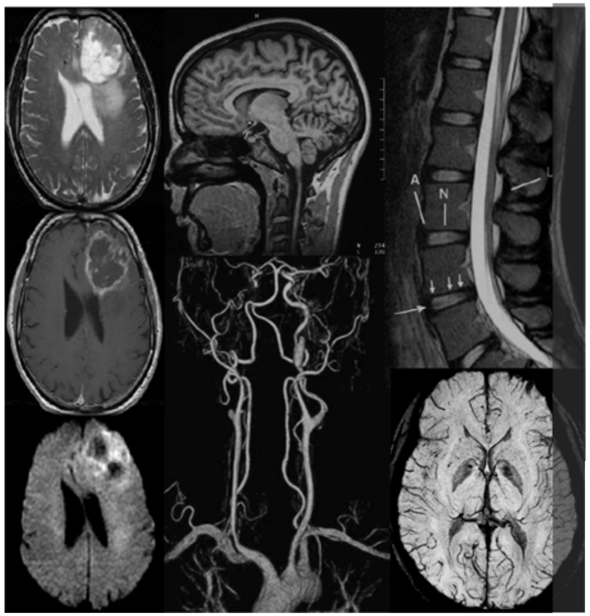
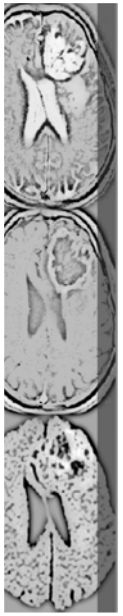


磁振影像學MRI
組織壓抑技術

盧家鋒 副教授

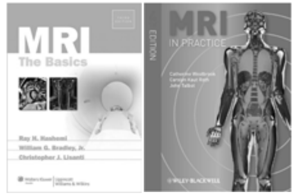
國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw



本週課程內容 http://cflu.lab.nycu.edu.tw

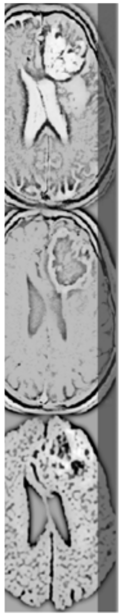
- 磁振造影流程
- 組織壓抑技術

- **MRI The Basics (3rd edition)**
  - Chapter 25: Tissue suppression techniques
- **MRI in Practice, (4th edition)**
  - Chapter 5: Pulse sequences
  - Chapter 6: Flow phenomenon

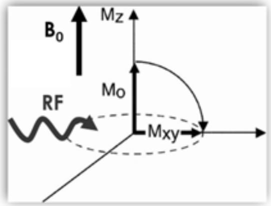


磁振造影流程

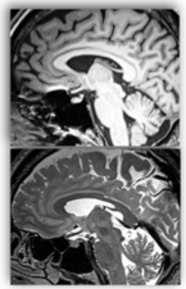
MRI Procedure



Procedure of MRI



- [x] Alignment (magnetization) B_0
- [x] Precession $\omega_0 = \gamma B_0$
- [x] 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 $\omega_0 = \omega_2$
- [x] MR signal (EMF, relaxation time)
- [x] Imaging (Pulse sequencing: SE, GRE, EPI)
  - [x] Tissue Contrast: Image weighting
  - [x] Spatial localization: Slice selection & Spatial Encoding
  - [x] Data space/K space
- [ ] Tissue Suppression Techniques

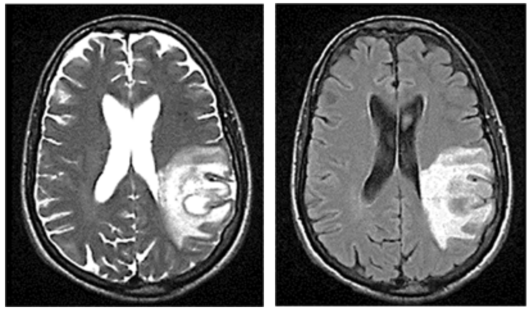


組織壓抑技術

Tissue Suppression Techniques

Glioblastoma MRI

T2 Weighted image | **T2 FLAIR** (Water suppression)



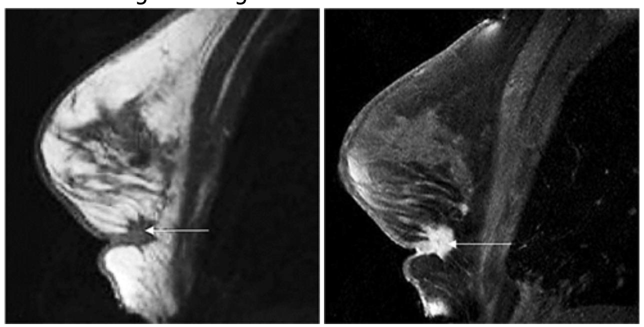
edema vs. water

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**



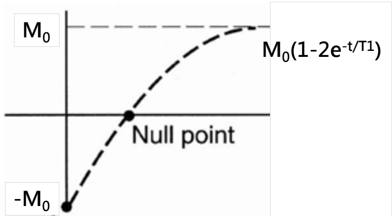
British Journal of Cancer (2003) 88(1), 4-10

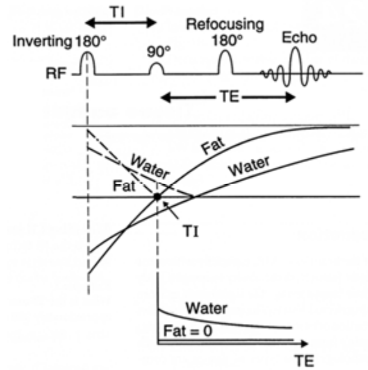
Suppression techniques

- 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)

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.**

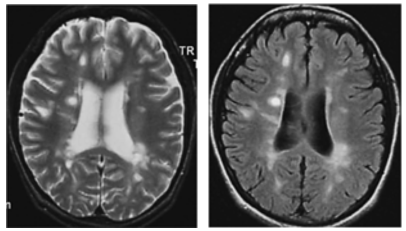




Tissue Suppression: STIR & FLAIR

- 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

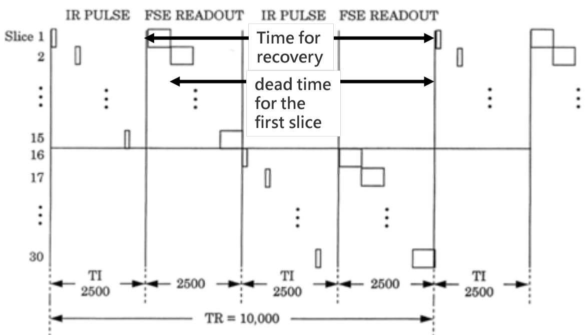
T2W



T2 FLAIR
(Better differentiation for multiple sclerosis)

Fast FLAIR: an example

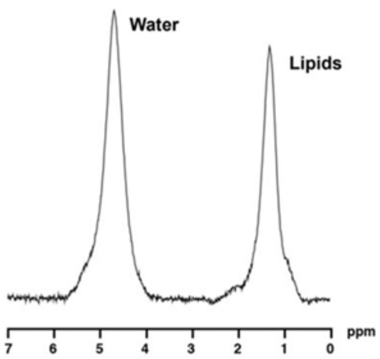
- IR for water + fast spin echo (FSE)
- Multi-slice + FSE
- The maximum # of slice in one TR is usually limited by TI



Advantages/Disadvantages of IR

- Advantage
  - No variability caused by magnetic field inhomogeneities
- Disadvantages
  - Tissues with similar T1 values are all suppressed (e.g. Gd effects).
  - Long acquisition times caused by long TRs
  - Cause extra 180° RF heating
  - Low SNR (due to the partial saturation of all tissues)

Water & fat chemical shift



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

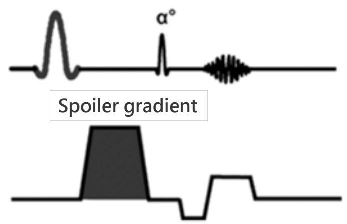
$$\omega = 42.6 \times 1.5T = 63.9 \text{ MHz} \\ = 42.6 \times 3.0T = 127.8 \text{ MHz}$$

- 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.
  - 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.

Fat sat 90° pulse



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

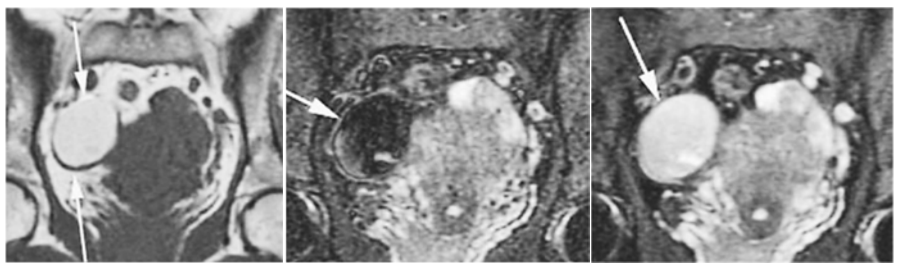
Chemical/spectral presaturation

- Advantages
  - Resolves tissues with similar T1 values (fat and Gd-enhanced tumors)
  - No influence on the signal from other tissues (in contrast, IR affects the contrast of all tissues)
- Disadvantages
  - Suffers from sensitivity to magnetic field inhomogeneities (e.g. metallic susceptibility artifacts).
  - Cause extra 90° RF heating
  - May lengthen TR, thus increasing the scan time (5~8 ms)

STIR vs. Fat Sat.

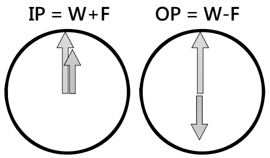
- Endometrioma (aka. chocolate cysts)

Coronal T1W | Coronal STIR | Chemical fat saturation



Lower SNR | Not a fat-containing lesion

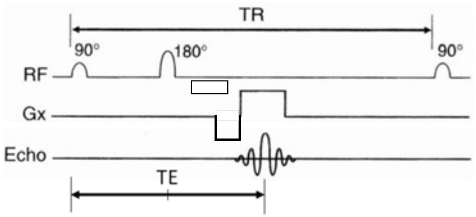
Dixon Method



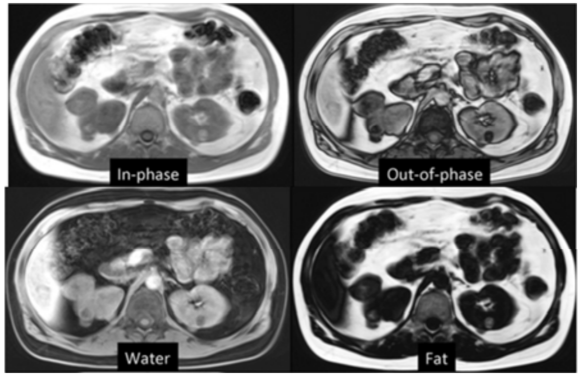
- Chemical shift between water and fat
- two sets of SE images were acquired with different echo times
  - the first with fat and water signals in phase (IP) at the center of the echo
  - the second with the TE adjusted by a few milliseconds so that the fat and water signals were out-of-phase (OP).

IP = W+F
OP = W-F

½(IP +OP) = W
½(IP - OP) = F



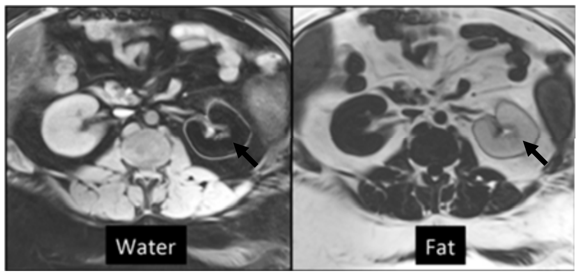
Dixon Method



http://mri-q.com/dixon-method.html

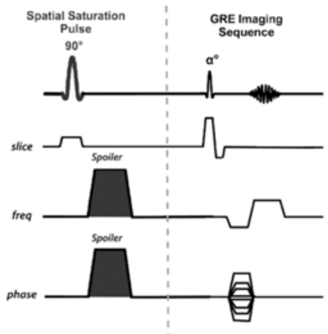
Fat-water swap

- Generally better than CHESS/Fat-Sat sequences
- Modern Dixon methods still have their limitations
  - particularly in highly inhomogeneous areas like the neck and around metal hardware → fat-water swap



Spatial presaturation

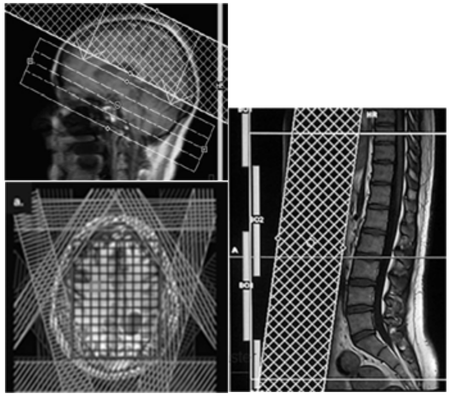
- 90° saturation pulses are applied on either side of selected volume (anterior/posterior, superior/inferior, right/left).
- To suppress phase ghosts caused by…
  - Motion artifacts
  - Flow-related artifacts



http://mri-q.com/saturation-pulses.html

Spatial presaturation

- Applications:
  - **Imaging of spine**: a sat. band is placed within the FOV anterior to the vertebral bodies.
  - **MR angiography**: sat. pulses are placed outside the FOV at one end of a vessel to suppress either venous or arterial flow.
  - **MR spectroscopy:** Sat. bands are placed on the skull regions.

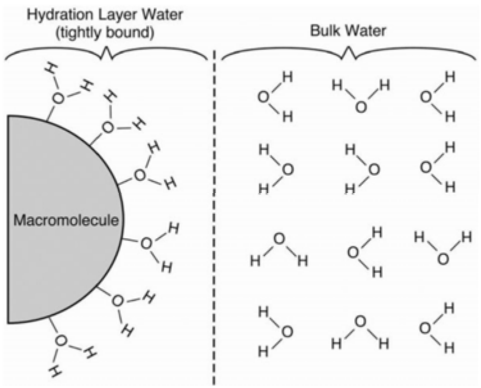


Spatial presaturation

- Advantages
  - Minimize phase ghosts (motion artifacts)
  - Minimize flow artifacts
- Disadvantages
  - May cause signal suppression in the reminder of the FOV
  - May lengthen TR, thus increasing the scan time (5~8 ms)

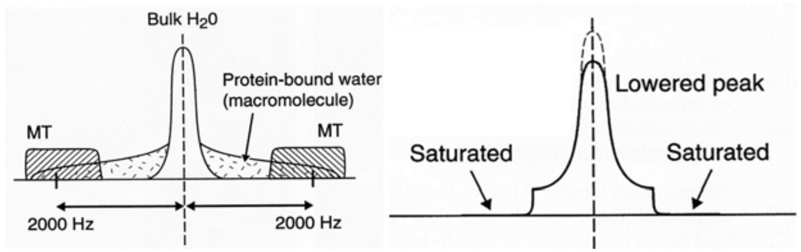
Non-fatty hydrogen nuclei

- Bulk (free) water
  - T1: 2000~3000 msec
  - T2: 1000~2000 msec
- Hydration layer (bound) water
  - T1: 10~100 msec
  - T2: 5~10 msec
- Macromolecules



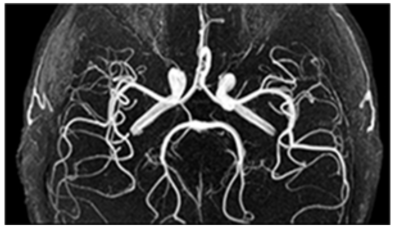
Magnetization transfer, MT

- To suppress protein-bound water
- Protons in protein-bound water exhibit a resonant frequency that is approximately 500 to 2500 Hz away from that of bulk water protons.



Magnetization transfer, MT

- MT is similar to spectral fat suppression techniques except that here, the off-resonant frequency is up to 2000 Hz as opposed to 220 Hz in the case of fat suppression.
- Used in time of flight (TOF) MR angiography to suppress the background brain tissue and enhance visualization of smaller vessels



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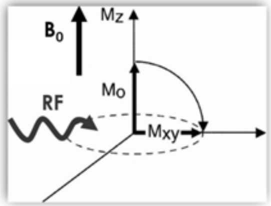

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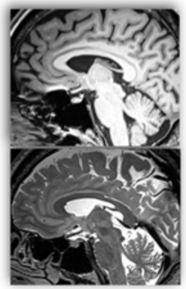

THE END

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