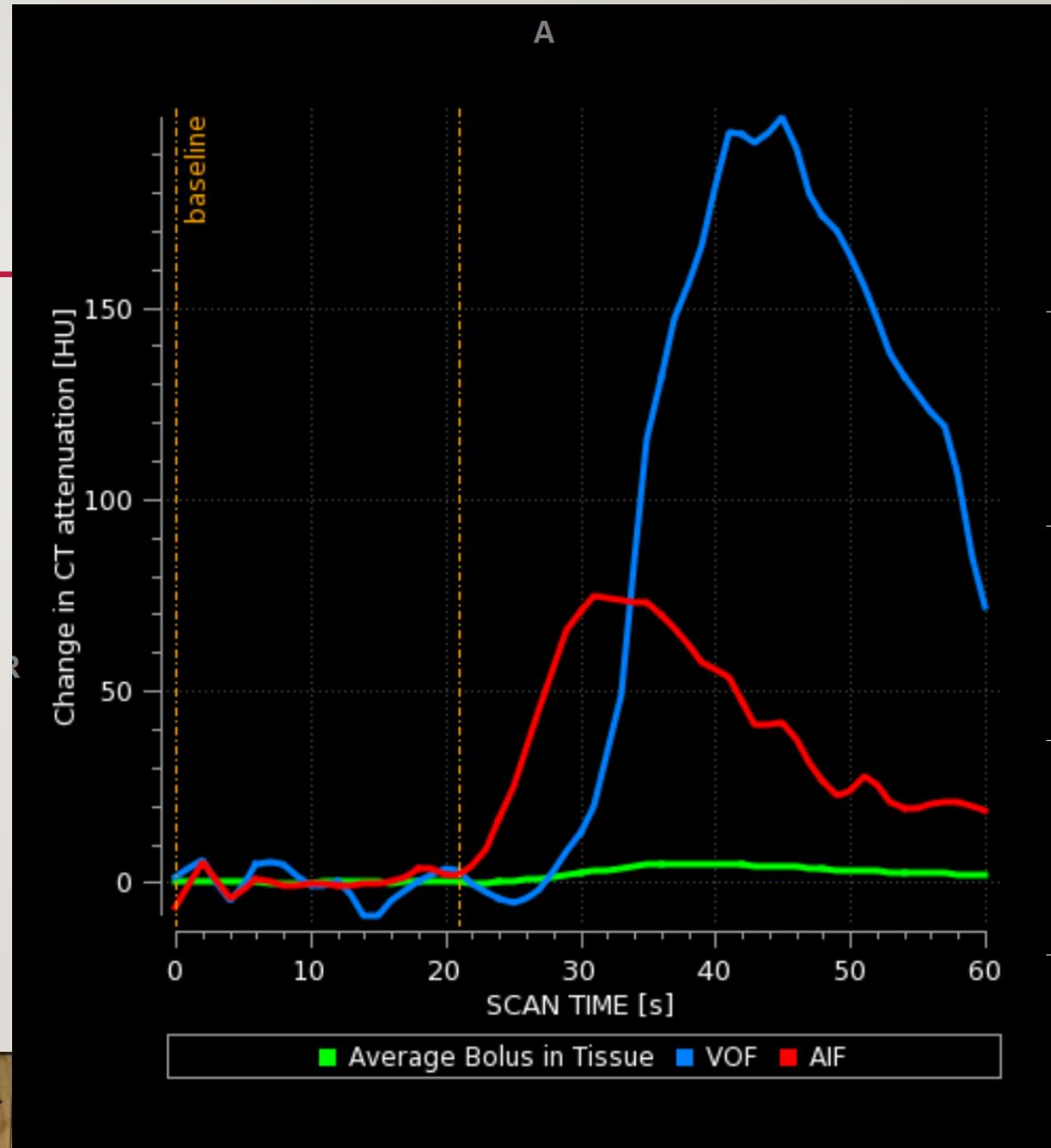


- Jagged multipeak AIF
 - Misregistration
- Broad slow rising AIF(<100HU)
 - Poor bolus of contrast delivery



LOW CARDIAC OUTPUT

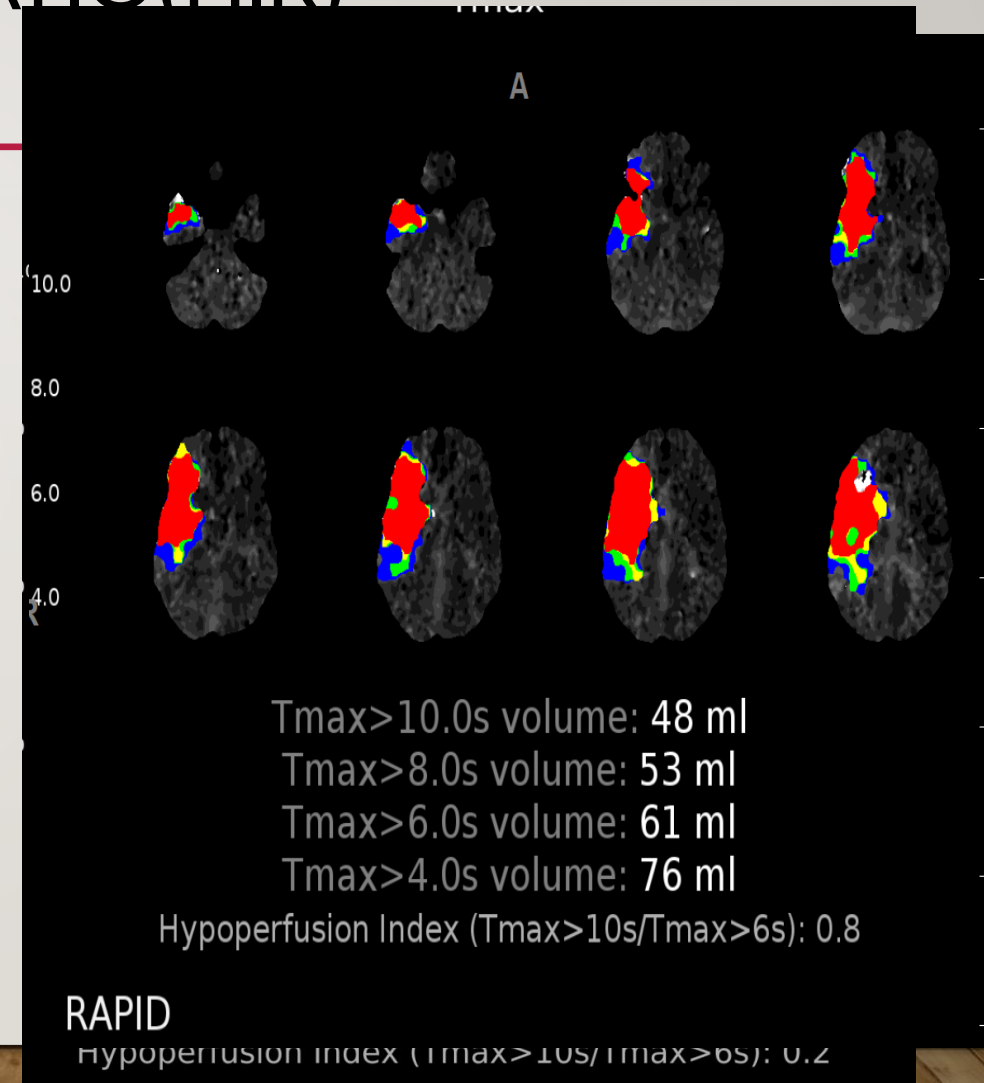
- Protocol adjustment
 - Engaged when contrast upslope
 - On CTA smartprep >15 sec
 - Extended delay of 7 s
 - Extended imaging to 77 sec

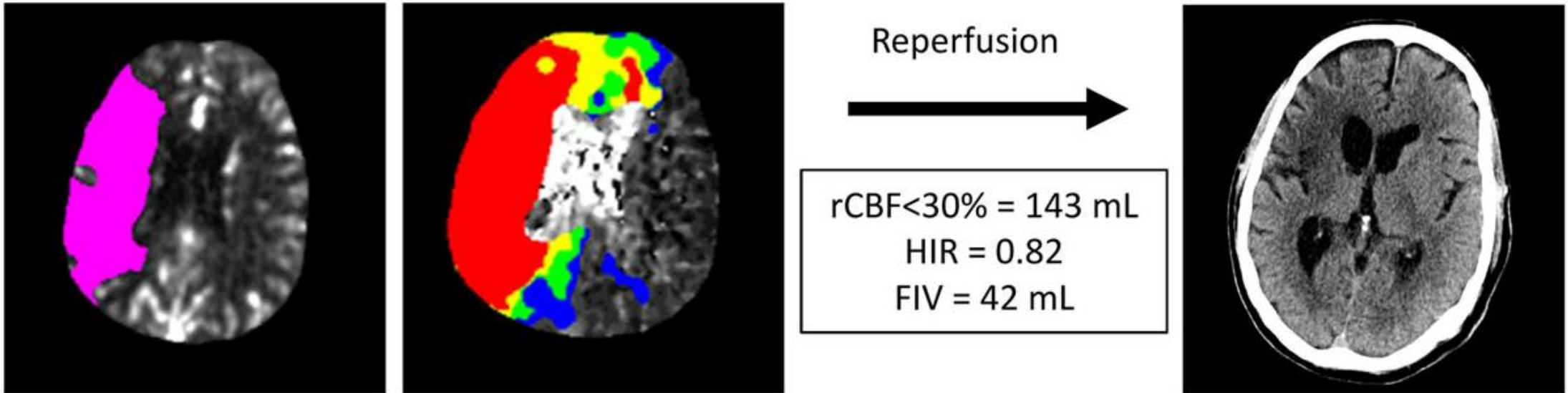


HYPOPERFUSION INTENSITY RATIO(HIR)

- HIR correlate of collateral status
 - $(T_{max.10}/T_{max>6})$
 - $HIR < 0.7$ cutoff for good collateral status
- Collateral status key for large core infarct response to EVT

■ Wang, J of Clin Med, 2021





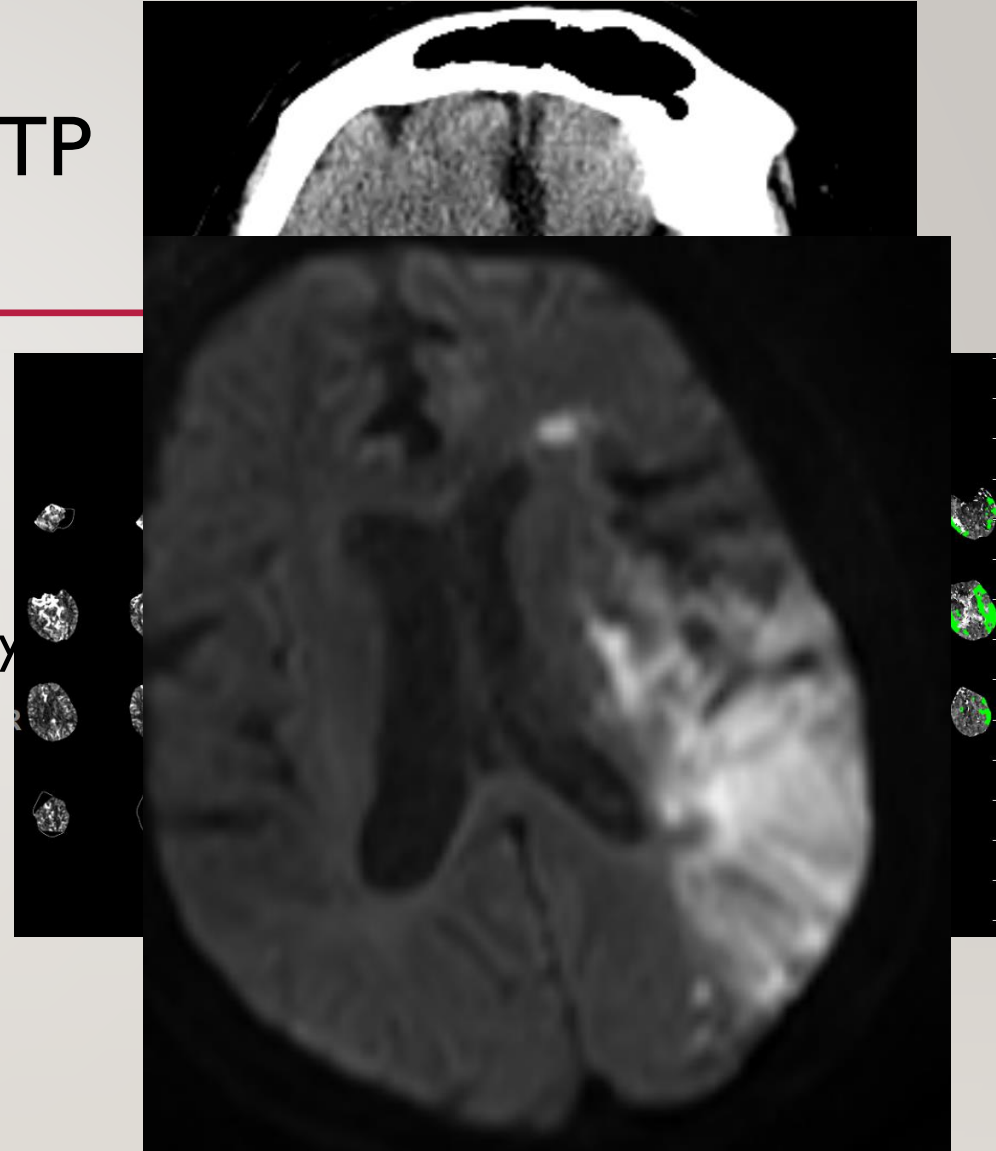
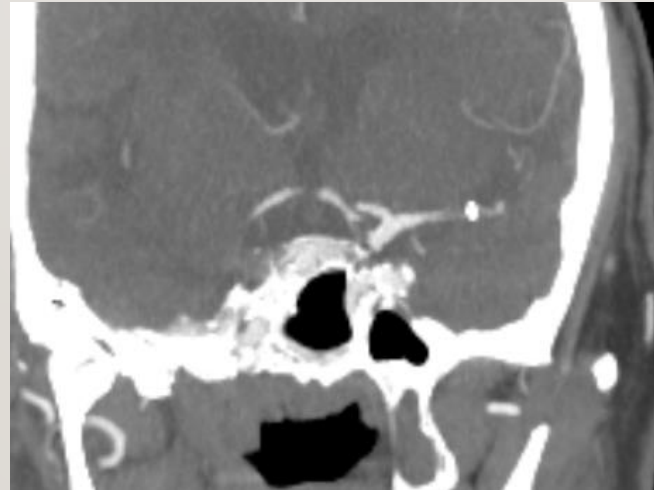
GHOST INFARCT

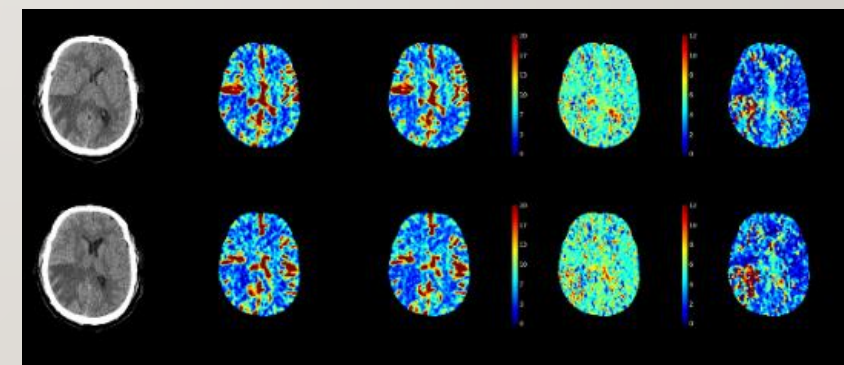
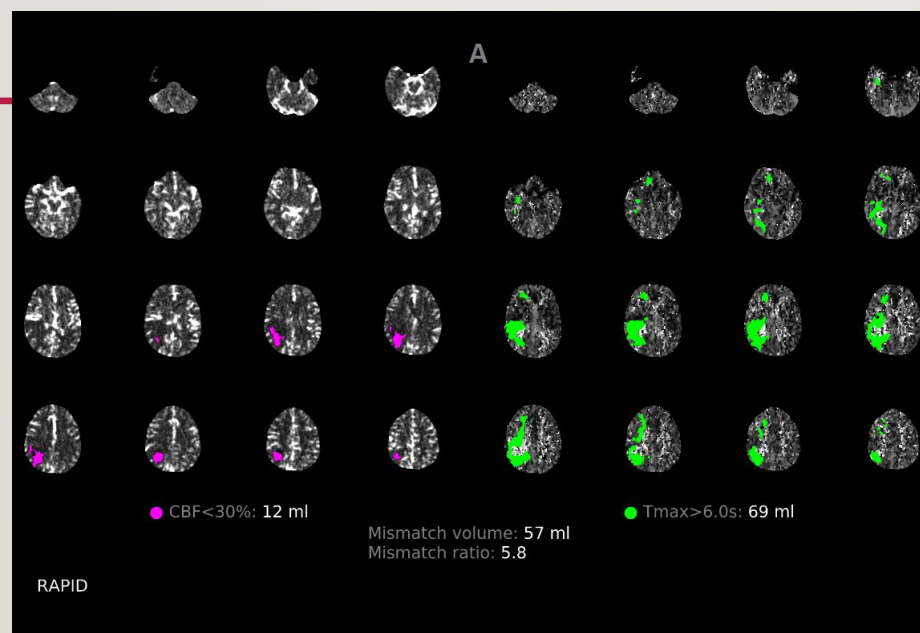
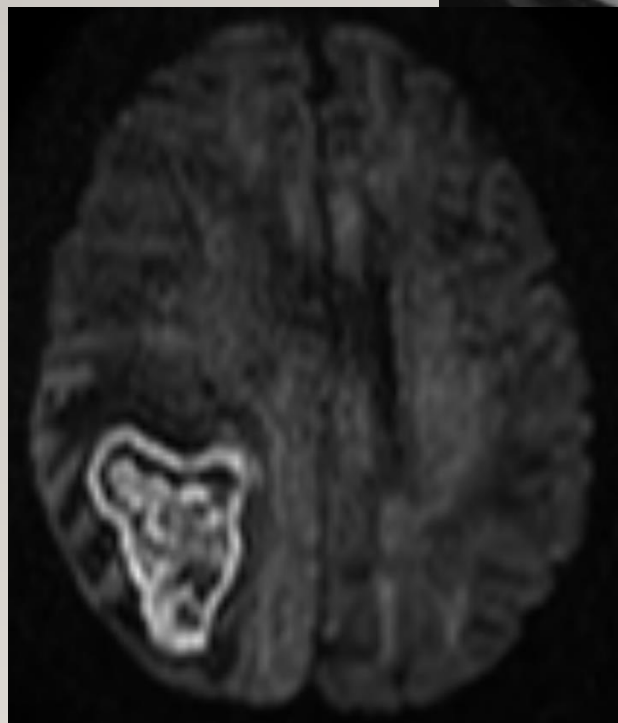
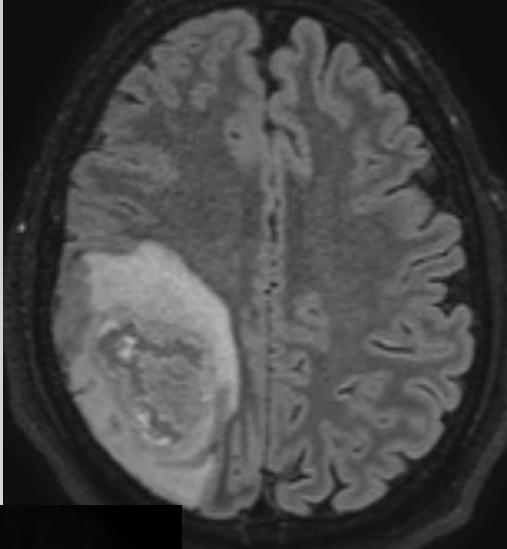
- Ischemic core overestimation with CBF thresholds
- Time and collateral dependent process
 - <3hrs of presentation
- Initial core size should not be included in treatment selection

Stroke: Volume 52, Issue 5, May 2021;
1751-1760

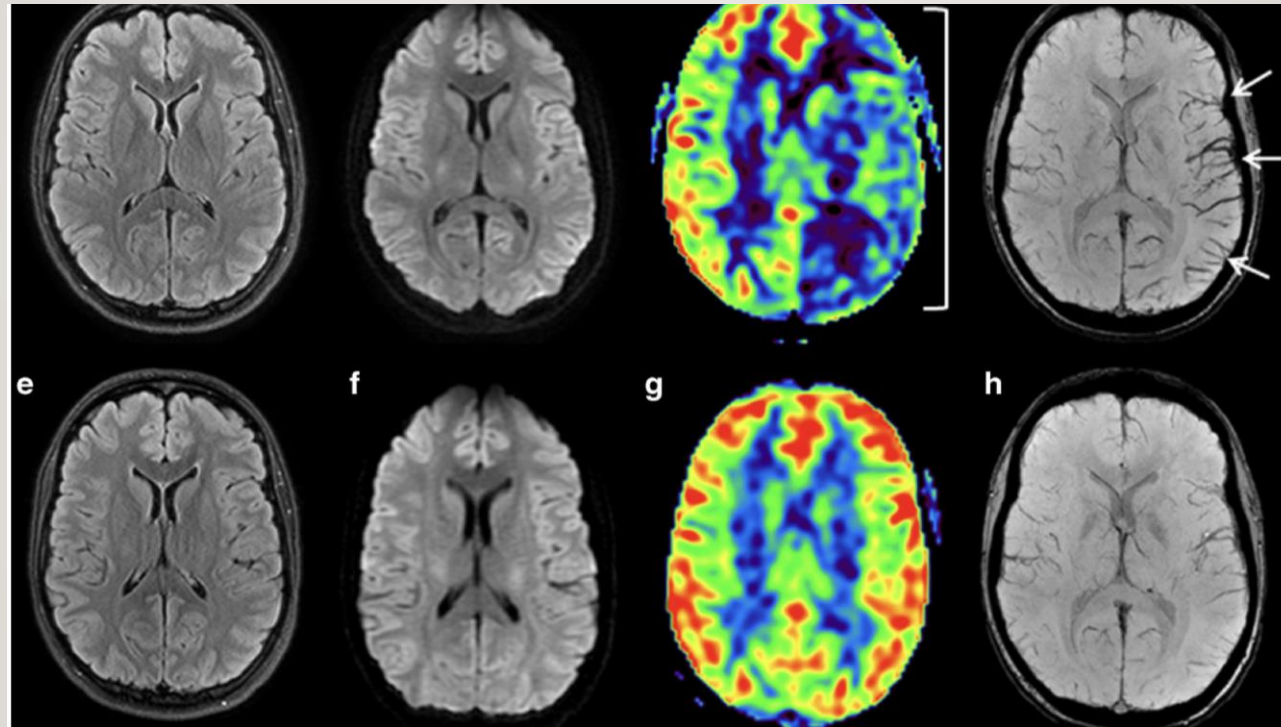
UNDERESTIMATED CORE ON CTP

- Small core infarct on CT perfusion but a low ASPECTS “perfusion scotoma.”
- Time: >6 hrs of symptom onset
- Early reperfusion from partial recanalization as well as luxury perfusion



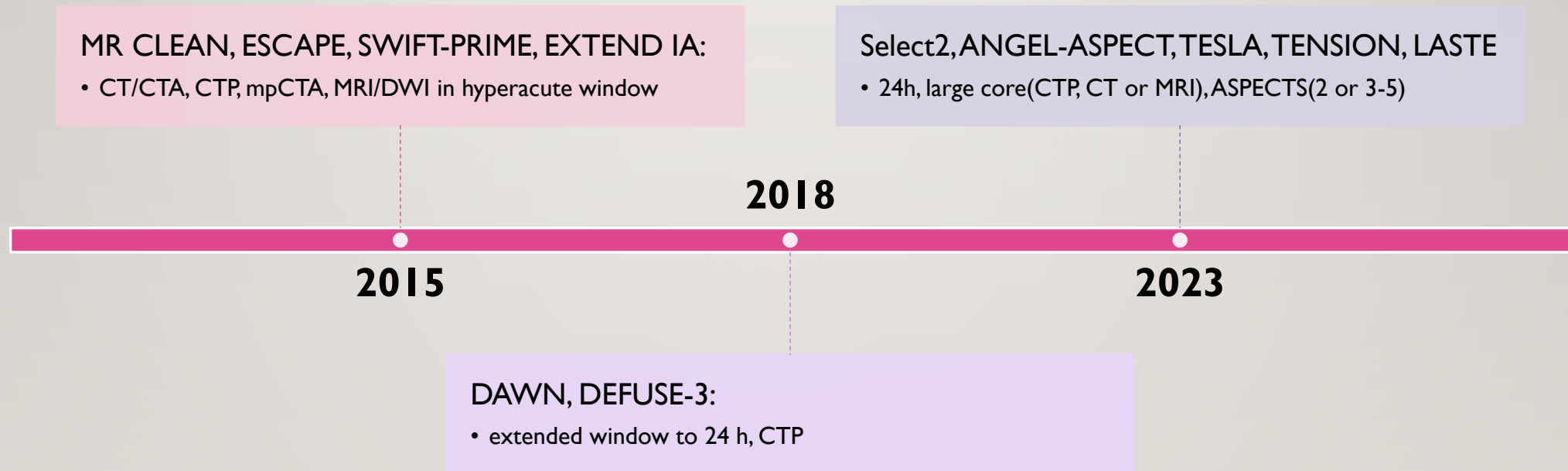


MIGRAINE AURA-ASL USEFULNESS



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STROKE STUDIES



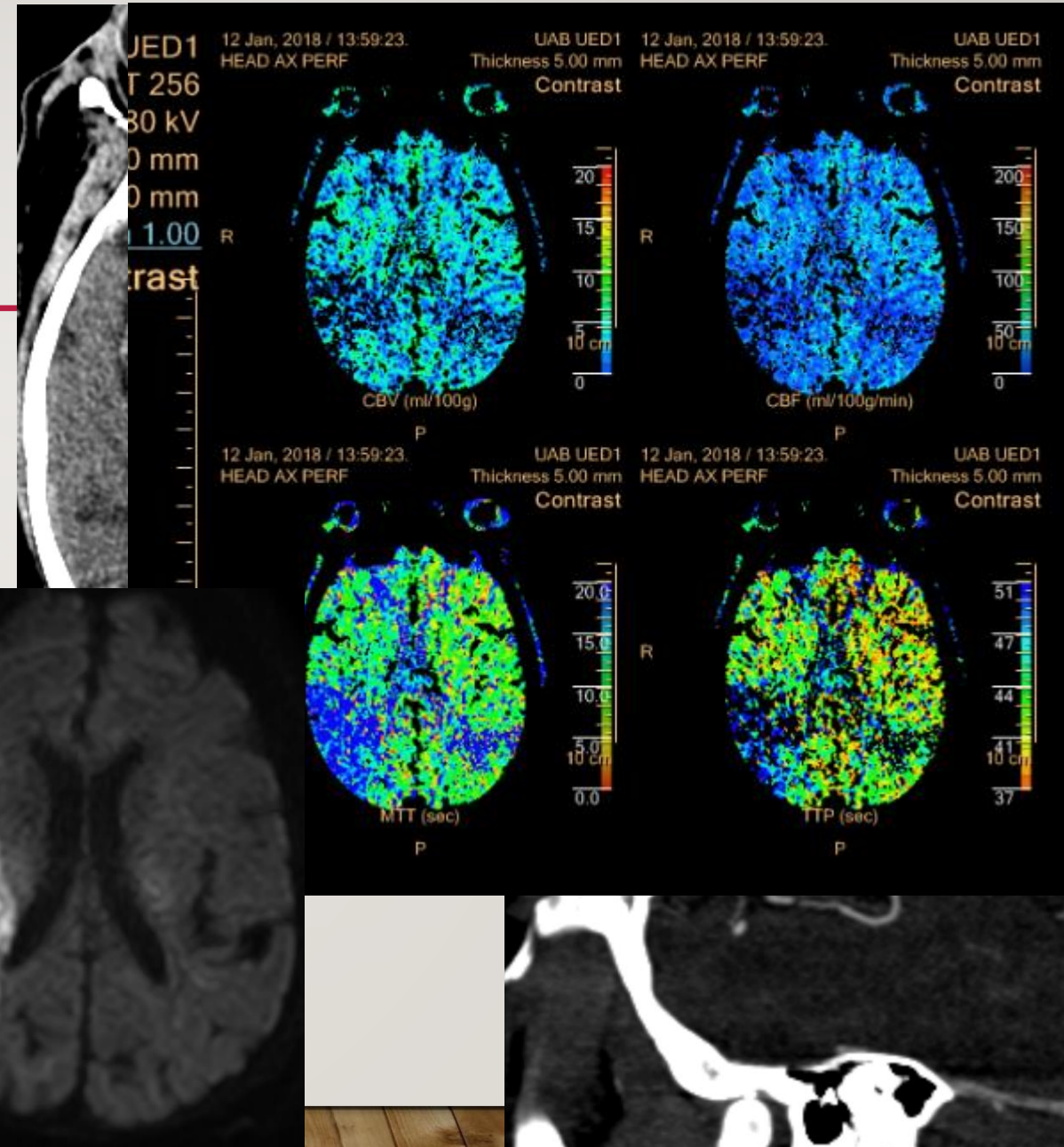
SUMMARY OF STROKE STUDIES

- 0-6 hours
 - Treat almost all LVO patients
- 6-16 hours(DEFUSE 3)
 - Look for small core and big penumbra
 - CTP or MRP required
- 6-24 hours(DAWN)
 - Look for clinical- imaging mismatch
 - Small core and big penumbra
- Up to 24 hours(SELECT 2)
 - Even large core patients qualify
 - ASPECTS 3-5 or large CTP core(upto 100mL)

DAWN and DEFUSE 3 taught us to treat small-core strokes up to 24 hours.
SELECT2 taught us that even large-core strokes can still benefit up to 24 hours

MEVO IDENTIFICATION

- Vessel diameter: 0.75 to 2 mm
- M3–M4 MCA, A2 ACA, P2 PCA
- 25-40% of acute stroke.
- 51% vs 77% in MeVO detection with CTP($p<.001$)
- CTP improved accuracy, sens, spec, inter-reader agreement and readout time

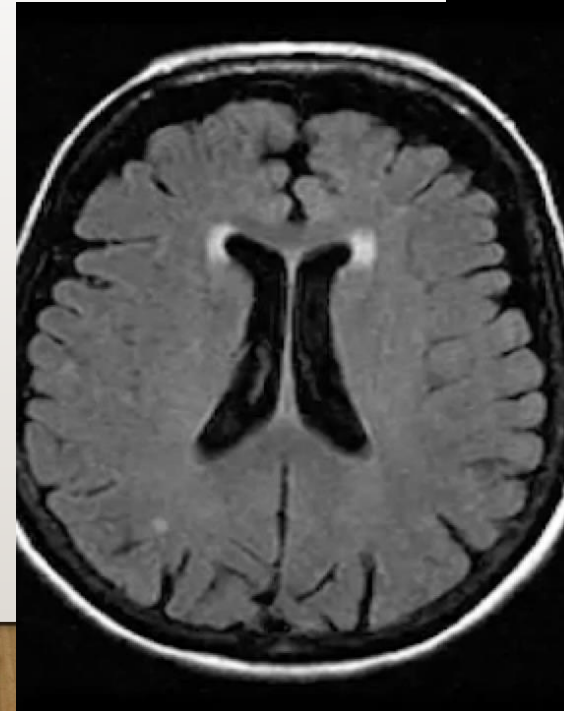
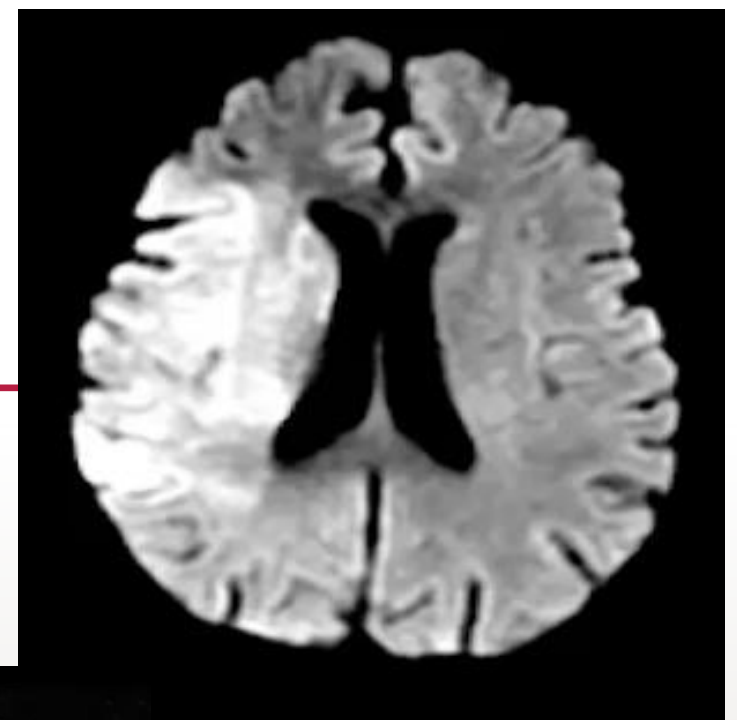


STROKE TREATMENT

- <4.5 hours since normal-IV tPa
 - may be extended with completion of trials looking out to 24 hrs
- IA intervention
 - <24 hours, ASPECTS ≥ 3
- MeVO's
 - controversy on IA intervention

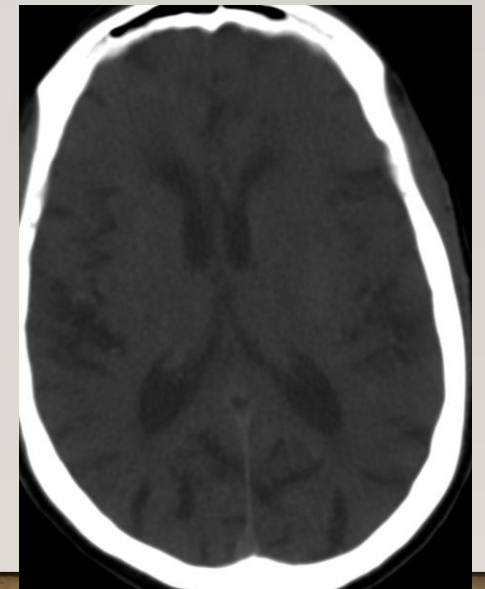
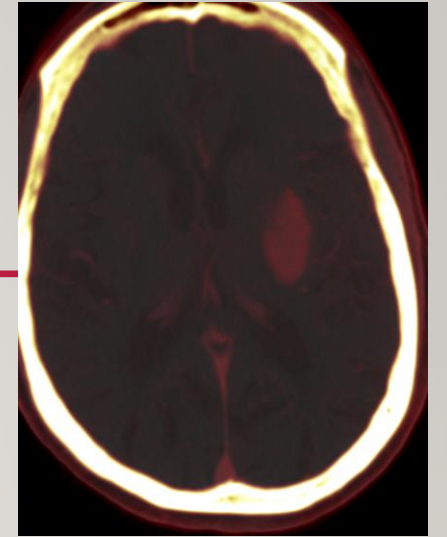
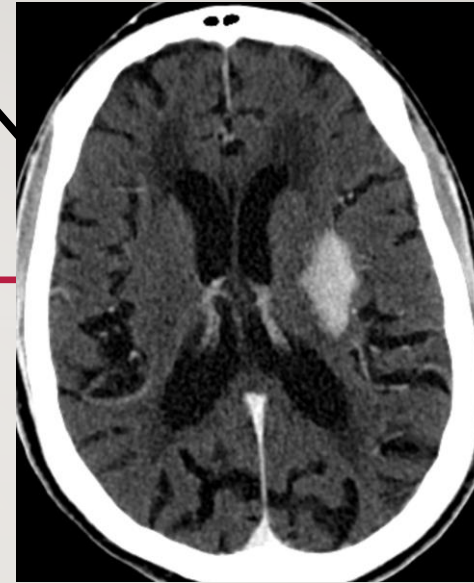
UNKNOWN LAST NORMAL

- In patients with DWI-FLAIR mismatch on MRI, IV tPA results in significantly increased likelihood of good outcome(OR 1.61)
- IV tPA given in these circumstances



POST INTERVENTION IMAGING

- DECT(Dual-Energy CT)
- Reliably separates between contrast stain and hemorrhage
- VNC images and iodine map
- Persistence on VNC: hemorrhage
- Loss of hyper density on VNC: contrast



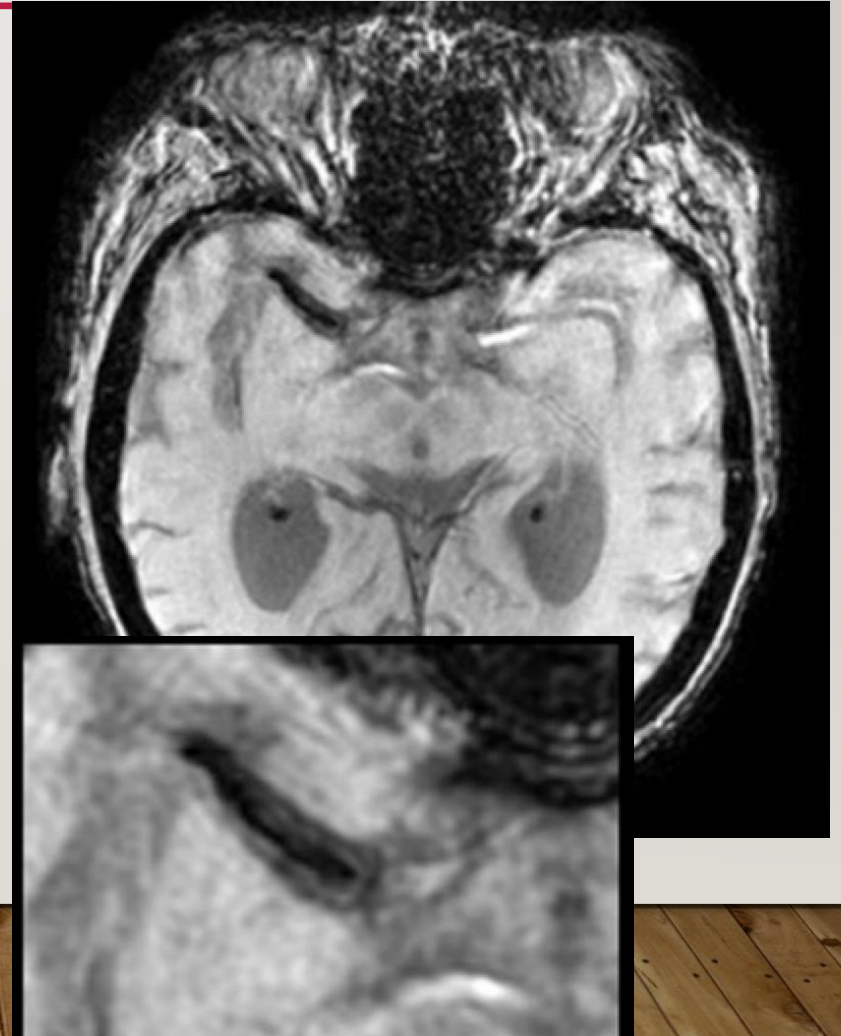
VNC

190 KeV

ASL AND SWI IN MANAGEMENT OF ACUTE INFARCT

- Can detect zones of parenchymal hypoperfusion
- SWI: thrombus localization and composition
- ASL: can identify stroke mimics
- Post-therapeutic ASL predicts outcome

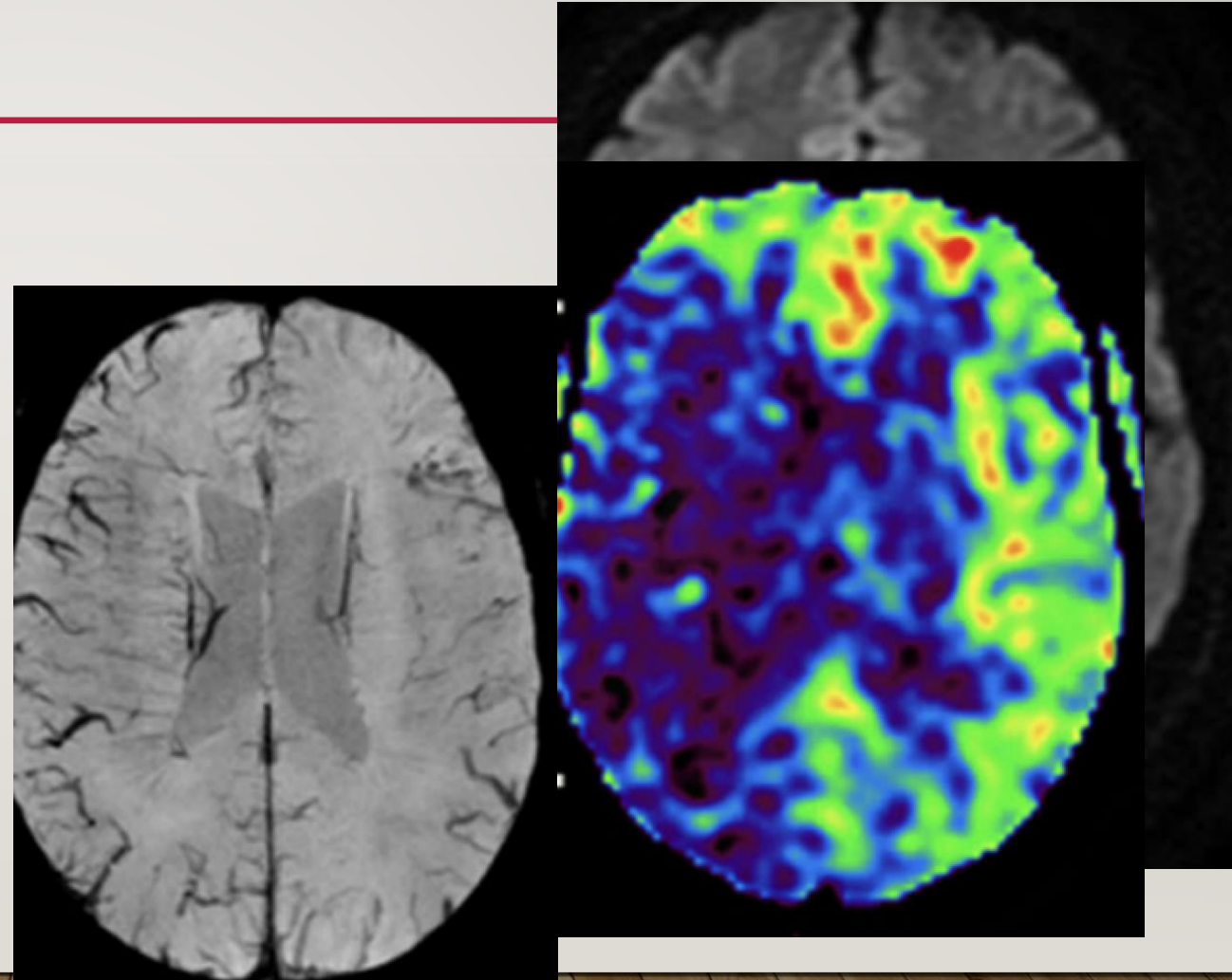
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ASL AND SWI IN MANAGEMENT OF ACUTE INFARCT

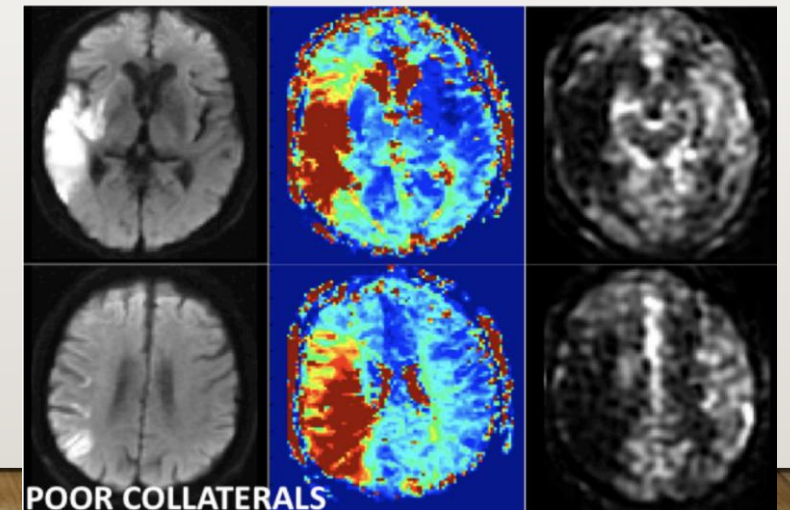
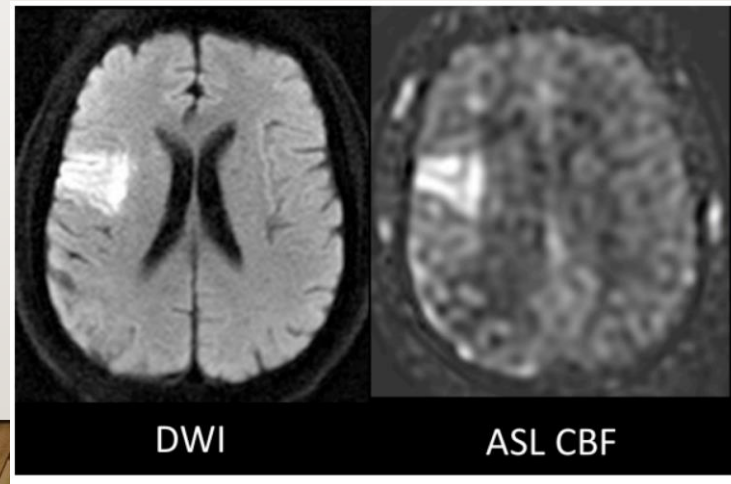
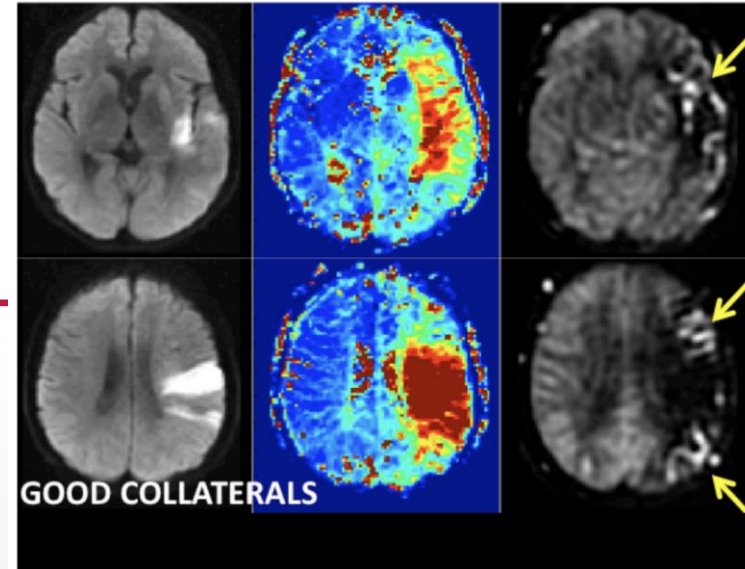
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ARTERIAL SPIN LABELLING(ASL)- COLLATERALS

- Assess the arterial collaterals
 - Increased ASL signal- good collaterals
 - Reduced ASL signal-poor collaterals
- Presence of hyperperfusion is a good prognostic factor



KEY TAKEAWAYS

- NCCT= rule out hemorrhage
- CTA= occlusion and collaterals
- Perfusion=identify salvageable tissue and helps us guide the treatment
- MRI=more sensitive for early stroke
- Advanced imaging expands treatment window

THANK YOU!

- Vprattipati@uabmc.edu