

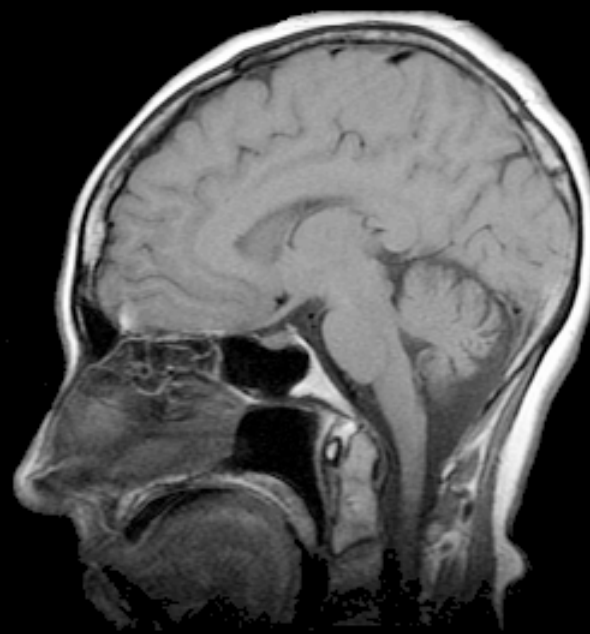


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September 2000

MRI of the Brain:

A Primer on What, How, Why, and When



Hornak, J.P. The Basics of MRI. 1996-2000

Amit Malhotra, Harvard Medical School, Year- IV
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Magnetic Resonance Imaging

A Brief History

- Magnetic Resonance phenomenon first described by Felix Bloch and Edward Purcell in 1946. In 1952 they were awarded the Nobel Prize.
- 1971 - Raymond Damadian showed that the nuclear magnetic relaxation times of tissues and tumors differed, sparking interest in medical uses (Science 03/19/71).
- In 1975 Richard Ernst proposed magnetic resonance imaging using phase and frequency encoding, and the Fourier Transform, which forms the basis of current MRI techniques.
- 1987 – MR angiography developed by Charles Dumoulin.
- 1993 functional MRI (fMRI) was developed.



Physical Principles

- Based on the absorption and emission of radiofrequency energy – so there is NO ionizing radiation.
- Uses magnets ranging in strength from 0.3 to 1.5 Tesla to create a magnetic field around the patient.
- Magnetic field causes protons in the body to align and then pulsed radiowaves are directed at the patient causing a disturbance of the proton alignment.
- Atoms then realign and in doing so, emit the absorbed radiofrequency.

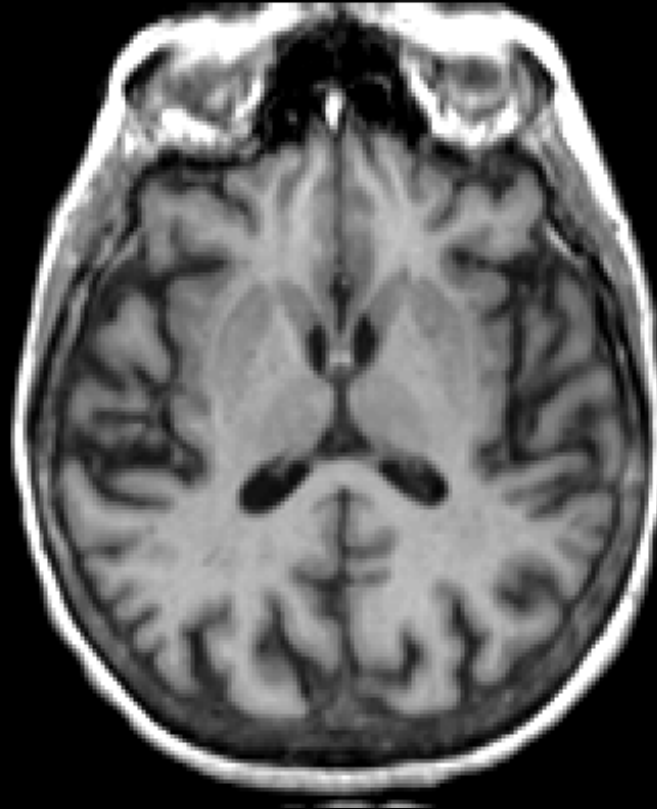
Physical Principles cont.

- The time it takes the protons to regain their equilibrium state = RELAXATION TIME.
- 2 types of relaxation time: T1 – Longitudinal (parallel to the magnetic field) and T2 –transverse (perpendicular to the mag field).
- Relaxation Time and Proton Density are the main determinants of signal strength.
- The main determinants of contrast or the weighting are:
 - ◆ 1)Repetition Time (TR) – the time between successive RF pulses
 - ◆ 2)Echo Time (TE) – time between the arrival of the RF pulse that excites and the arrival of the return signal at the detector.



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Short TR + Short TE = **T1 weighted**

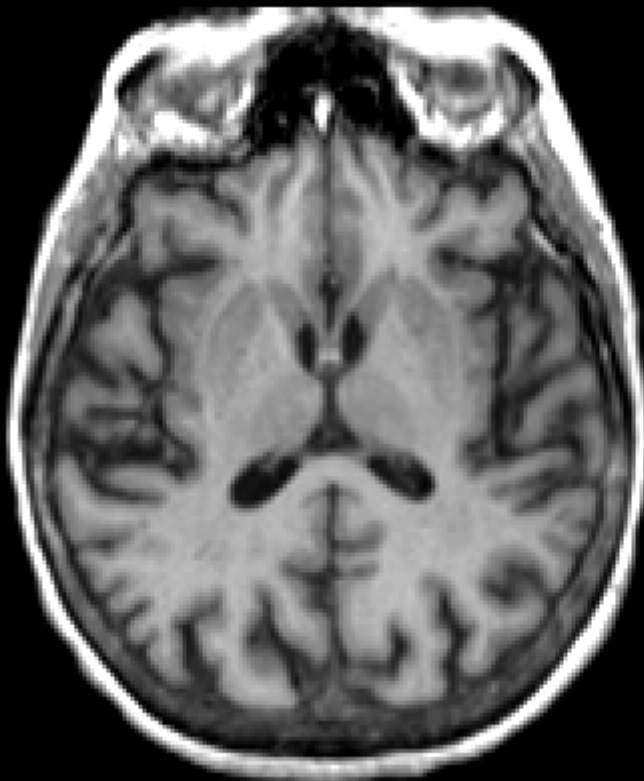


Johnson,KA and Becker, JA. *The Whole Brain Atlas*. 1995-1999



T1 Characteristics

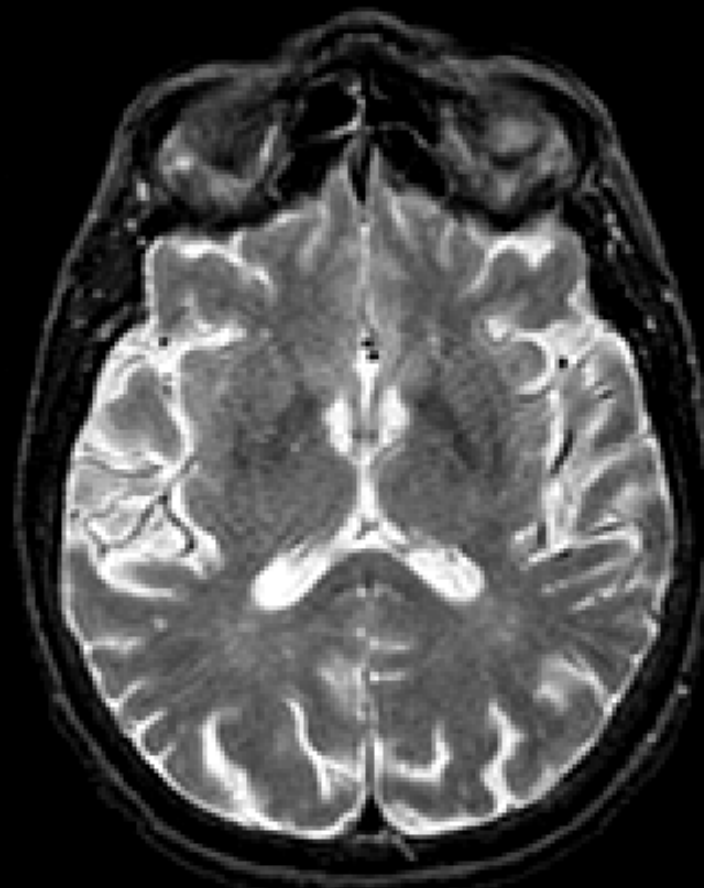
- Dark
 - CSF
 - Increased Water – edema, tumor, infarct, inflammation, infection, hemorrhage (hyperacute or chronic)
 - Low proton density, calcification
 - Flow Void
- Bright
 - Fat
 - Subacute hemorrhage
 - Melanin
 - Protein-rich Fluid
 - Slowly flowing blood
 - Gadolinium
 - Laminar necrosis of an infarct
- White matter brighter than Gray



Johnson,KA and Becker, JA. *The Whole Brain Atlas*. 1995-1999



Long TR + Long TE = **T2 weighted**

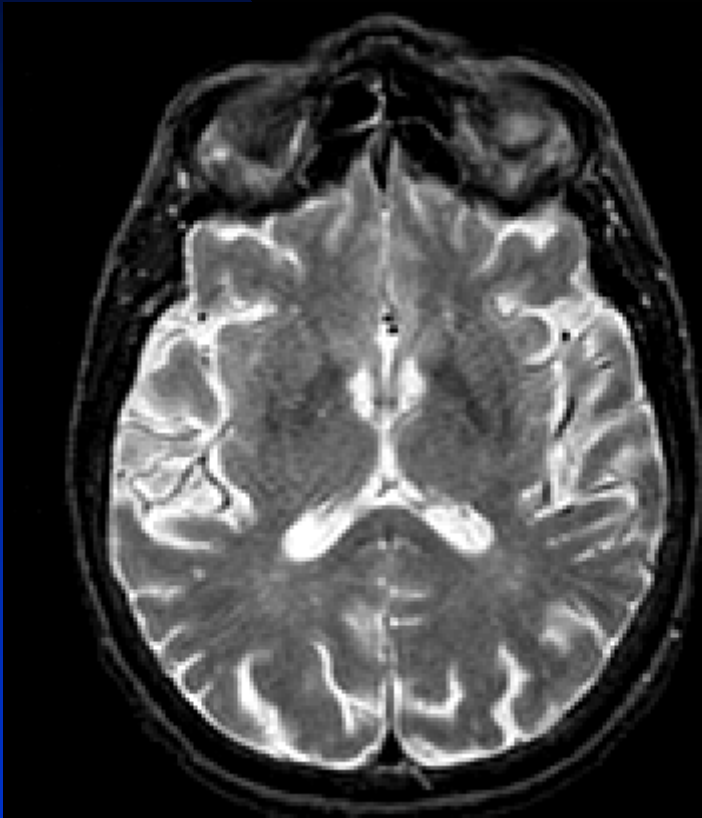


Johnson,KA and Becker, JA. *The Whole Brain Atlas*. 1995-1999



T2 Characteristics

- Dark
 - Low Proton Density, calcification, fibrous tissue
 - Paramagnetic substances - deoxyhemoglobin, methemoglobin (intracellular), iron, hemosiderin, melanin
 - Protein-rich fluid
 - Flow Void
- Bright
 - Increased Water – edema, tumor, infarct, inflammation, infection, subdural collection
 - Methemoglobin (extracellular) in subacute hemorrhage



Johnson,KA and Becker, JA. *The Whole Brain Atlas*. 1995-1999

- Gray matter brighter than white



Our patient K.G.:

43 yo male with h/o of Osler-Weber-Rendu, Hepatitis B Virus, and remote IV Drug Abuse presenting with headache, and episode of aphasia, and seizures.

Differential

- Traumatic bleed
- Stroke – Hemorrhagic vs. Ischemic
- TIA
- Neoplasm
- Infection



Menu of Tests for imaging suspected brain pathology

Plain films of the skull

Head CT

Head MRI

Radionuclide brain scan/PET

Cerebral angiography



A bleed was high on the differential because of the AVMs associated with Osler-Weber-Rendu and a history that the patient had fallen during a seizure

Head CT

- Imaging study of choice in acute situations . CT scanning is quicker than MR and acute blood is readily obvious without IV contrast. Further, bone windows will show skull fractures. Finally, intracranial calcifications are more apparent.
- Get the head CT first when considering a hemorrhagic event, possible skull fracture, or any cerebral event in an unstable patient.



A head CT was therefore first obtained on our patient, K.G.;



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No Intracranial bleed or fracture evident. No definite abnormality identified.
(? Subtle low attenuation adjacent to left occipital horn)



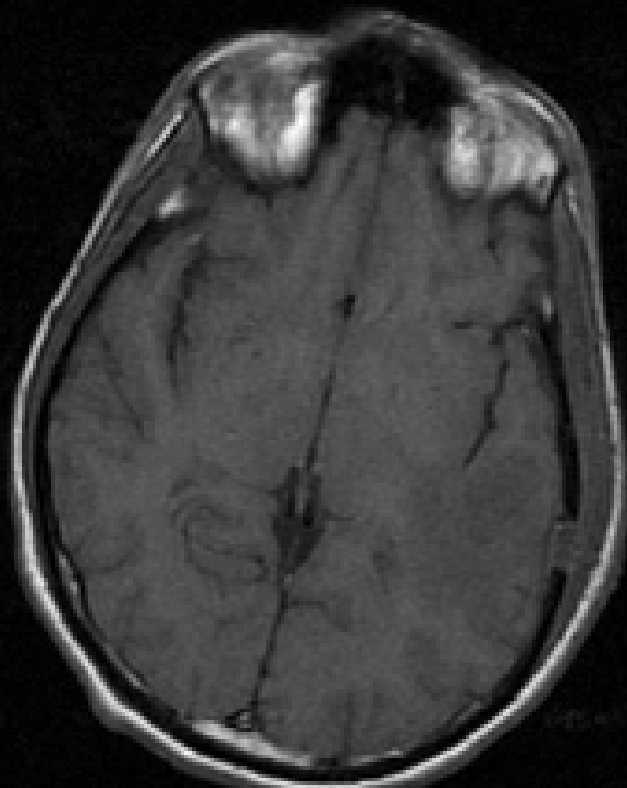
In view of our patient's significant CNS presentation , an MRI was obtained;

Menu of Head MRI Scans

1. Routine T₁, T₂ head MRI
2. Functional MRI
3. Diffusion Weighted Imaging (DWI)
4. Fluid Attenuated Inversion Recovery (FLAIR)
5. MR angiography (MRA)

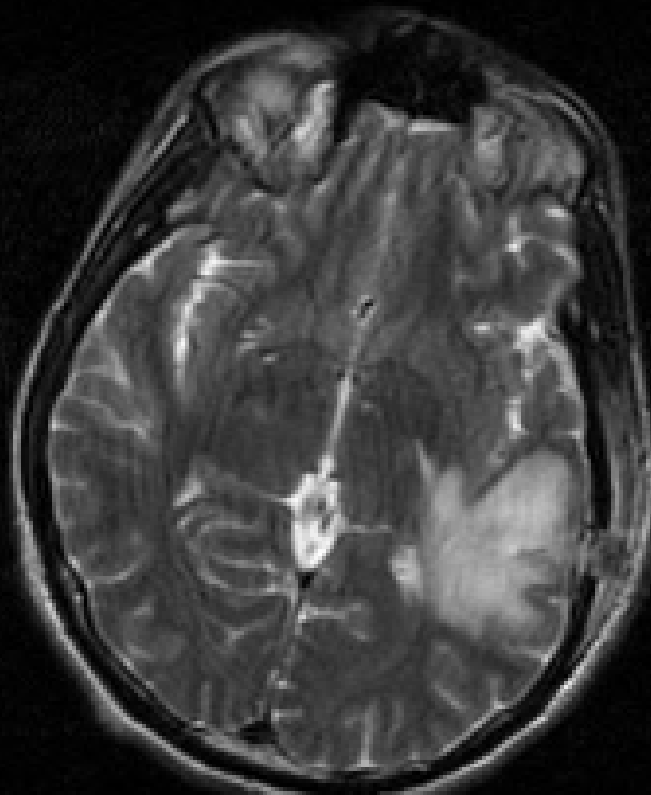


Our patient's MRI



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T1 axial



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T2 axial

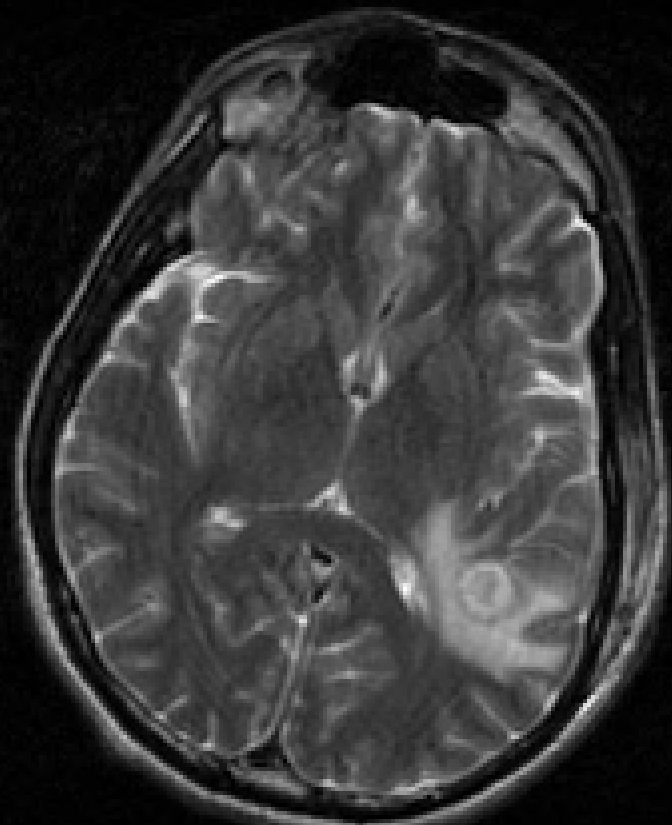
There is an abnormal area in the left temporo occipital region.¹⁴



Gadolinium enhanced MRI

Ddx Ring Enhancing Lesion

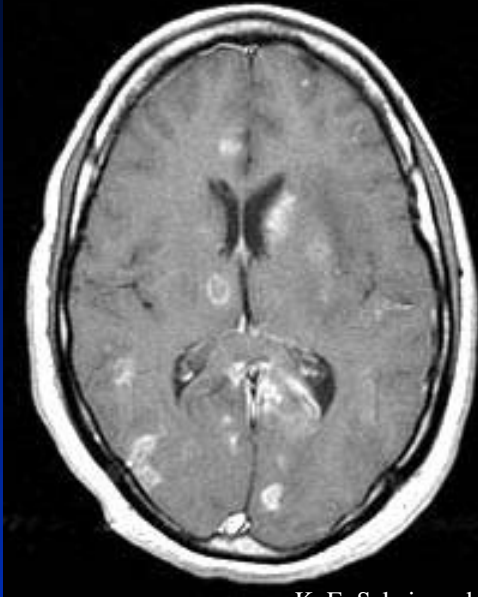
- Lymphoma
- Toxoplasmosis
- Cystercercosis
- Bartonella
- TB
- Listeria
- Whipple's
- Histoplasmosis
- Blastomycosis
- Nocardia
- Actinomycosis
- Coccidiomycosis
- Bacterial Abscess
- Necrotic Met
- Glioblastoma
- Inflammation
- Demyelination (active)
- Radiation Necrosis





- Our patient proved to have a bacterial brain abscess. In view of the past history of drug abuse, HIV was considered.

In a patient with HIV one must consider Lymphoma vs. Toxoplasmosis. Their classic presentation on MRI is ;



K. E. Sakaie and R. G. Gonzalez. Imaging of Neuroaids. NeuroAids; 1999; 2 (7)

Toxo

T1 axial

- Multiple Lesions
- Basal ganglia
- Brainstem

Lymphoma

T1 axial

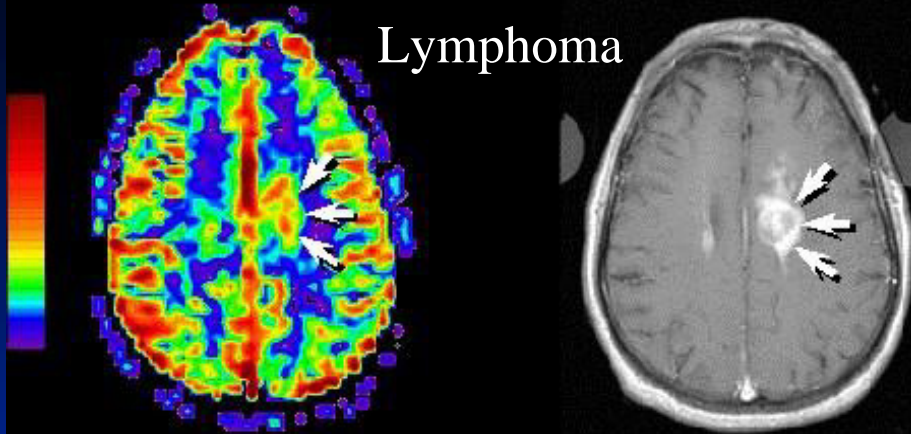
- Solitary lesion
- Periventricular or in the corpus callosum.
- Rapid progression
- +/- Mass effect



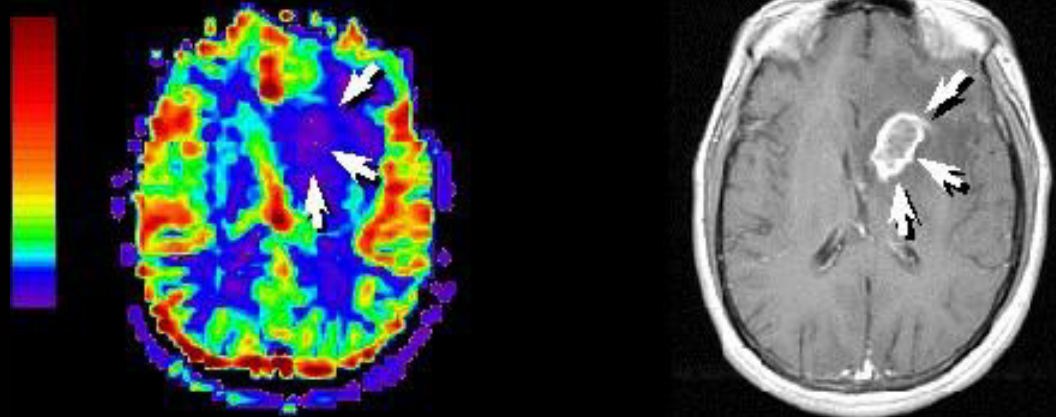
A Functional MRI aids their differentiation further:

Advanced Imaging fMRI

Lymphoma

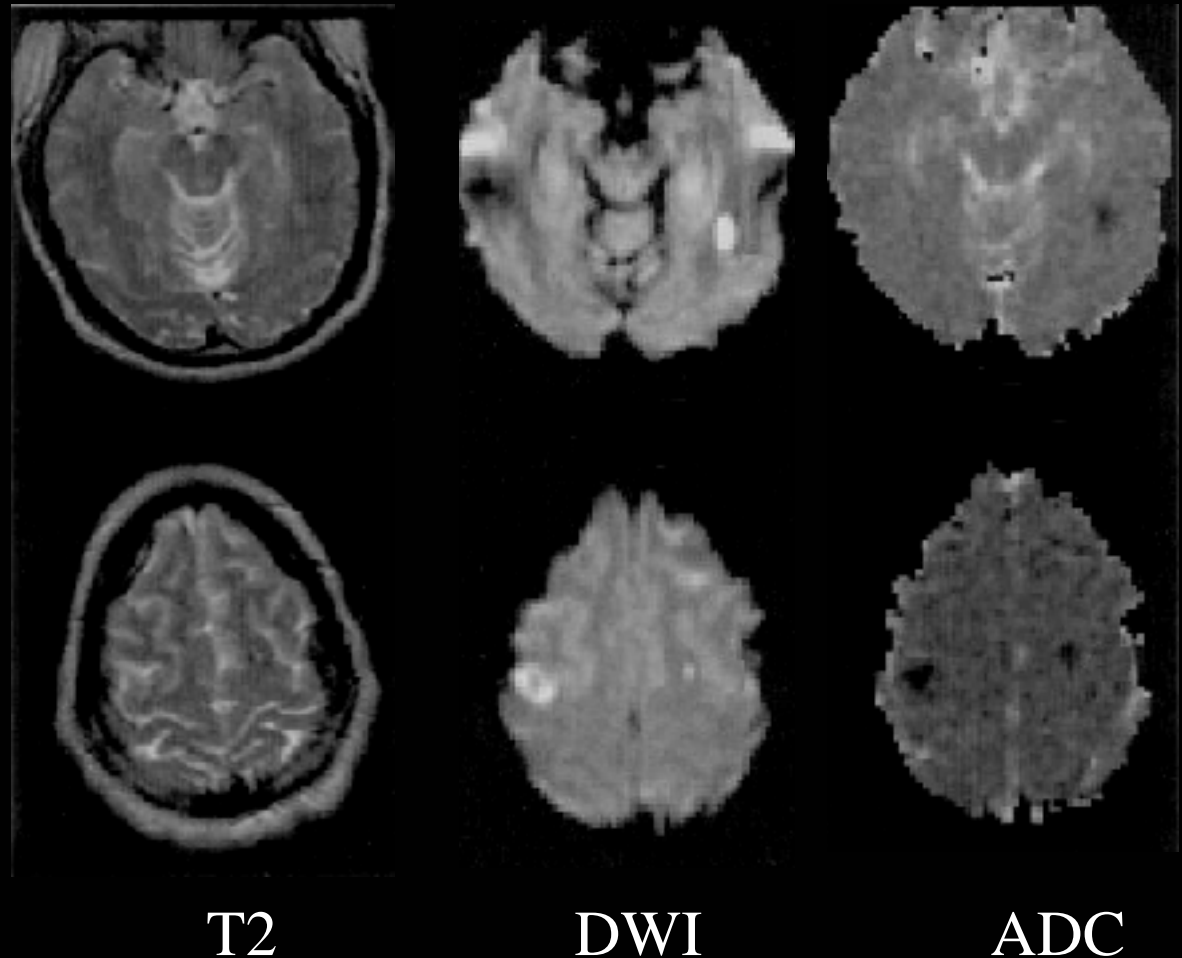


Toxoplasmosis





DWI



After: Fisher M and Albers GW. Applications of diffusion-perfusion magnetic resonance imaging in acute ischemic stroke. *Neurology* - 1999 Jun 10; 52(9): 1750-6

Advantages

- Detect hyperacute stroke - stroke in evolution, and within first 30min. Standard CT hypodense btw 12-36hrs.
- Differentiate acute ischemia from chronic infarct

Diffusion Weighted Imaging (DWI)/ Apparent Diffusion Coefficient (ADC)

- A high signal area on DWI is abnormal.
- Pitfall: The DWI is a manipulated T2 image and therefore high signal areas can be caused by “T2 shine through”. i.e. causing a false positive scan.
- An ADC scan is therefore mapped out with the DWI.
- Rule:
 - ◆ High signal DWI + low signal ADC= True abnormality.
 - ◆ High signal DWI + high signal ADC= False positive.



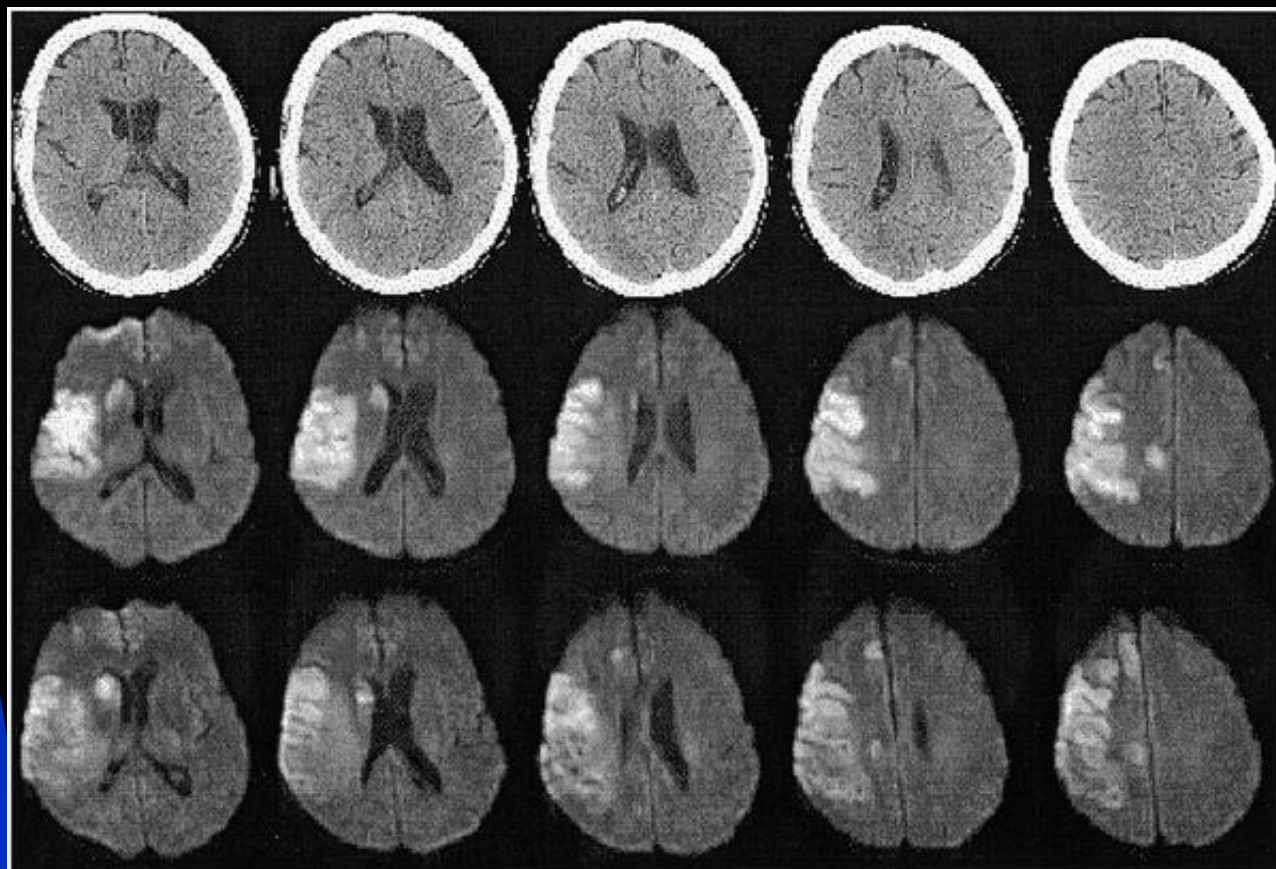


DWI continued

CT – 1.5hrs

DWI – 3.5hrs

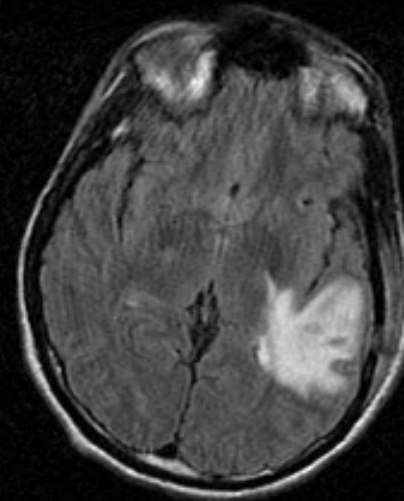
DWI – 36.5



Lansberg MG, Albers GW, Beaulieu C, Marks MP. Comparison of diffusion-weighted MRI and CT in acute stroke. *Neurology*; 2000 Apr 25; 54(8): 1557-61

Fluid-Attenuated Inversion Recovery FLAIR

- Basically T2 without CSF brightness
- TE > 80 and TR > 10,000
- Edema and Gliosis are hyperintense



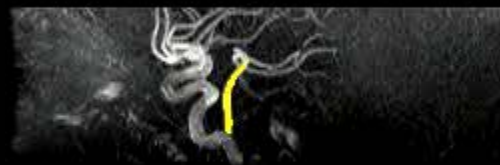
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MR Angiography

- Computer-assisted generation of images that result from the difference in signal between flowing blood next to stationary tissue.
- Type of Images:
 - Time-of-flight – utilizes inflow enhancement and highlights vessel morphology.
 - Phase-contrast - utilizes velocity-induced phase shifts and provides information on velocity and direction of blood flow.
 - Contrast Enhanced – utilizes T1 sequence with contrast to further delineate vasculature





MRI Summary

Normal tissue	T1	T2	T1	CT
dense bone	dark	dark	dark	bright
Air	dark	dark	dark	dark
Fat	bright	less bright	less bright	dark
Water	dark	bright	bright	dark
Brain	anatomic	intermediate	intermediate	intermediate



MRI Summary cont.

tissue	MR-T1	MR-T2	CT	enhancement ¹
Infarct	dark	bright	dark	subacute
Bleed	bright ²	bright ²	bright	no
Tumor	dark	bright	dark ³	yes
MS plaque	dark	bright	dark ⁴	acute

1. Blood brain barrier leak. For MR, gadolinium; for CT, iodinated contrast material.
2. Unless very fresh or very old.
3. Unless calcified.
4. Often isodense.



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All web pages referenced on 9/15-18/00



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The end.