RADIOLOGY
TEAM 435

Anatomy and investigation of the nervous system

[Color index: Important ★ | Notes | Extra | Editing file]

❖ Objectives:

- ➢ 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.

❖ Resources:

- **Doctor's slides**
- **434 team**
- **students note**

❖ Done by:

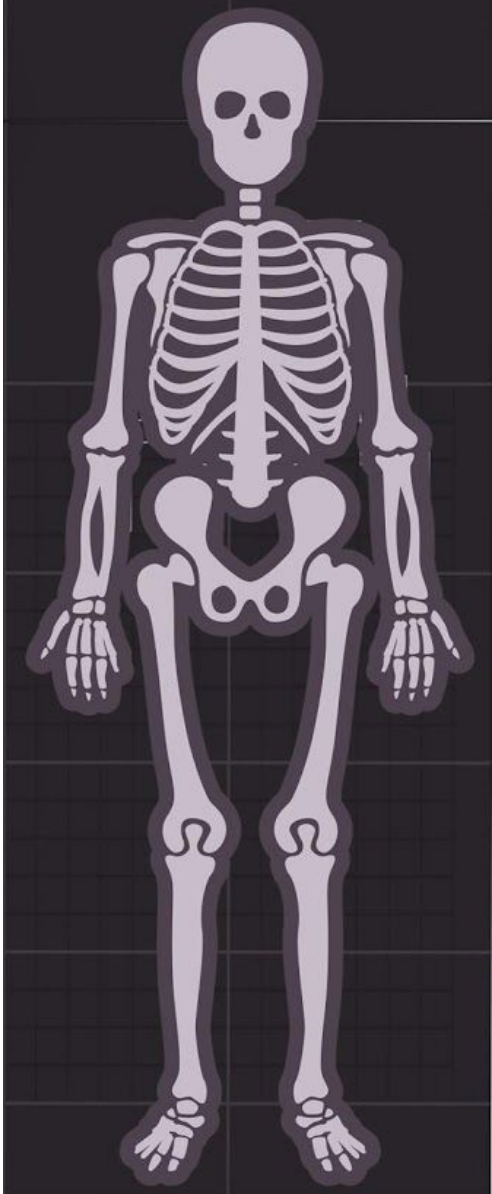
- **Raghda Alqassim**
- **Nora Alsomali**

❖ Team Leader:

- ❖ **Mohammed Alsahil**
- ❖ **Amjad Alduhaish**

- Revised by:

- **Ahmed Al Yahya**



Introduction

The radiological investigation used for evaluation if the brain and skull:

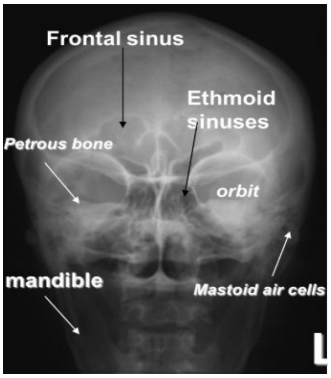
1-Plain X-ray skull	2-CT scan	3-MRI	4-MRA, MRV and CTA	5-Cath. angiogram. the gold standard.	6-Duplex U/S of carotid arteries.	7-US for neonatal brain.

1. The newer imaging modalities have had a great impact on the diagnosis of diseases of the central nervous system.
2. 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.
3. **Plain films (X-ray)** are still the initial investigations for disorders of the bones of the skull - particularly fractures, but otherwise have limited uses.

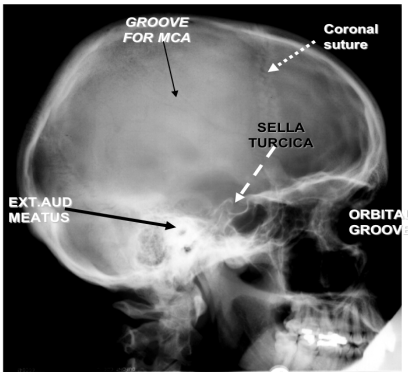
Plain X-ray skull

- **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, is there 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.
  - Multiple Myeloma.
  - Metabolic disorders in child.

The usual basic X-ray views of the skull are the lateral view and the Horizontal Frontal (AP) view.

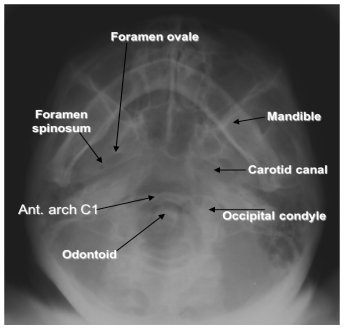


Skull PA view

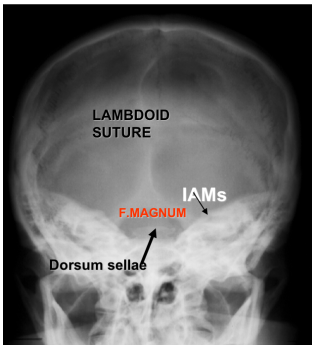


Skull X-ray lateral view

Other views that were replaced by CT nowadays are:



Submentovertical view used to assess foramina of the skull but now we use CT.



Towens view (AP) used to assess the petrous bone and the internal meatus canal.

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 setting are selected for the brain, but may be altered to show the bones. brain window and bone window.

Indications	Contraindications
• Trauma. the best modality to assess patients with trauma; it's very fast. Can detect calcification and infarctions. • Detection of blood. At any stage (acute, subacute and chronic). • Strokes. CT is the first investigation to be done in a pts with stroke 1- to exclude hemorrhage, 2- to confirm the presence of infarction. Acute stroke center (team) to assess acute stroke patient within 3-6 hours "the window time when you can save the area of infarction". MRI is more sensitive but we use CT more frequently in acute stroke (CT is much faster than MRI). • Tumors. • Infections. meningitis, encephalitis • Vascular disorders. note that we didn't mention white matter diseases here.	• Relative CI for pregnancy in CT brain because you can cover the abdomen and pelvis with leather apron. but without contrast. • no absolute CI.

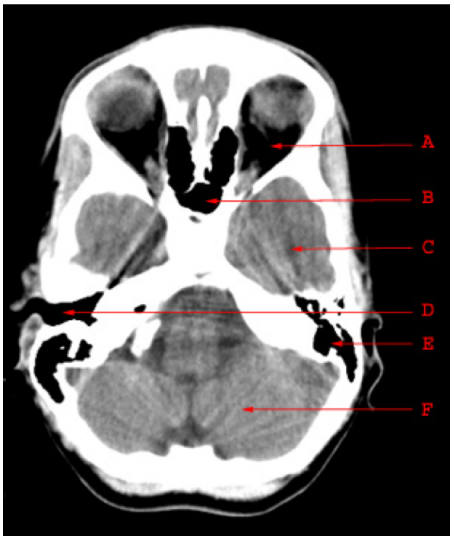
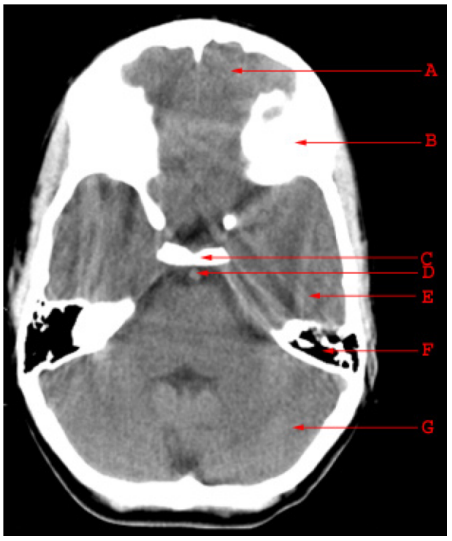
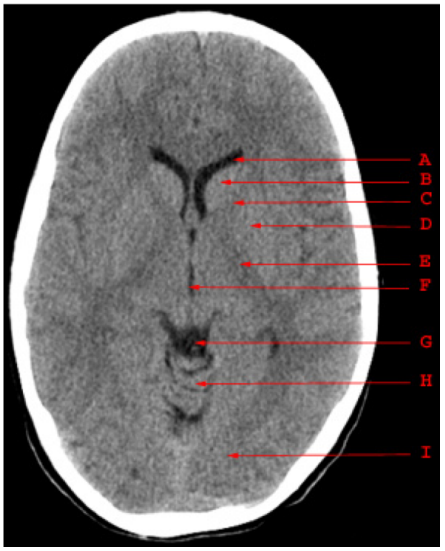
Advantages	Disadvantages
• Spiral CT scan perform a head scan in 15 mins pre and post contrast scans. spiral CT is very fast we can perform the whole body CT from head to toe in 1 min. • The scan itself can take as little as 10 seconds. • Patients preparation: nil. just ask about pregnancy and kids. the preparation if we give 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.

❖ Type of the contrast medium:

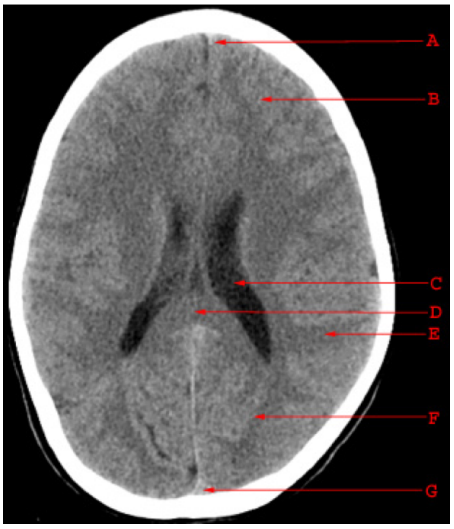
- ➢ iodinated contrast.
- ➢ nonionic low-osmolar contrast media (L.O.C.M)

❖ Normal CT brain:

- ➢ we have to know the normal appearance of grey matter, white matter ,and CSF spaces whether it's intraventricular or in sulci in CT.
- ➢ 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)
- ➢ one of the most importants scans in CT is for the deep nuclei (basal ganglia, thalami, internal capsule) because the hypertensive bleeds happen in basal ganglia most commonly. these deep nuclei are deeply embedded 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.
- ➢ MRI gives more clear 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[1]" comes from the thick bone makes artifacts lines that cover the brain tissue there.

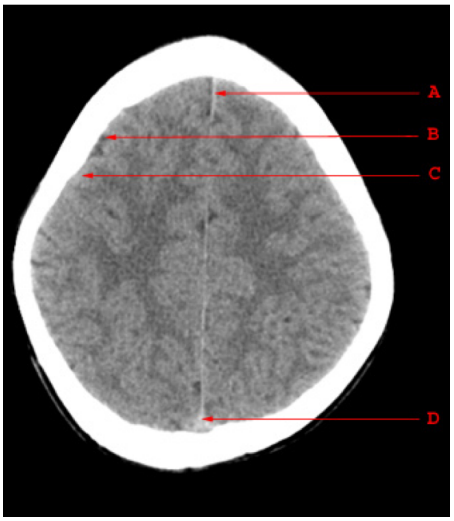
<table>
<tr>
<td> 
</td>
<td> 
</td>
<td> 
</td>
</tr>
<tr>
<td>This the area of lower part of the brain (lower skull).
A. Orbit.
B. Sphenoid sinus.
C. Temporal lobe in the middle cranial fossa.
D. External auditory canal.
E. Mastoid air cells.
F. Cerebellar hemisphere.
The posterior fossa which contains anteriorly the brainstem and cerebellum. you have to differentiate between midbrain, pons and medulla oblongata.</td>
<td>Consequence cuts of CT scan, you can see the orbit is getting smaller and the frontal lobe starts to appear.
A. Frontal lobe.
B. Frontal bone (superior surface of orbital part)
C. Dorsum sellae.
D. Basilar artery.
E. Temporal lobe.
F. Mastoid air cells.
G. Cerebellar hemisphere.</td>
<td>the ventricular level.
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. tracts of white matte.
internal capsule has: 1- anterior limb between caudate head and lentiform nucleus. 2- posterior limb between lentiform nucleus and the thalamus.
F. Third ventricle.
G. Quadrigeminal plate cistern.
H. Cerebellar vermis
I. Occipital lobe</td>
</tr>
</table>

[1] White stripes are seen along the lines between the thickest part of the skull.



at the level of lateral ventricles.

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.



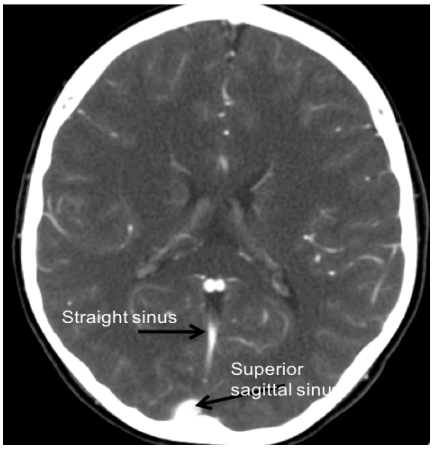
this cut is called supraventricular scan (above the level of ventricles) and it's the only part of the brain without ventricular system.
most of this image is frontal lobe and small part is parietal lobe.

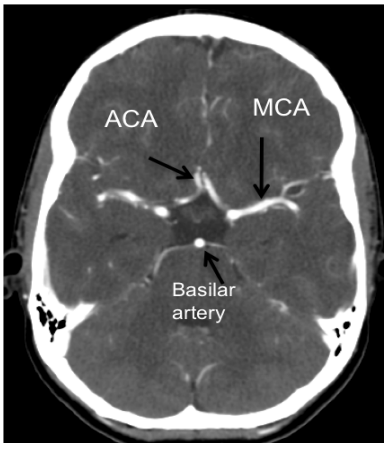
A. Falx cerebri.
B. Sulcus.
C. Gyrus.
D. Superior sagittal sinus.

so you should know the grey matter, white matter, ventricles are dark, CSF is dark on CT scan.

❖ Contrast enhanced CT:

- ➢ when do we need to inject contrast? to assess vasculature of the brain (vascular malformation, 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[2] that prevents any micromolecules from going inside the brain. we 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[3] and CTV[4])

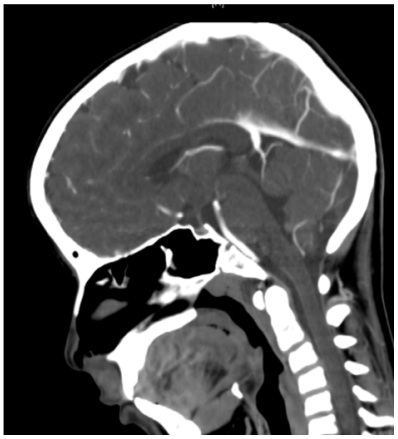
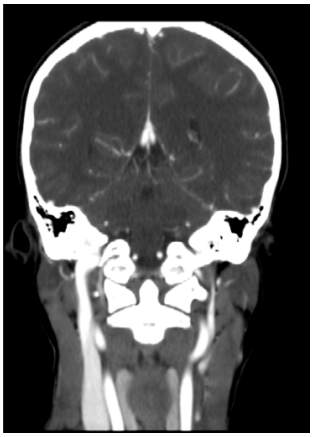




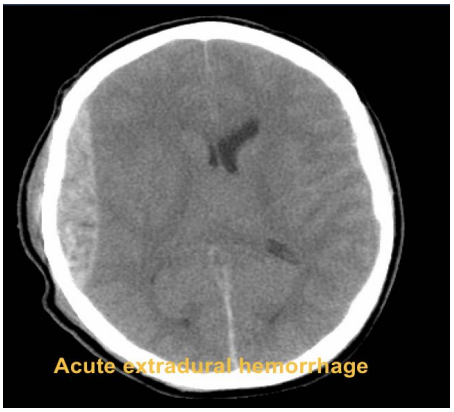
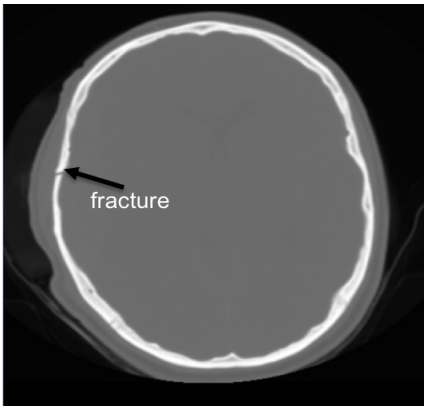
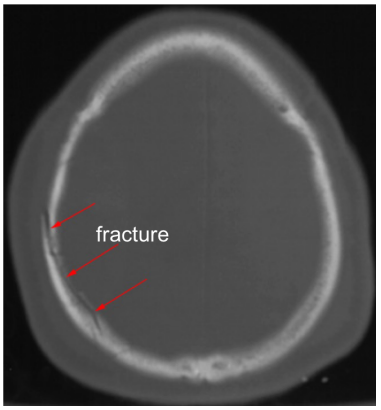
- IV injection of contrast medium is often given because the abnormality not seen in pre-contrast scans may be rendered visible following contrast enhancement (consequence of breakdown of blood brain barrier allowing contrast to enter the lesion particularly in neoplasm, infection, inflammation and certain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

[2] Blood brain barrier.
[3] CT angiogram.
[4] CT venogram.

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

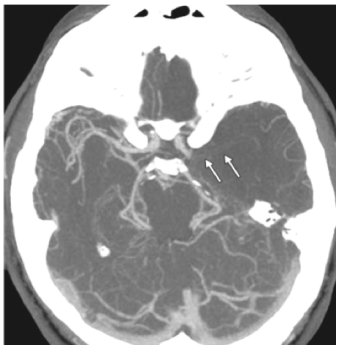
	
Sagittal reconstruction "sagittal reformatted-image"	Coronal reconstruction we can get either direct coronal section or reformatted coronal image.

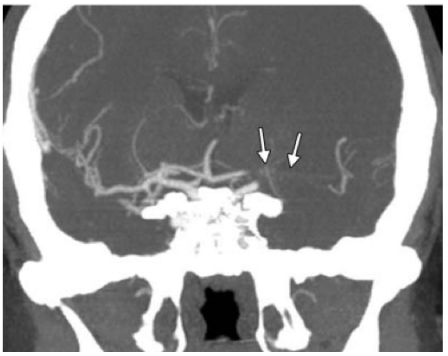
The window settings are selected for the brain, but may be altered to shows the bones.

		
Brain window this image demonstrates epidural hemorrhage but we cannot see the skull fracture so we shift to bone window.	**Bone window** It can assess any fracture in the skull which can be easily missed on brain window. We can't see the hemorrhage here.	

❖ **CT angiogram (CTA):**

- ➢ Uses contrast through injectors not manually. This injector helps us to inject contrast in a very short time and it's also computerized so that we can determine when the contrast is in the vein or in the arteries (timing). CTV is more late than CTA.
- ➢ CT angiography is helpful in diagnosis of vascular diseases and abnormalities such as stenosis, occlusion or vascular malformation.



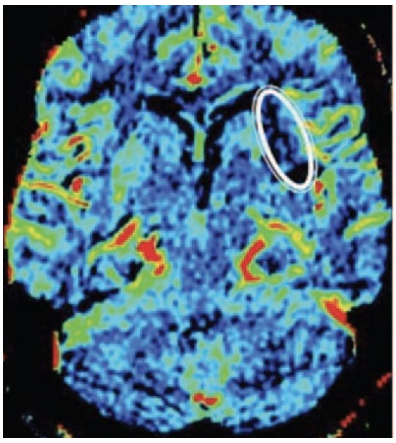


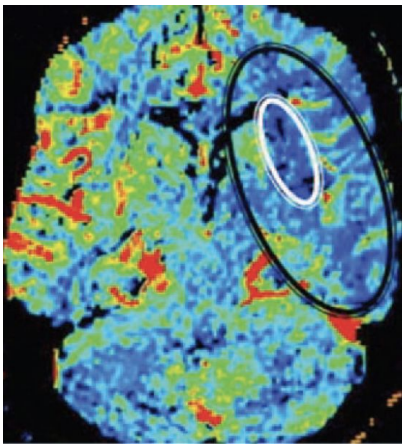
Occlusion of left middle cerebral artery.

So in stroke cases, we start with CT scan without contrast of the brain to detect whether there is hemorrhage or not or to assess the presence of infarction or not. Then we can inject contrast if there's infarction, to assess which vessel is occluded so we can know what intervention we should do.

❖ CT Perfusion:

- ➢ 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. iIf <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 <u>acute stroke</u>, 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 penumbra means the tissue is at risk but is not yet necrotized.
- ➢ 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.





Cerebral blood <u>volume</u>

red areas mean very high flow = blood vessels.
blue or green areas are also blood flow but in different gradient.
look at the circled area it demonstrates very low blood flow or zero blood flow. this is the infarcted tissue (dead cells)

Cerebral blood <u>flow</u>

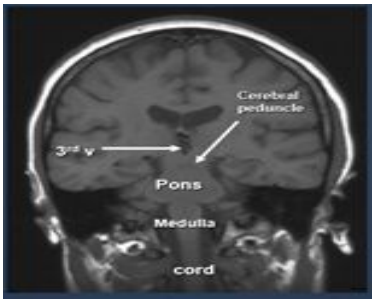
Here it shows a bigger hypoperfused area than cerebral blood volume. the black bigger circle demonstrates the hypoperfused area and if this patient starts on thrombolytic agents this hypoperfused area can go back to normal.

MRI

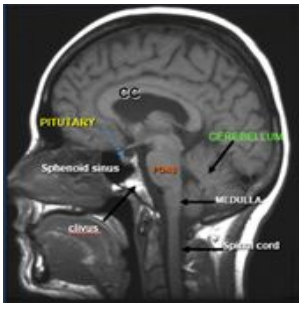
- **No ionizing radiation**
- **Patient preparation: Nil unless fasting for general anesthesia.**
- **Contrast medium: Gadolinium** we should evaluate every pt for renal function before injecting contrast.

Indications	Contraindications
Strokes **tumors** **infection** **Vascular disorders** **white matter disease** CT is not used in white matter diseases like pediatric congenital diseases and MS **some cases of trauma** unlike CT, MRI isn't usually used in trauma because it's time consuming	**cardiac pacemaker** was an absolute contraindication until 3-4 Years ago, now there are MRI compatible pacemakers, but since they don't use here yet we have to be cautious with pacemakers. **cochlear implants** **ocular prostheses** **intraocular ferrous foreign body** absolute CI !! **neurostimulators** **pregnancy (1st trimester)** relative CI **claustrophobia**

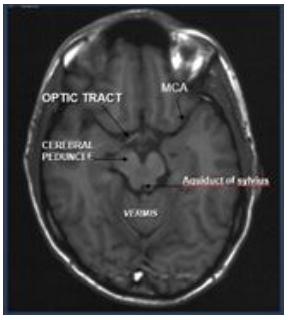
- **MRI is a multi-planar technique (can produce images in Sagittal, axial and coronal planes** directly unlike CT**) which is useful for assessment of extent of brain tumors and for better visualization of structures of posterior fossa and cranio-cervical junction.**
- **MRI is a multi-sequential technique (can create images in T1WI, T2WI, FLAIR, gradient and other sequences)**because of that MRI is more sensitive and better in diagnosing than CT but it is not used in acute settings.
- **It is possible to recognize flowing blood and therefore large arteries and veins stand out clearly without the need for contrast medium injection.**

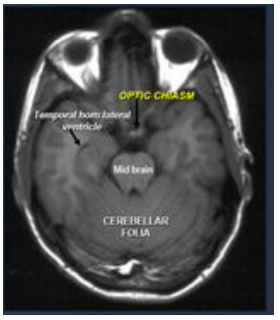


MRI BRAIN (CORONAL T1WI)
MRI gives a very clear evaluation of the brainstem

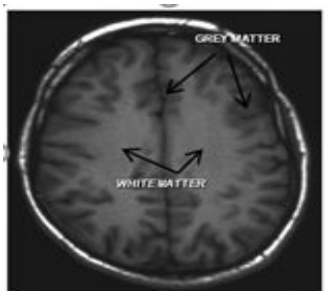


MRI BRAIN (SAGITTAL T1WI)

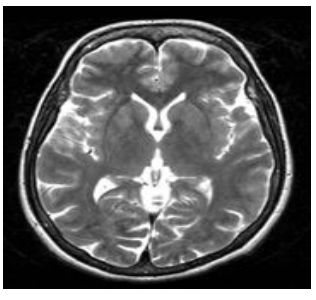




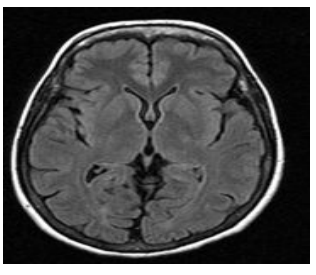
MRI BRAIN (AXIAL T1WI)
contrast between tissue (white and grey matter) is much greater in MRI, it shows the optic tract nicely and can even show blood vessels without the need of contrast material



MRI BRAIN (AXIAL T1WI)



T2WI



FLAIR

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

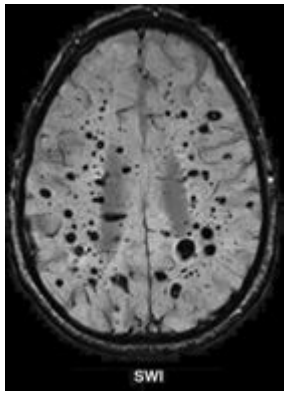
	Grey matter	White matter	CSF
T1WI	grey	light	dark
T2WI	light	dark	white
FLAIR	light	dark	dark

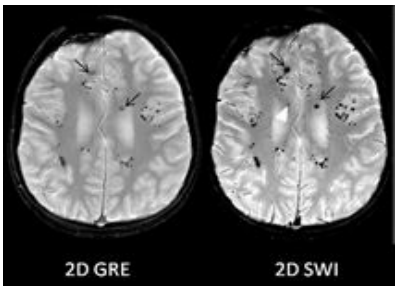
FLAIR stands for Fluid-attenuated inversion recovery, flair is like T2 except that in flair fluid is suppressed that's why it appears dark, flair only suppresses fluid within a free space (ventricles and subarachnoid space or fluid in a cyst) but not Interstitial fluid so if there is brian edema it will appear WHITE!! because of that flair is much more sensitive in detecting lesions than T2(all lesions in T2 are white so it's hard to distinguish them from CSF) MCQ.. also flair doesn't suppress turbulent fluids (hemorrhage and pus) completely. clear fluid like CSF is suppressed completely.

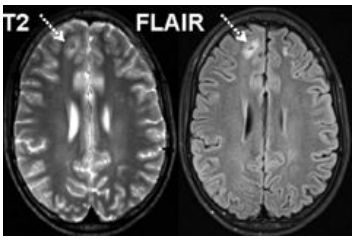
- **Susceptibility Weighted Sequence(SWI):** imp MCQ!! unlike T1,T2 and flair ,SWI poorly differentiates between brain tissue (grey matter, white matter and CSF) but it can detect lesions that contain iron and calcification even the small ones (blooming effect). very good in detecting micro-hemorrhages in pts w/ HTN and pts with cavernoma (vascular malformation).

Signal loss due to:

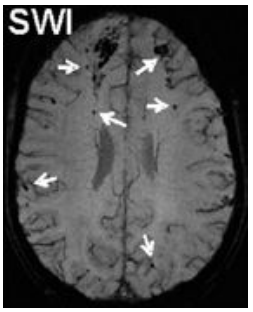
- Paramagnetic
- Diamagnetic
- Calcium
- Blood







☆



☆

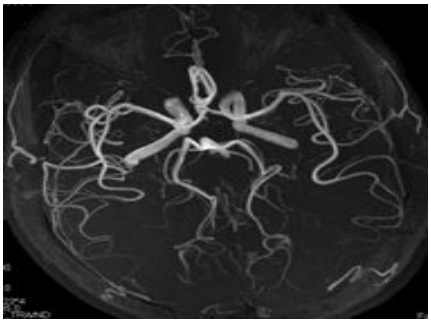
☆Patient post RTA with diminished level of consciousness the SWI shows multiple foci of dark signal intensity (blooming) at grey-white matter interface (not seen in T2WI and FLAIR) representing hemorrhagic diffuse axonal injuries. Very serious injury that happens in RTA due to acceleration-deceleration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

- **MR Angiography (MRA):**

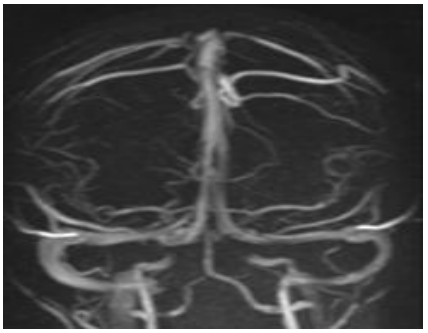
• Can be done without injection of contrast medium using time of flight technique.
• Can be used to assess intra and extra cranial arteries for any vascular abnormalities such as stenosis, occlusion or vascular malformation.

❖ **MR Venography (MRV):**

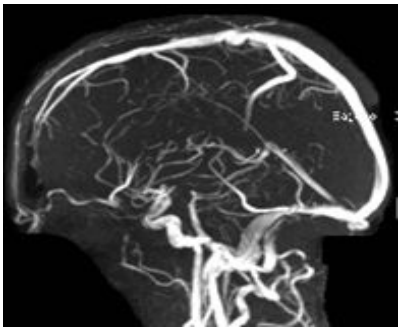
- Can be done either with or without injection of contrast medium. better to give contrast
- Assess venous dural sinuses, superficial and deep venous system.
- Can confirm presence of venous thrombosis.



MRA



MRV



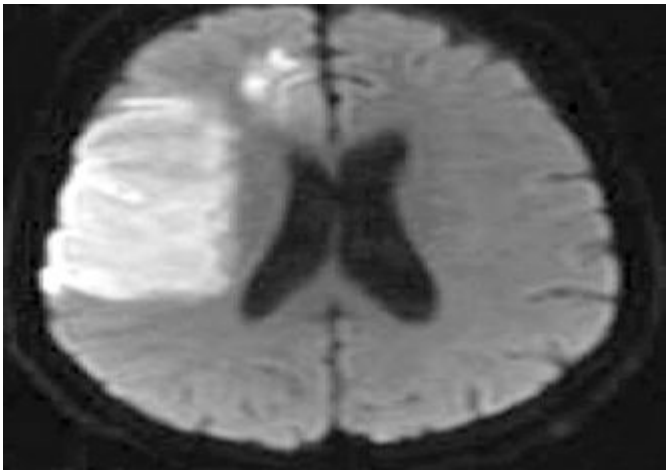
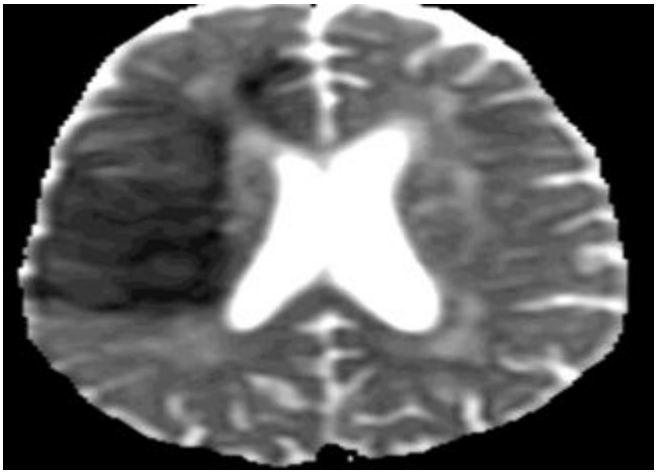
MRV

❖ **MRI 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.

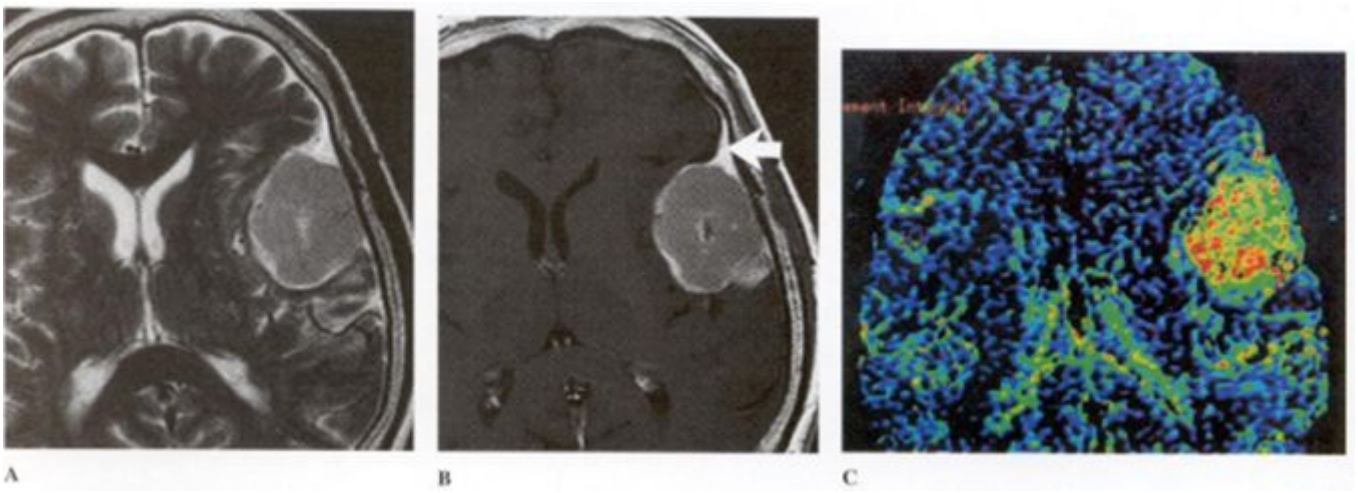
Very helpful in assessment of:

- Early brain infarction. can detect strokes within mins (CT after 6 h, T2 and flair after 2-3h)
- Brain abscess.
- Certain types of brain tumor.lymphoma,GBM,meningioma

to say that there is a diffusion restriction we should see two thing: DWI(diffusion weighted image) and ADC Map. the lesion must be white in DWI and dark in ADC map to be true diffusion restriction.

	
DWI	**ADC Map**

Meningioma



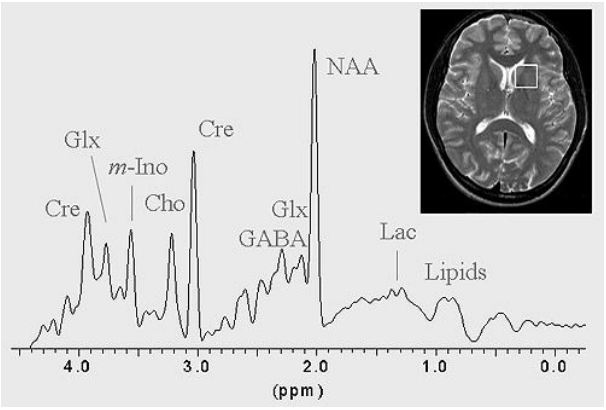
A:T2 B:Contrasted T1 C:Perfusion-Weighted

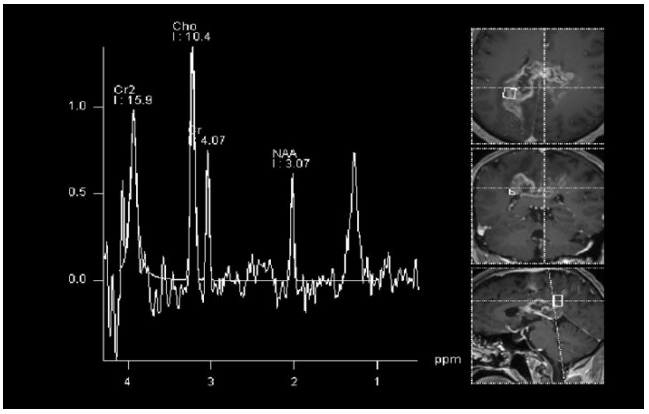
- **MR Spectroscopy:** it's a curve not an image

Unlike MRI, the technique of MRS does not generally produce images, instead creating spectra (see figure). Each peak in the spectrum arises from different brain metabolite (NAA, N-acetylaspartate; Cre, Creatine; Cho, Choline; *myo*I, *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.

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 neurodegenerative diseases.

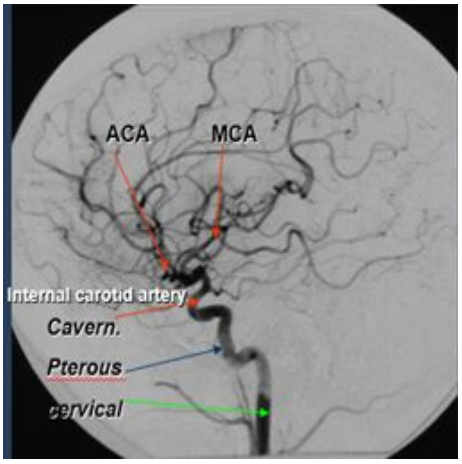
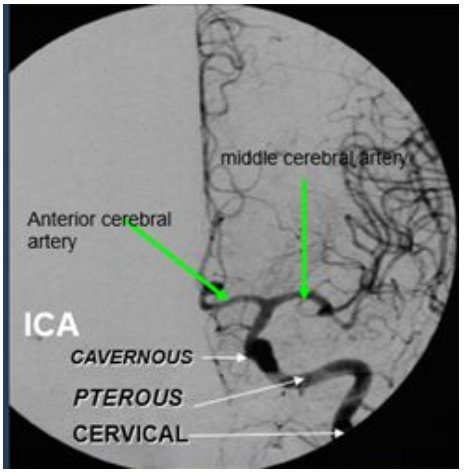
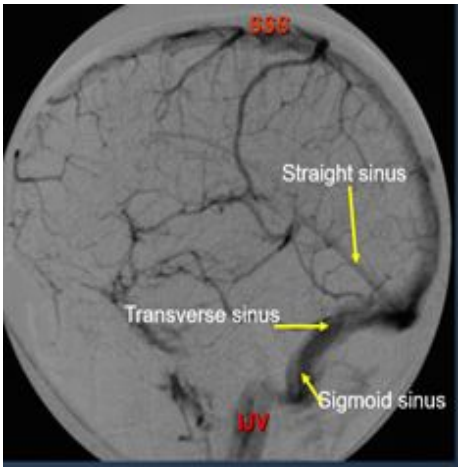




MR Spectroscopy in GBM

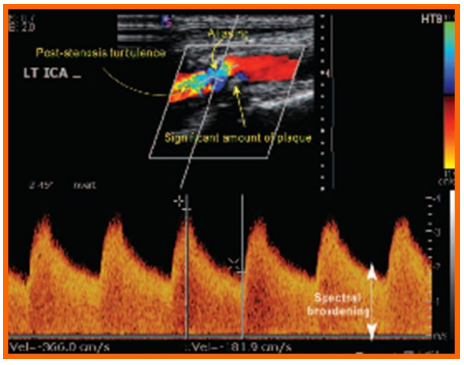
CEREBRAL ANGIOGRAM

- It is the gold standard technique for assessment of intra and extra cranial vessels.nowadays used only in management.
- 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 for intervention purposes such as treatment of vascular malformation (aneurysm/arteriovenous malformation) or pre operative embolization of vascular supply of tumor.

		
Internal carotid angiogram lateral view	**Internal carotid angiogram AP**	**VENOUS PHASE CEREBRAL ANGIOGRAM**

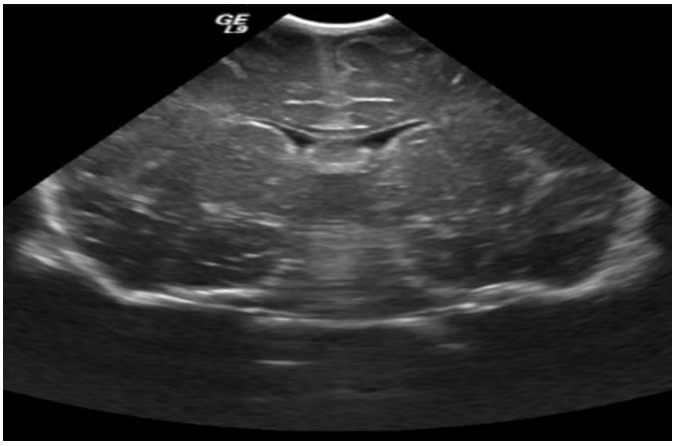
CAROTID DOPPLER

easiest and cheapest way to assess carotid narrowing and degree of narrowing.

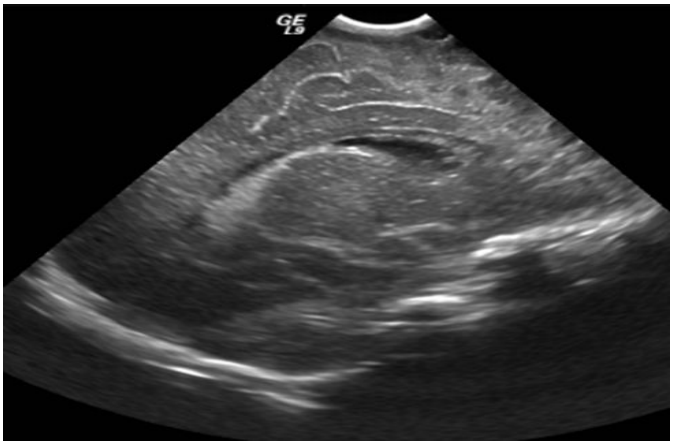


ULTRASOUND NEONATAL BRAIN

- **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 that is particularly useful in detecting ventricular dilatation (hydrocephalus), intracerebral hemorrhage and congenital abnormality of the brain.**



Coronal



Sagittal