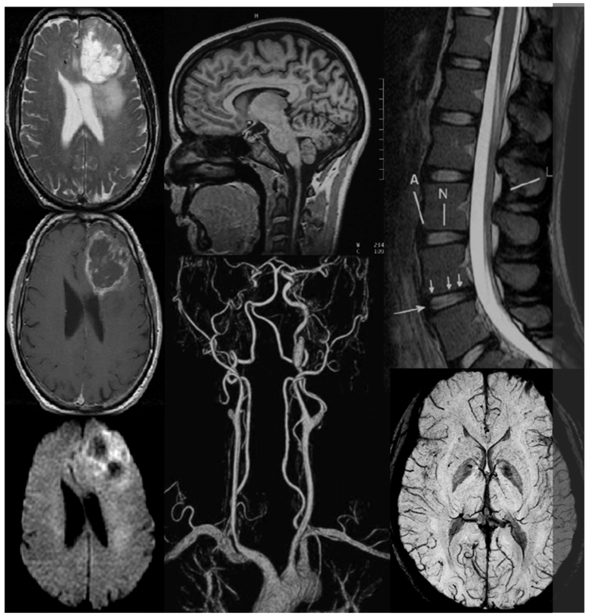

磁振影像學MRI
Gradient Echo

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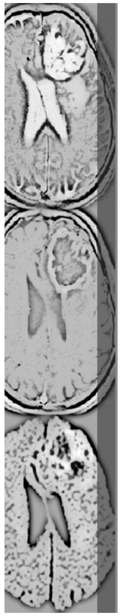
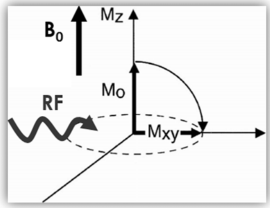
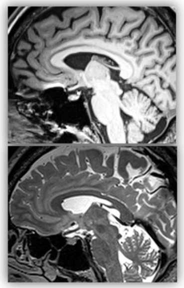
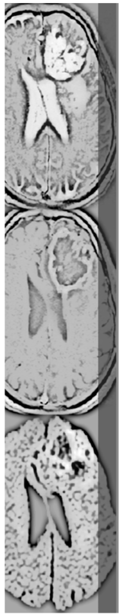


Procedure of MRI



- ☑ 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

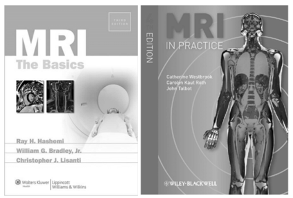




本週課程內容 http://cflu.lab.nycu.edu.tw/~cflu

- 梯度回音(gradient echo)基本觀念
- 梯度回音類型

- MRI The Basics (3rd edition)
  - Chapter 20: Gradient echo: Part I
  - Chapter 21: Gradient echo: Part II
- MRI in Practice, (4th edition)
  - Chapter 5: Pulse sequences



梯度回音基本觀念

Gradient echo (GRE)
Gradient-recall echo (GRE)

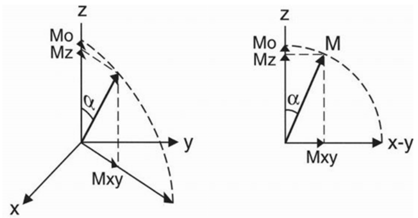
Scan Time for GRE

- $Scan\ time = (TR)(N_y)(NEX)$

Number of excitation (SNR)

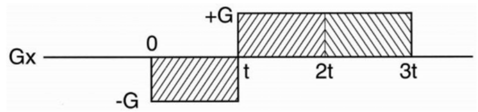
Number of phase encoding (spatial resolution)

Repetition time: can be controlled to minimize the scan time.



Properties of GRE

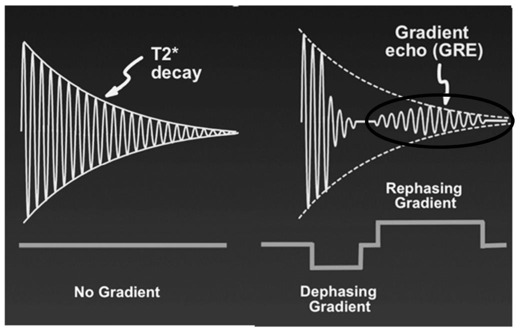
- A smaller flip angle is used instead of the 90º RF pulse
  - A shorter TR is demanded for full recovery of M_z
- Instead of 180º RF pulse, a bi-lobed readout gradient is used to obtain an echo.
  - Quicker to apply than a 180º RF pulse → reduce minimum TE
- T2* weighting is presented due to the absence of 180º RF pulse.



Negative lobe Positive lobe

Bi-lobed Readout Gradient

- Intentionally dephase the FID and rephase (or recall) it at time of TE.
- The maximum of echo occurs at the midpoint of the positive (rephasing) lobe.



http://mri-q.com/gre-vs-se.html

Tissue contrast in GRE

- Both flip angle and TR determine the T1 weighting
- TE controls the amount of T2* dephasing and therefore the T2* weighting.

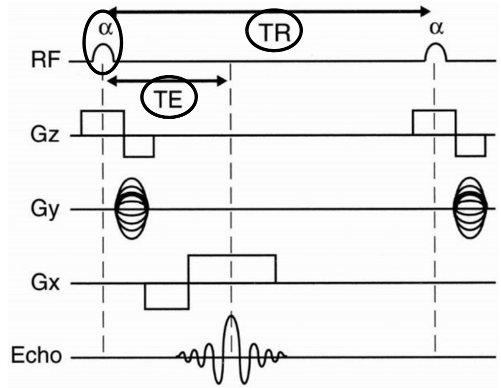
Tissue contrast in GRE

	T1 weighting	Proton density	T2* weighting
Flip angle	Large (70~110°)	Small (5~20°)	Small (5~20°)
TR	Short (< 50 ms)	Long (> 200 ms)	Long (> 200 ms)
TE	Short (1~5 ms)	Short (5~10 ms)	Long (15~25 ms)

In conventional gradient echo the TR does not always affect image contrast. Once a certain value of TR has been exceeded, the M_z recovers fully. Under these circumstances the flip angle and TE control the degree of saturation and dephasing respectively.

GRE Pulse Sequence Diagram

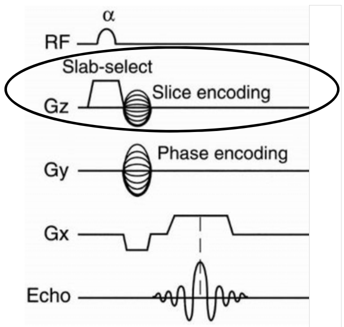
- Three operator-controlled parameters that affect the tissue contrast.

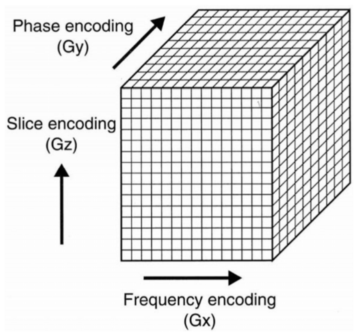


3D GRE imaging

- $Scan\ time = (TR)(N_y)(NEX)(N_z)$

Advantages of 3D GRE
- Rapid volume imaging of thin contiguous slices without cross-talk
- Reformation capabilities (if isotropic)
- Increased SNR





Advantages of GRE

- Increased speed
- Increased sensitivity to magnetic susceptibility effects of hemorrhage (allowing better detection compared with SE)
- 3D imaging (e.g., in the cervical spine) in a reasonable time
- Imaging of flowing blood (i.e., MR angiography)

  Because the gradient rephasing is not slice selective!

Disadvantages of GRE

- Decreased SNR caused by small α, reducing the transverse magnetization.
- Increased magnetic susceptibility artifacts (caused by lack of a 180° refocusing pulse), most noticeable at air-tissue.
- $T2^*$ decay because there are no 180° rephasing pulses.
  - sensitive to magnetic field inhomogeneities, intravoxel dephasing, and magnetic susceptibility artifacts.
- Introduction of chemical shift effects of the second kind (Dixon Effect)
  - resulting in a dark band around organs with water-fat interfaces
  - such as the kidneys, liver, spleen, etc.

梯度回音類型

Different formations of GRE

Steady state

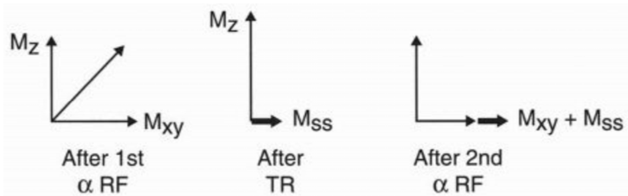
- Energy is given to hydrogen during excitation
  - the amount of energy applied is indicated by the flip angle.
- Energy is lost by hydrogen through spin-lattice energy transfer.
  - the amount of energy lost is determined by the TR.

The steady state is a term describing the stable condition that does not change over time.

Generally, flip angles of 30° to 45° in conjunction with a TR less than 50 ms achieve the steady state.

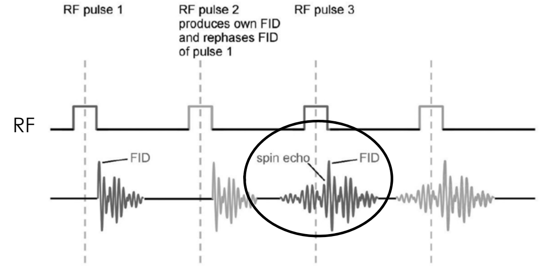
Steady-state M_{ss}

- The steady state of residual transverse magnetization.
- The steady state involves repeatedly applying RF pulses at time intervals less than the T2 (decay) and T1 (recovery) times of all the tissues.



Echo formation in GRE

- Two or more RF pulses produce a spin echo or stimulated echo.
  - The first RF pulse excites the nuclei;
  - the subsequent RF pulses rephase the FID and any residual magnetization present to produce an echo.



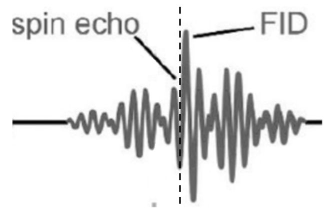
TR is similar to the TE/2 in CSE.

Mixture of 1st spin echo and 3rd FID

Signal weighting

- an *FID*, which occurs as a result of the withdrawal of the previous RF pulse and, contains either T2 * or T1 information
- a *spin echo* whose peak occurs at the same time as a subsequent RF pulse contains T2 * and T2 information.

The echo is generated from both FID and M_{ss}.



Formations of GRE

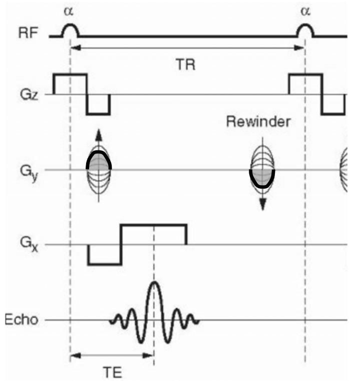
- Coherent gradient echo
  - The residual transverse magnetization is in phase
  - By applying a rewinder gradient
- Incoherent gradient echo
  - The residual transverse magnetization is out of phase
  - By applying a spoiler gradient

Terminology of GRE techniques

	Techniques	Full Name
Coherent	**GRASS/ FISP**	Gradient-recalled acquisition in the steady-state/ Fast imaging with steady-state precession
Incoherent	**SPGR/ FLASH**	Spoiled GRASS/ Fast low-angle shot

Coherent gradient echo

- A rewinder gradient is applied in the phase-encoding direction at the end of the cycle
  - to reverse the effects of the phase-encoding gradient applied at the beginning of the cycle
  - it "unwinds" the former dephasing effect.
  - insert T2* weighting
- GRASS and FISP



Parameters of coherent GRE

To maintain the steady state:

- flip angles 30~45°
- TR 20~50 ms
- long TE 15~25 ms

Properties of coherent GRE

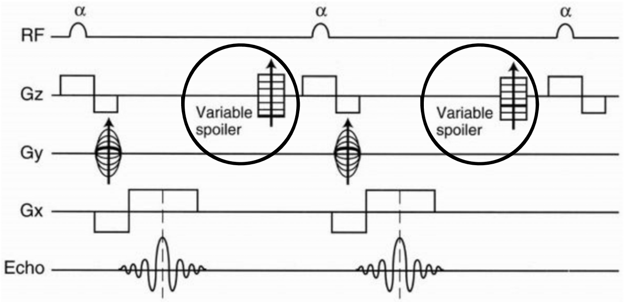
- Advantages
  - very fast scans, breath - holding possible
  - very sensitive to flow so good for angiography
  - can be acquired in a volume acquisition
- Disadvantages
  - reduced SNR in 2D acquisitions
  - magnetic susceptibility increases
  - loud gradient noise

Incoherent gradient echo

- These sequences dephase or spoil the residual magnetization so that its effect on image contrast is minimal
- Enable T1 contrast to dominate.
- Two ways to achieve spoiling:
  - RF spoiling
  - Gradient spoiling
- SPGR and FLASH

Gradient Spoilers

- In gradient spoiling, the slice select, phase encoding and frequency encoding gradients can be used to dephase the residual magnetization.



Parameters of incoherent GRE

To maintain the steady state:

- flip angles 30~45 °
- TR 20~50 ms

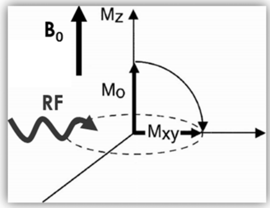
To maximize T1 weighting:

- short TE 5~10 ms

Properties of incoherent GRE

- Advantages
  - can be acquired in a volume or 2D
  - breath holding possible
  - good SNR and anatomical detail in volume
  - can be used after gadolinium contrast injection (dynamic contrast enhancement)
- Disadvantages
  - SNR poor in 2D
  - loud gradient noise

Procedure of MRI



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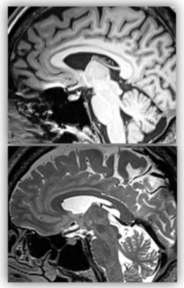

THE END

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