431

Radiology Team

Leader: Lama AlShwairikh

Sub-leader: Abdulaziz Almutair

Lecture 10: Anatomy and Investigations of The Nervous System

Done By: Maha Edrees

Revised By: Lama AlShwairikh

◆Important ◆Doctor's notes ◆Team's notes

We thank 430 Team for their helpful notes

Objectives:

Students at the end of the lecture will be able to:

- Identify the different radiological modalities used for evaluation of CNS
- Identify the indication and contraindication for each modality
- Identify the radiological anatomy of brain and its vasculatures in different modalities.

The Radiological Investigation Used For Evaluation of the Brain and Skull:

- **1.Plain x-ray Skull**
- **2.CT Scan**
- **3.MRI**
- **4.MRA (MR Angiography), MRV (MR Venography) & CTA (CT Angiography) [Evaluate vascular structure]**
- **5.Catheter angiogram (invasive)**
- **6.Duplex U/S of carotid arteries**
- **7.Ultrasound for neonatal brain**

-The newer imaging modalities have had a great impact on the diagnosis of diseases of the central nervous system.

-CT and MRI have become the standard investigations for disorders of the brain. (Most commonly used)

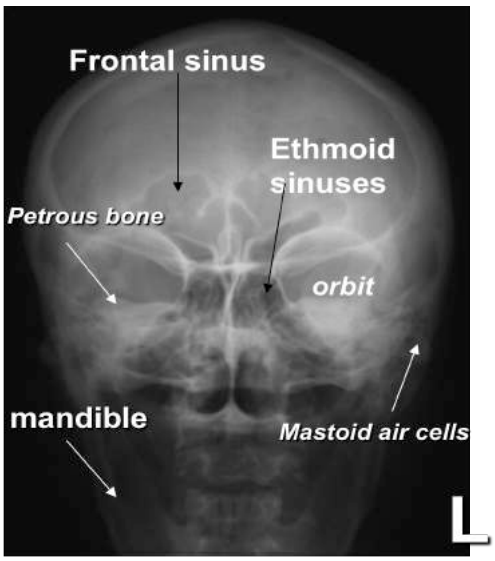
-Plain films are still the initial investigation for disorders of the bones of the skull – particularly fractures, but otherwise have *limited uses*.

Plain x-ray skull

Indications:

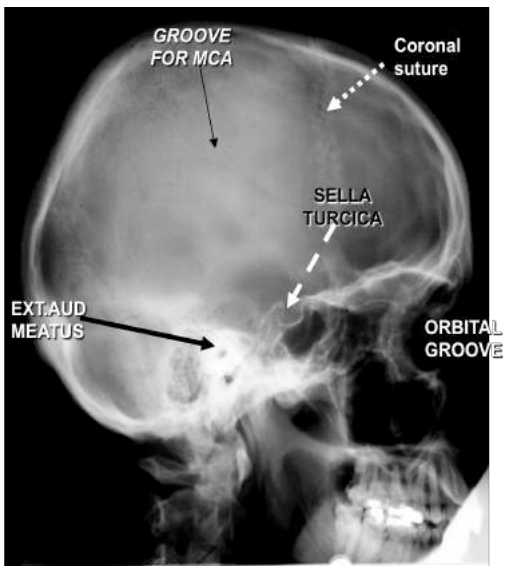
- **trauma. Only view skull fracture, can't exclude hemorrhage**
- **congenital anomalies of the skull shape**
- **calcification: normal or abnormal (vascular ,neoplasm)**
- **metastasis: lytic /sclerotic**
- **multiple myeloma**
- **metabolic disorders e.g. hyperthyroidism**

The role of x-ray is very limited because it can only view the skull. That's why in the exam I will not ask you about X-Ray but will emphasize more on CT and MRI.



SKULL PA VIEW

occipto-frontal view

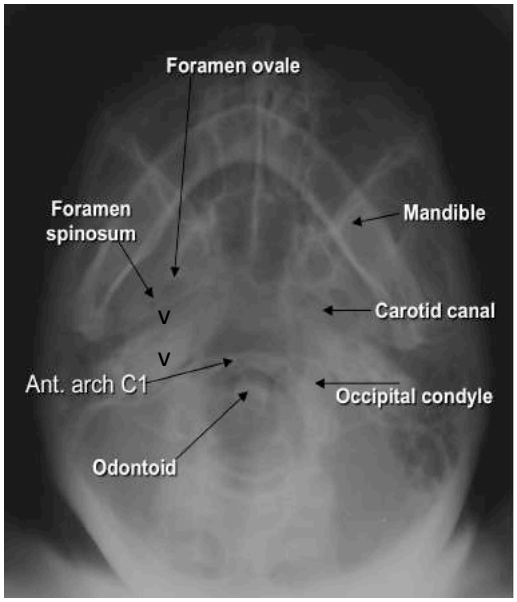


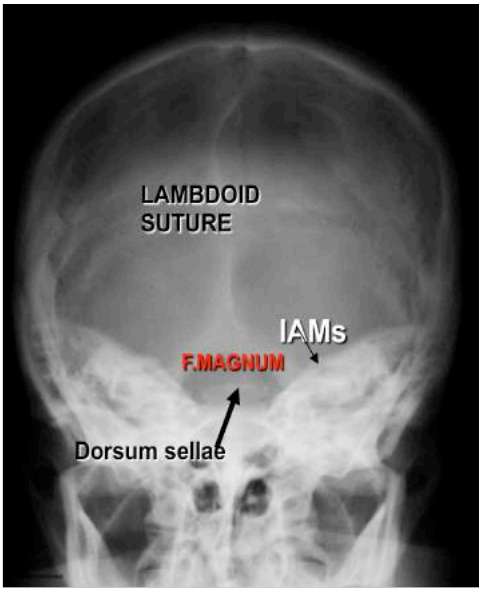
Skull X-RAY LAT. VIEW

lateral view

The two most important views in x-ray are the lateral view and the postero-anterior (occipto-frontal) view

The doctor didn't read the labels in those images





These two views are not routinely used. They are used to assess the base of the skull. It can be done in an easier way by using CT.

The doctor didn't read the labels in those images

submentovertical VIEW **TOWENS VIEW (AP)**

CT SCAN

- **Using ionizing radiation**
- **Spiral CT can perform a head scan in 10-15 minutes pre & post contrast scans.**
- **The scan itself can take as little as 10 seconds.**
- **Patient preparation: nil**
- **Type of the contrast medium: iodinated contrast (non ionic L.O.C.M) Low Osmolar Contrast Media**

Indications:

- **Trauma (to detect bone fracture, heamorrhage and its location (brain or out)**
- **detection of blood and the time of bleeding**
- **strokes (the first modality in emergency is CT but MRI is more sensitive)**
- **tumors**
- **infection**
- **Vascular disorders**

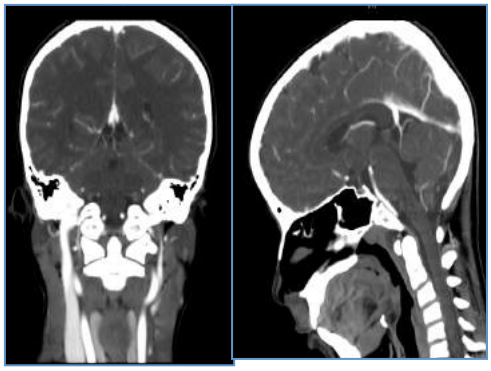
Contraindications:

- **Pregnancy (it's not an absolute contraindication, according to the clinical condition, if there are no other modalities available we can use CT on a pregnant woman while taking the necessary precaution.)**

Disadvantages:

- Using ionizing radiation

-The axial plane is the routine projection but it is sometimes possible to obtain direct coronal scans.
-The window settings are selected for the brain, but may be altered to show the bones.
-Computer reconstructions can in selected circumstances be made from the axial sections which then provide images in coronal or sagittal planes.
(While in MRI we can obtain all 3 plain fields without reconstruction.)



Coronal reconstruction

Sagittal reconstruction

NORMAL CT BRAIN

- **CSF is seen as water density (black) within ventricular system and subarachnoid space.**
- **Grey matter is differentiated from white matter (white matter is relatively darker than grey matter).**
- **The falx is denser than the brain.**
- **Large arteries and venous sinuses can be recognized when opacified by contrast medium.**
- **Posterior fossa may be obscured by artifacts from overlying temporal and occipital bone.**

(Lower cuts "base of skull"

A. Orbit

B. Sphenoid Sinus

C. Temporal Lobe

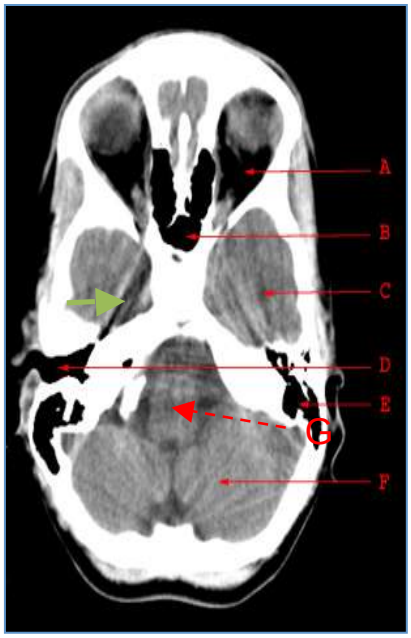
D.Externa Auditory Canal

E. Mastoid Air Cells

F. Cerebellar Hemisphere

G. BRAINSTEM

H.Artifact



What is Artifact?

(خطأ و تداخل بالصور) any dense bone next to soft tissue in CT can mistake it as an artifcat, Especially in narrow places eg: (posterior fossa) , the problem that if there is an infraction , it will be masked and hidden by the artifact , and that will minimize the sensitivity of CT in assessment of infarction as compared to MRI SO that explain why MRI is better in assessment of stroke than CT. MRI is better at evaluating the brainstem and cerebellum.

The doctor said there is no time to mention all the labels during the lecture; you can review them at home

(higher cuts are better visualized in CT)

A. Frontal Lobe (anterior cranial fossa)

B. Frontal Bone (Superior Surface of Orbital Part)

C. Dorsum Sellae

D. Basilar Artery

E. Temporal Lobe (middle cranial fossa)

F. Mastoid Air Cells

G. Cerebellar Hemisphere

H. Pons

i. 4rth ventricle

A. Falx Cerebri

B. Frontal Lobe

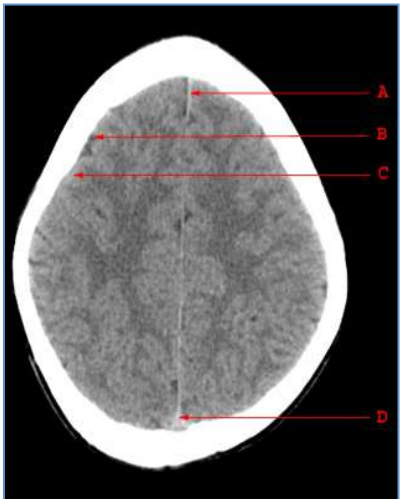
C. Body of the Lateral Ventricle

D. Splenium of the Corpus Callosum

E. Parietal Lobe

F. Occipital Lobe

G. Superior Sagittal Sinus

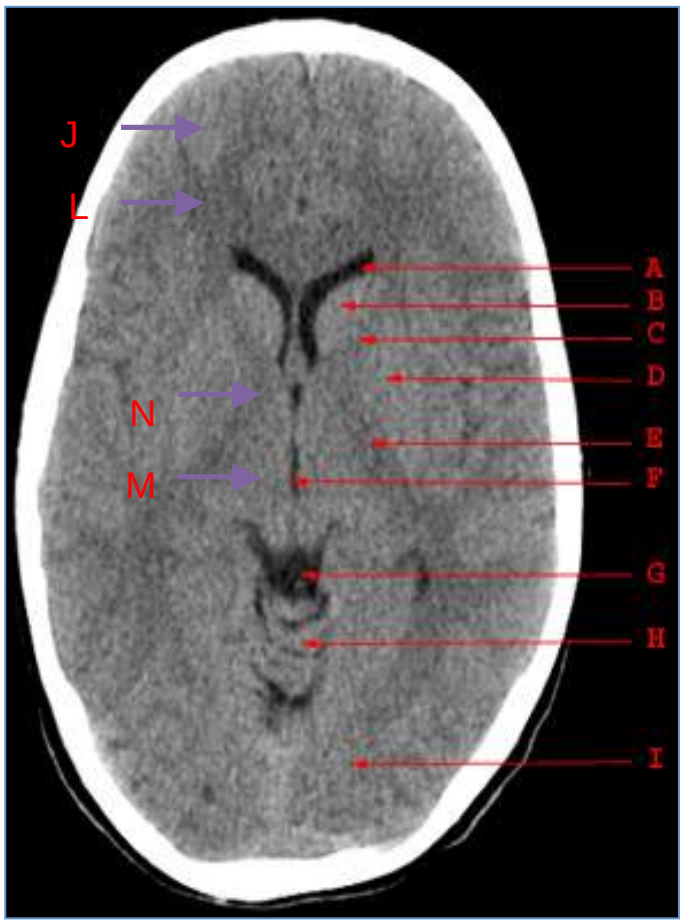


A. Falx Cerebri

B. Sulcus

C. Gyrus

D. Superior Sagittal Sinus



"Higher cut. Most important cut in case of stroke and because it illustrates the Basel ganglia and the internal capsule."

A. Anterior Horn of the Lateral Ventricle

B. Caudate Nucleus

C. Anterior Limb of the Internal Capsule "darker" (common place for infraction)

D. Putamen and Globus Pallidus

E. Posterior Limb of the Internal Capsule

F. Third Ventricle "very dark"

G. Quadrigeminal Plate Cistern

H. Cerebellar Vermis

I. Occipital Lobe

J. Gray matter "lighter"

L. Wight matter "darker"

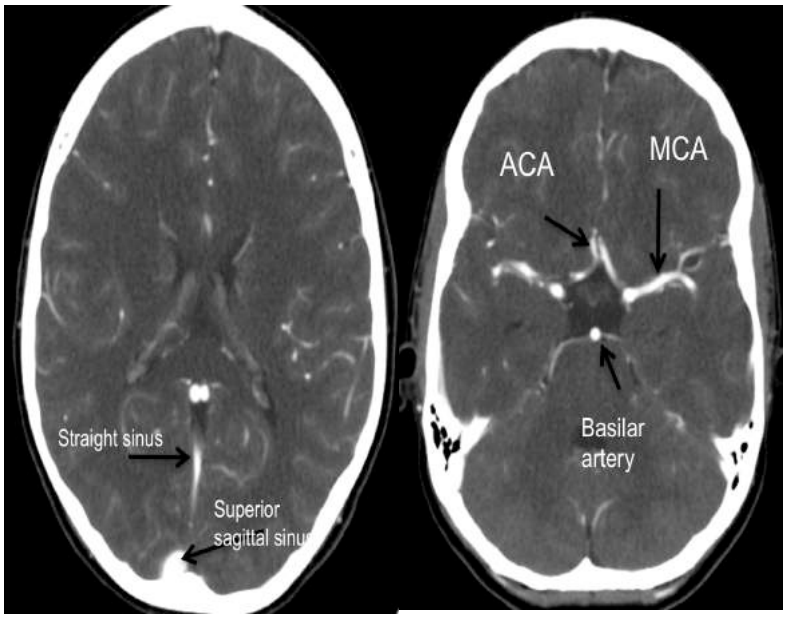
M. Thalamus

N. Genu of internal capsule

Contrast enhanced CT:

IV injection of contrast medium is often given because the abnormality not seen in pre contrast scans may be rendered visible following contrast enhancement (consequence of breakdown of blood brain barrier allowing contrast to enter the lesion particularly in neoplasm, infection, inflammation and certain stage of ischemia).

Also it is helpful in demonstrating blood (evaluation of vascular structure of brain. The contrast doesn't go to the brain parenchyma due to BBB "blood brain barrier" except if it's injured or if there's a lesion e.g. abscess, tumor, infection.)



Contrast enhanced CT

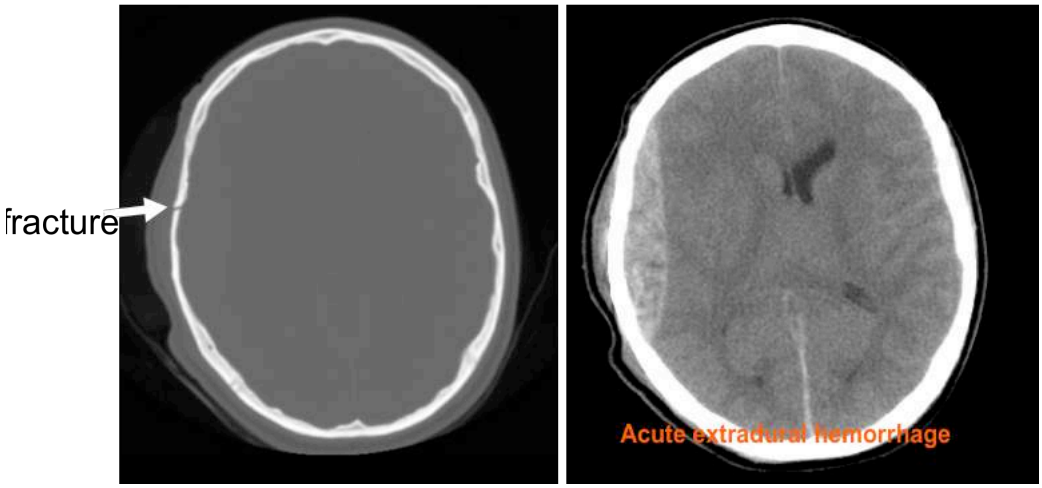
MRI can give an axial, coronal and sagittal view directly.

In CT, sagittal view is a reconstructed image

In CT:
Gray matter: light
White matter: dark
Anterior Limb of the Internal Capsule: darker
Ventricles with fluid (CSF): very dark

Bone window

Brain window

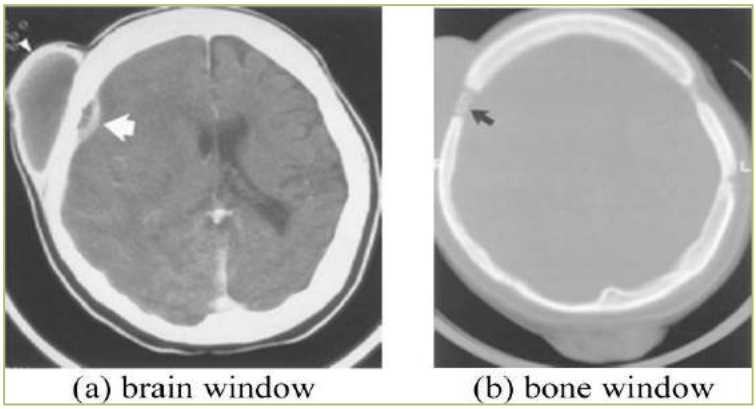


The window settings are selected for the brain, but may be altered to shows the bones (we can choose the structure to be assessed). We can't see the fracture in brain window but we can assess the brain parenchyma unlike the bone window where we can only assess the bone and therefore, see the fracture.

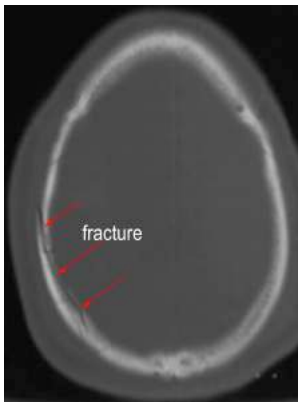
MCQ: you should understand the difference between the two windows and be able to identify them in images!

Bone window →skull"bone"

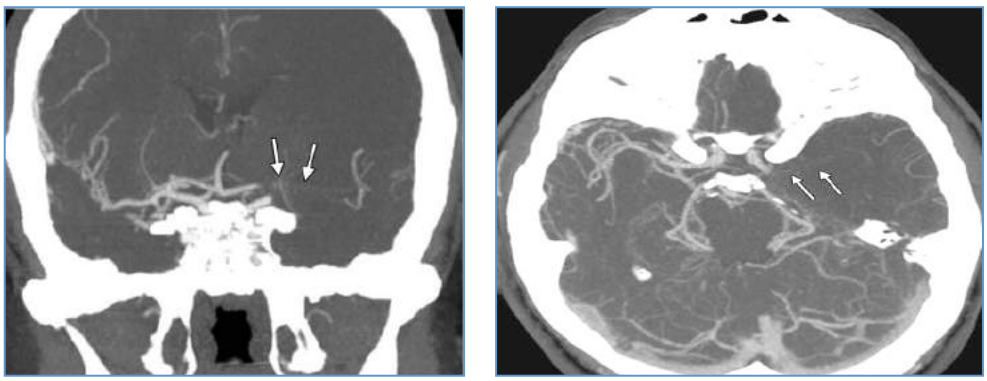
Brain window → soft tissue and brain parenchyma.



Bone window



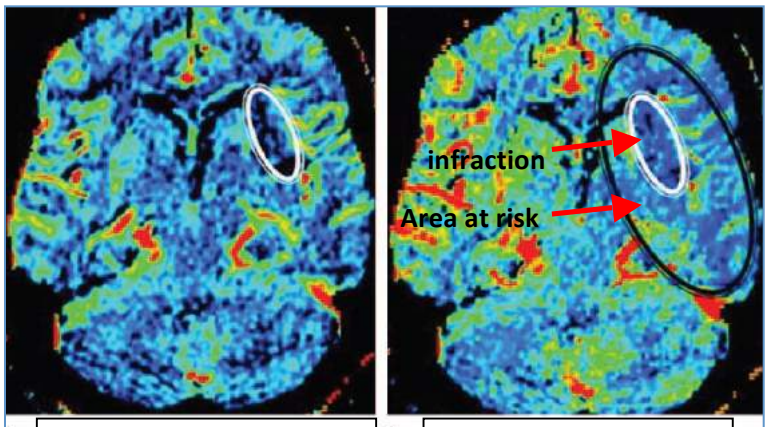
CTA "CT Angiography"



CT angiography is helpful in diagnosis of vascular diseases and abnormalities such as stenosis, occlusion or vascular malformation. It is used to assess the vasculature of the brain. Furthermore, it cannot be done without IV contrast with cretin time unlike MRI.

Occlusion of left middle cerebral artery

CT PERFUSION



a. **Cerebral blood volume**

b. **Cerebral blood flow**

In acute stroke, very early cranial CT may be normal. Perfusion CT shows great promise in refining the selection of patients suitable for thrombolysis, as it can accurately determine infarct core from potentially salvageable ischemic penumbra (salvage area at risk "see red arrow"). Some cerebral tumors are associated with angiogenesis and a breakdown of the blood-brain barrier. Angiogenesis can be detected as an increase in flow and volume parameters, and blood-brain barrier breakdown can be quantified as contrast accumulates in the interstitial space. Such aggressive features can distinguish malignant from benign tumors when standard imaging may not.

MRI

No ionizing radiation

Patient preparation: Nil, unless fasting for general anesthesia.

Contrast medium: Gadolinium (safer than the contrast used in CT-Scan)

Indications: (same indication as CT but different order)

Same indications as CT

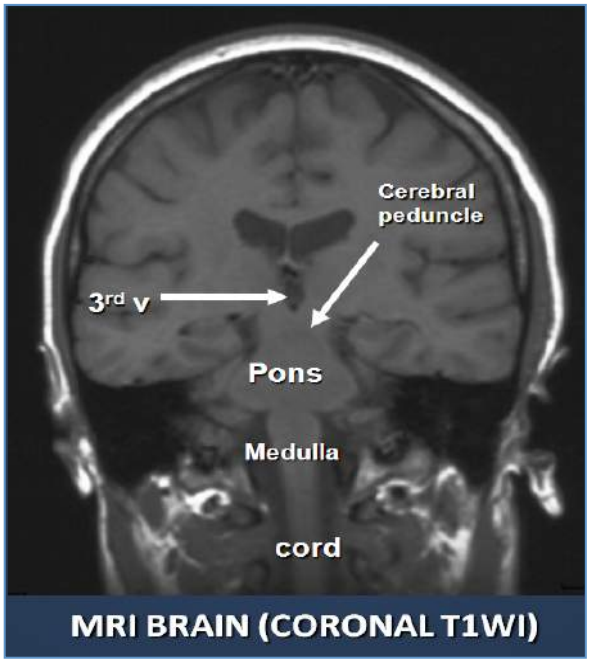
- Strokes (more sensitive than CT but we use CT in emergencies because it's faster)
- tumors
- infection
- Vascular disorders
- white matter disease (only MRI not used in CT)
- Some cases of trauma (Not acute trauma. MRI Can be helpful in these cases but it's not used as a first line.)

Contraindications (not absolute)

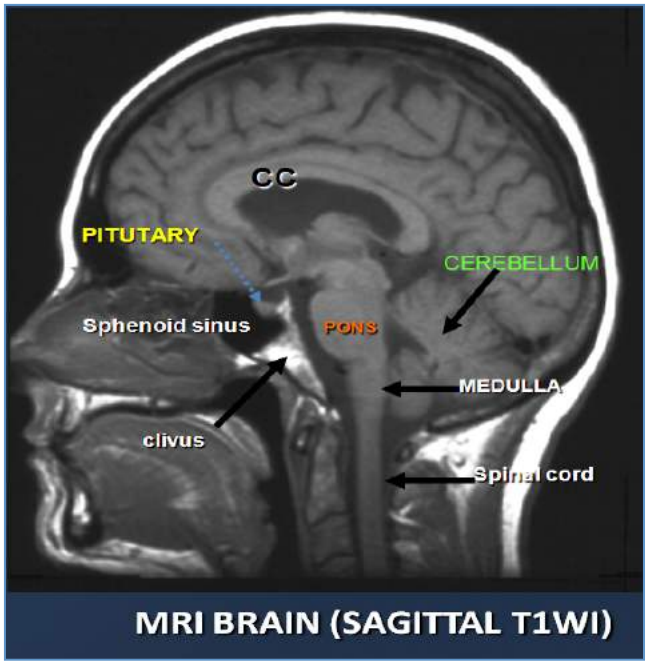
- Cardiac pacemaker (it used to be considered absolute because it was made of pure iron. Nowadays it's made of titanium)
- cochlear implants (could be considered as absolute)
- ocular prostheses
- intraocular ferrous foreign body
- neurostimulators
- pregnancy (1st trimester)
- claustrophobia

MRI is a multiplanar technique (can produce images in Sagittal, axial and coronal planes) which is useful for assessment of extent of brain tumors and for better visualization of structures of posterior fossa and cranio-cervical junction. (MRI has good contrast resolution, better than CT)
MRI is a multisequential technique (can create images in T1WI, T2WI, FLAIR, gradient and other sequences).
It is possible to recognize flowing blood and therefore large arteries and veins stand out clearly without the need for contrast medium injection. MRI is deficient at detecting bona and calcification.

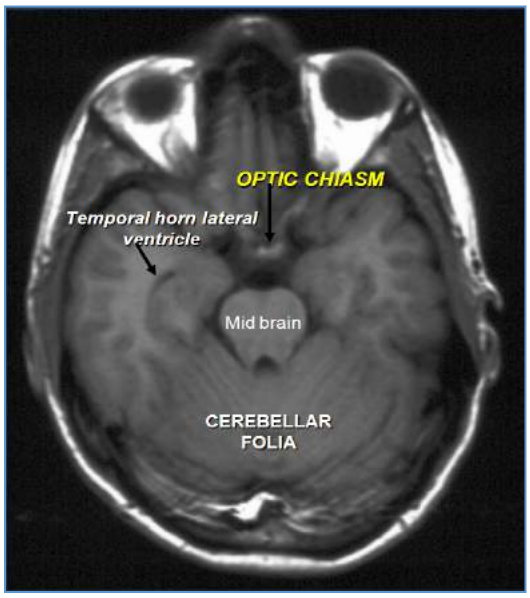
CT is better than MRI in: detecting calcifications and visualizing bones of skull.
MRI is better than CT in: contrast resolution. Also, it's a muliplanar and multisquential technique.
It has better tissue differentiation e.g. the difference between gray and white matter is clearer in MRI scan.

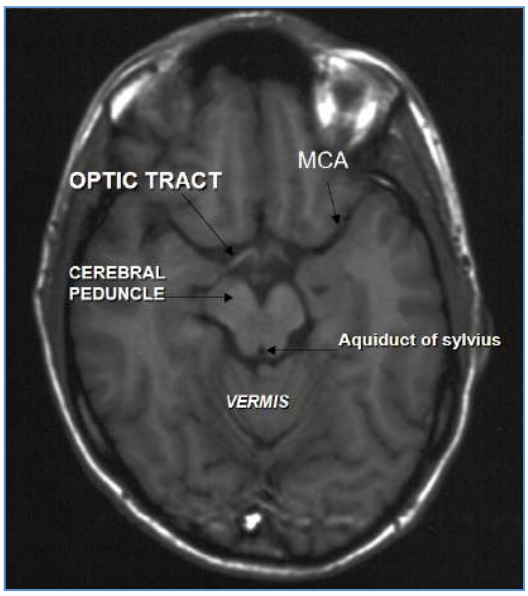


MRI BRAIN (CORONAL T1WI)



MRI BRAIN (SAGITTAL T1WI)

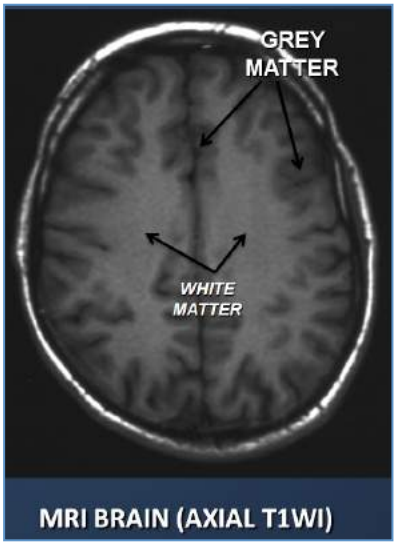




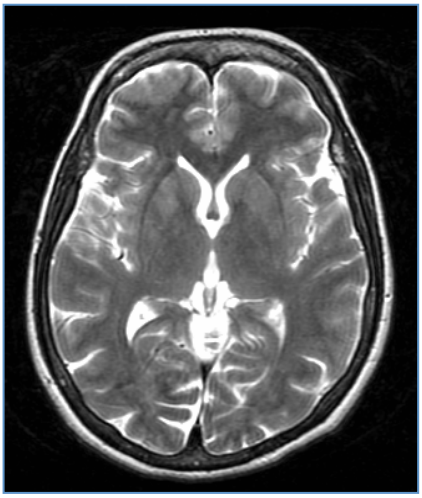
-Note that you can't see bone in MRI very clearly (dark area) unlike CT.

-also in CT (especially in the base) we can see artifacts while in MRI it's very clear. Therefore, any small lesion in cerebellum or brain stem can be easily detected.

MRI BRAIN (AXIAL T1WI)

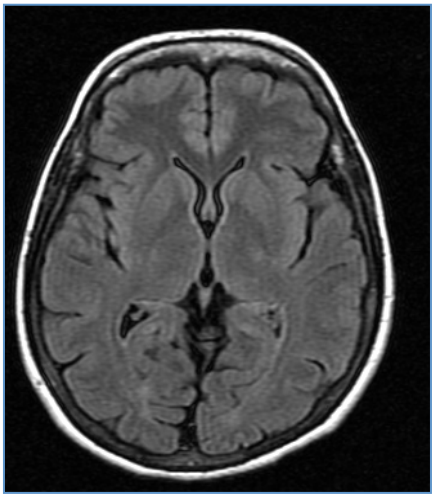


T1WI= T1 Weighted Image



T2WI

T2WI= T2 Weighted Image



FLAIR

FLAIE = fluid-attenuated inversion recovery

MCQ: You have to be able to identify the different sequences of MRI and differentiate between them and CT.

The Characteristic signal intensity of brain structures in different MRI sequences:

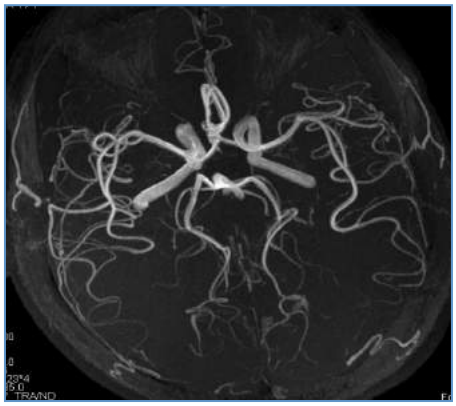
	Grey matter	White matter	CSF
T1WI	grey	light	dark
T2WI	light	dark	white
FLAIR	light	dark	dark

-When you see white CSF, it is always **T2W1**

-You can notice the white matter (inside) darker than the gray matter (periphery) in **FLAIR**
(Gray M=white White M=black)

-and the opposite in **T1WI** (gray matter (periphery) darker than the (white) matter (inside))
T1WI
(Gray M= black White M= white)

MR Angiography (MRA)



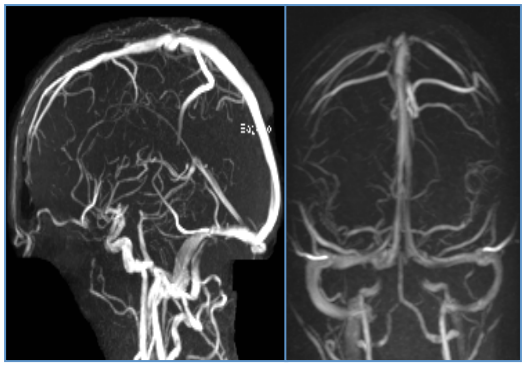
MRA: (assessment of the arteries)

--Can be done without injection of contrast medium using time of flight technique. (MRA in brain can be done without contrast but MRA in Aorta **can't** be done without contrast)

--Can be used to assess intra and extra cranial arteries for any vascular abnormalities such as stenosis, occlusion or vascular malformation.

MCQ: You have to be able to identify and differentiate between MRA and MRV images. They'll ask about the study type

MR Venography



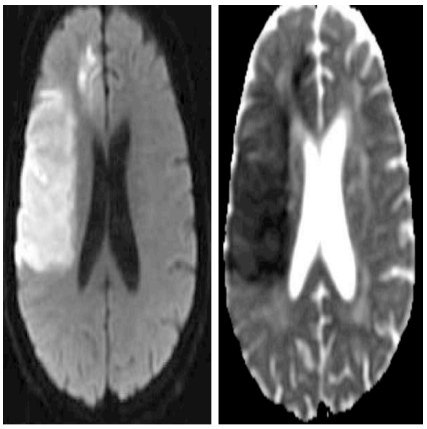
MRV: (assessment of the veins)

-Can be done either with or without injection of contrast medium.

-Assess venous dural sinuses superficial and deep venous system.

-Can confirm presence of venous thrombosis

MR Diffusion



DWI ADC map

MR diffusion:

- Very helpful in assessment/(detection) of:
- Early brain infarction.
- Brain abscess. (and infection)
- Certain types of brain tumor. (very helpful in grading of the tumors)

MRI is more sensitive than CT-Scan in detection of infraction

Q: Which sequence is more sensitive in detection of infraction?

A: MRI Diffusion>FLAIR>T2WI>T1WI

MRI diffusion is the est, it can detect infraction as early as 1 or 2 hours.

Q: what is the best modality to assess stoke or infarction ?

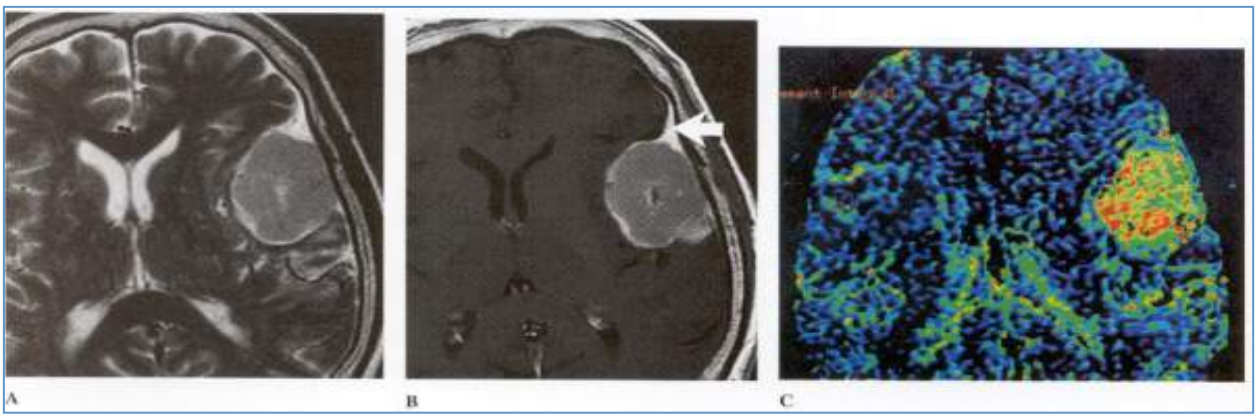
A:MRI

MCQ: You should know the order of the best modality to use in case of infraction (stroke…) based on the ***sensitivity*** because it's going to be "choose the best answer" in the exam. **MRI Diffusion>FLAIR>T2WI>T1WI>CT**

But in case of an ***emergancy*** we use **CT** because MRI is going to take more time.

MRI

Meningioma:

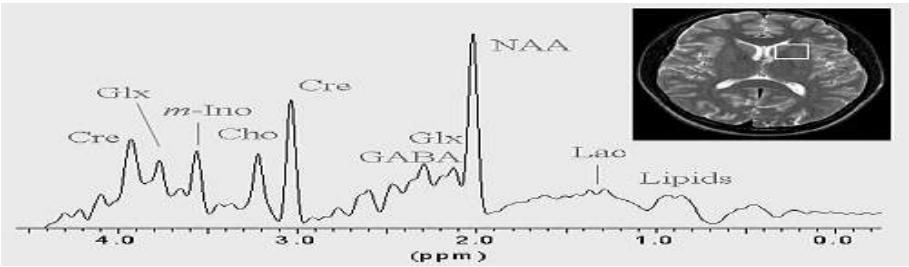


T2 Contrasted T1 Perfusion-Weighted

MR perfusion is also helpful in tumor grading. Highly vascular tumors would indicate high grade tumors except in cretin benign tumors e.g. hemangioblastoma and meningioma →benign character but very high perfusion.

MR Spectroscopy

Unlike MRI, the technique of MRS does not generally produce images, instead creating spectra (curve) (see figure). Each peak in the spectrum arises from different brain metabolite (NAA, N-acetylaspartate; Cre, Creatine; Cho, Choline; myoI, myo-Inositol; Lac, lactate; Glx, Glutamate and Glutamine; GABA, gamma amino butyric acid). The height of each peak is an indication of metabolite concentrations. The NAA peak arises from the neurons in the brain. Loss of this metabolite indicates damage or loss of neurons. **(MRS is used to assess different metabolites in brain)**

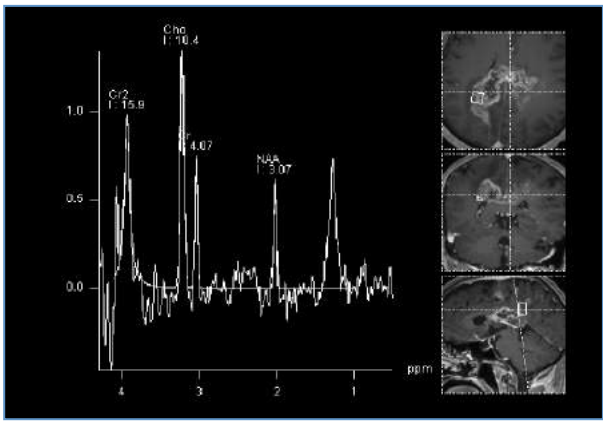


MR Spectroscopy

Very helpful in:

- **Differentiating neoplastic from non neoplastic processes.**
- **Differentiating benign from malignant tumors.**
- **Determination of certain types of tumors.**
- **Assessment of white matter diseases**
- **Assessment of neurodegeneartive diseases**

MR Spectroscopy in GBM



CEREBRAL ANGIOGRAM

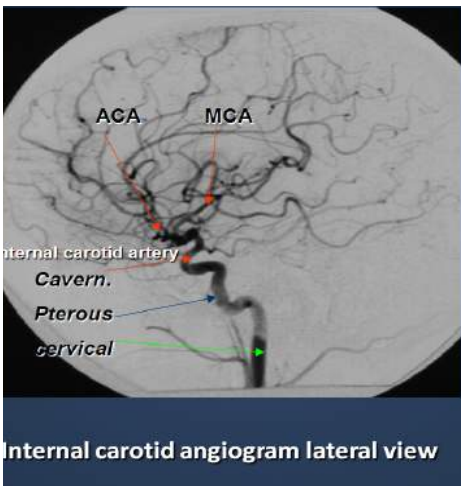
It is **the** gold standard **technique** for **assessment** of intra and extra cranial vessels. (**Nowadays,** it is not used in diagnosis anymore because it an **invasive** procedure. **But it's used for management and can be used as a diagnostic tool for difficult cases.)**

It can demonstrate different vascular diseases (stenosis, occlusion, vascular malformation and blood supply of brain tumors.

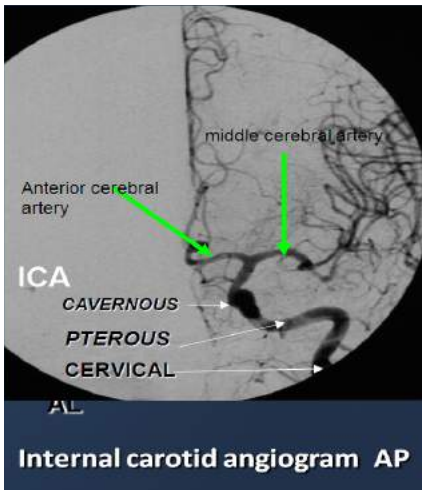
It is an **invasive** technique. (Timing is important in this procedure in order to choose arterial or venous phase)

Recently its main role for intervention purposes such as **treatment** of vascular malformaion (aneurysm/arterovenous malformation) or pre operative embolization of vascular supply of tumor.

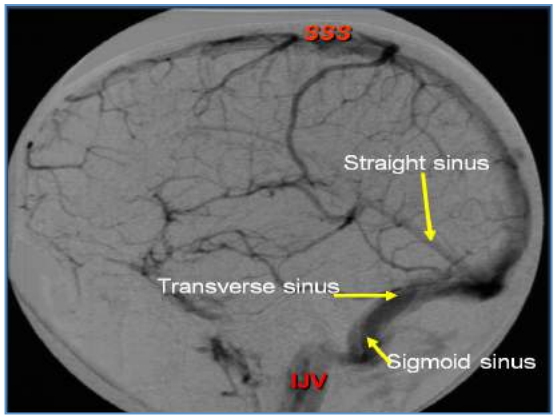
The doctor didn't mention these labels



Internal carotid angiogram lateral view



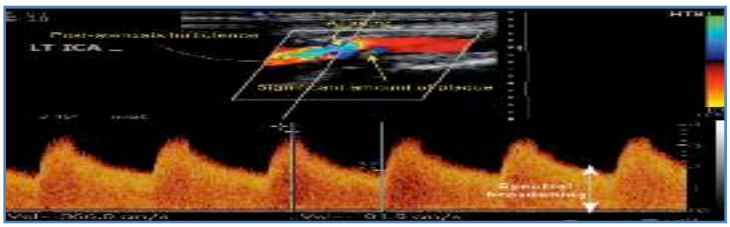
Internal carotid angiogram AP



VENOUS PHASE CEREBRAL ANGIOGRAM

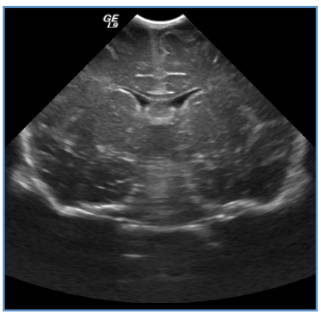
CAROTID DOPPLER

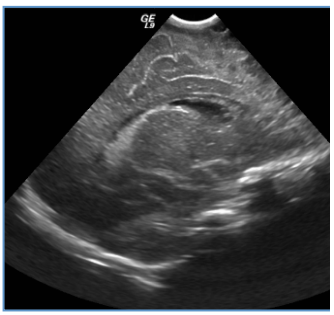
It's the easiest way to assess the vessels supplying the brain to see if there's any occlusion or narrowing to the vessels by using Doppler ultrasound.



ULTRASOUND NEONATAL BRAIN

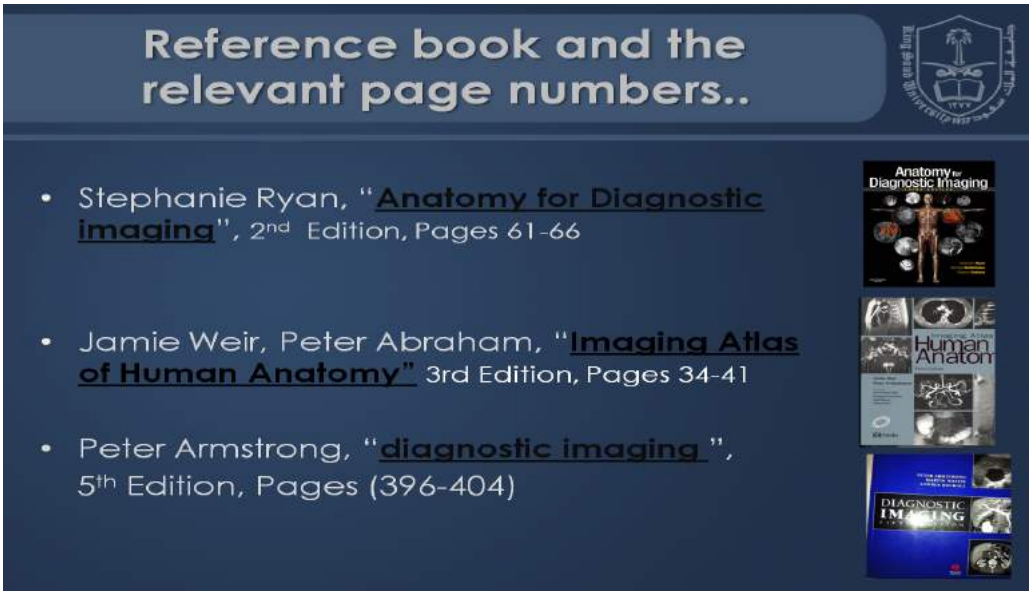
- It is a simple and easy way to scan the head of neonates and young babies.
- Not using ionizing radiation
- Scanning is best done through an **open fontanelle**.
- Little discomfort to the baby.
- Readily carried out even on ill babies in intensive care units.
- It has proved particular useful in detecting ventricular dilatation **(hydrocephalus)**, intracerebral hemorrhage and congenital abnormality of the brain


CORONAL


SAGITTAL

MCQ: what is the easiest way to examine a neonate suspected to have hydrocephalus? **Ultrasound**

Summary



The Radiological Investigation Used For Evaluation of the Brain and Skull:

- **1.Plain x-ray Skull**
- **2.CT Scan**
- **3.MRI**
- **4.MRA , MRV (no contrast used) & CTA (with contrast)**
- **5.Catheter angiogram (invasive)**
- **6.Duplex U/S of carotid arteries**
- **7.Ultrasound for neonatal brain**

Ct-scan → contrast medium: iodinated contrast (non ionic L.O.C.M)
Mri → Contrast medium: Gadolinium

The best modality to use based on the ***sensitivity*** in case of fraction: **MRI Diffusion>FLAIR>T2WI>T1WI>CT**
The best modality to use based on ***emergency*** is **CT**

MRA: (assessment of the arteries)

Can be done without injection of contrast medium using time of flight technique

MRV: (assessment of the veins)

Can be done either with or without injection of contrast medium.

MR diffusion: Very helpful in detection of Early brain infarction.

MRS: is used to assess different metabolites in brain

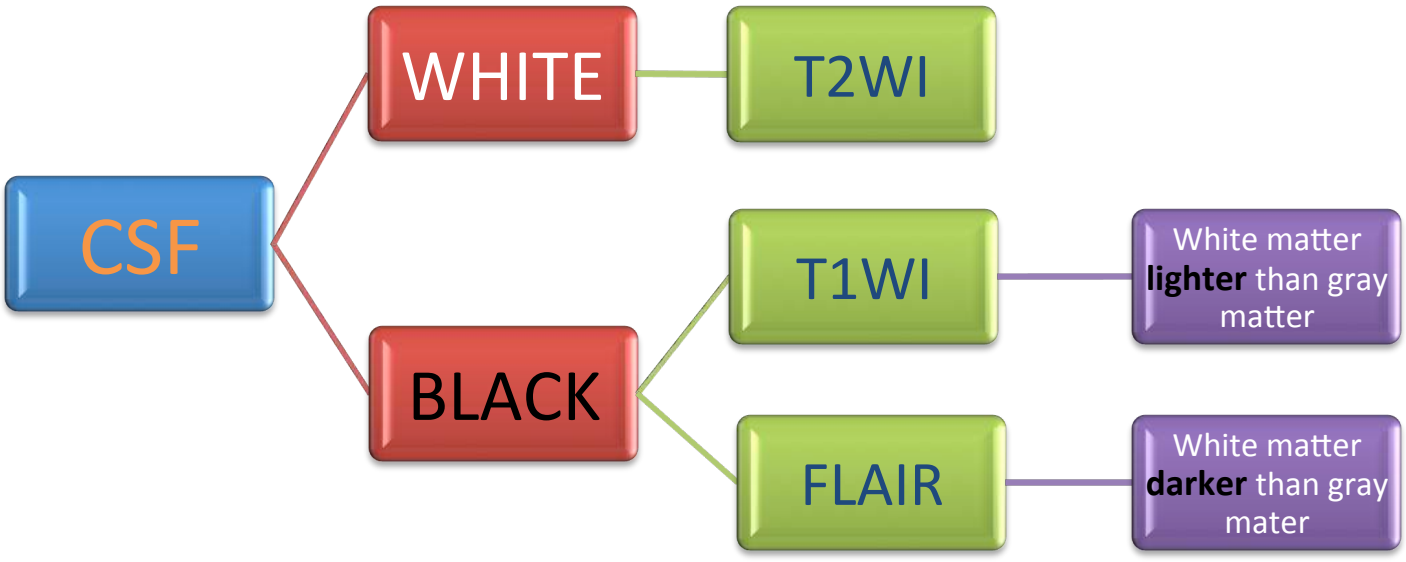
Cerebral Angiogram: is used for **management** and can be used as a diagnostic tool for difficult cases.

Carotid dupplor: easiest way to assess the vessels supplying the brain to see if there's any occlusion or narrowing

ULTRASOUND NEONATAL BRAIN: scaning is done through an open fontanelle and it's useful in detecting mainly ventricular dilatation (hydrocephalus), intracerebral hemorrhage and congenital abnormality of the brain

x-ray (limited role)	CT (ionizing radiation)		MRI	
indications	indications	contraindications	indications	contraindications
trauma	Trauma to detect fracture ..	pregnancy	Strokes(more sensitive than CT)	Cardiac pacemaker
congenital	detection of blood			cochlear implants
calcification: normal or abnormal (vascular ,neoplasm)	strokes (1ST In emergancies_)		tumors	ocular prostheses
metastasis: lytic /sclerotic	tumors		infection	intraocular ferrous foreign body
multiple myeloma	infection		Vascular disorders	neurostimulators
metabolic disorders	Vascular disorders		white matter disease	pregnancy (1st trimester)
			Some cases of trauma	claustrophobia

To differentiate between different MRI sequences:

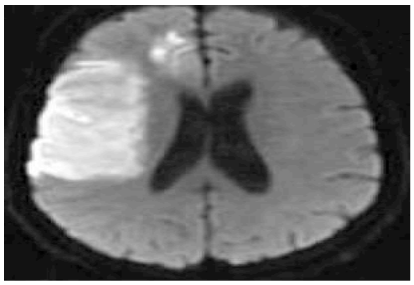


Questions:

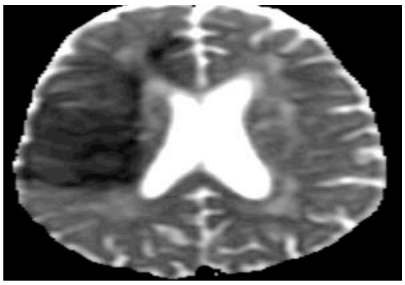
Q1: A patient represents with acute onset hemiplegia.

What will you use to detect infraction?

A) MRI diffusion
B) T1WI
C) T2WI
D) FLAIR

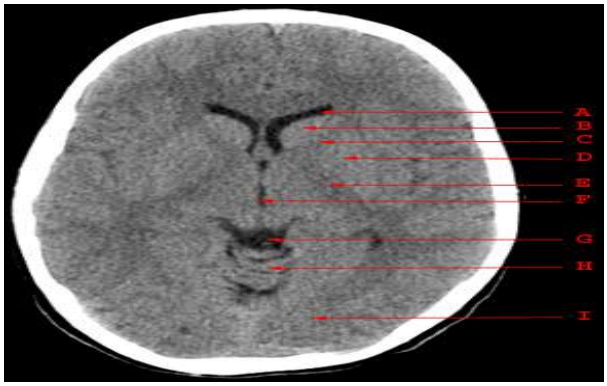


DWI



ADC map

Q2: regarding CT image A is:



a) Third vertical
b) Anterior horn of lateral ventricle
c) Caudate nucleus
d) Quadrigeminal plate cistern

Q3: regarding CT and MRI all the following are true except:

a) White matter disease is better assessed by using MRI rather than CT
b) Usually CT is more available than MRI
c) MRI is better in bone assessment than CT
d) IN CT it is easy to detect acute hemorrhage

Q4: the following are enhanced after contrast injection, except:

a) Normal pituitary glad
b) Infracted pituitary gland
c) Vascular area of cerebrum
d) Meningioma

Good Luck

Q1: A

Q2: B

Q3: C

Q4: B