

NEWER MR TECHNIQUES & THEIR ROLE IN NEUROSURGERY

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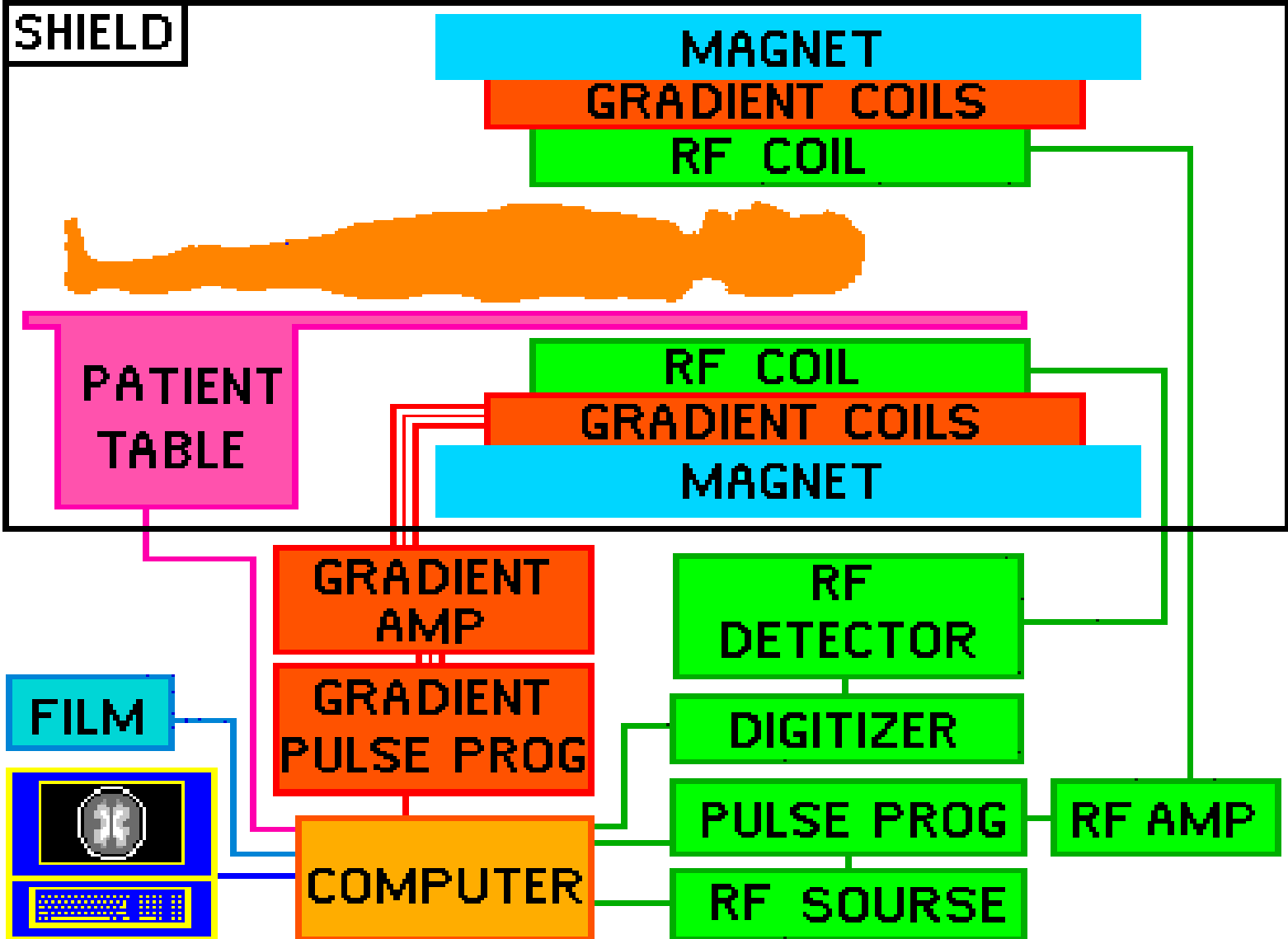
Moderators

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BASICS OF MRI

- Based on complex interaction between
 - Protons in human body
 - Magnetic field
 - Radiofrequency energy
- Object to be imaged is placed in a powerful, uniform magnetic field, (B_0).
- The spins of atomic Nuclei are characterized by
 - Nuclei align parallel or anti-parallel to B_0
 - Precession : Wobbling sort of motion undergone by spinning object ,frequency of precession is called the Larmor frequency.



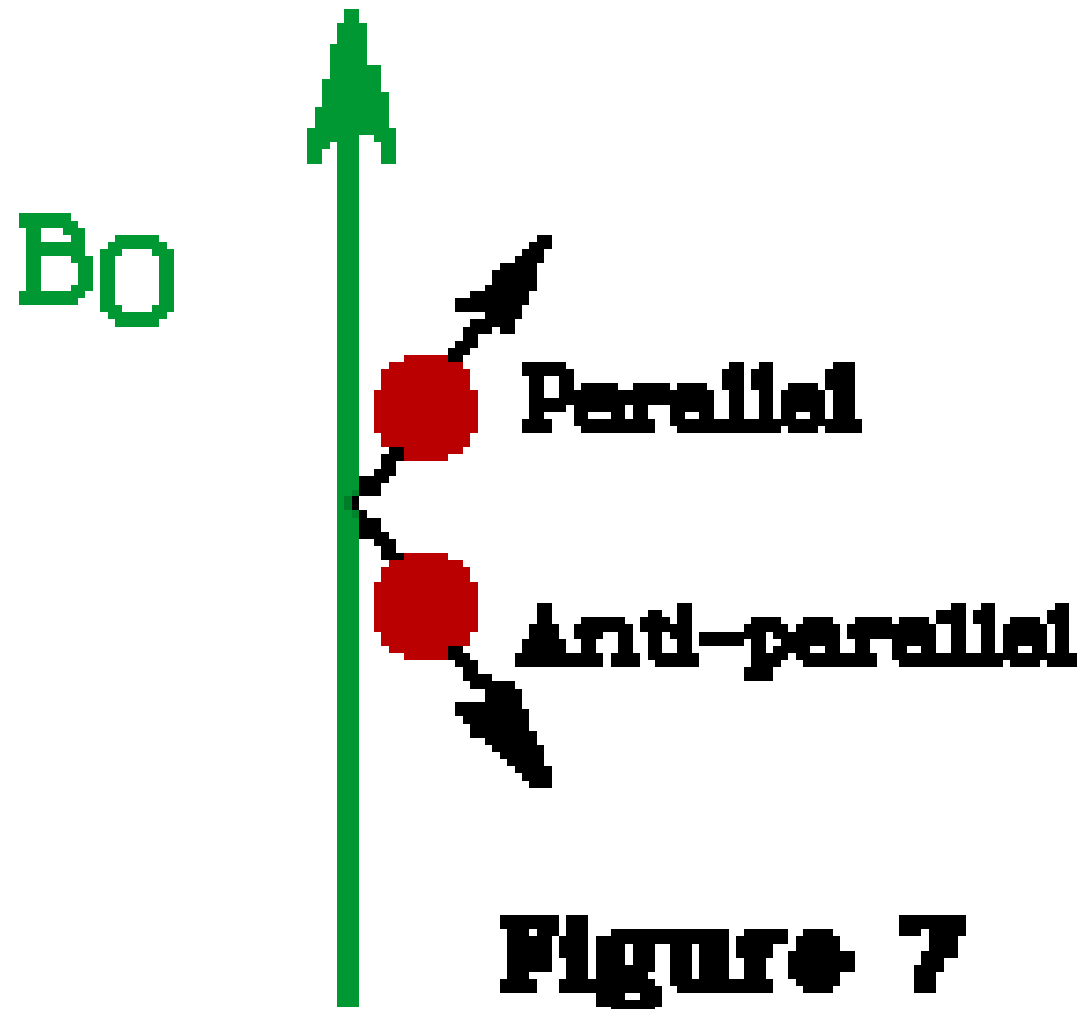
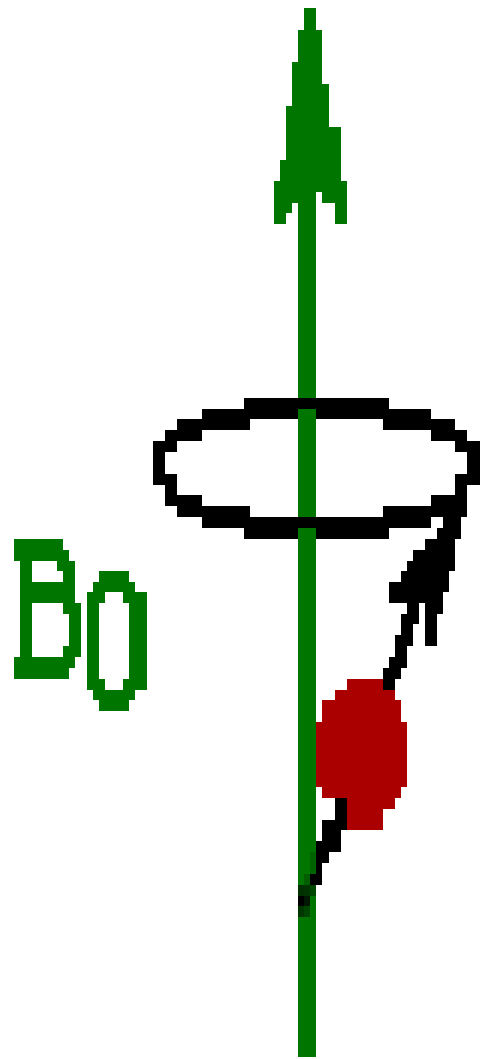


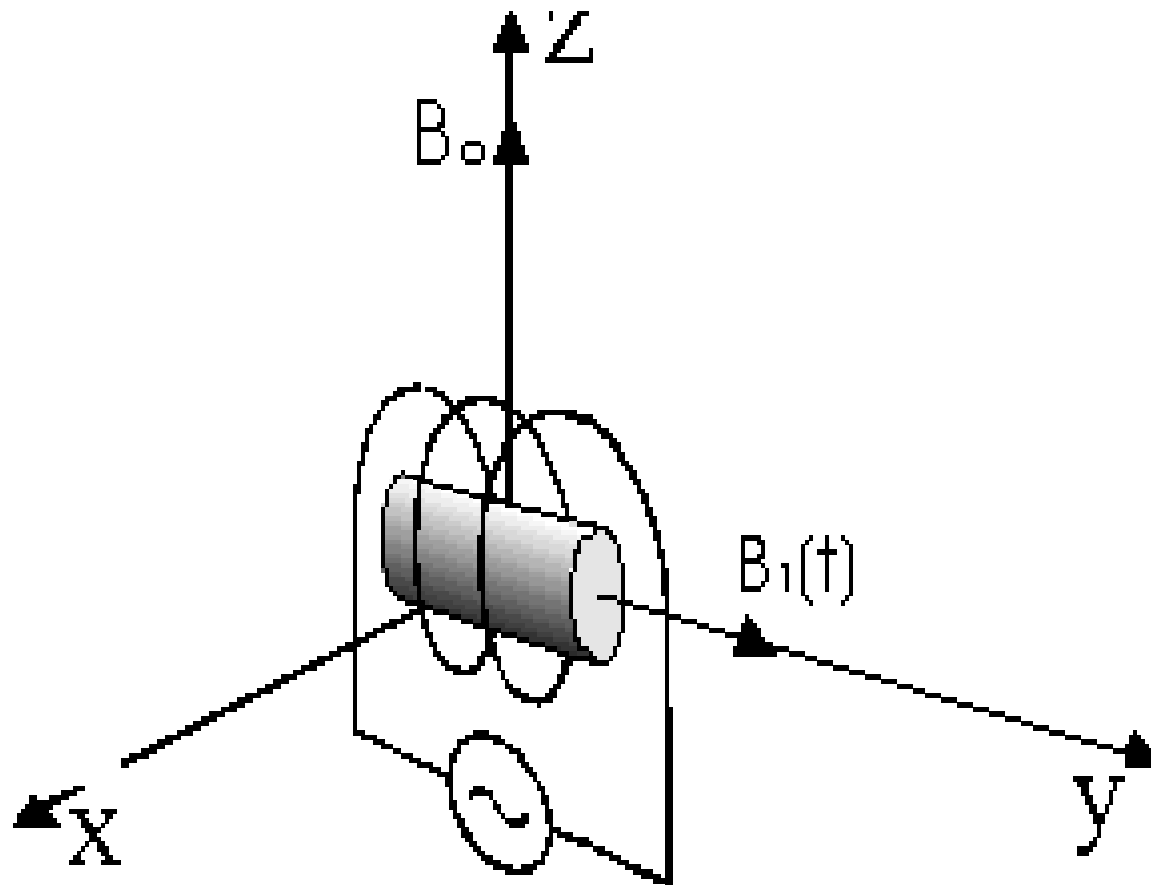
Figure 7



Precession

- Brief exposure to pulses of electromagnetic field B_1 (RF pulse at LARMOR frequency) at 90° to B_0 .
- As the RF pulse continues, the spins change lower energy to higher energy state.
- This leads to “tipping” of the net magnetization toward the transverse plane.
- Spins phases are coherent (aligned with each other).

- B1- Rf



- When R_f is shut off
 - Spins lose their phase coherence & the signal decays. This process is called transverse relaxation (because it happens while the spins are in the transverse plane).
 - Characterized by an exponential time constant, T_2 (tens to hundreds of ms).
- T_1 is time taken by protons to return to normal equilibrium (longitudinal relaxation).

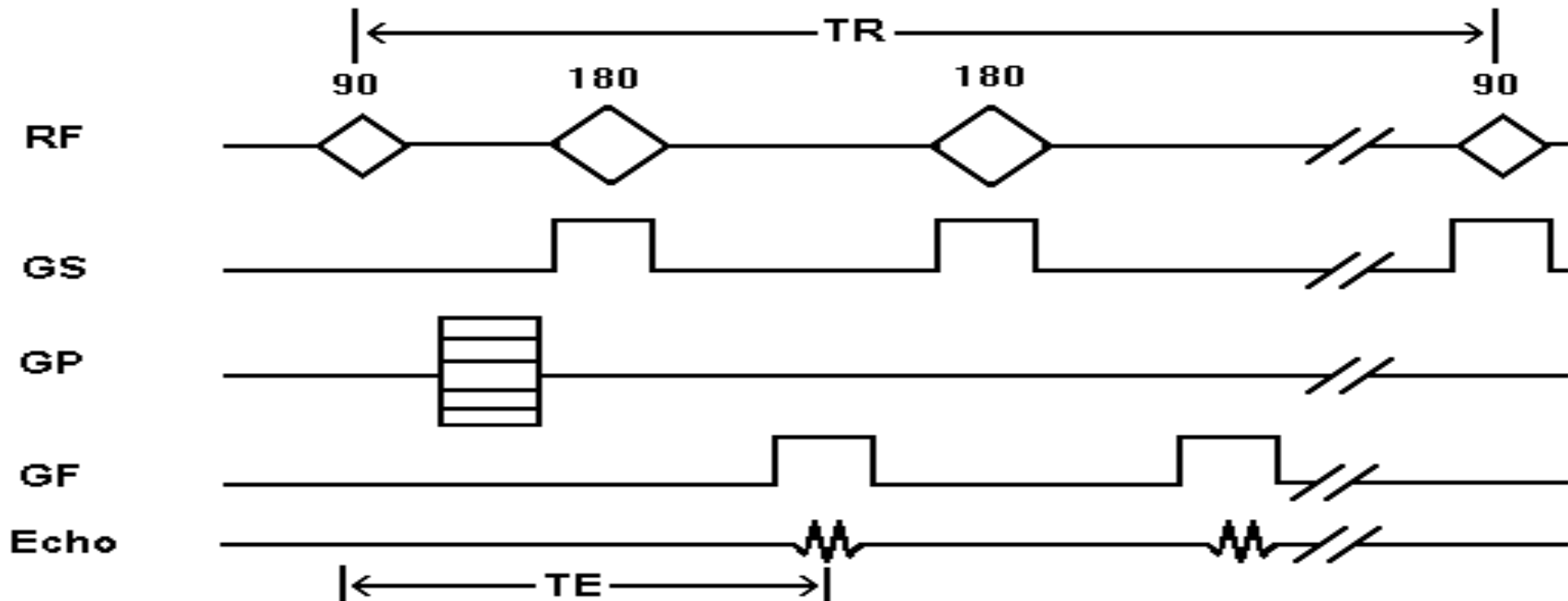
- The RF coil is switched from transmitter to receiver mode.
- The signal is digitized & stored for later processing.

BASIC TERMINOLOGY

- **SPIN ECHO**

- TR (Repetition Time): Interval between Rf pulses.
- TE (Echo time): Time between Rf pulse & signal reception.

Dual echo spin echo sequence



- T1 WI: TR & TE short
- T2 WI: TR & TE long
- T1 WI: Dark - Water, CSF, edema, Calcium
Bright - Lipid ,Gadolinium
- T2 WI: Dark - Calcium, bone
Bright - CSF, water, edema

The first MR image was published in 1973 and the first cross-sectional image of a living mouse was published in January 1974. The first studies performed on humans were published in 1977. By comparison, the first human X-ray image was taken in 1895.




Magnetic resonance imaging was developed from knowledge gained in the study of nuclear magnetic resonance. In its early years the technique was referred to as nuclear magnetic resonance imaging (NMRI). However, as the word *nuclear* was associated in the public mind with ionizing radiation exposure it is generally now referred to simply as MRI

The body is largely composed of water molecules which each contain two hydrogen nuclei or protons. When a person goes inside the powerful magnetic field of the scanner, the magnetic moments of these protons align with the direction of the field

A radio frequency electromagnetic field is then briefly turned on, causing the protons to alter their alignment relative to the field. When this field is turned off the protons return to the original magnetization alignment. These alignment changes create a signal which can be detected by the scanner. The frequency at which the protons resonate depends on the strength of the magnetic field.

The position of protons in the body can be determined by applying additional magnetic fields during the scan which allows an image of the body to be built up. These are created by turning gradient coils on and off which creates the knocking sounds heard during an MR scan.

Diseased tissue, such as tumors, can be detected because the protons in different tissues return to their equilibrium state at different rates. By changing the parameters on the scanner this effect is used to create contrast between different types of body tissue.

- **Fast spin echo:**  scan time by  efficiency of data collection. Collects multiple views in each TR time (echo train length).
- With increased efficiency image contrast may .
- To image uncooperative patient single shot FSE may be used.
 - T2*
 - **Inversion recovery** - allows to eliminate the signal of tissues according to their T1 time by choosing an appropriate TI.
 - FLAIR (Fluid attenuated inversion recovery)
 - STIR (Short tau inversion recovery)

- **GRADIENT ECHO - BASIS:**

- An excitation pulse with a flip angle lower than 90°

- No 180° rephasing pulse

- TR is very short and scan time very less (sec).

- » Visualize hemosiderin and ferritin

- » MRA

- » CISS (Constructive interference in steady state).

- **ECHOPLANAR IMAGING:**

- Single excitation used to collect all multiple images(40ms).

- Used in applications highly sensitive to even minor patient movement.

USED IN:

- ❖ Diffusion MR
- ❖ Perfusion MR
- ❖ Functional MR

***T1*-weighted MRI**

- *T1*-weighted scans use a (GRE) sequence, with short *TE* and short *TR*. This is one of the basic types of MR contrast and is a commonly run clinical scan. The *T1* weighting can be increased (improving contrast) with the use of an inversion pulse as in an MP-RAGE sequence. Due to the short repetition time (*TR*) this scan can be run very fast allowing the collection of high resolution 3D datasets. A *T1* reducing gadolinium contrast agent is also commonly used, with a *T1* scan being collected before and after administration of contrast agent to compare the difference. In the brain *T1*-weighted scans provide good gray matter/white matter contrast.

T2-weighted MRI

- *T2-weighted* scans use a spin echo (SE) sequence, with long *TE* and long *TR*. They have long been the clinical workhorse as the spin echo sequence is less susceptible to inhomogeneities in the magnetic field. They are particularly well suited to edema as they are sensitive to water content (edema is characterized by increased water content)

T^*2 -weighted MRI

- T^*2 (pronounced "T 2 star") weighted scans use a (GRE) sequence, with long TE and long TR . The gradient echo sequence used does not have the extra refocusing pulse used in spin echo so it is subject to additional losses above the normal $T2$ decay (referred to as $T2'$), these taken together are called T^*2 . This also makes it more prone to susceptibility losses at air/tissue boundaries, but can increase contrast for certain types of tissue, such as venous blood.

Spin density weighted MRI

- Spin density, also called proton density, weighted scans try to have no contrast from either $T2$ or $T1$ decay, the only signal change coming from differences in the amount of available spins (hydrogen nuclei in water). It uses a spin echo or sometimes a gradient echo sequence, with short TE and long TR .

DIFFUSION MRI

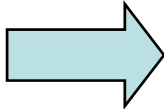
- Based on echo planar imaging.
- Assesses microscopic motion of water.
- Restriction of motion appears as high signal intensity.
- Water molecules that are not “restricted” will have greater net diffusion over a given period of time than water molecules surrounded by cell organelles membranes, large proteins etc.

- In the first few minutes after vascular occlusion, cytotoxic edema develops.
- Shift of water molecules into the intracellular compartment.
- Diffusion characteristics of the hydrogen ions in the ischemic brain decrease (increase in restriction (barriers) to water diffusion).
- Precipitous drop in the apparent diffusion coefficient (ADC). ADCs in ischemic areas are lower by 50% or more than those of normal brain areas.
- Diffusion Weighted Images (DWI) are constructed.

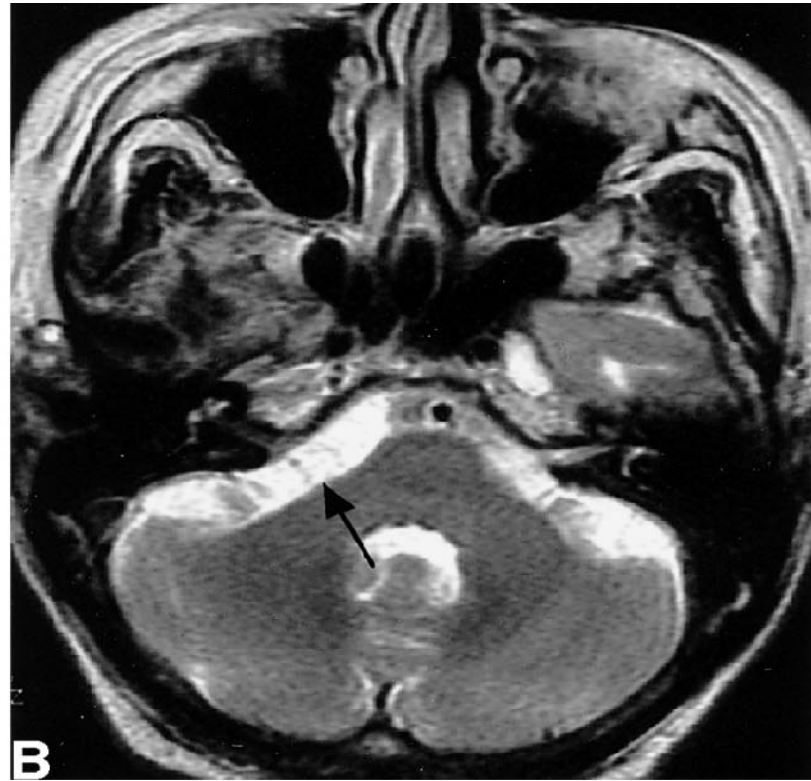
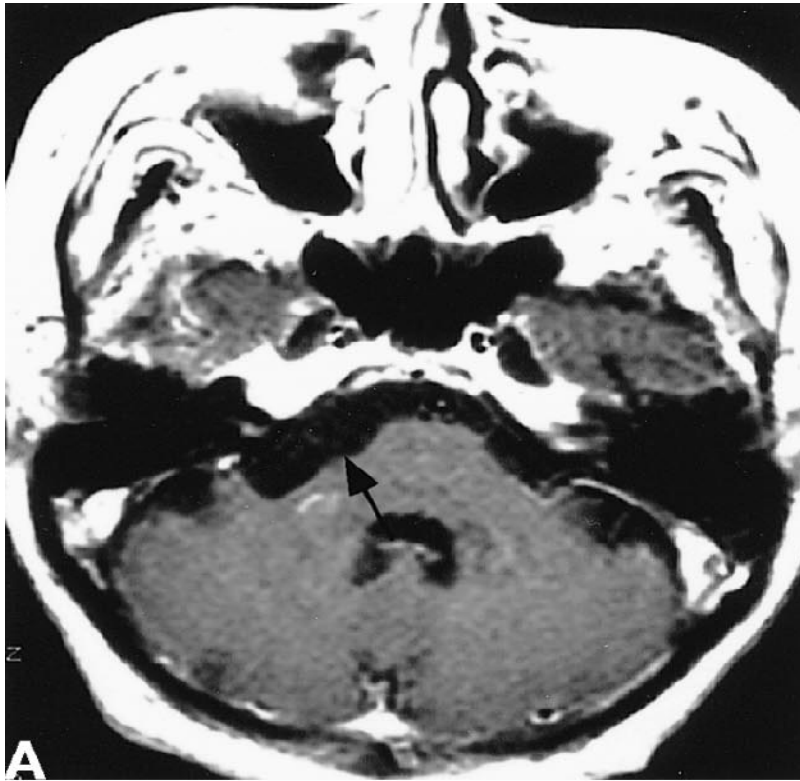
USES

- DWI is highly sensitive in identifying hyperacute(0-6hr) & acute infarction(6-24hr), within minutes of occlusion, while conventional MRI takes 6-10 hours. MRI can help to define :
 - acutely ischemic region (DWI)
 - the tissue at risk for further ischemia (PWI)
 - vascular anatomy (MRA)
- Abscess shows : decreased diffusion & increased signal intensity.

- DWI can discriminate brain abscess from necrotic or cystic tumors (low SI, high apparent diffusion coefficient (ADC))
 - Abscess cavity: numerous WBCs & proteinaceous fluid with high viscosity.
 - Restricted diffusion -low ADC values high signal intensity on DWI.
 - In contrast, the cystic or necrotic portions of brain tumors : less cellular and have less viscous fluid consistency.
 - Tumors show low signal intensity on DWI and higher ADC values.

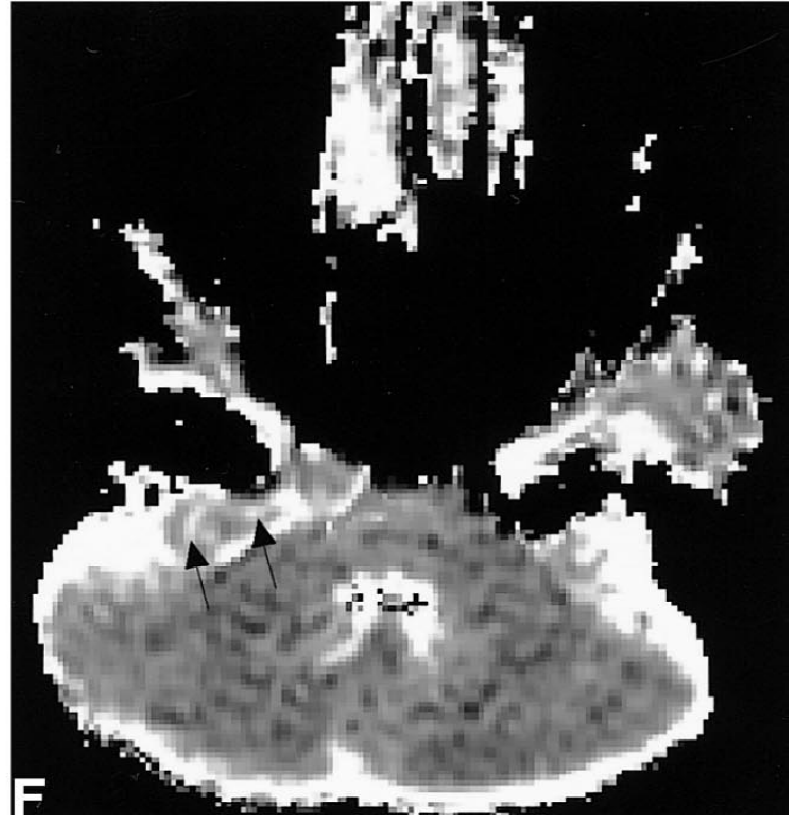
- DWIs allow easier differentiation of the
 - Arachnoid cyst vs epidermoid
 - CSF contents of arachnoid cysts  signal intensity on DWI is low
 - Epidermoid cysts have a high signal on DWI.

Epidermoid



, Contrast-enhanced T1-weighted (400/8/2 [TR/TE/excitations]) (A), fast T2-weighted (3000/98/2) (B)

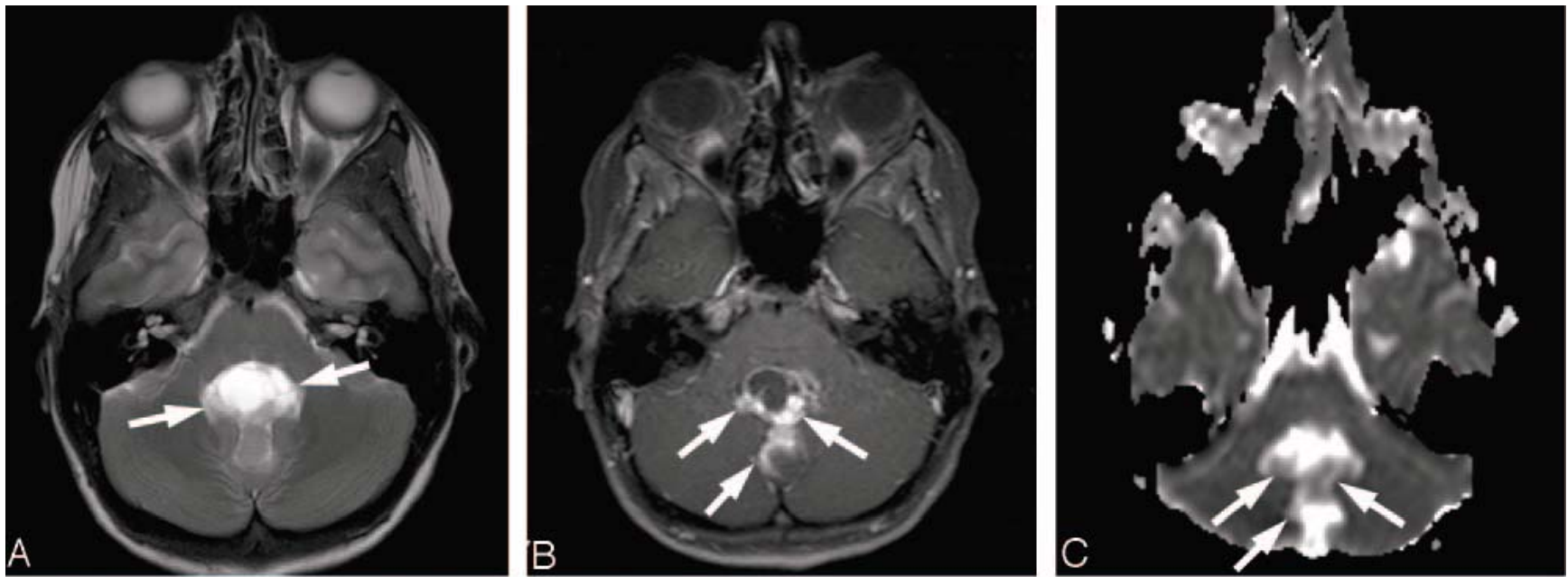
Epidermoid



E, Echo-planar DW imaging reveals the tumor as a sharply hyperintense lesion (arrows) relative to the brain and CSF.

F, ADC map shows that the intensity of the tumor is similar to that of surrounding brain tissue but much different from that of CSF.

Note the uneven diffusion in the lesion (arrows).

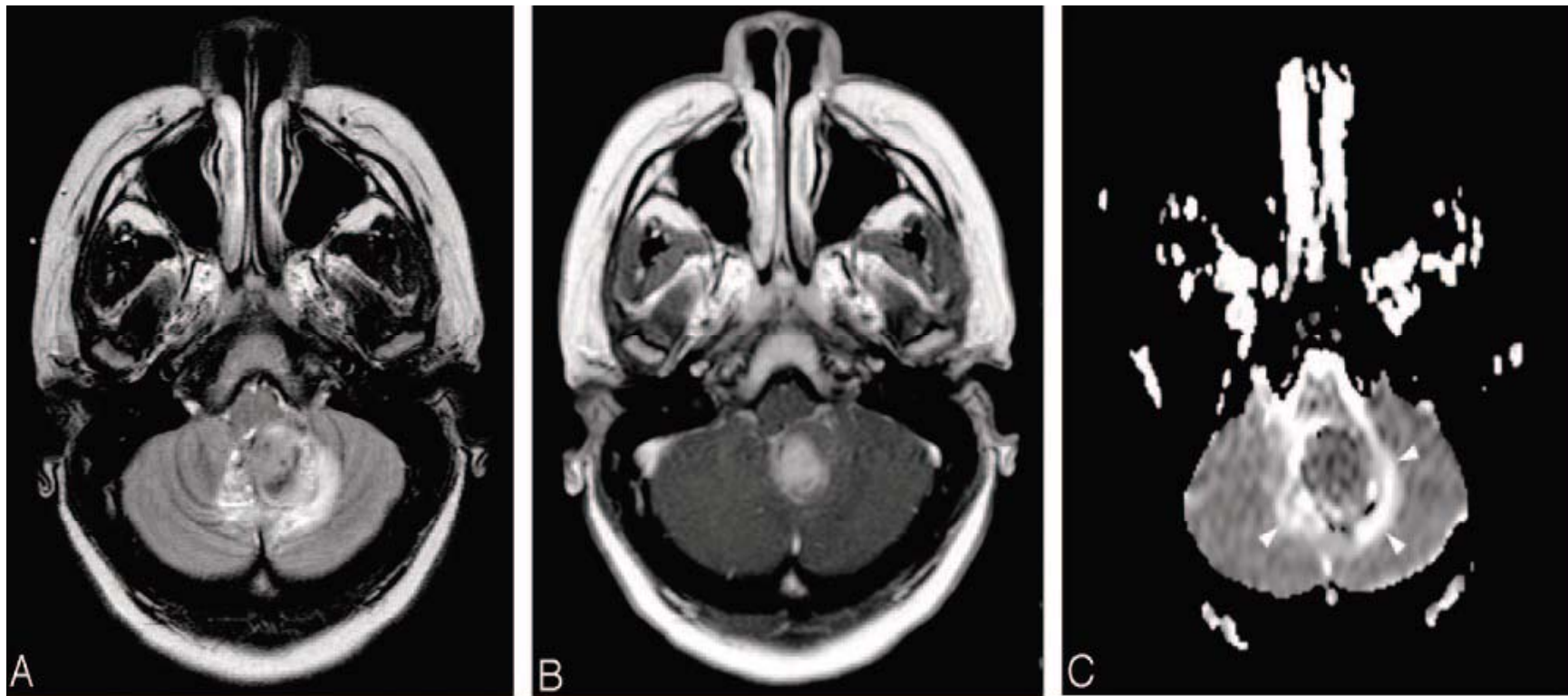


Sixteen-year-old boy with ependymoma

A, Axial T2-weighted image at level of middle cerebellar peduncles shows a very heterogeneous abnormality (*arrows*) within the fourth ventricle.

B, Corresponding contrast-enhanced T1-weighted image demonstrates enhancement of the solid portion of this mass (*arrows*).

C, ADC map at a level similar to that of A and B shows that diffusion within the solid portion of the tumor (*arrows*) is slightly higher compared with normal cerebellum

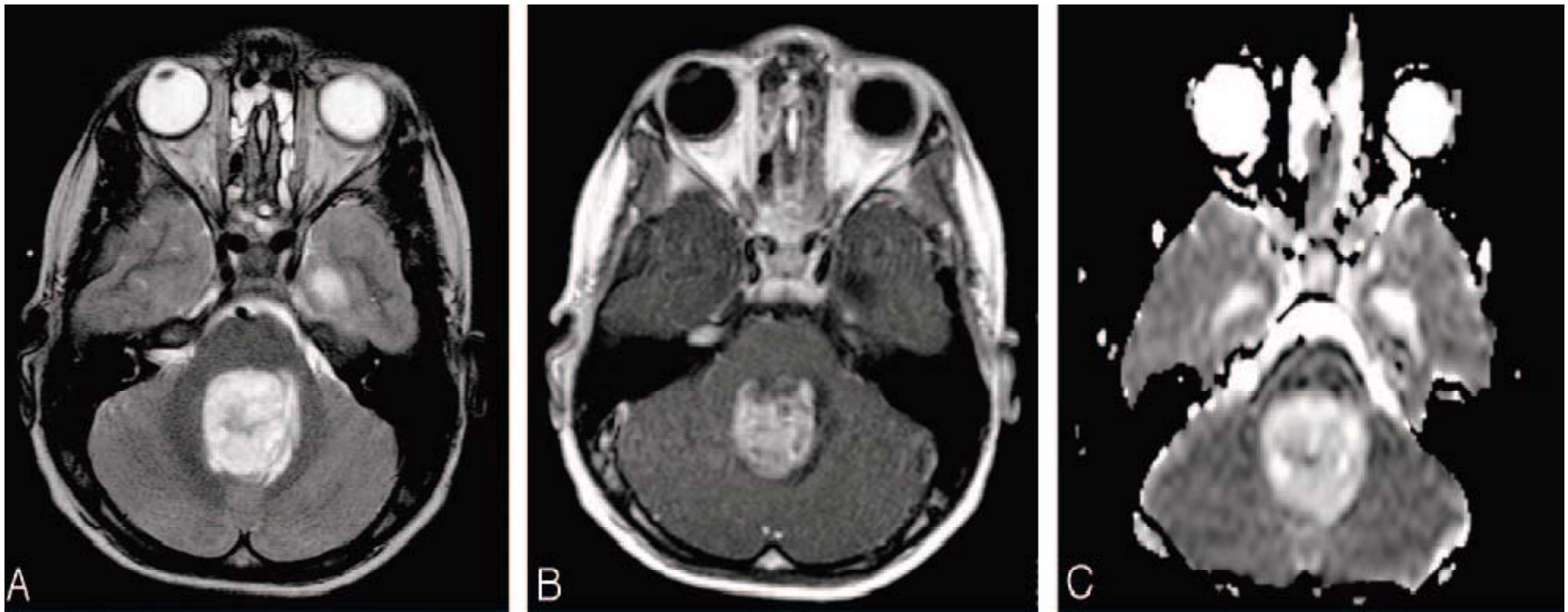


Sixteen-year-old boy with cerebellar medulloblastoma

A, Axial T2-weighted image at level of medulla oblongata shows heterogeneous mass in left paramedian location that is predominantly hyperintense. There is surrounding edema and compression of fourth ventricle.

B, Contrast-enhanced T1-weighted image corresponding to *A* demonstrates avid, slightly heterogeneous, enhancement of tumor.

C, ADC map corresponding to *A* and *B* reveals that mass is hypointense to normal cerebellar parenchyma, consistent with decreased diffusion. Hyperintense ring surrounding tumor (*arrowhead*) represents increased diffusion of vasogenic edema



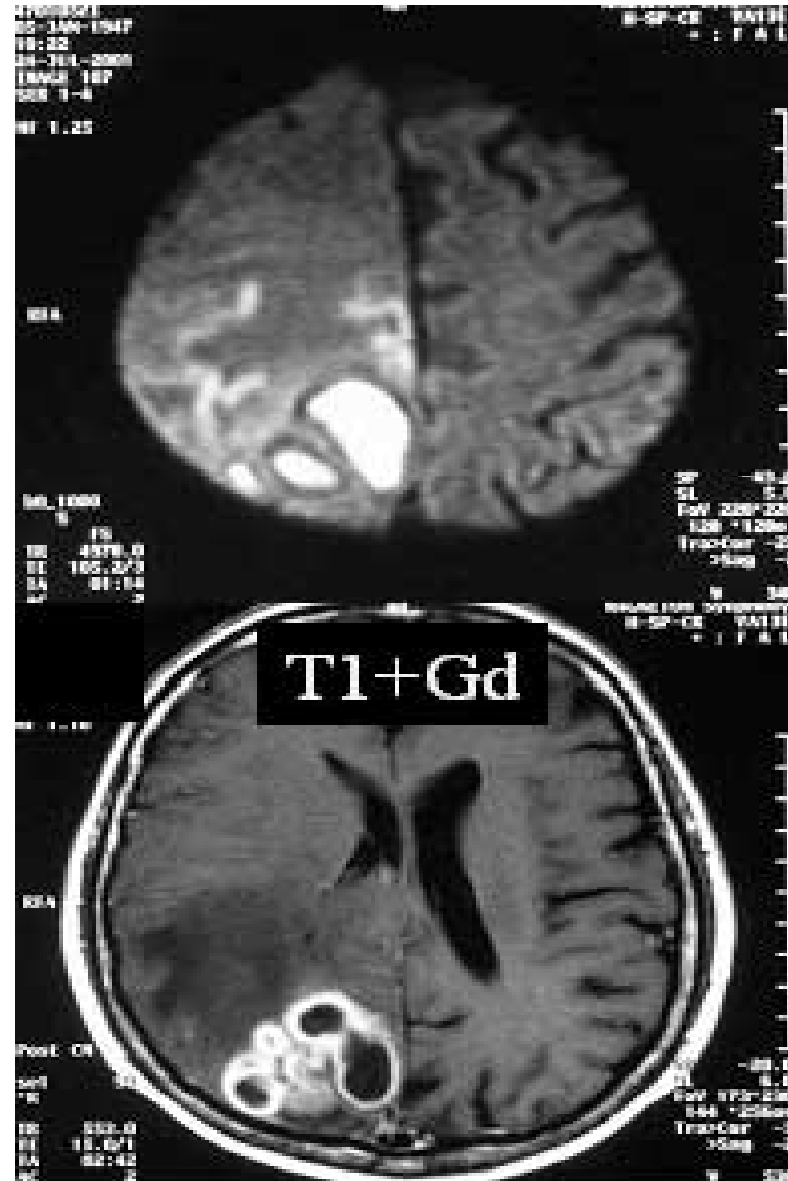
Eleven-year-old boy with cerebellar juvenile pilocytic astrocytoma (JPA)

A, Axial T2-weighted image at the level of middle cerebellar peduncles shows slightly heterogeneous, predominantly hyperintense midline mass without significant surrounding edema. There is associated effacement of the fourth ventricle.

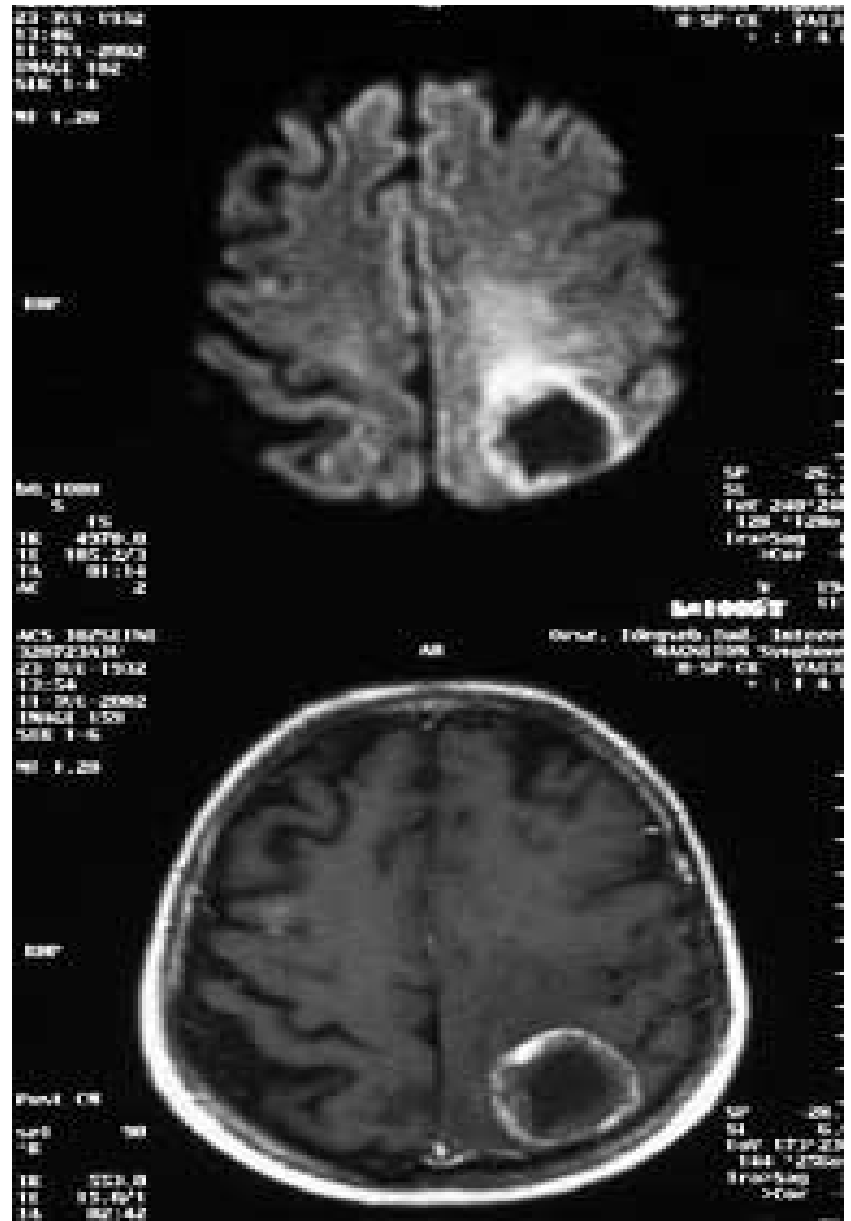
B, Contrast-enhanced T1-weighted image at same levels as *A* demonstrates strong, slightly heterogeneous enhancement of the tumor.

C, Apparent diffusion coefficient (ADC) map corresponding to *A* and *B* reveals that lesion is very hyperintense compared with normal brain parenchyma, representing increased diffusion of water.

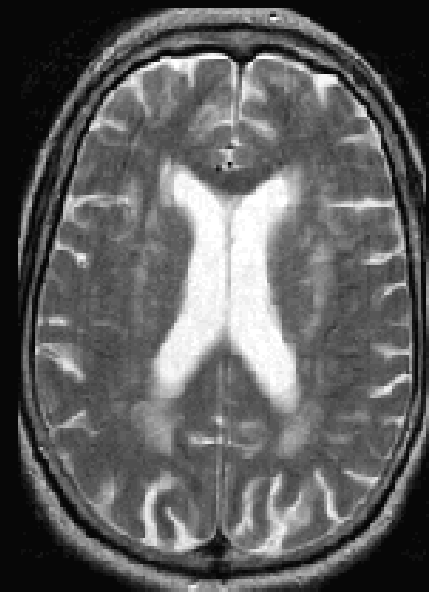
- **ABSCESS : LOW ADC, HIGH SIGNAL INTENSITY**



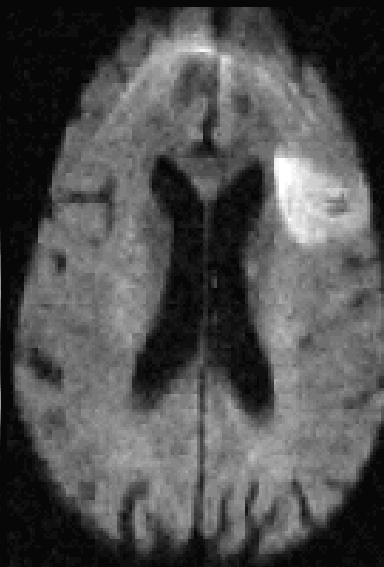
- NECROTIC TUMOR (HIGH ADC ,LOW SIGNAL INTENSITY)



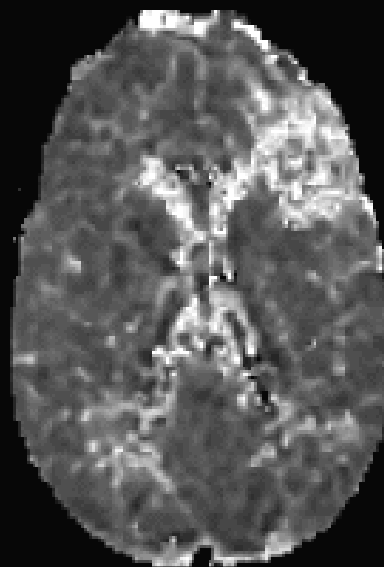
**78 y.o. female 3 hours after acute onset
of aphasia during cardiac catheterization**



T2 FSE



Initial DWI



Initial MTT



**Follow-up DWI
(5 days later)**

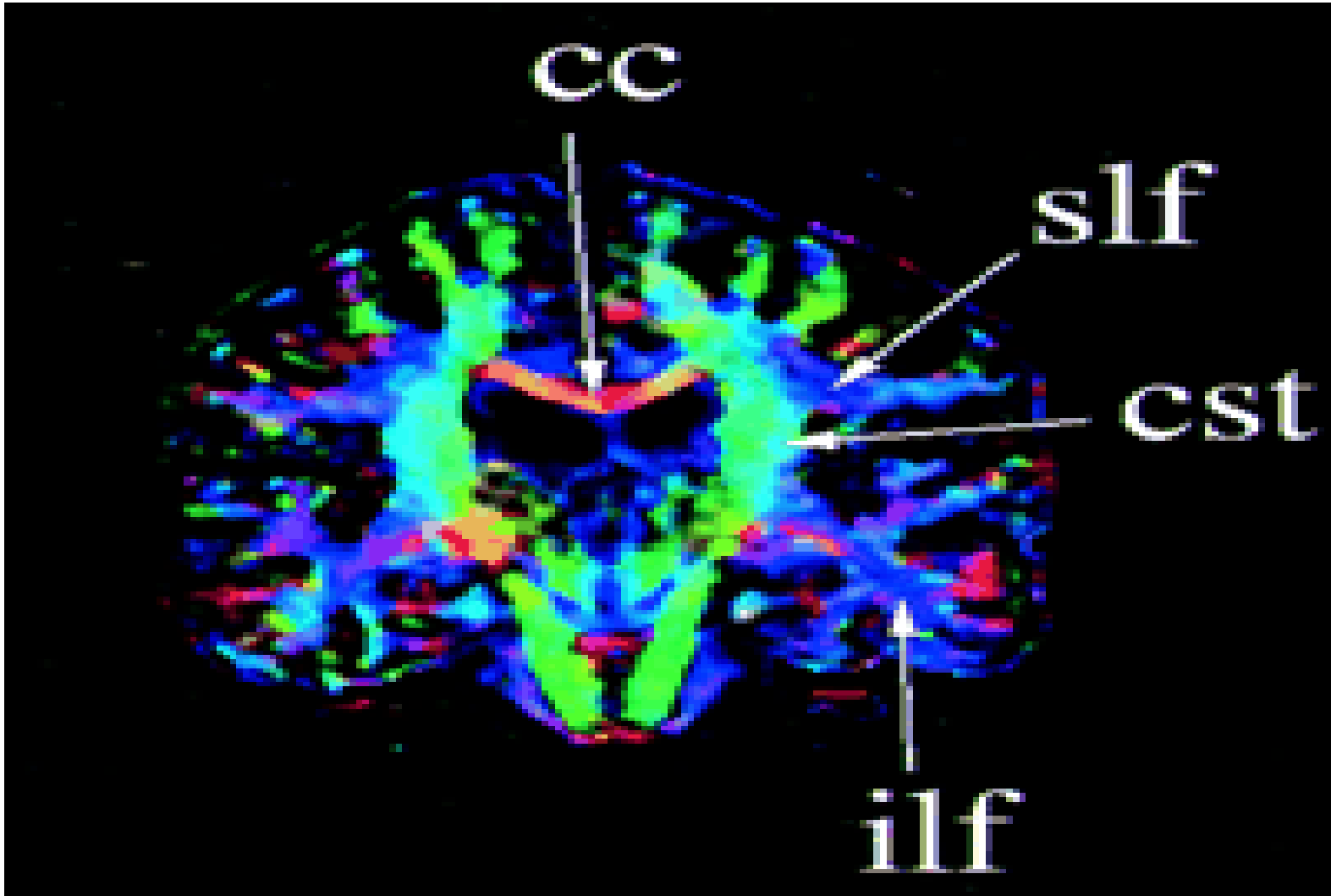
- ***Brain Tumors evaluation***

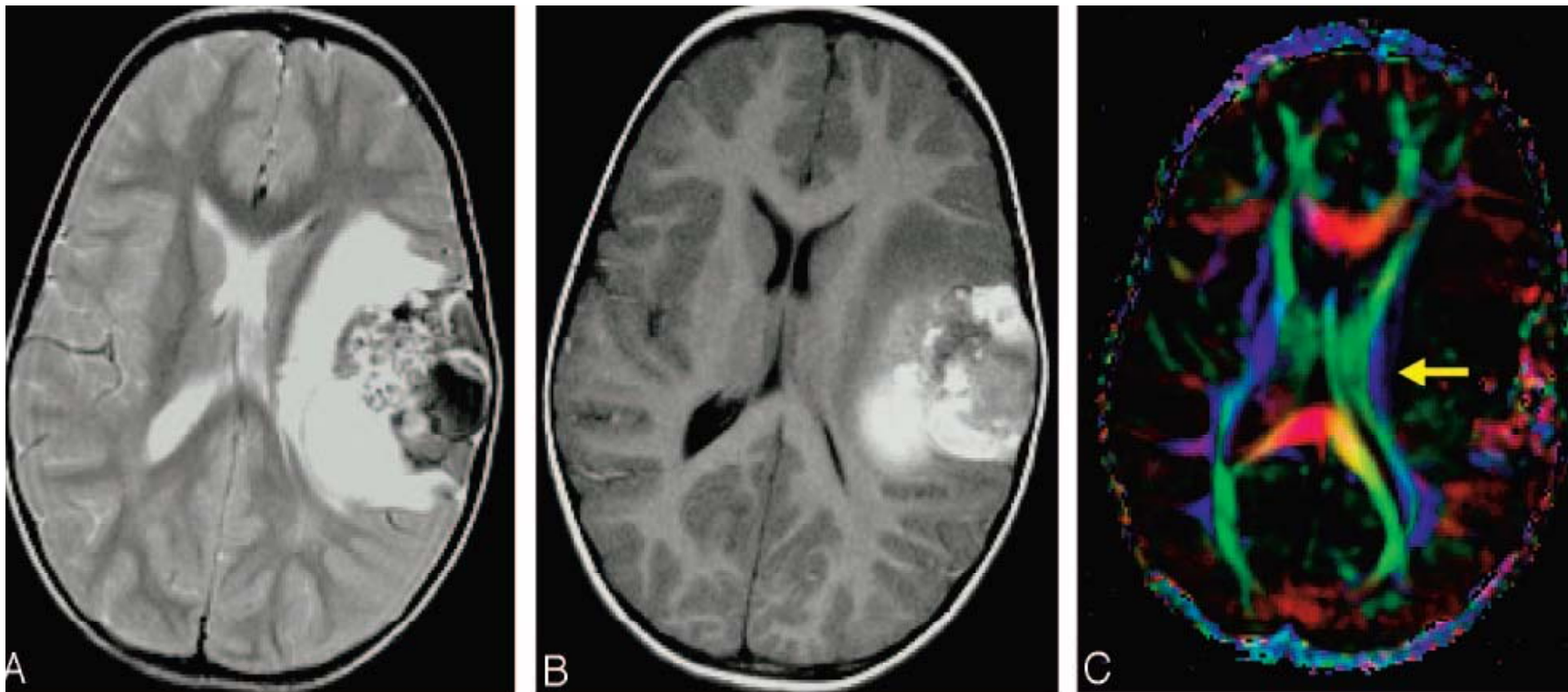
- Highly cellular tumors such as lymphoma and meningioma have a lower ADC than the brain parenchyma.
- not specific to allow tumor characterization.
- Viable tumor shows normal-high SI on DWI (normal-decreased ADC).
- In areas of tumor necrosis, low SI on DWI, increased ADC.

DIFFUSION TENSOR IMAGING

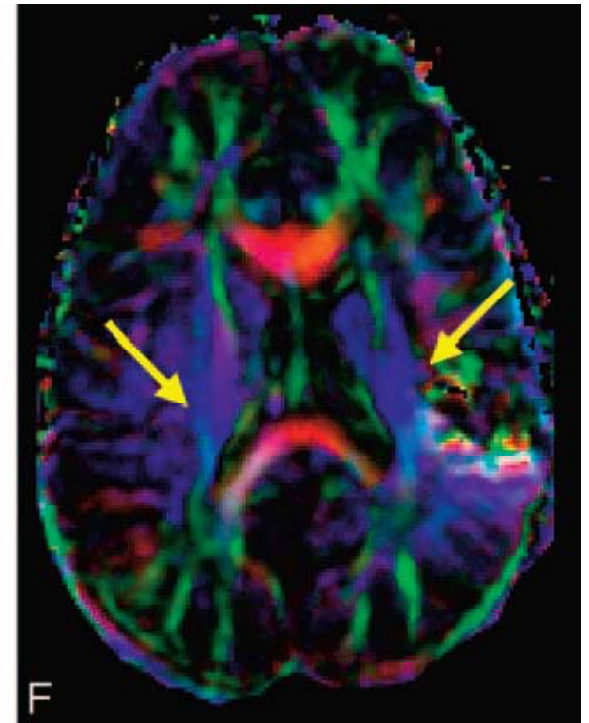
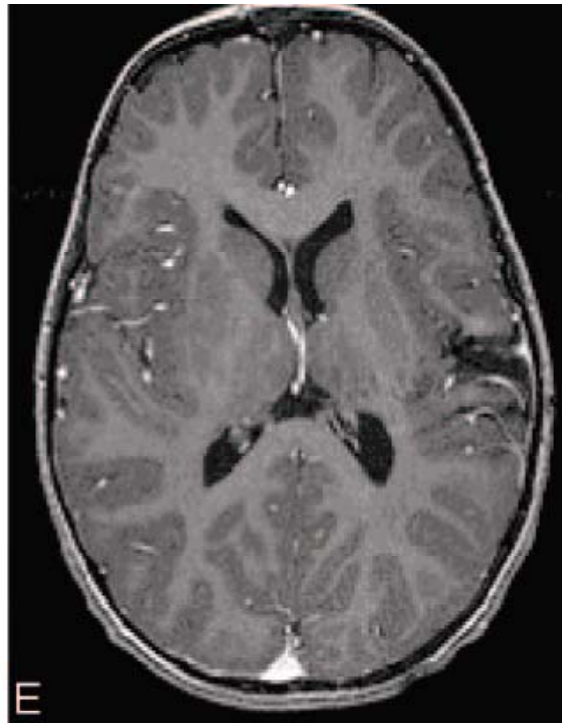
- Special diffusion technique capable of demonstrating white matter tracts and their relationship to lesions.
- BASIS: Detection of preferential motion of water along white matter fiber tracts.
- Diffusion has to be measured in multiple directions & the fractional anisotropy (diffusion rate depends on direction) in each direction is calculated for each voxel.

Diffusion tensor MR images in 30-year-old healthy man. cc = corpus callosum, slf = superior longitudinal fasciculus, ilf = inferior longitudinal fasciculus, cst = corticospinal tract





Before surgery,
the color images show postero-medial
deviation and deformation (compression)
of the posterior limb of the internal capsule
(*arrow, C*)



After surgery, the tract appears more symmetric with the contralateral tract (*arrows, F*) in position, cross-sectional shape, and orientation.

USES

- Intraoperative Neuronavigation Using Diffusion Tensor MR Tractography e.g. Resection of a deep tumor adjacent to the Corticospinal Tract, optic radiation.
- This enables researchers to make brain maps of fiber directions to examine the connectivity of different regions in the brain (tractography).
- To examine areas of neural degeneration & demyelination in diseases like Multiple Sclerosis (white matter diseases)

PERFUSION MRI

- Perfusion MRI techniques are sensitive to microscopic levels of blood flow.
- Two methods are used - *FIRST METHOD* :
 - Acquisition of EPI image during rapid bolus of contrast.
 - Gadolinium causes loss of MR signal, most marked on T2* (gradient echo) - weighted & T2 (spin echo) weighted sequences - caused by the magnetic field distorting effects of paramagnetic substances.

- Passage of contrast causes drop in signal intensity – calculate rate of change of $T2^*$
 - *LINEARLY PROPORTIONAL TO CONTRAST CONCENTRATION.*
- Contrast concentration time course in each voxel is analyzed.
- Data is analyzed to calculate
 - Relative cerebral blood volume (rCBV).
 - Mean transit time (contrast arrival time to time to peak contrast concentration) – MTT.
 - Relative cerebral blood flow (rCBF).

Second method : Create endogenous contrast by presaturating blood flowing through organ with Rf pulse. EPI of organ are made with presaturation on & off.

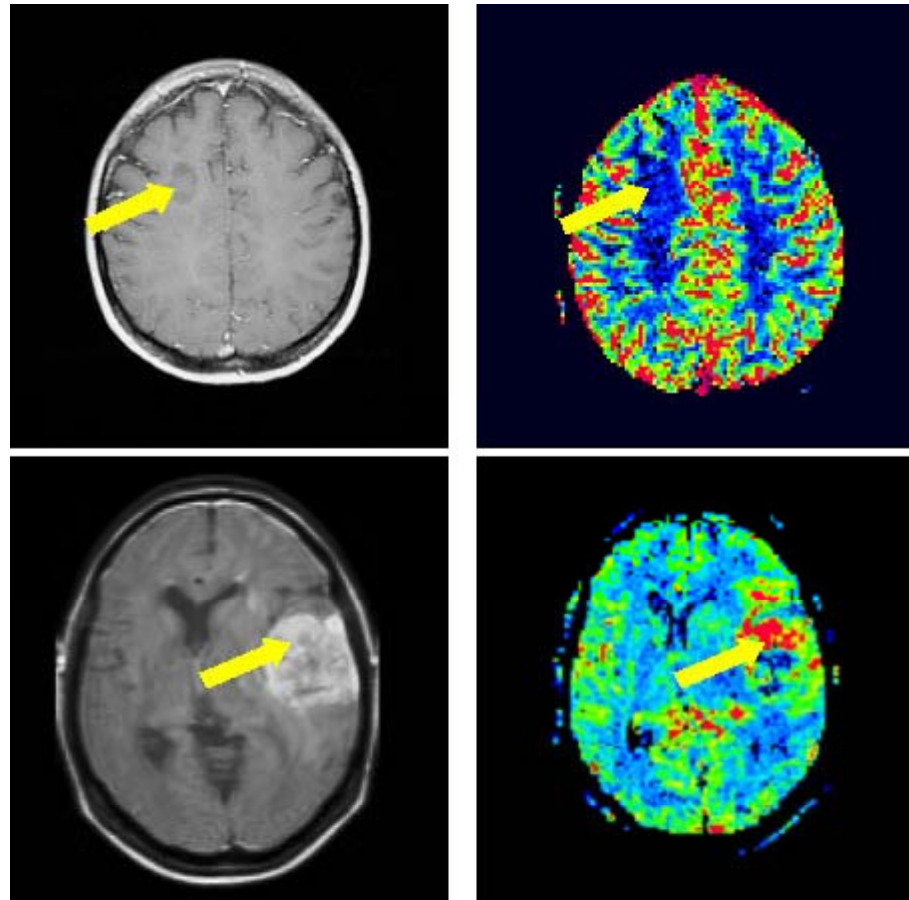
- By subtracting two images, tissue perfusion image is created.
- Relative perfusion abnormality can be identified.

USES

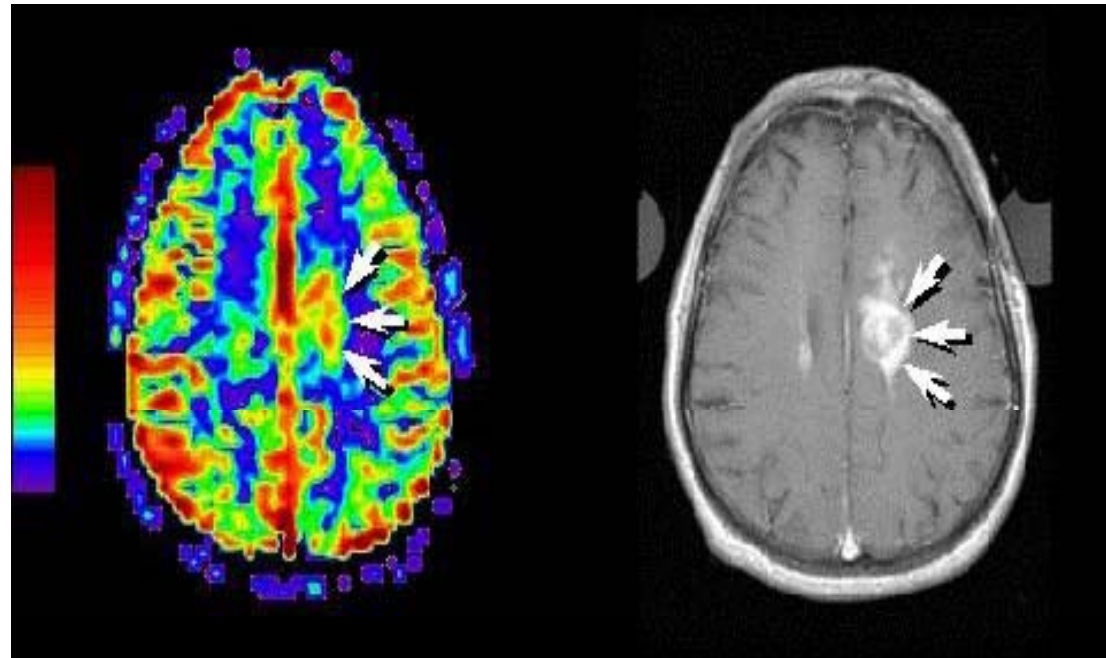
1. Infarction: Delay in mean transit time, reduction in cerebral blood volume, reduced cerebral blood flow.
2. Blood flow decreased with elevated or normal cerebral blood volume indicates tissue at risk of infarction.
 - PWI may show hypoperfusion in a much larger area of tissue than shown by the DWI.
 - Indicates a much larger area of tissue is at risk for infarction, a "diffusion-perfusion mismatch", indicating part still salvageable.
3. Assessment of brain tumors- vascularity.
4. Differentiating between neoplastic vs. non neoplastic lesion.

- Perfusion MRI may be a valuable tool for characterizing and monitoring ischemia in *Moya Moya* disease.
- Perfusion MRI provides additional functional information not available from conventional MRI.
- Has potential role comparable to SPECT in the evaluation of *Moya Moya* disease.

In the upper two images, tumor has a low perfusion, which indicates a slow-growing tumor. The lower images show very high perfusion within the tumor, which is typical of an aggressive tumor.



- Primary brain lymphoma : lesion shows areas of greatly increased rCBV (arrows, left image)



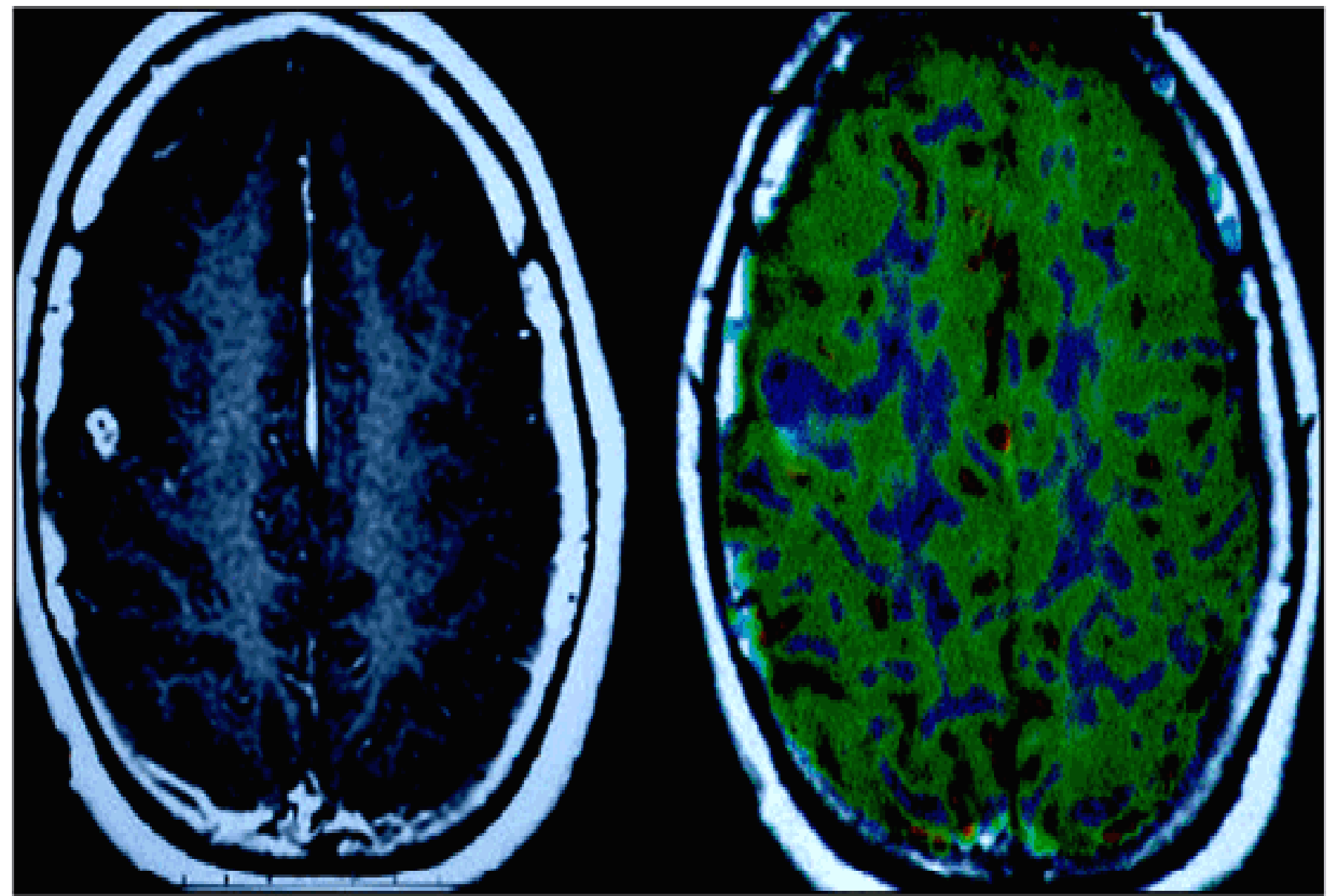


Fig 13. MRI T1WI postcontrast (Gd-DTPA) - ring enhanced lesion in the frontal lobe. MR PWI - without high perfusion. Follow-up confirmed cysticercosis.

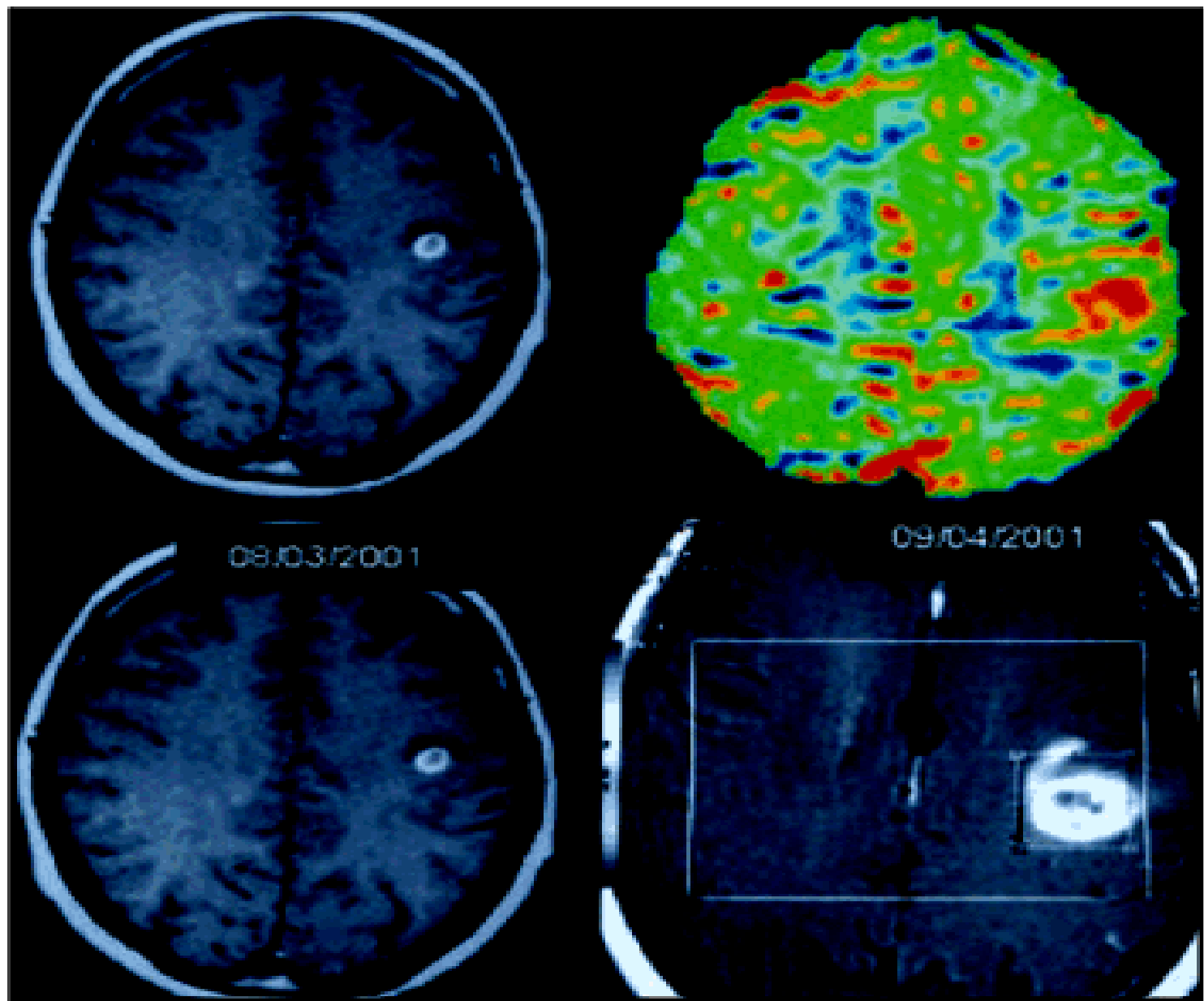
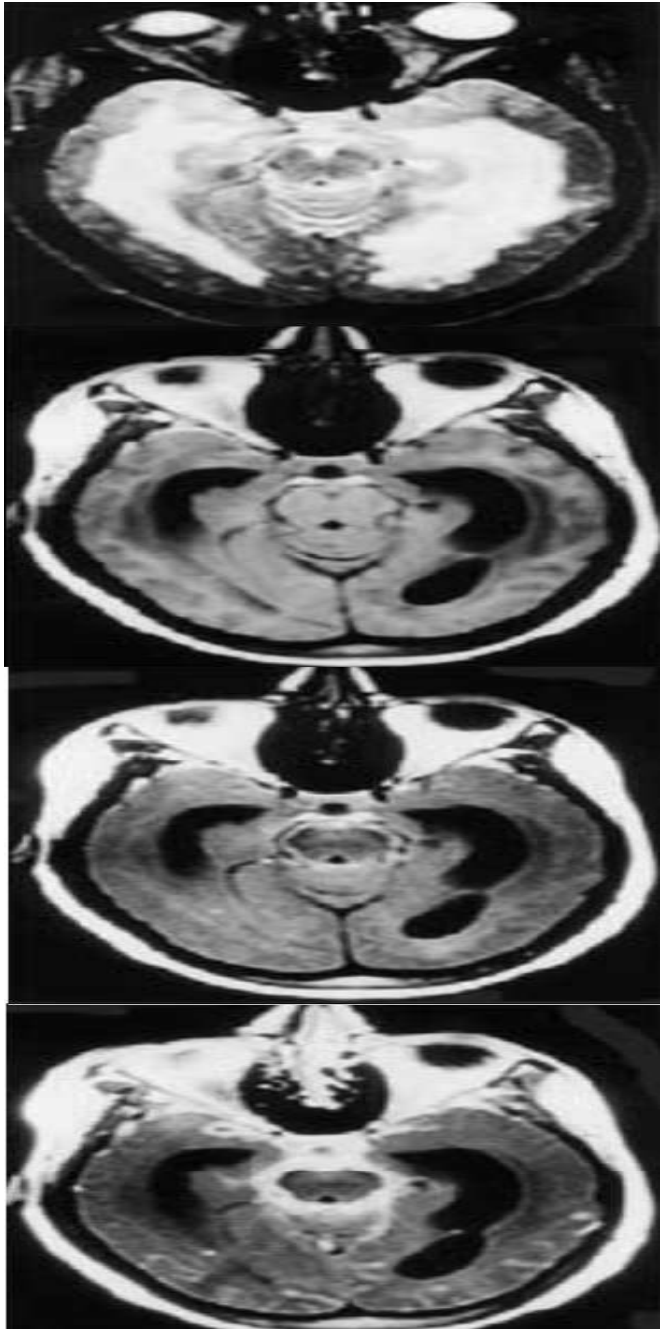


Fig 14. Similar lesion in the left frontal lobe with high perfusion. Follow-up confirmed GBM.

- **Magnetization Transfer MRI**

- Magnetization transfer (MT) refers to the transfer of longitudinal magnetization from free water protons to hydration water protons in NMR and MRI.
- In magnetic resonance imaging of molecular solutions, such as protein solutions, two types of water molecules, free (bulk) and hydration, are found. Free water protons have faster average rotational frequency and hence less fixed water molecules that may cause local field inhomogeneity. Because of this uniformity, most free water protons have resonance frequency lying narrowly around the normal proton resonance frequency of 63 MHz (at 1.5 teslas). This also results in slower transverse magnetization dephasing and hence longer T_2 . Conversely, hydration water molecules are slowed down by interaction with solute molecules and hence create field inhomogeneities that lead to wider resonance frequency spectrum.



- **a-d): Tuberculous meningitis. T2-W image (a) shows presence of hydrocephalus along with periventricular ooze. Pre-contrast T1-W MT image (c) shows thick basal meninges as periparenchymal hyperintensity not seen on T1-W image (b). Multiple hyperintense granulomas are also seen in the cerebral parenchyma. Post-contrast T1-W MT image (d) demonstrates thick enhancement of the basal meninges and exudates, extending along the sylvian cisterns along with enhancement of the granulomas.**

FLUID ATTENUATED INVERSION RECOVERY (FLAIR)

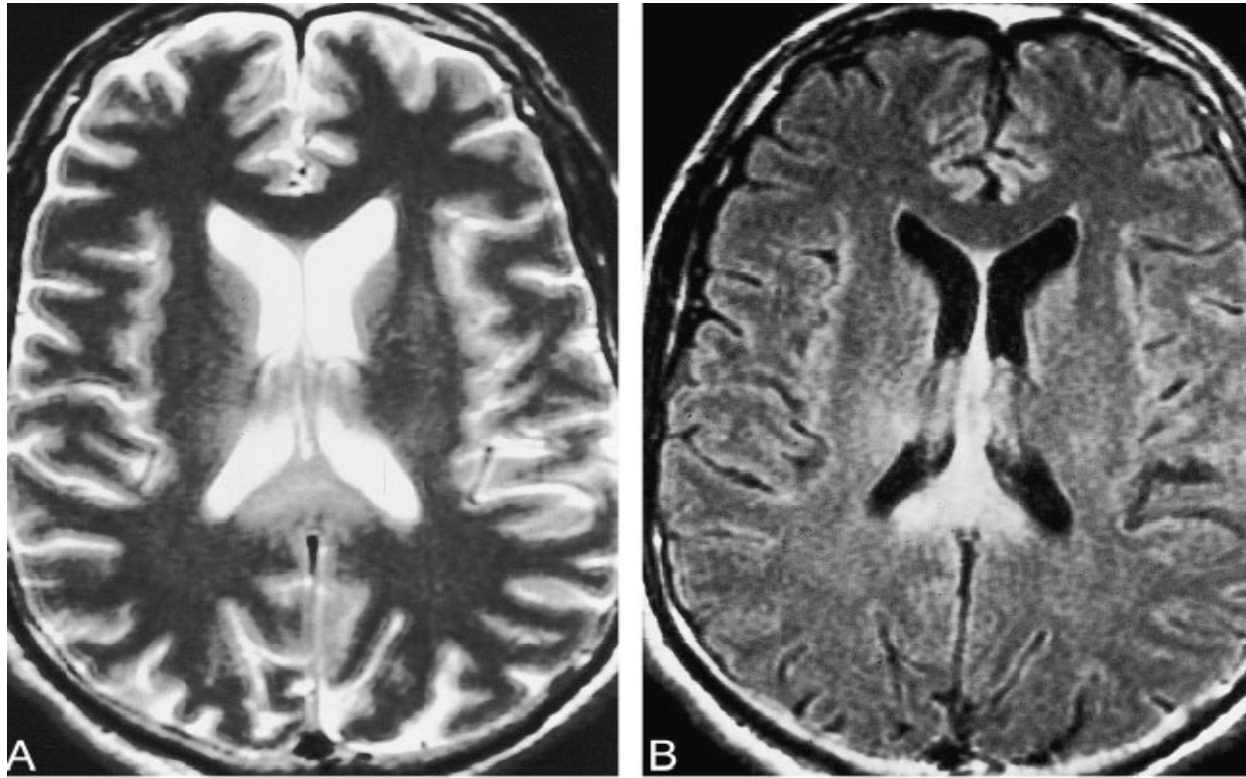
- Fluid Attenuated Inversion Recovery (FLAIR) is an inversion-recovery pulse sequence used to null signal from fluids. For example, it can be used in brain imaging to suppress cerebrospinal fluid (CSF) so as to bring out the periventricular hyperintense lesions, such as multiple sclerosis (MS) plaques. By carefully choosing the inversion time TI (the time between the inversion and excitation pulses), the signal from any particular tissue can be suppressed
- **FAST FLAIR:**
 - Fast spin echo plus flair

USES

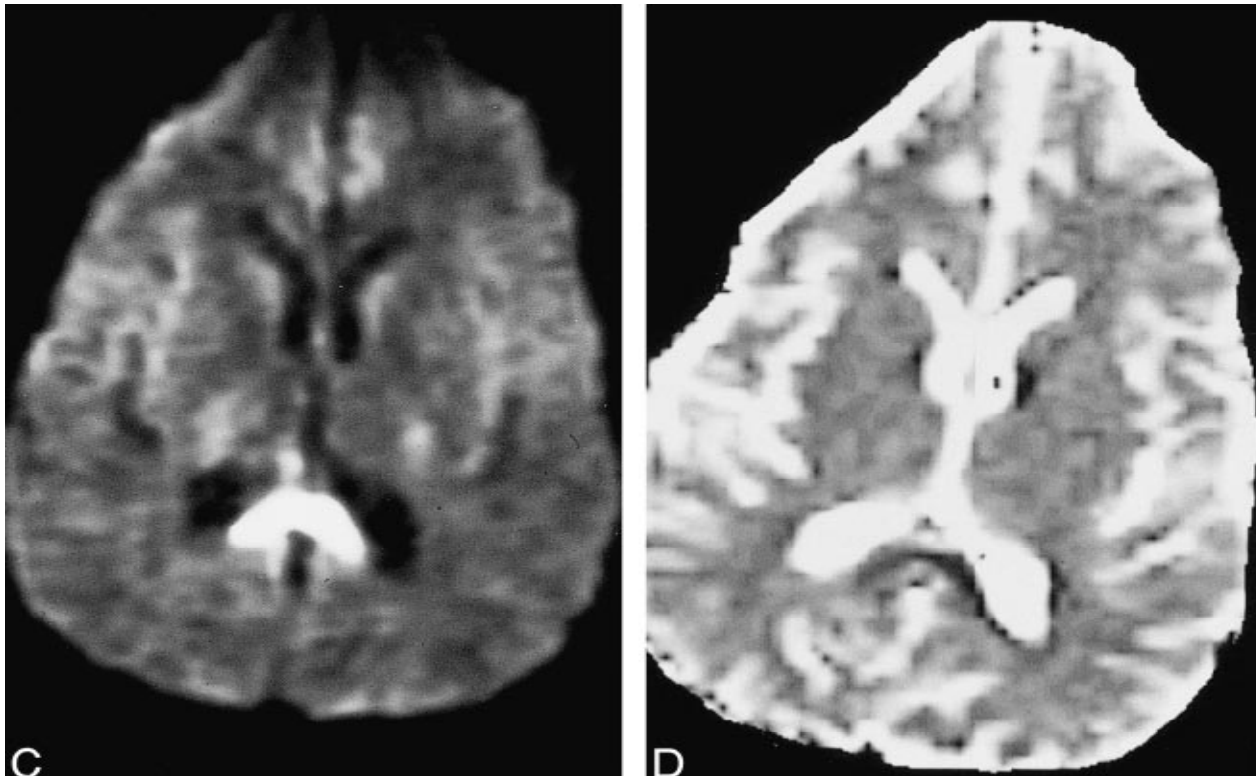
1. *For periventricular & sub cortical abnormalities:*
(Cortical & juxtacortical multiple sclerosis lesions, degenerative diseases).
2. *In seizure disorders (e.g. MTS):*
 - Sensitive for detecting signal abnormalities demonstrating size asymmetry & abnormal signal within the atrophied hippocampus.
3. *FLAIR MR may be helpful in differentiating epidermoid from arachnoid cyst*
 - Signals of epidermoid being similar to that of brain parenchyma ,arachnoids cyst signal suppressed.

4. *Diffuse axonal injury*: White matter lesion volume can be quantitatively assessed. Patients with greater DAI volume have poorer functional outcomes.

5. *Stroke* : Hyperintensity on FLAIR as early as 4-6 hrs after ictus & T1, T2 - normal.
 - Slow-flowing arteries are depicted by FLAIR as hyperintensities against darker brain tissue, leading to the "hyperintense vessels sign" (HVS).
 - HVS is a reversible sign, with hypoperfusion without infarction.

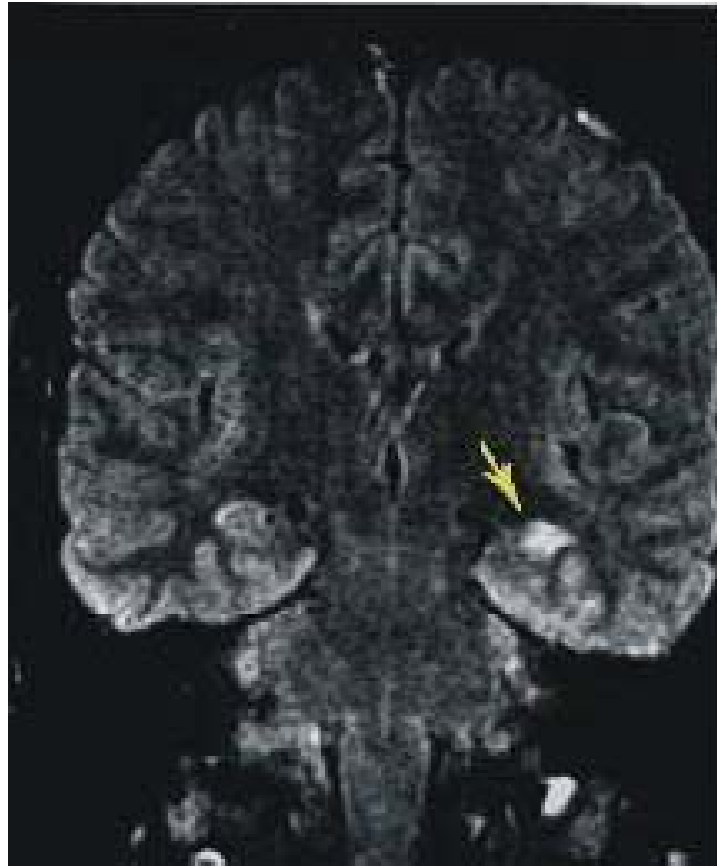


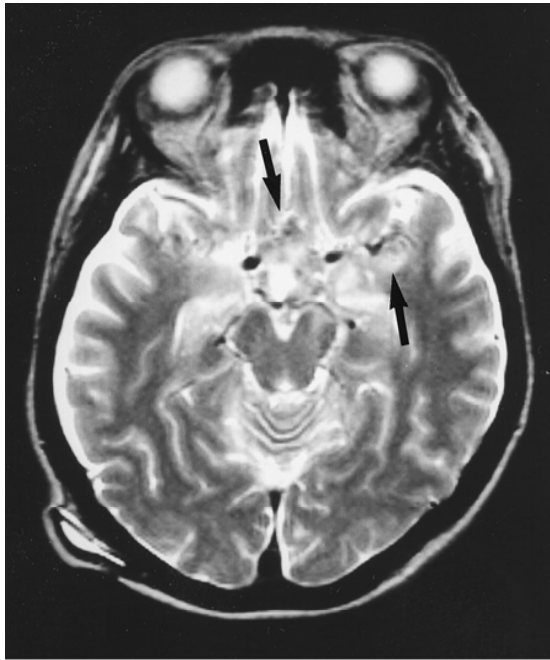
A and B, Axial fast spin-echo T2-weighted (A) and FLAIR (B) images both show evidence of diffuse axonal injury, as evidenced by hyperintense signal in the splenium.



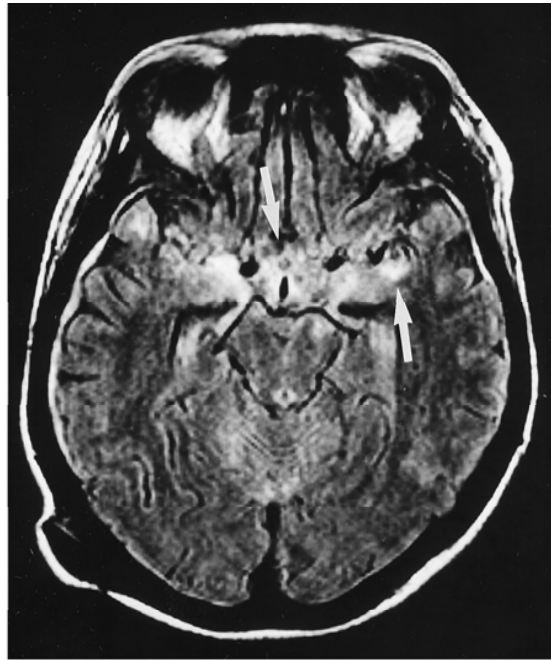
C and D, Isotropic diffusion-weighted (C) and diffusion trace (D) images show hyperintense signal and decreased ADC values, respectively, consistent with cellular edema.

MTS

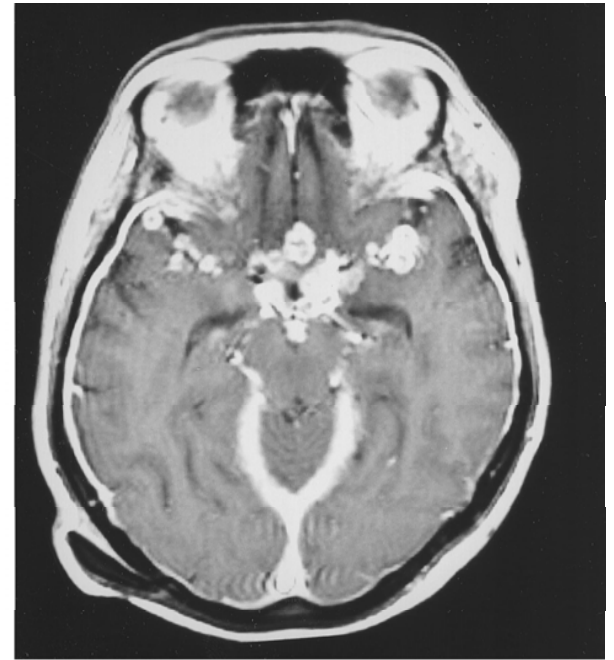




A



B



C

Tuberculous meningitis.

A, T2-weighted fast spin-echo image (4000/90/1) at 1.5 T shows lesions isointense with CSF in the suprasellar cistern and left sylvian fissure (*arrows*).

B, Fast FLAIR image (9000/119/1, inversion time of 2200) shows the lesions as slightly hyperintense relative to CSF (*arrows*).

C, Postcontrast T1-weighted spin-echo image (500/19/2) depicts the lesions best, since they show apparent contrast enhancement—note the thick enhancement of the convexity dura and tentorium cerebelli

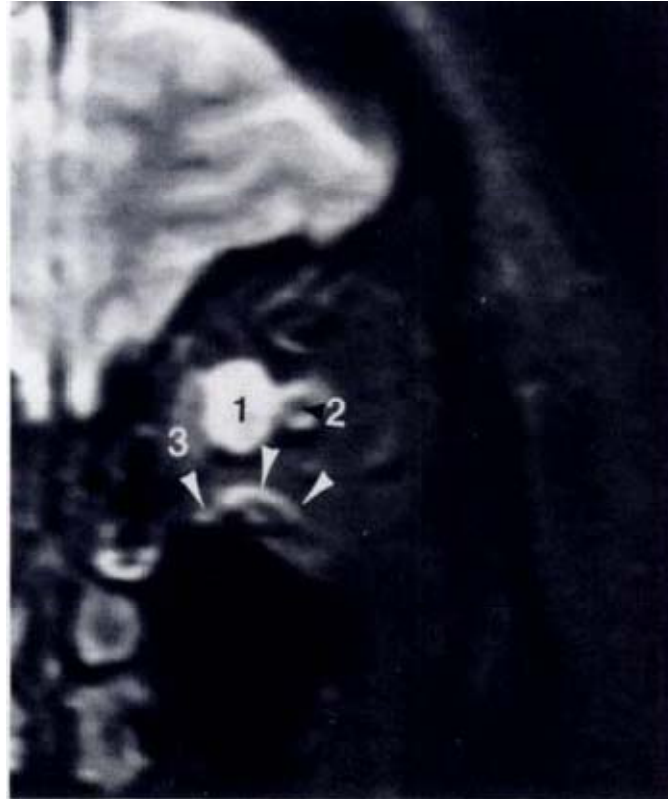
FAT SUPPRESSION SEQUENCE

- Short tau inversion recovery (**STIR**)

Intraconal cavernous hemangioma



Well-circumscribed **mass (1)** is well delineated between **optic nerve (2)** and **medial** rectus muscle (3) **Mass is isointense relative to muscle on short TRITE (T1W)**



Mass is markedly hyperintense on long TR/TE (T2W)



Mass is hyperintense relative to fat, but approximately isointense relative to muscle, on STIR image

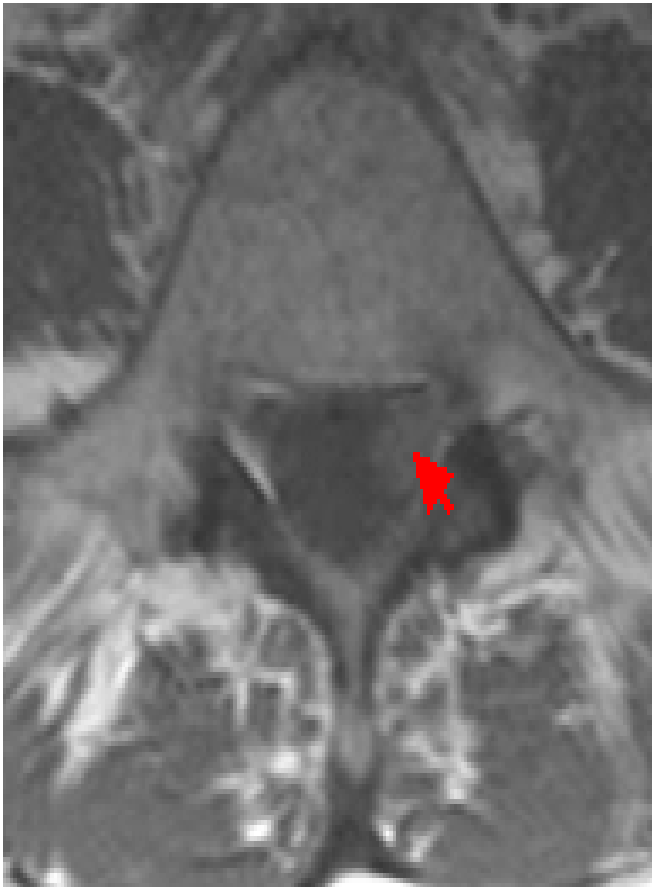
STIR

- Using adequate inversion time (100-150ms) signal from fat is suppressed while it becomes very sensitive to change in water content.
- Uniform & consistent fat suppression and excellent T2-like contrast when long repetition times are used.

USES

1. Lesions in the optic nerve can be visualized e.g. traumatic, demyelinating.
2. Metastasis to vertebral body in fatty marrow
– These can be missed on T2.
3. Useful for fractures of vertebral body.
4. Useful in carpal tunnel syndrome & brachial plexus injury (in 2 planes – direct coronal & oblique sagittal).
5. Musculoskeletal imaging.

A dumbbell shaped enhancing IDEM mass (arrow) appearing isointense on T1W and hyperintense on STIR



Carpal tunnel syn. – flattened
median nerve & signal from
denervated muscles

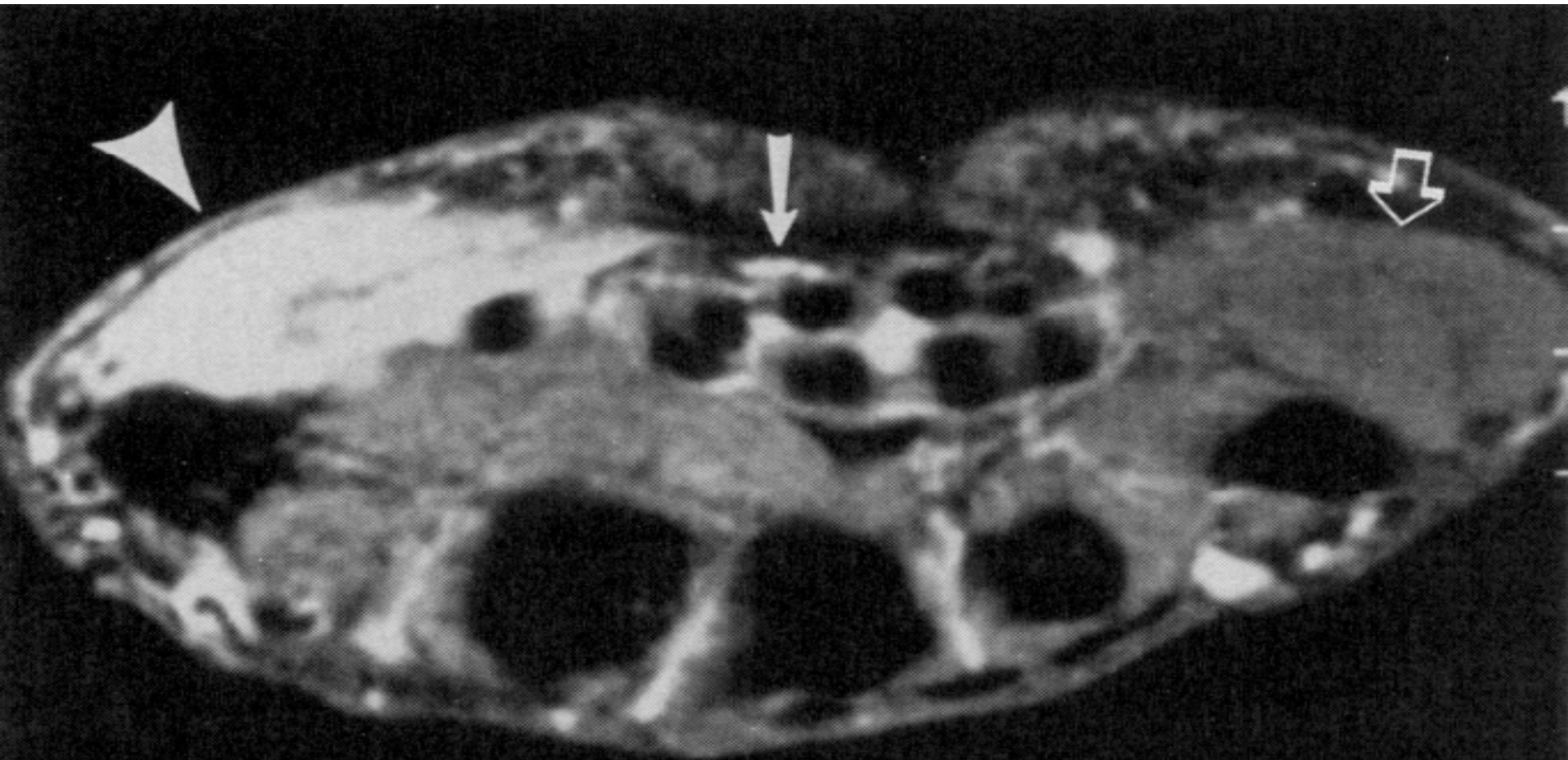
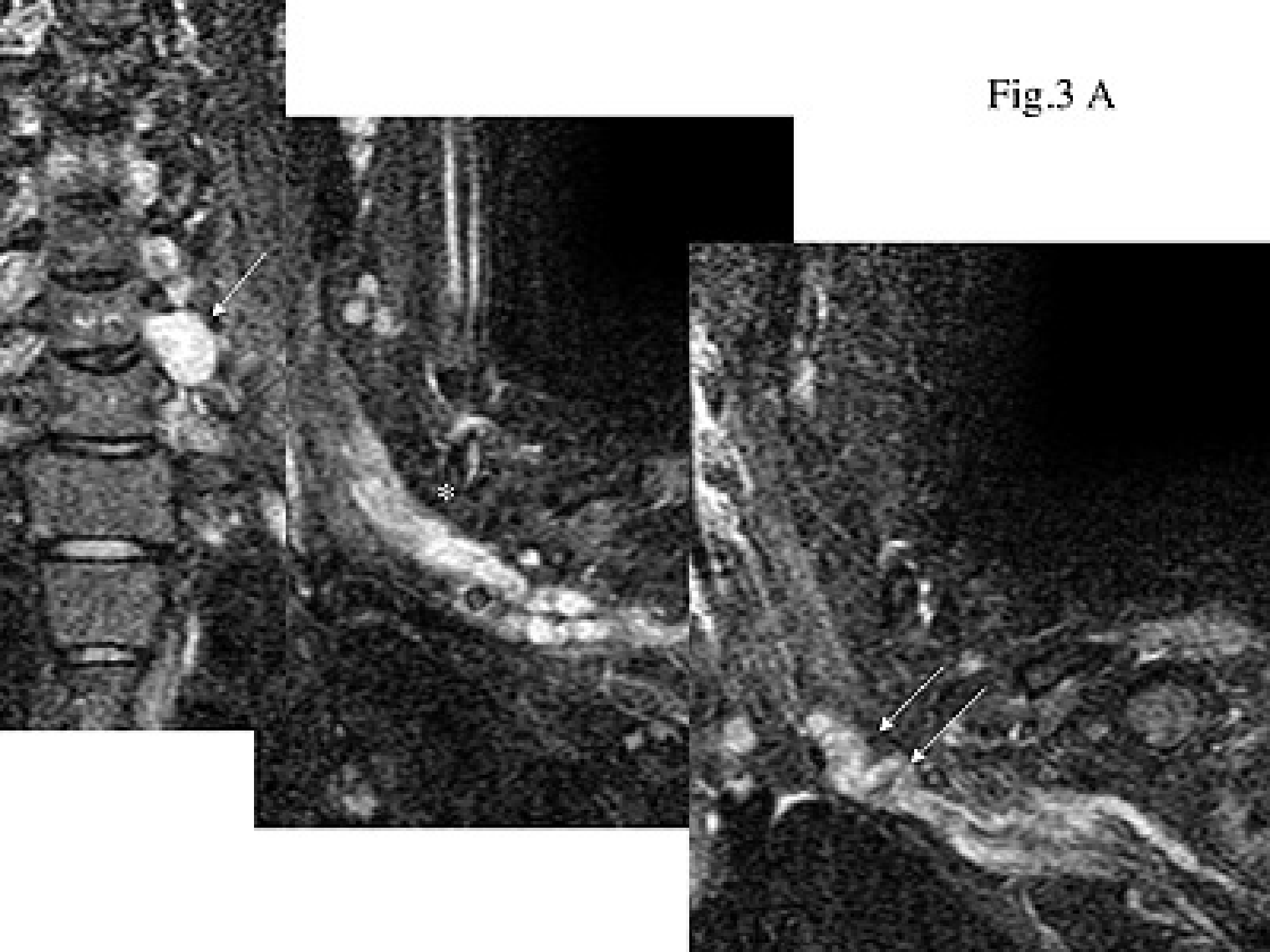


Fig.3 A



- **Figure 3: Avulsion injury:**
 - Coronal STIR sequences through the left brachial plexus in a 19-year-old male after a motorcycle accident (3A).
 - There is a left C7 pseudomeningocele (*arrow*) with retraction of the distal C7 root & middle trunk (*double arrow*).
 - Enlargement & abnormal signal are also seen in the left C5 & C6.

- **DISADVANTAGES:**

- Has a relatively low signal-to-noise ratio.
- Offers relatively low tissue contrast.
- More susceptible to flow artifacts than other methods.

CONSTRUCTIVE INTERFERENCE IN STEADY STATE (CISS)

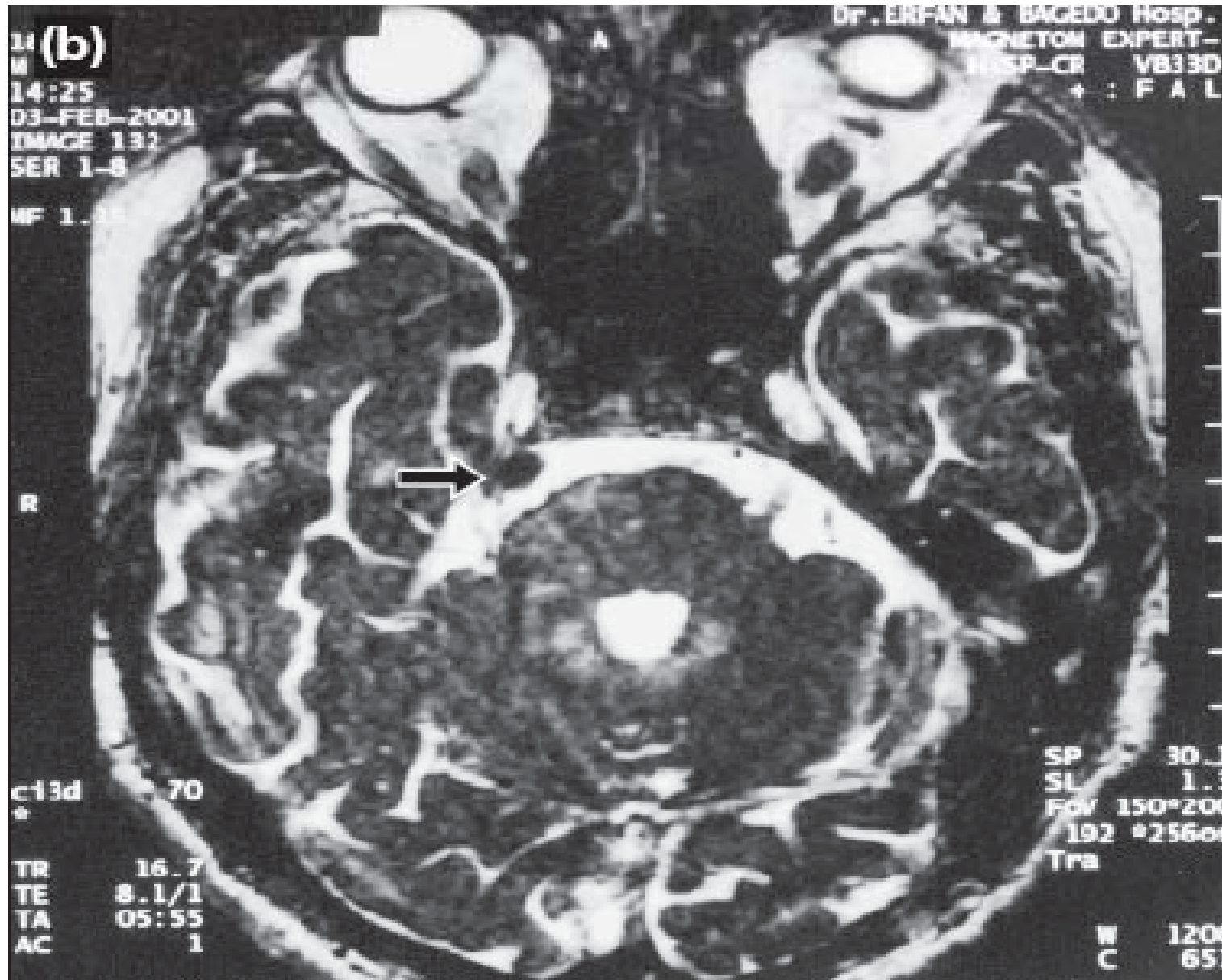
- 3D-CISS is a heavily weighted T2 sequence with a strong and constant signal for cerebrospinal fluid.
- This is a 3-D gradient technique, where signal from brain parenchyma is suppressed.
- It gives excellent demonstration of cranial nerves, including the intracanalicular components of eighth nerve. Fluid appears bright.

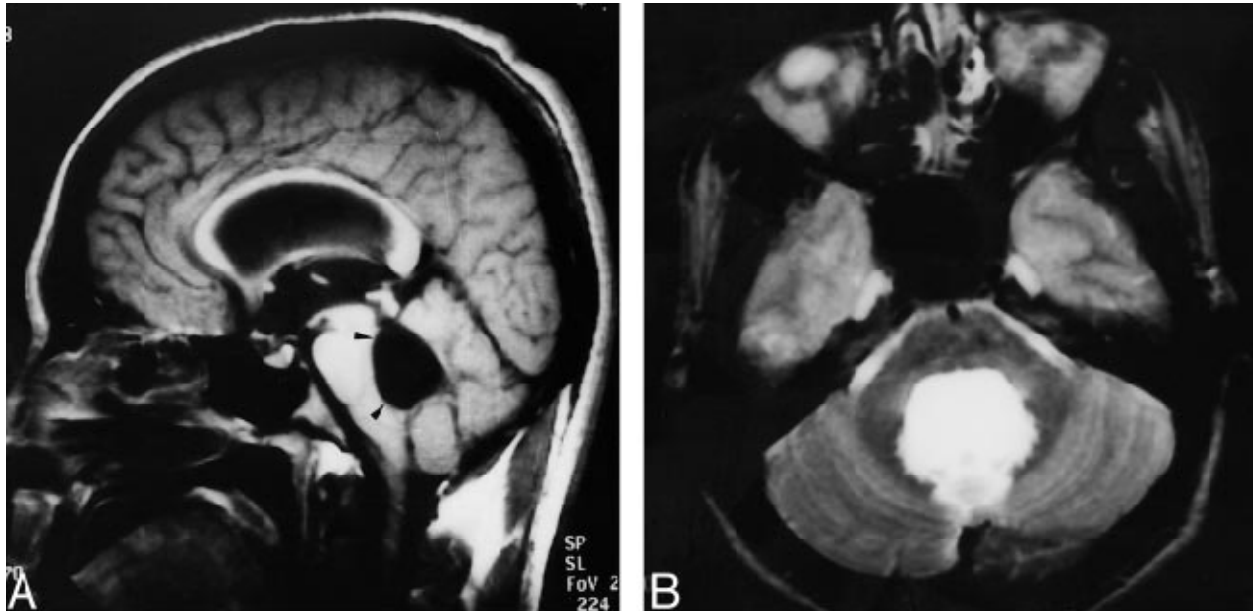
- Gradient echo sequence is used.
- Two true FISP (FAST IMAGING WITH STEADY PRECESSION) sequences are acquired with differing RF pulses & then combined for strong T2 weighted high resolution 3D images.
- Reconstruction process also done.
- Advantage of the **3D CISS** sequence high signal levels
 - Extremely high spatial resolution.
Used for, e.g. inner ear, cranial nerves & cerebellum.

USES

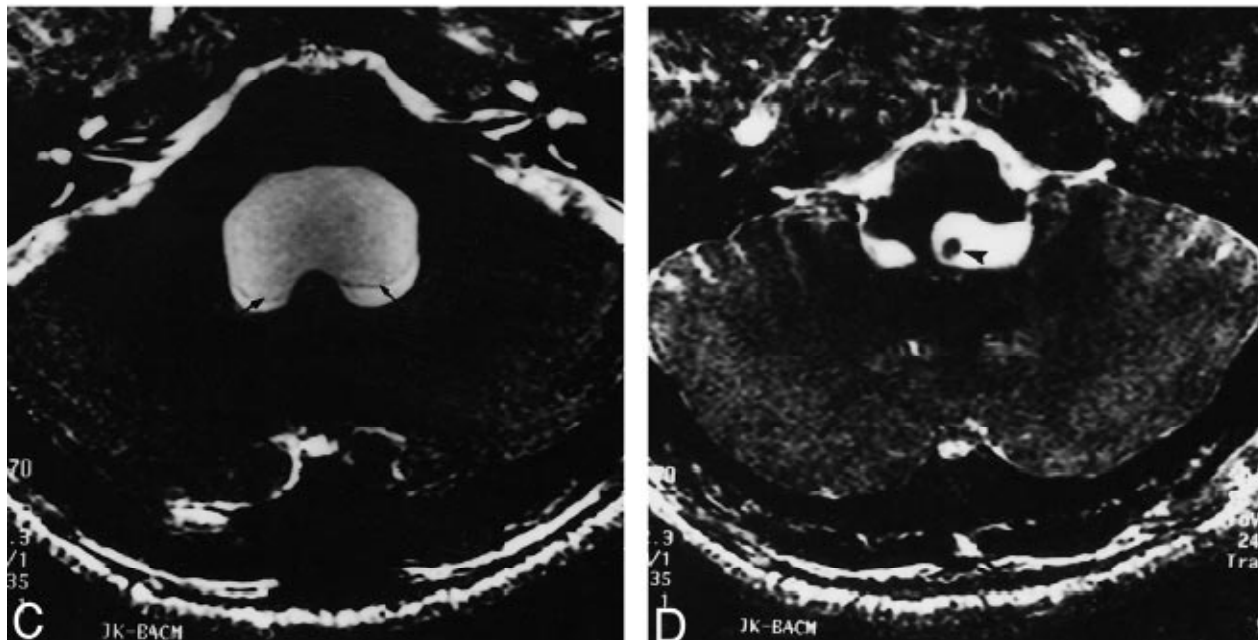
1. Detailed images of the cerebellopontine angle, internal auditory canals, cranial nerves.
2. PERIOP. Evaluation in endoscopic approach to the intraventricular cysts, suprasellar cysts & the cyst associated with hydrocephalus, located in the midline.
3. 3D CISS MR imaging with MPR (multiplanar reconstruction) is useful in the detection of NVC in patients with trigeminal neuralgia.

Impingement on the rt. 5th N. by the basilar artery in a patient with right trigeminal neuralgia





A and B, Sagittal SE T1-weighted (650/14/1) (A) and axial T2-weighted (3800/90/2) (B) images show a dilated fourth ventricle (arrowheads). No cyst is seen.



C and D, Axial 3D-CISS (12.3/5.9/1) images show the cystic wall (arrows) and hypointense scolex (arrowhead)

4. In evaluation of brachial plexus injuries, if root avulsion is suspected, CISS is used to perform 3-D MR myelography.

- Uniform signal intensity and high contrast between CSF & neural structures are obtained.
- Enabled detection of meningoceles, avulsed or intact nerve roots, dural sleeve abnormalities & dural scars.
- Evaluation of nerve root integrity -89% sensitivity, 95% specificity.

5. Used for evaluation of CSF rhinorrhea (MR cisternography)

- The sensitivity & specificity of the MR method (88.9% & 95.1%) is higher compared with CT cisternography (77.8% & 87.8%).
- Less than 2mm, multiple defects.
- Noninvasive.
- Administration of contrast & agent is no longer necessary.

MR ANGIOGRAPHY

- Time of Flight MR Angiography
- Phase Contrast MR Angiography
- Contrast Enhanced MR Angiography

MAGNETIC RESONANCE ANGIOGRAPHY

- Fast flowing blood returns no signal on routine T1 & T2 (flow voids). Slow flowing blood (veins) may appear high.
- Gradient echo sequence: Signal intensity of moving protons increases compared to low signal background.
- Technique :
 1. Time-of-flight sequences (e.g. 2D & 3D "flow-related enhancement") where most of the signal on an image is due to blood which has recently moved into that plane.

- Series of contiguous thin MR sections which are manipulated to create image.
- Vascular flow map rather than anatomic map.

2. Phase contrast MRA :

- Utilizing the change in the phase shifts of the flowing protons. two data sets with a different amount of flow sensitivity are acquired.
- longer acquisition time than TOF.
- It can produce anatomic information ,velocity & direction of blood flow.
- Selective venous & arterial images can be obtained.

3. Administration of a paramagnetic contrast agent (gadolinium) MRA :

Standard for extracranial vascular MRA. During bolus infusion TOF sequence is used.

USES

- Excellent for screening of stenosis, occlusion, dissections in carotids of neck.
- Useful for noninvasive diagnosis of intracranial aneurysm/vascular malformations.
 - Especially when contrast angiography is not permitted.
- ICA & initial branches of ACA, MCA & PCA can be assessed.

DRAWBACKS

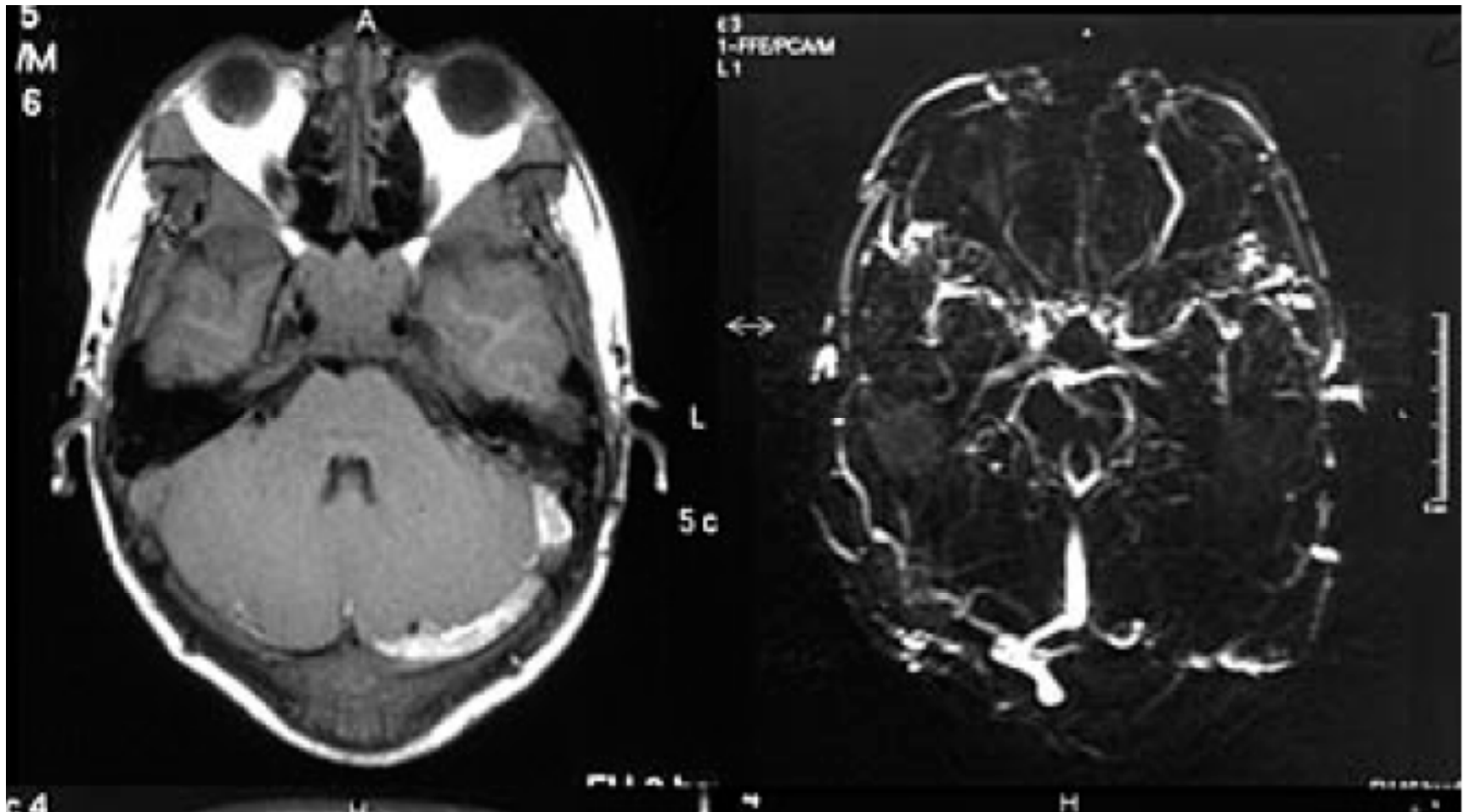
1. Spatial resolution poor compared to conventional angiography. Detection of small vessel diseases is problematic.
2. MRA is also less sensitive to slow flowing blood and may not reliably differentiate complete from near- complete occlusion
3. Motion artifacts by patient or anatomic structure may distort image.
4. Signal loss in complex flow.

- MRA showing Rt. MCA ANEURYSM





B/L TRANSVERSE SINUS THROMBOSIS



- Techniques involving phase accumulation (known as phase contrast angiography) can also be used to generate flow velocity maps easily and accurately. Magnetic resonance venography (MRV) is a similar procedure that is used to image veins. In this method the tissue is now excited inferiorly while signal is gathered in the plane immediately superior to the excitation plane, and thus imaging the venous blood which has recently moved from the excited plane

Magnetic resonance gated intracranial CSF dynamics (MR-GILD)

- Magnetic resonance gated intracranial cerebrospinal fluid (CSF) or liquor dynamics (MR-GILD) technique is an MR sequence based on bipolar gradient pulse used to demonstrate CSF pulsatile flow in ventricles, cisterns, aqueduct of Sylvius and entire intracranial CSF pathway. It is a method for analyzing CSF circulatory system dynamics in patients with CSF obstructive lesions such as normal pressure hydrocephalus. It also allows visualization of both arterial and venous pulsatile blood flow in vessels without use of contrast agents.

INTRAOPTATIVE MRI

- Provides real time image guidance .
- Open magnet design/horizontal flat plane design.
- Pt. is wheeled In & out for imaging.
- All anesthesia equipment & microscope has to be MR compatible.

USES

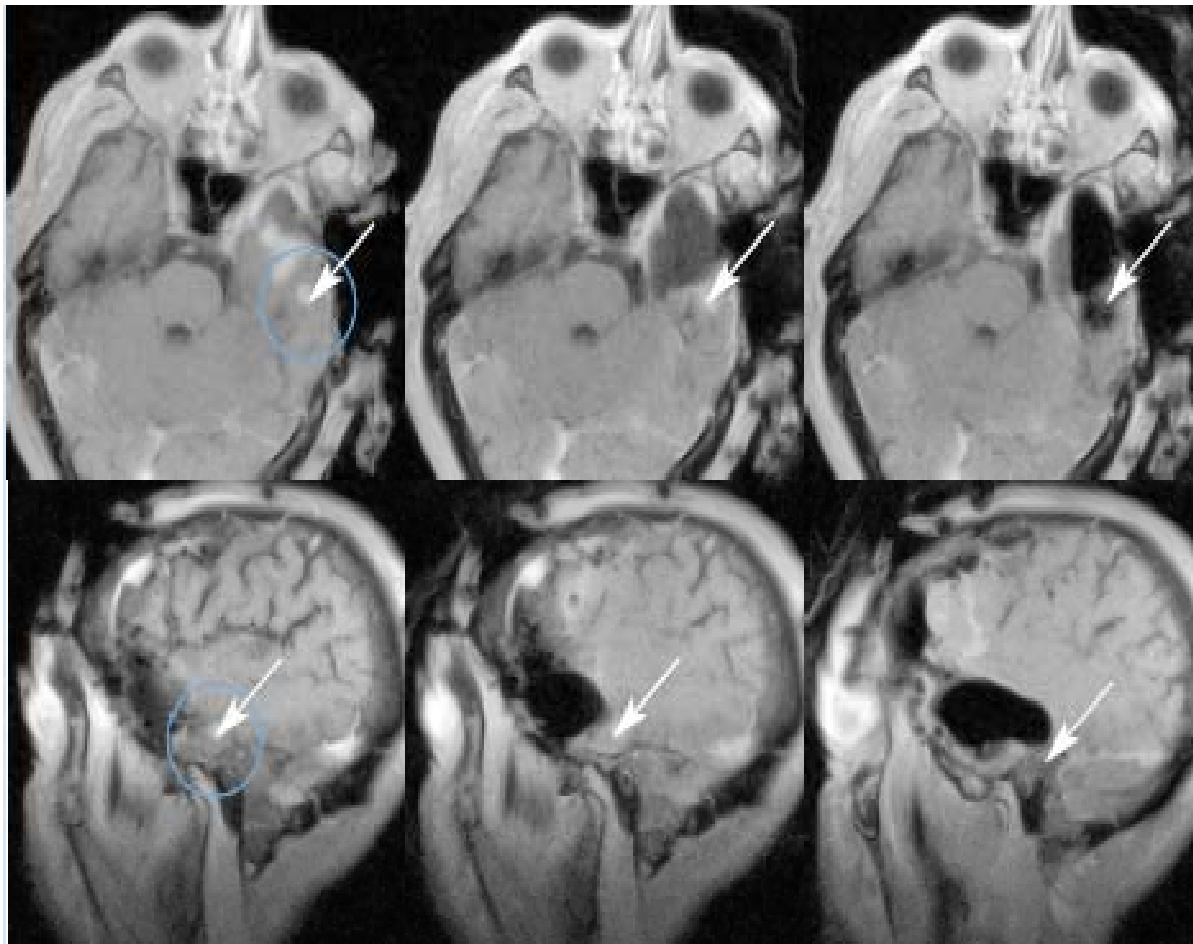
- For craniotomy- gliomas ,deep seated especially.
- Surgery for Intracranial cysts : intraop lining of cyst after contrast injection.
- For biopsy of deep seated lesions.
- Transsphenoidal surgery : MR used to optimize angle of entry in sella.
 - Intraop normal gland versus tumor can be identified.
 - Resection guided in large tumors with parasellar extension.

ADVANTAGES

- Accurate real time localisation.
- Increased safety of approach through choice of optimal trajectory.
- Definite intraop. identification of surrounding structures & their relationship to surgical anatomy.
- Immediate evaluation of extent of resection.
- Monitoring of any intraop. complication e.g. hemorrhage.

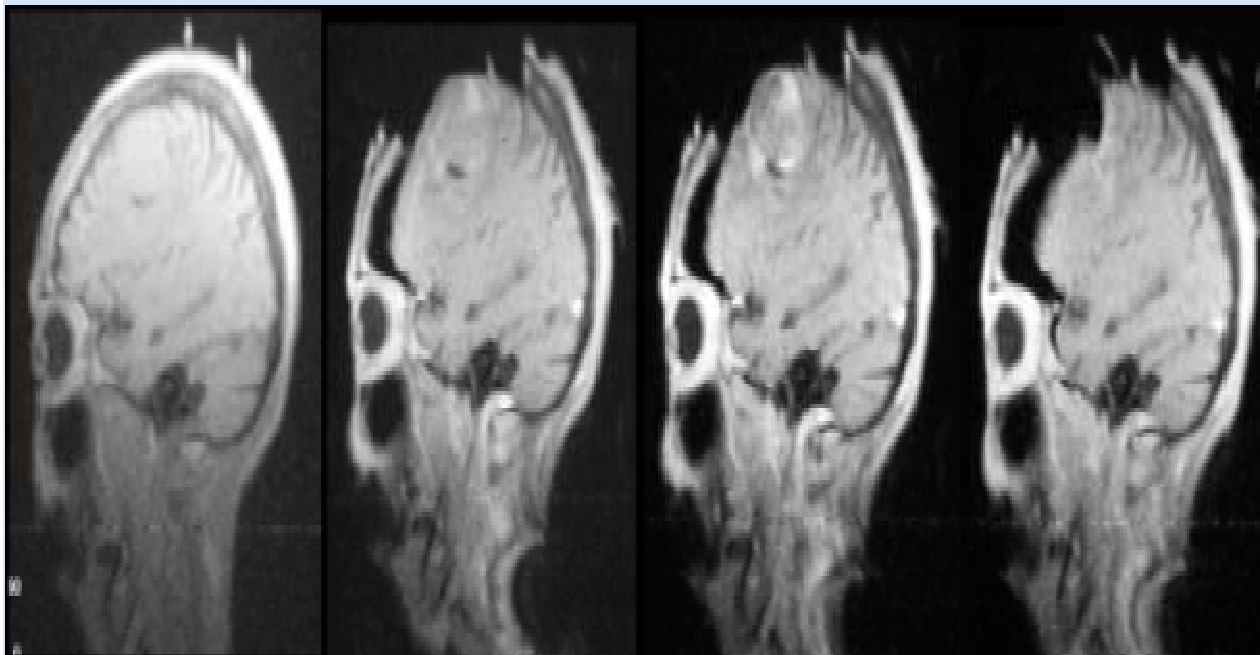
The double tilt operating room table during neurosurgical procedures





Operation

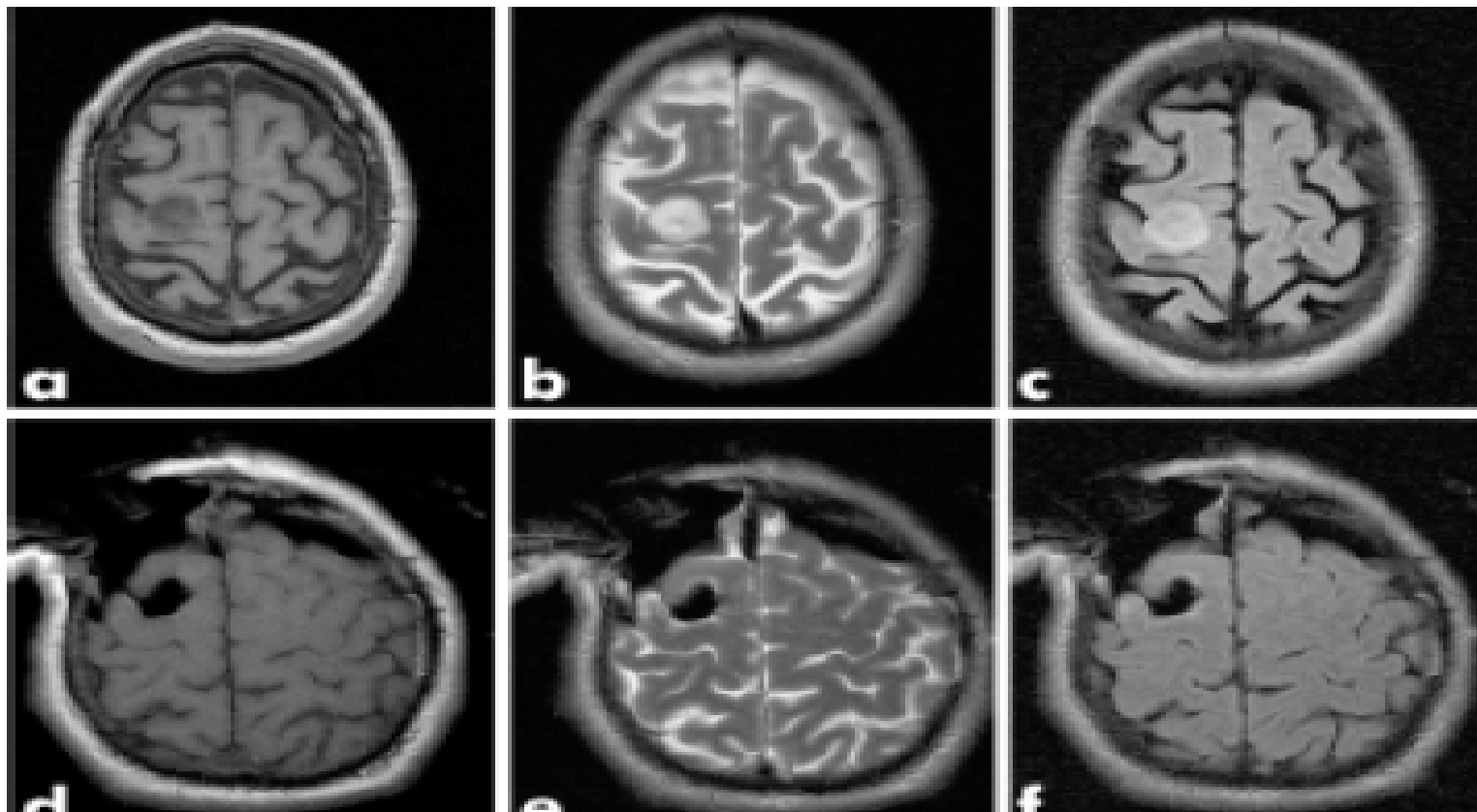
*Astrocytoma 5 mm slices,
post contrast T1 W,
2.30 minutes per study
(MAGNETOM Concerto)
Courtesy of Jonathan
Lewin, M.D. University
Hospitals of Cleveland,
USA*



Operation

*iMRI-guided neurosurgery –
meningioma resection
(MAGNETOM Concerto)*

*Courtesy of G. J. Rubino,
M.D., iMRI Program of the
UCLA Division of Neuro-
surgery Los Angeles, USA*



Resection of lowgrade Glioma

The tumor is in close proximity to the motor cortex.

a, b, c: pre operative MR

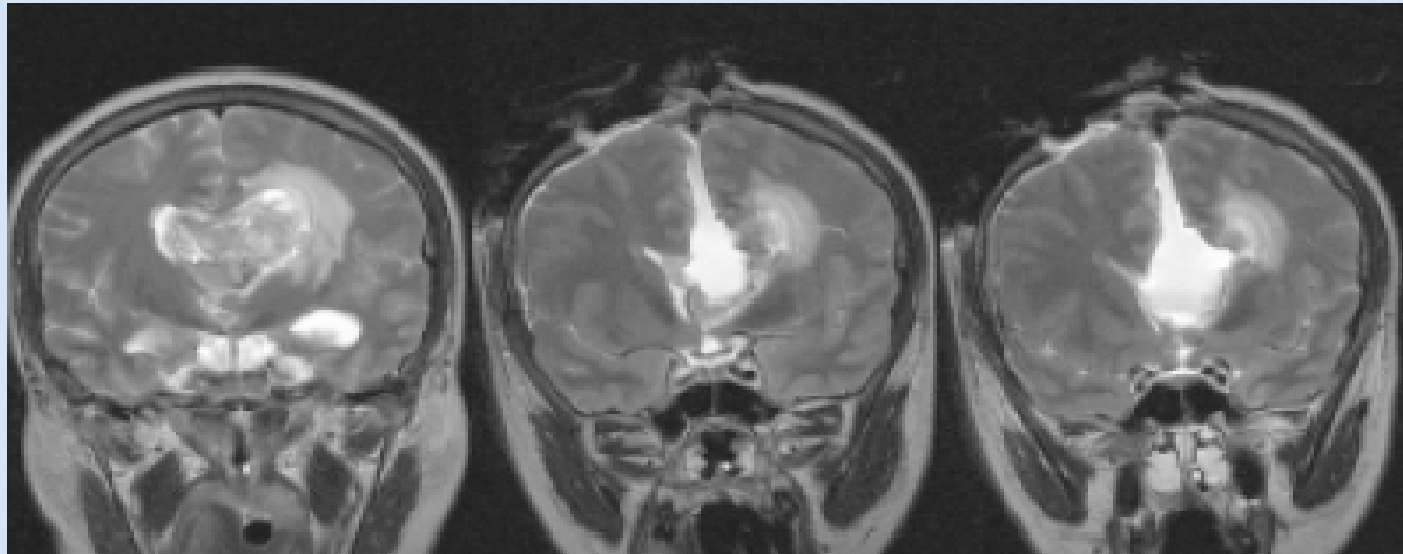
d, e, f: Intraoperative MR for monitoring complete resection. Intraoperative MR shows complete resection.

a / d: SE, T1-weighted

b / e: TSE, T2-weighted

c / f: Darkfluid T2

Courtesy of Prof. R. Fahlbusch, Universität Erlangen, Germany



Resection of intraventricular Neurocytoma

left: Pre operative MR

Middle: Intraoperative MR showing some residual tumor

Right: Second Intraoperative MR shows complete resection.

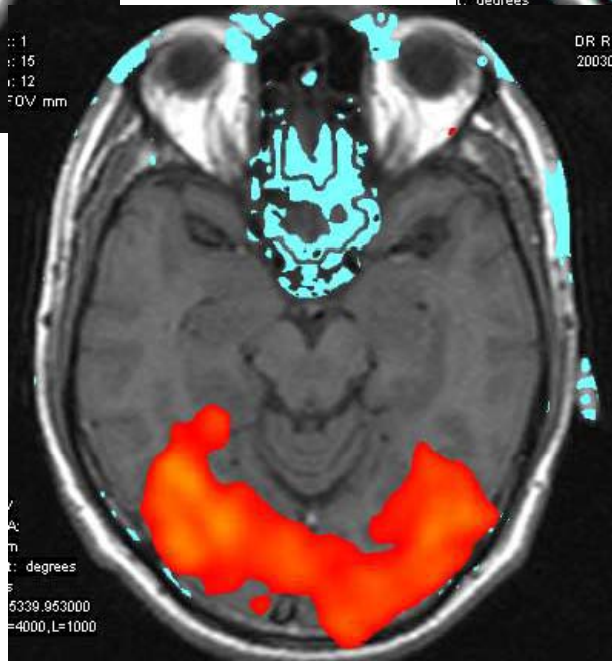
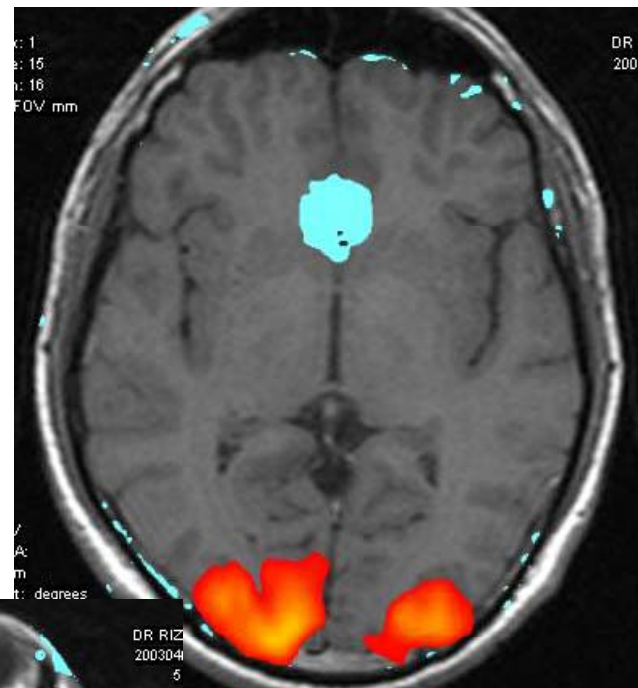
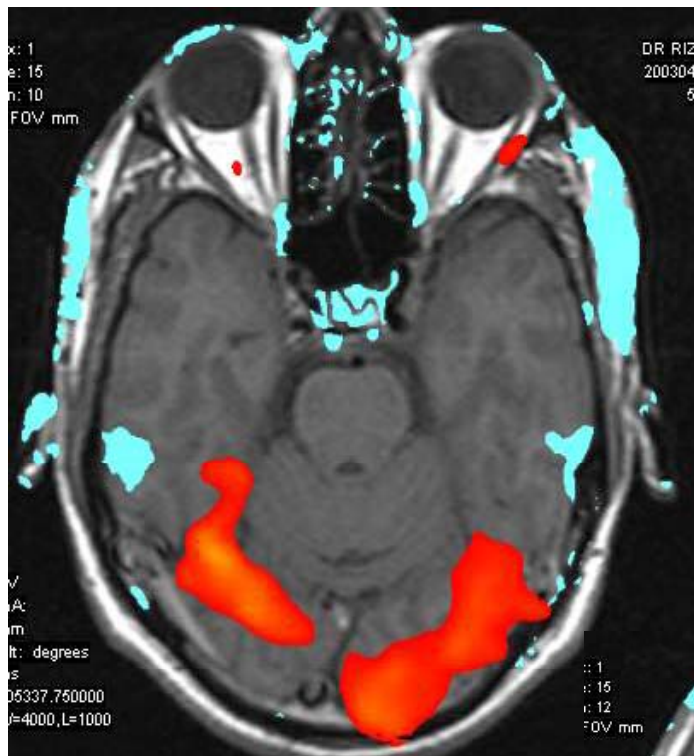
*Courtesy of Prof. R. Fahlbusch, Universität Erlangen,
Germany*

FUNCTIONAL MRI

- Functional MRI (fMRI) measures signal changes in the brain that are due to changing neural activity.
- Scanning low resolution but at a rapid rate (typically once every 2-3 seconds).
- Increases in neural activity cause changes in the MR signal via $T2^*$ changes.
- This mechanism is referred to as the BOLD (blood-oxygen-level dependent) .

- Neural activity increases demand for O₂, vascular system overcompensates for this, increasing the amount of oxygenated Hb relative to deoxygenated Hb.
- Because deoxygenated Hb attenuates the MR signal (less paramagnetic), the vascular response leads to a signal increase.
- Change in intensity is slight (6%) at 1.5T images are repeatedly acquired at same location over course of stimulus using EPI sequence.

VISUALACTIVATION



- **LOCALISES:**
 1. Visual cortex
 2. Motor cortex
 3. Somatosensory cortex
 4. Broca's area of speech
 5. language-related activities.

ADVANTAGES OF fMR

1. Does not require injections of radioactive isotopes, (PET requires it).
2. The total scan time required can be very short, i.e. in the order of 1.5 to 2.0 min per run, (PET -multiple acquisitions & therefore, extended imaging times).

USES

1. ROLE IN NEUROSURGICAL PLANNING:

- When the presence of a tumor alters the expected location of a function.
- When the location of the tumor is in an area with an uncertain function such as association cortices or language-related processes.

2. FUTURE ROLE IN PAIN MANAGEMENT

Identification of cortical areas that are modified by the reduction of pain following pain therapy using fMRI to investigate cortical representations of specific pain types.

3. ROLE IN UNDERSTANDING THE PHYSIOLOGICAL BASIS FOR NEUROLOGICAL DISORDERS

fMRI may contribute to improved precision of seizure localization & understanding of seizure progression & suggests a future direction for investigation.

- **Magnetic resonance spectroscopy**
- Magnetic resonance spectroscopy (MRS) is used to measure the levels of different metabolites in body tissues. The MR signal produces a spectrum of resonances that correspond to different molecular arrangements of the isotope being "excited". This signature is used to diagnose certain metabolic disorders, especially those affecting the brain, and to provide information on tumor metabolism.

MRS

- Method of studying the chemical composition of living tissue *NON INVASIVELY*.
- Provides 'metabolic signature' of tissue.
- Detects normal & new/unexpected metabolites.
- Basis: uses the signal from hydrogen protons to determine the concentration of metabolites.

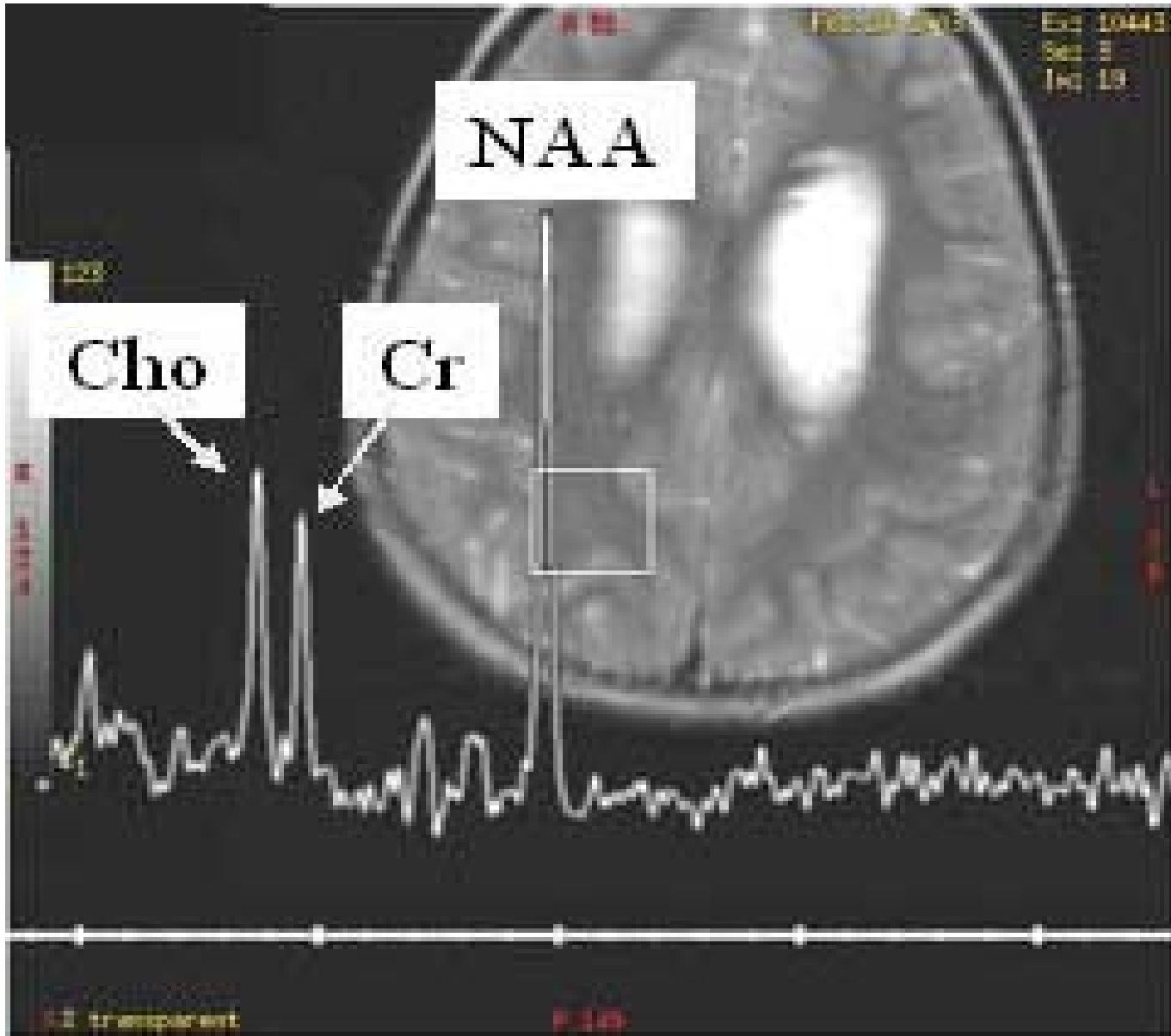
- Chemical elements used: hydrogen, phosphorus carbon.
- Proton (^1H) resonance is nowadays the method most frequently used in neuro spectroscopy.
 - Most abundant atom in the human body nucleus.
 - Emits the most intense radiofrequency signal, when in an external magnetic field.

- Measured with ^1H MRS: water and lipids
- N acetyl aspartate, creatine, carnosine, intra & extracellular lipids & with some extra work, lactate.

- N-acetyl aspartate : Neuronal marker & as such its concentration will decrease in the presence of aggression to the brain.
- Choline : Marker of membrane turnover.
Main indicator of neoplastic diseases.
- Myoinositol is raised in patients with Alzheimer's disease.
- Amino acids are encountered in brain abscesses.
- The presence of lipids is related to necrotic processes.

- Chemical shift is measured in Hz or parts per million (ppm). The preferred unit is ppm.
- **NAA** **2.0 ppm**
- **Cr** **3.0**
- **Cho** **3.2**
- **Lac** **1.3**
- **Lip0** **0.8-1.4**

Normal



USES

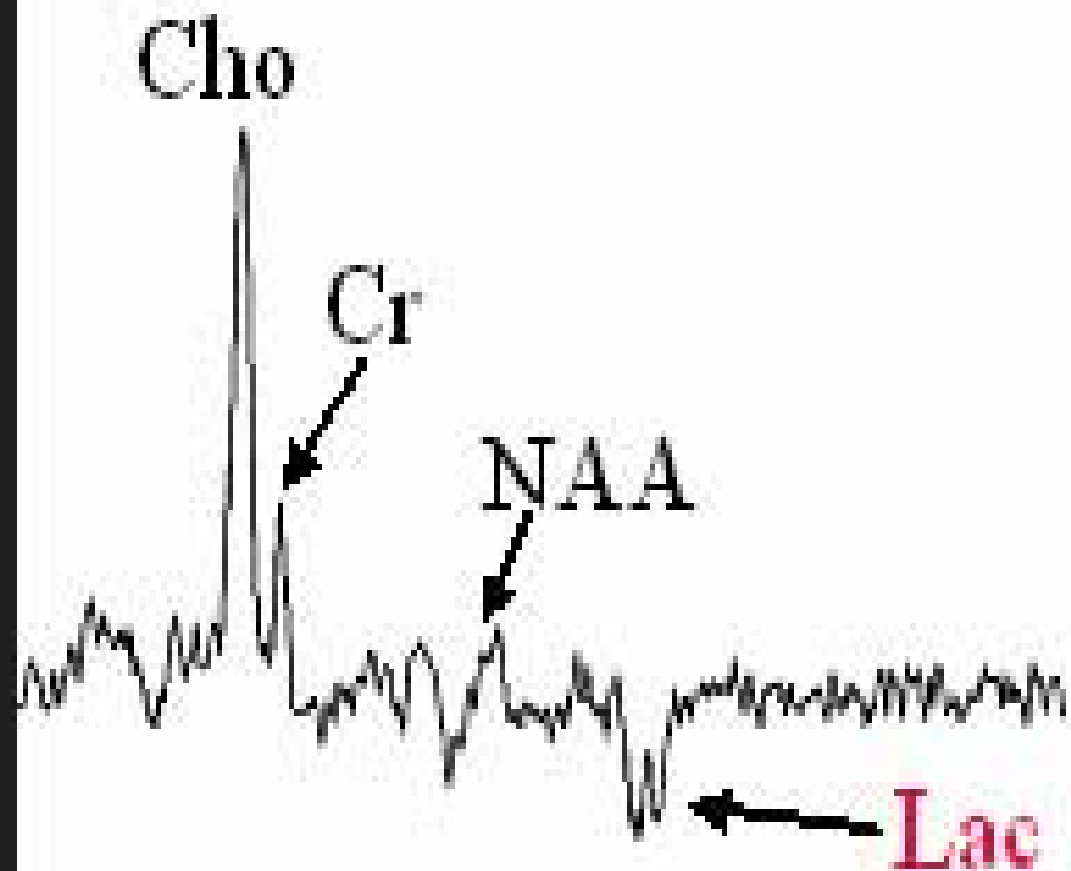
- **1. Differential diagnosis of focal brain lesions** (neoplastic & non-neoplastic diseases)
: Very sensitive method for detecting brain tumors.
 - Gliomas : Decreased intensity of the N-acetyl aspartate peak and increased choline occur.
 - Lactate peaks may be found ,independent of their malignancy grade, indicating hypoxia.
 - There is controversy regarding the capacity of proton spectroscopy to distinguish between different histological grades of gliomas.
 - Most non- glial tumors have little or no NAA.

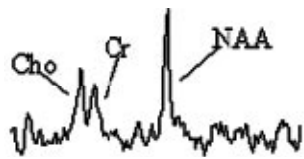
- Detection of lipids is typical of multiform glioblastoma i.e. tissue necrosis.
- Multi- voxel spectroscopy is best to detect infiltration of malignant cells beyond the enhancing margins of tumors.
- Differentiating glioma from infection.
- ❖ Proton MRS is useful because in neoplastic processes there is a remarkable increase in the choline peak.

2. **Tumor recurrence VS. radiation effects**

- Elevated choline is a marker for recurrent tumor.
- Radiation change generally exhibits low NAA, creatine & choline .
- If radiation necrosis is present, the spectrum may reveal elevated lipids & lactate.

- Tumor

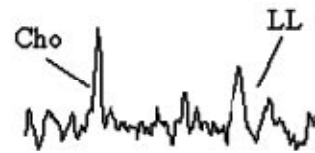




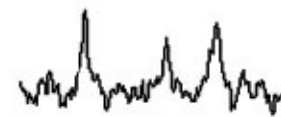
normal brain



melanoma metastasis



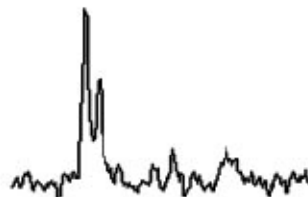
lung metastasis



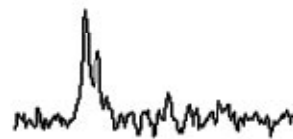
lung metastasis



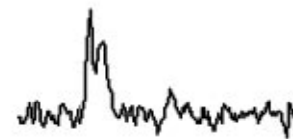
grade 2 glioma



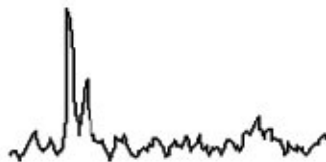
grade 2 glioma



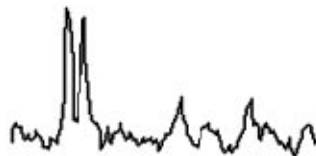
grade 3 glioma



grade 3 glioma



grade 4 glioma



grade 4 glioma



grade 4 glioma



center of grade 4 glioma

- MRS can sometimes identify the most malignant portion of a large tumor, guiding the surgeon to the best biopsy site

- ***Diagnosis of Meningioma*** :Useful in atypical cases.
 - Pronounced rise in choline levels.
 - Associated with absence or considerable reduction of N-acetyl aspartate.
 - Presence of an alanine peak can confirm the diagnosis.

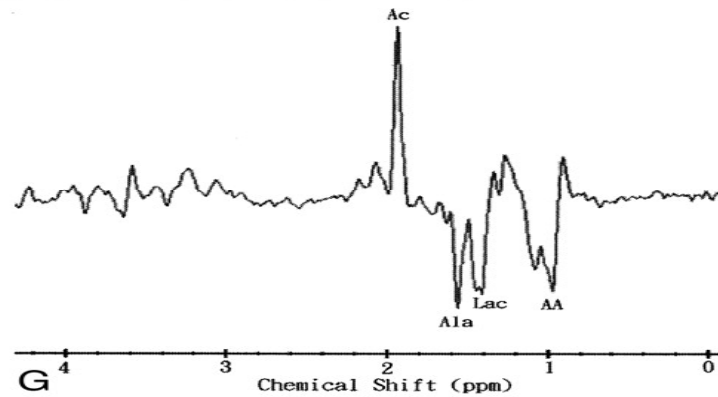
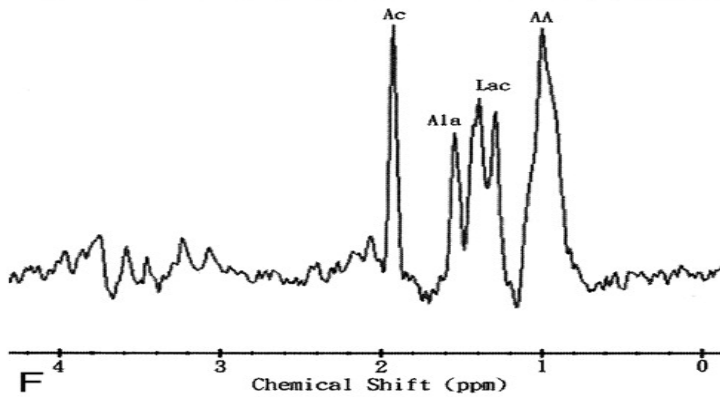
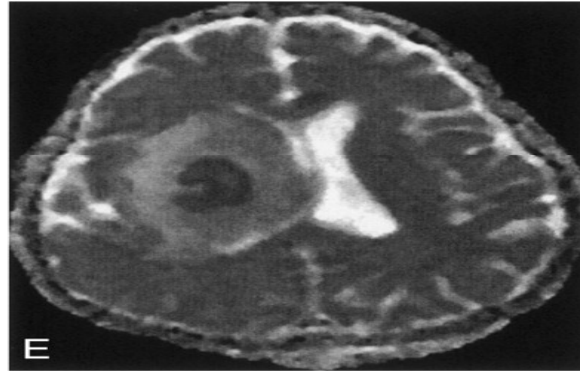
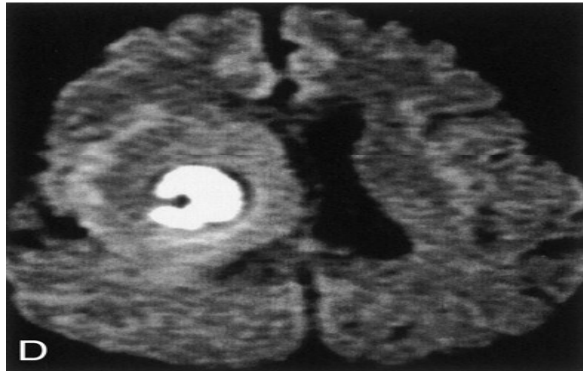
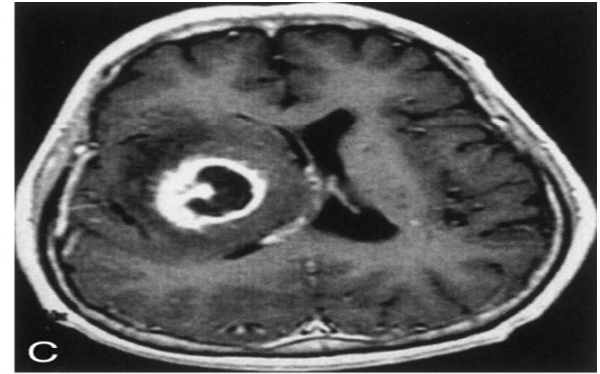
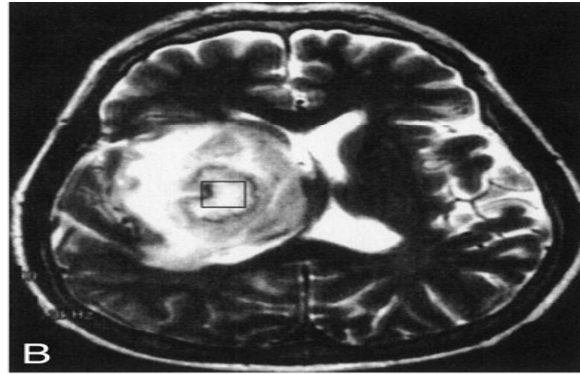
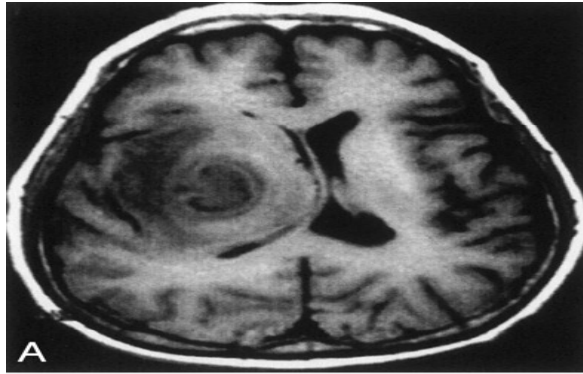
INFLAMMATORY & INFECTIOUS PROCESSES

- To differentiate between these & tumors.
- In focal inflammatory processes :
In patients with AIDS such as toxoplasmosis
 - Tuberculosis
 - Cryptococcosis
 - ❖ MRS shows a broad lipid peak & occasionally a lactate peak, with a decrease or absence of N-acetyl aspartate & slight increase of choline.

- ***IN PYOGENIC ABSCESS :***

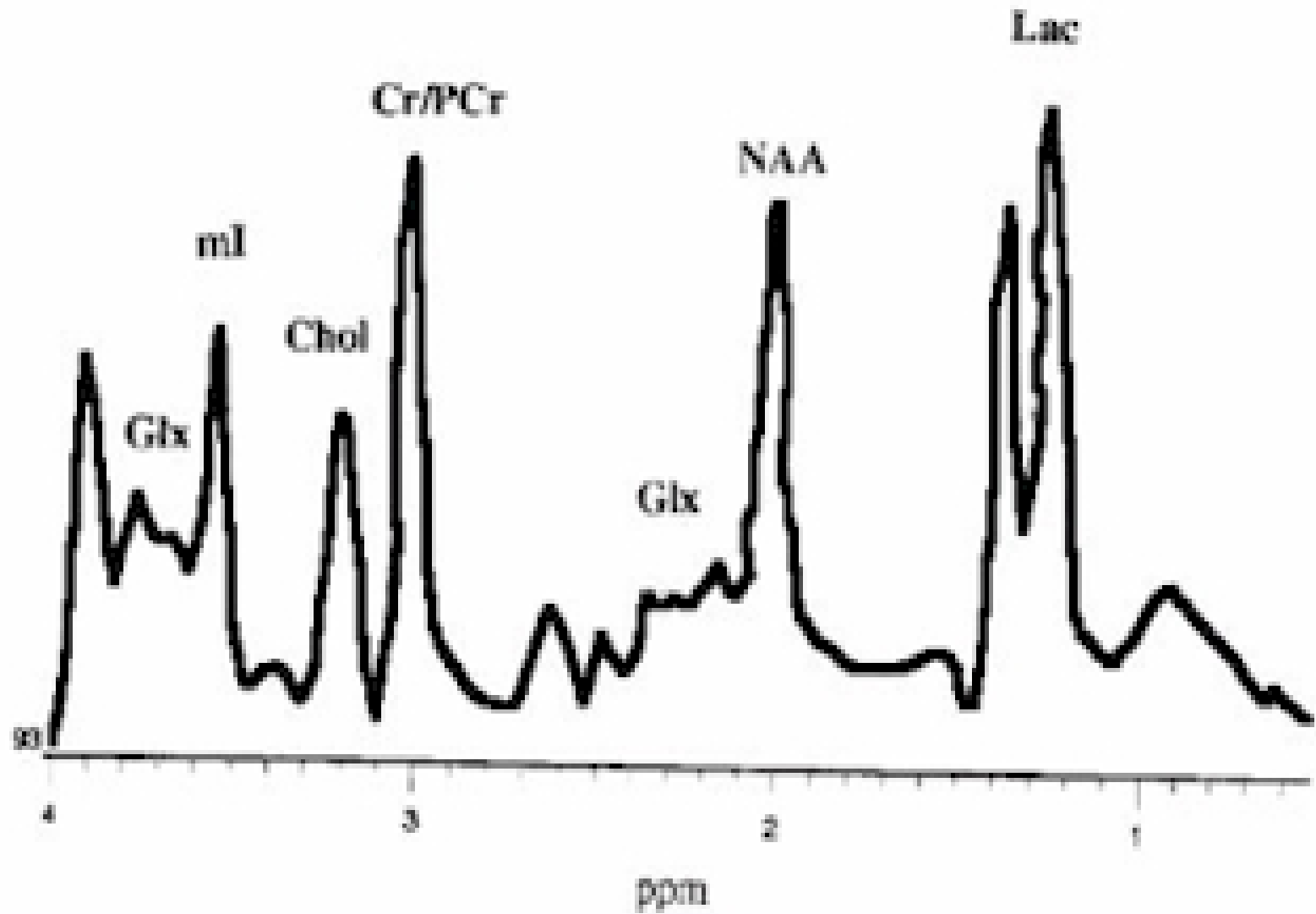
- Amino acid peaks, especially succinate, acetate.
- Due to the great quantity of hydrolytic enzymes produced by bacteria.
- N-acetyl aspartate, creatine and choline peaks are not detected.

- Acetate (*Ac*), Alanine (*Ala*), Lactate (*Lac*) & amino acids (*AA*) peak in ABSCESS



ISCHEMIC LESIONS

- In acute brain ischemia :
 - Early appearance of a lactate peak.
 - Decrease of N-acetyl aspartate.
 - Slight increase of choline.

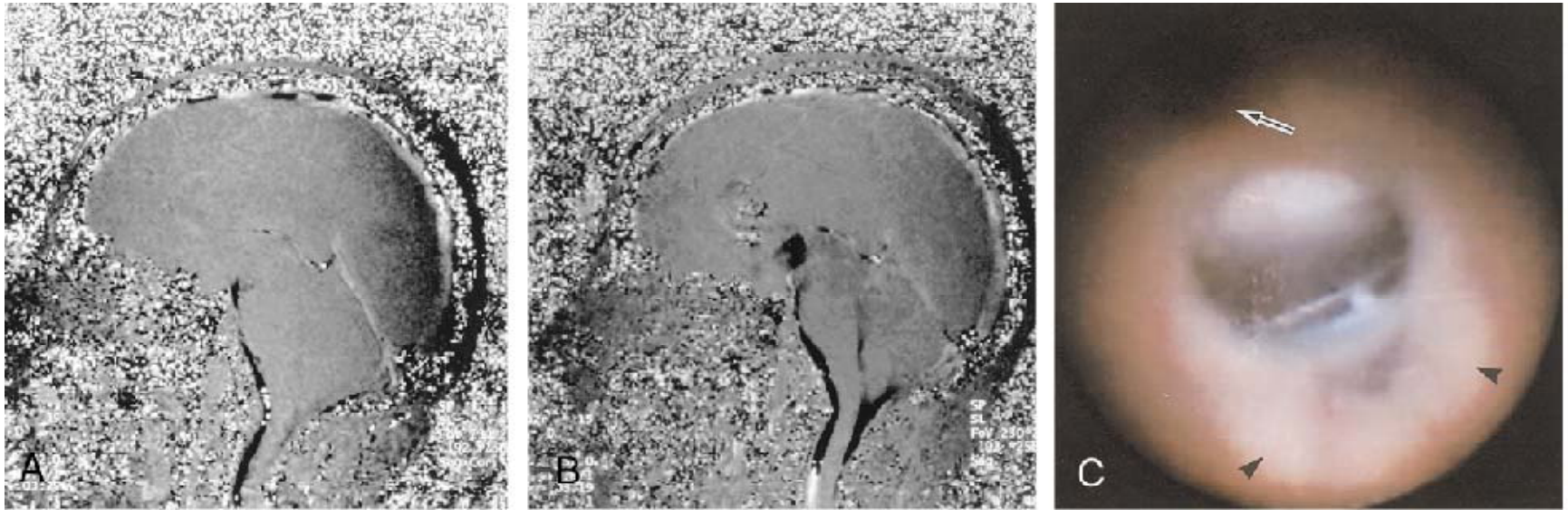


CINE Phase Contrast MRI

- Can demonstrate qualitatively & quantitatively alterations in CSF flow during the cardiac cycle.
- Cine MRI synchronizes MR data acquisition to a motion cycle to enable imaging of moving tissue.
- Cine MRI collects image data over many cycles of periodic motion.
- Used for evaluating cranial & spinal CSF flow.

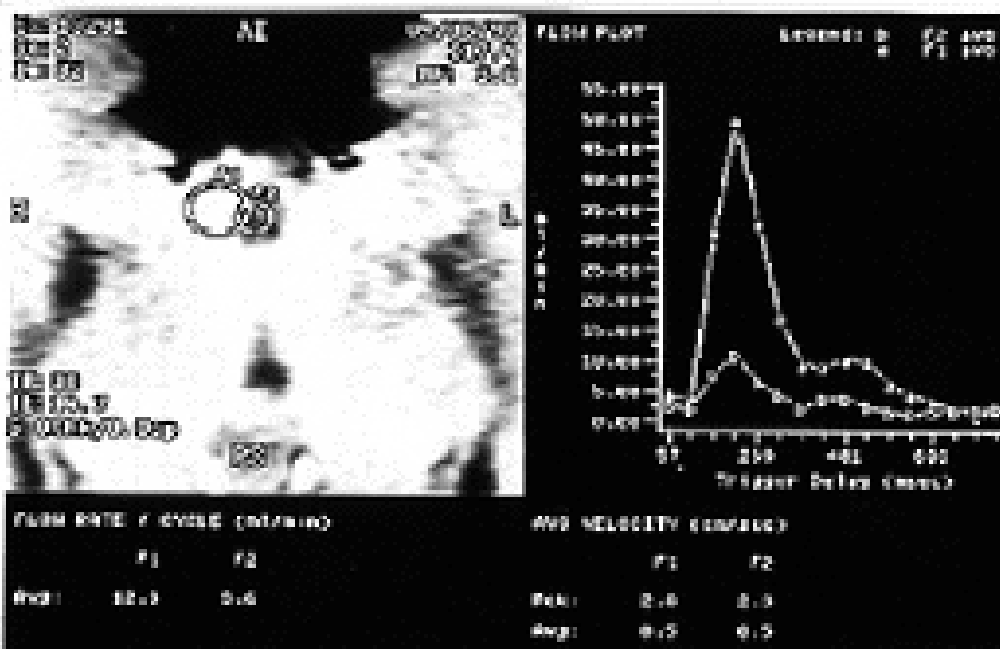
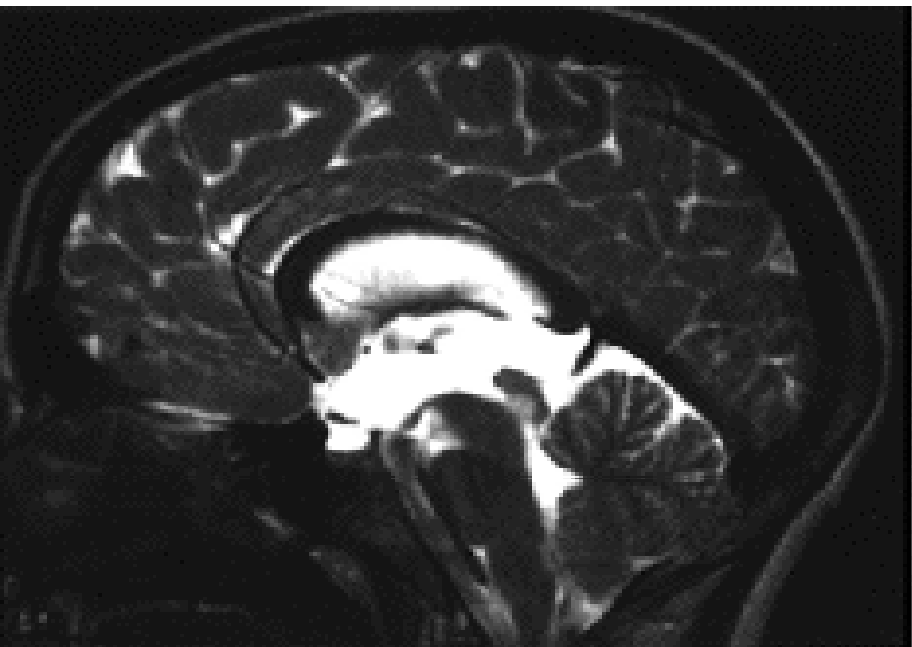
USES

1. Physiology of the normal CSF circulation.
2. Pathological CSF flow dynamics in communicating & obstructive hydrocephalus, Chiari malformation, syrinx.
3. Cine MR imaging has been recommended for evaluating the patency of third ventriculostomies.
4. Cerebrospinal Fluid Flow After Endoscopic Aqueductoplasty.



A, Preoperative cine PC MR image reveals obstructive hydrocephalus with no flow in the aqueduct. No flow is apparent in the third ventricle.

B, Cine PC MR image after the third ventriculostomy shows obvious in-phase third ventricular flow, which is categorized as patent. In the anterior horn of the lateral ventricle, an artifact of air is observed.



- Upper Left: Sagittal T2-weighted MR image obtained at admission demonstrating triventricular hydrocephalus with aqueduct stenosis due to a small tectal lesion. Upper Right: Cine PC MR imaging flow measurement, focusing on the aqueduct, revealing the absence of systolic/diastolic flow and confirming the diagnosis of aqueductal stenosis. Lower Left: Sagittal T2-weighted MR image obtained 2 days after the patient underwent third ventriculostomy, which resulted in complete resolution of the symptoms. Note the decreased ventricular dilation and the flow-void artifact through the floor of the third ventricle. Lower Right: Cine PC MR imaging flow measurements, focusing on the third ventriculostomy, revealing a systolic/diastolic flow at the level of the two cursors (F1 and F2) placed at the site of the stoma, confirming the patency of the third ventriculostomy

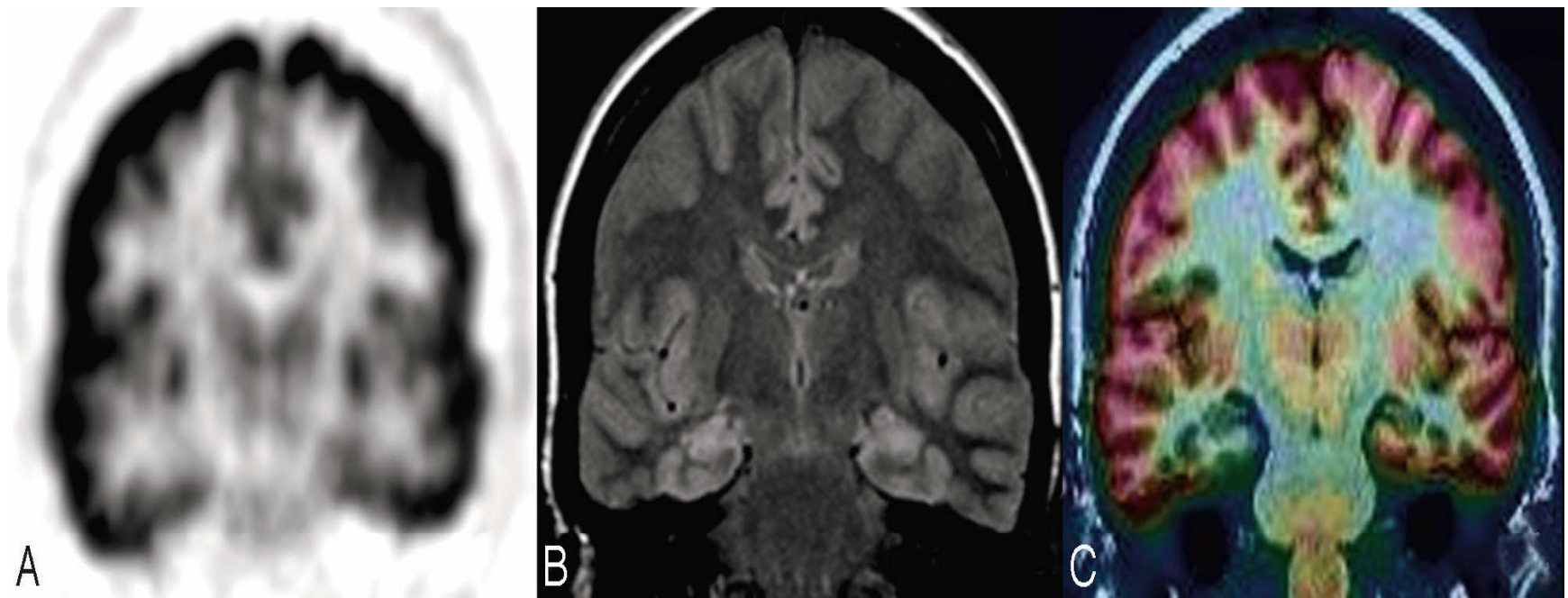


Cine MRI: On the left, no posterior flow (arrow) in a patient before decompression of their Chiari I malformation



Cine MRI, return of CSF flow represented by the white space behind the cerebellar tonsils after decompression (white arrow)

**[18F] Fluorodeoxyglucose–Positron-
Emission Tomography and MR Imaging
Coregistration for Presurgical
Evaluation of Medically Refractory
Epilepsy**



MTS in a 31-year-old woman. *A*, FDG-PET image was read as having normal findings. *B*, However, the FLAIR image shows some question of increased T2 signal intensity in the right hippocampus. *C*, FDG-PET/MR imaging coregistration demonstrates subtle hypometabolism of the right mesial temporal structures. Because neurocognitive testing also demonstrated impaired function of right mesial temporal structures, right anteromedial temporal lobectomy and hippocampectomy were performed. FDG-PET/MR imaging coregistration facilitated localization of the metabolically abnormal area that was subtle when read by FDG-PET alone

- **Image Fusion**
- Image fusion (exactly overlapping the images in three dimensional space) bring all of the above information together in the operating room.
- This information is used during the course of the operation to help achieve a safer, more effective surgery.
- Intra operative image fusion. gives a "road map" showing unique features of the tumor as well as the location of critical structures that must be avoided to preserve speech, walking and other functions.

- The demand for high–performance imaging is demonstrating clear medical benefit in cases where we can't see lesions well enough with 1.5 tesla, such as scanning for developmental abnormalities or performing high–resolution MR angiography, diffusion or perfusion imaging.
-
- The biggest payoff for 3 tesla, is in presurgical planning to avoid invasive angiography or direct cortical mapping at the time of surgery. Coupled with anatomic detail, 3–tesla perfusion studies plot a patient's physiology up to the edge of a lesion, and diffusion tensor images trace white–matter tracks that must be preserved.
- The signal changes that we look at with blood oxygenation level–dependent contrast at 1.5 tesla is on the order of 1% to 2%, that signal change goes to 3% to 5% at 3 tesla, meaning that we can do reliable individual patient mapping and interpretation.

THANKS