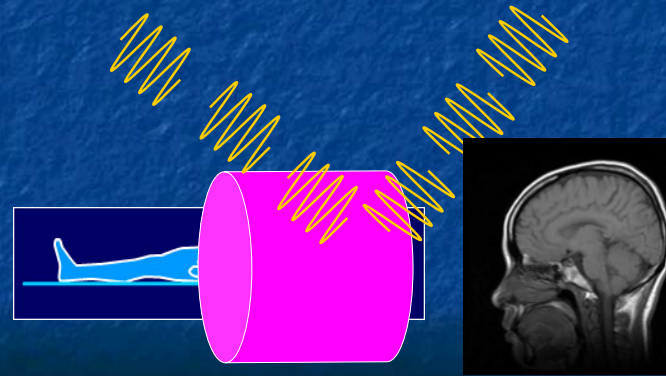


Basic MR Imaging (MRI) and MR spectroscopy (MRS)

Xiaojuan Li, PhD
Dept of Radiology, UCSF
PT210, March 1st, 2005

MRI Overview

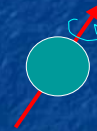


Questions

- How do we get MR signals?
- How do we reconstruct MR images?
- How do we interpret MR images?

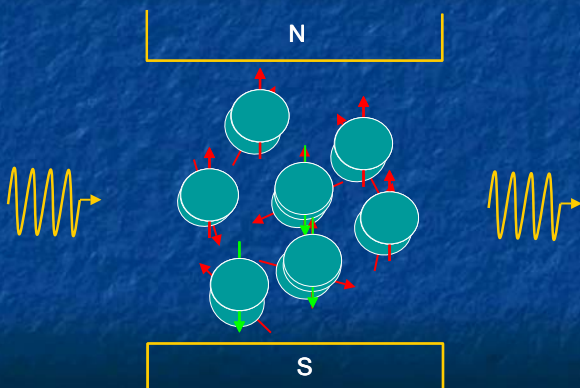
Spins

- Protons constantly spins around an axis

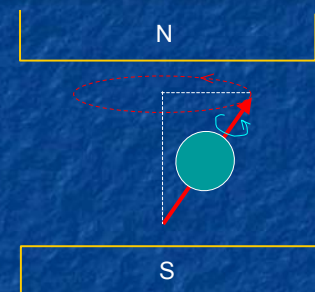


- The positive charge attached with protons also moves
- Electrical current \leftrightarrow magnetic field

MR Signals -- Spins

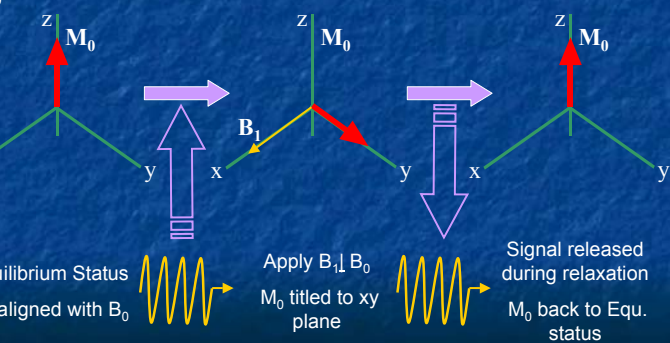


Precession

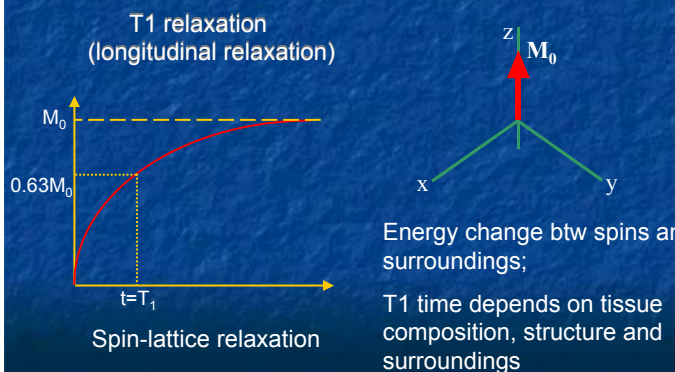


Larmor frequency $\omega_0 = \gamma \cdot B_0$

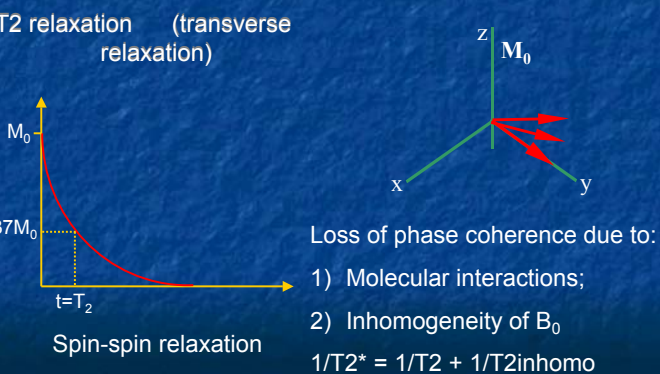
MR Signals -- Magnetic Vectors



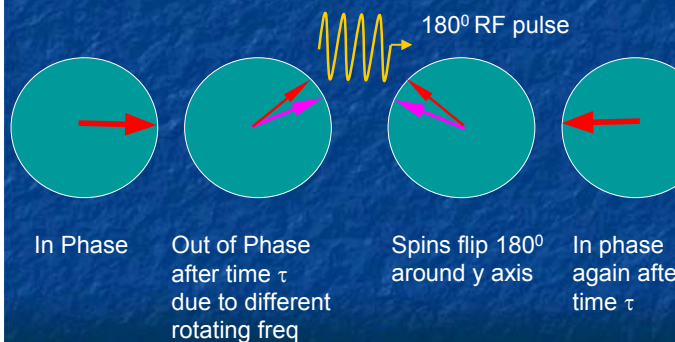
Relaxation -- T1



Relaxation -- T2



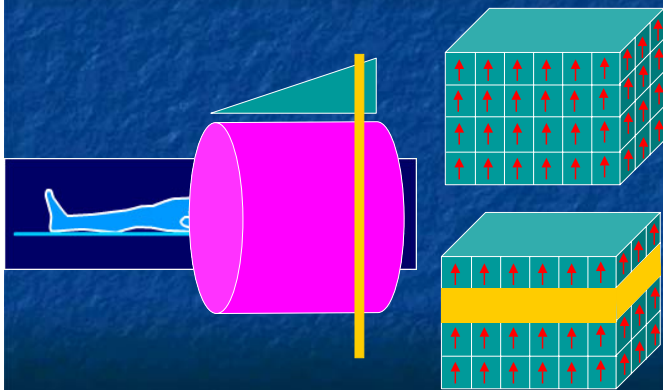
Spin Echo



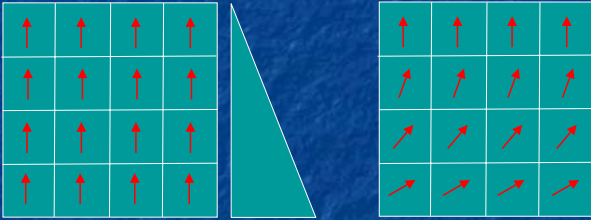
Localization

- Slice selection
- Phase encoding
- Frequency encoding

Slice Selection

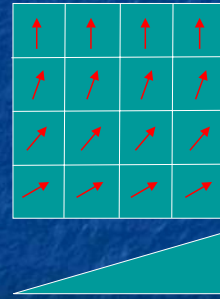


Phase encoding



Turn the gradient on for a period of time then off

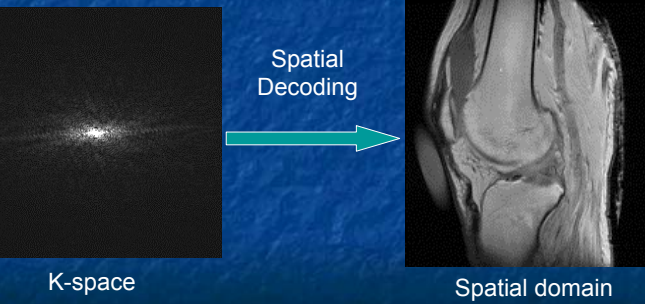
Frequency Encoding



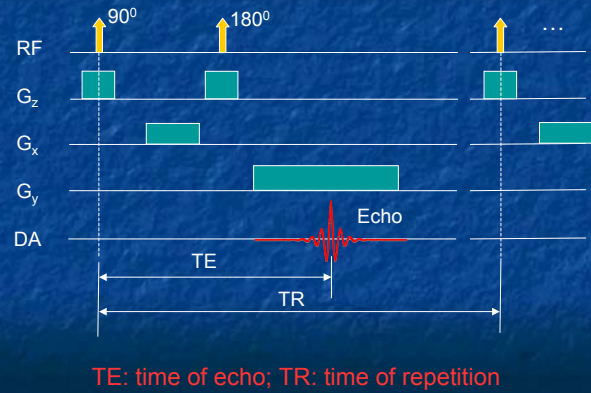
- Spins with the same phase have different frequencies
- Spins with the same frequencies have different phases

The gradient is on during data acquisition

Image Reconstruction

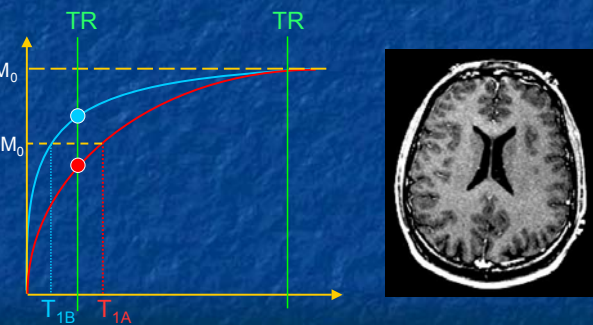


Pulse Sequence



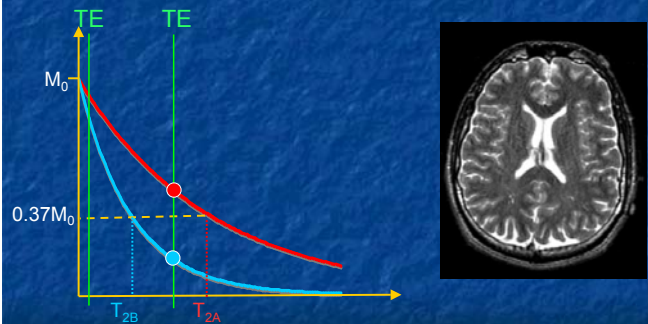
TE: time of echo; TR: time of repetition

Image Contrast - T1 weight



Short TR give T1 weight. Tissues with short T1 are brighter

Image Contrast - T2 weight



Long TE gives T2 weight. Tissues with long T2 are brighter

Image Contrast

	Short TE	Long TE
Short TR	T1	T1, T2
Long TR	Proton Density	T2

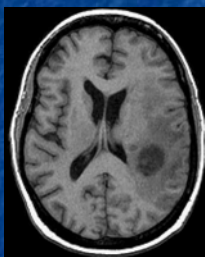
fluids normally have longest T1 and T2, so it appears darker in T1-weighted images and brighter in T2-weighted images. (Be careful to images with fluid suppression though!)

Factors affecting MR signals

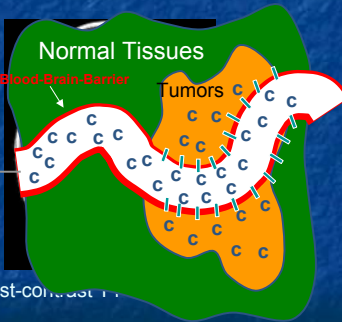
PD: Proton density at location (x,y,z)
 T1: Longitudinal relaxation time
 T2: Transverse relaxation time

TR: Time of Repetition
 TE: Time of Echo
 TI: Time of Inversion
 FA: Flip angle
 Pulse sequence, flow, contrast medium etc

Contrast agent



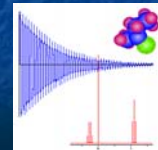
contrast



Pre-contrast T1-weighted image Post-contrast T1-weighted image

MR Spectroscopy

- MRS is a powerful, non-invasive, non-destructive tool to study chemical compositions and metabolic processes.
- Proton MRS detects signal from protons from metabolites other than water.



Chemical Shift

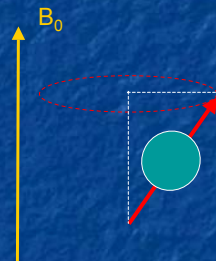
$$\omega_0 = \gamma \cdot B_0$$

In presence of B_0 , the electrons surrounding atoms will also interact with the field.

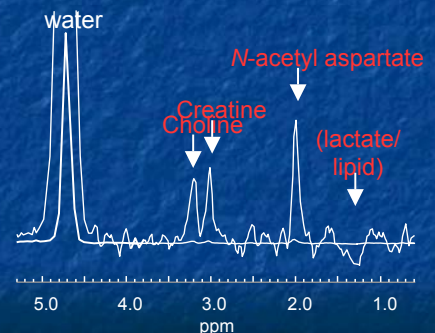
$$\omega_i = \gamma B_0 (1 - \sigma_i)$$

The σ_i depends on molecular environment a spin experiences. To get rid of B_0 dependency, this chemical shift is defined as parts per million (ppm):

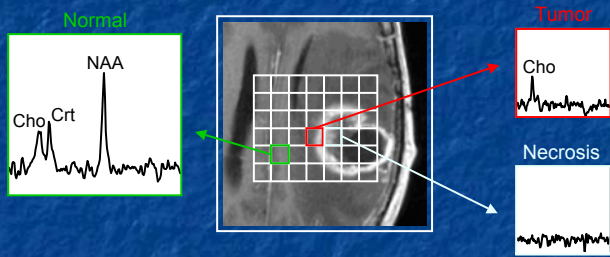
$$\delta = \frac{\omega_i - \omega_{ref}}{\omega_{ref}} \times 10^6$$



1-H MRS for brain tissue



MR spectroscopic imaging

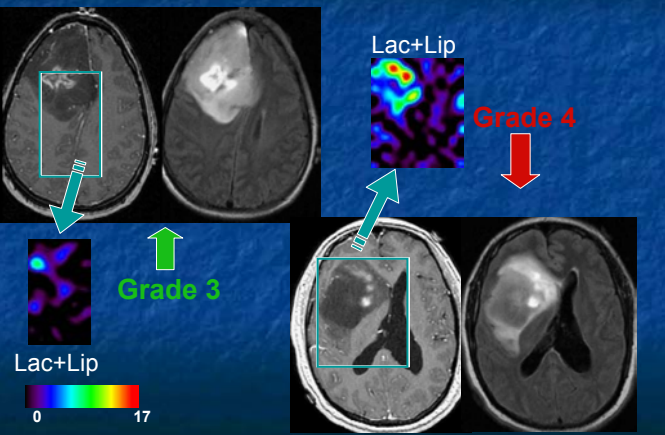


MR spectroscopy provides a unique 'biochemical' window to study cellular metabolism non-invasively, which helps to improve the sensitivity and specificity for detecting active tumor.

Comparison with MRI

- No frequency encoding during acquisition
- Long acquisition time
- Low SNR and low resolution due to low concentration of metabolites of interest
- Provides metabolic or functional information that may help to improve diagnosis and treatment monitoring

Grade 4 vs. Grade 3 of brain tumors



References

- MR Made Easy, GE and BERLEX
- <http://www.cis.rit.edu/htbooks/mri/>
- <http://www.cis.rit.edu/htbooks/nmr/>