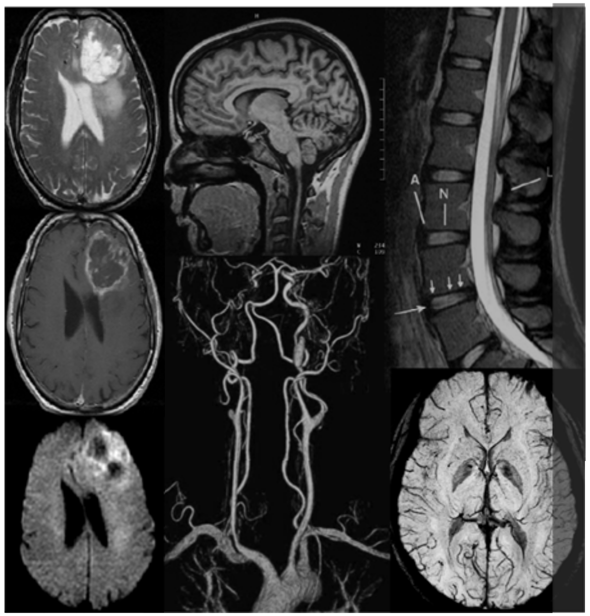

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Magnetic Resonance in Medicine
Course Introduction & Principle Review

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alvin4016@ym.edu.tw

Guests from Eulji University, Korea

- Department of Radiological Science

Prof. Hong, Joo Wan	Jung, Ho Sung	Namkoong, Hee	Kwon, Heoi Jun	Kang, Myung Ji

---

Congratulations!

- You are **HERE**!

License of Radiological Technologist

From Basics to Bedside

- **Magnetic Resonance Imaging**
  http://www.ym.edu.tw/~cflu/CFLu_course_BIRSmri.html
  Principles of MRI
  Equipment, pulse sequence, tissue contrast, image reconstruction, MRI artifacts, safety issues

- **Magnetic Resonance in Medicine**
  http://www.ym.edu.tw/~cflu/CFLu_course_BIRSmrm.html
  Clinical Applications of MRI
  MR contrast agent, functional MRI, diffusion weighted imaging, angiography, MR spectroscopy
  Visiting NYMU 3T MRI Facility

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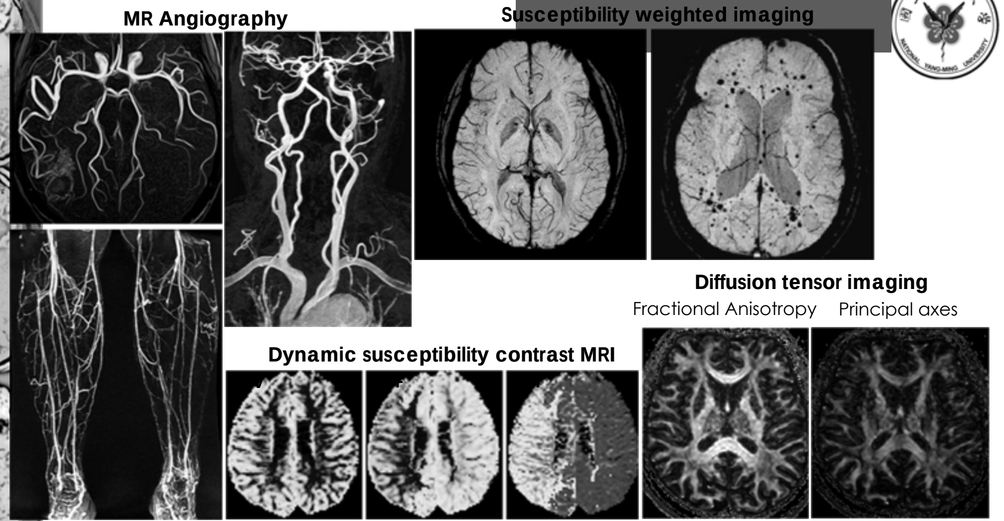
Syllabus

1	Review of MRI basic principles
2	Review of Pulse sequences
3	**Diffusion weighted imaging (DWI)**
4	**Diffusion tensor imaging (DTI)**
5	**MR angiography**
6	**MR contrast agent**
7	**MR perfusion: DCE & DSC**
8 (4/8)	**No class this week due to cross-university activities**
9	MR perfusion: arterial spin labeling (ASL)
10 (4/22)	**16:00-18:00 Yang-Ming 3T MRI room visiting and scanning**
11	**Susceptibility weighted imaging (SWI)**
12	Functional MRI (fMRI)
13 (5/13)	**No class this week due to ISMRM annual meeting**
14	**MR Spectroscopy (MRS)**
15	**Cardiac MR imaging**
16	**MR muscle skeleton imaging**
17 (6/17)	**Final Competition**



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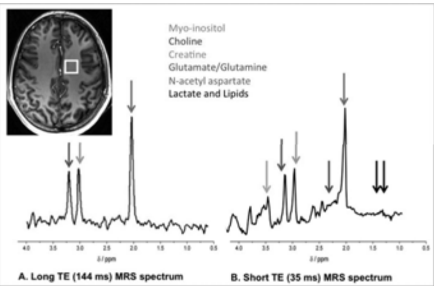

MR spectroscopy

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)

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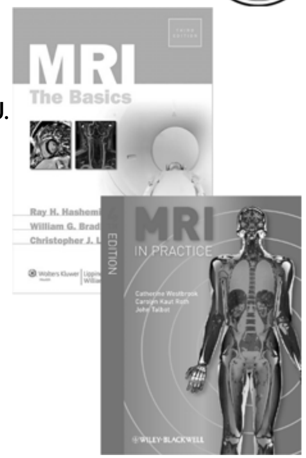
Textbooks

- MRI The Basics (3rd edition)
  - Ray H. Hashemi, William G. Bradley, Christopher J. Lisanti
  - Lippincott Williams & Wilkins,2010
- MRI in Practice, (4th edition)
  - Catherine Westbrook, Carolyn Kaut Roth, John Talbot
  - Wiley Blackwell, 2011



Online Teaching Materials

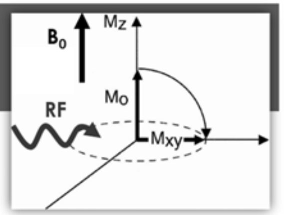
- http://www.ym.edu.tw/~cflu Teaching Materials → MRM(UG)

Evaluation

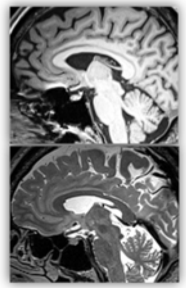
- **Attendance (10%)**
  - Attendance of at least one-third lectures is required.
- **Participation of class discussion (30%)**
- **Final exam (60%)**
  - Group competition.

Review of MRI Principles

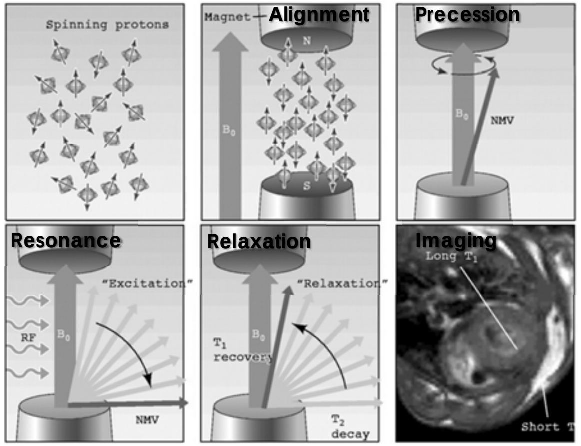
Procedure of MRI



- ☑ 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
- ☑ Artifacts and Safety Issues



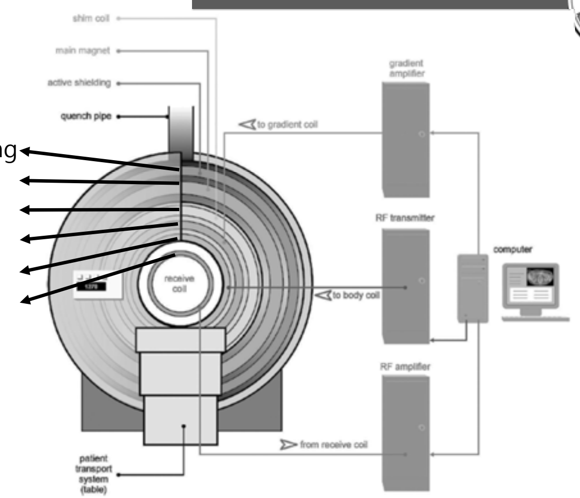
Principles of MR imaging



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

Setup

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



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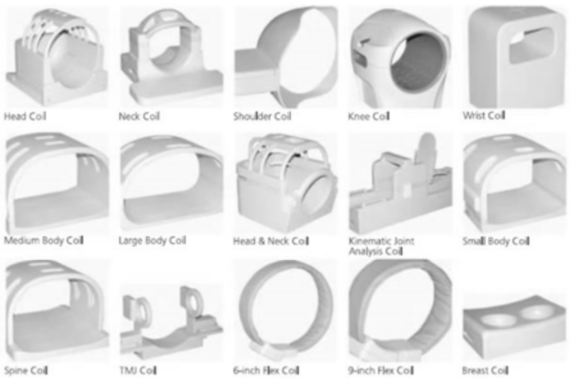
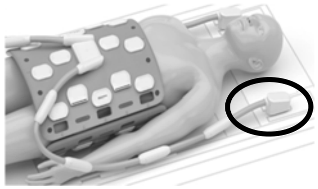
RF Coil Shapes





RF coils need to be plugin on table!!

medical.neusoft.com

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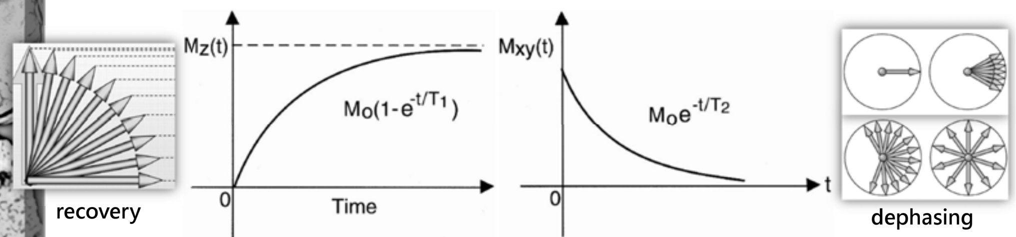
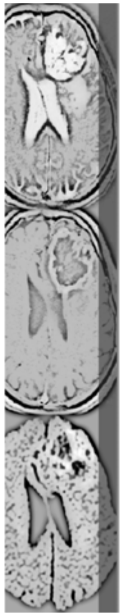
T1 & T2 Relaxation Time

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*



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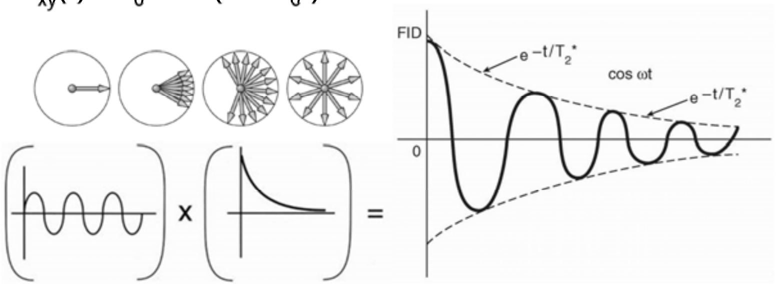
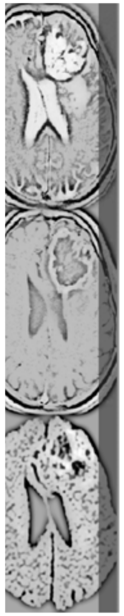
Received Signal: Free Induction Decay

- The oscillating, decaying signal is called an FID.
- $M_{xy}(t)=M_0e^{-t/T2^*}(\cos\omega_0 t)$



The frequency of the received signal is also ω_0.



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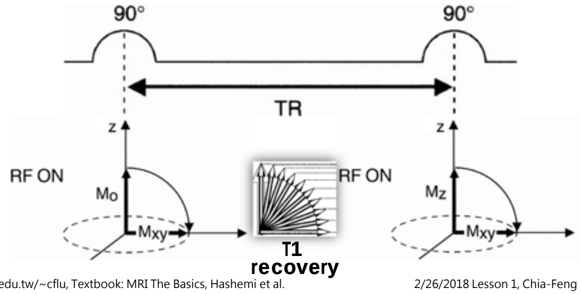
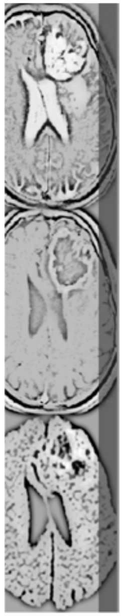
TR (Repetition Time)

- 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.

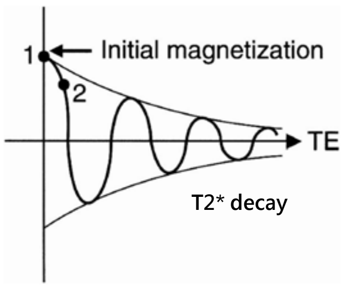




[redacted]

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 $M_0(1-e^{-TR/T1})$ on the T1 recovery curve and then decays very quickly.



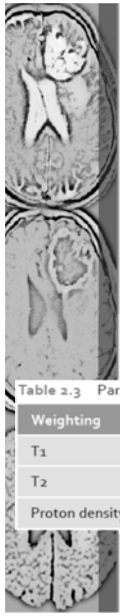


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Image Contrast

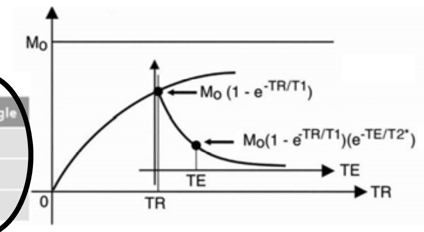
- Long TR, short TE ➔ proton density
- Long TR, long TE ➔ T2*-weighted
- Short TR, short TE ➔ T1-weighted
- Short TR, long TE ➔ no signal

Example:

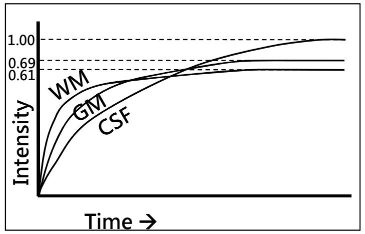
Long TR	2000 ms
Short TR	300–700 ms
Long TE	60 ms+
Short TE	10–25 ms

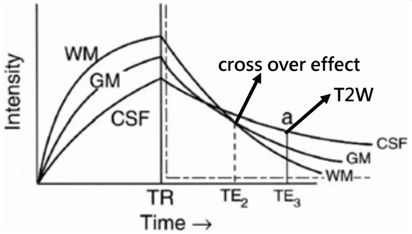
Table 2.3 Parameters used in gradient echo.

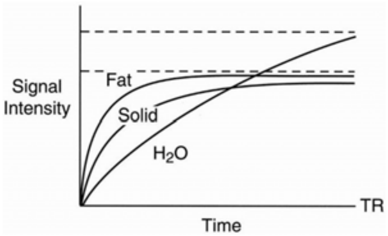
Weighting	TR	TE	Flip angle
T1	short	short	large
T2	long	long	small
Proton density	long	short	small



Adjust T1 and T2 weighting



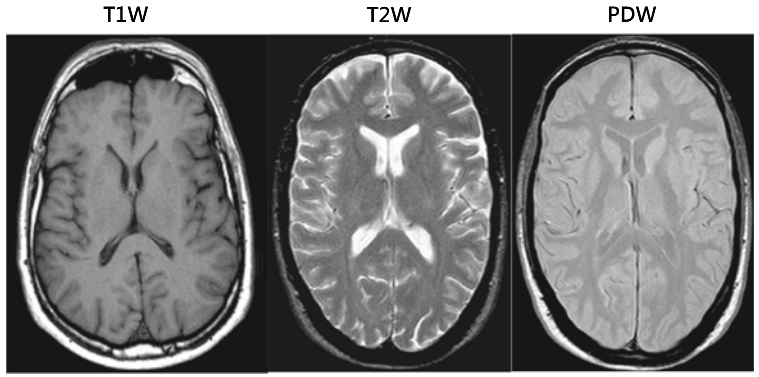




T1: **CSF>GM>WM**
T2: **CSF>GM>WM**
N(H): **CSF>GM>WM**

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)

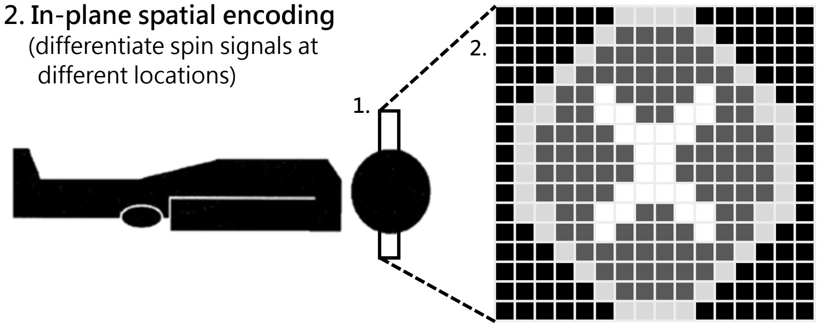
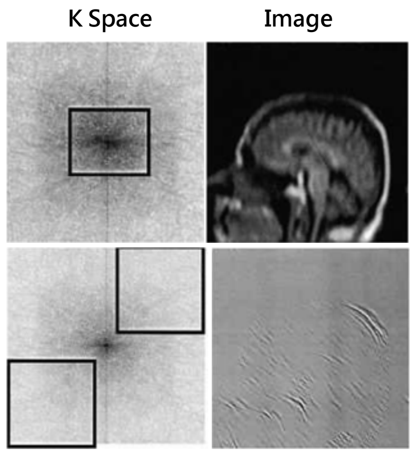
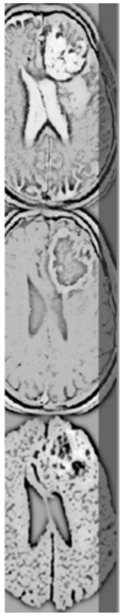


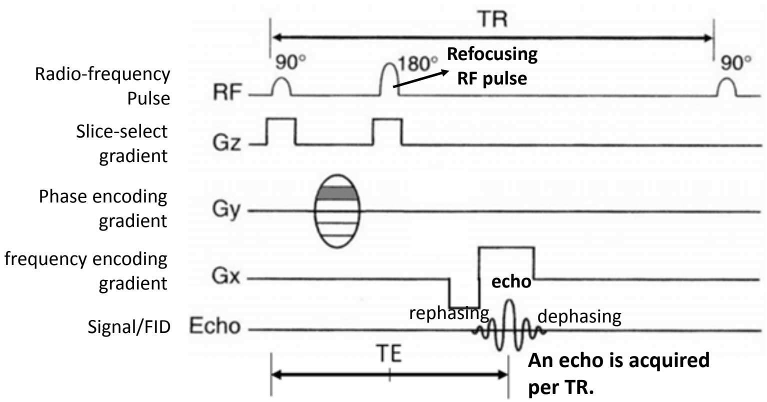
Image of K-Space

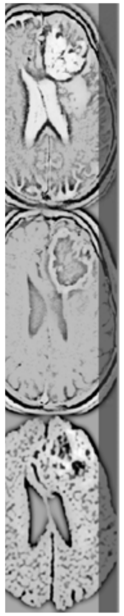
- The center of k-space contributes to the primary information of image.
- The periphery of k-space provides information regarding fitness of the image and clarity at sharp interfaces





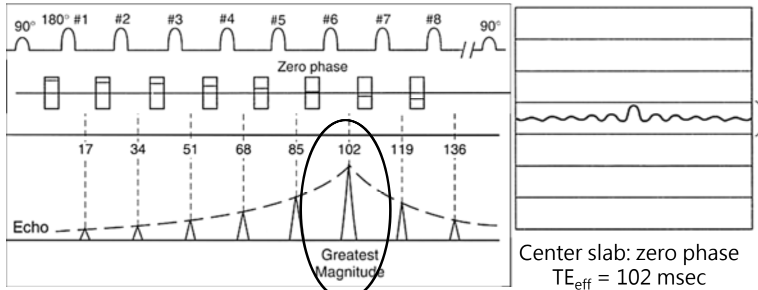
Spin-echo pulse sequence diagram



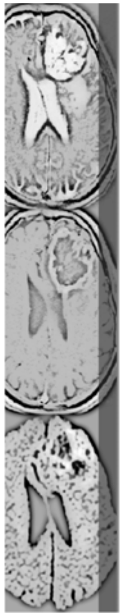


Fast spin echo

- 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.

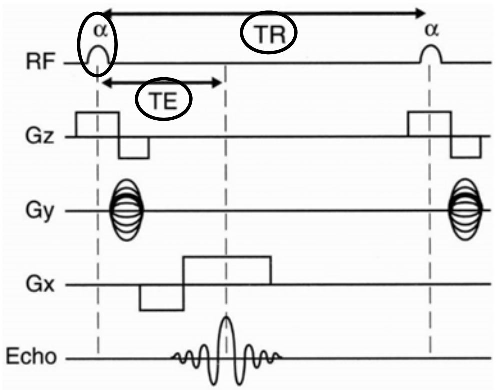


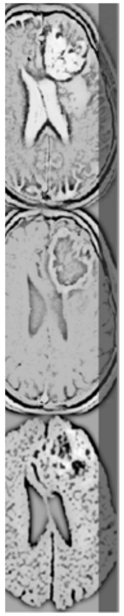
Center slab: zero phase
TE_{eff} = 102 msec



GRE Pulse Sequence Diagram

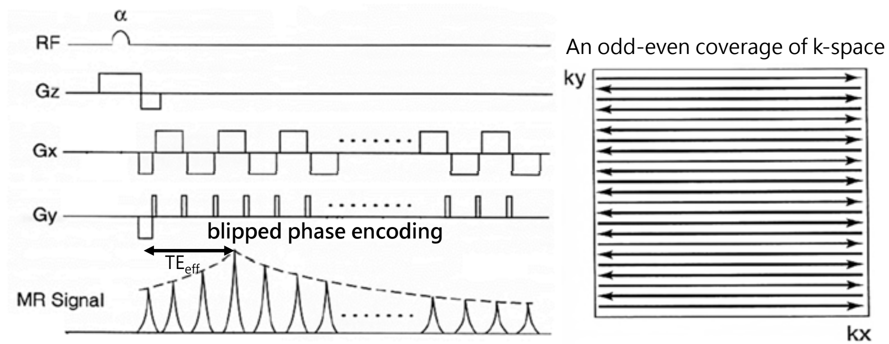
- Three operator-controlled parameters that affect the tissue contrast.





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)

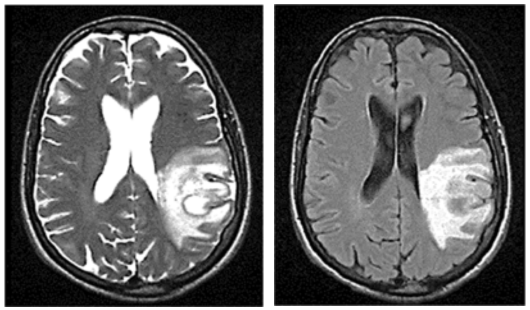
Suppression techniques

- 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)



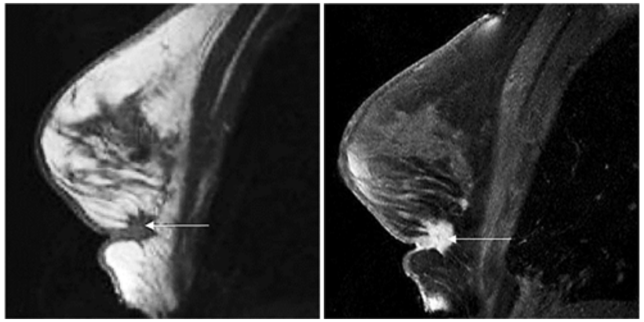
edema vs. water

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

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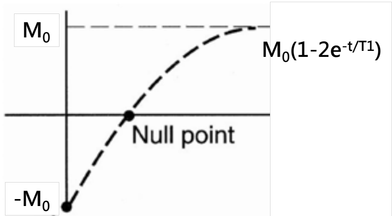
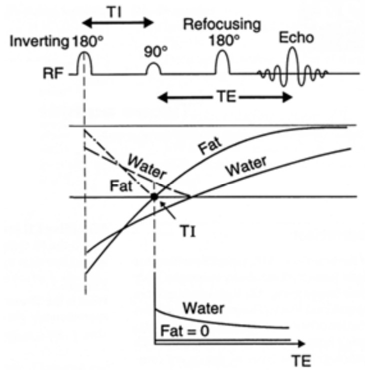
Inversion recovery, IR

- After the 180° RF pulse, the magnetization starts to recover from $-M_0$ instead of zero.
- TI(null) = (ln2)T1 ≒ **0.693 T1.**





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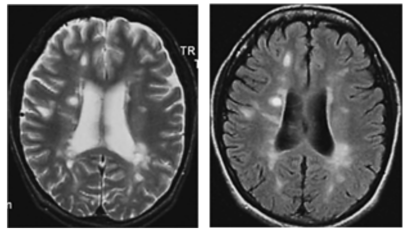
Tissue Suppression: STIR & FLAIR

- 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)

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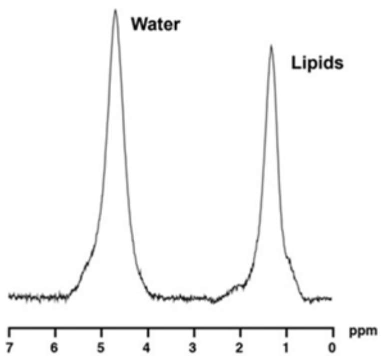
Water & fat chemical shift



- 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

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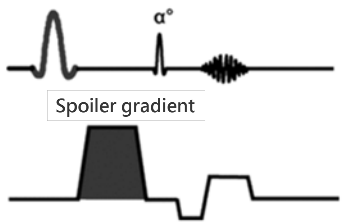
Chemical/spectral presaturation

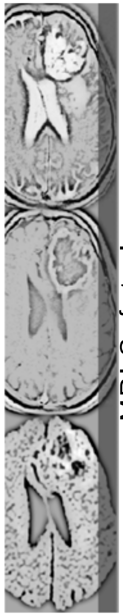
- A frequency-selective presaturation pulse is applied before the RF excitation pulse.
- CHESS: Chemical shift selective
- We select appropriate frequency (based on the Larmor equation) to suppress fat or water.

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



MRI Safety Issue

Mumbai MRI death: Nair hospital radiologist arrested in connection to Rajesh Maru's death, released on bail

India PTI **Feb 02, 2018**

Comment 0 | Share 0 | Tweet

Mumbai: A radiologist of the Nair hospital was arrested in connection with the death of a man in a freak Magnetic Resonance Imaging (MRI) machine accident at the facility on 27 January, police said on Friday.


File image of Rajesh Maru. News18

Agripada police said Dr Siddhant Shah was arrested on Thursday after the family of the 32-year-old victim, Rajesh Maru, told them that the radiologist was also present when the accident occurred.

Shah was charged with dereli
released on bail. Shah's was t

Earlier, police had arrested th
Lanjekar, ward boy Vitthal Ch
negligence causing death.

Maru had accompanied a relative to the hospital for an MRI examination. W
liquid oxygen cylinder, the strong magnetic field got activated, pulling him
oxygen cylinder burst on impact and he died after inhaling copious quanti

Metal objects are not allowed inside rooms having MRI machines.

THE END

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