436 Teams

Radiology Teams 436

Anatomy and Investigation of the Nervous System

Objectives

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

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Color Coding

Important | Notes | Extra

Editing File

Introduction

- **The radiological investigation used for evaluation of the brain and skull:**
  1. Plain X-ray skull (For skull, intracranial or dural calcification).
  2. CT scan.
  3. MRI.
  4. MRA, MRV and CTA (For vessels).
  5. Catheter angiogram (The gold standard for vessels, but now used mainly for intervention).
  6. Duplex US of carotid arteries.
  7. US 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. Nowadays they're only limited for certain complications like trauma to assess the presence of fracture.
- Plain films (X-ray) are still the initial investigations for disorders of the bones of the skull, particularly fractures, but otherwise have limited uses.

1) Plain X-ray skull

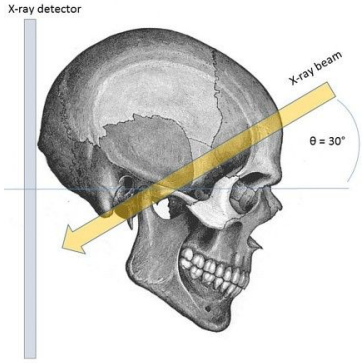
Indications:

- Trauma (X-rays cannot detect hemorrhage in the brain it will only show the fracture, and this is not useful because we want to see the secondary effect of trauma, if there is a hemorrhage or not).
- Congenital anomalies (to see the size of the skull whether it's small 'microcephaly' or large 'macrocephaly').
- Calcification: normal or abnormal (vascular, neoplasm).
- Metastasis: lytic/sclerotic (can show metastasis in the skull either osteolytic which is destructive metastasis or osteoblastic which is sclerotic metastasis but nowadays it's replaced by CT).
- Multiple Myeloma.
- Metabolic disorders in children.

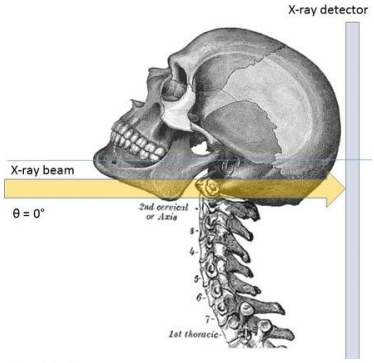
Extra pictures for illustration:

Click here for Helpful video for SMV

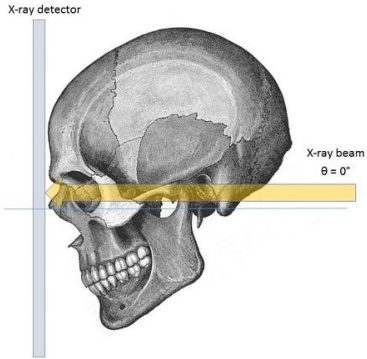
Townes view (AP)



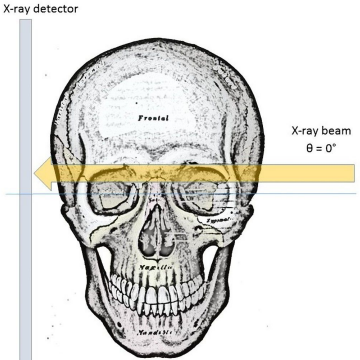
Submentovertical view

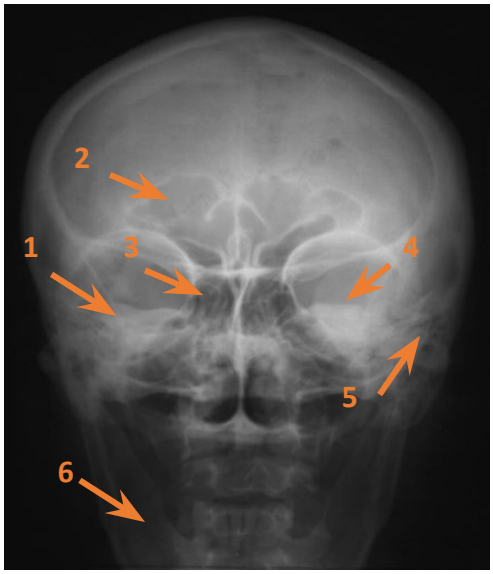


Skull PA view

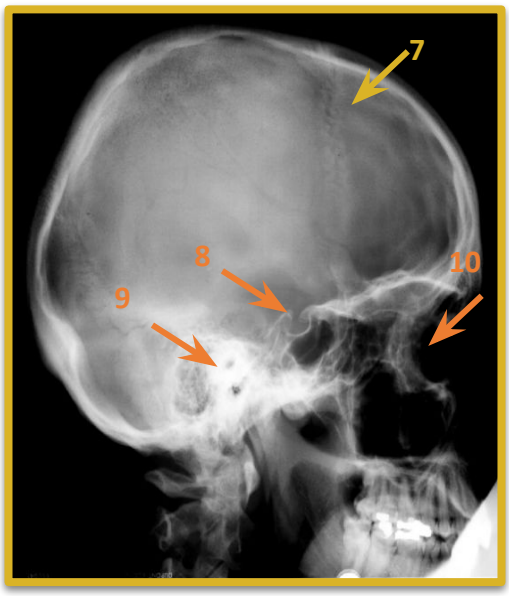


Skull lateral view



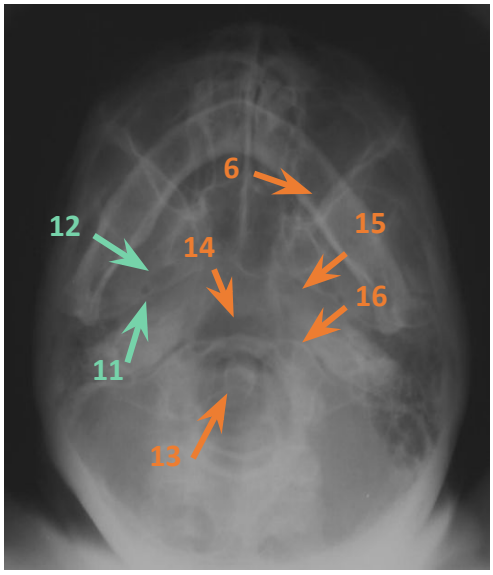


Skull PA view
(also called occipitofrontal view)

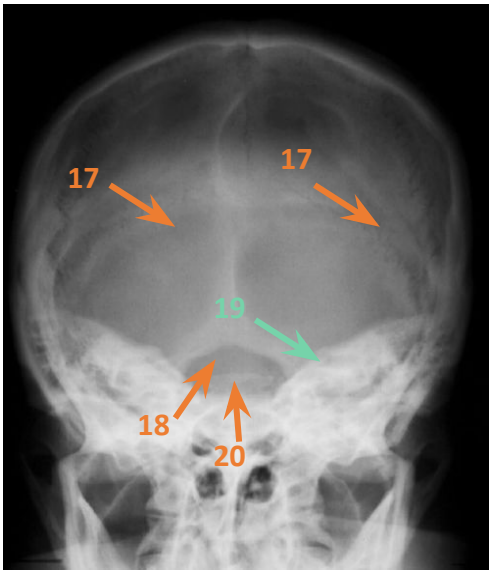


Skull lateral view

Used to assess foramina of the skull but now we use HRCT



Submentovertical view



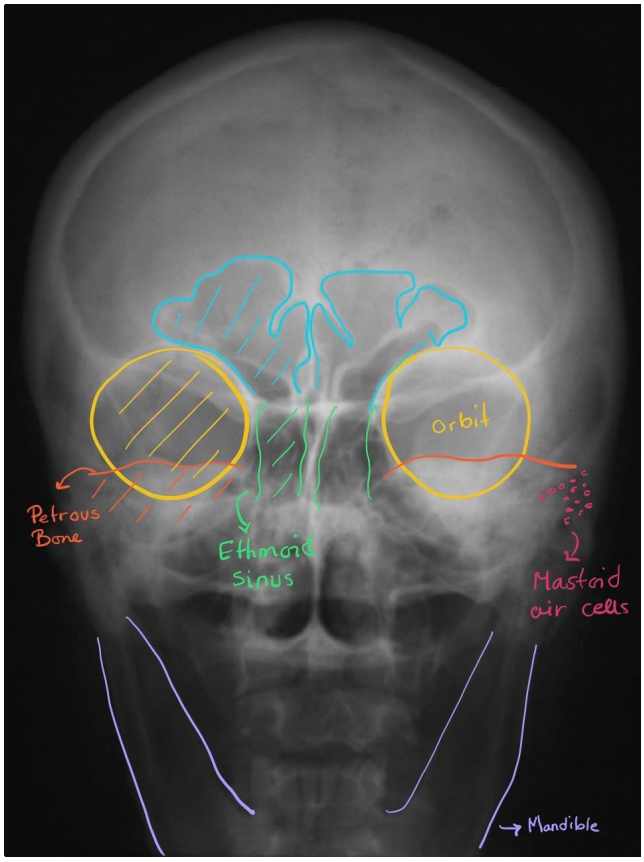
Townes view (AP)

Used to assess the petrous bone and the internal meatus canal.

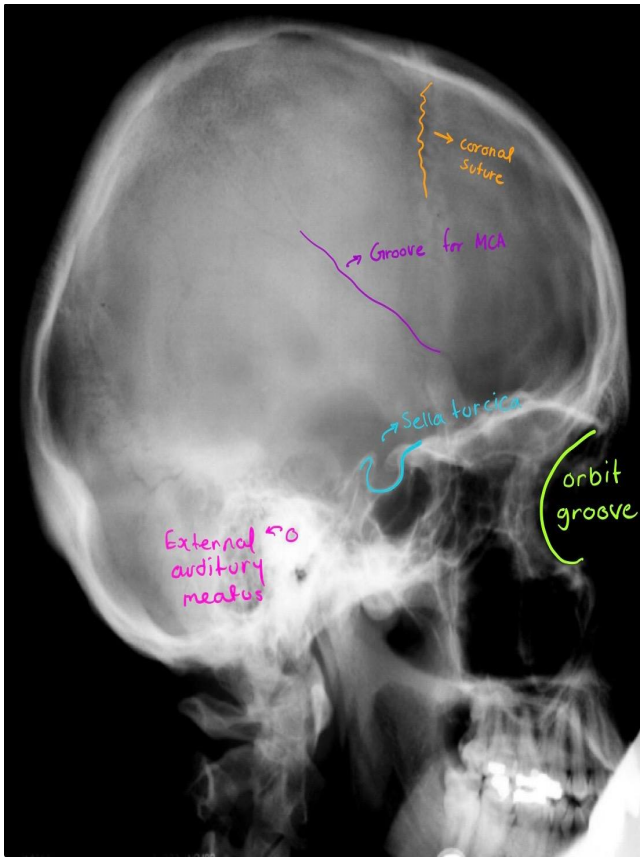
1. Petrous bone.
2. Frontal sinus.
3. Ethmoid sinuses.
4. Orbit.
5. Mastoid air cells.
6. Mandible.
7. Coronal suture.
8. Sella turcica.
9. External auditory meatus.
10. Orbital groove.
11. Foramen spinosum.
12. Foramen ovale.
13. Odontoid.
14. Anterior arch of C1.
15. Carotid canal.
16. Occipital condyle
17. Lambdoid suture.
18. Foramen magnum.
19. Internal auditory meatus.
20. Dorsum sellae.

Kindly, check the next slide for amazing illustrations.

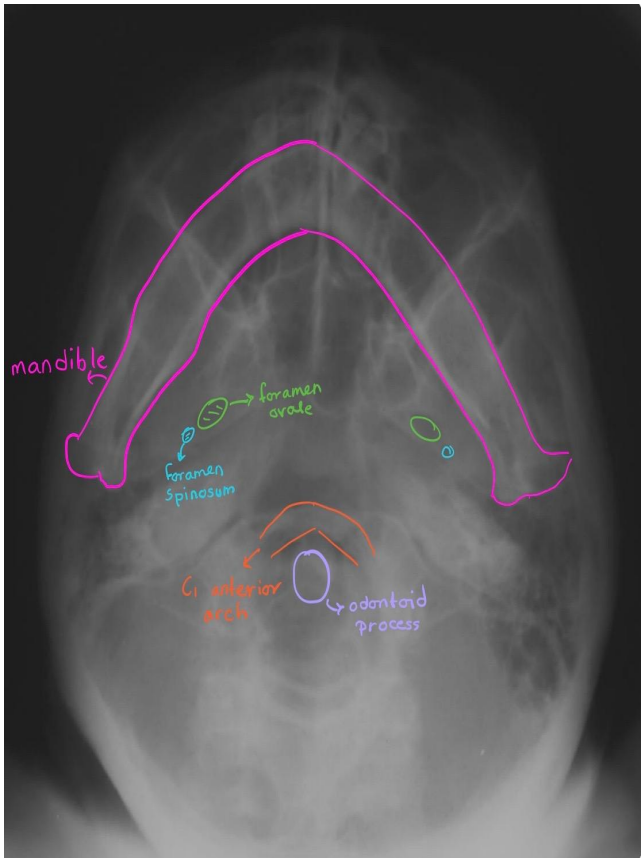
Extra slide for more illustration of the previous one



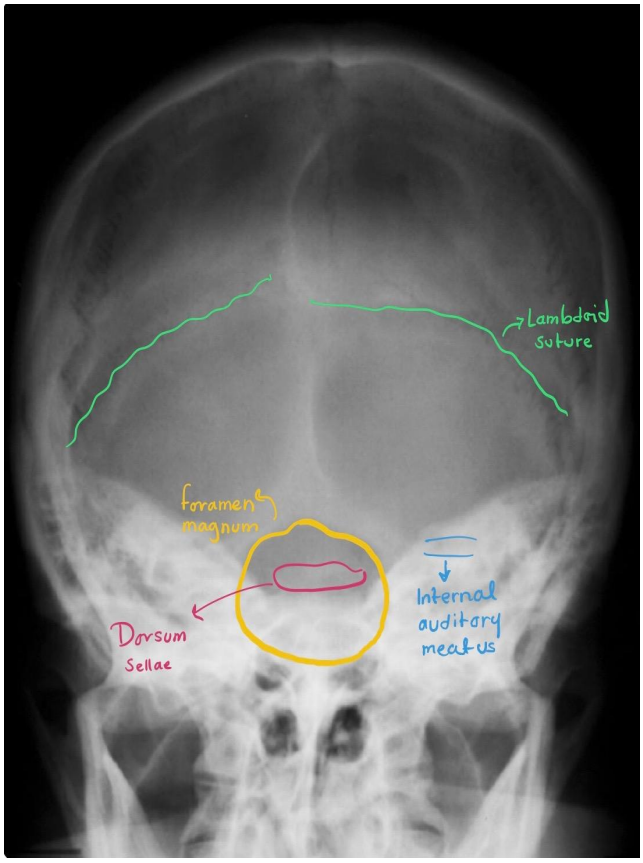
Skull PA view



Skull lateral view



Submentovertical view



Townes view (AP)

2) CT scan

Principles:

- The axial plane is the routine projection, but it's sometimes possible to obtain direct coronal scans by changing the position of the patient. But we cannot get direct sagittal unlike MRI which we can take axial, coronal and sagittal directly. **So how can we have a sagittal image on CT?** we do CT image-reformatting by the computer.
- The window settings are selected for the brain, but may be altered to show the bones.

Advantages	Disadvantages
➔ Spiral CT can perform a head scan in 15 mins pre and post contrast scans. ➔ The scan itself can take as little as 10 seconds for the brain. ➔ Patients preparation: nill (just ask about pregnancy and kids. If you are giving IV contrast, ask about allergies and renal function).	➔ Using ionizing radiation (if we ask **which is better CT or MRI?** MRI because it uses microwaves and magnetic field). ➔ Contraindicated in pregnancy.

Indications:

- Trauma (the best and initial modality to assess patients with trauma; it's very fast. to detect fracture and hemorrhage → CT without contrast).
- Detection of blood → at any stage (acute, subacute and chronic) or any location.
- Strokes (CT is the first investigation to be done in a patient with stroke, 1- To exclude hemorrhage, 2- To confirm the presence of infarction. Acute stroke center (team) will assess acute stroke patient within 3-6 hours (the window time when you can save the area of infarction) and help to plan management and the need for anti-thrombolytic injection depending on the findings. MRI is more sensitive but we use CT more frequently in acute stroke.
- Tumors.
- Infections (meningitis, encephalitis).
- Vascular disorders (e.g aneurysm).

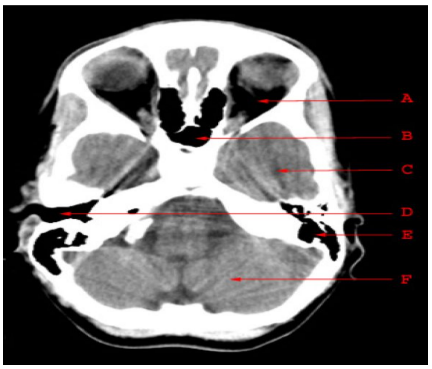
Contraindications:

- **Dr. Hamdy:** No absolute CI. Relative CI for pregnancy in CT brain because you can cover the abdomen and pelvis with a leather apron, but without contrast.
- **Dr. Fahad:** For your level, you just need to know that it is contraindicated.

Type of contrast media:
Iodinated contrast → nonionic low-osmolar contrast media (L.O.C.M).

Normal CT brain:

- CSF is seen as water density (Black) within the 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 (dural folds between the hemispheres).
- 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.
- MRI gives clearer evaluation of brainstem rather than CT. You cannot detect small infarctions in brainstem by CT scan, **why?** because there are artifacts called "beam hardening artifacts" coming from the thick bones making artifact lines that cover the brain tissue there.

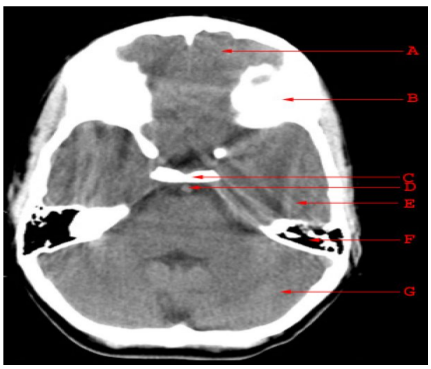


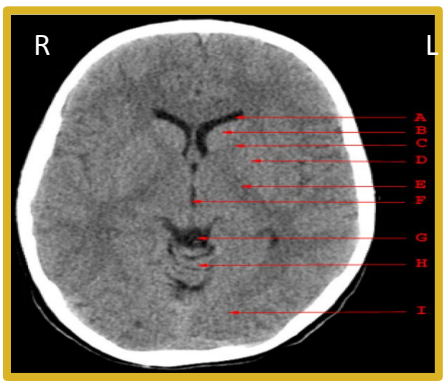
At the level of the lower part of the brain (lower skull).

A. Orbit.
B. Sphenoid sinus.
C. Temporal lobe.
D. External auditory canal.
E. Mastoid air cells (they are thought to protect the delicate structures of the ear, regulate ear pressure and possibly protect the temporal bone during trauma).
F. Cerebellar hemisphere.

A. Frontal lobe.
B. Frontal bone (superior surface of orbital part)
C. Dorsum sellae is part of the sphenoid bone in the skull.
D. Basilar artery.
E. Temporal lobe.
F. Mastoid air cells protects the structures of the ear, regulates pressure and protects the temporal bone.
G. Cerebellar hemisphere.

Consequence cuts of CT scan, you can see the orbit is getting smaller and the frontal lobe starts to appear.



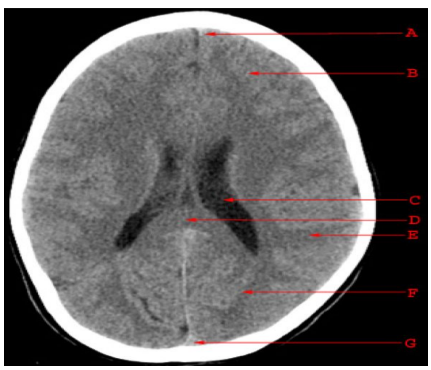


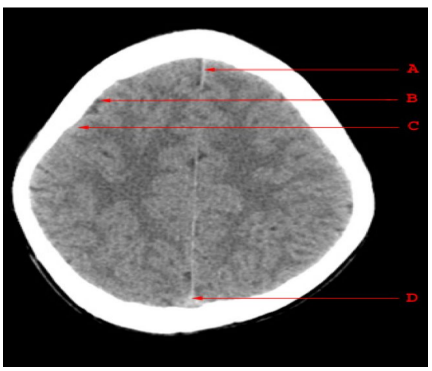
important & you have to mention R\L

A. Anterior horn of the lateral ventricle.
B. Caudate nucleus.
C. Anterior limb of the internal capsule.
D. Putamen and globus pallidus.
E. Posterior limb of the internal capsule.
F. Third ventricle.
G. Quadrigeminal plate cistern the portion of the midbrain tectum upon which the superior and inferior colliculi sit.
H. Cerebellar vermis unpaired medial structure which connects the **cerebellar** hemispheres.
I. Occipital lobe.

At the level of lateral ventricles.

A. Falx cerebri.
B. Frontal lobe.
C. Body of the lateral ventricle.
D. Splenium of the corpus callosum, the thickest and most posterior portion of the corpus callosum.
E. Parietal lobe.
F. Occipital lobe.
G. Superior sagittal sinus.

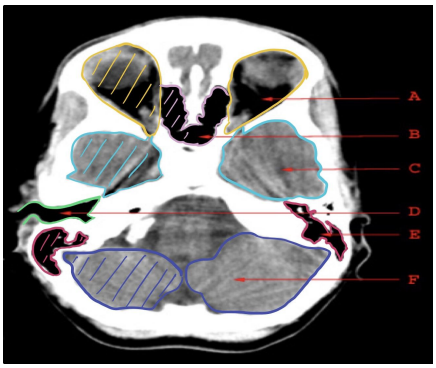




A. Falx cerebri.
B. Sulcus (hypodense).
C. Gyrus (hyperdense).
D. Superior sagittal sinus.

This cut is called supraventricular scan (above the level of ventricles) and it's the only part of the brain without the ventricular system. Most of this image is related to the frontal lobe and a small part is related to the parietal lobe.

Extra slide for more illustration of the previous one



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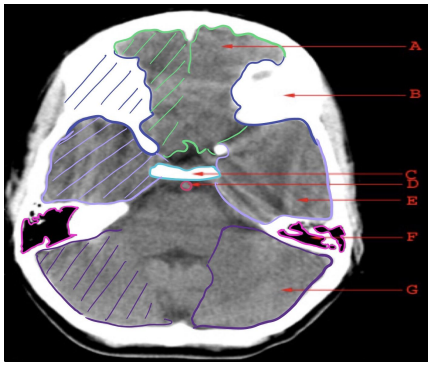

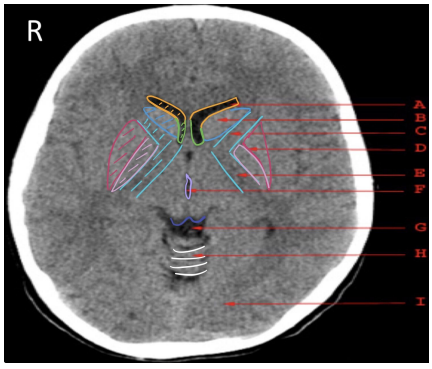

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At the level of lateral ventricles.

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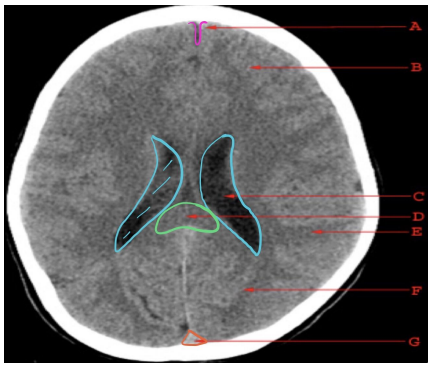
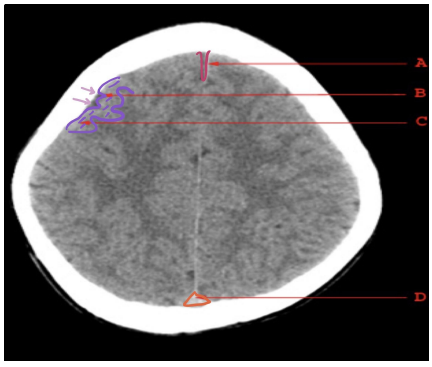
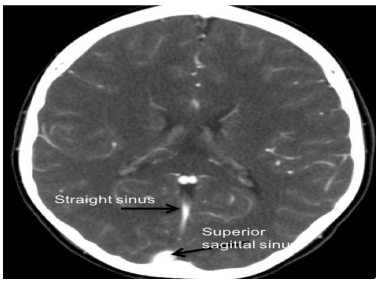
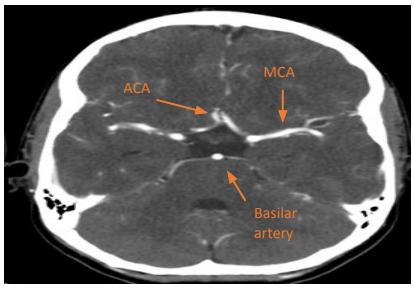




A. Falx cerebri.
B. Sulcus.
C. Gyrus.
D. Superior sagittal sinus.

Contrast enhanced CT:

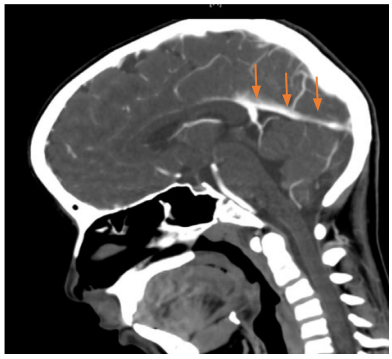




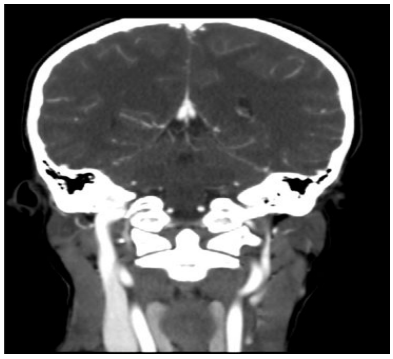
- **When do we need to inject contrast?** To assess vasculature of the brain (vascular malformations, aneurysms, neoplastic lesion, infection meningitis, cerebritis) but **we don't need to inject contrast in trauma or stroke.**
- **Is there enhancement for the brain parenchyma?** No. **Why?** Because we have BBB that prevents any macromolecules from going inside the brain. We only can see the contrast in the parenchyma in invasive tumors or infections that break the BBB.
- You can adjust the time while injecting the contrast, we have a certain time we can catch the contrast either in the arteries or in the veins (CTA and CTV).
- IV injection of contrast medium is often given because the abnormality is not seen in pre-contrast scans, it 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 helps in demonstrating blood vessels.

Computer reconstructions can, in selected circumstances, be made from the axial sections which then provide images in coronal or sagittal planes:

The arrows are pointing to Straight sinus (IMP)

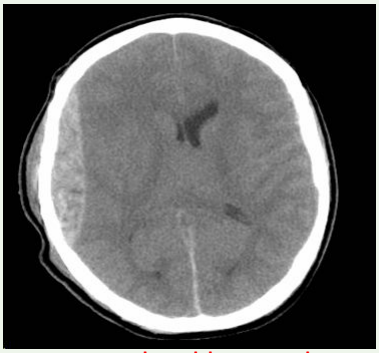
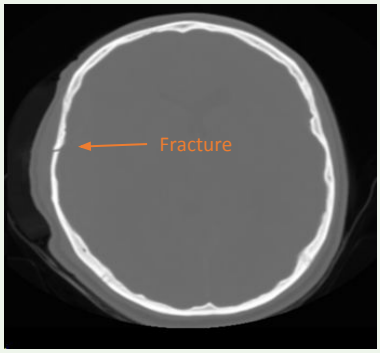
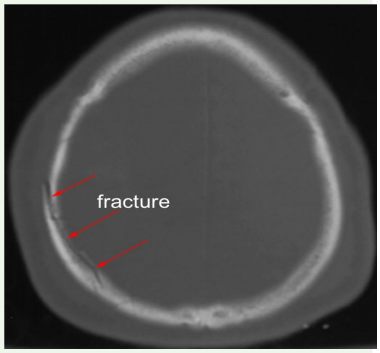


Sagittal reconstruction



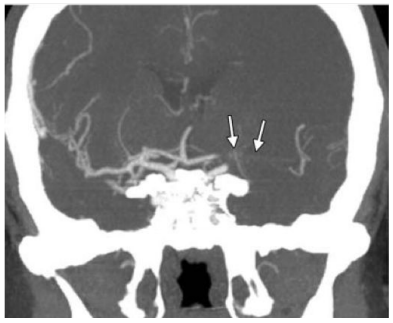
Coronal reconstruction

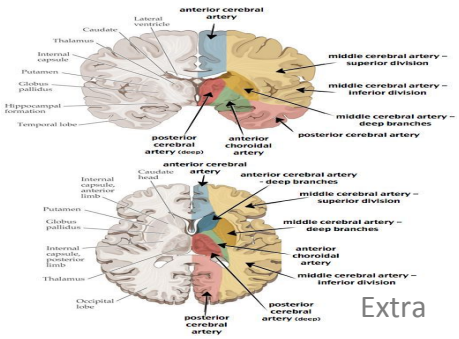
The window settings are selected for the brain, but may be altered to show the bones:

Brain window	Bone window	
		
Acute extradural hemorrhage Shows brain parenchyma, we cannot see skull fractures.	It shows details of the bones & can assess any fracture in the skull. We can't see the hemorrhage here.	

CTA (CT Angiogram):

- CT angiography is helpful in the diagnosis of vascular diseases and abnormalities such as stenosis, occlusion or vascular malformation.





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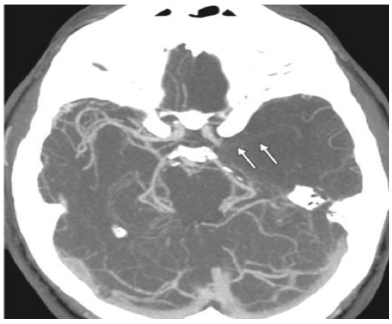


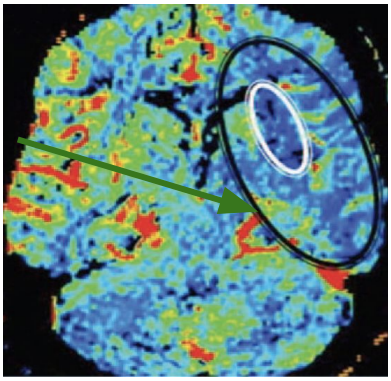
Occlusion of left middle cerebral artery

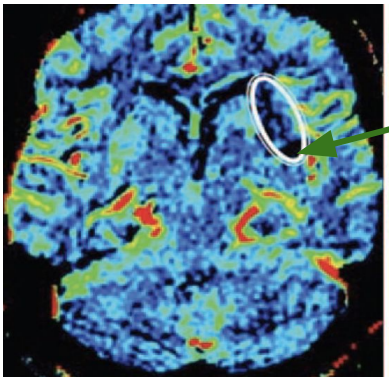
The contrast is not filling the vessels beyond the arrows, so it means there is an occlusion

CT Perfusion: Asses brain blood flow and volume

- It assesses blood flow to the brain tissue. We can also get colored images that show areas with high flow and low flow to tell us whether we can re-perfuse the tissue or not.
- The normal blood flow to the brain is 600 ml/100 g tissue/min. If <20 ml, hypoperfusion happens and it can go back to normal when reperfusion occurs. If <10 ml, true infarction happens (cellular death) this tissue won't go back to normal again.
- **How will we know if this patient will benefit from thrombolytic agents or not?** By CT perfusion.
- 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 ischaemic penumbra.
- Some cerebral tumours 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 tumours when standard imaging may not.

Hypoperfusion area





Infarction

Cerebral blood <u>flow</u>

- Here it shows a bigger hypoperfused area than cerebral blood volume. The black bigger circle demonstrates the hypoperfused area and if this patient starts on thrombolytic agents this hypoperfused area can go back to normal.

Cerebral blood <u>volume</u>

- Red areas mean very high flow = blood vessels.
- Blue or green areas are also blood flow but in a different gradient.
- The circled area demonstrates very low or zero blood flow. This is the infarcted tissue (dead cells).

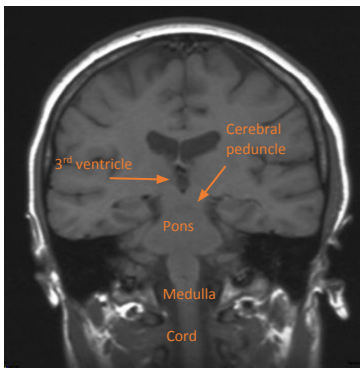
3) MRI

- No ionizing radiation.
- **Patient preparation:** Nil, unless fasting for general anesthesia.
- **Contrast medium:** Gadolinium less allergic side effects than CT contrast. We should evaluate every patient for renal function before injecting contrast.

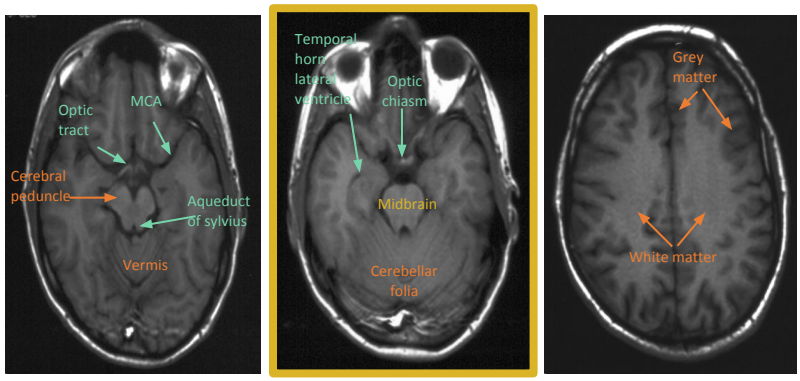
Indications	Contraindications
- Strokes more sensitive in early detection of a stroke, but CT is faster. - Tumors. - Infection. - Vascular disorders. - White matter disease more sensitive than CT (like pediatric congenital diseases and MS). - Some cases of trauma if clinical scenario is not explained by CT. Unlike CT, MRI isn't usually used in trauma because it's time consuming.	- Cardiac pacemaker (Not absolute because now we have compatible PM), but you have to make sure. - Cochlear implants (Absolute). - Ocular prosthesis. - Intraocular ferrous foreign body (absolute CI)!! - Neurostimulators. - Pregnancy (1st trimester) not absolute, but without contrast. - Claustrophobic: extreme or irrational fear of confined places.

- MRI is a multi-planar technique (can produce images in sagittal, axial and coronal planes directly unlike CT) which is useful for assessment of the extent of brain tumors and for better visualization of structures of posterior fossa and craniocervical junction.
- MRI is a multi-sequential technique (can create images in T1WI, T2WI, FLAIR*, gradient and other sequences), and because of that MRI is more sensitive and better in diagnosing than CT but not in acute settings.

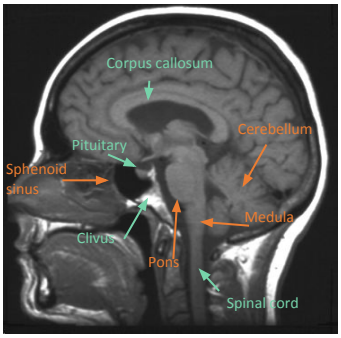
  *Fluid attenuation inversion recovery يعني إضعاف السائل من أبيض إلى غامق
  but not all fluid will be attenuated it has to be 1. Clear 2. Within a space.
- It is possible to recognize flowing blood and therefore large arteries and veins stand out clearly without the need for contrast medium injection.



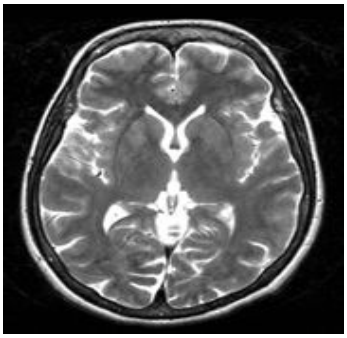
MRI Brain (Coronal T1WI) MRI gives a very clear evaluation of the brainstem



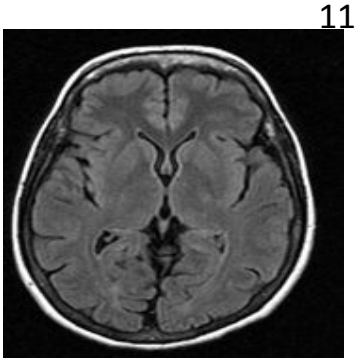
MRI Brain (Axial T1WI)



MRI Brain (Sagittal T1WI)



T2WI



FLAIR

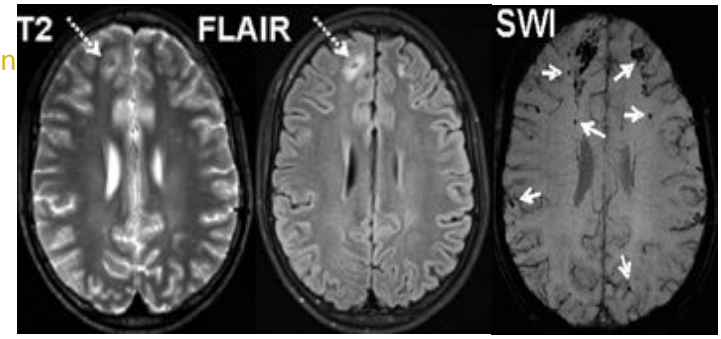
The Characteristic signal intensity of brain structures in different MRI sequences:

	Grey matter	White matter	CSF (IMPORTANT)
T1WI	Grey	Light	Dark
T2WI	Light	Dark	White The only white CSF
FLAIR for lesions adjacent to ventricles	Light	Dark	Dark

FLAIR is like T2 except that fluid is suppressed and that's why it appears dark, it only suppresses fluid within a free space (Ventricles and subarachnoid space or fluid in a cyst) but not Interstitial fluid so if there is brain edema it will appear WHITE (hyperintense or bright)!! because of that it is much more sensitive at detecting lesions than T2 (All lesions in T2 are white so it's hard to distinguish them from CSF), Also flair doesn't suppress turbulent fluids (Hemorrhage and pus) completely, while clear fluid like CSF is suppressed completely.

Susceptibility Weighted Sequence (SWI): Unlike T1,T2 and flair, SWI poorly differentiates between brain tissue (grey matter, white matter and CSF) but it can detect lesions that contain iron and calcification even the small ones (blooming effect).

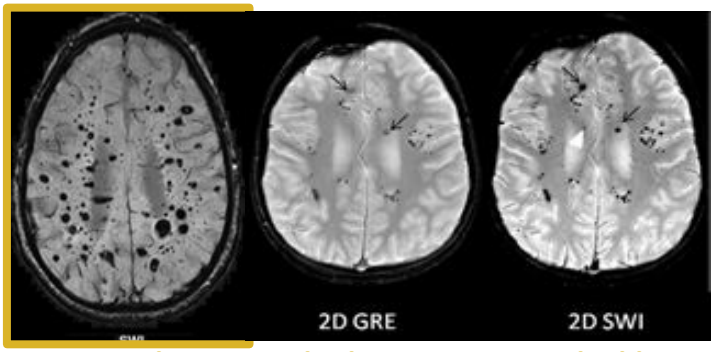
The best way to detect subarachnoid and micro-hemorrhages in patients with HTN and patients with cavernoma (vascular malformation).



Signal loss due to:

- Paramagnetic.
- Diamagnetic.
- Calcium.
- Blood.

Patient post RTA with diminished level of consciousness the SWI shows multiple foci of dark signal intensity (blooming) at grey-white matter interface (not seen in T2WI and FLAIR) representing hemorrhagic diffuse axonal injuries. Very serious injury that happens in RTA due to acceleration-deceleration trauma, cannot be detected in CT and is poorly detected in T2 and flair.

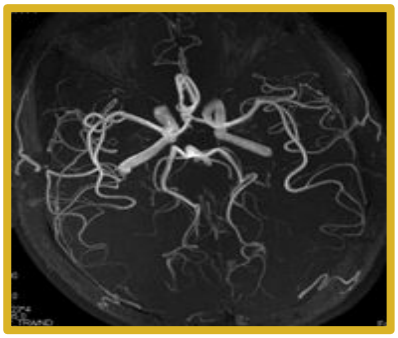


SWI showing multiple cavernoma with old hemosiderin

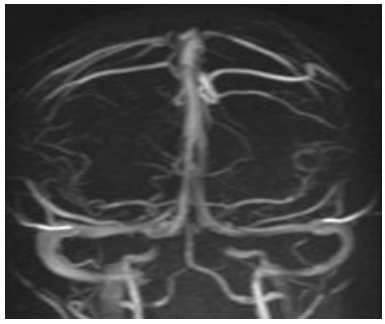
4) MRA & MRV

MRA	MRV
• Can be done without injection of contrast medium using time of flight technique. • Can be used to assess intra and extracranial arteries for any vascular abnormalities such as stenosis, occlusion or vascular malformation.	• Can be done either with or without injection of contrast medium but it is better to give contrast. • Assess venous dural sinuses, superficial and deep venous system. • Can confirm presence of venous thrombosis.

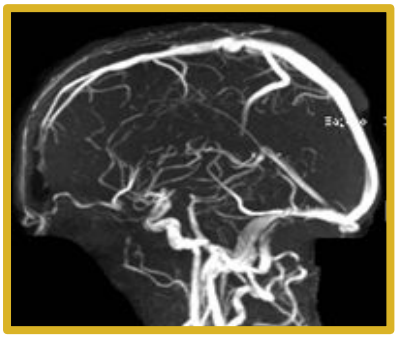
A patient comes with papilledema, the patient uses oral contraceptive.
You suspect venous thrombosis. **What is the best modality?** MRV.



MRA



MRV

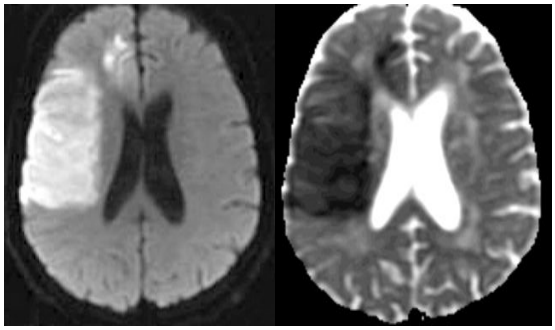


MRV

MR Diffusion: Depends on movement of water molecules in the extracellular space, any lesion that narrows the ECF, like tumors and edema, will cause diffusion restriction.

Very helpful in assessment of:

- Early brain infarction (Most sensitive, detect infarction at time of stroke or after min CT after 6 h, T2 and flair after 2-3h).
- Brain abscess.
- Certain types of brain tumor: Lymphoma, GBM, meningioma.



DWI **ADC map**

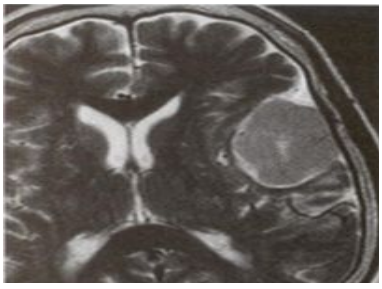
True diffusion: bright in DWI and dark in ADC map, which happens in stroke, some types of tumors, and abscess.

A patient comes with acute upper limb weakness, you suspect ischaemia. **What is the best modality detect ischaemia?** MRI Diffusion.

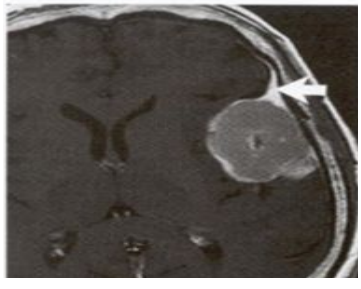
Sensitivity of detecting infarction in order:

1. MRI diffusion.
2. FLAIR.
3. T2WI.

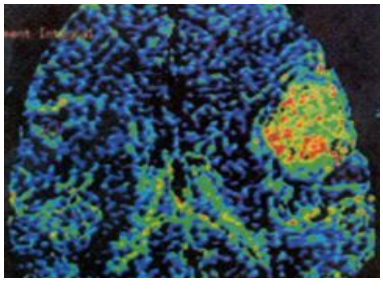
Meningioma



T2



Contrasted T1



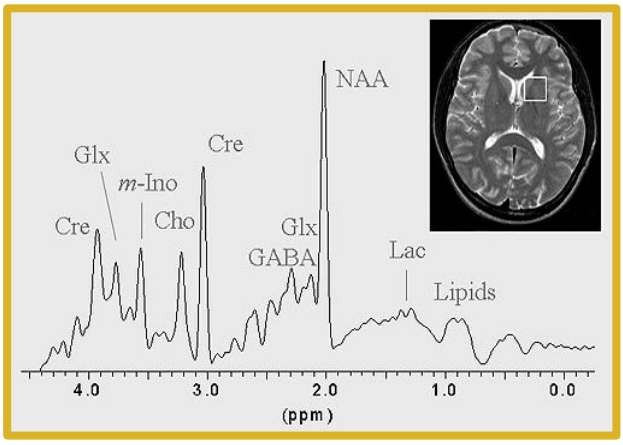
Perfusion-Weighted

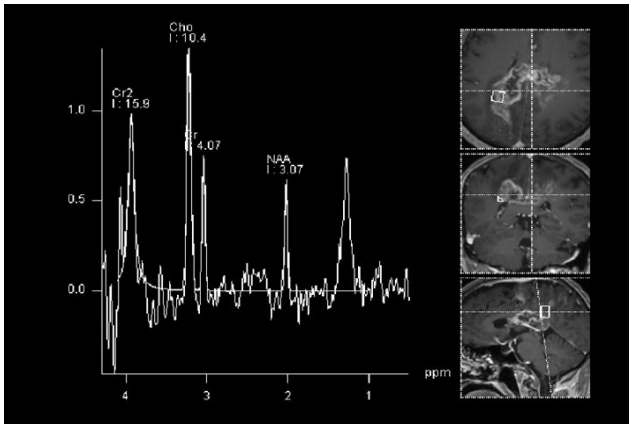
MR Spectroscopy: "I just want you to know what is MR Spectroscopy"

Unlike MRI, the technique of MRS does not generally produce images, instead creates spectra (see figures). Each peak in the spectrum arises from a different brain metabolite (NAA, N-acetylaspartate; Cre, Creatine; Cho, Choline; myoI, myo-Inositol; Lac, Lactate; Glx, Glutamate and Glutamine; GABA, gamma aminobutyric 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.

Very helpful in:

- Differentiating neoplastic from non neoplastic processes, if Choline is high and NAA is low > neoplastic processes.
- Differentiating benign from malignant tumors.
- Determining of certain types of tumors.
- Assessment of white matter diseases.
- Assessment of neurodegenerative diseases.
- It also helps to detect tumor recurrence or post radiation necrosis.





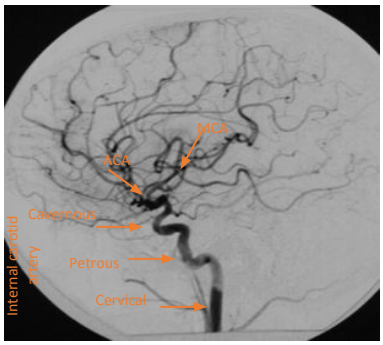
MR Spectroscopy in GBM

(GBM = Glioblastoma multiforme)

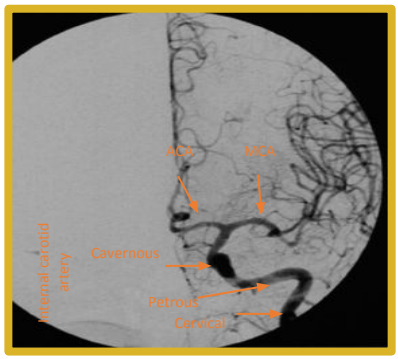
Notice the high Cho and low NAA

5) Cerebral Angiogram

- It is the gold standard technique for assessment of intra and extracranial vessels.
- It can demonstrate different vascular diseases (stenosis, occlusion, vascular malformation and blood supply of brain tumors).
- It is an invasive technique.
- Recently its main role is for intervention purposes such as treatment of vascular malformation (aneurysm/arteriovenous malformation) or preoperative embolization of vascular supply of tumor. So it helps in diagnosis of early aneurysm which can't be detected by CT or MRI, and manages it as the same time.

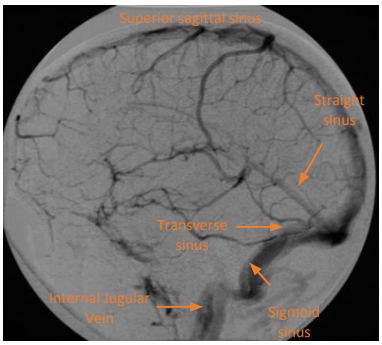


Internal carotid angiogram (lateral view)



Internal carotid angiogram (AP)

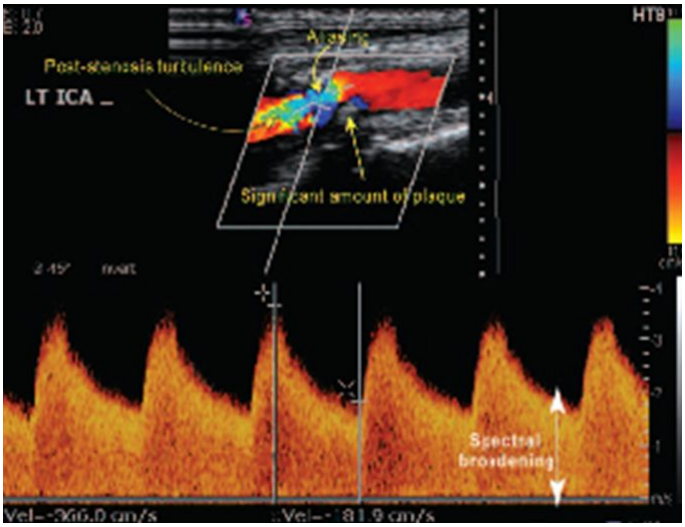
Catheter angiography



Venous phase cerebral angiogram (Lateral view)

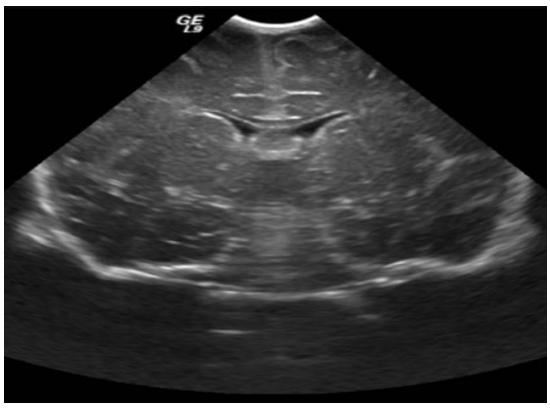
6) Carotid Doppler

Easiest and cheapest way to assess carotid narrowing and the degree of narrowing.

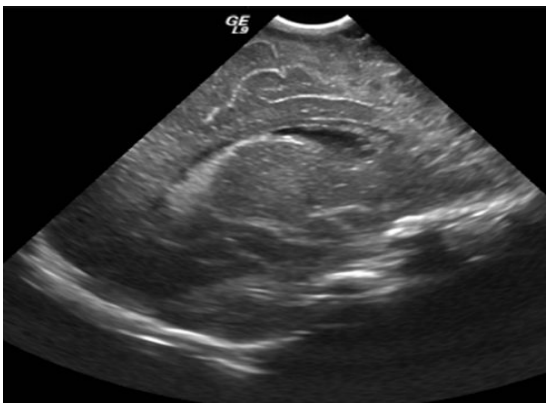


7) Ultrasound (In Neonatal brain)

- It is a simple and easy way to scan the head of neonates and young babies (not used in adults because of their skull).
- Doesn't use 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 that it is particularly useful in detecting ventricular dilatation (hydrocephalus), intracerebral hemorrhage and congenital abnormalities of the brain.



Coronal



Sagittal

Brain anatomy - Radiology assistance

Short cases from Dr. Fahad:

- **A 35y old lady on OCP presented with headache and papilledema and you requested an imaging and the radiologist asked you what are you looking for?**

Superior sagittal sinus as there might be a thrombosis.

- **If there is a thrombosis in the basilar artery which structure will be affected?**

Brain stem -> Pons.

- **If there is a thrombosis in the middle cerebral artery which structure will be affected?**

Basal ganglia and patient will present with a sudden hemiplegia. keep in mind if Rt MCA then Lt Hemiplegia and vice versa.

- **CT Angiography was done and showed lack of visualization of left MCA .. what is the expected clinical presentation?**

Right hemiparesis.

- **A patient diagnosed with subarachnoid hemorrhage after a CT Scan, how will we know the cause of it?**

Do a CT Angio to know the cause, it'll most likely be an aneurysm if it's not trauma, usually they are 40-50y old.

Reference books

- Stephanie Ryan, "**Anatomy for Diagnostic imaging**", 2nd Edition,Pages 61-66.
- Jamie Weir, Peter Abraham, "**Imaging Atlas of Human Anatomy"** 3rd Edition, Pages 34-41.
- Peter Armstrong, "**diagnostic imaging**", 5th Edition, Pages 396-404.

Special thanks to Fahad Alzahrani & Abdullah Jammah

Summary

- Plain X-ray has limited use, only for fractures and metastases.

- CT and MRI are the best and are considered the standard investigations for brain imaging.

- Trauma patients need faster techniques (CT).

- Every patient with a tumor should do MRI.

- Intraocular ferrous foreign body is an absolute C/I in MRI.

- We can assess brain stem & cerebellum nicely with MRI + we can see the anatomy of each part of the brain.

- Vessels can be seen without contrast in MRI.

- **MRI diffusion is very helpful in the assessment of:**
1- Early brain infarction.
2- Brain abscess.
3- Certain types of brain tumor.

- **CEREBRAL ANGIOGRAM** is the gold standard technique for assessment of intra and extracranial vessels.

Thanks to 434 teamwork for the summary

Questions

Q1: Which of the following is an indication for plane x-ray?

a) Stroke.
b) Multiple myeloma.
c) Meningitis.
d) Aneurysm.

Q2: An absolute contraindication for MRI is?

a) Pregnancy.
b) Incompatible Cardiac Pacemaker.
c) Dental braces.
d) Rubber band.

Q3: The most sensitive technique to detect infarction is:

a) MRA.
b) FLAIR.
c) MRI diffusion.
d) T1WI.

Q4: Which one of the following is the best technique for detecting empyema as complication of meningitis?

a) MRI brain perfusion sequence and ADC map.
b) MR spectroscopy.
c) Contrast enhanced CT brain.
d) MRV.

Q5: First investigation to be done in stroke:

a) MRI.
b) X-RAY.
c) CT.
d) Catheter angiogram.

Answers:
1-b.
2-b.
3-c.
4-a.
5-c.