Taking a Picture of Stroke

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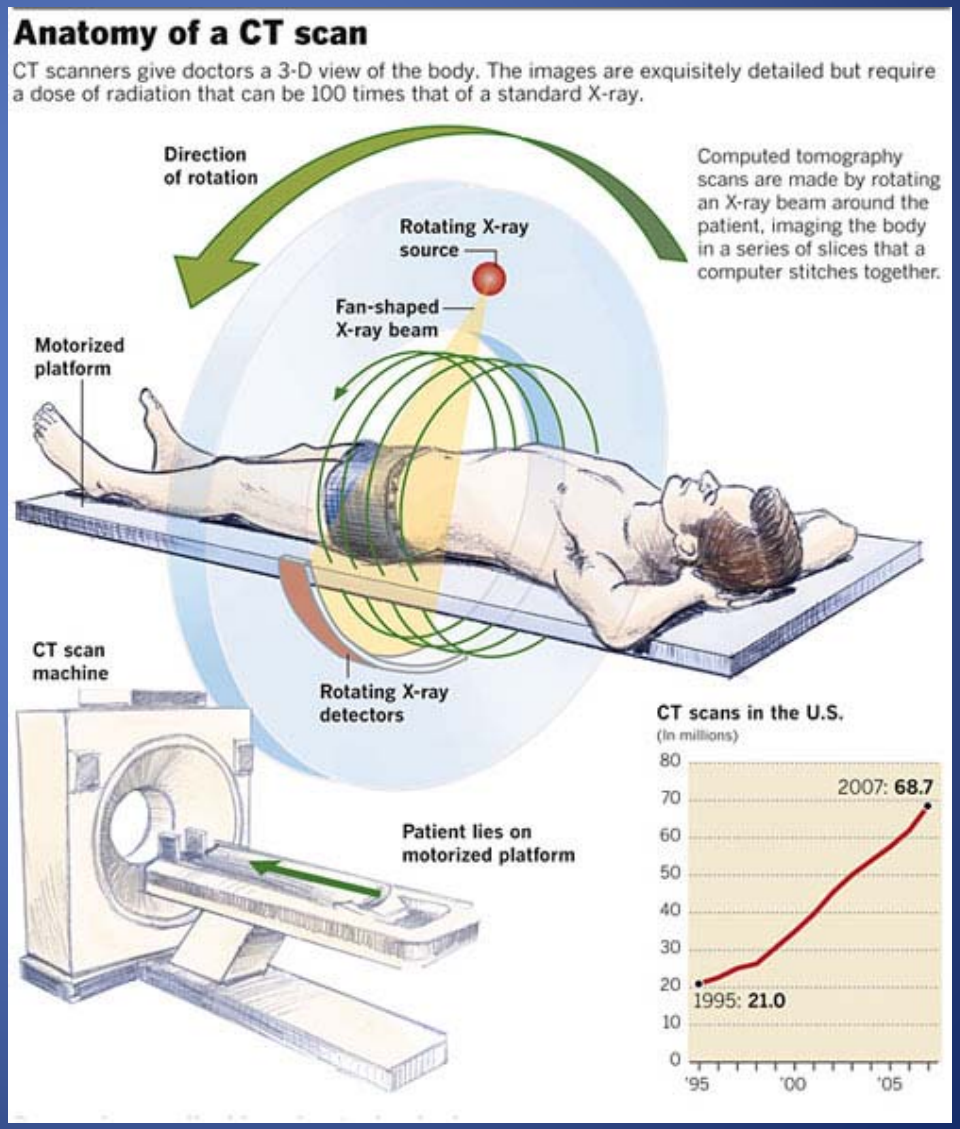
Lecture outline

- CT
- MRI
- Cases

Understanding CT Scan

- CT : Computed Tomography
- Radiation
- High density tissue is bright
- Low density tissue is dark

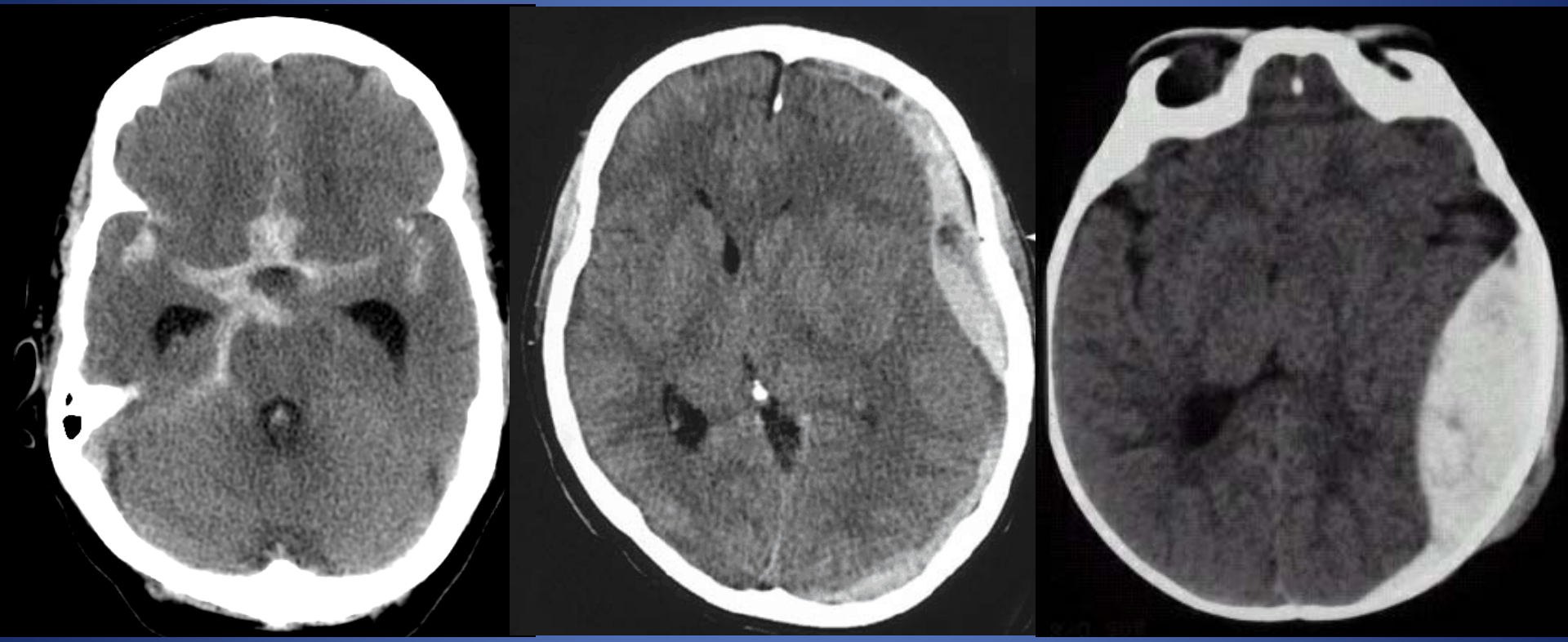


Head CT is great at showing acute hemorrhages

Normal Noncontrast Head CT

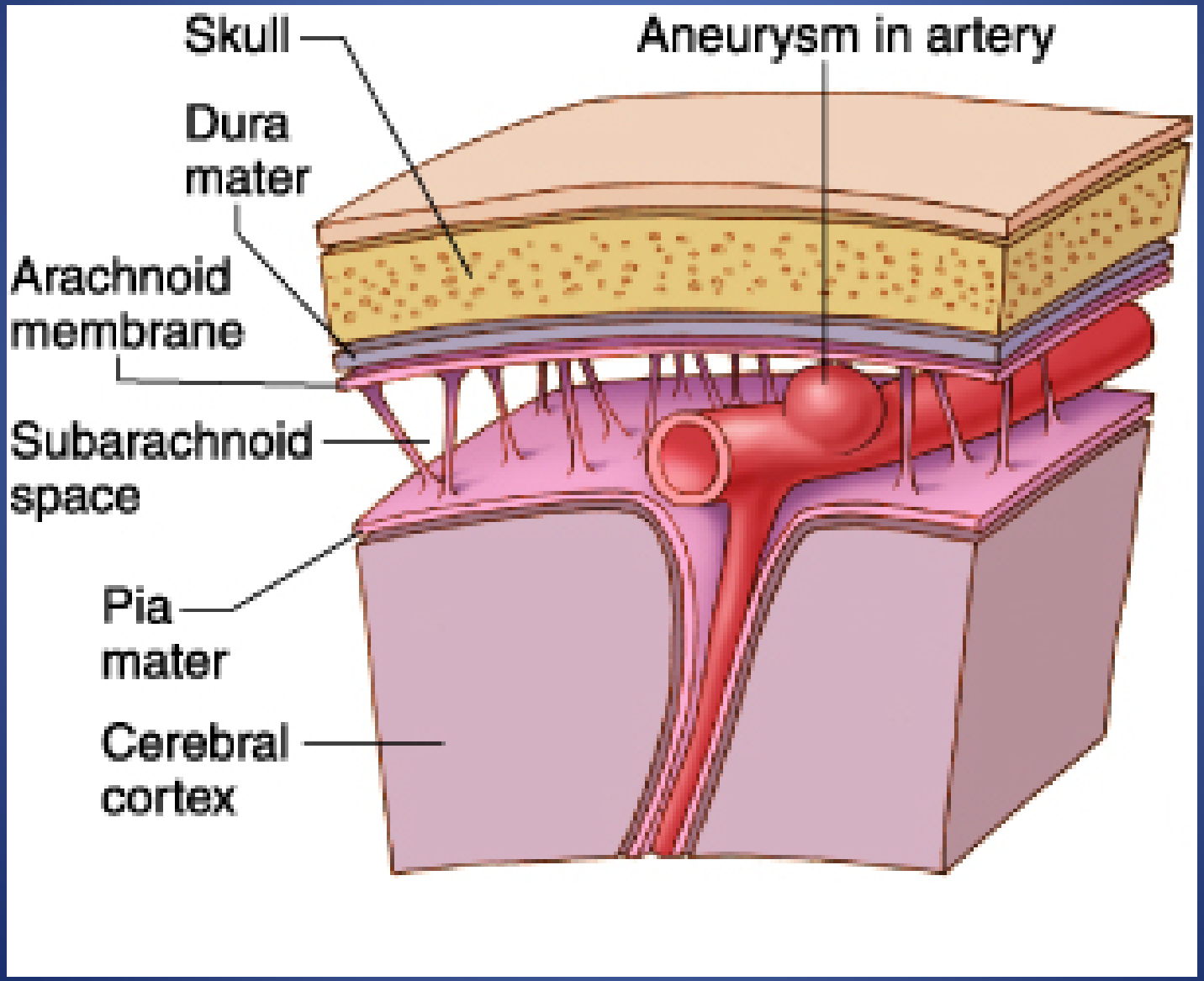
Head CT with intraparenchymal hematoma (IPH)

What types of intracranial hemorrhages are these?



A. Epidural hematoma (EDH)
B. Subarachnoid hemorrhage (SAH)
C. Subdural hematoma (SDH)

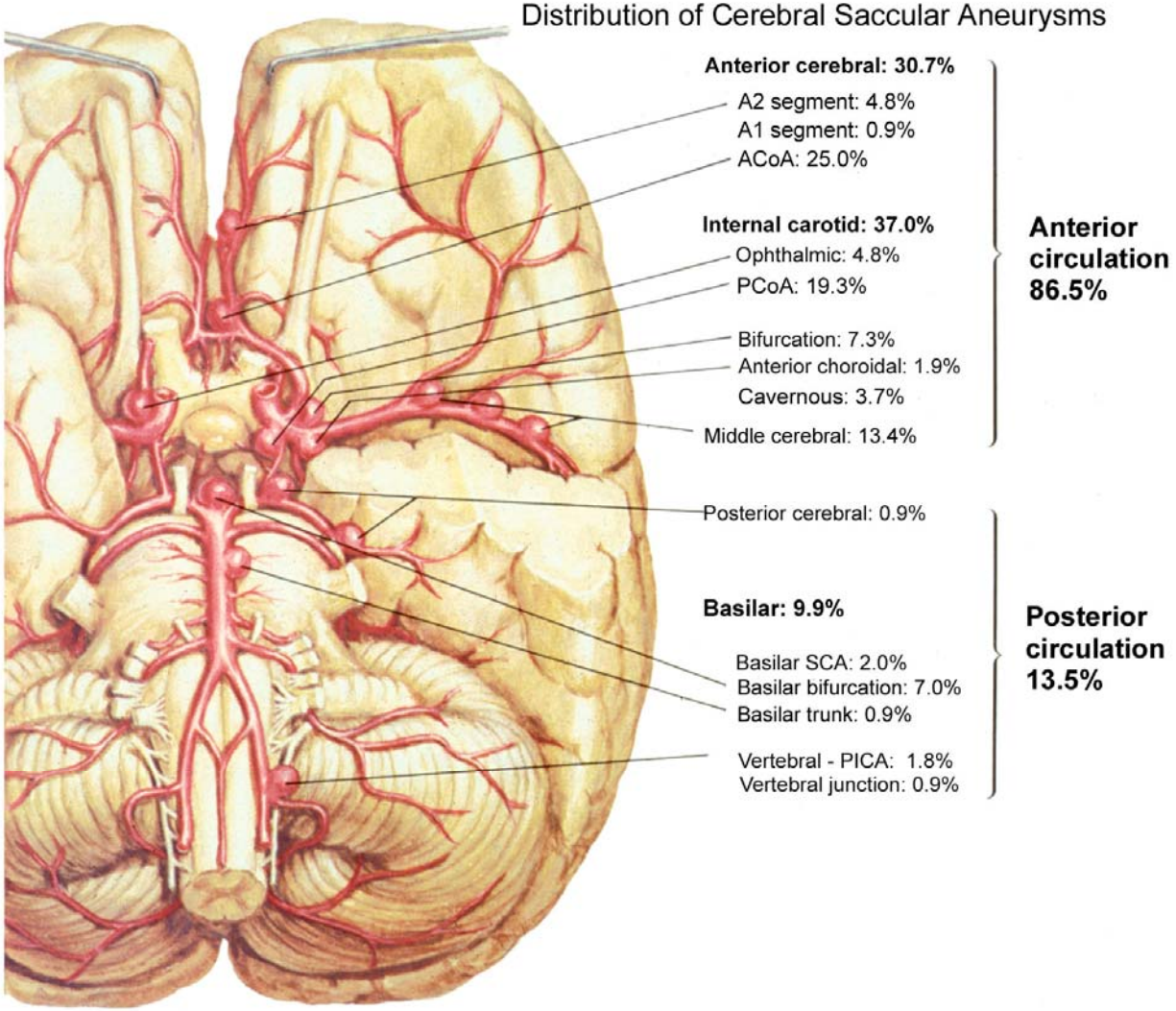
Review of the layers covering the brain



What problems do you see here?

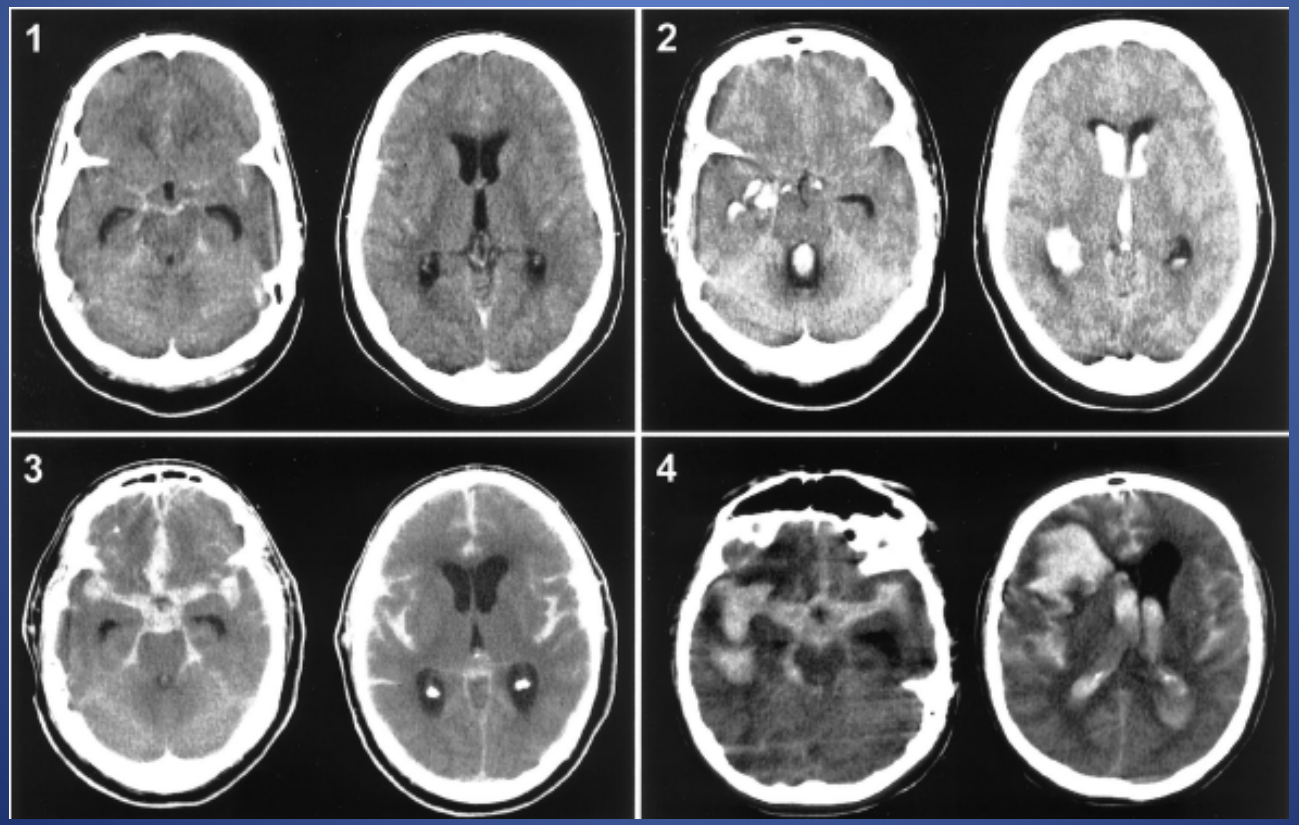
Diagnosis? What is the most likely cause?

Aneurysms cause ~85% of NONtraumatic SAH
Review of Circle of Willis (COW) arteries



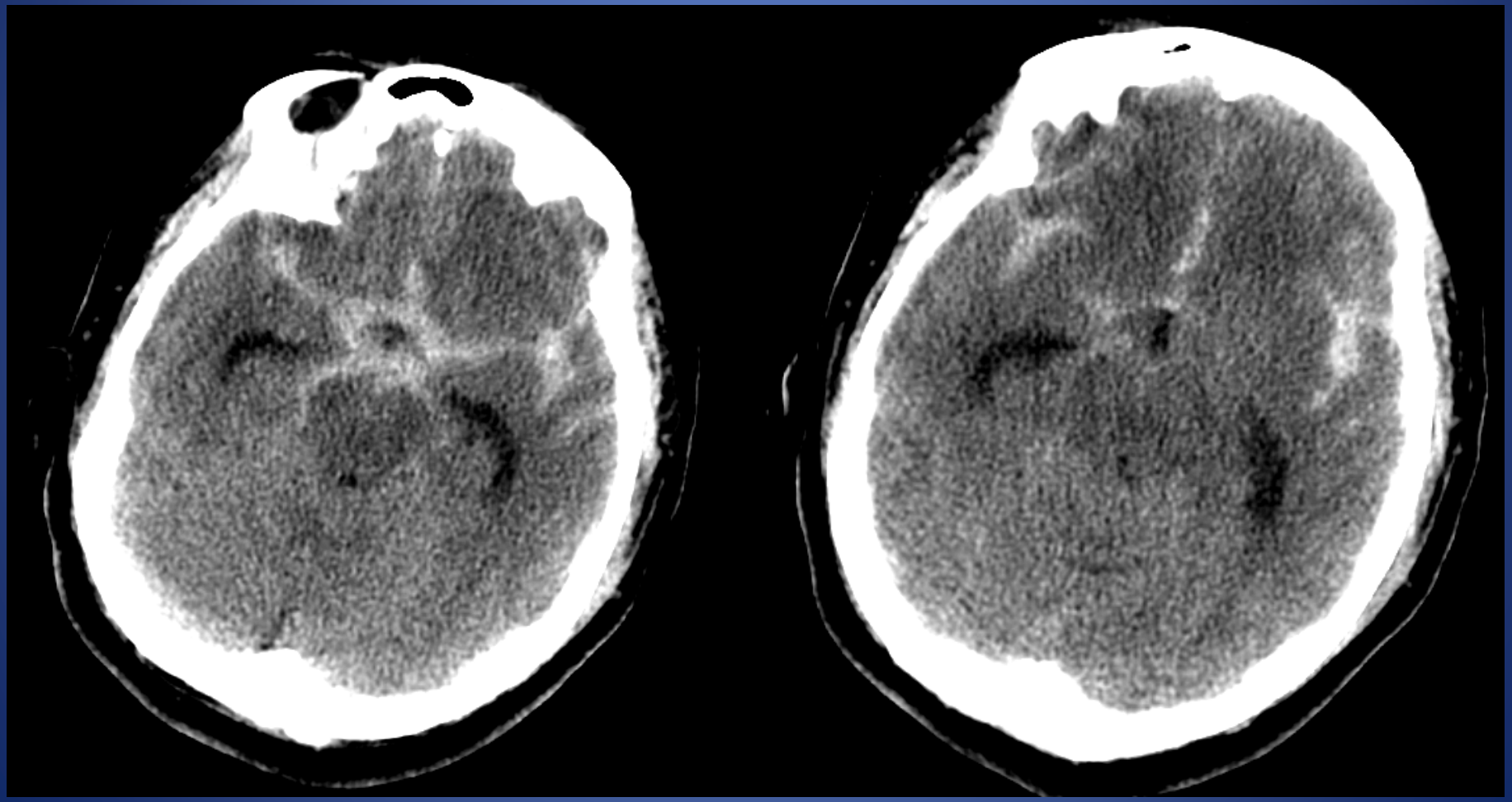
Modified Fisher Scale (CT) for aneurysmal SAH

- 0 No SAH detected
- 1 Thin SAH without IVH
- 2 Thin SAH with IVH
- 3 Thick SAH without IVH
- 4 Thick SAH with IVH

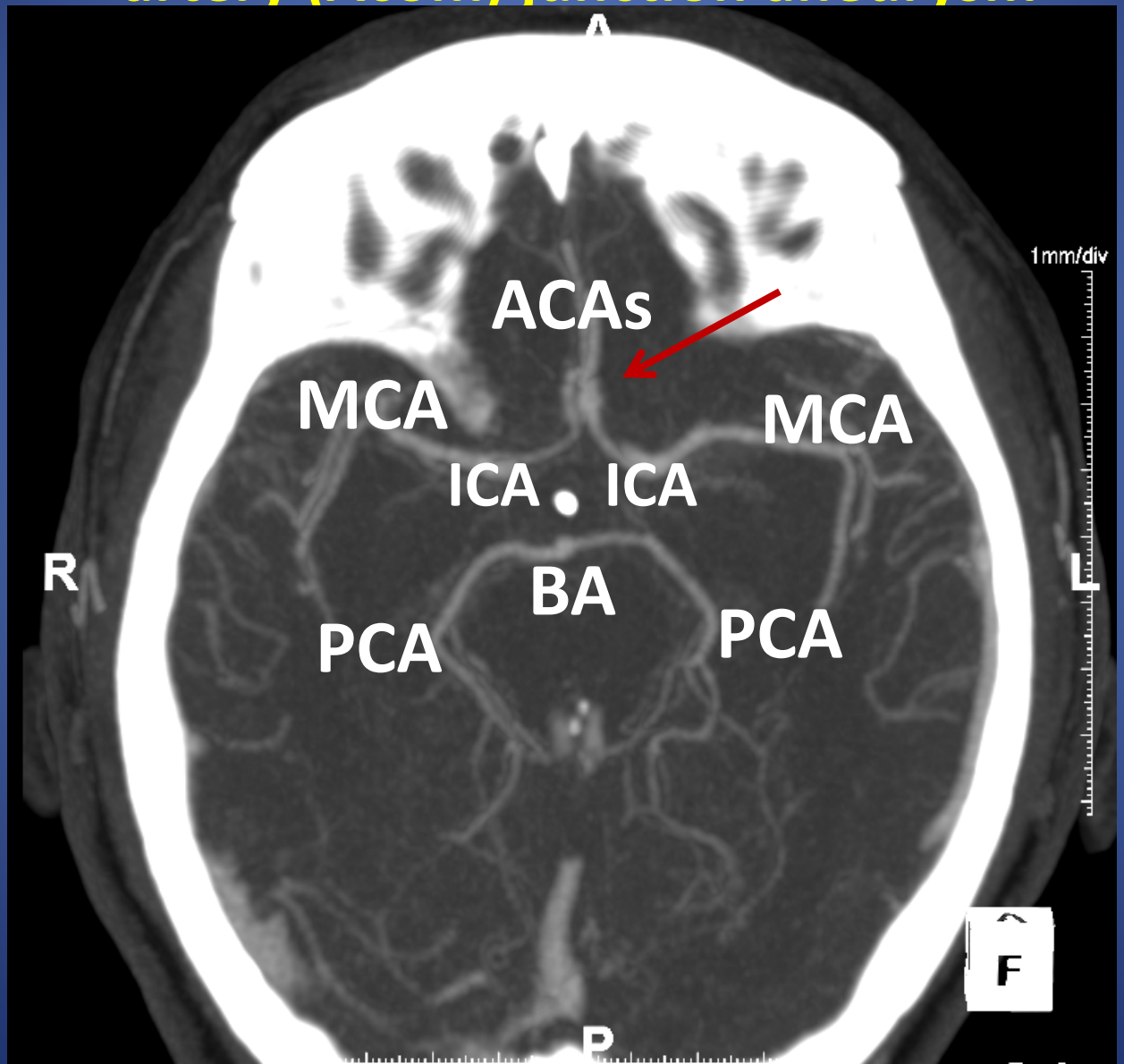


Claassen Stroke 2001.

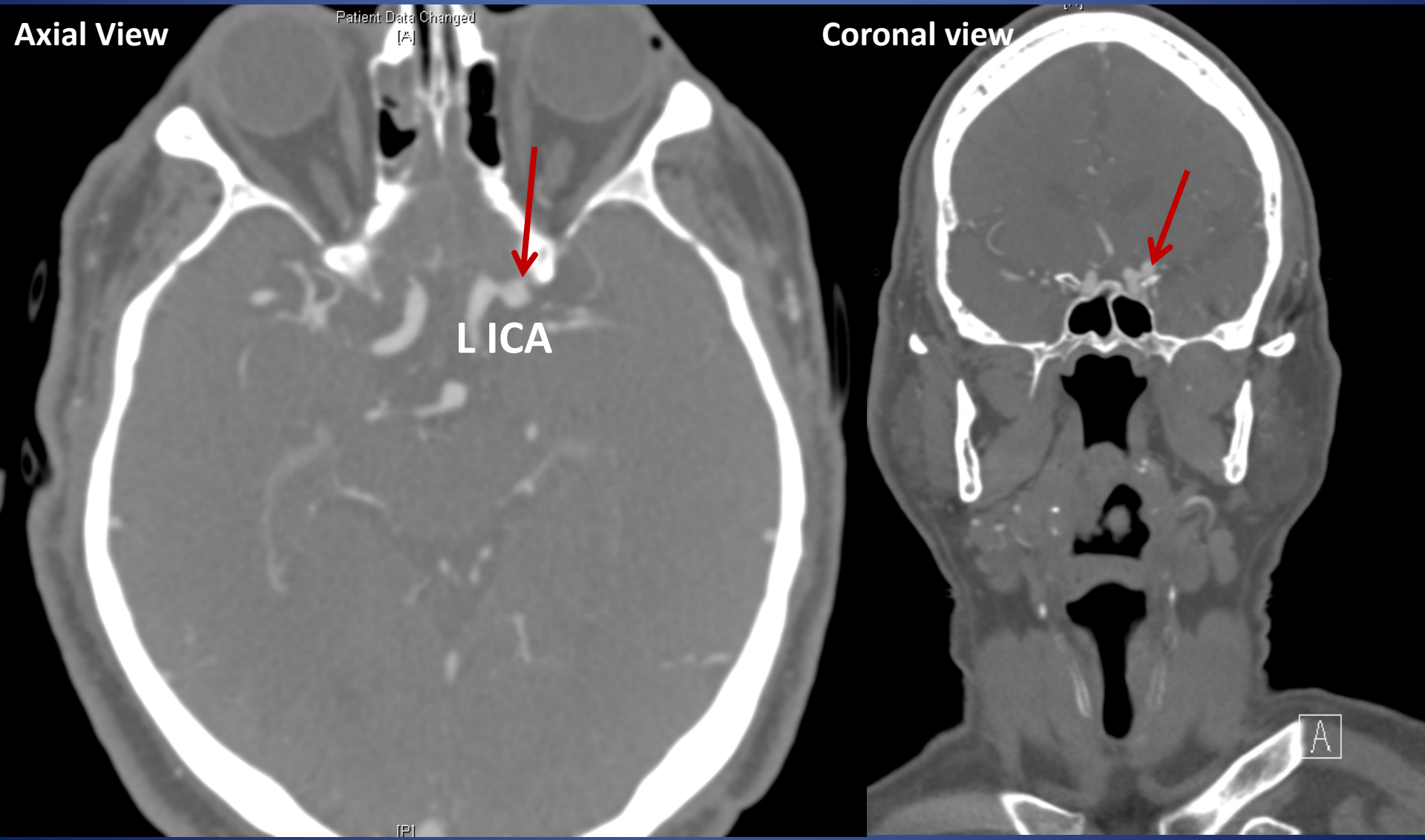
What modified Fisher score would you give this patient's scan?



CT Angiogram (Birds Eye View)
Left Anterior Cerebral Artery (ACA)/Antr. Communication artery (Acom) junction aneurysm



CT Angiogram
Left ICA aneurysm

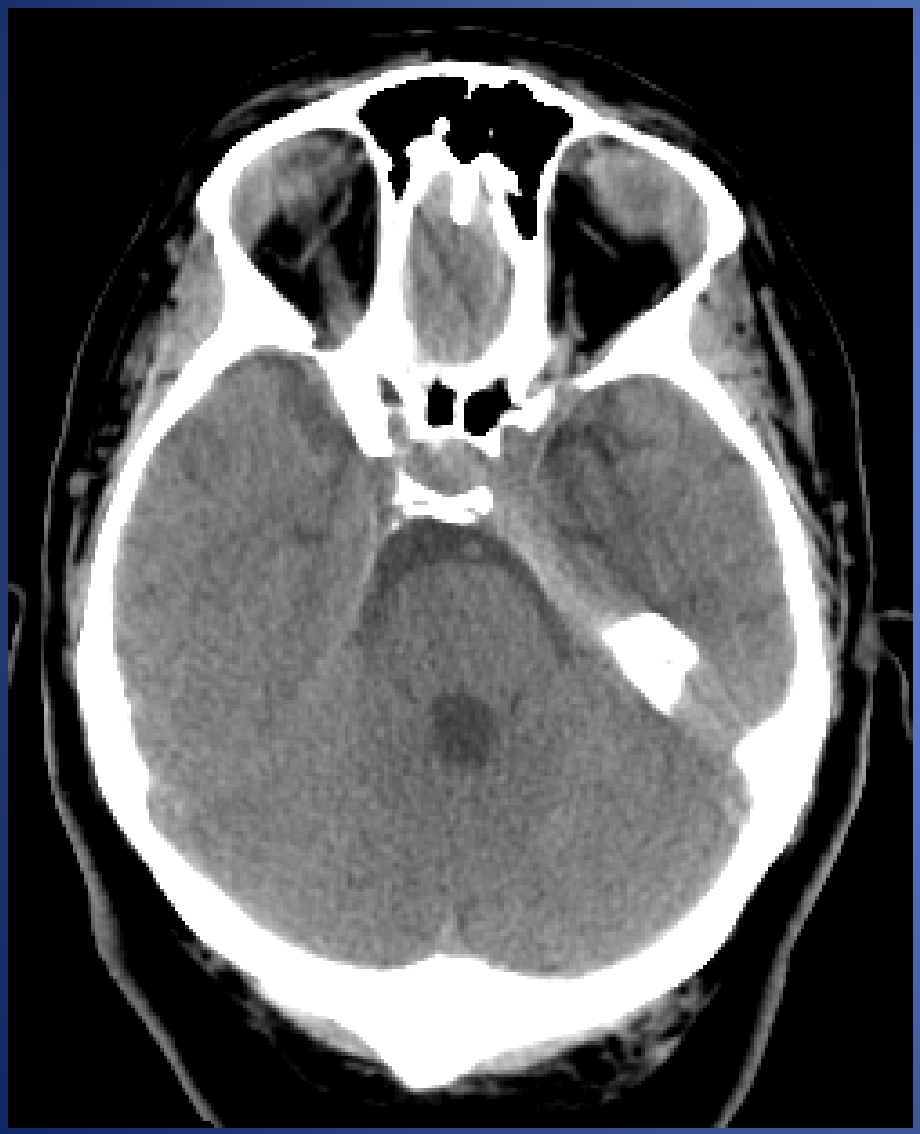


How good is CT in acute ischemic strokes?

- Sensitivity for noncontrast head CT increases AFTER 24 hours

Head CT at ~1 hour *vs* ~48 hours after symptom onset

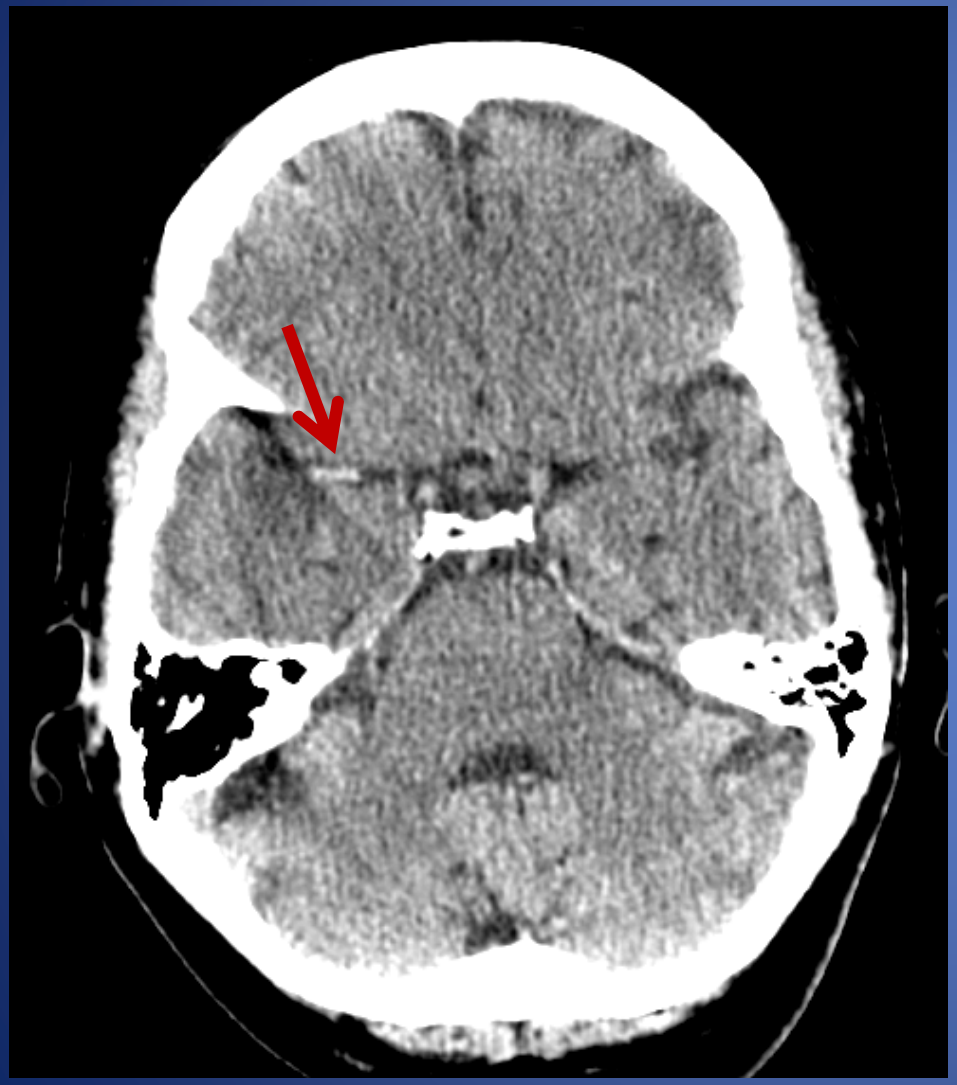
Initial Head CT *vs.* 36 hours later



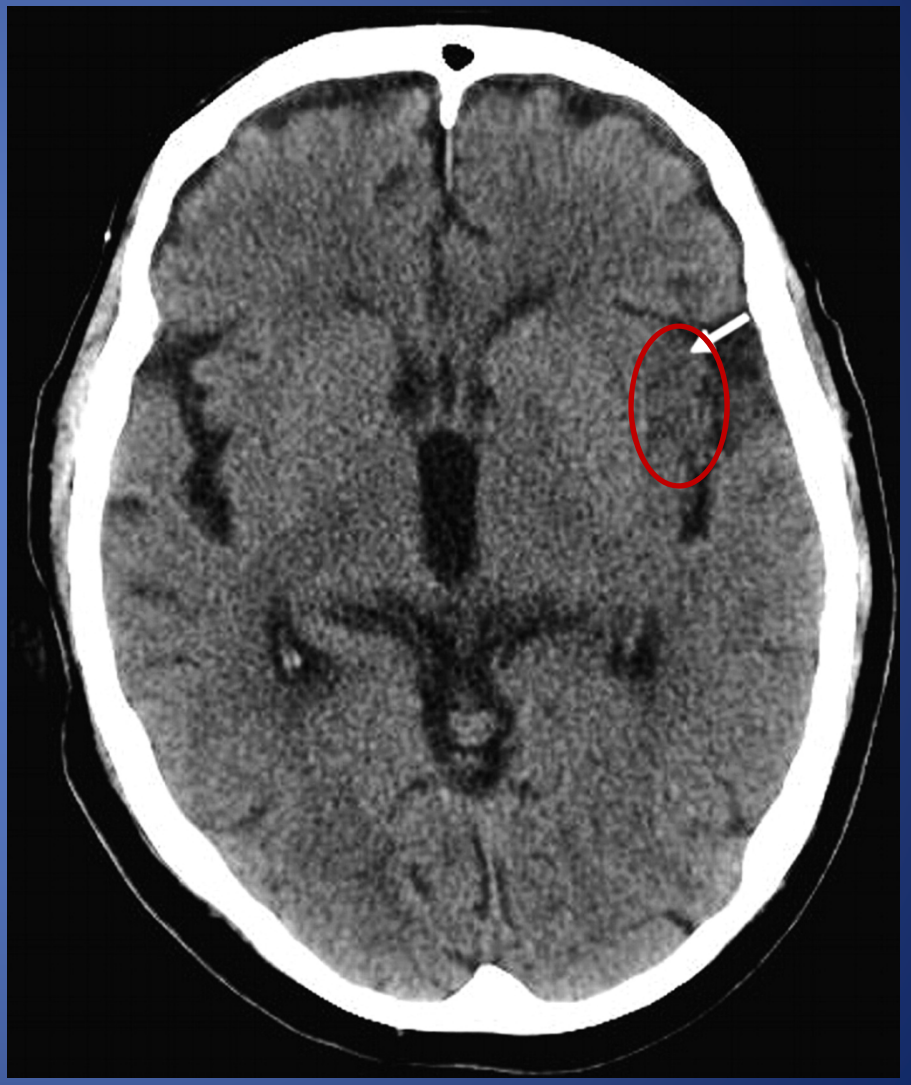
How good is CT in acute ischemic strokes?

- HOWEVER – may see early infarct signs within 6 hours of stroke onset in ~60% patients
- Early infarct include:
  - Subtle darkening (hypodensity) of the tissue
  - Loss of differentiation in gray and white matter
  - Brain swelling with loss of sulci (sulchal effacement)
- Also look for hyperdense (bright) artery that is filled with blood clot

Hyperdense MCA (middle cerebral artery) sign



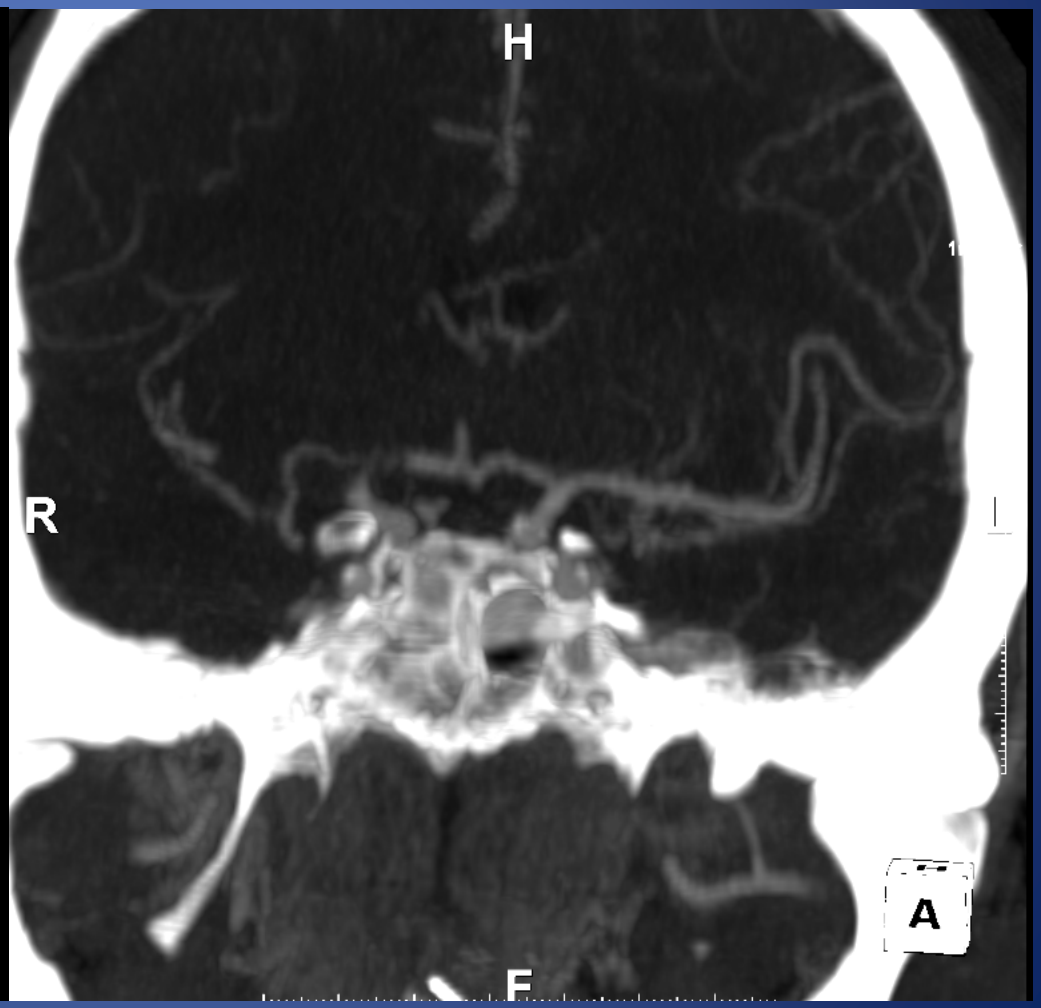
Insular ribbon sign
Darkening of the brain tissue



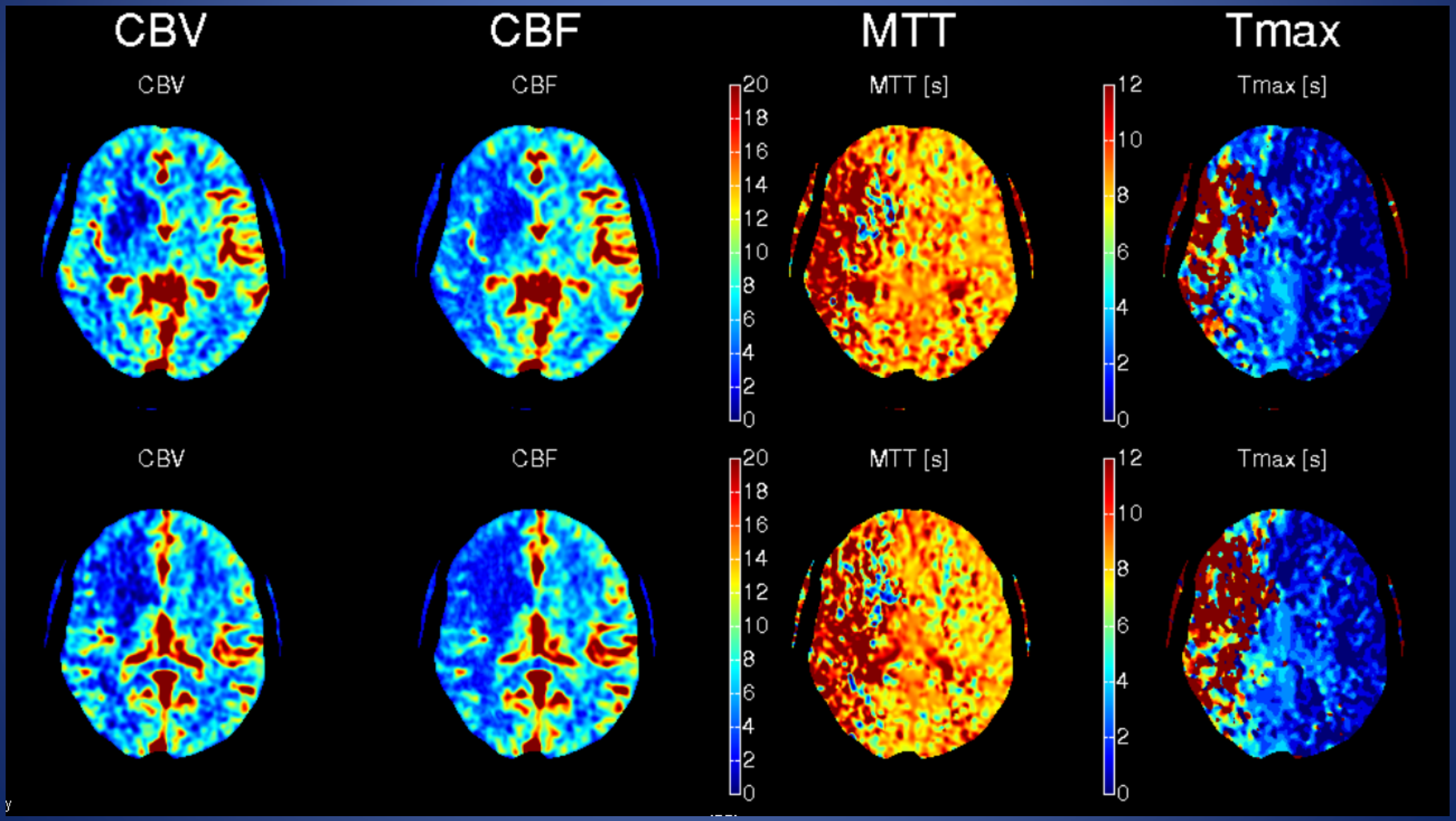
Because of the delay of CT changes with ischemic stroke, multimodal CT imaging has become the preferred method to image acute ischemic strokes

- CT Angiogram (CTA) of the head and neck
  - Sensitivity ~90% in detecting flow of the arteries of the Circle of Willis compared to conventional cerebral angiogram
- CT Perfusion (CTP)
  - Identifies areas of decreased perfusion to the brain tissue

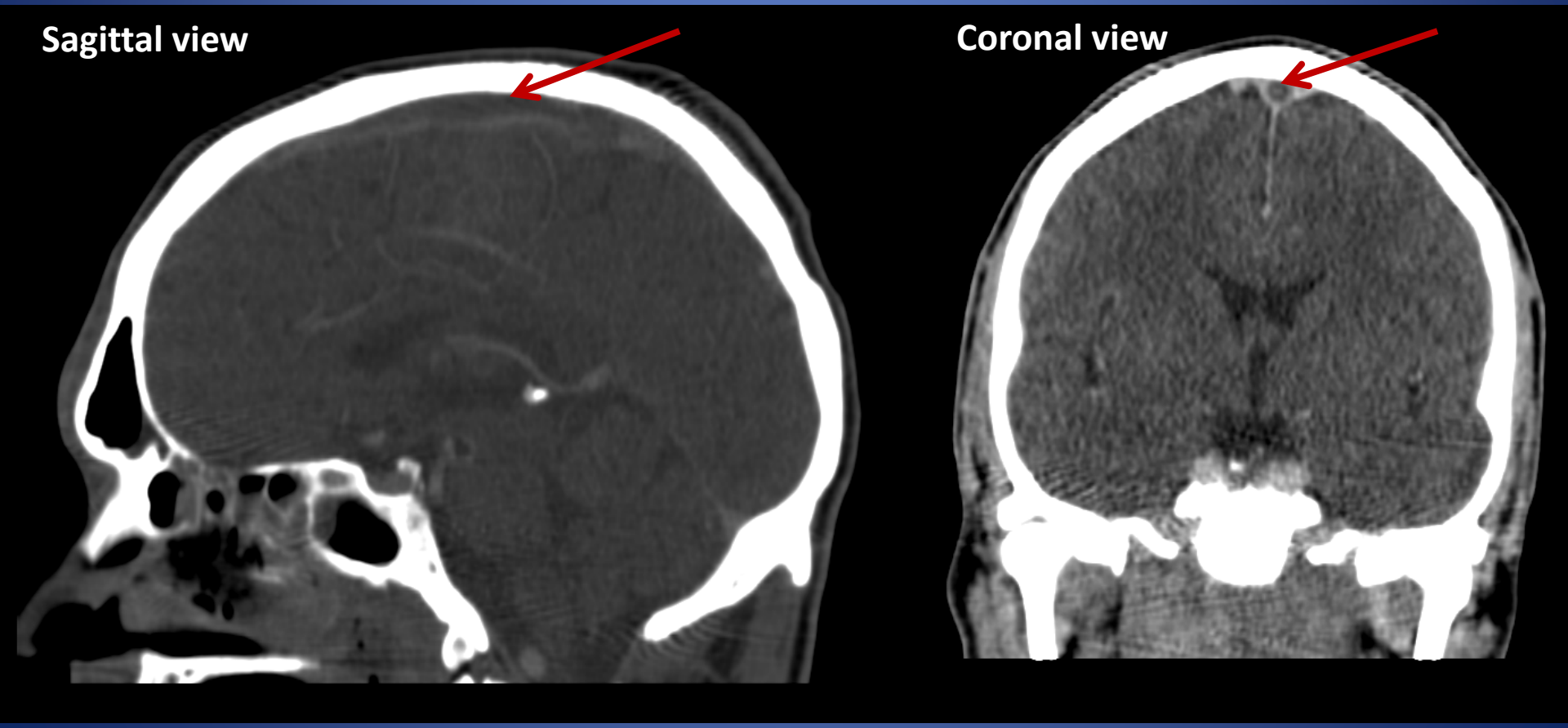
Noncontrast Head CT and CTA at ~1 hour post symptom onset



CT Perfusion at ~ 4.5 hours



CT venogram (CVT)



"The Good, the Bad, and the Ugly" of CT

- "Good": quick and usually quite accessible 24 hours/7 days a week at hospitals
- "Bad": radiation, potential allergic reaction to contrast, acute kidney injury from contrast
- "Ugly": doesn't provide as detailed pictures of the brain tissue compared to MRI, especially at the base of the brain (brainstem and cerebellum)

Adult neurologic effective doses of medical imaging

Procedure	Modality	Average effective dose (mSv)	Number of chest x-rays (PA/lateral) with equivalent radiation dose*
Skull radiograph	Conventional radiography	0.1	1
Cervical spine radiograph	Conventional radiography	0.2	2
Thoracic spine radiograph	Conventional radiography	1.0	10
Lumbar spine radiograph	Conventional radiography	1.5	15
CT head	Computed tomography	2	20
CT neck	Computed tomography	4	40
Angiogram head/neck	Conventional fluoroscopy or interventional radiology	5	50
CT spine	Computed tomography	6	60
Brain perfusion	Nuclear medicine	6.9	69
CT angiogram (rule out stroke)	Computed tomography	14	140
Brain PET	Nuclear medicine	14	140

PET: positron-emission tomography.
* PA and lateral chest radiograph = .1 mSv.

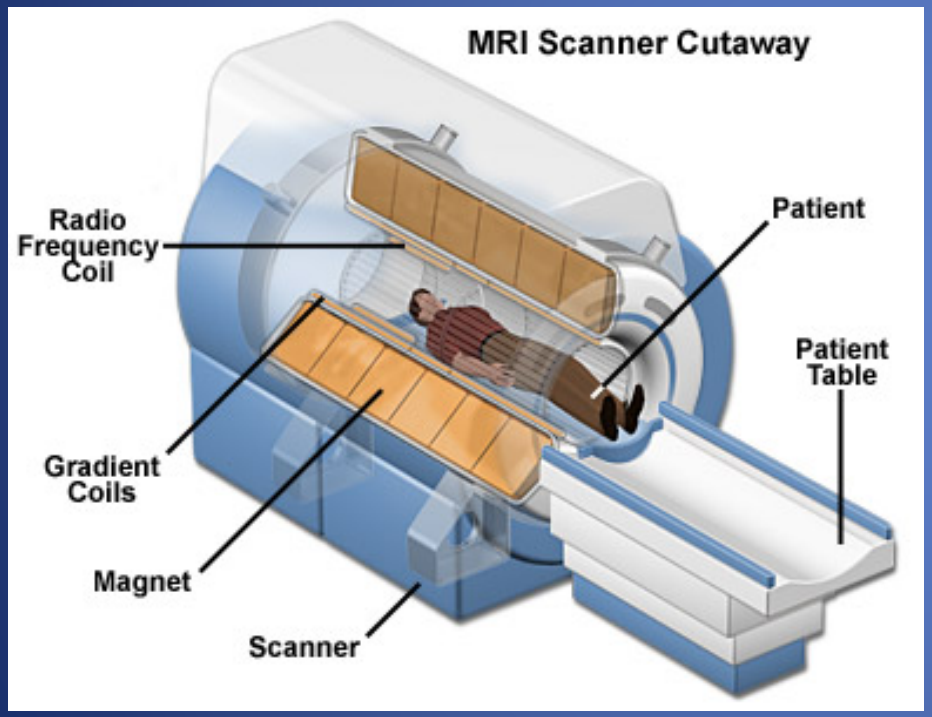
Data from:

1. *Mettler, FA, Huda, W, Yoshizumi TT, Mahesh, M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology 2008; 248:254.*
2. *Smith-Bindman, R, Lipson, J, Marcus, R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med 2009; 169:2078.*
3. *Shrimpton, PC, Hillier, MC, Lewis, MA, Dunn, M. National survey of doses from CT in the UK: 2003. Br J Radiol 2006; 79:968.*

CT Safety

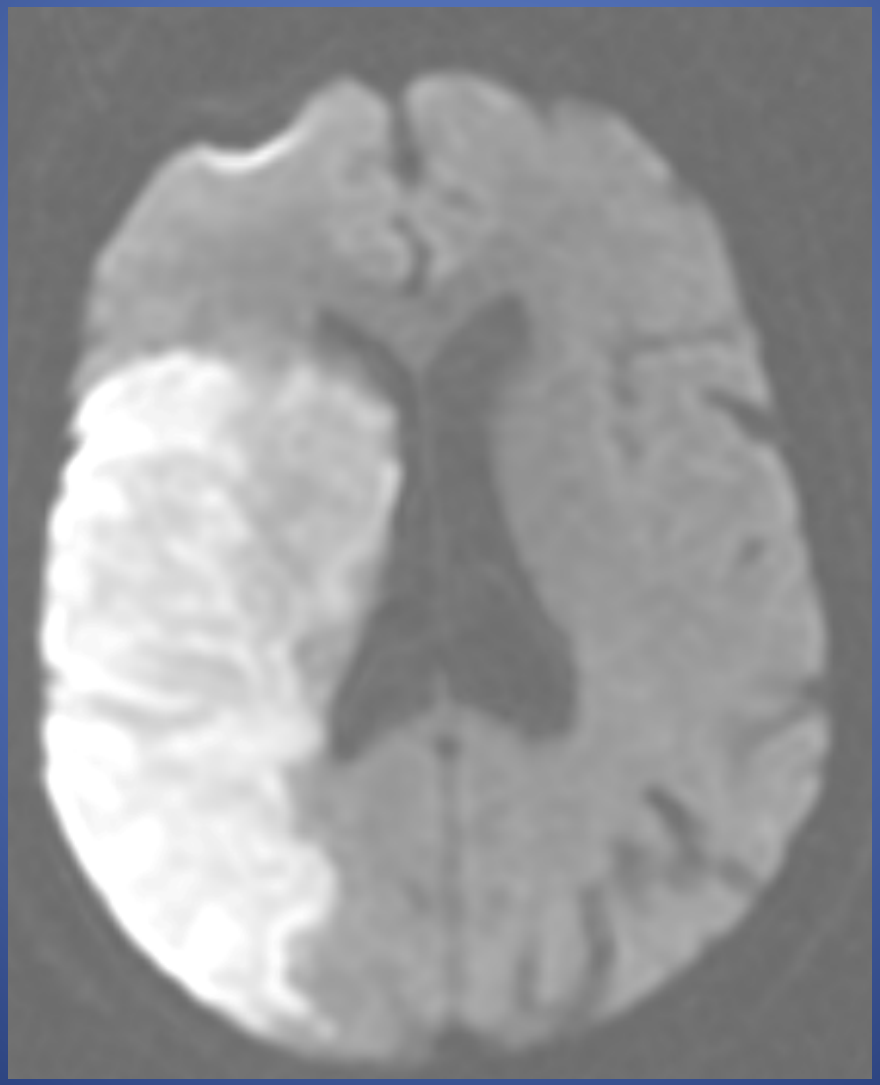
- Contrast for CT, CTA or CTP cannot be given if estimated glomerular filtration rate (GFR) is under 30.
- Assess for any allergies to radiocontrast media.
- Consider whether the patient will tolerate lying down.
- Rule out pregnancy in women of childbearing age

Understanding MRI

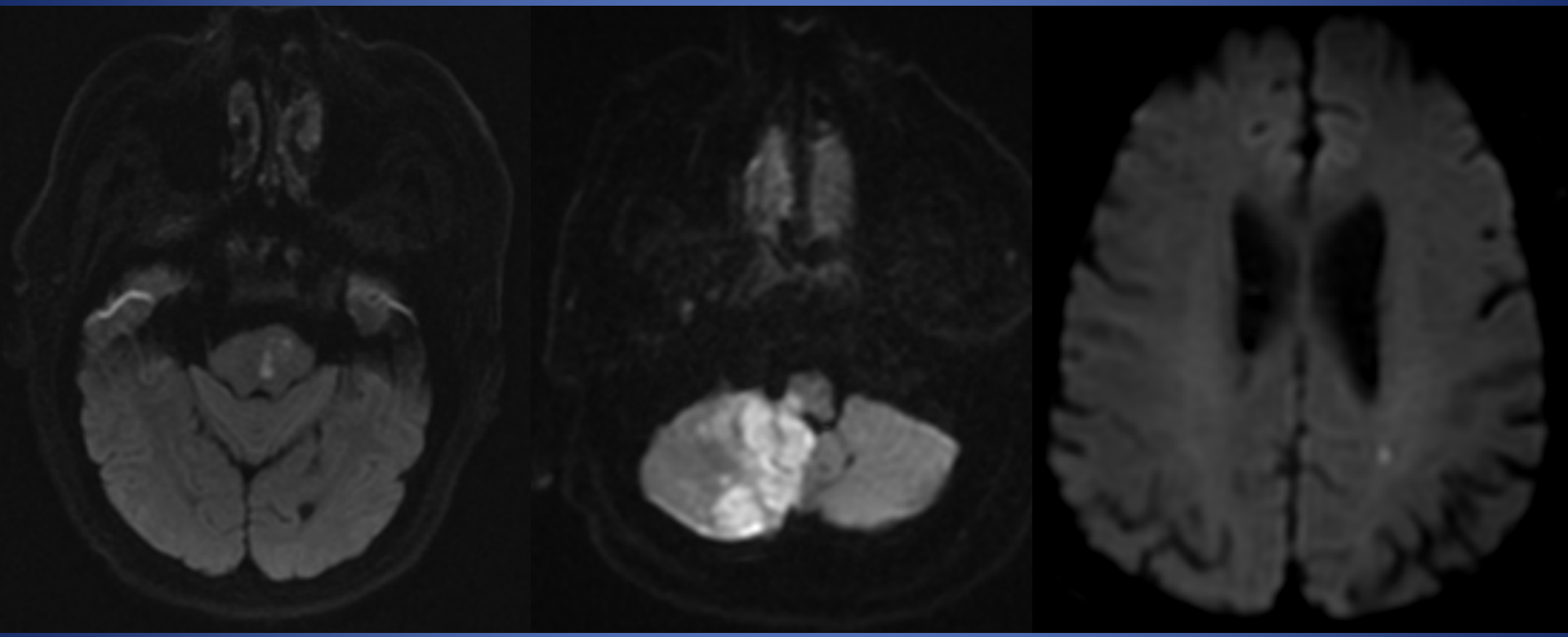


- MRI = Magnetic Resonance Imaging
- Uses powerful magnets to magnetize the proton of a hydrogen atom, which is in abundance in the body.
- Detect small differences in the microenvironment of different tissues
- Why is that good? It takes better pictures of the brain tissues using a variety of MRI sequences .
- 3 Tesla MRI is approved for clinical usage. Will likely replace current 1.5 T MRI.

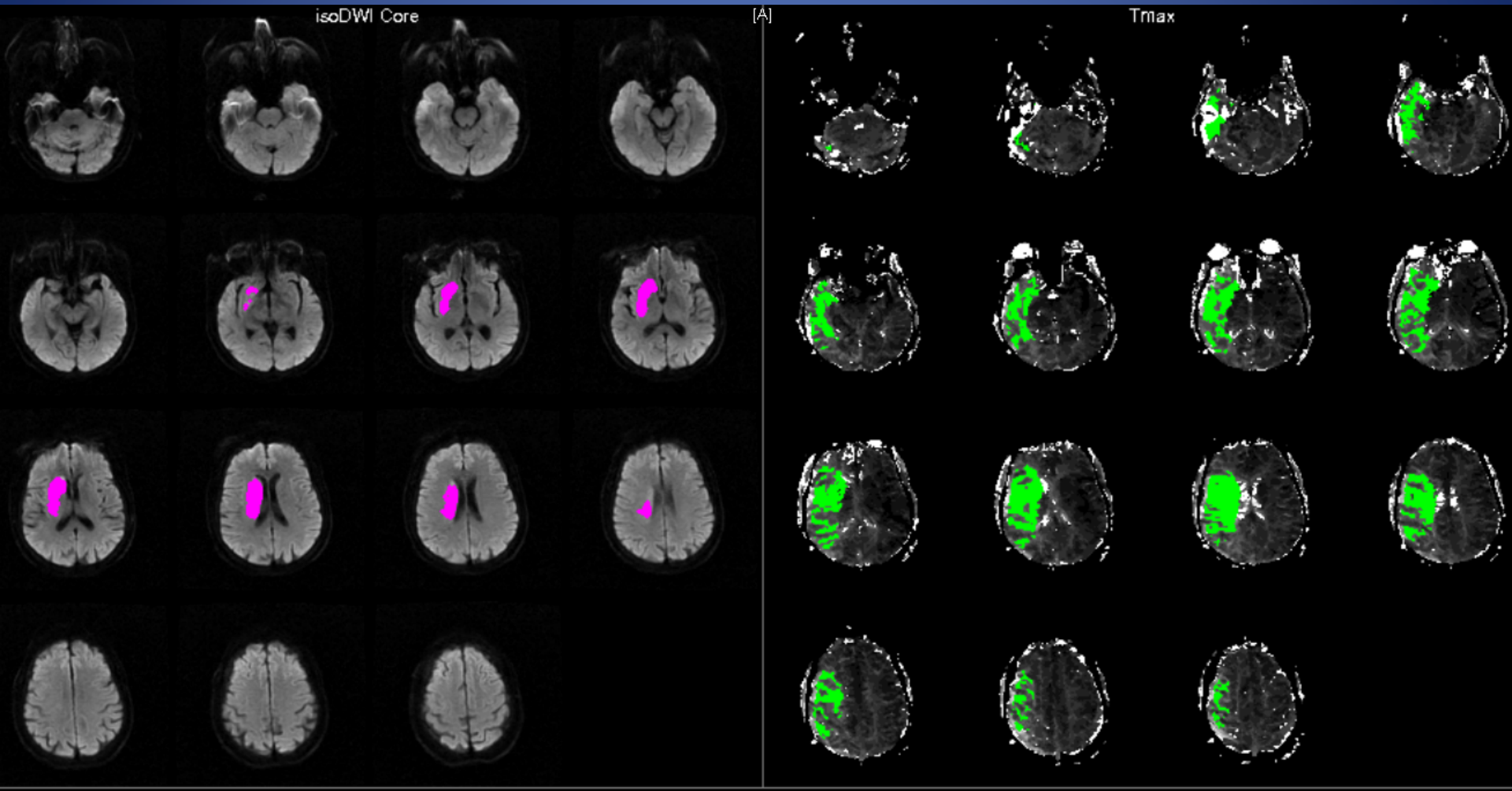
MRI Diffusion Weighted Imaging (DWI)



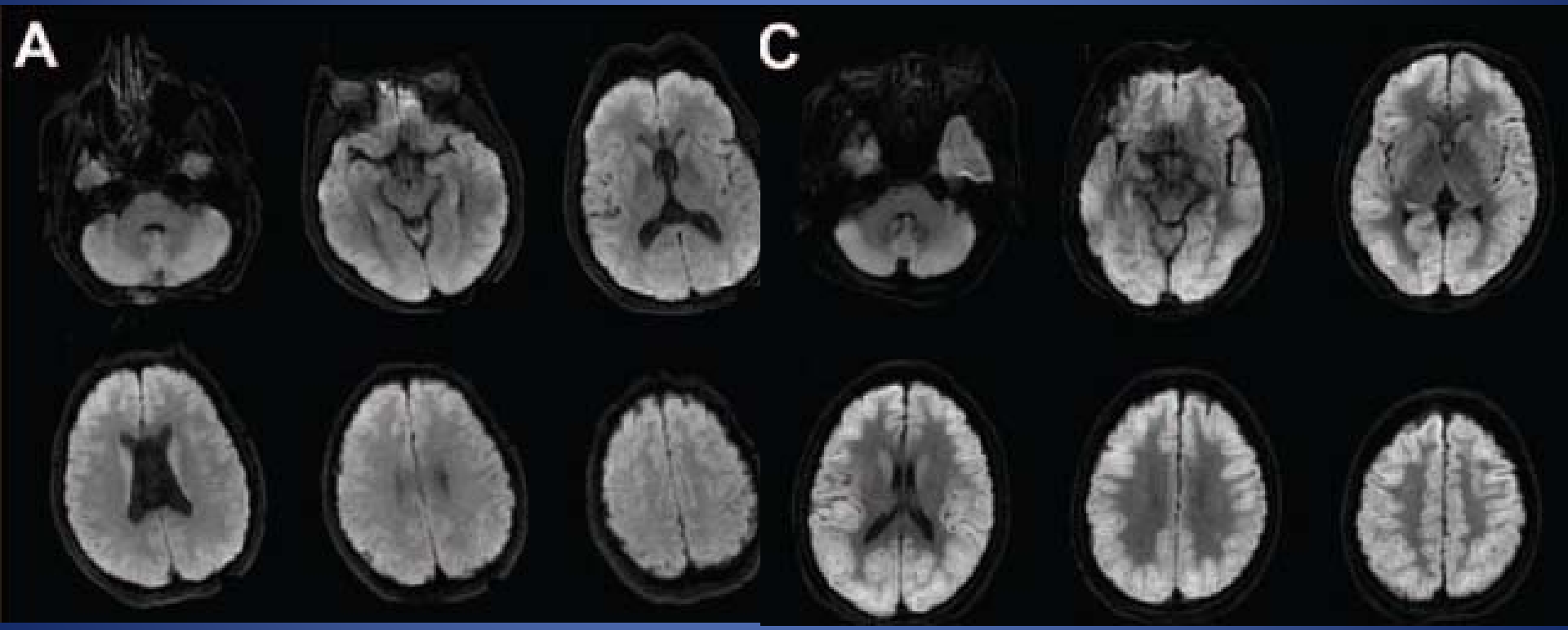
MRI Diffusion Weighted Imaging (DWI)



MRI DWI and Perfusion Weighted Imaging (PWI)

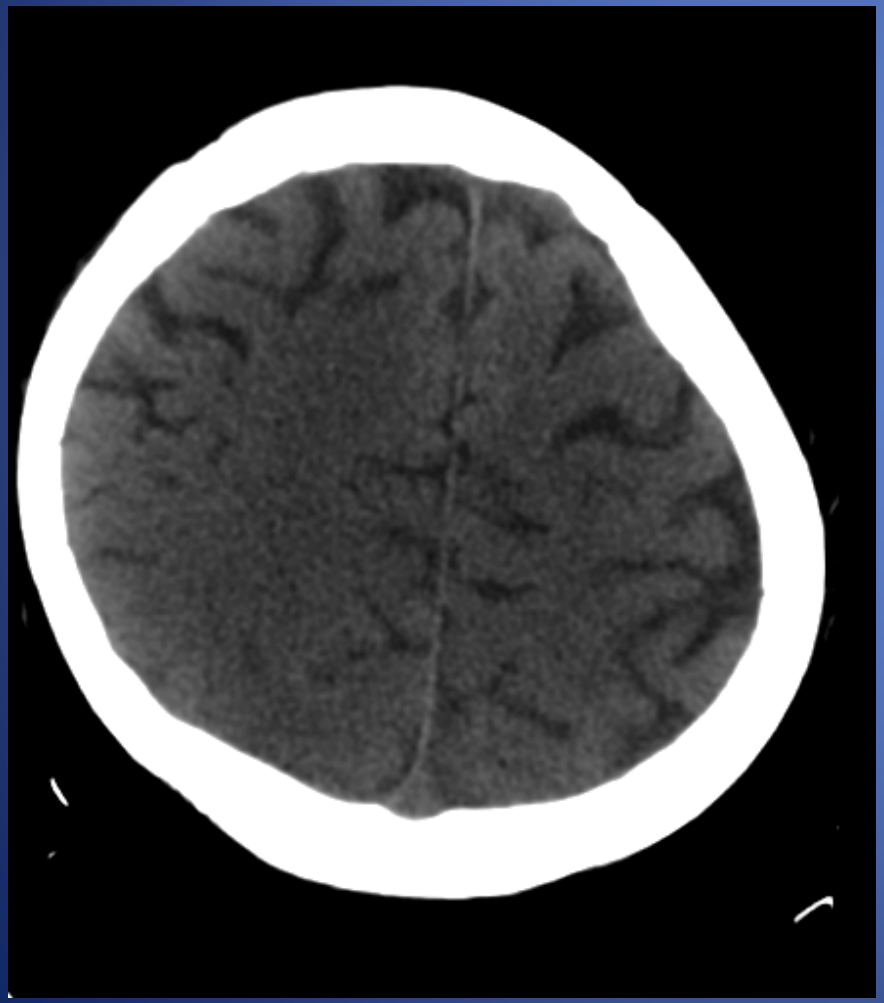


MRI DWI after cardiac arrest

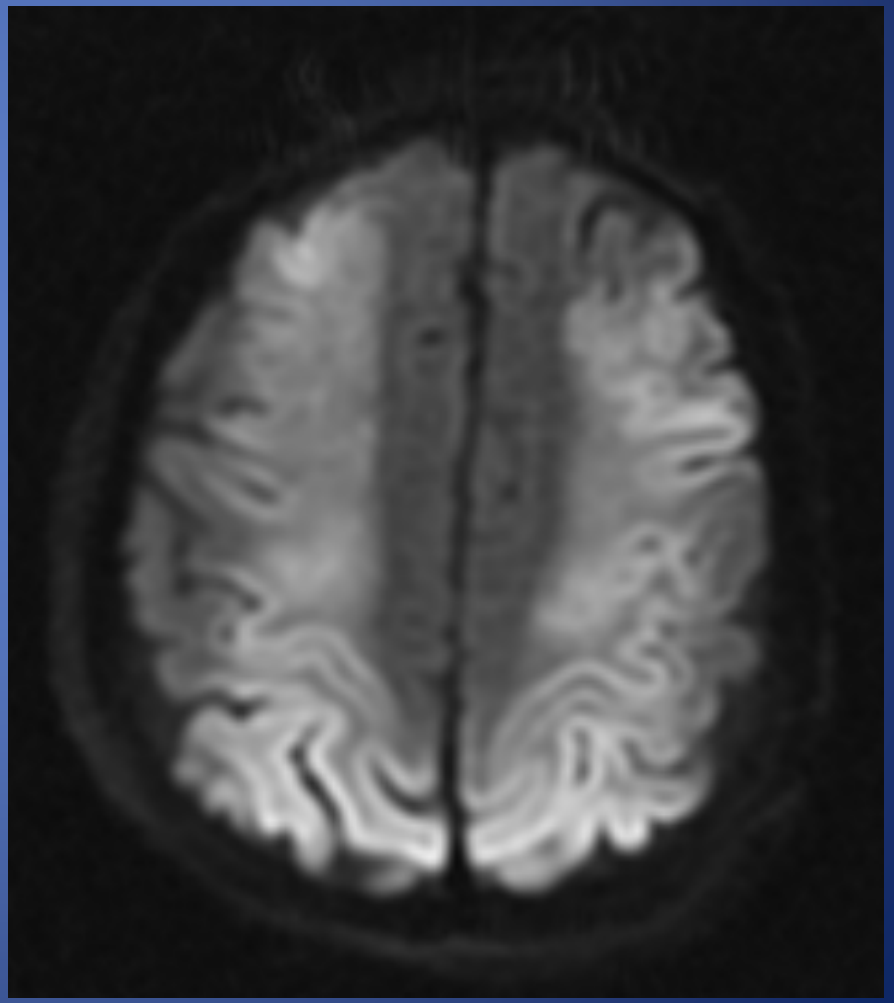


MRI DWI after severe hypoglycemia

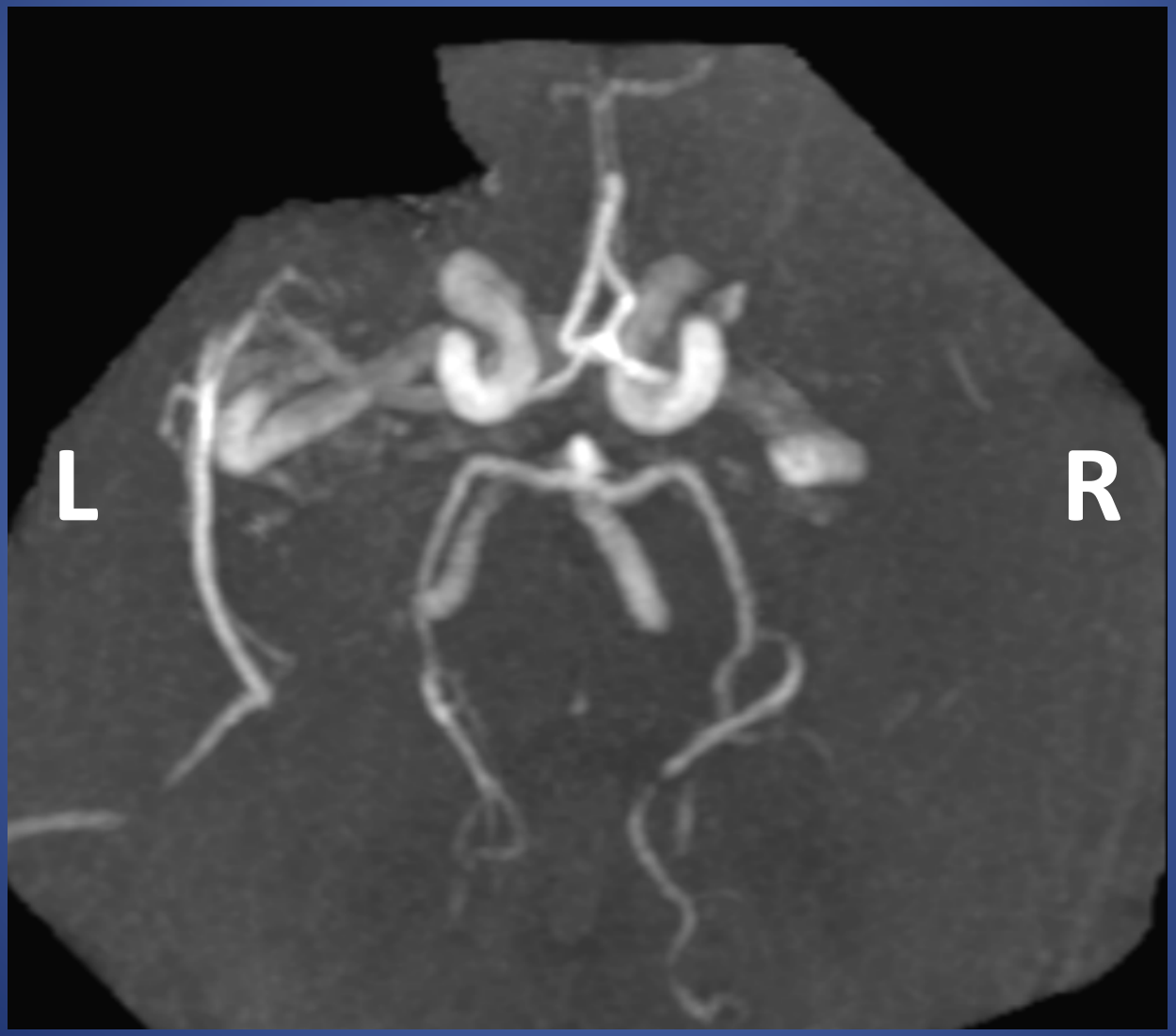
Initial Head CT



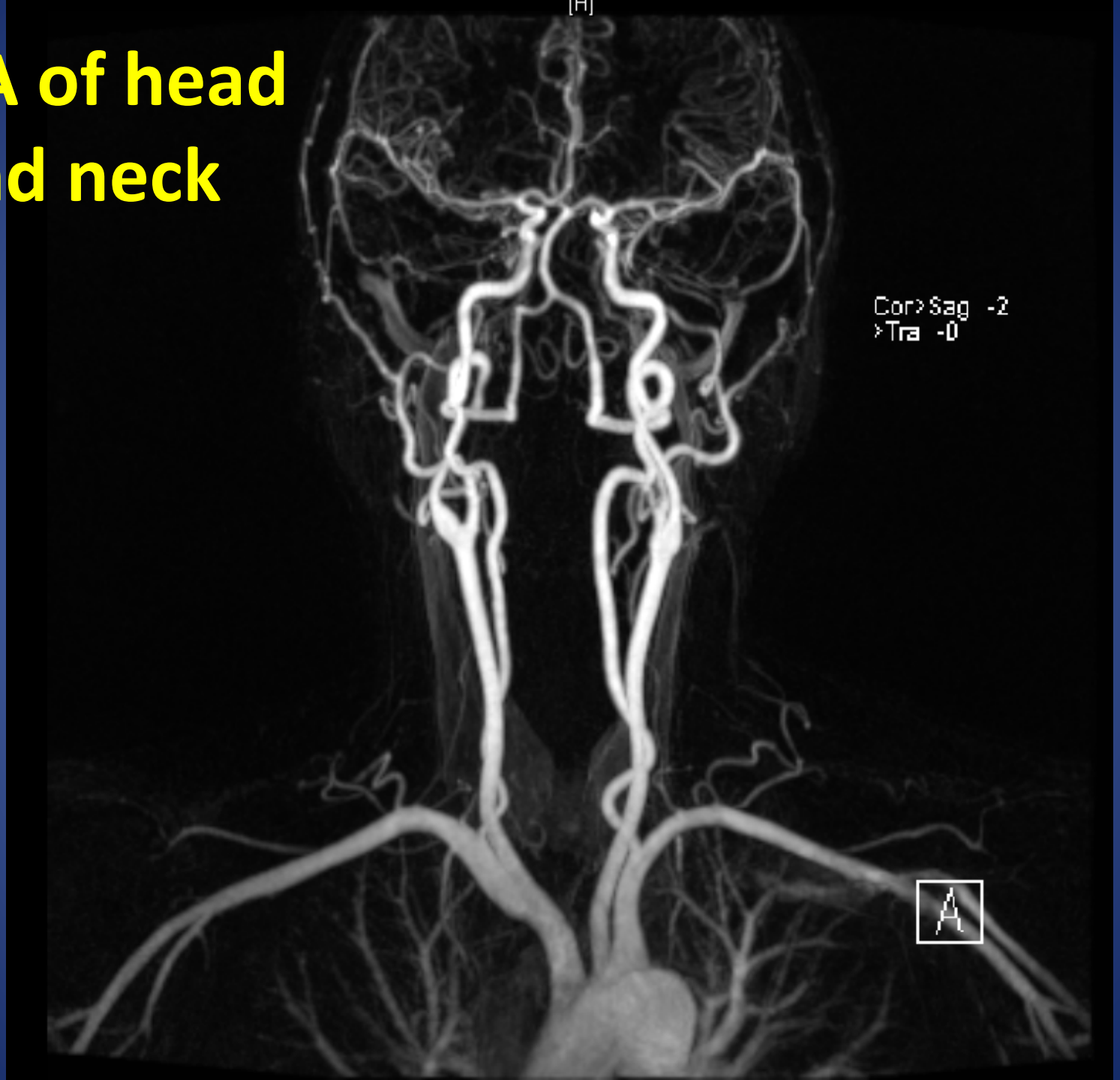
MRI DWI ~ 36 hours later



MR Angiogram (MRA) of the head



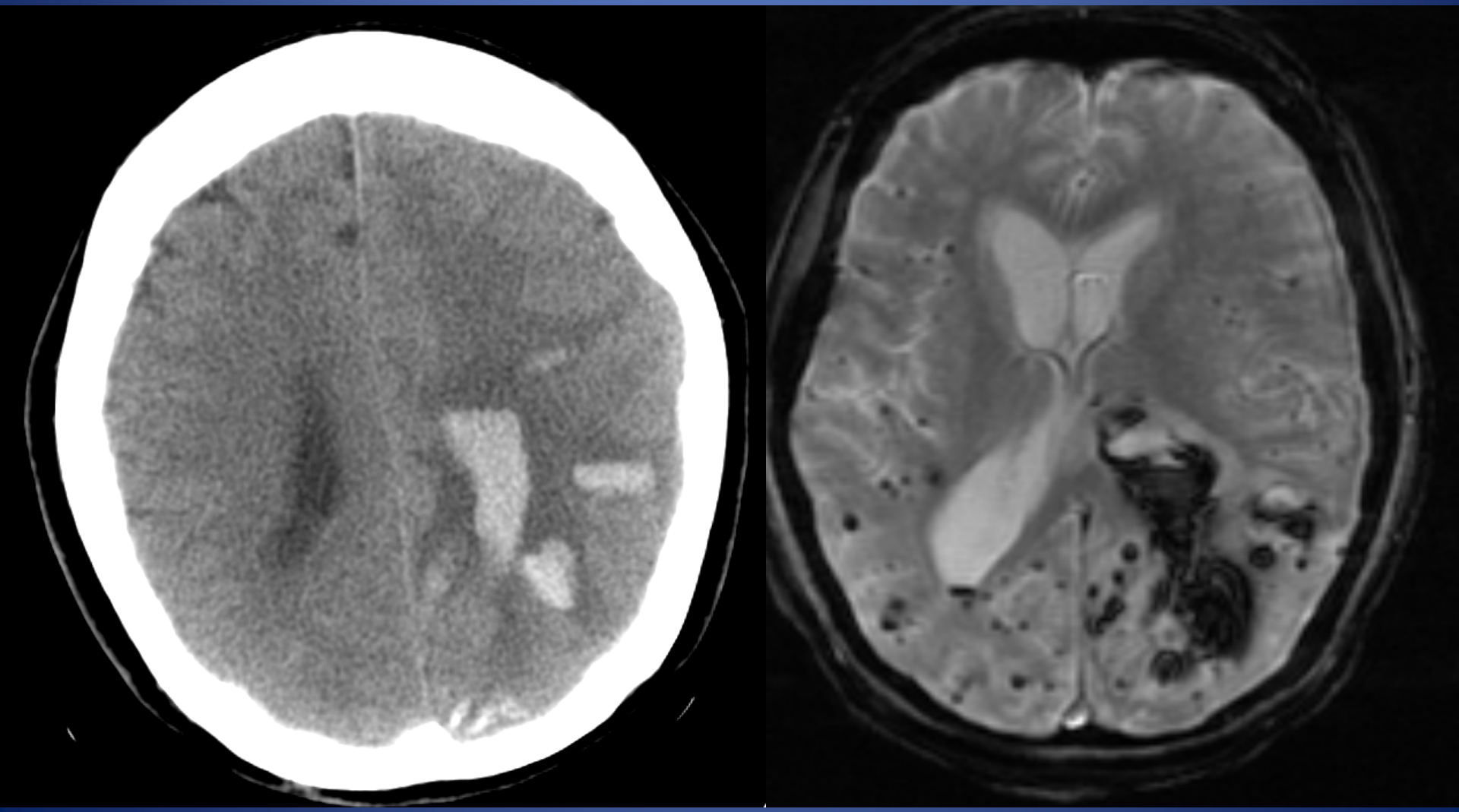
MRA of head and neck



MRI Gradient Recall Echo (GRE)
Good for showing blood (acute and chronic)

CT head

MRI GRE

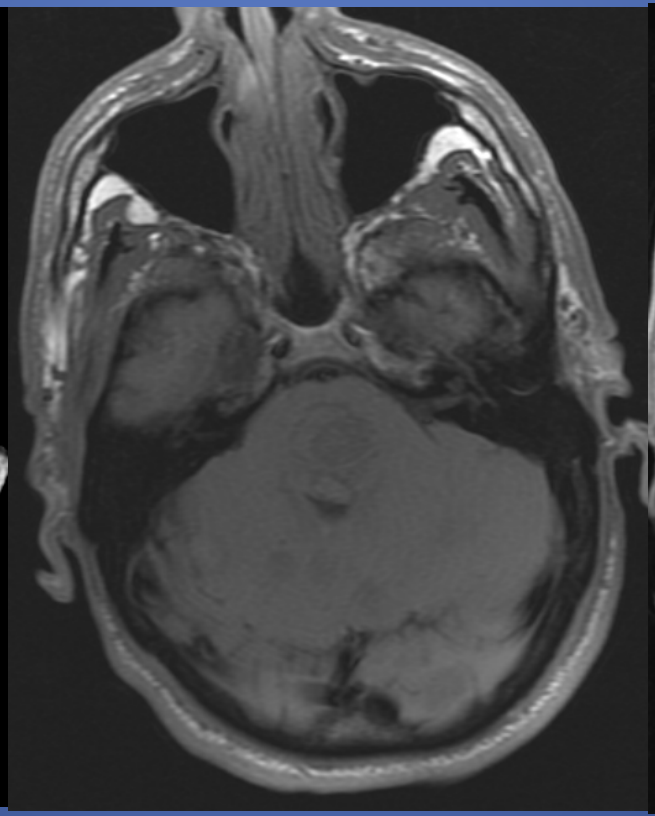


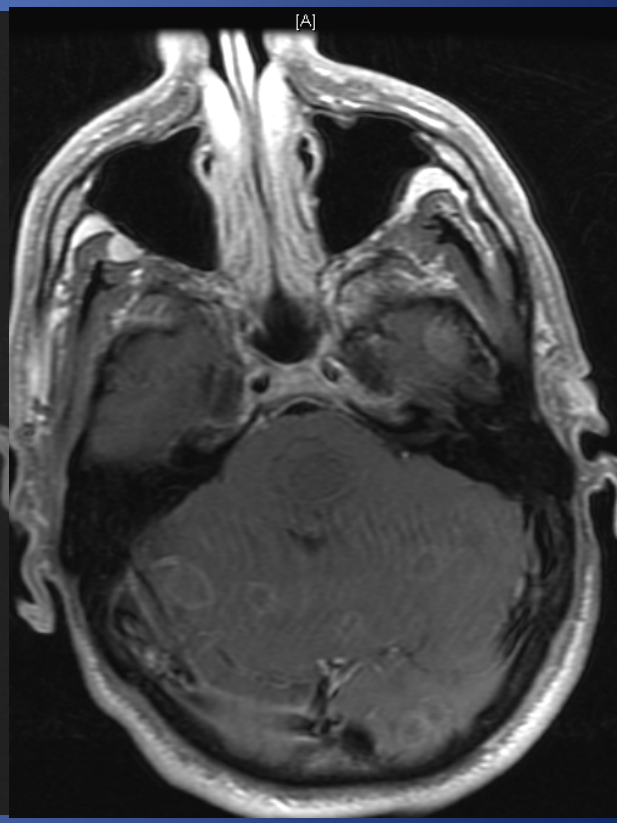
MRI with contrast

Noncontrast Head CT

Pre-contrast MRI

Post-contrast MRI

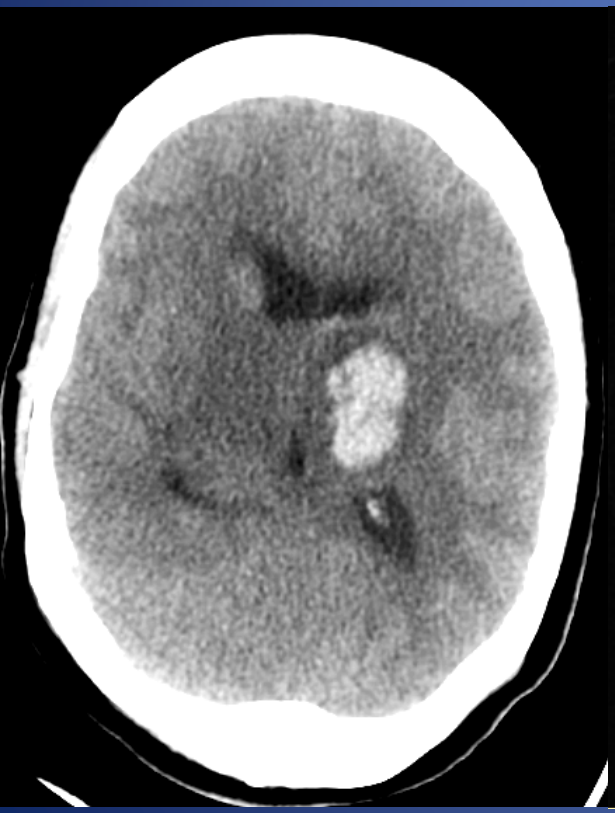


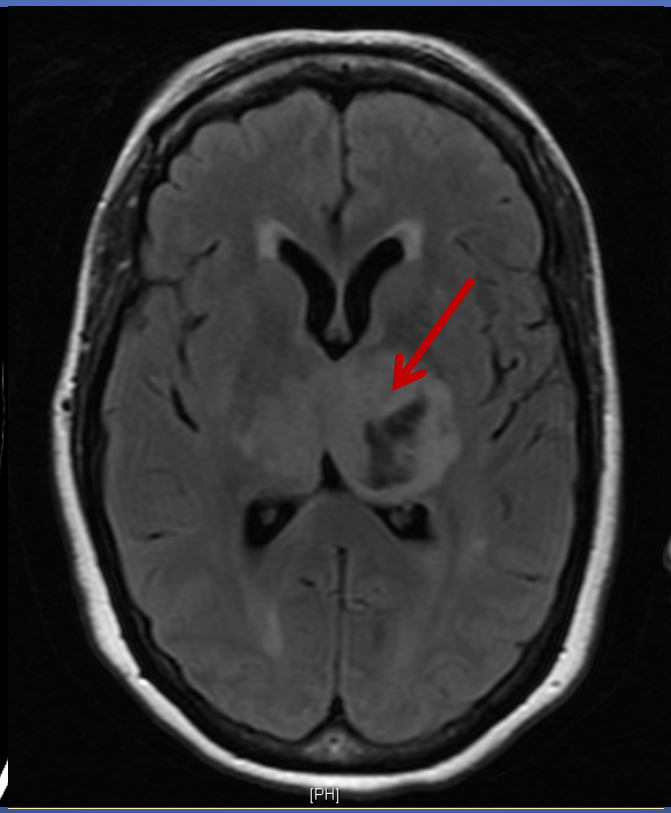


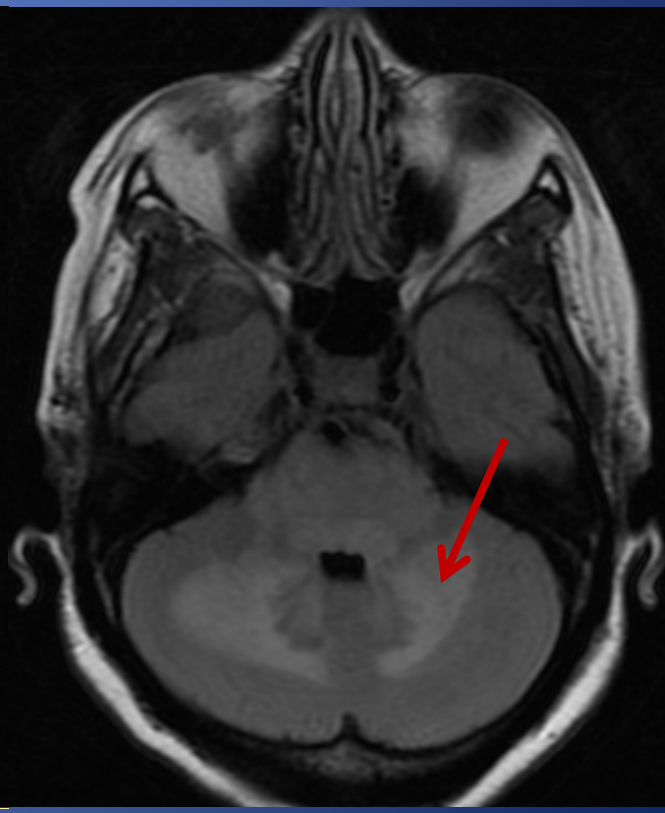
MRI FLAIR

Head CT

MRI FLAIR imaging



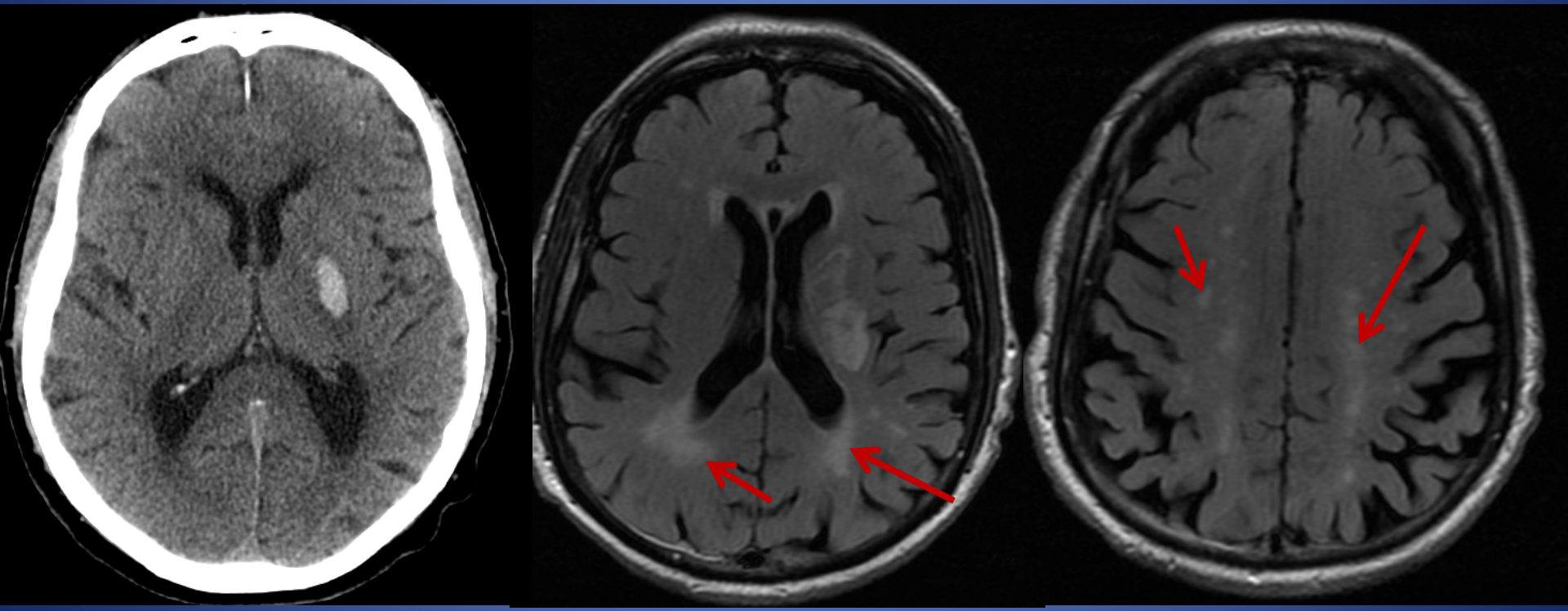




MRI FLAIR

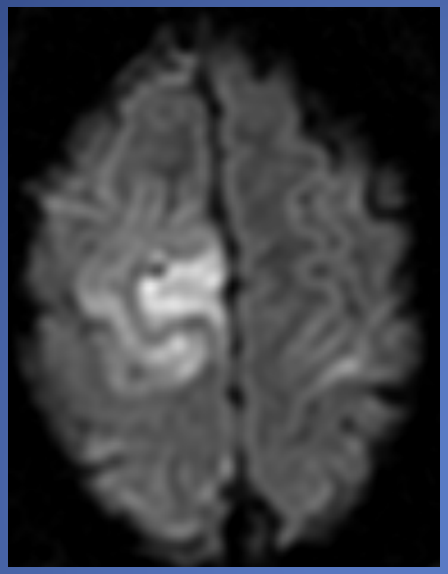
CT head

MRI FLAIR imaging

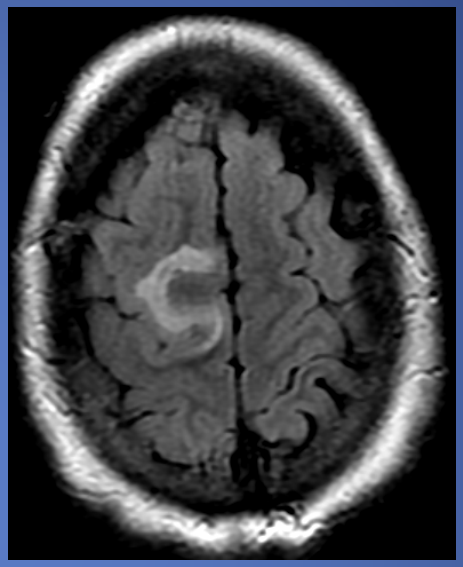


MR venogram (MRV)

DWI

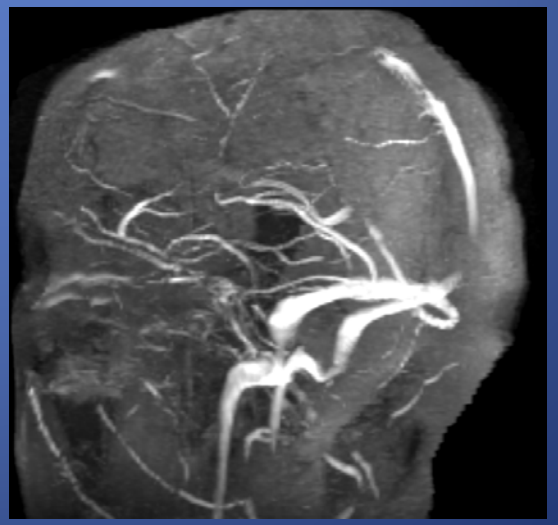


FLAIR



Coronal view MRV

Sagittal view MRV



"The Good, the Bad, and the Ugly" of MRI

- "Good": Variety of sequences help make a diagnosis
- "Bad": loud, claustrophobic conditions, takes longer than CT, no metal allowed
- "Ugly": more difficult to obtain in real time situation

MRI Safety

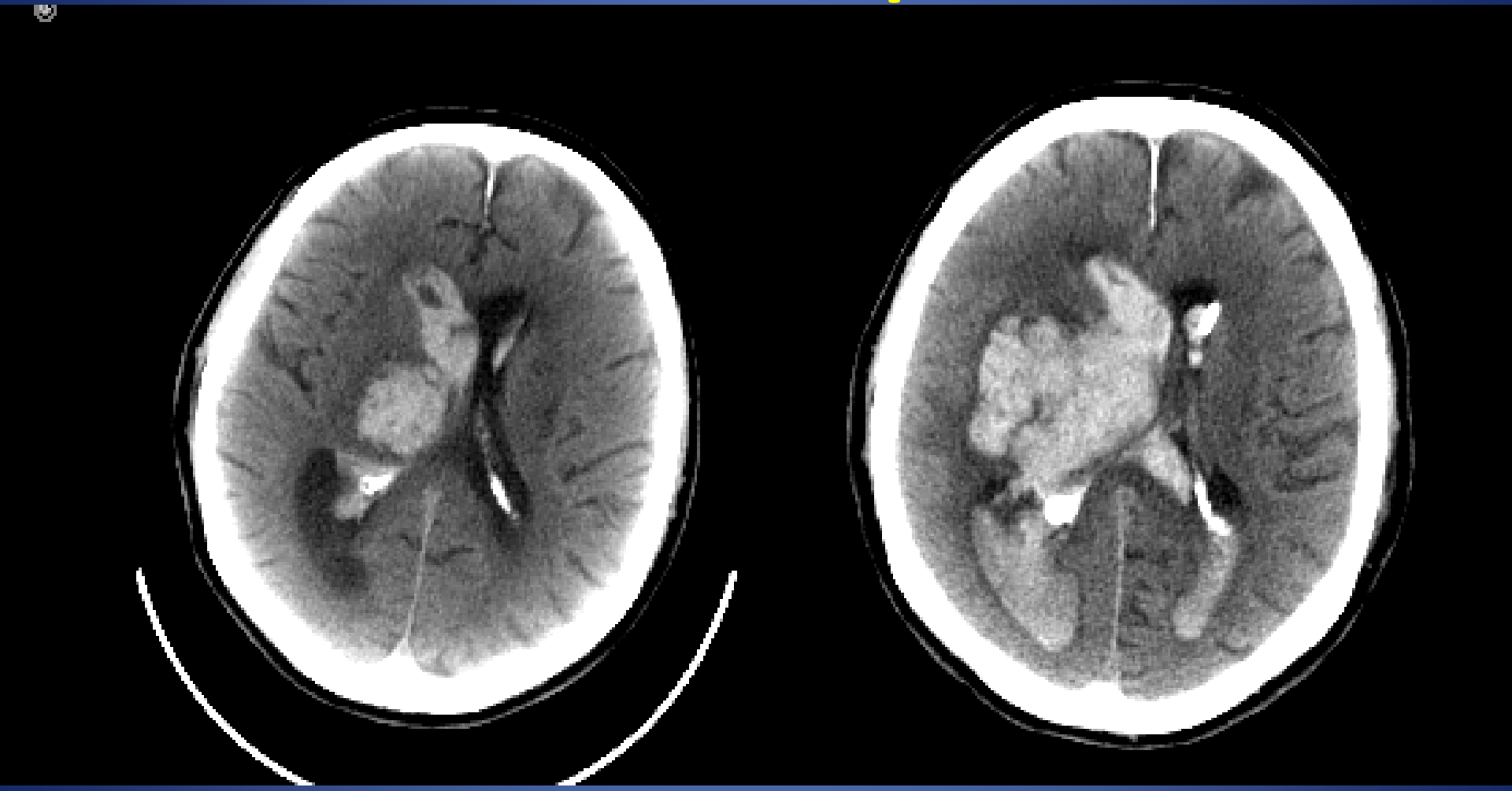
- Complete the checklist
- Inquire about allergies
- For contrast - must have good kidney function, GFR greater than 60 because of the concern of nephrogenic systemic fibrosis
- Will the patient tolerate lying flat?

Why do we get follow up imaging?

A variety of reasons…

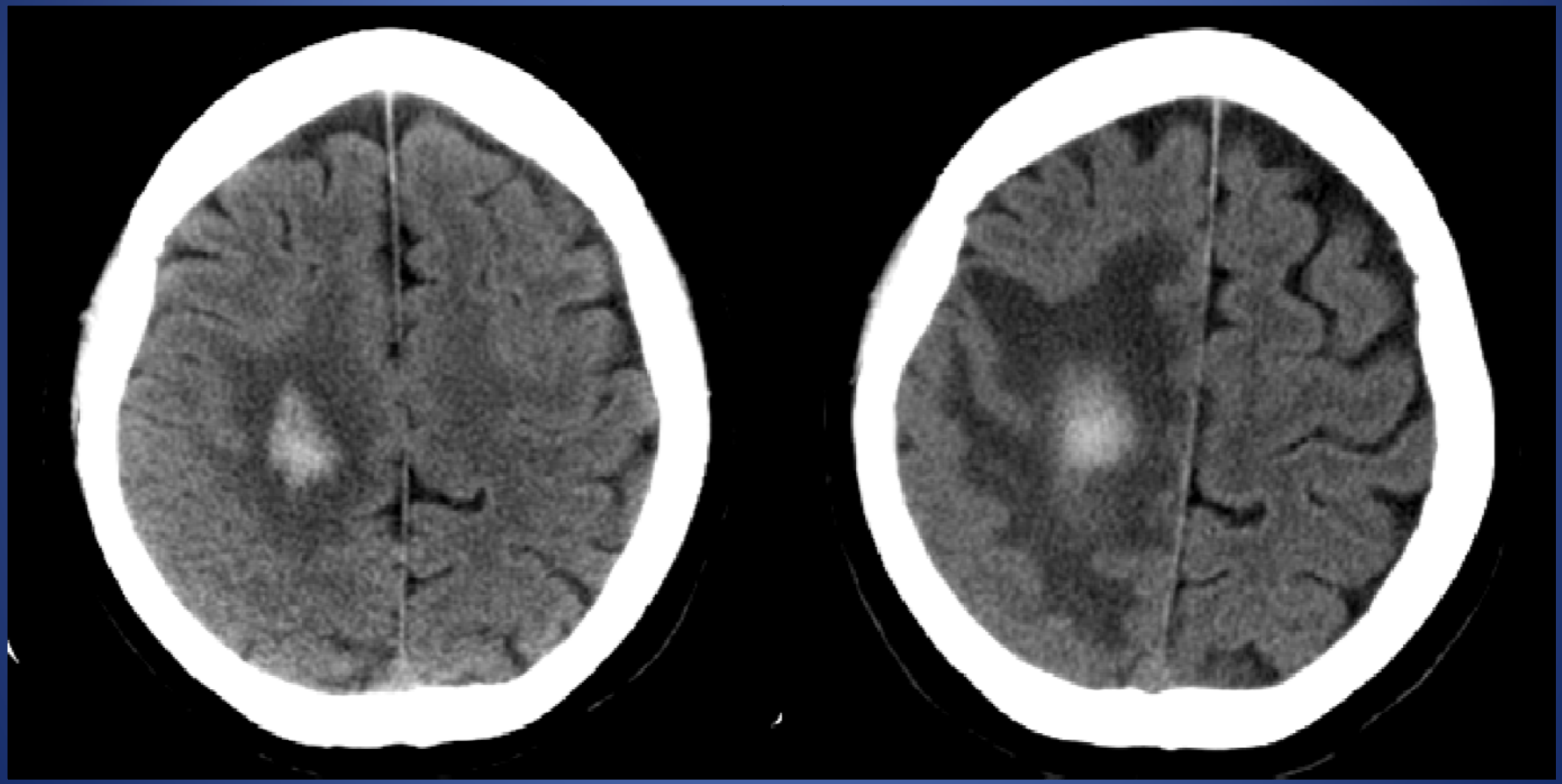
- Many times need multiple types of imaging (CT and MRI) to help make the diagnosis
- If the patient is intubated and sedated – the reliability of neuro exam diminishes and we may choose to do serial imaging
- Follow up imaging may help guide our BP parameters to perfuse the brain and adjust the intensity of our hypertonic saline therapy to treat cerebral edema
- Helps us assess whether the patient needs surgery
- Helps us assess if a patient has vasospasm from a subarachnoid hemorrhage

Hematomal Expansion



Perihematomal edema

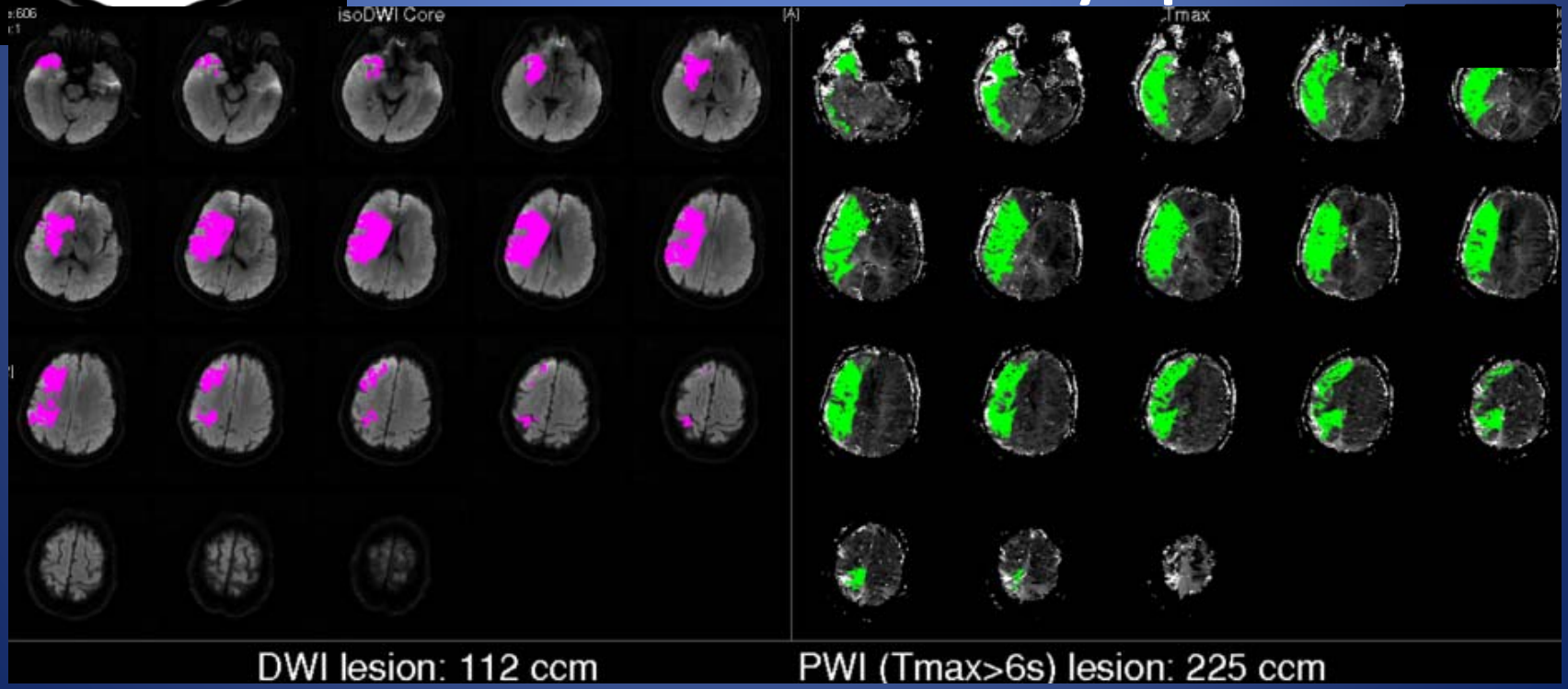
HCT 2 weeks later



Evolving ischemic stroke

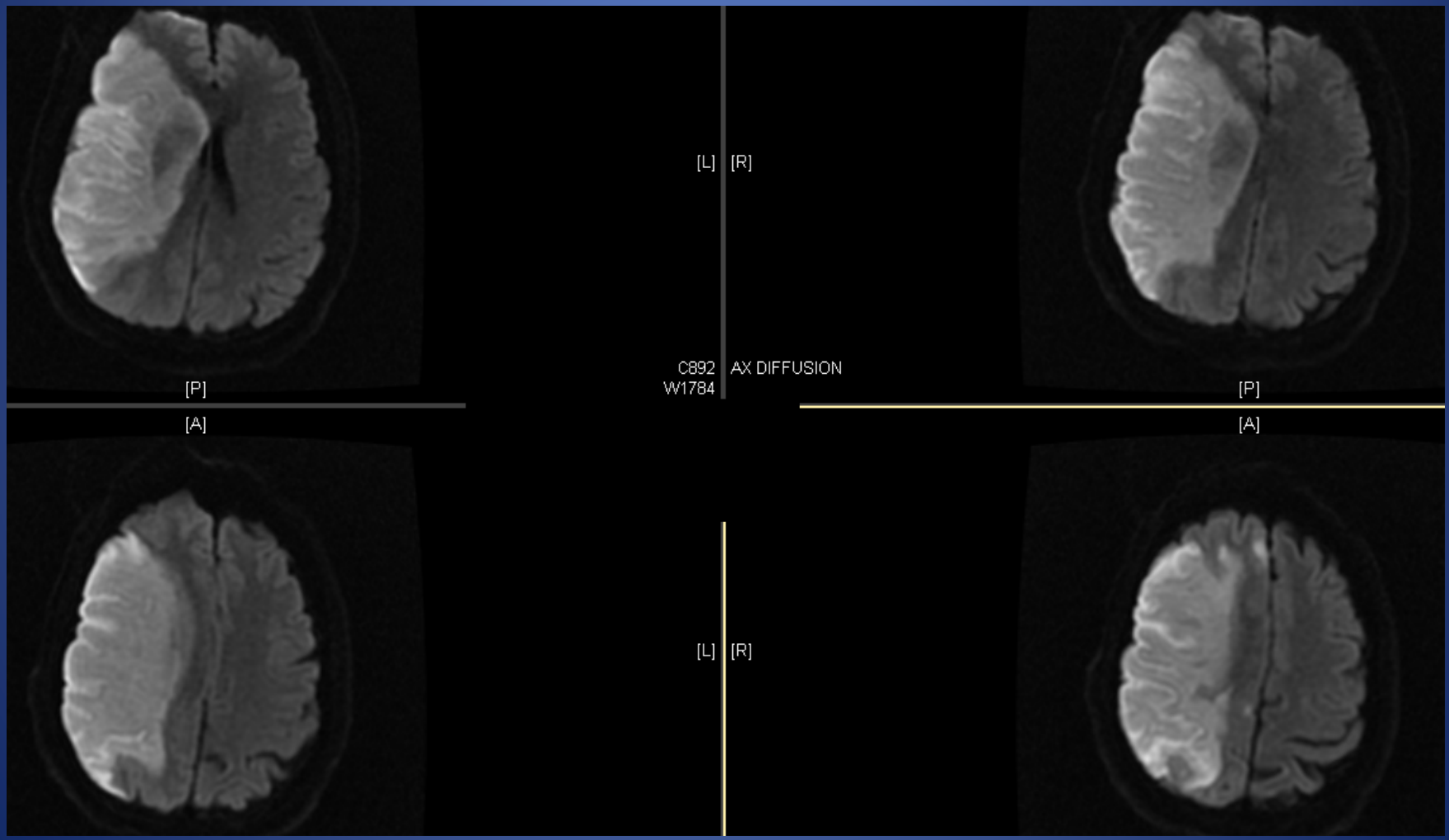
Head CT at ~1 hour from symptom onset

MRI at ~6 hours from symptom onset

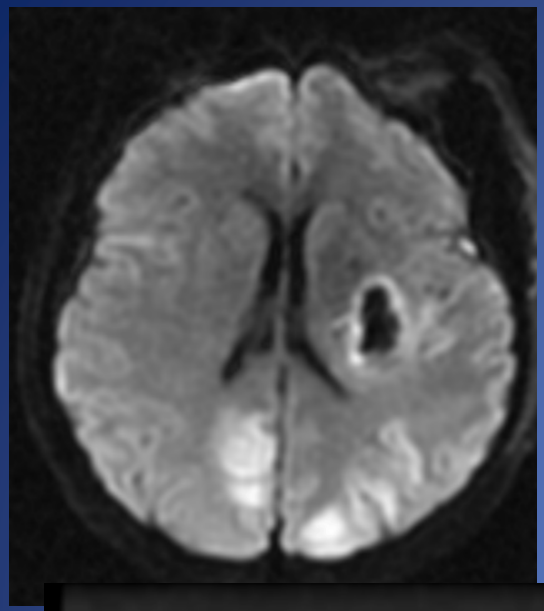


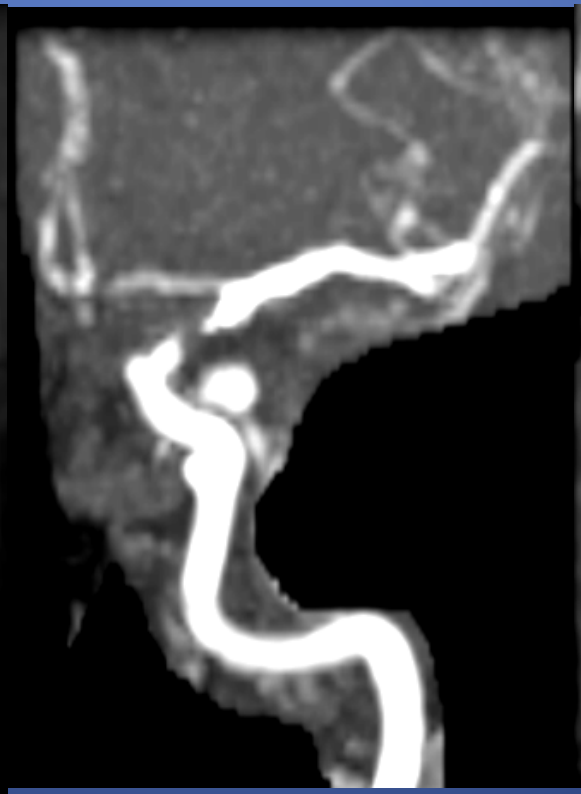
Evolving ischemic stroke

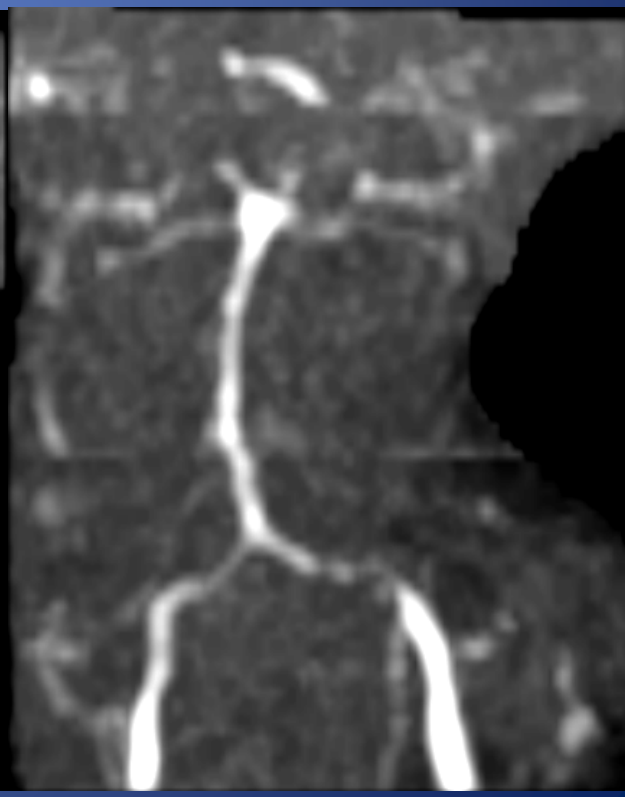
MRI at ~ 28 hours



Vasospasm?

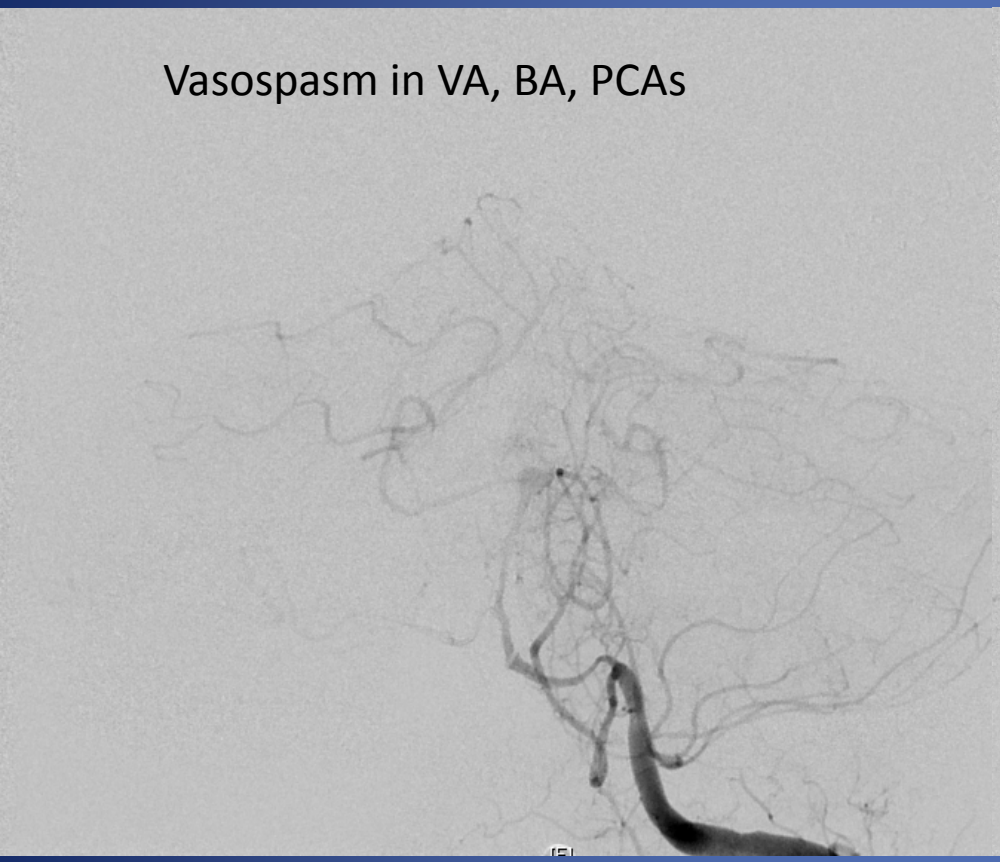




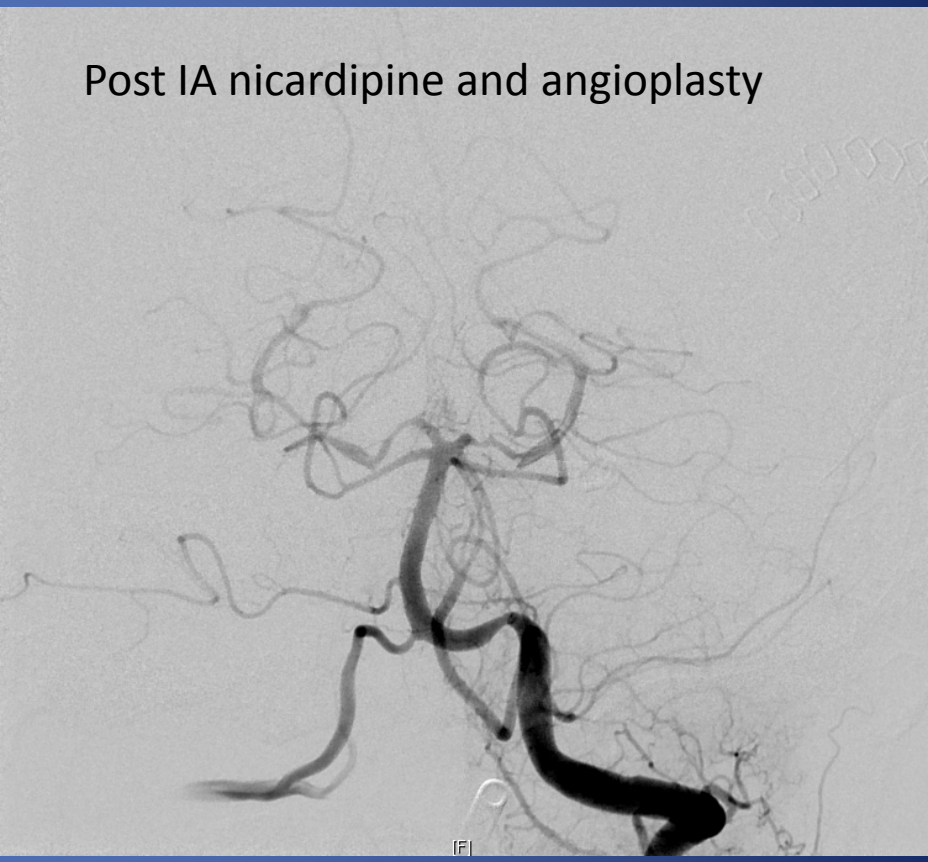


Vasospasm

Vasospasm in VA, BA, PCAs



Post IA nicardipine and angioplasty



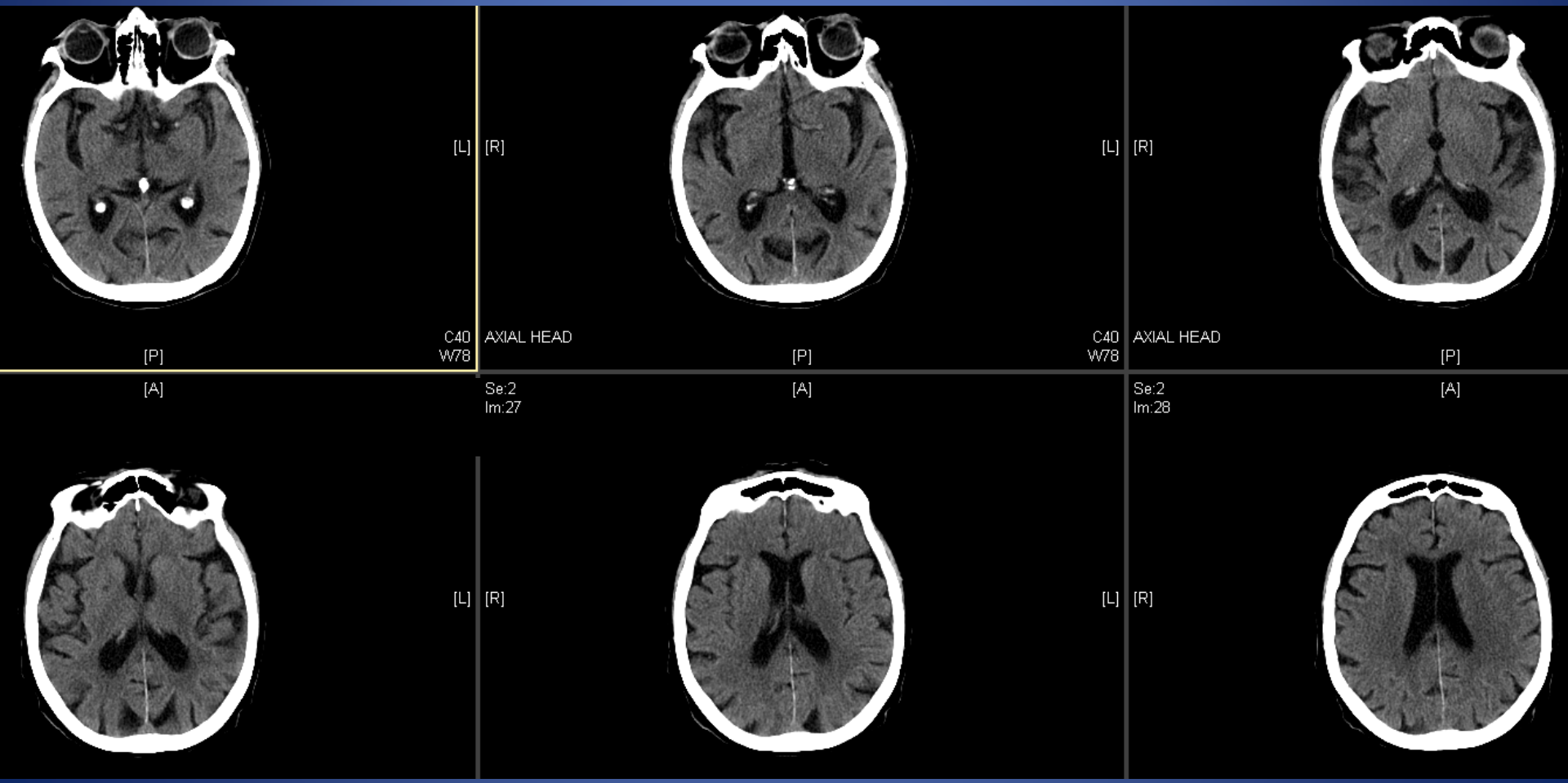
Case 1.

- 80 y/o F presents with right sided weakness and inability to speak. Pt ate dinner with her family and reportedly was in her usual state of health with no complaints after dinner when she went to bed. Pt was last seen normal at 7:15pm. At 9:45 pt's son-in-law heard a noise. Family went to check on her and found her unable to speak with R face, arm, and leg weakness. EMS was called, found the same symptoms, blood sugar 114 in the field. Pt arrived in ED at 10:15 (3 hrs) and stroke code was called.
- PMH: remote h/o stroke, dvt's, and lupus anticoagulant who at baseline, reportedly with intact language and cognition, ambulating with a walker.
- Meds: Coumadin
- Vitals: 36.4 155/49 66 99%
- Neuro exam: moderate aphasia; right facial droop; right arm flaccid weakness > leg weakness

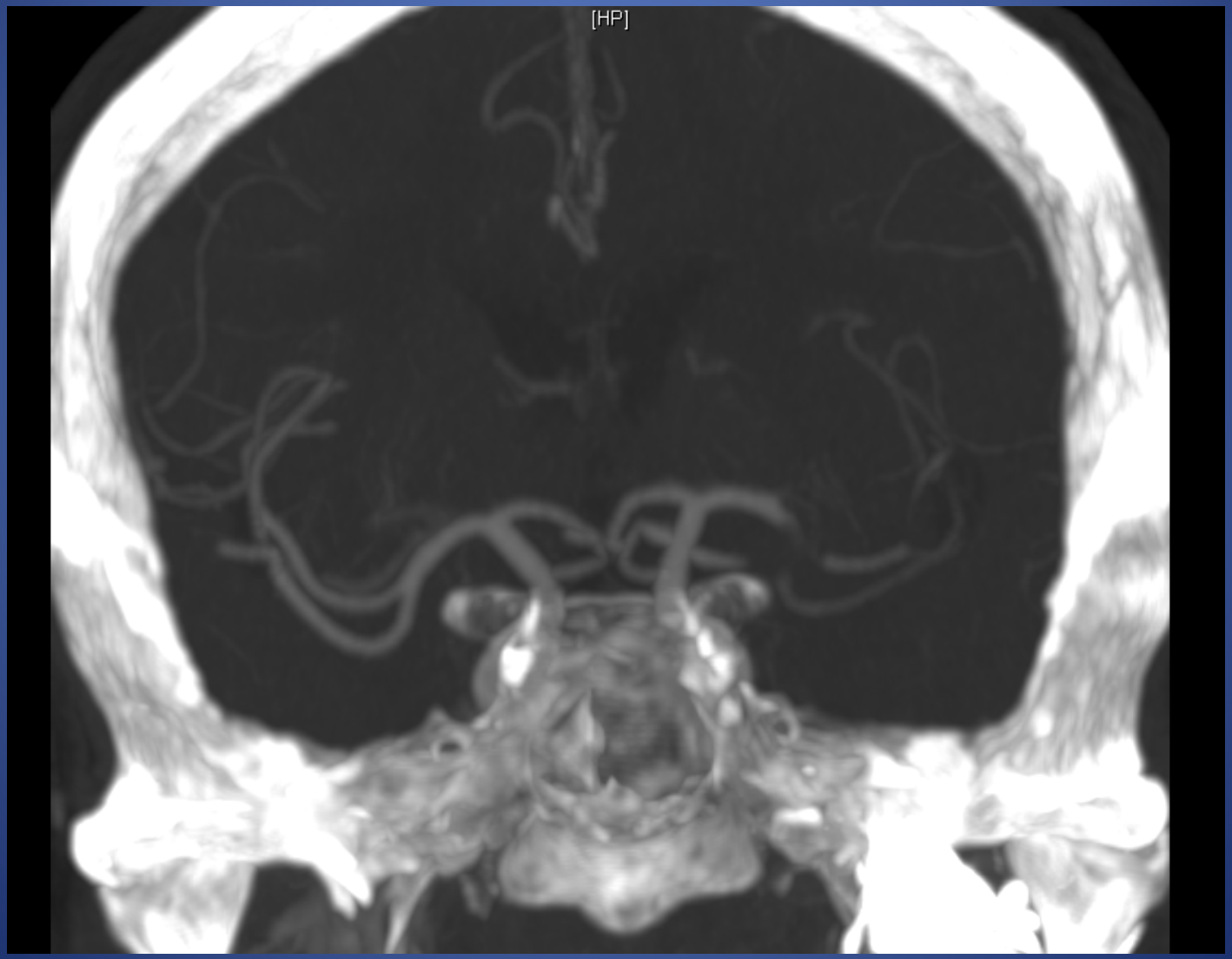
Case 1.
Tests

- Labs
  - WBC 5.6, H/H 13/38, Platelets 233
  - PT 14.9, PTT 34.6, INR 1.2
  - Glu 82, creat 1.3

Case 1.
CT head



Case 1. CTA



Case 1. Treatment options?

- ASA
- IV tPA
- Mechanical Thrombectomy and/or IA thrombolysis

Excellent Outcome at 3 months IV tPA vs. Placebo

Time (min)	Odds of Excellent Outcome
0–90	2.8
91–180	1.5
181–270	1.4
271–360	1.2

Pooled analysis of ATLANTIS, ECASS, and NINDS rt-PA stroke trials. *Lancet*. 2004;363:768

An extended window of opportunity for IV tPA?

- European Cooperative Acute Stroke Study Trial III (ECASS 3), 2008
- Randomly assigned 821 patients to IV tPA or placebo 3 to 4.5 hour window
- Excluded patient greater than 80 y/o, very high NIHSS scores >25, and combination of prior stroke and DM
- Primary outcome assess favorable (mRS 0-1) vs unfavorable (mRS 2-6) 3-month functional outcome

Hacke W et al for ECASS Investigators. Thrombolysis with Alteplase 3 to 4.5 hours after Acute Ischemic Stroke. NEJM Sept 2008; 359 (13): 1317-29.

ECASS III

- Results:

1. The treated group had significantly more patients with favorable outcome (52% vs 45%, OR 1.34 95% CI 1.02-1.76)
2. Symptomatic ICH significantly higher in treated group (2.4% vs 0.2%, by NINDS criteria 7.9% vs 3.5%)
3. No significant difference in mortality (7.7% vs 8.4%)
4. NNT 14 for a favorable outcome

Case 1. Follow Up

- Patient within 24 hours was back to her baseline function
- Patient discharged to family's home
- Anticoagulation resumed for stroke prevention

Case 2.

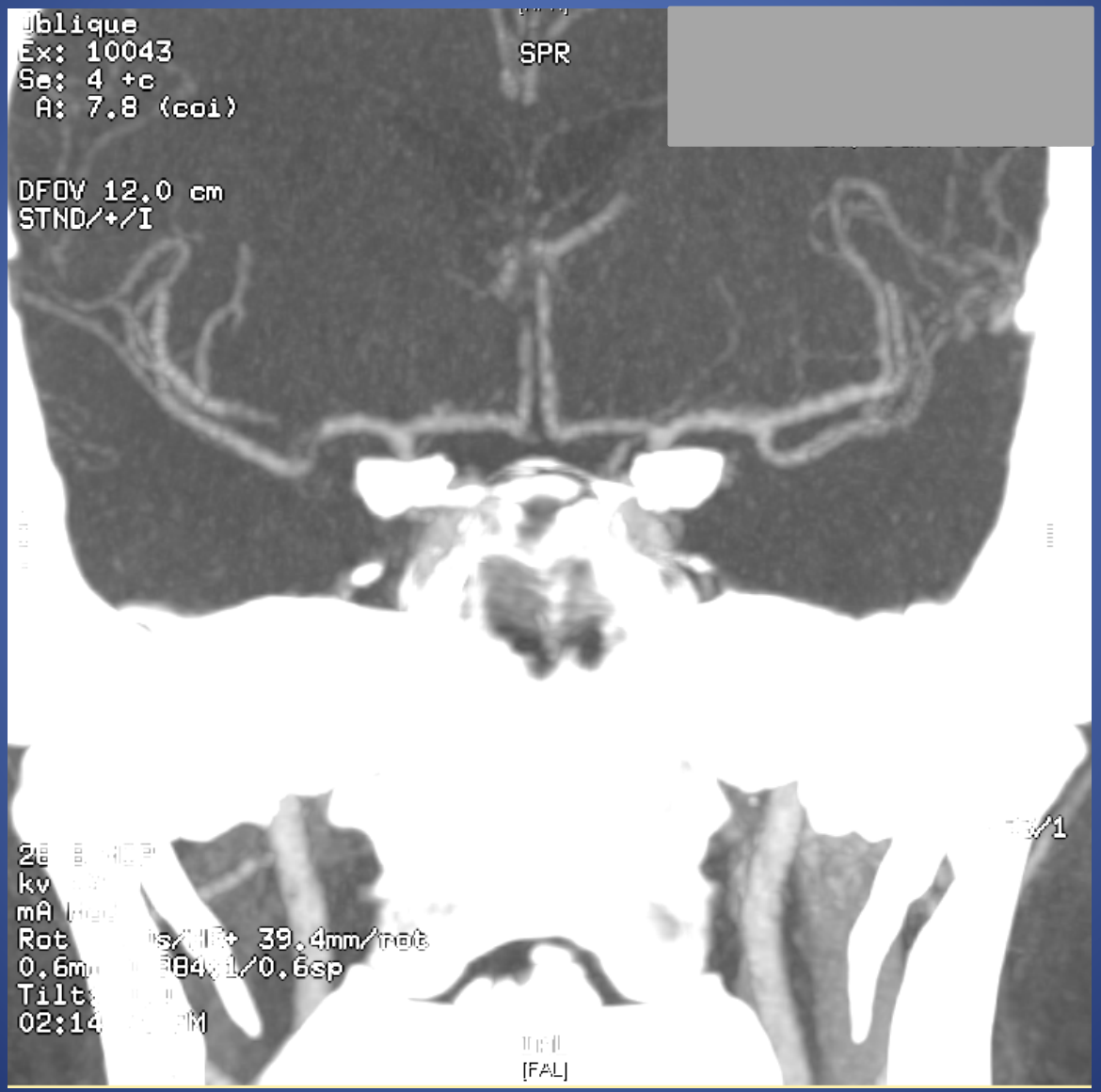
- 52-year-old male presents with acute onset of left-sided weakness. Patient was last well when he went to bed at 10pm. Patient awoke next morning around 11 a.m. and was unable to get out of bed. Eventually 911 was called and the patient was brought to the ED.
- PMH: Recent STEMI 2 weeks prior with 3 bare metal stents placed, hypertension, hepatitis C, diabetes.
- MEDS: ASA, Plavix , atorvastatin, lisinopril , Coreg, glyburide, metformin.
- VITALS: T 37.5 BP 116/69 P 63
- Neuro exam: Drowsy; no aphasia, but dysarthric; forced right gaze deviation; decreased L vision; mild L lower facial droop; L hemiparesis and hemisensory loss; L neglect

Case 2.
Tests

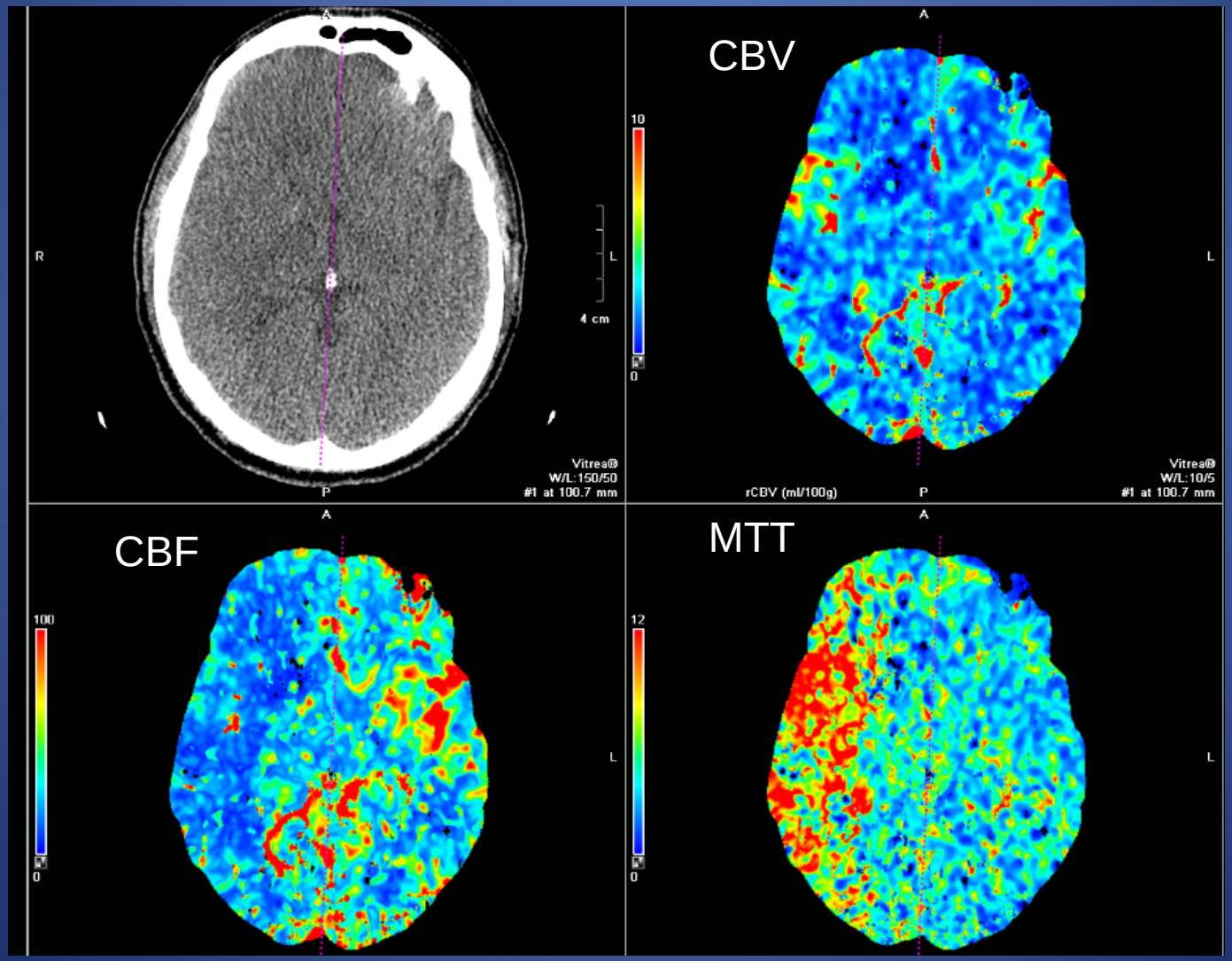
- Labs
  - WBC 5.5, H/H 13/36, platelets 125
  - PT13.7, INR 1.1
  - Glu 174, Creatinine 0.9

Case 2. CT head

Case 2. CTA


Ex: 10043
Se: 4 +c
A: 7.8 (coi)
SPR
DFOV 12.0 cm
STND/+/I
kv
mA
Rot
39.4mm/rot
0.6sp
Tilt:
[FAL]

Case 2. CT Perfusion



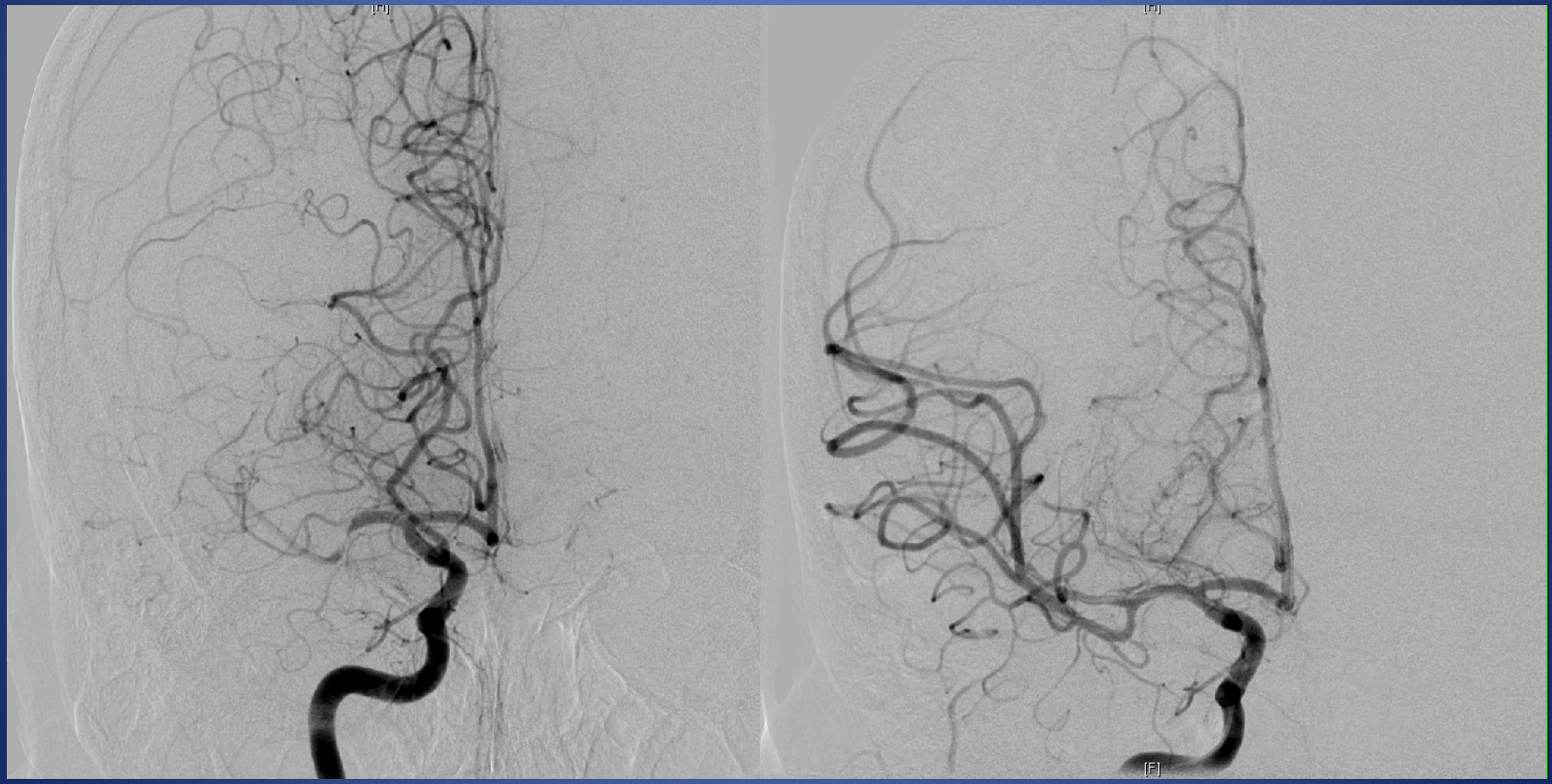
Case 2. Treatment Options?

- ASA/Plavix continued
- IV tPA
- Mechanical Thrombectomy and/or IA thrombolysis

Case 2.

- NOT IV tPA CANDIDATE
  - recent MI
  - unknown onset time patient
- With the prolonged MTT and Tmax, reduced CBF, and relatively normal CBV the patient was acutely taken for mechanical thrombectomy

Case 2. Cerebral Angiogram



PRE

POST

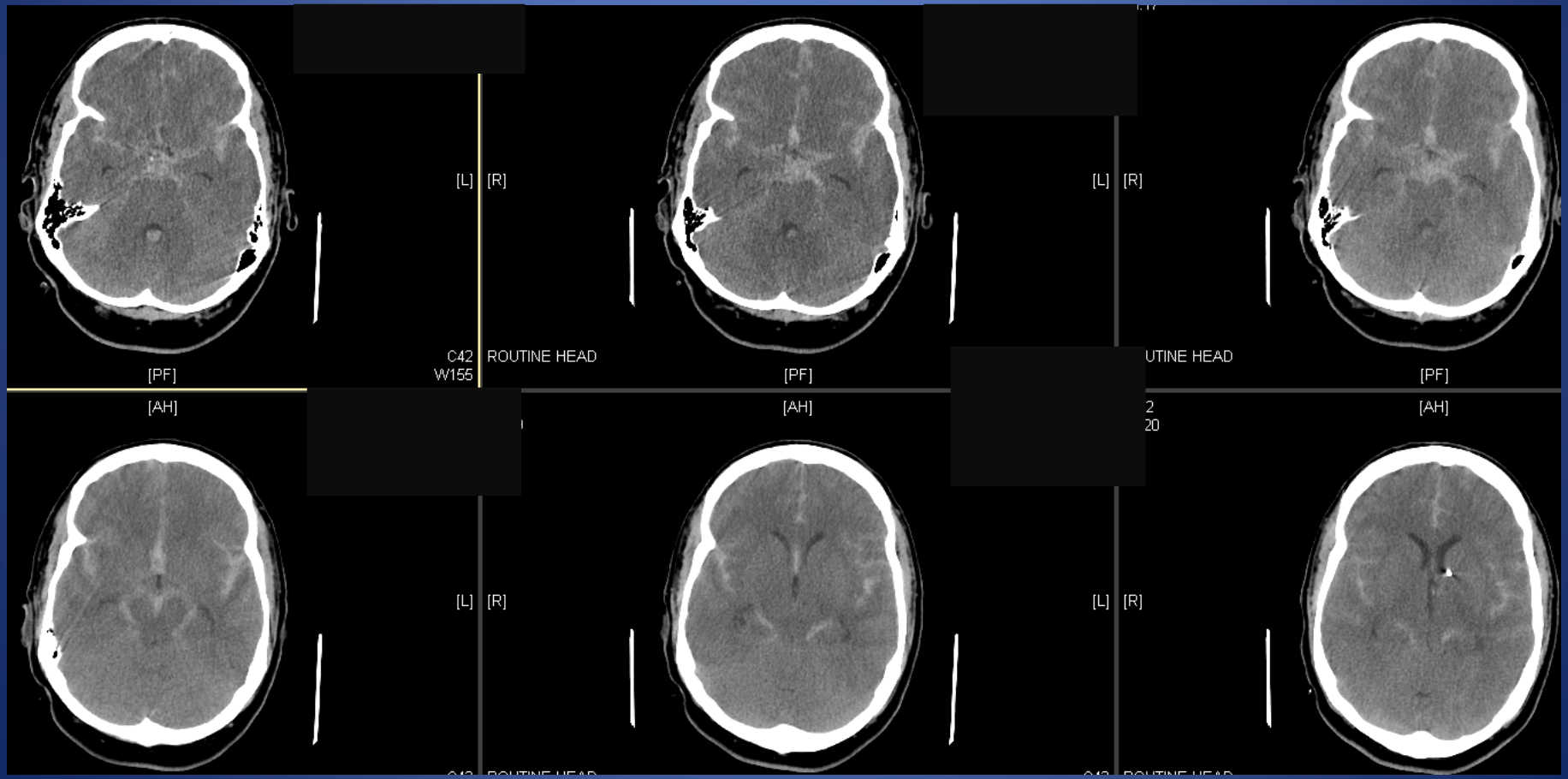
Case 2. Follow Up

- Patient's left sided strength improved to antigravity over the next 24 hours after the procedure
- Patient was discharged to acute rehab

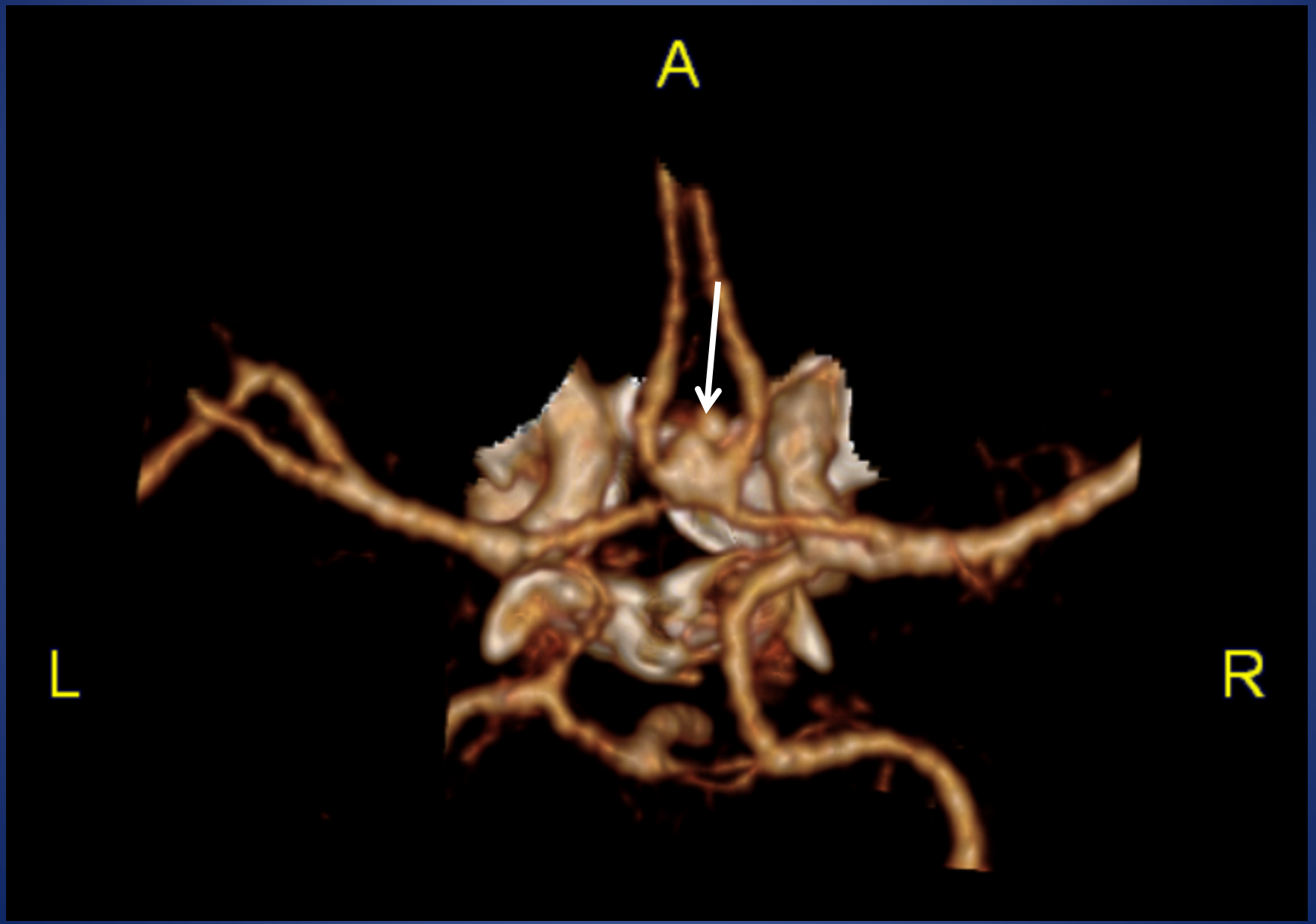
Case 3.

- **CC**: headache and sudden loss of consciousness
- **HPI**: 48 y/o man traveled from Chicago on business and went to local bar. Reportedly patient complained of headache to the bartender and then suddenly slumped over and fell off his bar stool. He had not been served ETOH yet. EMS called.
- **PMH**: reportedly hypertension and hyperlipidemia; other medical history unable to obtain
- **Exam**: Vitals: 37.7 200/100 90 25 Neuro exam: Mental status does not open eyes to verbal or noxious stim; Cranial Nerves: pupils small but reactive B. Motor/sens: decerebrate (extensor) posturing movements of the arms.

Case 3. Noncontrast CT Head

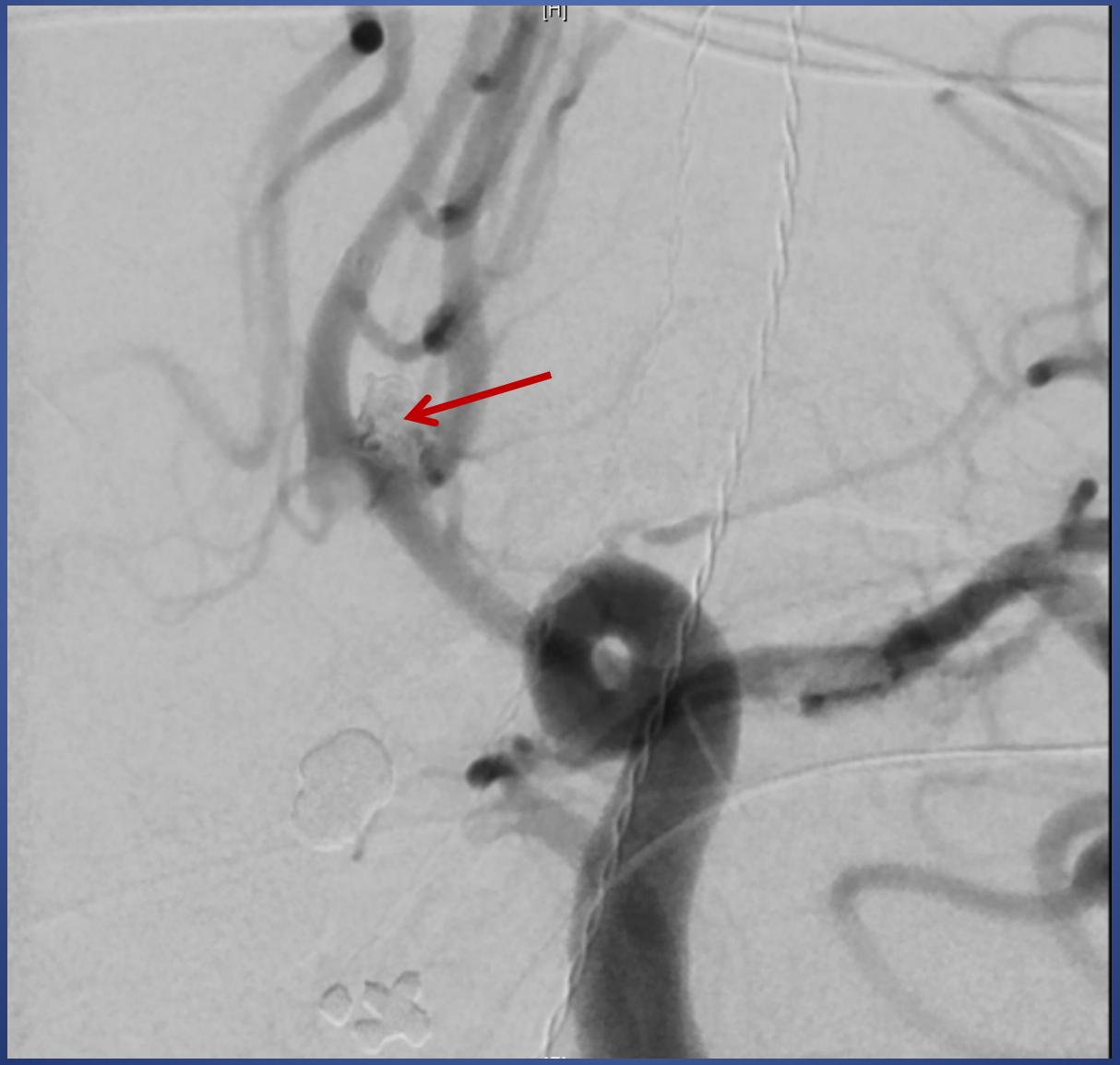


Case 3. CTA



Case 3. Cerebral Angiogram

Case 3. Aneurysm coiled



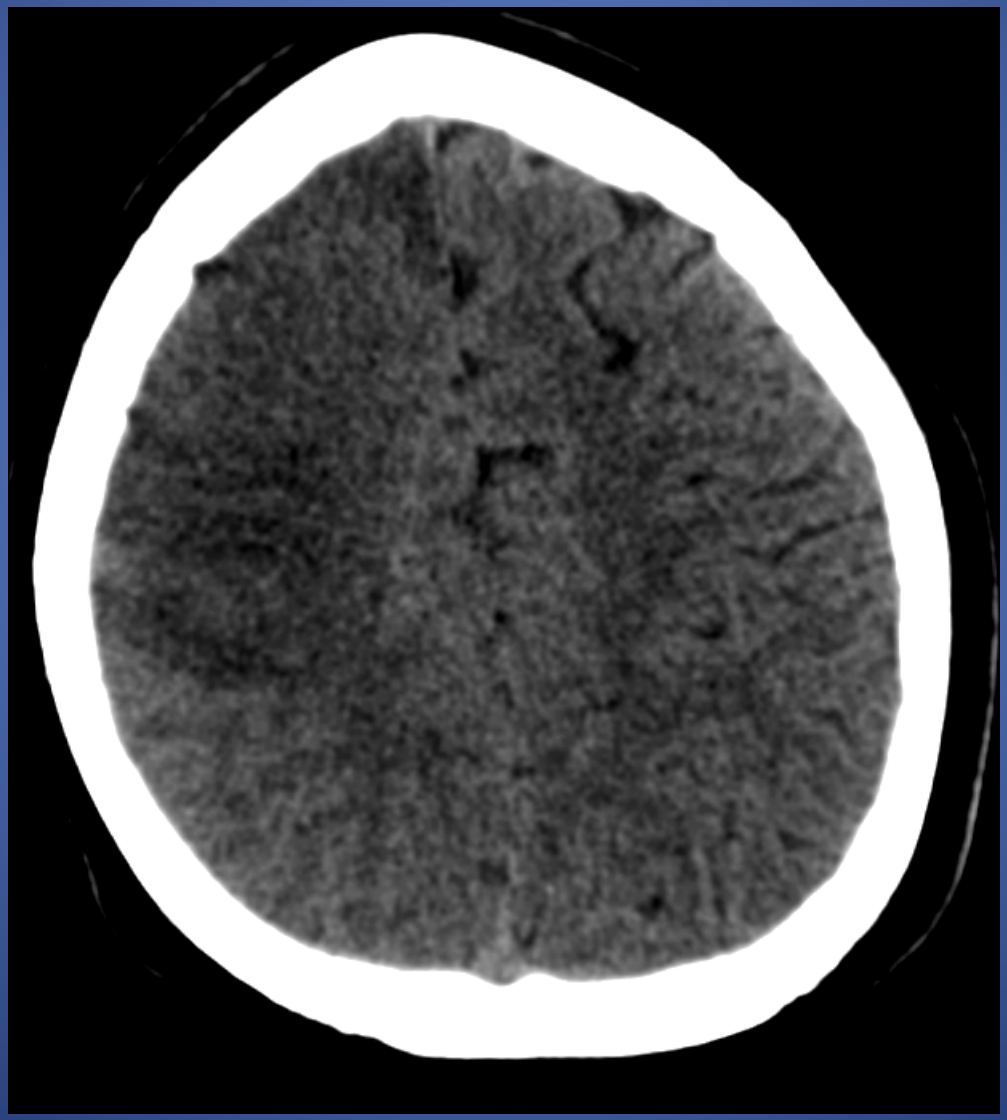
Case 3. Follow up

- Eventually extubated
- GCS 14 for disorientation
- Mild right LE weakness
- Discharged to fly back to Chicago for rehab

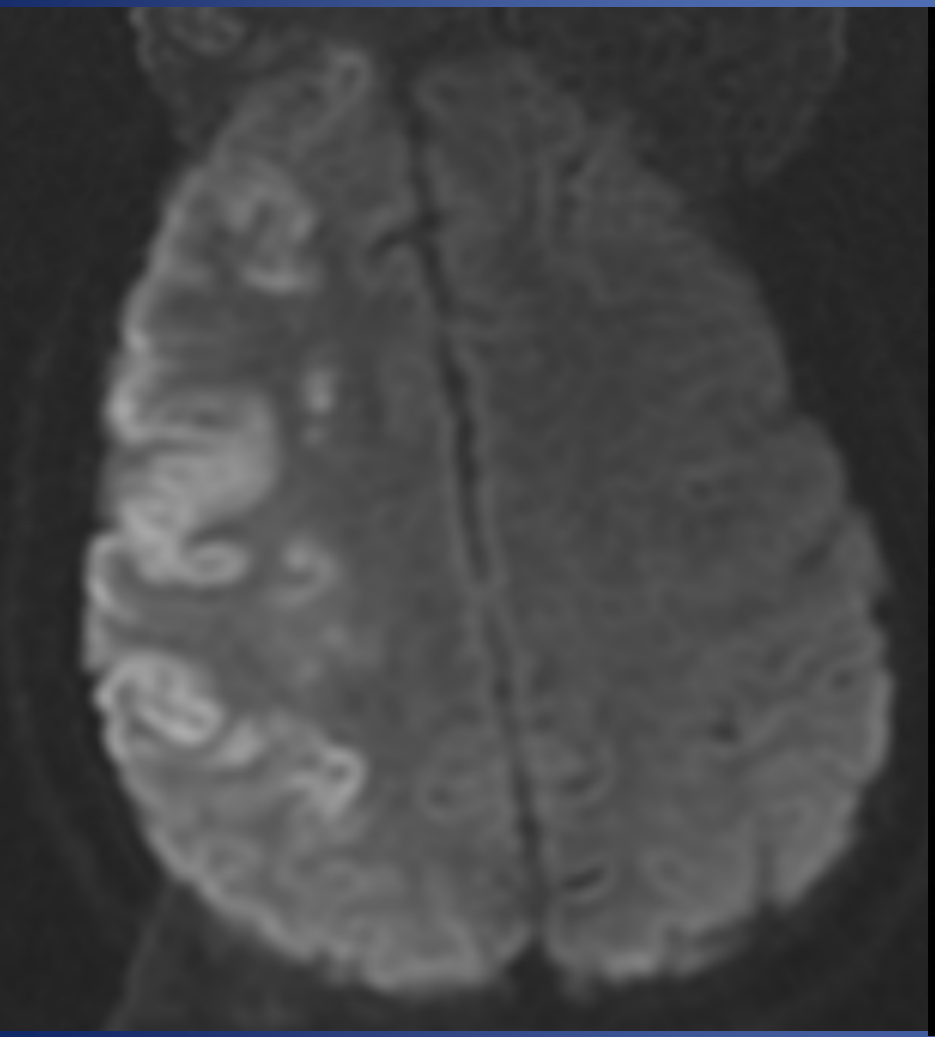
Case 4.

- 19 yo woman with sudden onset of left sided weakness
- PMH: amphetamine usage otherwise no other PMH or PSH
- Allg: nkda
- Meds: none
- Exam: Afebrile 120/70 100 20 Neuro exam: Mental Status: awake, alert, appropriately interactive, following commands; Cranial Nerves: Pupils 3 to 2 mm briskly reactive bilaterally. Visual fields full to confrontation bilaterally. Extraocular movements intact. L-sided facial weakness. Tongue deviates to L side on extension; Motor: 5/5 R upper and lower extremities. 1/5 in all L upper extremity muscle groups, 5/5 in L lower extremity muscle groups; Sensory: sensation intact to light touch

Case 4. CT head

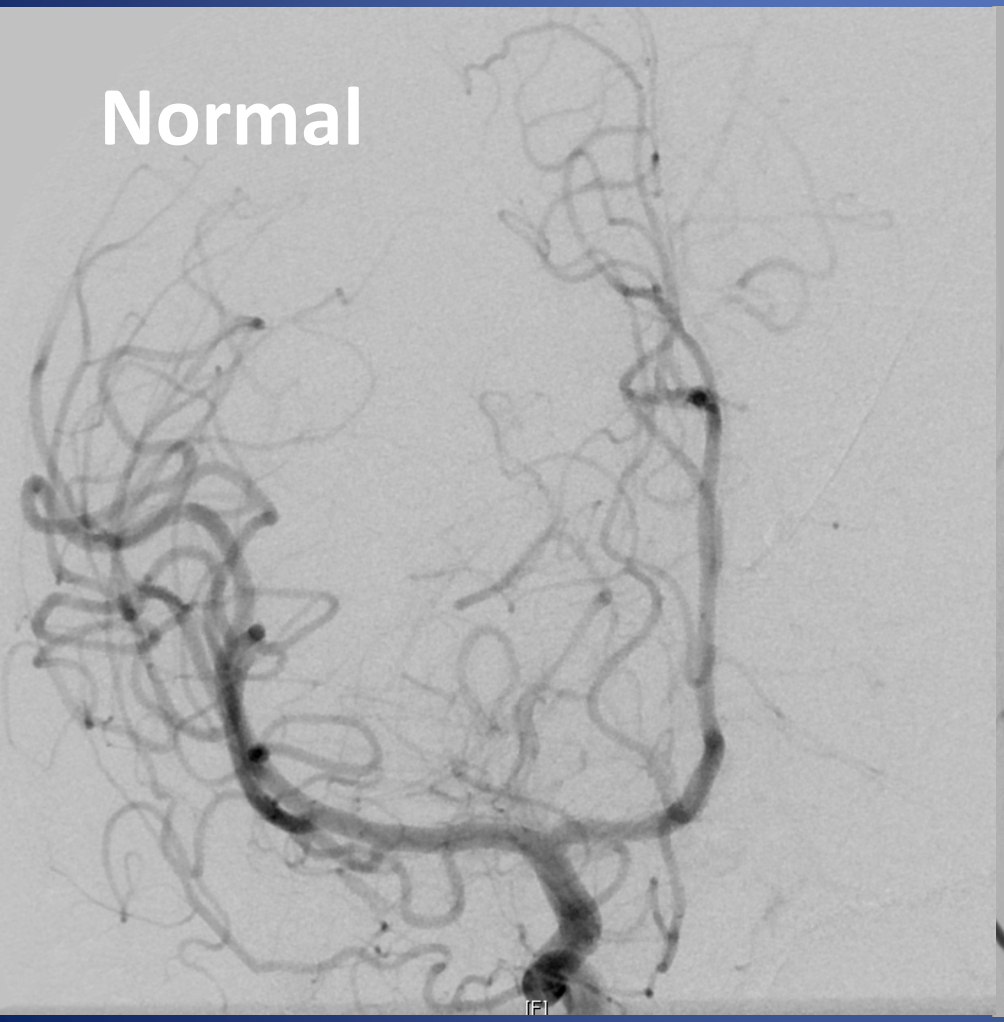


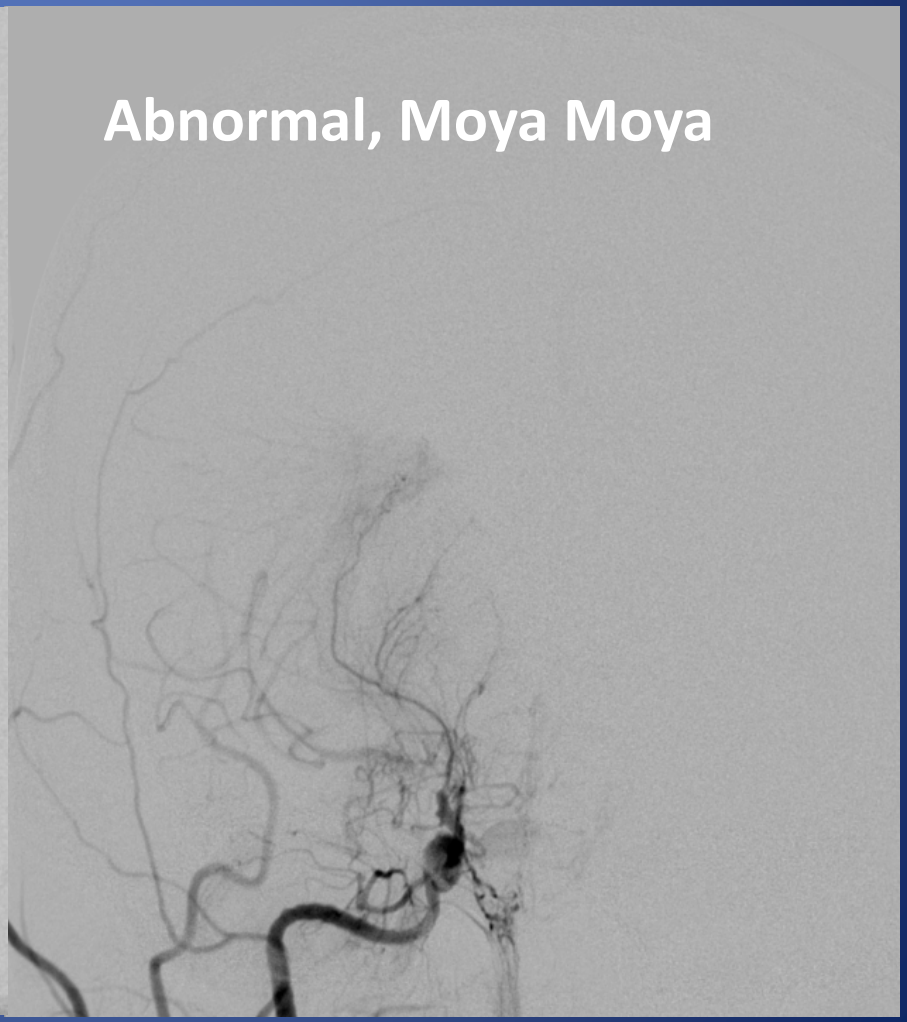
Case 4. MRI DWI brain and MRA of COW



Case 4. Cerebral Angiogram

Right ICA injection





Case 4. Follow up

- Patient suffered a second stroke right cerebral hemisphere.
- Stabilized with HTN therapy in the ICU
- Received right EC –IC bypass 1st followed later with a left EC –IC bypass
- Remained with left sided hemiparesis (face and arm much worse than leg)
- Gradually improved arm strength and was ambulatory at the time of discharge.

Thanks!