Chapter 6: Neuro Imaging

Imaging Modalities

- Structural Imaging Modalities
  - Plain Radiographs
  - Computed Tomography
  - Magnetic Resonance Imaging
  - Cerebral Angiography
  - MRA/CTA
  - Myelography

Plain Radiographs

- Detect fractures
- Exclusion of foreign bodies prior to MRI
- Less sensitivity than CT

Computed Tomography

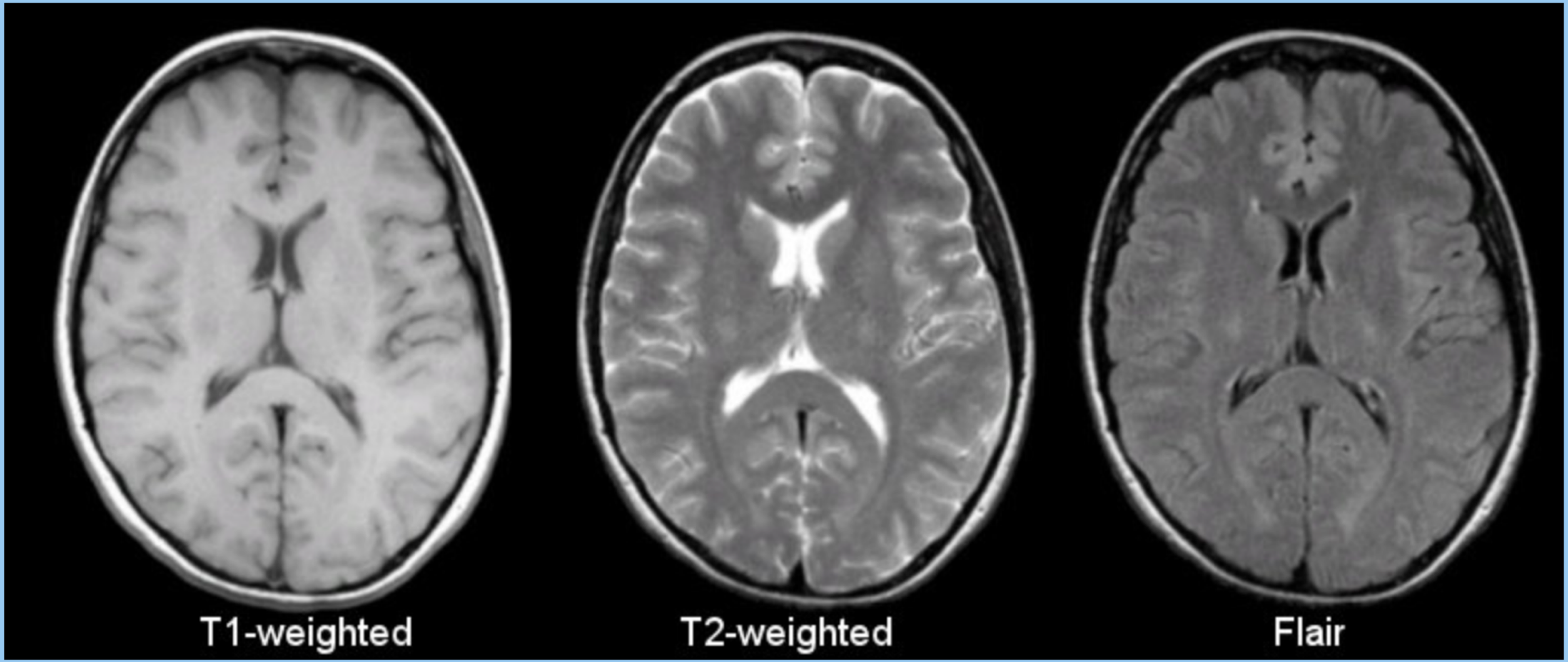
- Widespread availability, short scan time
- Useful in stroke, trauma for early detection of hemorrhage, hydrocephalus, impending herniation
- Disadvantage: ionizing radiation exposure
- Difficult to assess posterior fossa, floor of middle cranial fossa
- Contrast agents are iodine based

Magnetic Resonance Imaging

- Good for detailed anatomy, complex CNS lesions
- Signals emitted by relaxation of hydrogen nuclei in water after they have been excited by radiofrequency pulses in a magnetic field
- T1 Weighted: fat appears bright, water and CSF appear black
- T2 Weighted: fat is grey, water and CSF are bright
- Cortical bone does not produce a signal, flowing blood does not produce a signal, “signal void”

- Pathologic processes usually contain excess free water and are dark on T1 weighted images, bright on T2 weighted images
  - Anatomy = better on T1
  - Pathology = better on T2
- Paramagnetic contrast agents e.g. Gadolinium
  - Better seen on T1 weighted images

Comparison of T1 vs. T2 vs. Flair (Brain)

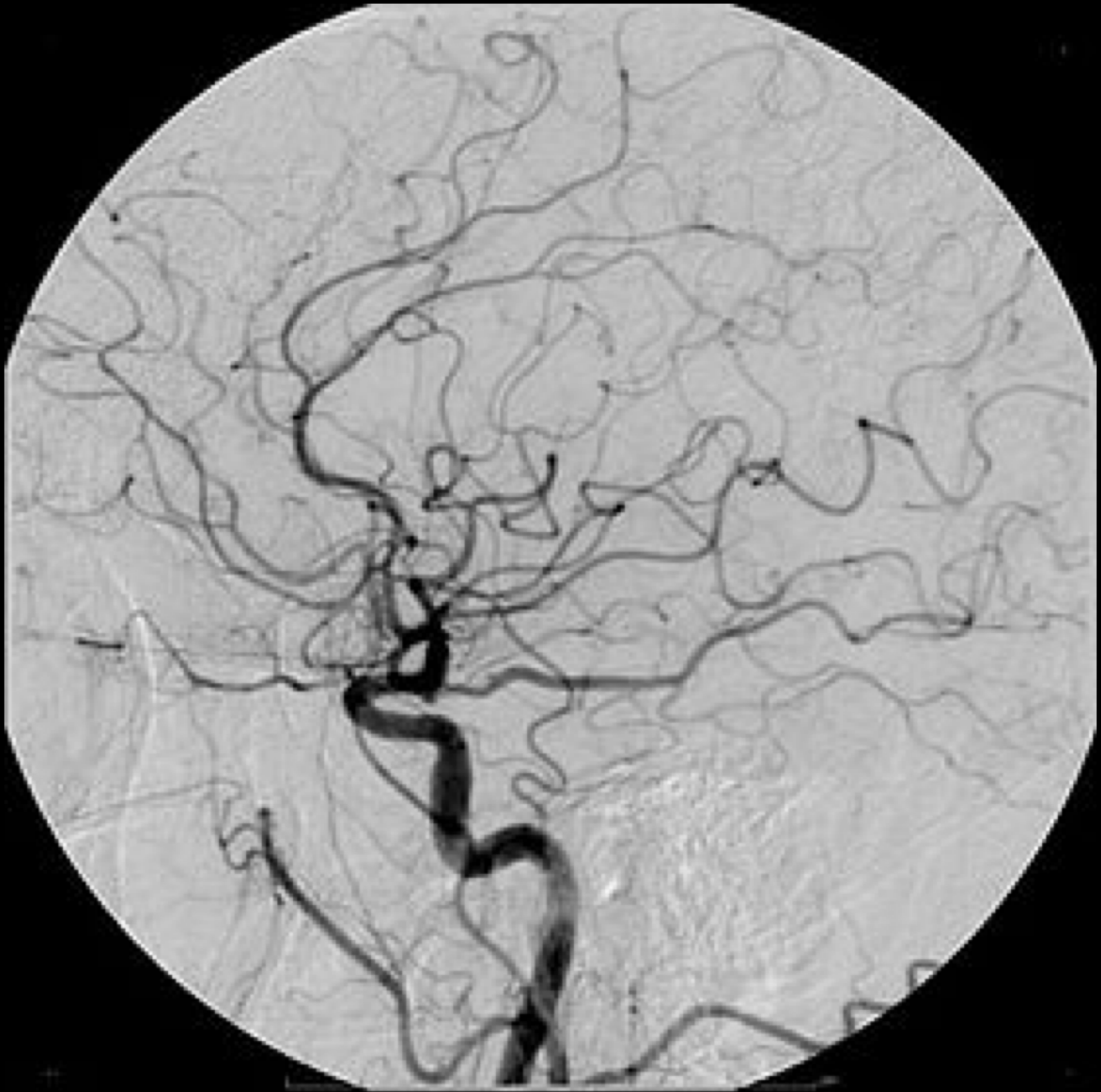


Tissue	T1-Weighted	T2-Weighted	Flair
CSF	Dark	Bright	Dark
White Matter	Light	Dark Gray	Dark Gray
Cortex	Gray	Light Gray	Light Gray
Fat (within bone marrow)	Bright	Light	Light
Inflammation (infection, demyelination)	Dark	Bright	Bright

- Different pulse sequences can be used for different types of lesions
    - Diffusion weighted imaging (DWI) – helps detect early ischemia
    - Fluid attenuated inversion recovery (FLAIR) – increases focal hyperintense T2 signal in pathologic lesions by eliminating the hyperintense CSF signal
        - DAI or MS are easier to see
        - Increased sensitivity for acute or subacute SAH
    - Gradient Echo (GRE) T2 sequence shows increased sensitivity for intracranial blood
    - Susceptibility Weighted Imaging (SWI) – more sensitive and better in detecting hemorrhage and calcification

Cerebral Angiography

- Flexible catheter introduced through femoral artery to visualize intracranial arteries
- Routinely, four vessel angiogram is performed
  - Bilateral internal carotid and vertebral arteries
  - 6 vessel angio includes bilateral external carotids
- Digital Subtraction Angiography (DSA) – iodinated contrast injected into cerebral vasculature and bony details are subtracted
- Gold standard for evaluation of cerebrovascular disease, invasive, carries risk



Magnetic Resonance and Computed Tomography Angiography

Myelography and CT Myelography

- Injection of iodinated, water-soluble contrast material into spinal subarachnoid space via lumbar puncture
- Plain radiographs are obtained in multiple projections while the contrast is moved cranially or caudally to evaluate multiple levels
- Myelography is usually followed by immediate or delayed CT examination

Functional Imaging Modalities

- Perfusion CT
- Diffusion-weighted MRI
- Perfusion-weighted

Perfusion CT

- CT imaging is performed by monitoring the first pass of iodinated contrast agent bolus through the cerebral circulation
- As the change in CT enhancement (Hounsefield units) is proportional to the concentration of contrast, perfusion parameters are calculated by deconvolution from the changes in density-time curve for each pixel using mathematical algorithms based on central volume principle
    - Mean transit time (MTT) – indicates the time difference between the arterial inflow and the venous outflow
    - Time to bolus peak (TTP) – time from the beginning of contrast injection to peak concentration within a region of interest
    - Cerebral blood volume (CBV) – volume of blood/unit of brain mass (normal in gray matter 4-6 ml/100g)
    - Cerebral blood flow (CBF) – volume of blood flow per unit of brain mass per minute (normal 50-60 ml/100 g/min
    - CBV = CBV/MTT

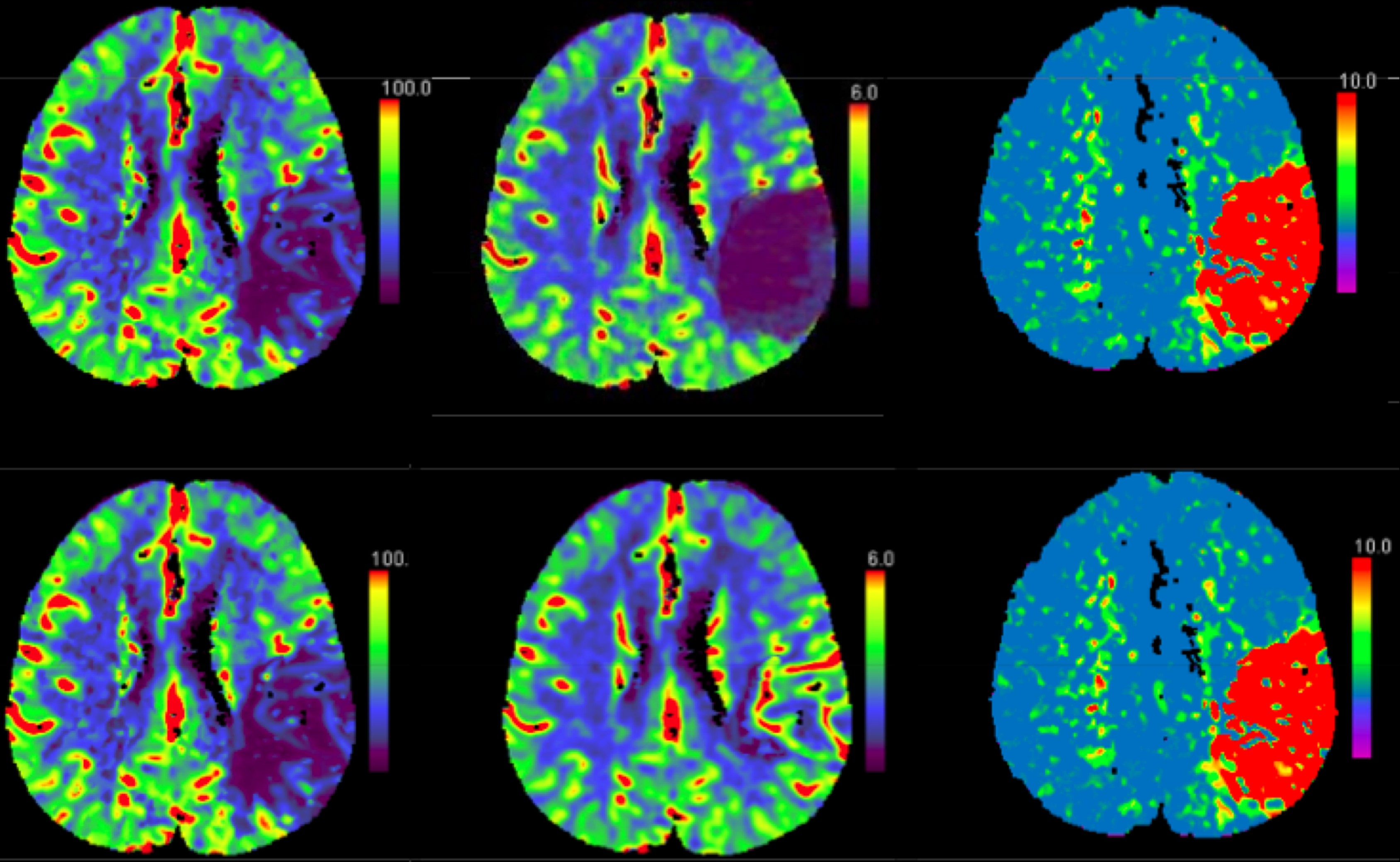
CBF

CBV

MTT / TTP

Core infarct

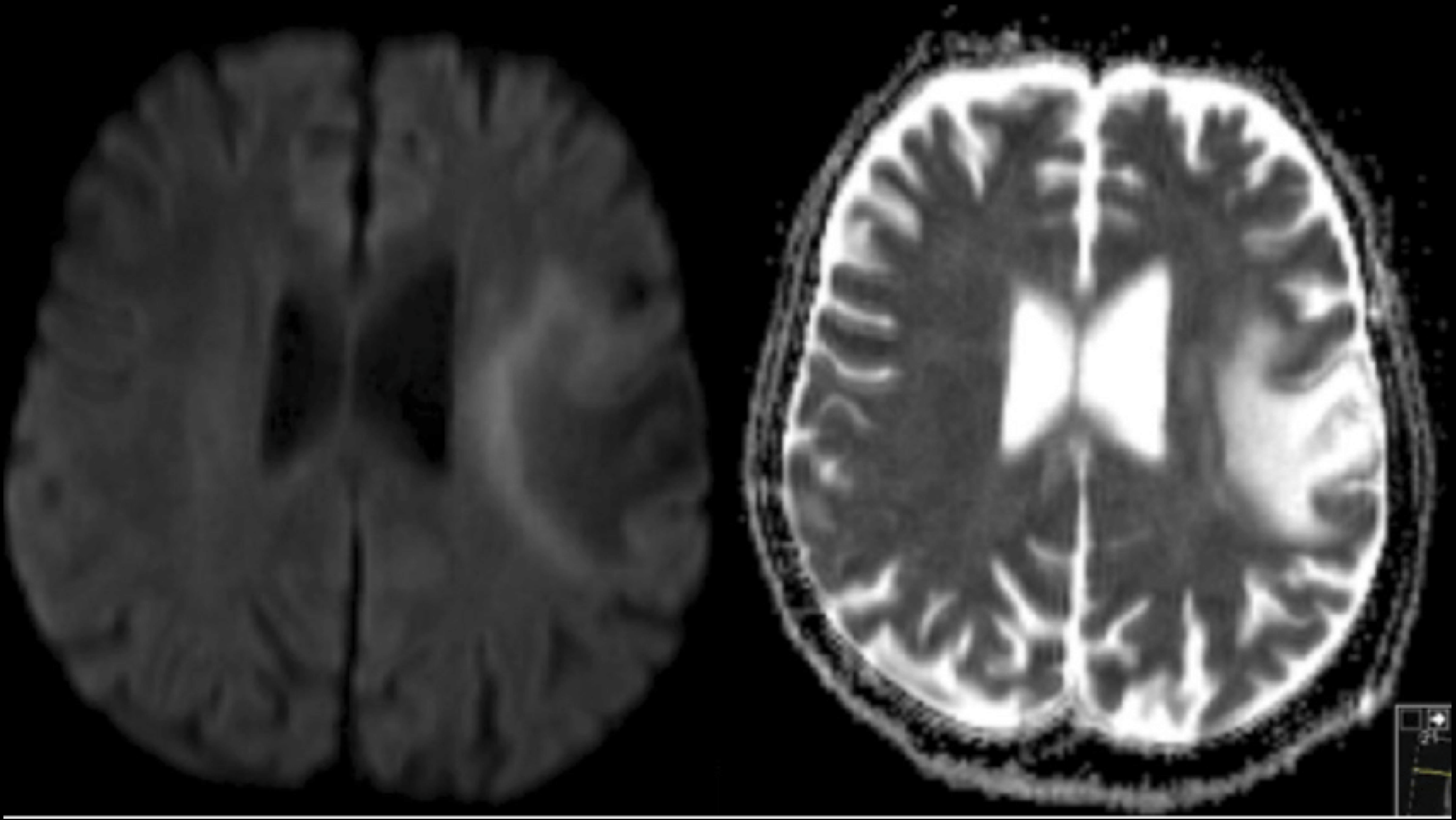
Ischemic penumbra



DWI MRI

- Most useful for detecting irreversibly infarcted tissue
- Based on the measurement of random motion of water molecules, detects degree of mobility of water molecules within tissues
  - By introducing magnetic field gradients, it is possible to obtain MR sequences that are sensitive to the diffusivity of water along a chosen direction obtaining diffuse weighted images
- Compute a quantitative measure of 'mean diffusivity' known as the apparent diffusion coefficient (ADC) which measures water diffusion and mirrors changes in DWI signal
  - In areas of increased diffusion like vasogenic edema, DWI is low and there is an increase in ADC
  - In regions of restricted diffusion like cytotoxic edema, DWI signal intensity is increased and ADC signal decreases

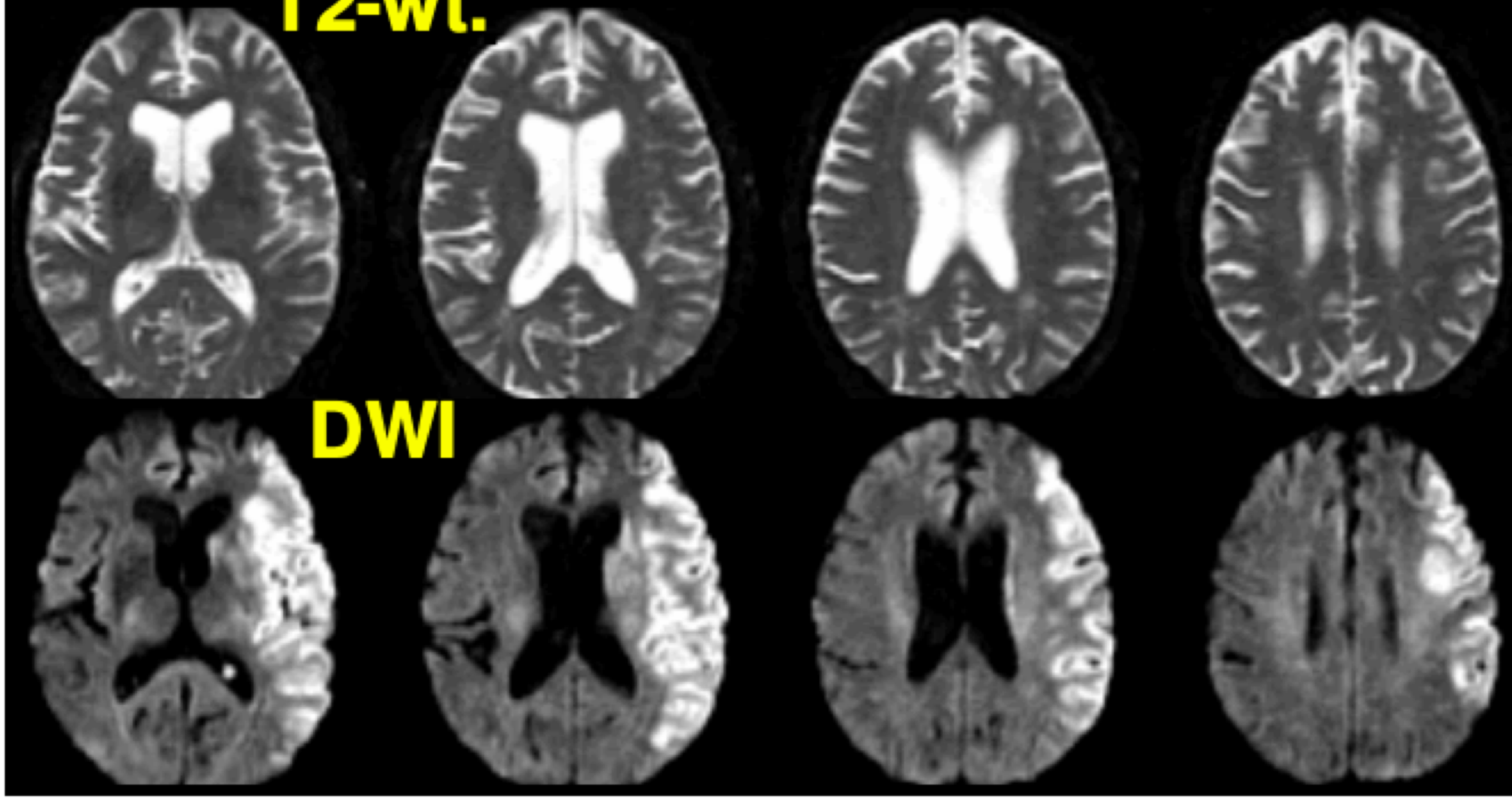
- DWI is widely used in ischemic stroke, reduced diffusion results in increased DWI signal and reduced ADC is seen before onset of abnormalities of conventional MRI
- DWI also used to study abscesses, epidermoid cysts, TBI



Axial diffusion weighted imaging (DWI; b = 1000) (left) and apparent diffusion coefficient (ADC) (right) showing peripheral restricted diffusion

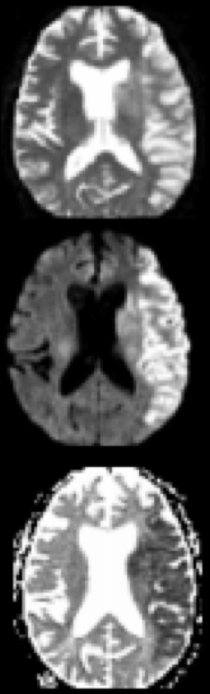
MRI and Acute Stroke

4 hours



Why does ADC of water decrease in acute stroke ?

perfusion deficit
↓
energy deficit
↓
failure of Na⁺/K⁺ pumps
↓
intracellular accumulation of Na⁺
↓
influx of water
→ glial and neuronal swelling
→ reduction in extracellular space



glial and neuronal swelling → *Mobility hindered = ADC drop*
reduction in extracellular space → *Mobility hindered = ADC drop*

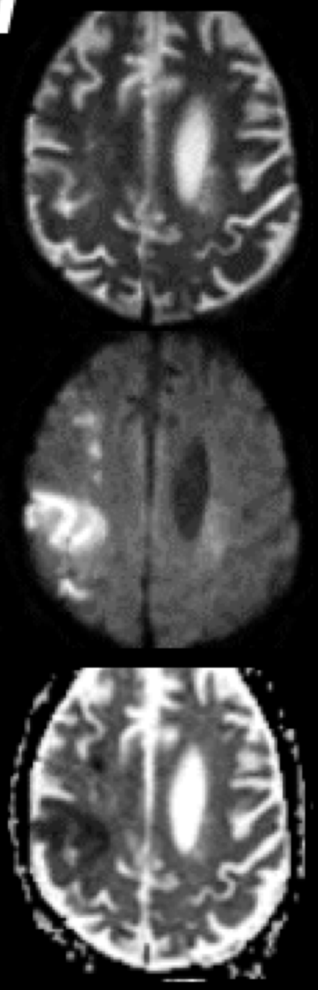
Mobility hindered = ADC drop
↑
DWI hyperintensity
↑
Eventual lysis/edema

Perfusion Weighted Imaging

- PWI used to identify areas of reversible ischemia
  - IV bolus of gadolinium contrast
  - Passage of contrast through brain capillaries causes a transient loss of signal because of the T2 effects of the contrast agent
  - A hemodynamic time-signal intensity curve is produced with subsequent calculation of MTT, TTP, CBF, and CBV
- PWI can also be performed using T1 weighted imaging, but slower, longer acquisition
- Arterial spin labeling, no exogenous contrast but uses endogenous diffusible tracer, applies MR pulses to magnetically labelled water protons
  - Good for patients who cannot receive contrast 2/2 renal failure

The Diffusion - Perfusion Mismatch

DWI

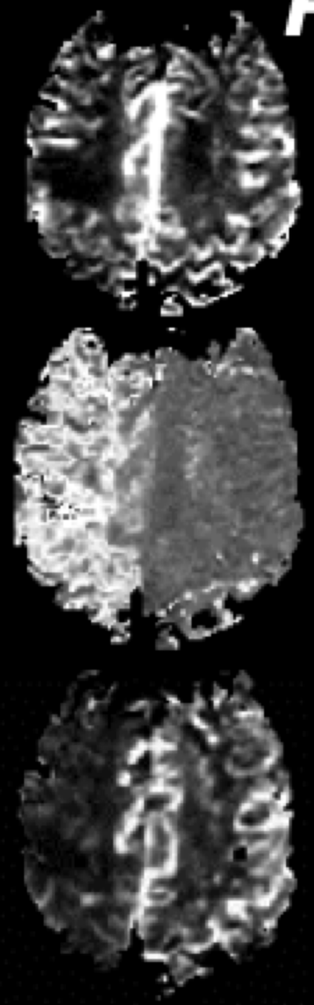


T2-wt
Early stroke not seen

Diffusion-wt
Clear depiction of lesion

Apparent Diffusion
Acute stroke has low ADC

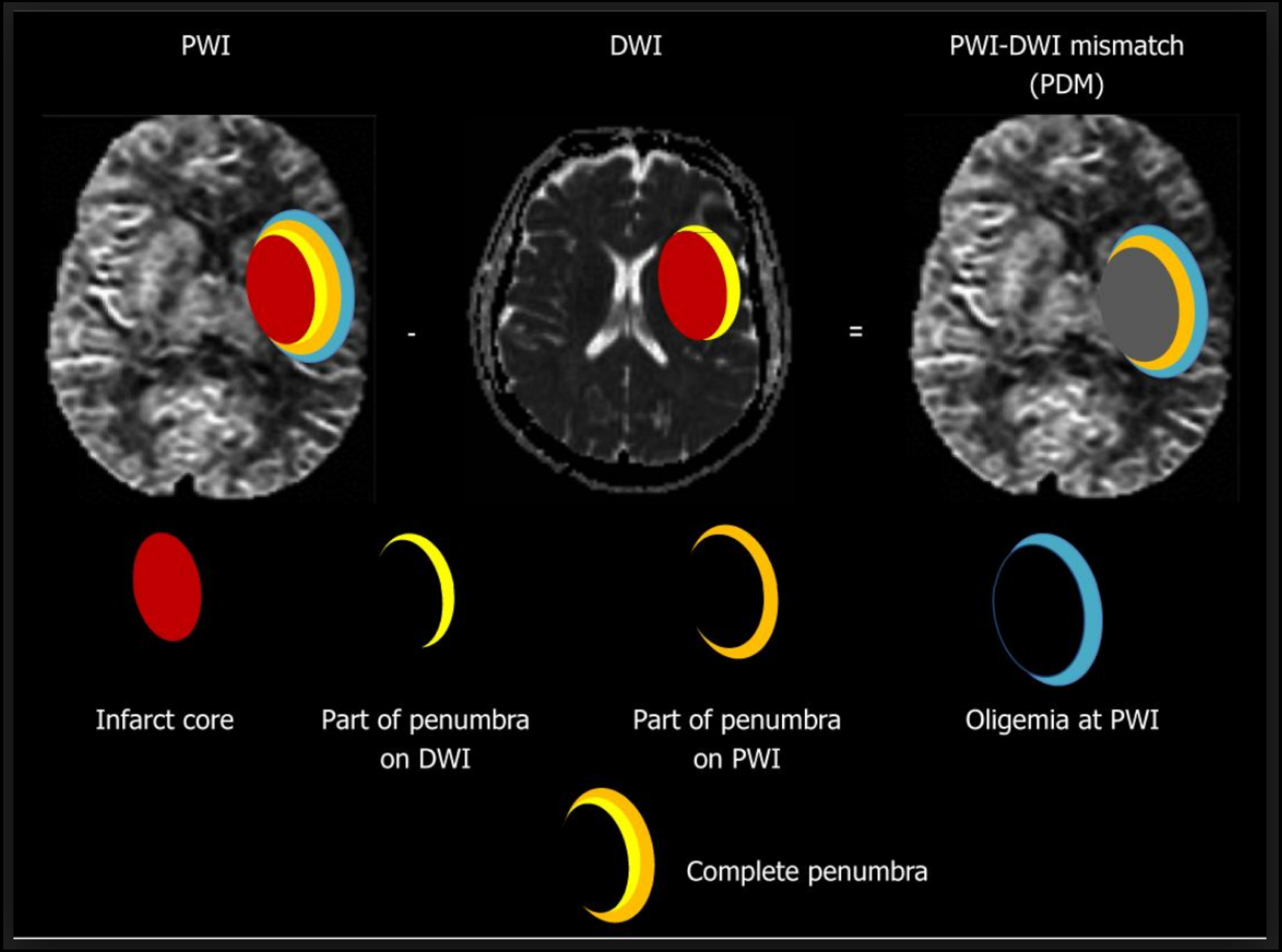
PWI



Blood Volume
Lesion has reduced CBV

Mean Transit
large perfusion deficit

Blood Flow
Reduced flow around lesion


PWI
DWI
PWI-DWI mismatch (PDM)
-
=
Infarct core
Part of penumbra on DWI
Part of penumbra on PWI
Oligemia at PWI
Complete penumbra

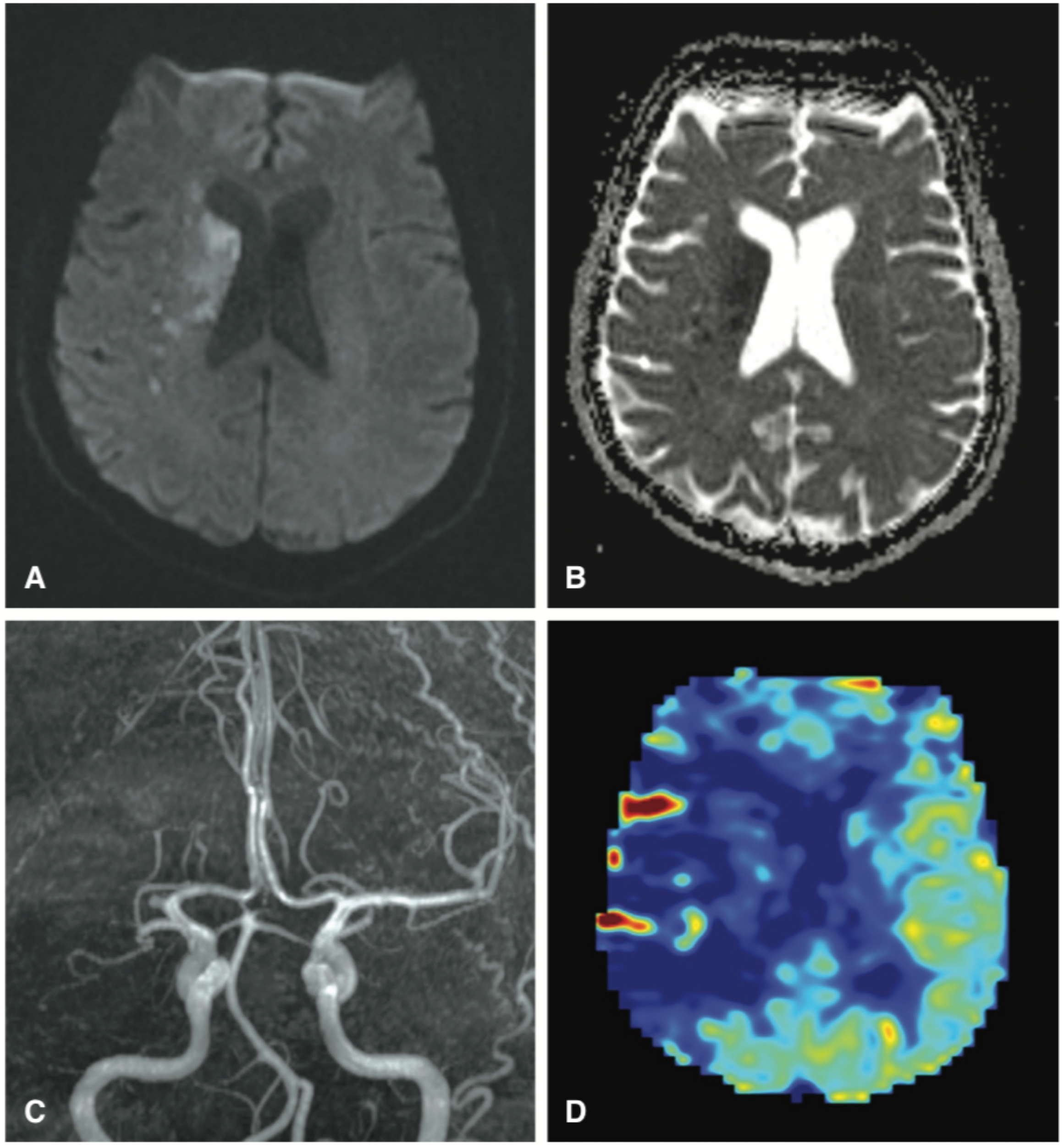
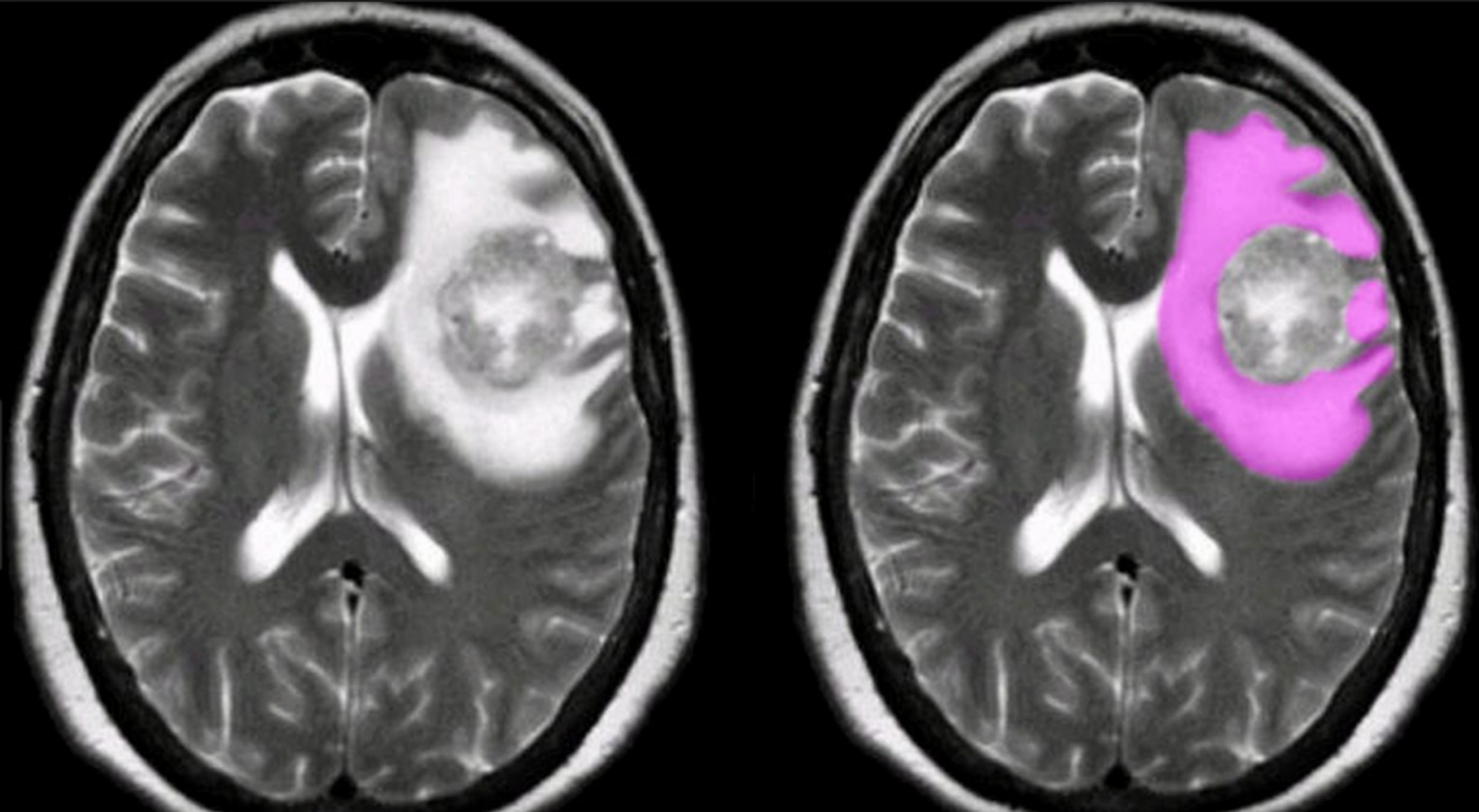


Fig. 5.6 A 57-year-old female who presented with left pronator drift and right gaze preference. She was found to have right middle cerebral artery territory infarct involving right basal ganglia and periventricular white matter on diffusion-weighted imaging (DWI) **(A)** and apparent diffusion coefficient (ADC) **(B)** maps. Time-of-flight magnetic imaging angiogram **(C)** showed abrupt cut-off of right middle cerebral artery in M1 segment. Arterial spin labelling (ASL) map **(D)** showed reduced perfusion in right MCA distribution.

Intracranial Disorders

- Edema
- Hemorrhage
- Mass Effect, Shift, Herniation
- Hydrocephalus

- Edema
  - Dark on T1, bright on T2
  - Results from increase in one brain volume parenchymal compartment at the expense of another
    - Vasogenic – associated with brain mets, abscesses, trauma, and hemorrhage; physical disruption of vascular endothelium or functional alterations in endothelial tight junction, fluid extravasation from vessels into EC fluid brain spaces, most commonly involves white matter
    - Cytotoxic – fluid accumulating within cells as a result of injury, toxicity, ischemia, or hypoxia; failure of Na-K ATPase pumps, involves both gray and white matter; fluid moves from extracellular to intracellular compartment with no net change in brain volume
    - Interstitial – CSF migration into periventricular white matter, commonly due to conditions that impede CSF circulation and/or absorption



Axial T2: A neoplastic focal lesion with marked adjacent focal vasogenic odema confined to white matter, an overlying grey matter is spared.

Key Concept

Cerebral oedema

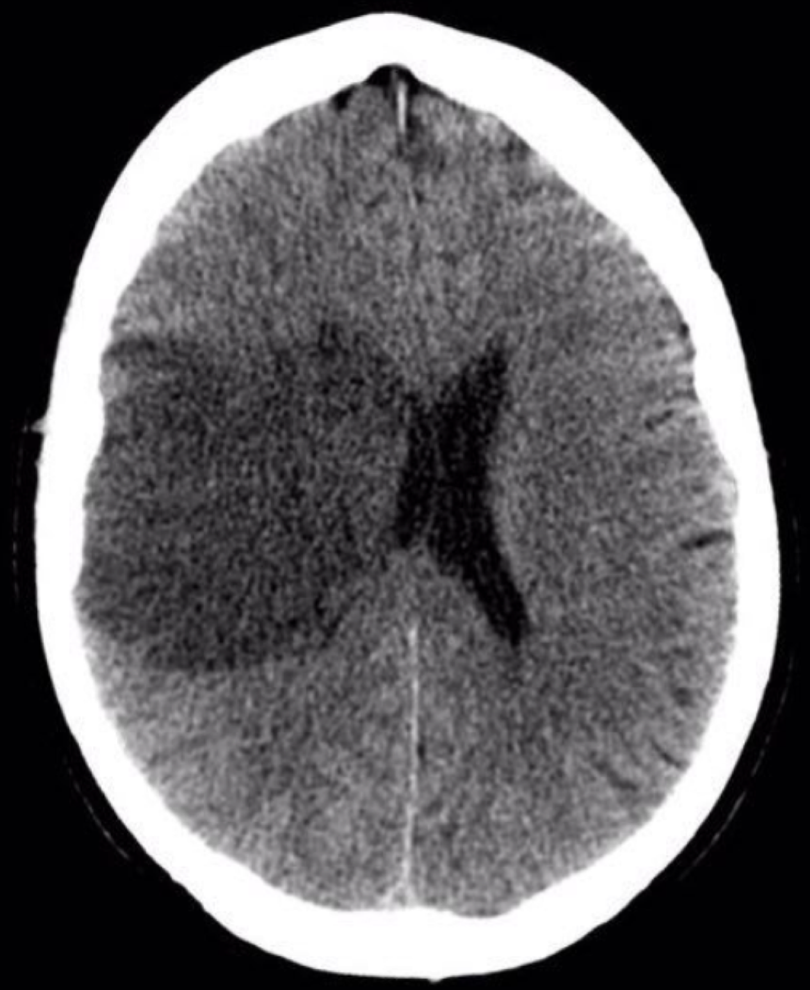
Cytotoxic oedema

- cellular swelling
- BBB intact

Grey and white matter becomes hypodense

Loss of grey-white differentiation

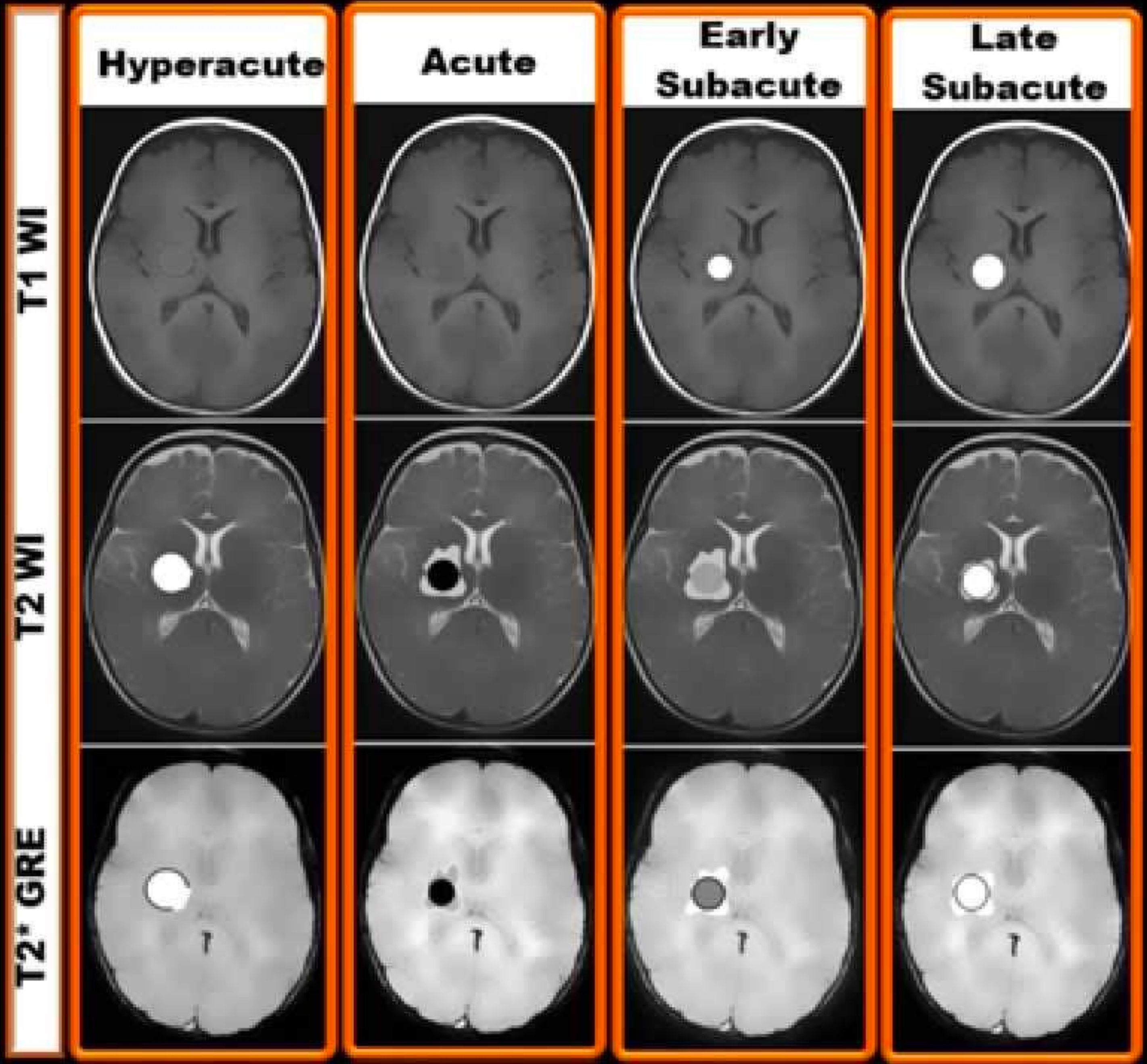
Infarct
HSV encephalitis
Hypoxic injury



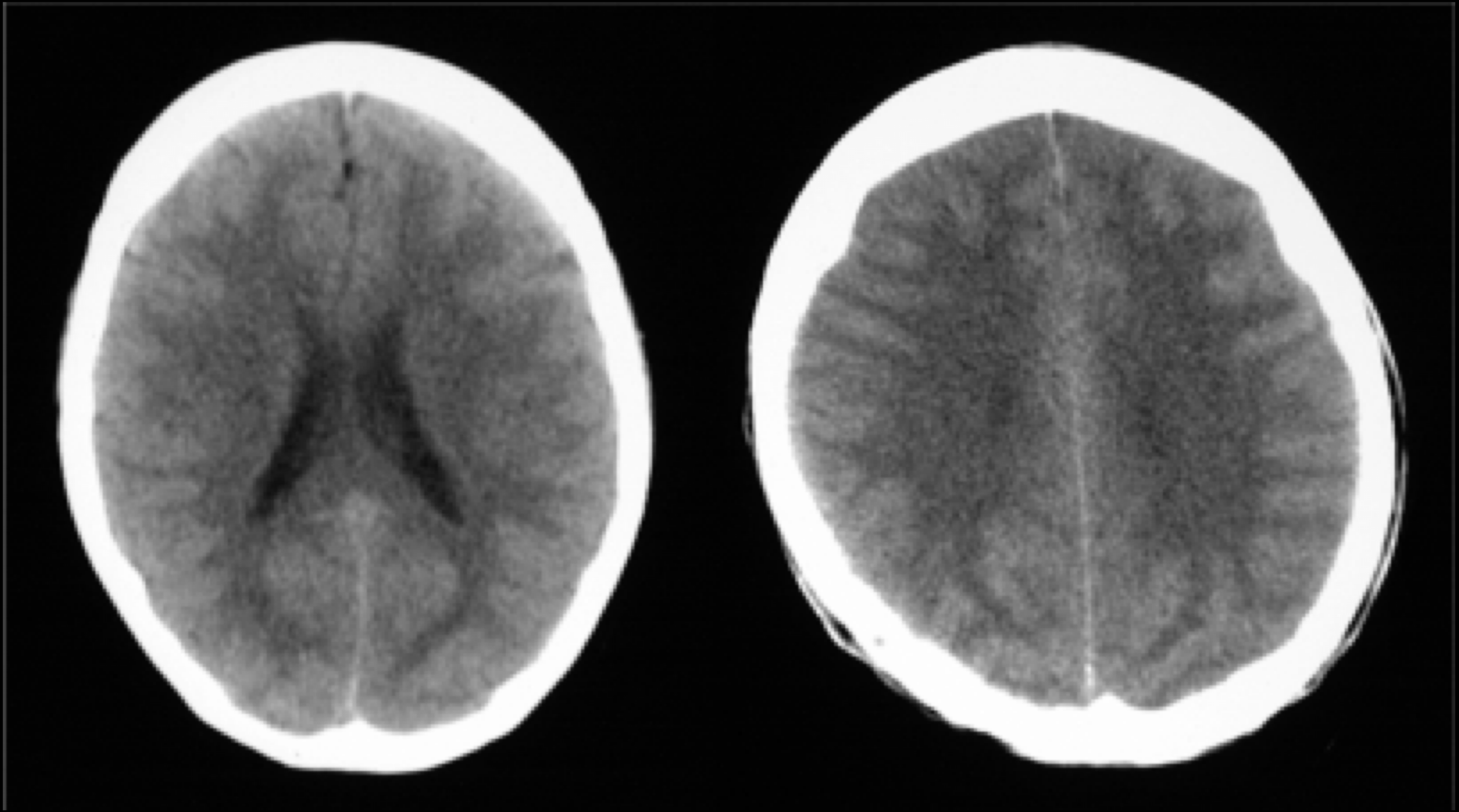
MCA infarct

Frank Gaillard rID: 21459

- Hemorrhage
  - Traumatic vs nontraumatic
  - SAH may be traumatic or associated with ruptured aneurysms
  - Parenchymal hemorrhage is more likely to be nontraumatic and secondary to underlying disease e.g. HTN, neoplasm, vascular anomaly
  - Hemorrhage on MRI can be complicated by the paramagnetic properties of blood breakdown products
  - Acute blood = hyperintense on T2
  - Chronic blood (3-7 days post infarct) = hyperintense on T1


T1 WI
T2 WI
T2* GRE
Hyperacute
Acute
Early
Subacute
Late
Subacute

- Mass Effect, Shift, Herniation
  - An enlarging mass, hemorrhage or edema can cause mass effect and lead to brain herniation
  - Repeat serial imaging may be necessary, especially in light of rapidly changing neurologic status
  - Imaging features of intracranial mass effect include
    - Sulcal effacement
    - Midline shift
    - Basal cistern effacement
    - Obstructive hydrocephalus
    - Herniation



Basal Cistern Effacement

Normal

Tight Swollen Brain

- Hydrocephalus
  - Communicating – excessive CSF production or decreased of arachnoid villi absorption
  - Obstructive – obstruction to CSF flow along the pathway between lateral ventricles and the fourth ventricular outlet

Surgical Intracranial Disorders

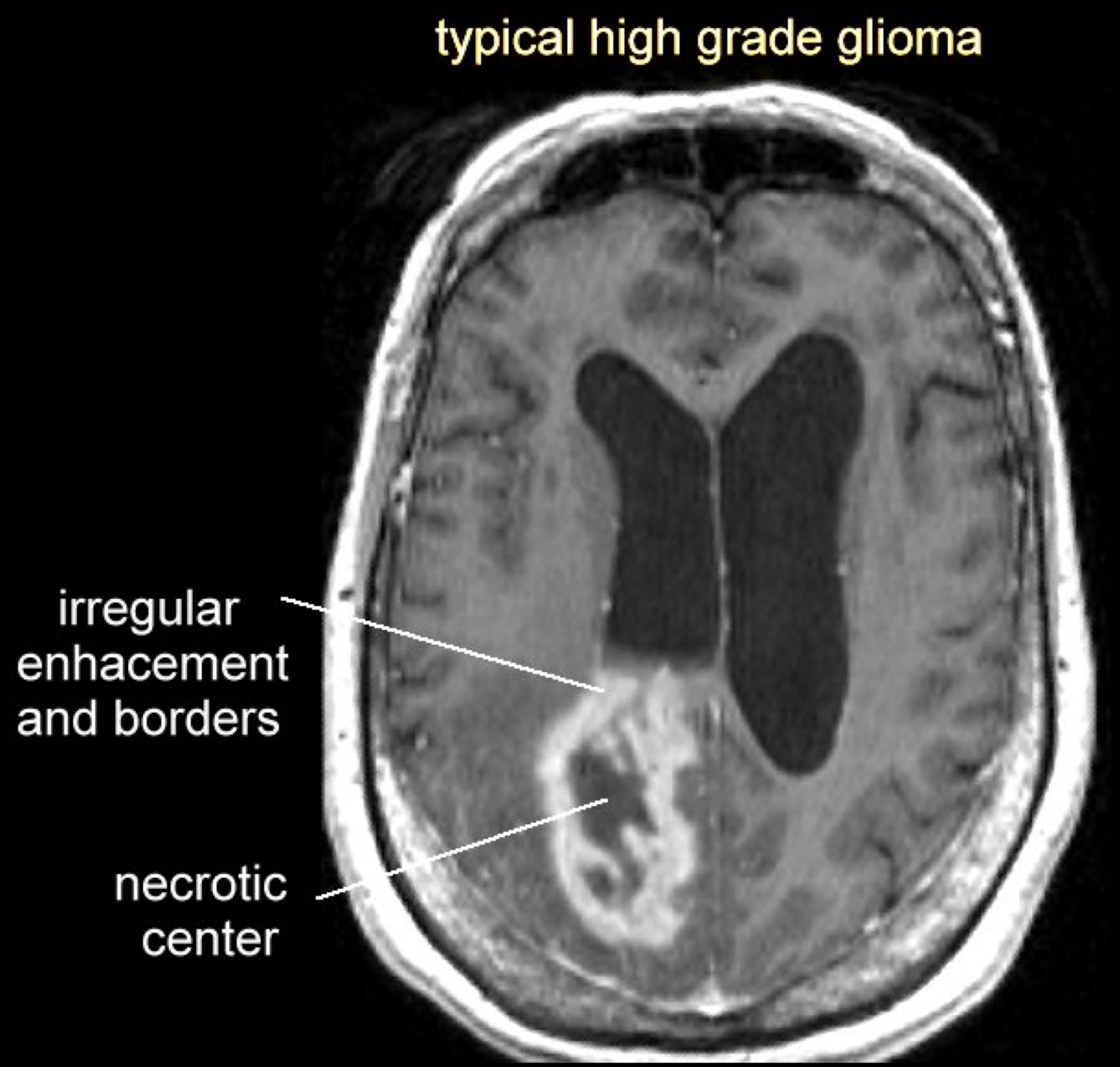
- TBI
- Neoplasm
- Aneurysms and Vascular Malformations
- Ischemic Stroke

- TBI
  - CT is fast, cost effective way to assess TBI and indication for emergent surgical intervention
  - Indications for CTH in acute trauma
    - GCS < 8
    - HA, vomiting, worsening consciousness
    - LOC, focal neurologic findings
    - Seizures
    - Penetrating skull injuries
  - MR is better for DAI, and deep gray matter injury

- TBIs are divided into extra-axial and intra-axial lesions
  - Extra-axial = skull fractures, epidural, subdural, subarachnoid and intraventricular hemorrhage
  - Intra-axial lesions include hemorrhagic and non-hemorrhagic contusions, parenchymal hematomas and DAI

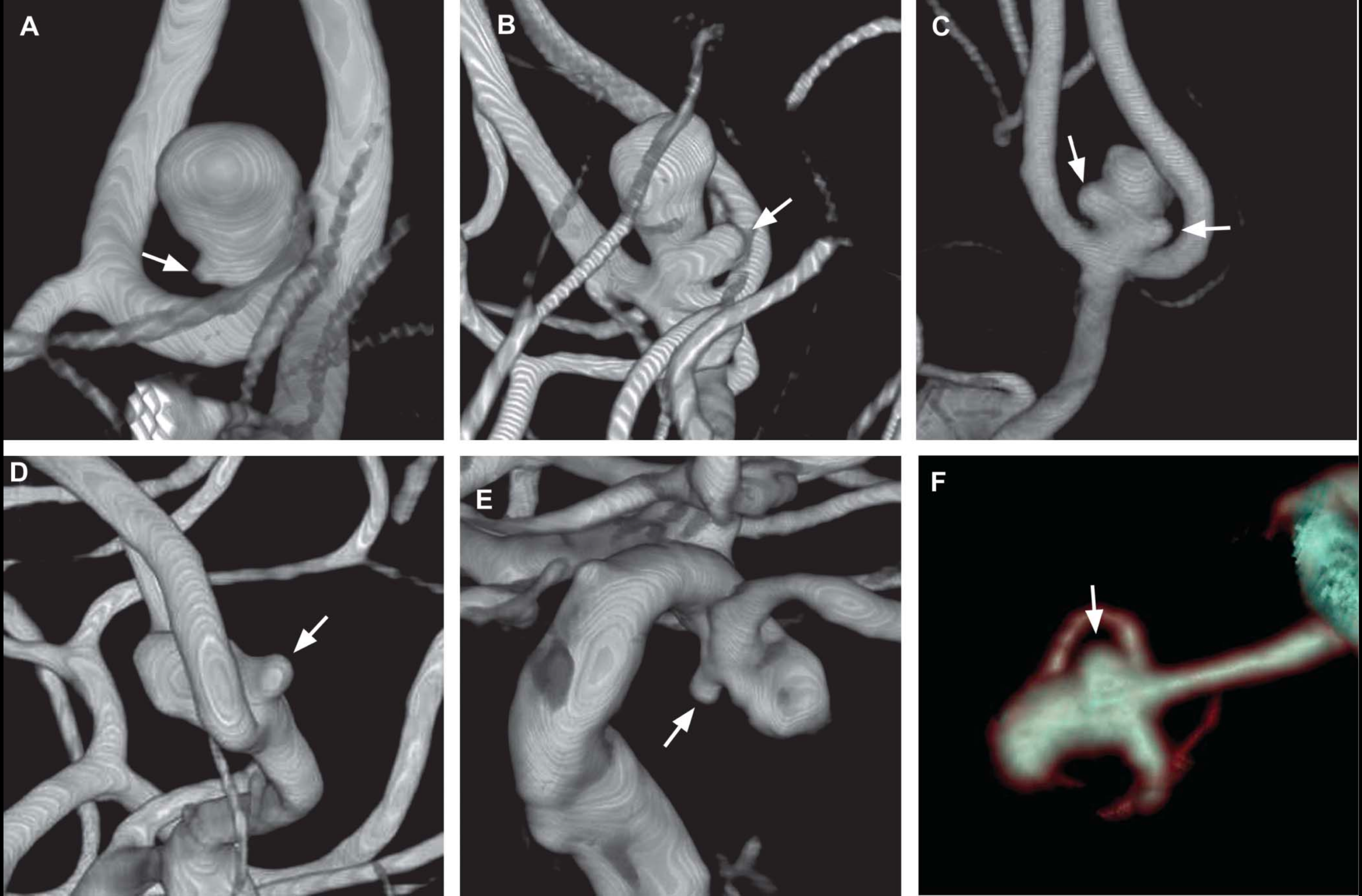
- Neoplasm
  - Imaging features:
    - Mass lesion
    - Hydrocephalus
    - CT hypodensity
    - MRI increased T2 signal reflects either edema or tumor infiltration
    - Hemorrhagic complication, cystic necrosis
  - Extra-axial vs Intra-axial
    - Extra = meningiomas, schwannomas
    - Intra = metastases (although can be extra too)

- CT used to assess for tumor complications: hemorrhage, mass effect, hydrocephalus
- MRI used for tumor diagnosis and classification, treatment planning and post treatment follow-up
- DWI used to differentiate between necrotic tumors (increased ADC) and abscesses (decreased ADC)
- Gliomas have a propensity for infiltration of adjacent brain parenchyma and migrate along white matter tracts

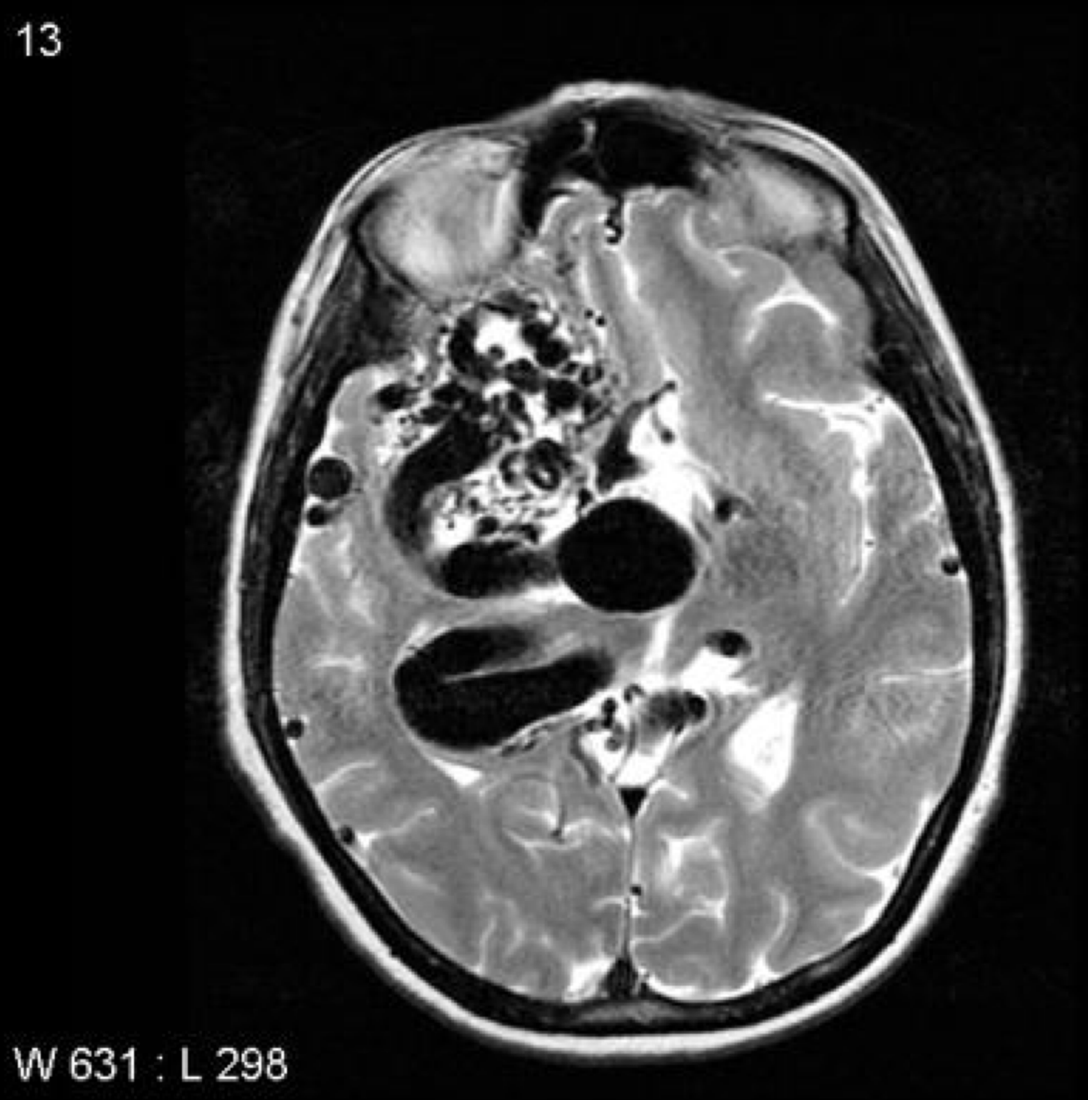

typical high grade glioma
irregular enhacement and borders
necrotic center

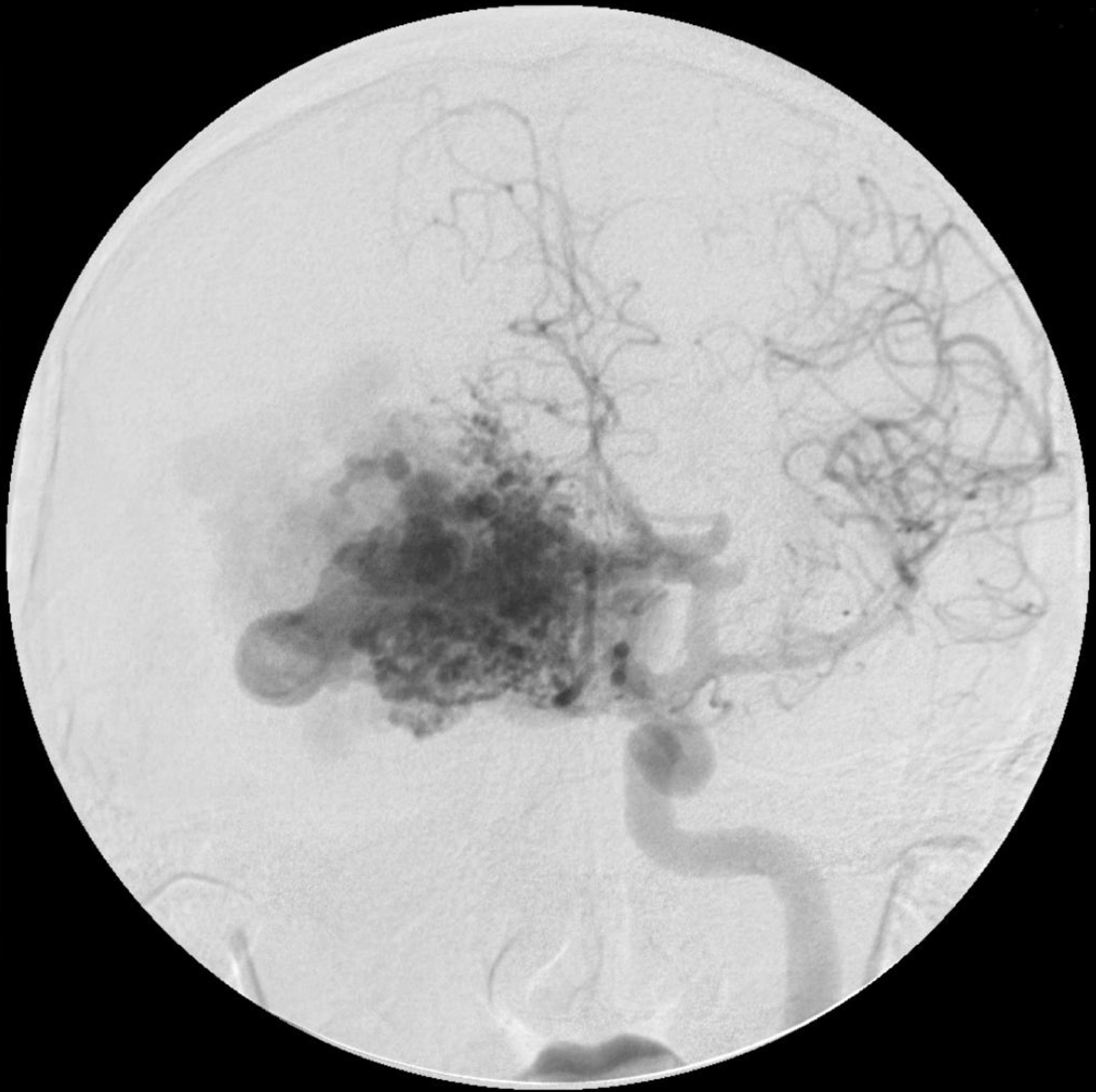
- Aneurysm and Vascular Malformation
  - 10% of patients presenting with intracranial hemorrhage have a vascular malformation
  - SAH = most morbid type of ICH
  - 5 types of vascular malformations:
    - Intracranial aneurysms
    - AVMs
    - Capillary telangiectasia
    - Developmental venous abnormalities
    - Cavernous malformations

- Intracranial Aneurysms
  - 4 types: berry/saccular, fusiform, septic/mycotic, pedicular
  - Berry = most common, leading cause of spontaneous SAH
  - Noncontrast CTH = primary screening tool
  - DSA = gold standard for aneurysm detection, also treatment modality as it permits coiling


A
B
C
D
E
F

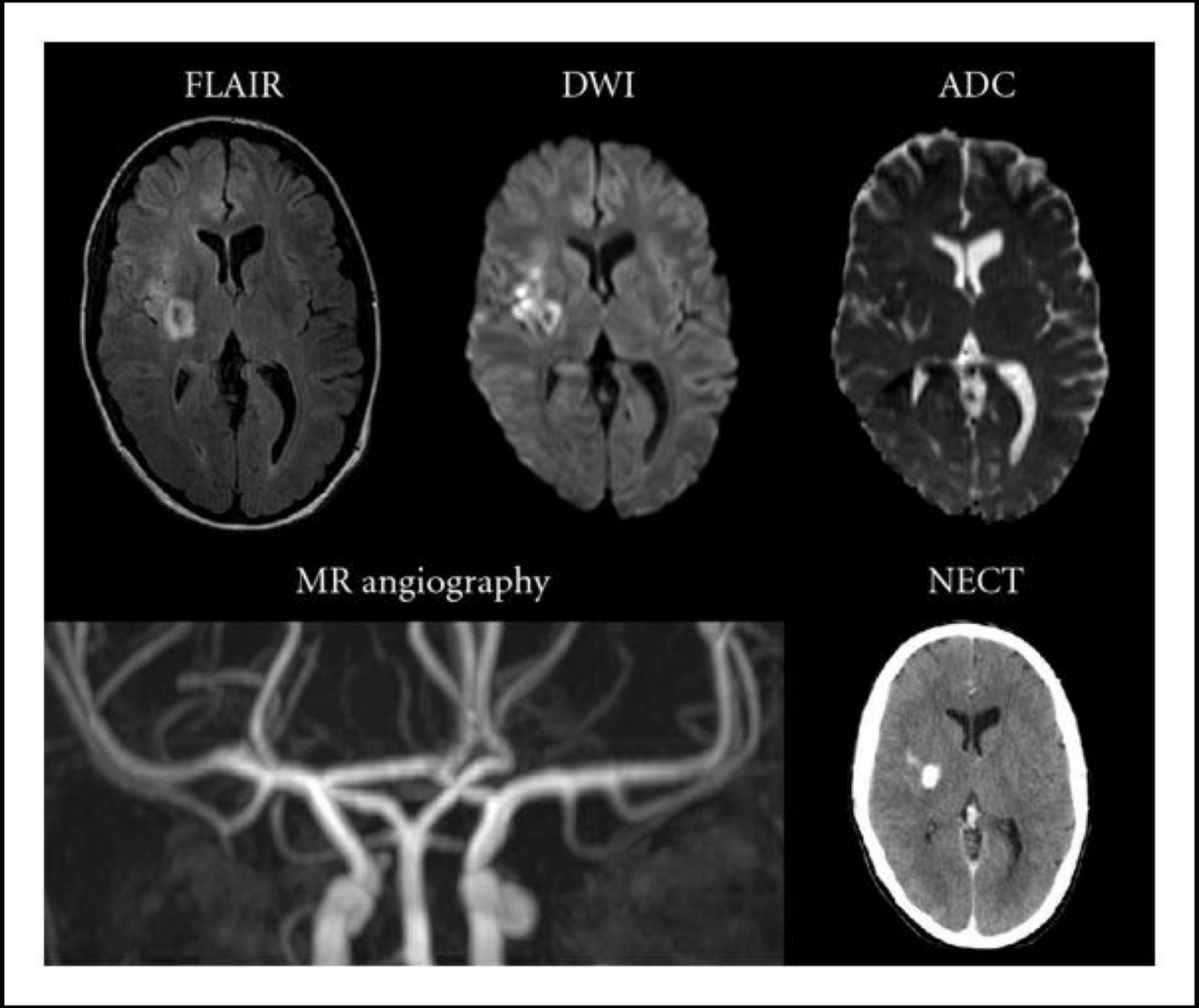
- AVMs
  - Vascular anomalies characterized by network of abnormal vessels with an abnormal connection or shunt between a feeding artery and a draining vein bypassing an intervening capillary bed
  - AV shunting with rapid flow
  - DSA = gold standard imaging technique


13
W 631 : L 298

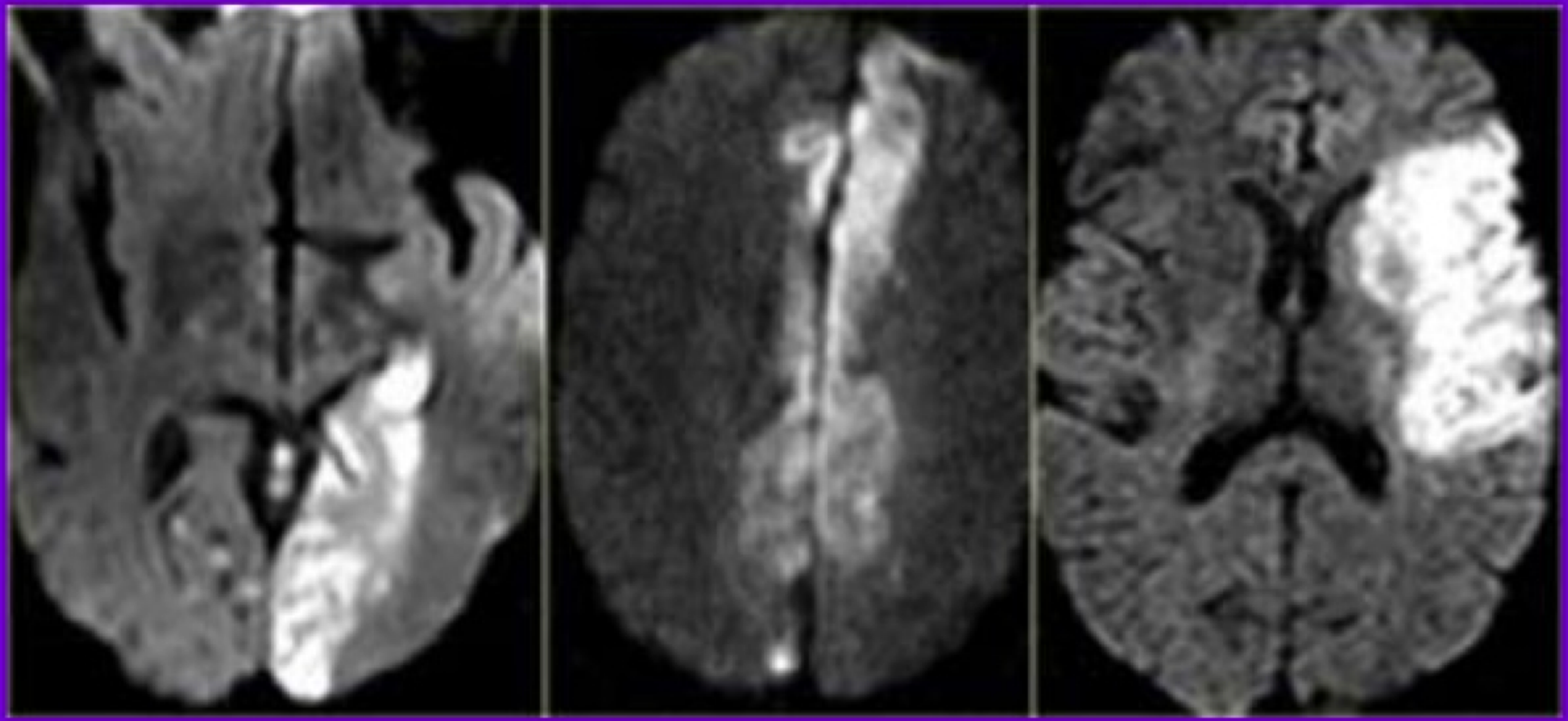


- Ischemic Stroke
  - Abrupt onset of focal neuro deficit due to disturbance in blood supply to a vascular territory
  - Noncon CTH = first line imaging study as it can detect early signs of stroke and rule out hemorrhage, contraindication for tPA
    - Loss of contrast between white and gray matter
    - Early mass effect
    - Presence of hyperdense artery
  - CTA allows quick and detailed evaluation of the intra and extracranial vasculature

- Multimodal MRI including DWI, PWI, and MRA affords similar results to CT based techniques
- DWI shows infarct core
- DWI-PWI mismatch represents the penumbra
- MRA allows assessment of vascular patency across the whole brain with high resolution structural imaging
- DWI is more sensitive for hyperacute ischemia


FLAIR
DWI
ADC
MR angiography
NECT

Diffusion Weighted Imaging (DWI)



DWI in posterior, anterior and middle cerebral infarction

THE END!!!!!!!