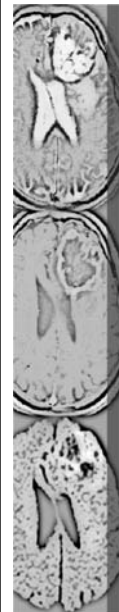




磁振影像學MRI Gradient Echo – Part I

盧家鋒 副教授

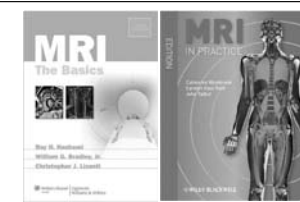
國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw



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

- 磁振造影流程
- 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



<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

2022/11/26

2

磁振造影流程

MRI Procedure

<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

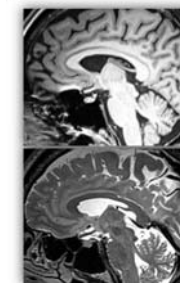
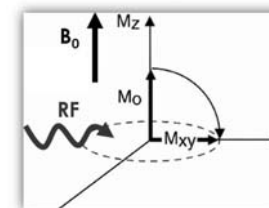
2022/11/26

3



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



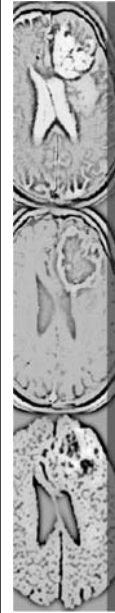
<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

2022/11/26

4

梯度回音基本觀念

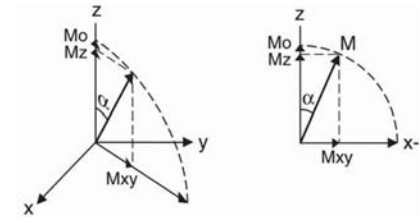
Gradient echo (GRE)
Gradient-recall echo (GRE)



Scan Time for GRE

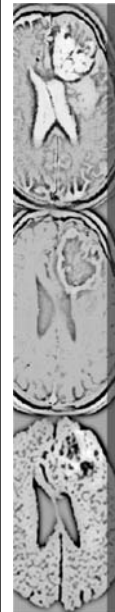
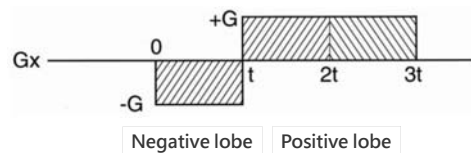
• $Scan\ time = (TR)(N_y)(NEX)$

Number of excitation (SNR)
Number of phase encoding (spatial resolution)
Repetition time: can be controlled to minimize the scan time.



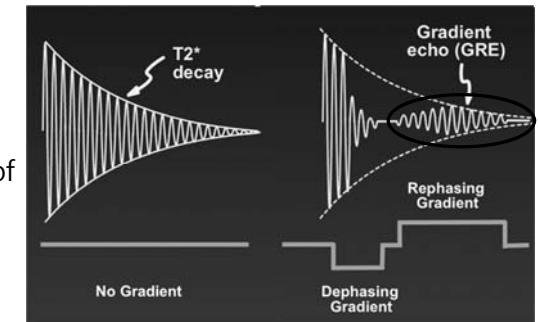
Properties of GRE

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



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.



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.

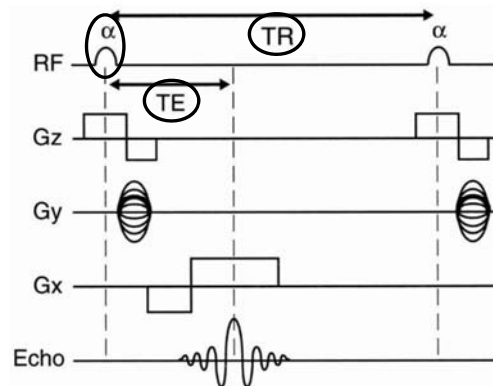
Tissue contrast in GRE

	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.

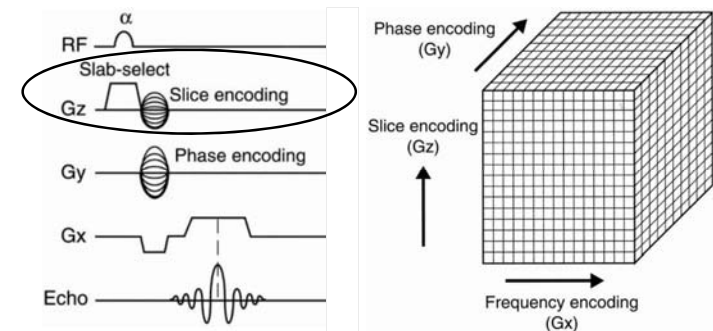


3D GRE imaging

• $Scan\ time = (TR)(N_y)(NEX)(N_z)$

Advantages of 3D GRE

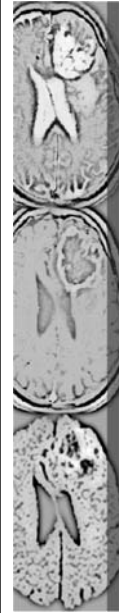
- Rapid volume imaging of thin contiguous slices without cross-talk
- Reformation capabilities (if isotropic)
- Increased SNR





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!

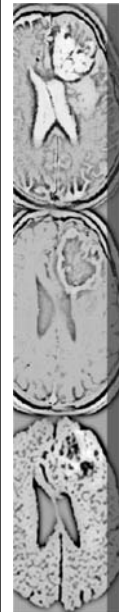


Disadvantages of GRE

- 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

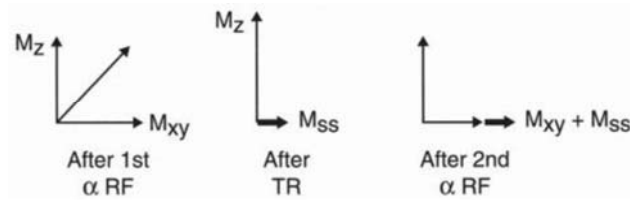
- Energy is given to hydrogen during excitation
 - the amount of energy applied is indicated by the flip angle.
- Energy is lost by hydrogen through spin-lattice energy transfer.
 - the amount of energy lost is determined by the TR.

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.

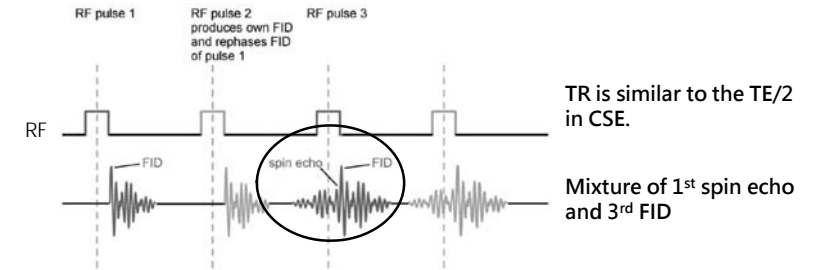
Steady-state M_{ss}

- 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

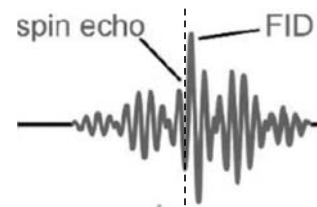
- Two or more RF pulses produce a spin echo or stimulated echo.
 - The first RF pulse excites the nuclei;
 - the subsequent RF pulses rephase the FID and any residual magnetization present to produce an echo.



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

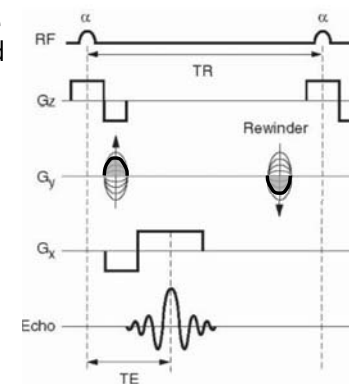
- Coherent gradient echo
 - The residual transverse magnetization is in phase
 - By applying a rewinder gradient
- Incoherent gradient echo
 - The residual transverse magnetization is out of phase
 - By applying a spoiler gradient

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

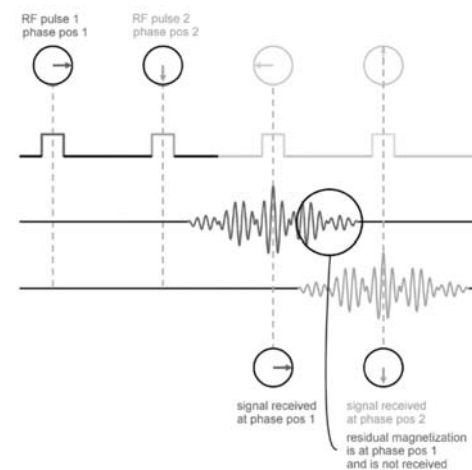
- Advantages
 - very fast scans, breath - holding possible
 - very sensitive to flow so good for angiography
 - can be acquired in a volume acquisition
- Disadvantages
 - reduced SNR in 2D acquisitions
 - magnetic susceptibility increases
 - loud gradient noise

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

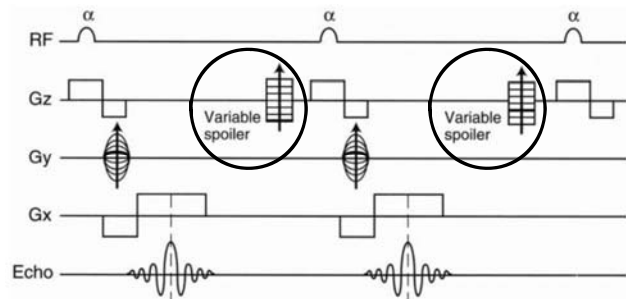
RF spoiling

- A phase offset is added to each successive RF pulse.
- The receiver can differentiate the sampled echoes by their phase difference.



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

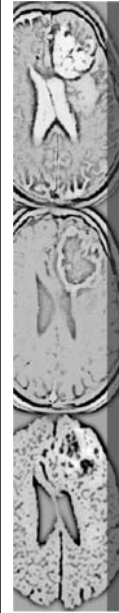
To maximize T1 weighting:

- short TE 5~10 ms



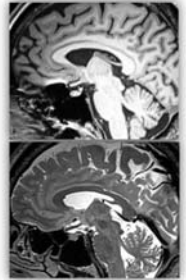
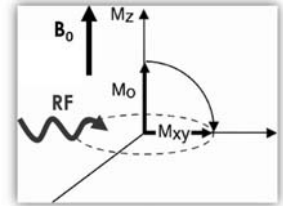
Properties of incoherent GRE

- 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

- 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



THE END

alvin4016@ym.edu.tw