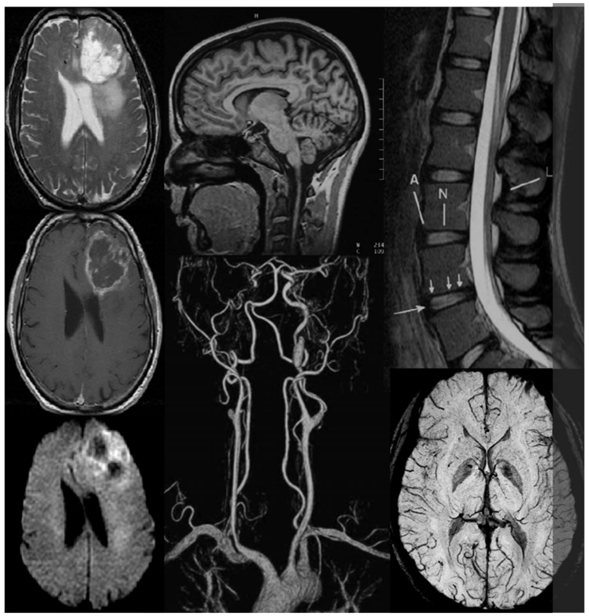

Magnetic Resonance in Medicine
Course Introduction & Principle Review

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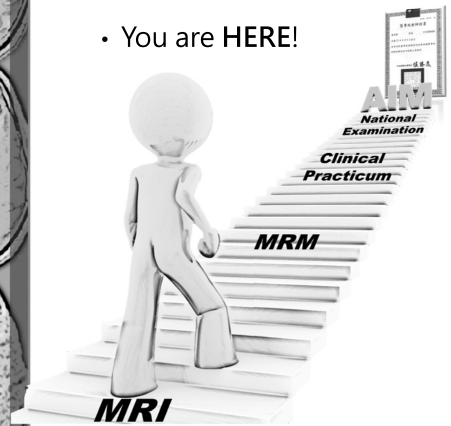
Congratulations!

- You are **HERE**!



License of Radiological Technologist

Syllabus

1	Course Overview & Review of MRI basic principles
2	**Diffusion weighted imaging (DWI)**
3	**Diffusion tensor imaging (DTI) & tractography**
4	**MR angiography**
5	**MR contrast agent**
6	**MR perfusion: DCE & DSC**
7	MR perfusion: arterial spin labeling (ASL)
8	**Susceptibility weighted imaging (SWI)**
9 (4/15)	**MRI Examination Procedure**
10 (4/22)	**Yang-Ming 3T MRI room visiting and scanning**
11	Functional MRI (fMRI) I
12 (5/6)	**Functional MRI (fMRI) II (online video)**
13	**MR Spectroscopy (MRS)**
14	**Cardiac MR imaging**
15	**MR muscle skeleton imaging**
16 (6/3)	**Final Competition**
17	端午節放假
18	Literature survey: MRI clinical research

Evaluation

- **Attendance & participation in class activities (40%)**
- **3T MRI visiting (30%)**
- **Final exam (30%)**
  - Group competition.

From Basics to Bedside

- **Magnetic Resonance Imaging 磁振影像學**
  http://cflu.lab.nycu.edu.tw/CFLu_course_BIRSmri.html
  Principles of MRI
  Equipment, pulse sequence, tissue contrast, image reconstruction, MRI artifacts, safety issues

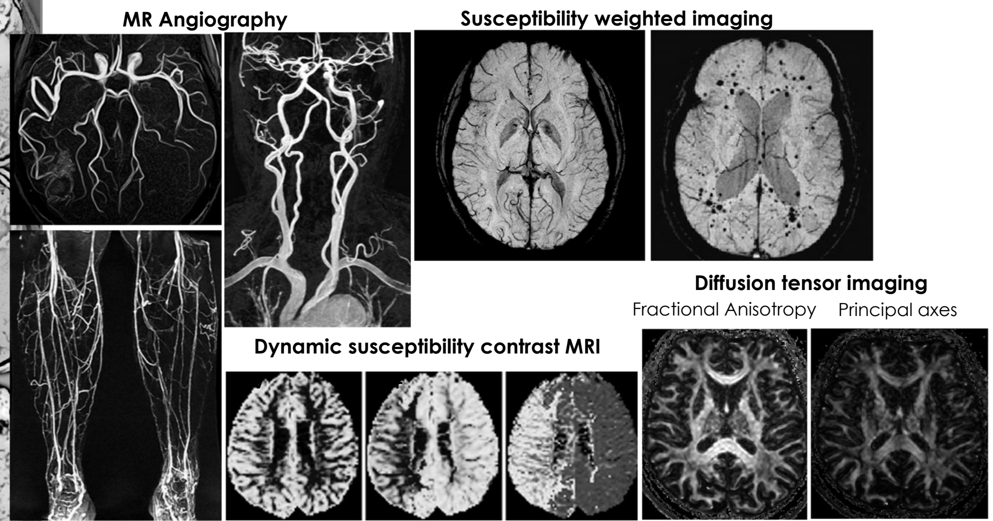
- **Magnetic Resonance in Medicine 醫用磁振學**
  http://cflu.lab.nycu.edu.tw/CFLu_course_BIRSmrm.html
  Clinical Applications of MRI
  MR contrast agent, functional MRI, diffusion weighted imaging, angiography, MR spectroscopy
  Visiting NYCU 3T MRI Facility

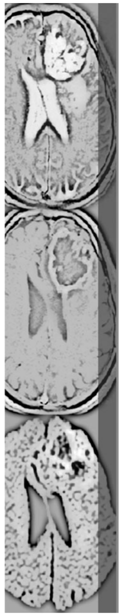
Textbooks

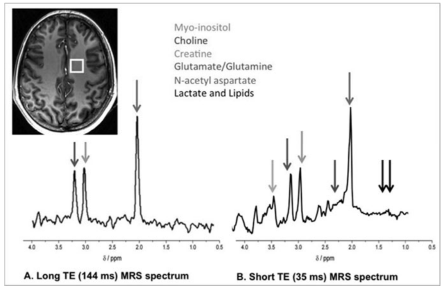
- MRI The Basics (4th edition)
  - Ray H. Hashemi, William G. Bradley, Christopher J. Lisanti
  - Lippincott Williams & Wilkins,2017
- MRI in Practice, (5th edition)
  - Catherine Westbrook, Carolyn Kaut Roth, John Talbot
  - Wiley Blackwell, 2018

Online Learning Materials

- Review/Overview/Self Learning
- http://cflu.lab.nycu.edu.tw
  Teaching Materials → MRM(UG)







A. Long TE (144 ms) MRS spectrum B. Short TE (35 ms) MRS spectrum

MR spectroscopy

http://www.massgeneral.org/imaging/news/radrounds/july_2012/

Metabolite	Major resonance (ppm)	Significance	Visible only at short TE
Lipids (Lip)	0.8�1.4	Breakdown of tissue	Y
Lactate (Lac)	1.3	Marker of anaerobic glycolysis	N
NAA	2.0	Marker of neuronal health	N
Glutamate & Glutamine (Glx)	2.1�2.6	Excitatory neurotransmitter	Y
Cho	3.2	Marker of membrane metabolism, cell proliferation	N
Cr	3.0 (and 3.9)	Marker of cellular energetics	N
Myo-inositol (MI)	3.5	Osmolytic marker; proposed glial marker	Y

Disease	Metabolic Changes
Brain tumors	Cho↑, NAA↓, Cr↓, Lac and Lip↑
Stroke	Lac↑, NAA↓, Glx↑, Cr↓, Cho↓
Epilepsy	NAA↓, Lac↑
Multiple sclerosis	NAA↓, Cho↑, (Cr↓)
HIV/AIDS	NAA↓, Cho↑, MI↑
Traumatic Brain Injury	NAA↓, Cho↑, Lac↑
Hepatic Encephalopathy	Cho↓, MI↓, Glx↑
Hypoxic Ischemic Injury	Lac↑, NAA↓, Glx↑, Cr↓
Neurodegenerative diseases	
Alzheimer	NAA↓, MI↑
Parkinson	NAA↓ (Striatum)
Huntington	NAA↓, Cho↑ (Basal ganglia)
ALS	NAA↓ (Motor cortex, Brain stem)

Let's Review What We Have Learned!

https://miro.com/app/board/uXjVNrz9yO0=/?share_link_id=413130478279

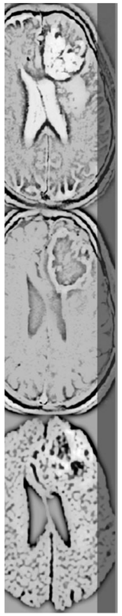
miro

Using App or Chrome

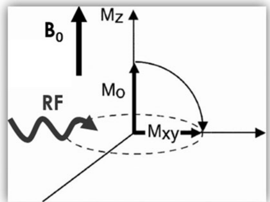
Password: ilovemri

Review Materials of MRI Principles

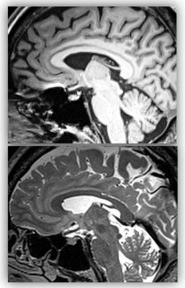
磁振造影原理複習教材



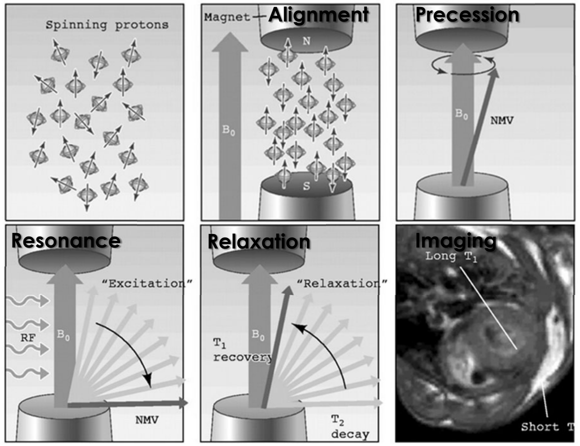
Procedure of MRI



- Alignment (magnetization) B_0
- Precession $\omega_0 = \gamma B_0$
- Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- MR signal (EMF, relaxation time)
- Imaging (Pulse sequencing: SE, GRE, EPI)
  - Tissue Contrast: Image weighting
  - Spatial localization: Slice selection & Spatial Encoding
  - Data space/K space
- Tissue Suppression Techniques
- MR artifacts and safety issues



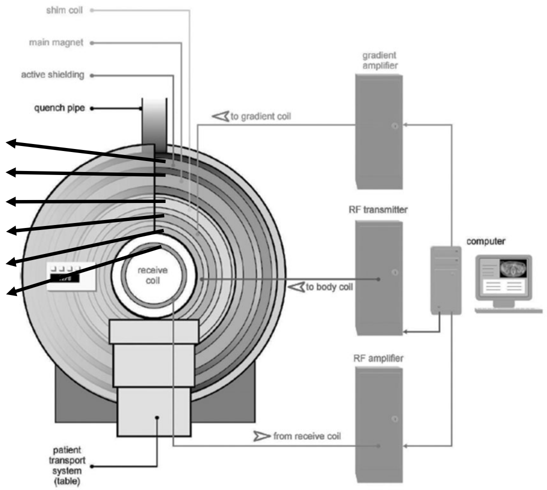
Principles of MR imaging



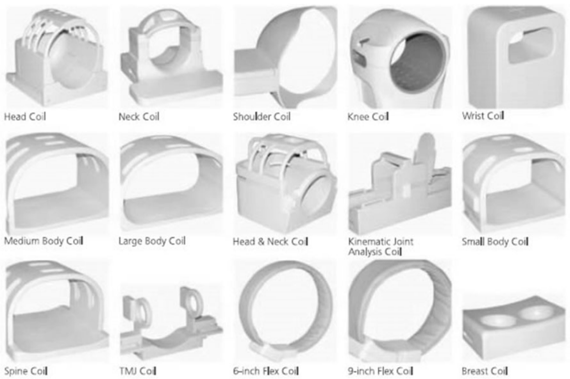
http://physiologyonline.physiology.org/content/19/4/168

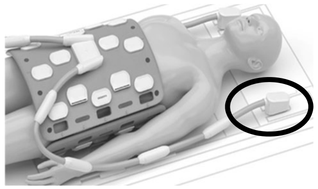
Setup

- Outer → inner
  - Active shielding
  - Main magnet
  - Shim coil
  - Gradient coil
  - Body coil
  - Receive coil

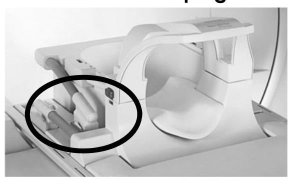


RF Coil Shapes





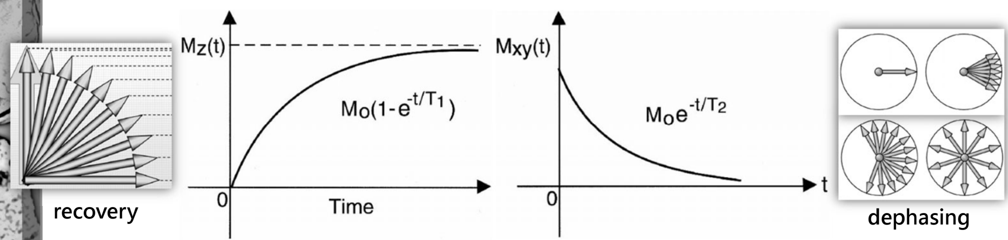
RF coils need to be plugin on table!!



medical.neusoft.com

T1 & T2 Relaxation Time

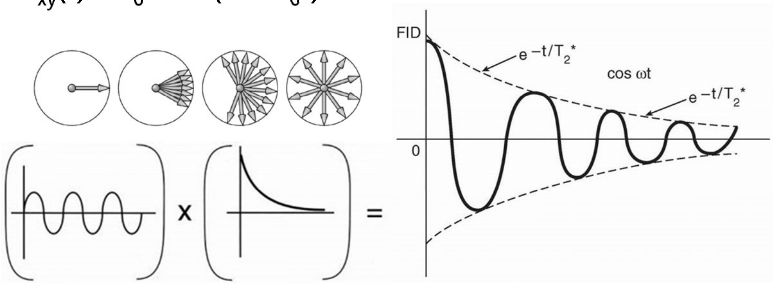
T1:	T2:
The longitudinal relaxation time The spin-lattice relaxation time $M_z(t)=M_0(1-e^{-t/T1})$	The transverse relaxation time The spin-spin relaxation time $M_{xy}(t)=M_0e^{-t/T2}$



T1>T2>T2*

Received Signal: Free Induction Decay

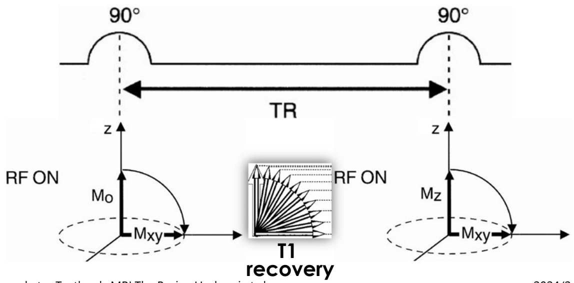
- The oscillating, decaying signal is called an FID.
- $\mathbf{M_{xy}(t)=M_0 e^{-t/T2^*}(\cos\omega_0 t)}$



The frequency of the received signal is also ω_0.

TR (Repetition Time)

- To spatially encode the signal and to increase the signal-to-noise ratio, we have to apply the RF pulse *multiple times* while varying the gradients.
- The time interval between RF pulses is called TR.



TE (Time to Echo or Echo Delay Time)

- We wait a short period of time (TE) after RF pulse and then make the measurement.
- The T2* decay curve (FID) starts out at the value of $\mathbf{M_0(1-e^{-TR/T1})}$ on the T1 recovery curve and then decays very quickly.

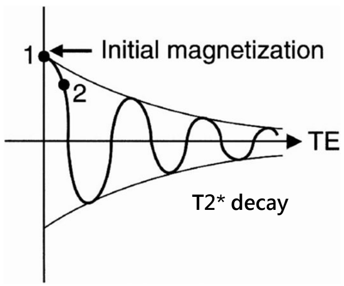


Image Contrast

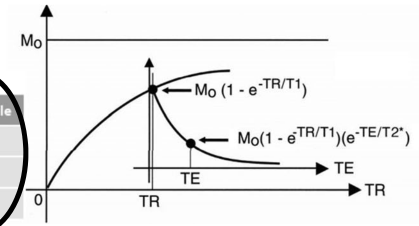
- Long TR, short TE ➔ proton density
- Long TR, long TE ➔ T2*-weighted
- Short TR, short TE ➔ T1-weighted
- Short TR, long TE ➔ no signal

Example:

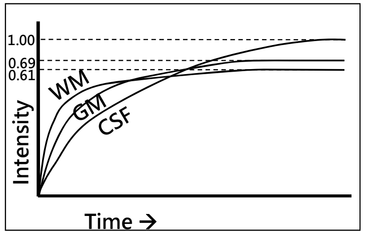
Long TR	2000 ms
Short TR	300–700 ms
Long TE	60 ms+
Short TE	10–25 ms

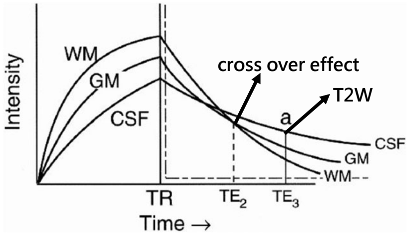
Table 2.3 Parameters used in gradient echo.

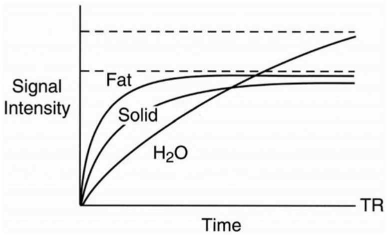
Weighting	TR	TE	Flip angle
T1	short	short	large
T2	long	long	small
Proton density	long	short	small



Adjust T1 and T2 weighting



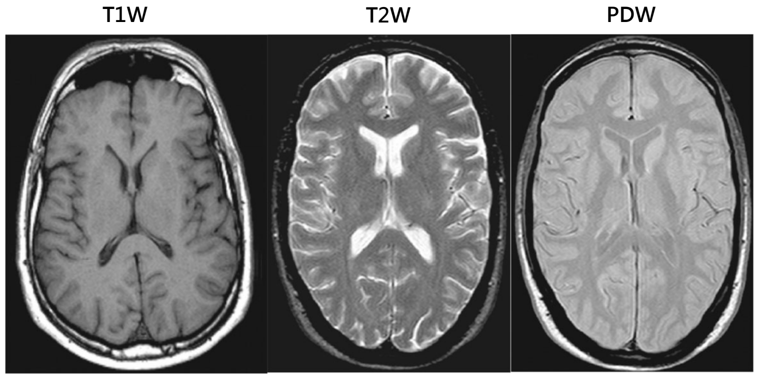




T1: **CSF>GM>WM**
T2: **CSF>GM>WM**
N(H): **CSF>GM>WM**

T1: **H_2O > Solid tissue > Fat**
T2: **H_2O > Fat > Solid tissue**
N(H): **H_2O > Fat > Solid tissue**

T1/T2/PD weighted Images



CSF > edema > GM > WM

Image Construction

1. **Slice selection**
   (only excite spins on a specific slice location)
2. **In-plane spatial encoding**
   (differentiate spin signals at different locations)

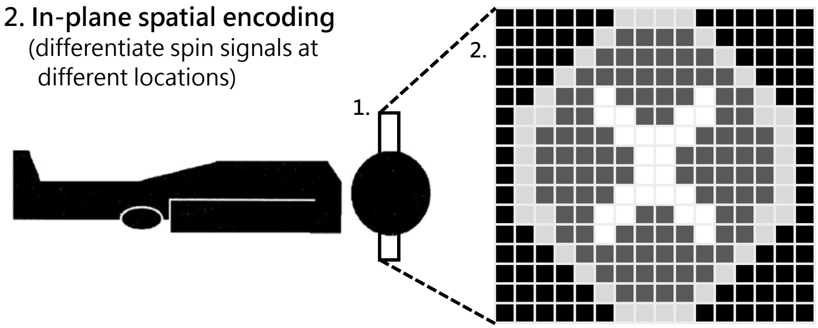
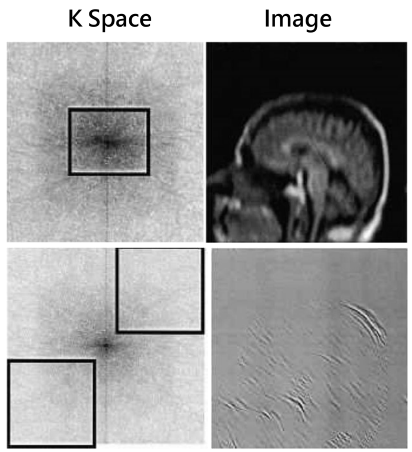
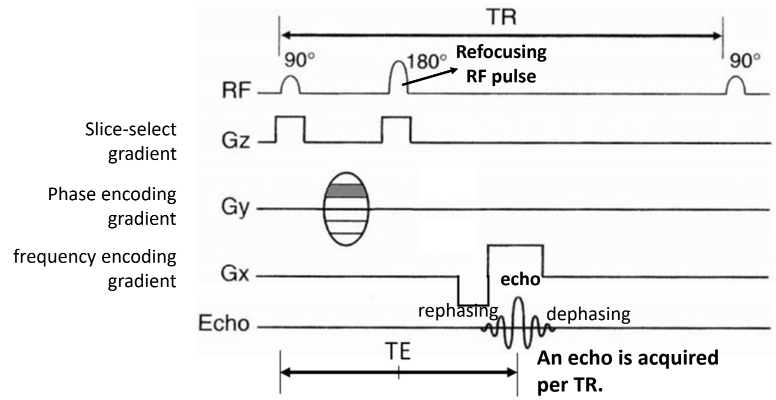


Image of K-Space

- The center of k-space contributes to the primary information of image.
- The periphery of k-space provides information regarding fitness of the image and clarity at sharp interfaces

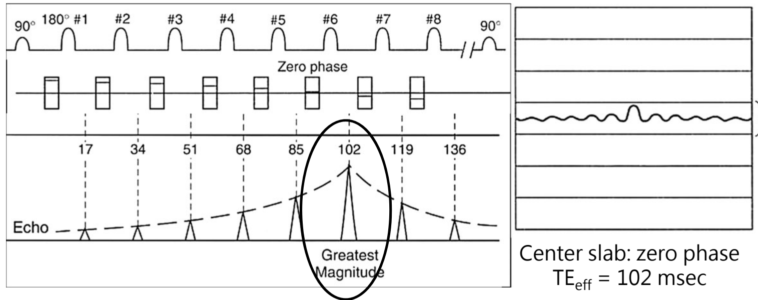


Spin-echo pulse sequence diagram



Fast spin echo

- In FSE, before each 180° pulse, we place a different value of the phase-encoding gradient.
- For the 180° pulse before the echo we choose as the TE_{eff} (in this case, 102 msec), we use a phase-encoding gradient with the lowest strength.

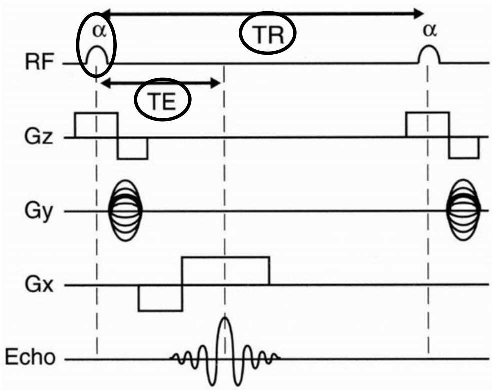


Center slab: zero phase
TE_{eff} = 102 msec

GRE Pulse Sequence Diagram

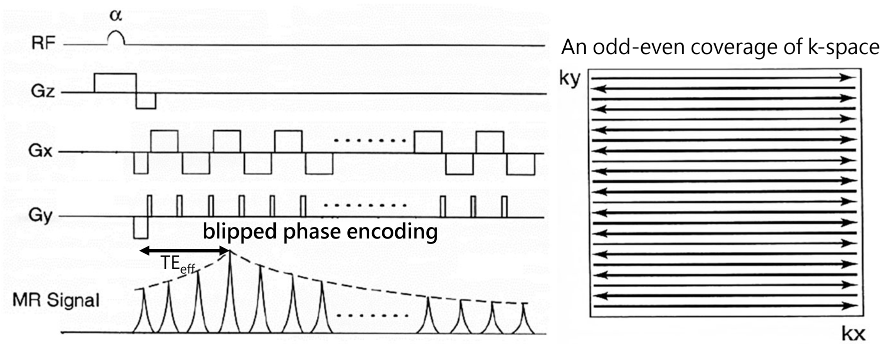
- Three operator-controlled parameters that affect the tissue contrast.

- **Coherent GRE**
- **Incoherent GRE**



Single-shot EPI

- The phase-encode gradient is subsequently applied briefly during the time when the readout gradient was zero (200 μsec).



Contrast in EPI

- Contrast in EPI depends on the "**root**" pulsing sequence

- SE-EPI (90°-180°-EPI)
- GRE-EPI (α°-EPI)
- IR-EPI (180°-90°-180°-EPI)
  - inversion-recovery (IR)

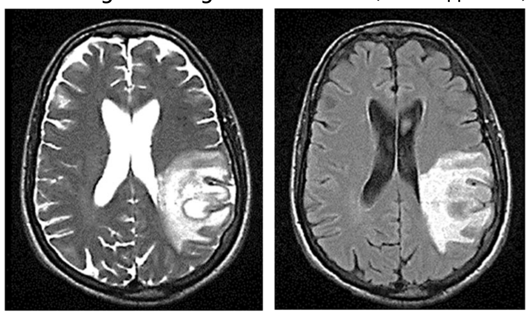
Suppression techniques

- To suppress the signal coming from a certain tissue.
  - Two common targets (tissues): fat and water

- Suppression techniques
  - Inversion recovery (IR) techniques
  - Chemical/spectral saturation
  - Dixon method
  - Spatial presaturation
  - Magnetization transfer (MT)

Glioblastoma MRI

T2 Weighted image T2 FLAIR (Water suppression)



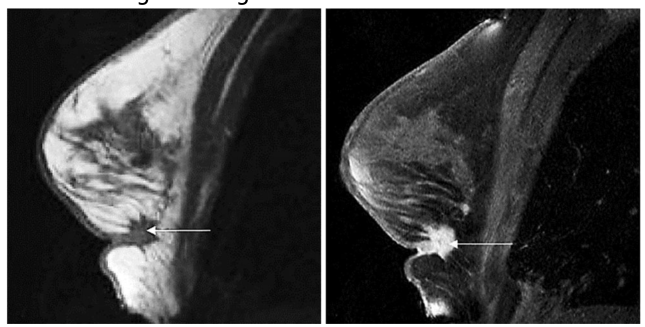
edema vs. water

http://journal.frontiersin.org/article/10.3389/fonc.2013.00066/full

Breast cancer MRI

T1: H_2O > Solid tissue > Fat
Gd contrast agent can shorten tissue T1

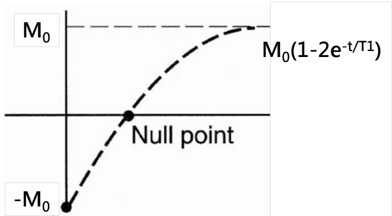
T1 Weighted image Fat saturation + Gd enhancement

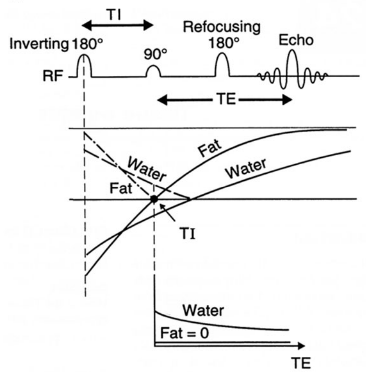


British Journal of Cancer (2003) 88(1), 4-10

Inversion recovery, IR

- After the 180° RF pulse, the magnetization starts to recover from $-M_0$ instead of zero.
- TI(null) = $(\ln 2)$T1 ≒ **0.693 T1.**

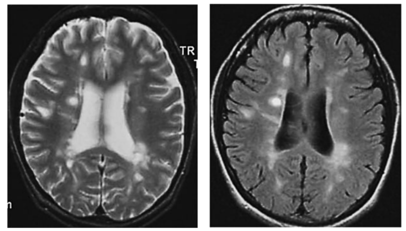




Tissue Suppression: STIR & FLAIR

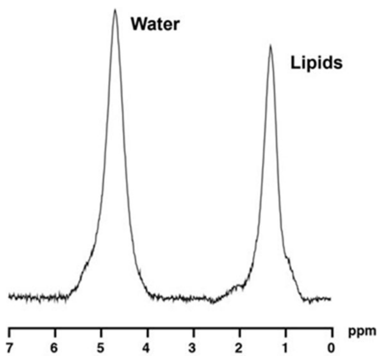
- STIR: Short tau inversion recovery, fat suppression
  - At 1.5T, TI = 0.693 x 200 = 138.6 msec
- FLAIR: Fluid attenuated inversion recovery, water suppression
  - At 1.5T, TI = 0.693 x 3600 = 2494.8 msec

T2W



T2 FLAIR
(Better differentiation for multiple sclerosis)

Water & fat chemical shift



- Peak location
  - Water **4.7 ppm**
  - Fat (lipids) **1.3 ppm**
- ppm: parts per million

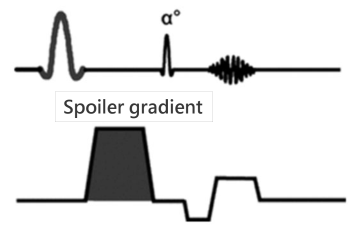
$$\omega = 42.6 \times 1.5T = 63.9 \text{ MHz}$$
$$= 42.6 \times 3.0T = 127.8 \text{ MHz}$$

- 1.5T: (4.7-1.3) x 63.9 = 217.36 Hz
- 3.0T: (4.7-1.3) x 127.8 = 434.52 Hz

Chemical/spectral presaturation

- A frequency-selective presaturation pulse is applied before the RF excitation pulse.
- CHESS: Chemical shift selective
- We select appropriate frequency (based on the Larmor equation) to suppress fat or water.

Fat sat 90° pulse



- At 1.5T, water protons precess 210-220 Hz faster than fat protons;
- At 3.0T, water protons precess 420-440 Hz faster than fat protons.

http://mri-q.com/fat-sat-pulses.html

THE END

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