Brain MRI

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Magnetic resonance imaging

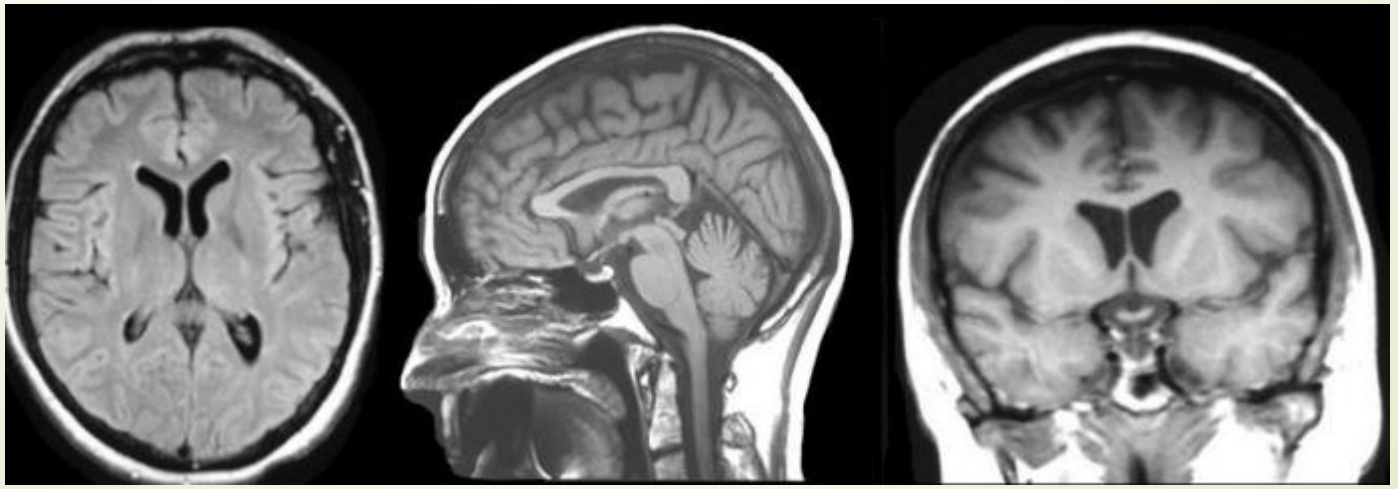
provides exquisite detail of brain, spinal cord and vascular anatomy

has the advantage of being able to visualize anatomy in all three planes: axial, sagittal and coronal

and has no beam-hardening artifacts such as can be seen with CT

Thus, the posterior fossa is more easily visualized on MRI than CT

performed without any ionizing radiation



LIMITATIONS OF MRI

- Subject to motion artifact
- detecting acute hemorrhage
- detection of bony injury
- Requires prolonged acquisition time for many images

NEUROLOGICAL INDICATIONS FOR CRANIAL MRI

- Vascular (ischemic and hemorrhagic stroke, AVM, aneurysm, venous thrombosis)
- Tumor (primary CNS and metastatic)
- Infection (abscess, cerebritis, encephalitis, meningitis)
- Inflammatory/Demyelinating Lesions (multiple sclerosis, sarcoidosis)
- Trauma (epidural hematoma, subdural hematoma, contusion)
- Hydrocephalus
- Congenital Malformations

MRI Physics

Most of the human body is made up of water molecules, which consist of hydrogen and oxygen atoms

At the centre of each hydrogen atom is a proton. Protons are like tiny magnets and are very sensitive to magnetic fields.

under the powerful, uniform, external magnetic field scanner, the protons line up in the same direction, . This alignment (or magnetization) is next perturbed or disrupted by introduction of an external Radio Frequency (RF) energy. The nuclei return to their resting alignment through various relaxation processes and in so doing emit RF energy. After a certain period following the initial RF, the emitted signals are measured

These signals provide information about the exact location of the protons in the body.

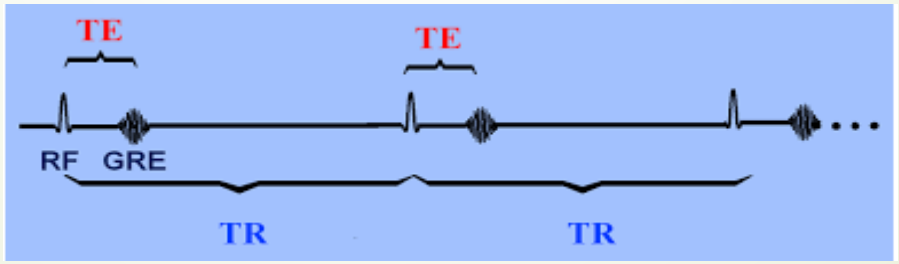
They also help to distinguish between the various types of tissue in the body, because the protons in different types of tissue realign at different speeds and produce distinct signals.

In the same way that millions of pixels on a computer screen can create complex pictures, the signals from the millions of protons in the body are combined to create a detailed image of the inside of the body.

Fourier transformation is used to convert the frequency information contained in the signal from each location in the imaged plane to corresponding intensity levels, which are then displayed as shades of gray in a matrix arrangement of pixels.

By varying the sequence of RF pulses applied & collected, different types of images are created.

Repetition Time (TR) is the amount of time between successive pulse sequences applied to the same slice. **Time to Echo (TE)** is the time between the delivery of the RF pulse and the receipt of the echo signal.



MRI IMAGING SEQUENCES

The most common MRI sequences are T1-weighted and T2-weighted

T1-weighted images

are produced by using short TE and TR times

The contrast and brightness of the image are predominately determined by T1 properties of tissue

the most 'anatomical' of images, resulting in images that most closely approximate the appearances of tissues macroscopically

In general, T1- and T2-weighted images can be easily differentiated by looking the CSF. *CSF is dark on T1-weighted imaging and bright on T2-weighted imaging*.

signal hyperintensity on T1WI

Fat : lipoma dermoid cyst

Methemoglobin : hemmorhage , thrombosed aneurysm

paramagnetic contrast media e.g. gadolinium-based agents

Melanin melanoma met

slow-flowing blood

proteinaceous fluid

calcium

copper

manganese

iron

T2-weighted images

are produced by using longer TE and TR times. In these images, the contrast and brightness are predominately determined by the T2 properties of tissue

Fluid Attenuated Inversion Recovery (Flair)

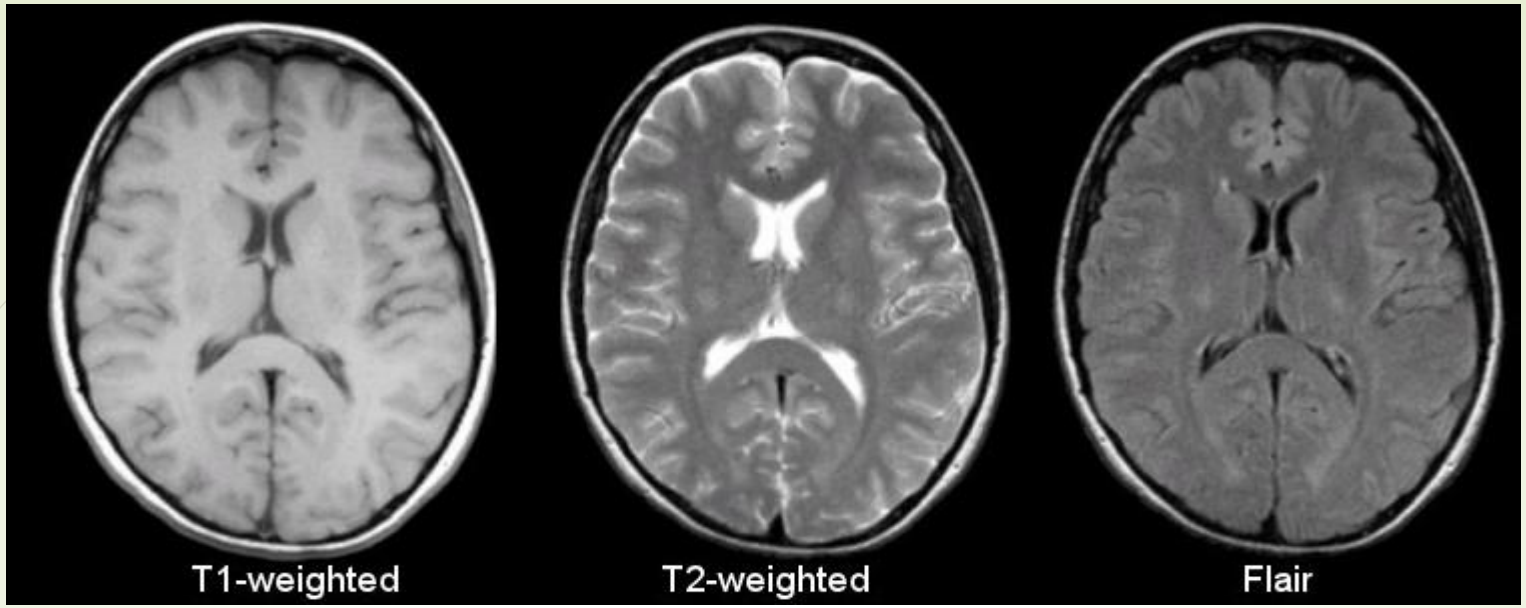
similar to a T2-weighted image except that the TE and TR times are very long.

By doing so, abnormalities remain bright but normal CSF fluid is attenuated and made dark. This sequence is very sensitive to pathology and makes the differentiation between CSF and an abnormality much easier

Similarly in the brain, we often want to detect parenchymal edema without the glaring high signal from CSF. To do this we suppress CSF

Importantly, at first glance FLAIR images appear similar to T1 (CSF is dark). The best way to tell the two apart is to look at the grey-white matter. T1 sequences will have grey matter being darker than white matter. T2 weighted sequences, whether fluid attenuated or not, will have white matter being darker than grey matter.

	TR (msec)	TE (msec)
T1-Weighted (short TR and TE)	500	14
T2-Weighted (long TR and TE)	4000	90
Flair (very long TR and TE	9000	114

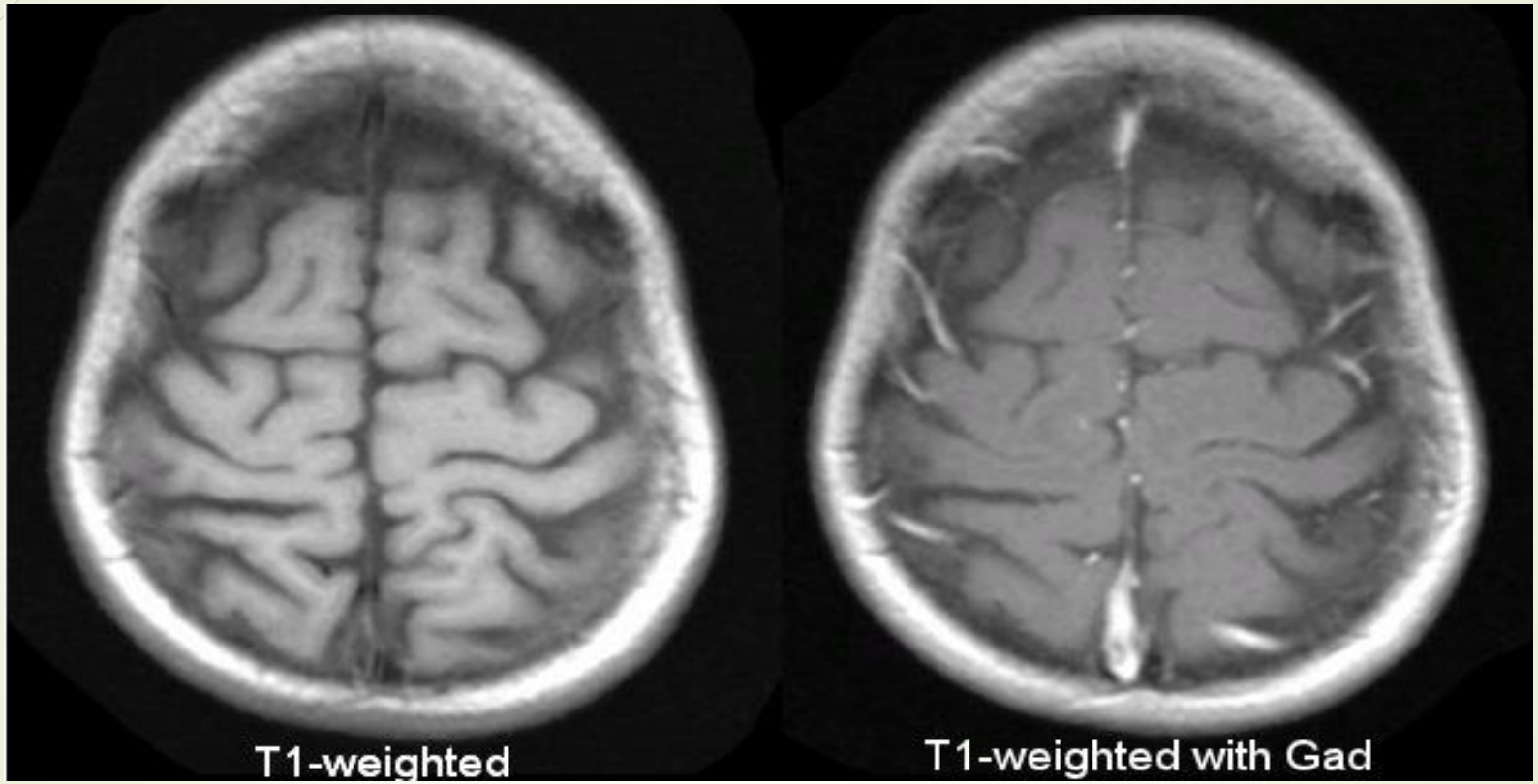


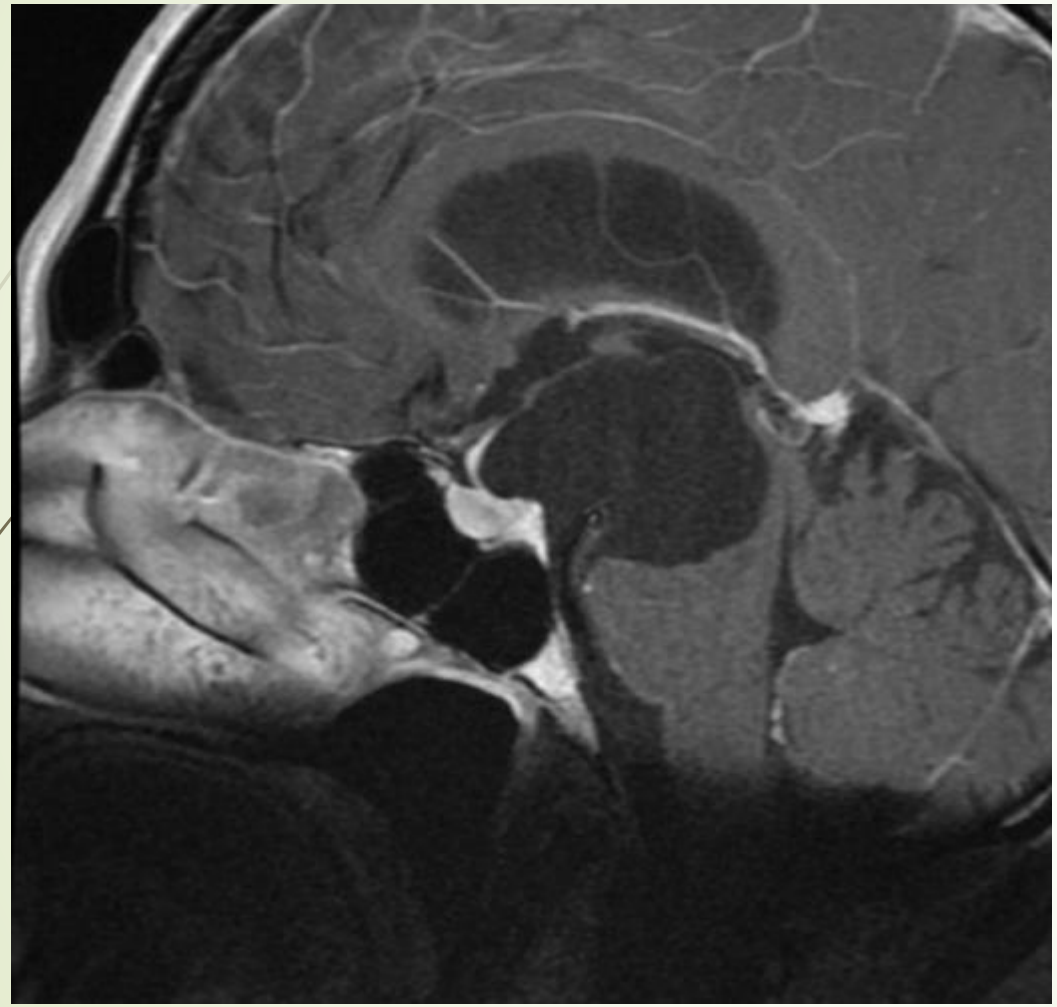
Tissue	T1-Weighted	T2-Weighted	Flair
CSF	Dark	Bright	Dark
White Matter	Light	Dark Gray	Dark Gray
Cortex	Gray	Light Gray	Light Gray
Fat (within bone marrow)	Bright	Light	Light
Inflammation (infection, demyelination)	Dark	Bright	Bright

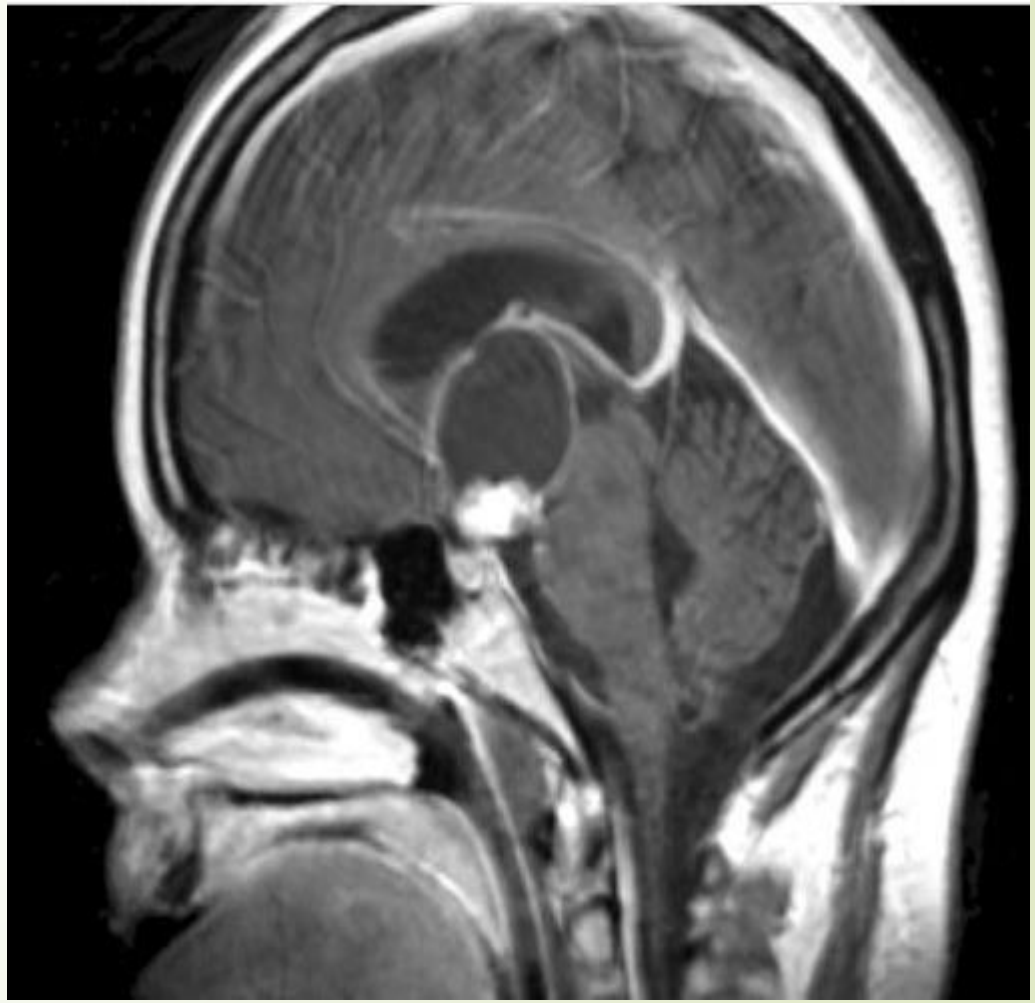
T1-weighted imaging can also be performed while infusing **Gadolinium (Gad)**.

Gad is a non-toxic paramagnetic contrast enhancement agent

When injected during the scan, Gad changes signal intensities by shortening T1. Thus, Gad is very bright on T1-weighted images. *Gad enhanced images are especially useful in looking at vascular structures and breakdown in the blood-brain barrier* [e.g., tumors, abscesses, inflammation (herpes simplex encephalitis, multiple sclerosis


T1-weighted
T1-weighted with Gad





Diffusion weighted imaging (DWI)

is designed to detect the random movements of water protons. Water molecules diffuse relatively freely in the extracellular space; their movement is significantly restricted in the intracellular space. Spontaneous movements, referred to as diffusion, rapidly become restricted in ischemic brain tissue. During ischemia, the sodium - potassium pump shuts down and sodium accumulates intracellularly. Water then shifts from the extracellular to the intracellular space due to the osmotic gradient. As water movement becomes restricted intracellularly, this results in an extremely bright signal on DWI. Thus, DWI is an extremely sensitive method for detecting acute stroke.

Clinical application

early identification of **ischemic stroke**

differentiation of **acute** from **chronic** stroke

differentiation of **acute stroke** from other stroke **mimics**

differentiation of **epidermoid cyst** from an **arachnoid cyst**

differentiation of **abscess** from **necrotic tumors**

assessment of cortical lesions in **Creutzfeldt-Jakob** disease (CJD)

differentiation of **herpes encephalitis** from **diffuse temporal gliomas**

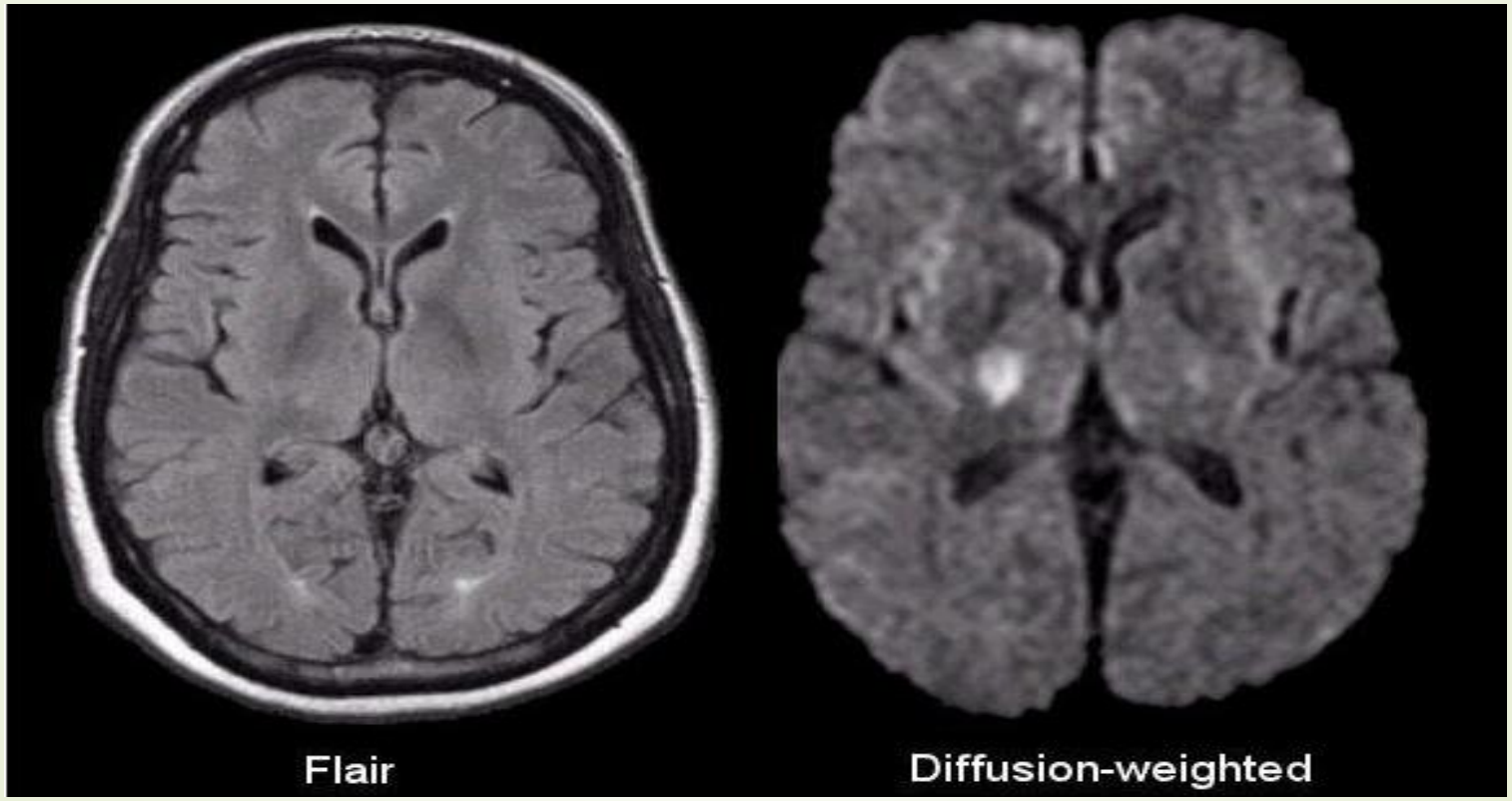
assessment of the extent of **diffuse axonal injury**

grading of diffuse **gliomas** and **meningiomas**

assessment of **active demyelination**

differentiation between **cholesteatoma** and **otitis media**

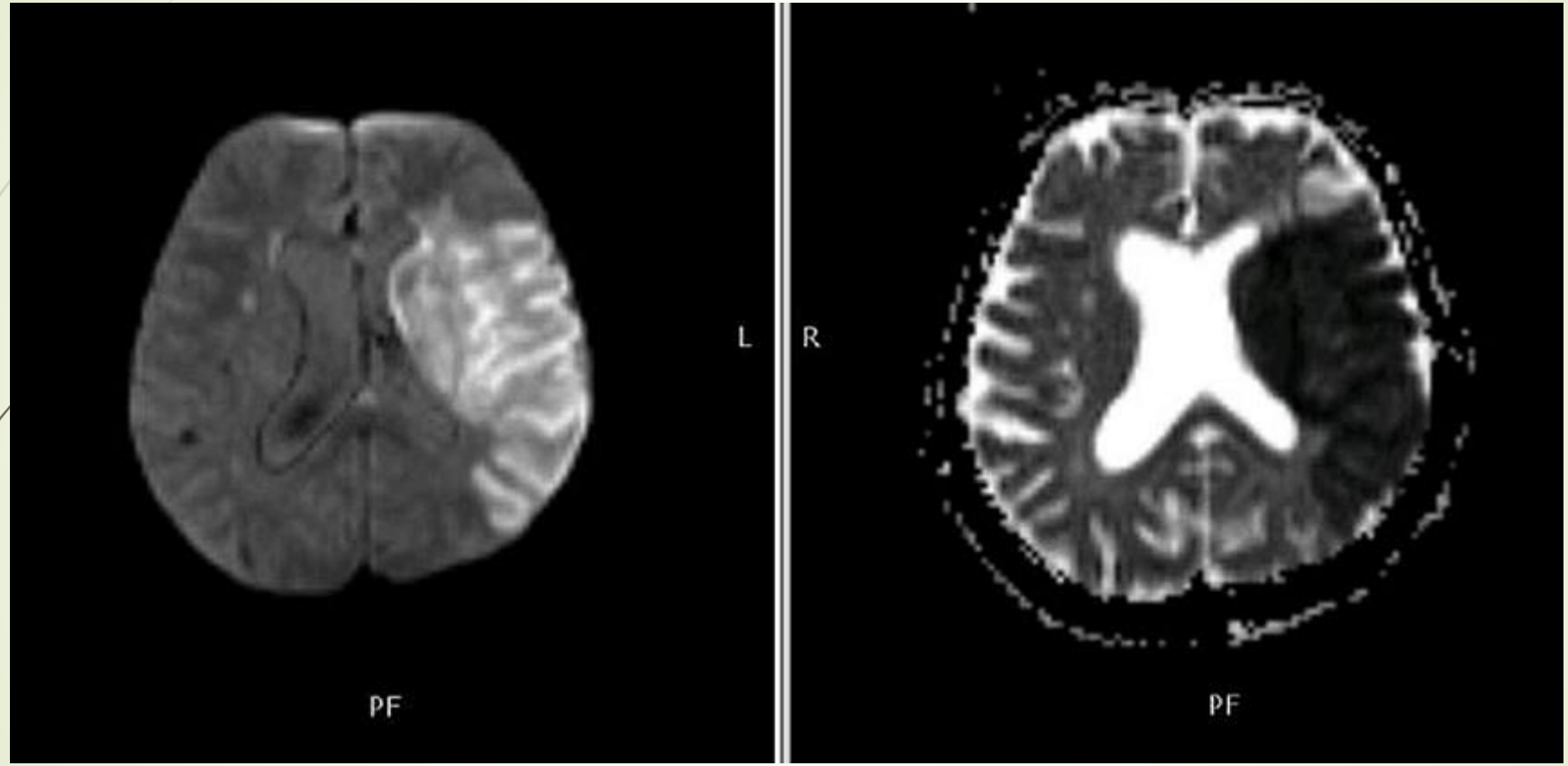
Comparison of Flair vs. Diffusion-weighted



Apparent diffusion coefficient

measure of the magnitude of diffusion (of water molecules) within tissue, and is commonly clinically calculated using MRI with diffusion-weighted imaging (DWI)

This impedance of water molecules diffusion can be quantitatively assessed using the apparent diffusion coefficient (ADC) value. This assessment can be done using different b values via changing gradient amplitude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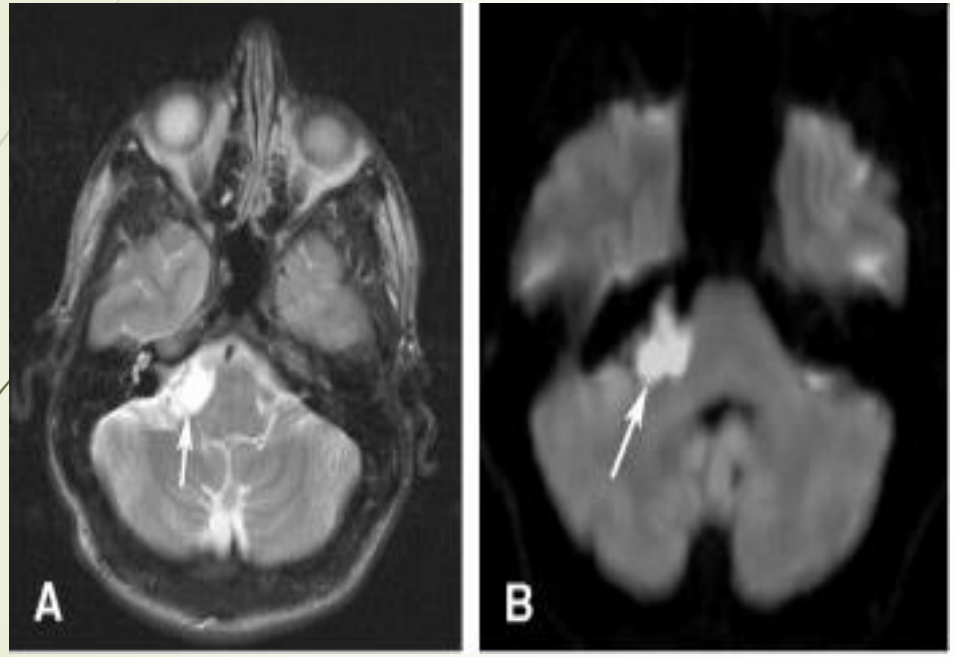
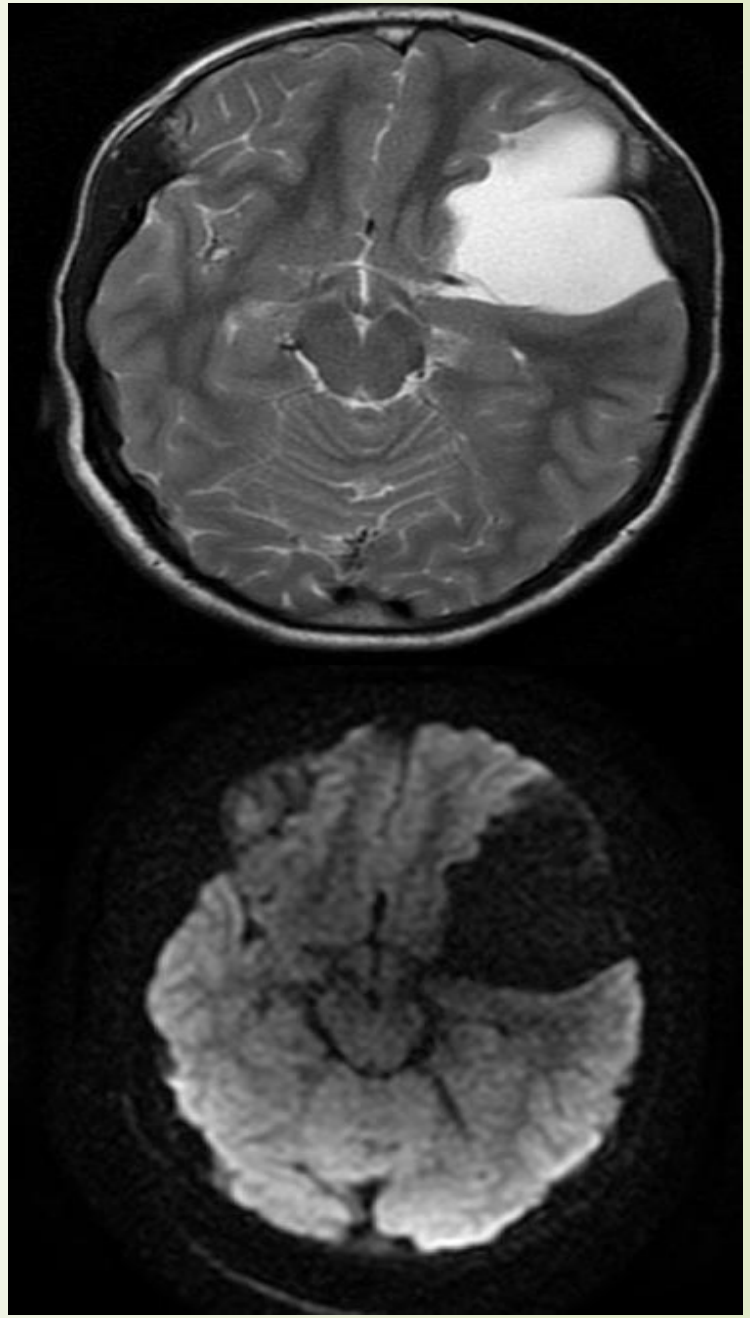

A
B



Susceptibility sensitive sequences

Being able to detect blood products or calcium is important in many pathological processes

MRI offers a number of techniques that are sensitive to these sort of compounds

Generally these sequences exploit what is referred to as T2* (T2 star) which is highly sensitive to small perturbations in the local magnetic field

The most sensitive of these sequences is known as susceptibility weighted imaging (SWI) and is also able to distinguish calcium from blood.

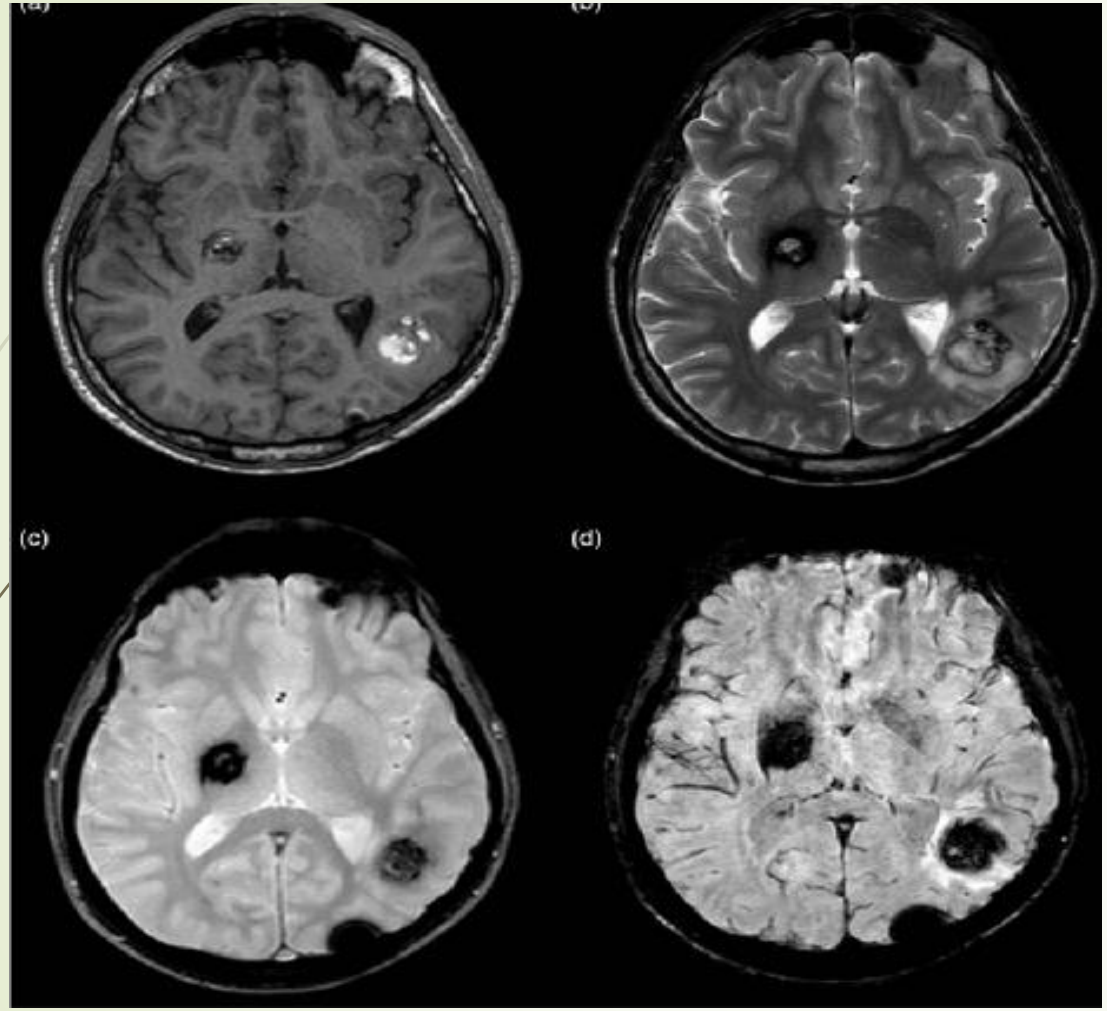
SWI

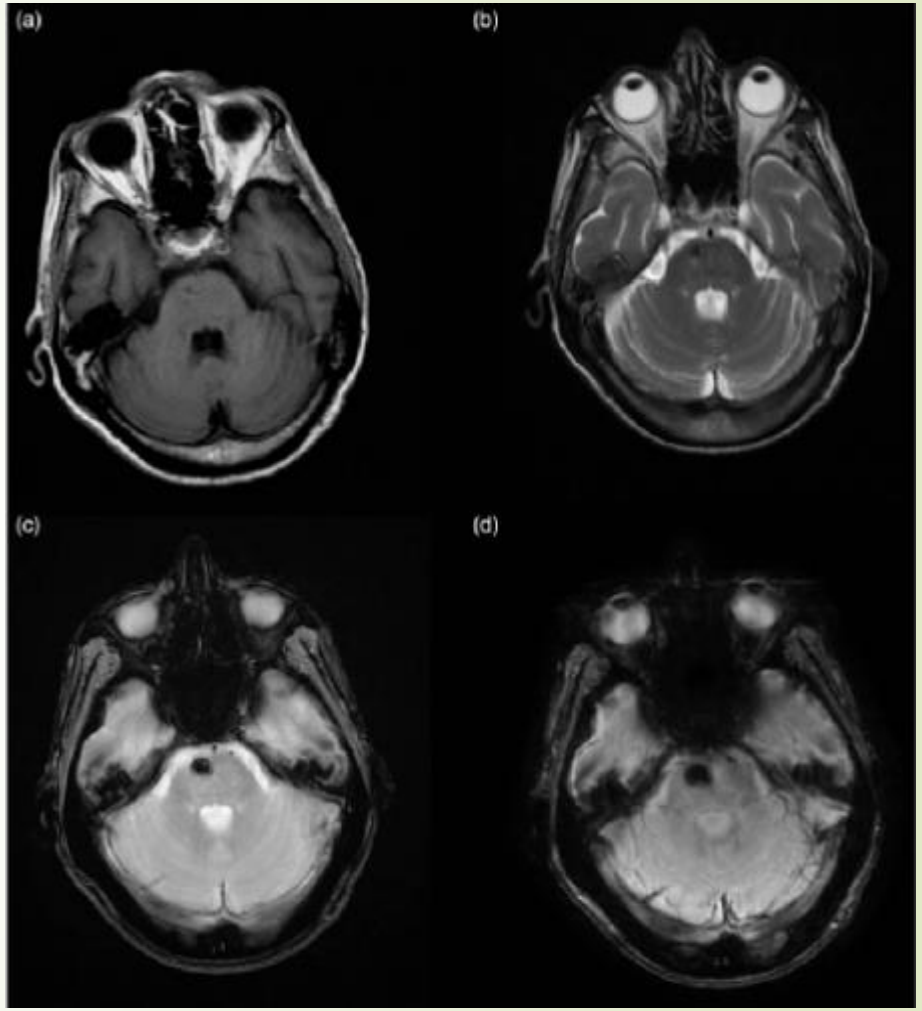
The most common use of SWI is for the identification of small amounts of hemorrhage/blood products or calcium, both of which may be inapparent on other MRI sequences.

They are also well suited to assess veins as deoxyhemoglobin results in both a loss in magnitude and a shift in phase

Distinguishing between calcification (made up primarily of calcium phosphate, but also containing very small amounts of copper (Cu), manganese (Mn), zinc (Zn), magnesium (Mg), and iron (Fe)) [3] and blood products is not possible on the post-processed SWI images as both demonstrate signal drop out and blooming.

The filtered phase images are, however, able to (in most cases) distinguish between the two as diamagnetic and paramagnetic compounds will affect phase differently (i.e. veins/hemorrhage and calcification will appear of opposite signal intensity


(c)
(d)


(a)
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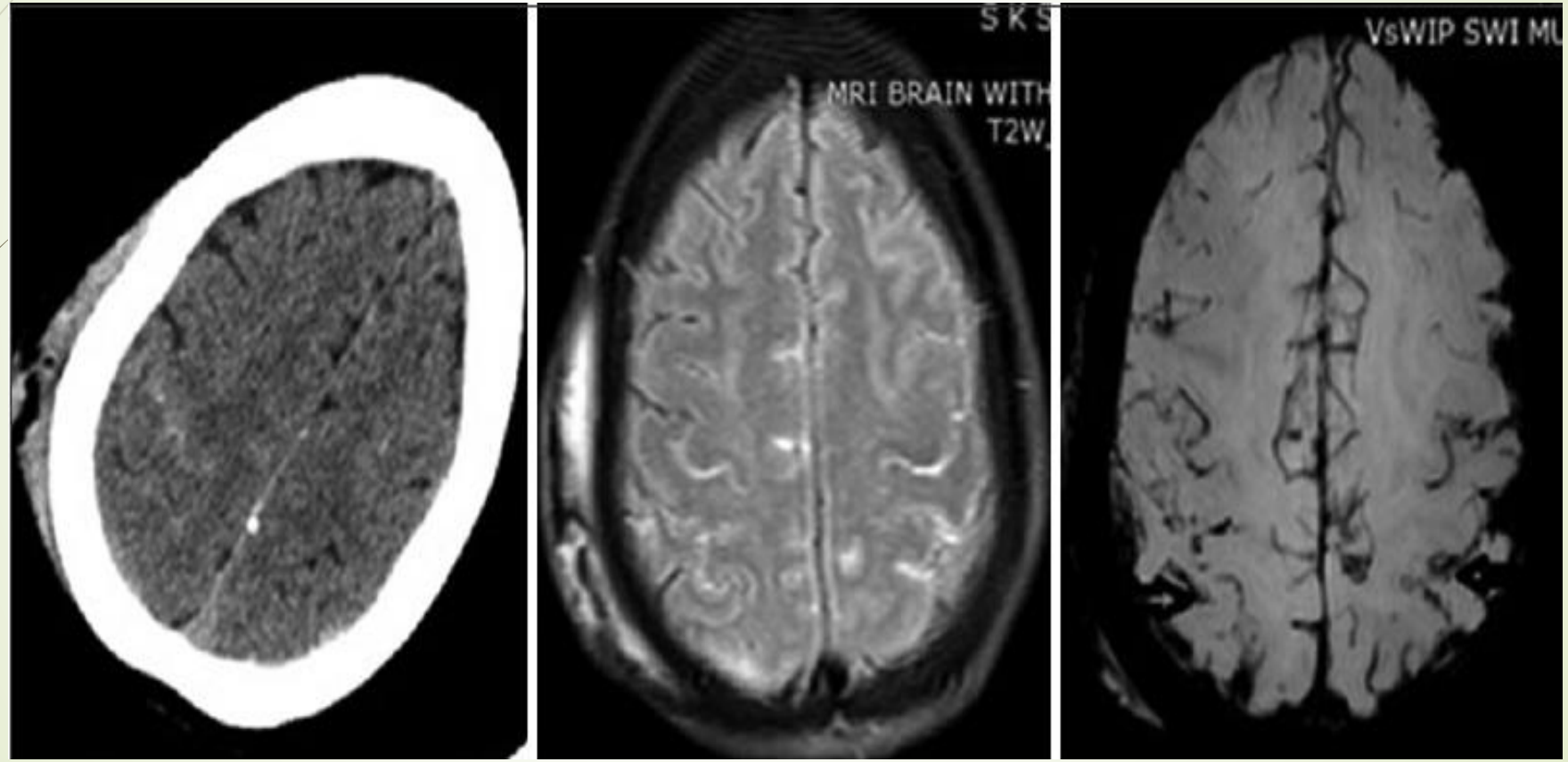

MRI BRAIN WITH
T2W
VsWIP SWI MU

Magnetic resonance angiography MRA

(usually shortened to **MR angiography** or to conventional angiography and CT angiography, eliminating the need for ionizing radiation and iodinated contrast media, and sometimes contrast media altogether. It has evolved into several techniques with different advantages and applications:

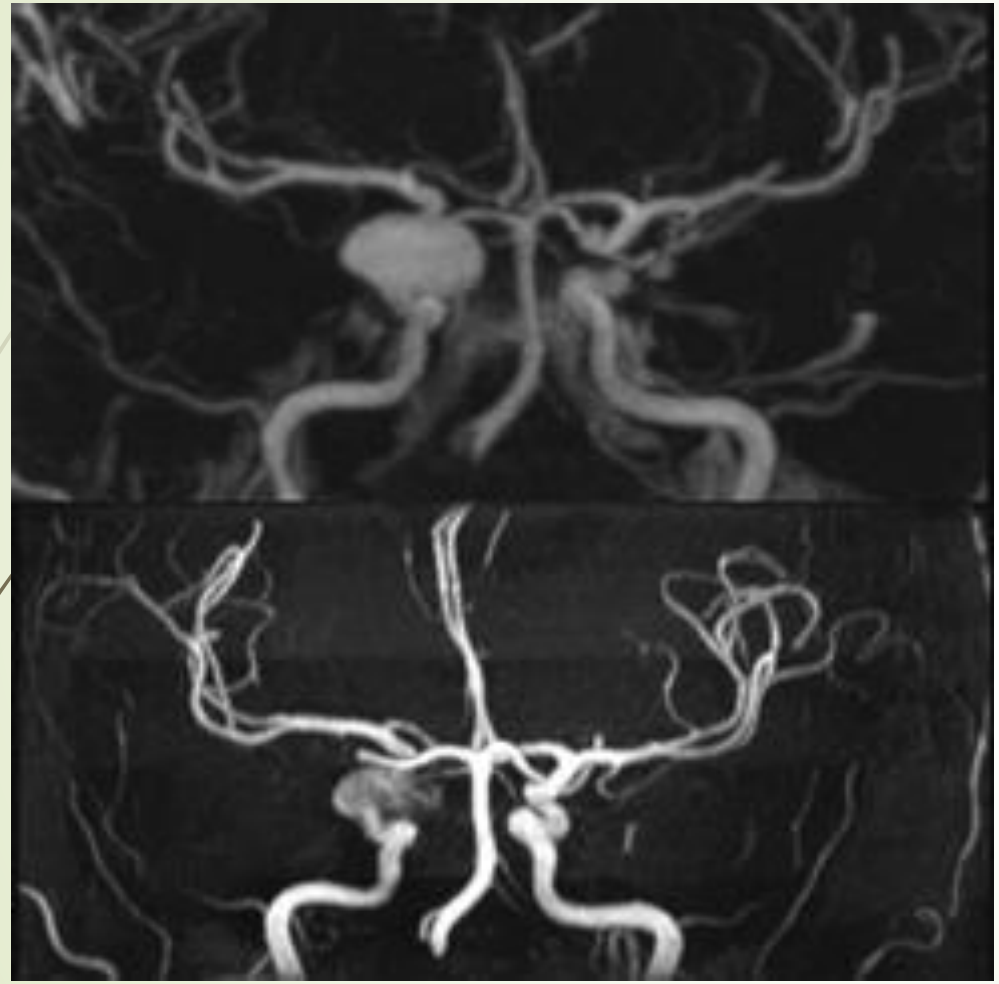
contrast enhanced MR angiography

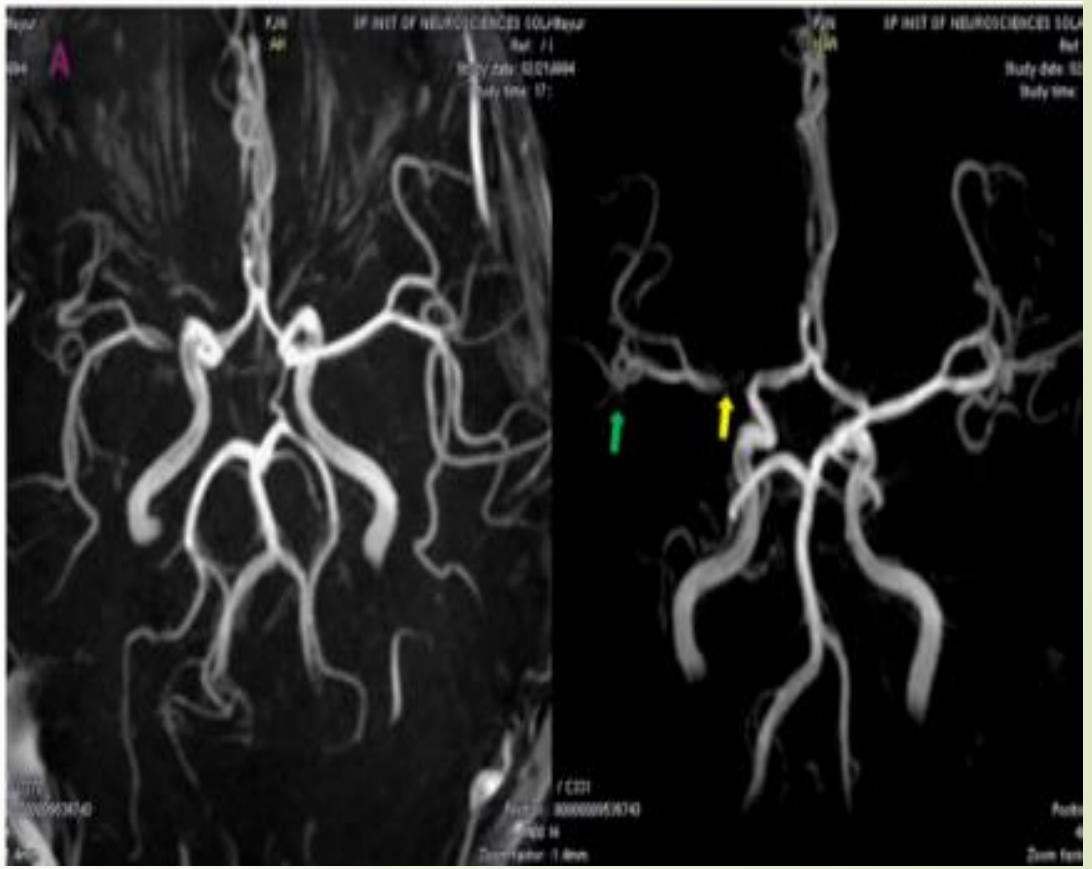
Non contrast enhanced MR angiography

time of flight angiography

phase contrast angiography

Generally, these techniques are time-consuming as compared with contrast enhanced MR angiography





MR cerebral venography MRV

assess patency of the dural venous sinuses and cerebral veins

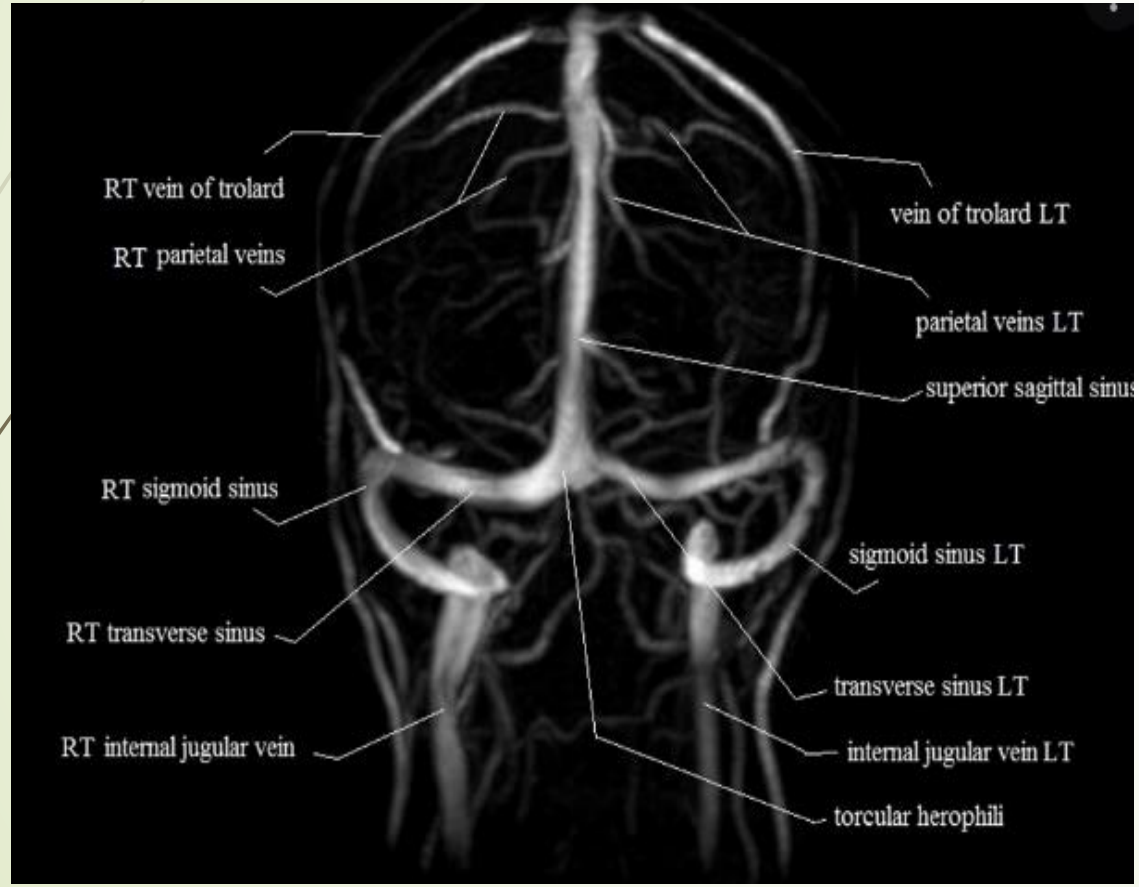
Suspected cerebral venous thrombosis is the primary indication. Preoperative assessment of anatomy, particularly for posterior fossa surgery where the sigmoid sinuses may be compressed (e.g. retrosigmoid craniotomies) may also warrant an MRV

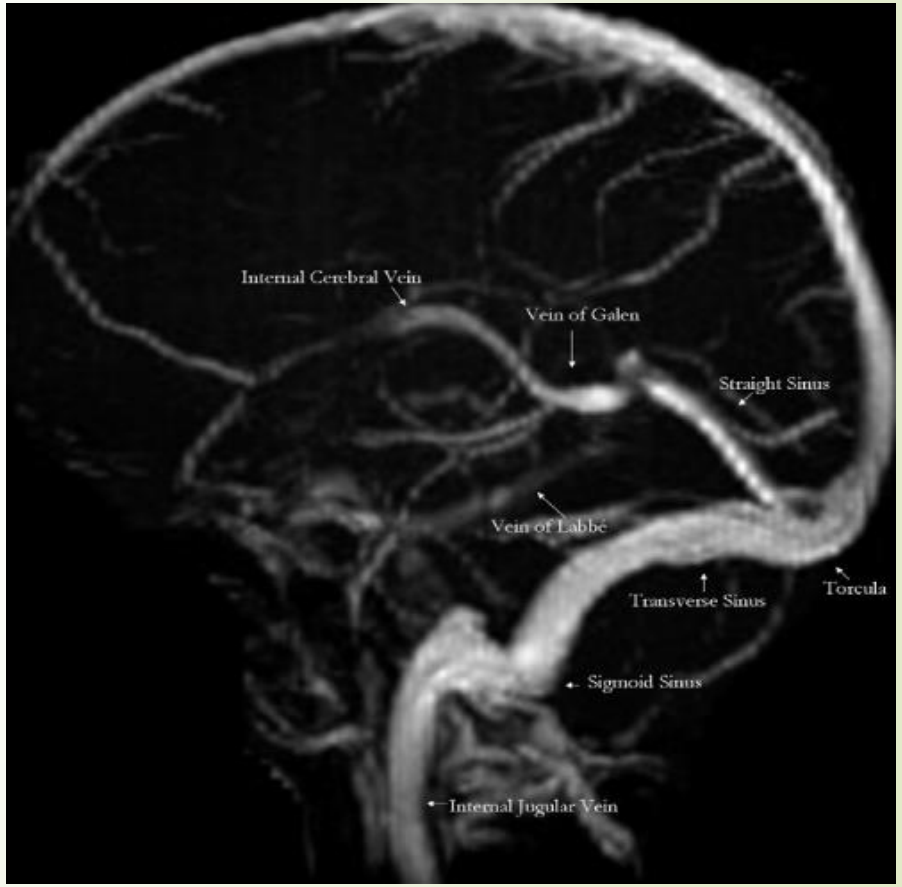
CT venography is a reliable and very rapid alternative exam, however it utilizes ionizing radiation and iodinated contrast media

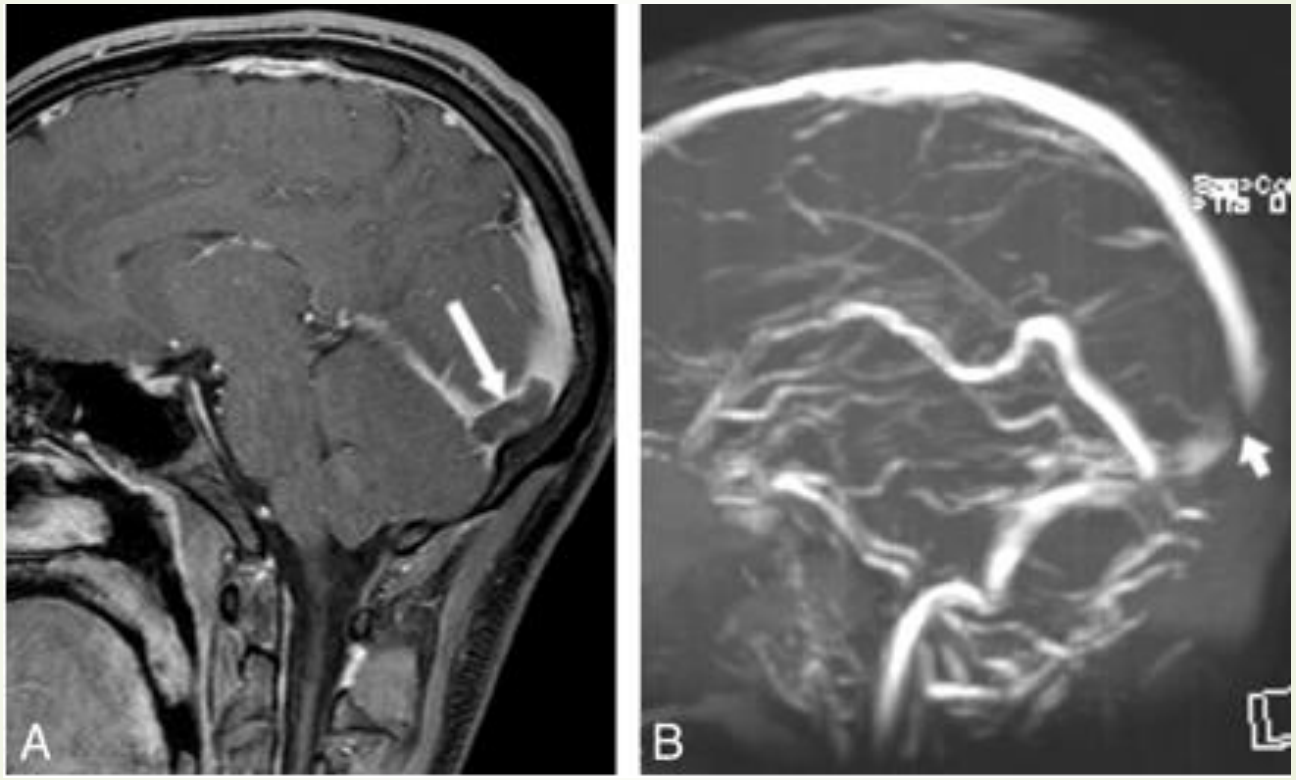
Non-contrast-enhanced flow related MRI

Contrast-enhanced MRV

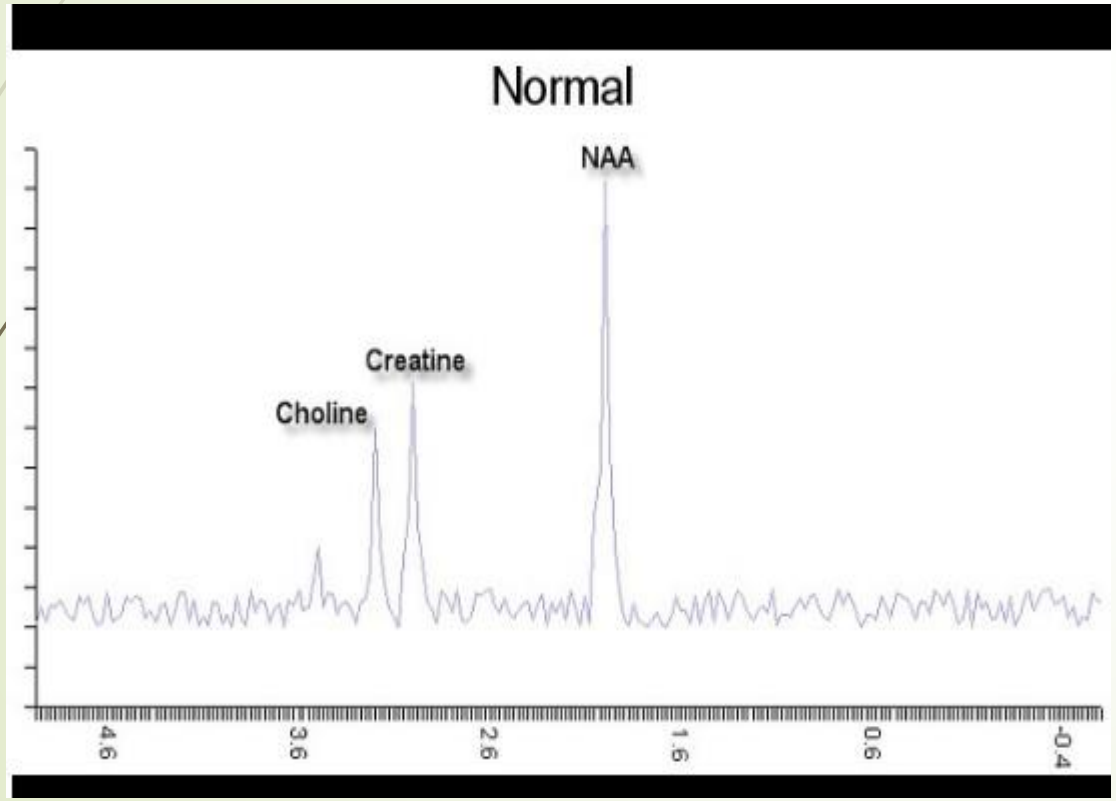
Contrast-enhanced dynamic MRV is more sensitive and specific in the diagnosis of intracranial venous sinus thrombosis than non-contrast techniques such as time of flight

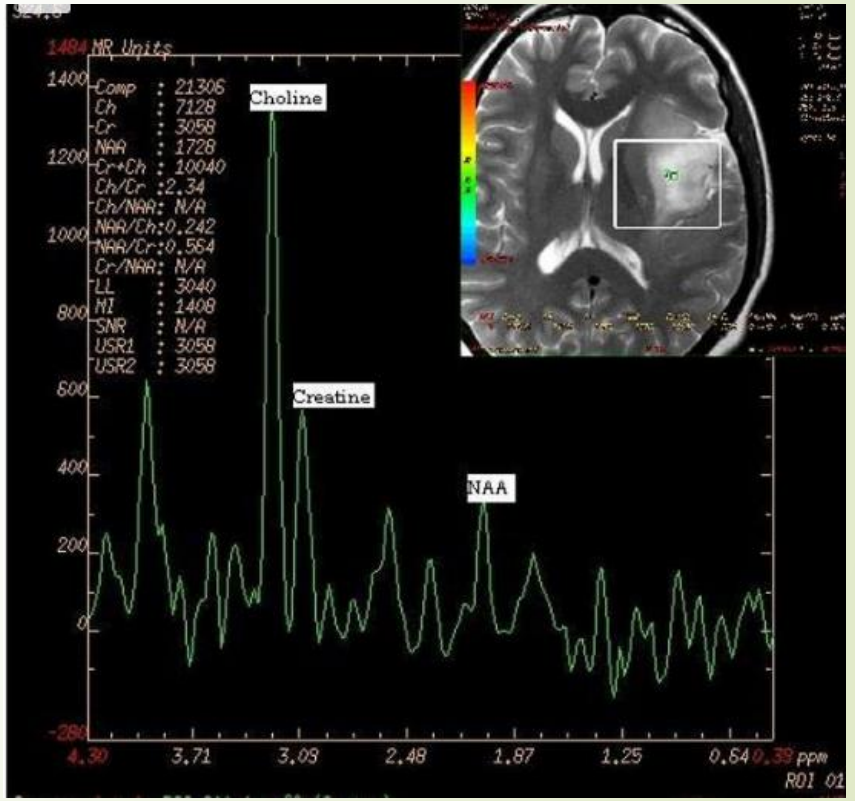

RT vein of trolard
RT parietal veins
vein of trolard LT
parietal veins LT
superior sagittal sinus
RT sigmoid sinus
sigmoid sinus LT
RT transverse sinus
transverse sinus LT
RT internal jugular vein
internal jugular vein LT
torcular herophili


Internal Cerebral Vein
Vein of Galen
Straight Sinus
Vein of Labbé
Transverse Sinus
Torcula
Sigmoid Sinus
Internal Jugular Vein


A
B

MR spectroscopy





CONTRAINDICATIONS TO MRI

There are few contraindications to MRI. Most contraindications to MRI can be divided into the following groups:

- Implanted devices and other metallic devices

- Pacemakers and other implanted electronic devices
- Aneurysm clips and other magnetizable materials
- Cochlear implants
- Some artificial heart valves

- Intraocular metallic foreign bodies