

## 磁振影像學MRI Gradient Echo

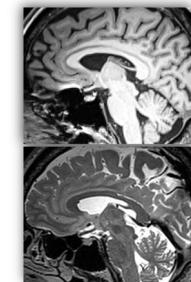
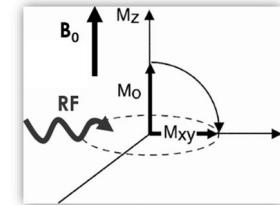
盧家鋒 教授

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



## Procedure of MRI

- Alignment (magnetization)  $B_0$
- Precession  $\omega_0 = \gamma B_0$
- Resonance (given  $B_1$  by RF with  $\omega_2$ )  $\omega_1 = \gamma B_1$ ,  $B_1 \perp B_0$ 
  - 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



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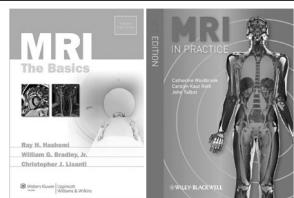
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本週課程內容 <http://cflu.lab.nycu.edu.tw/~cflu>

- 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



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## 梯度回音基本觀念

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

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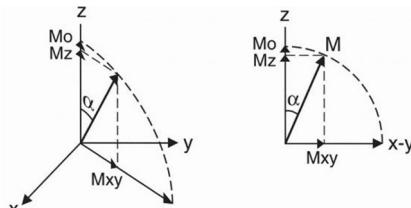
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## Scan Time for GRE

- $\text{Scan time} = (\text{TR})(N_y)(\text{NEX})$
- Number of excitation (SNR)
- Number of phase encoding (spatial resolution)
- Repetition time: can be controlled to minimize the scan time.



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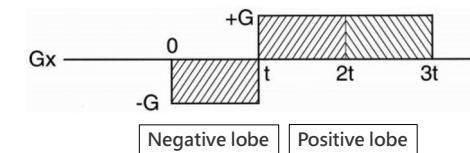
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## Properties of GRE

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



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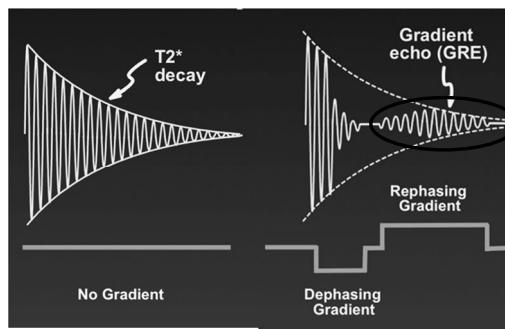
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## Bi-lobed Readout Gradient

- 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>

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## 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.



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## Tissue contrast in GRE

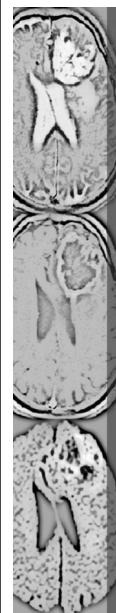
	T1 weighting	Proton density	T2* weighting
Flip angle	Large (70~110°)	Small (5~20°)	Small (5~20°)
TR	Short (< 50 ms)	Long (> 200 ms)	Long (> 200 ms)
TE	Short (1~5 ms)	Short (5~10 ms)	Long (15~25 ms)

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.

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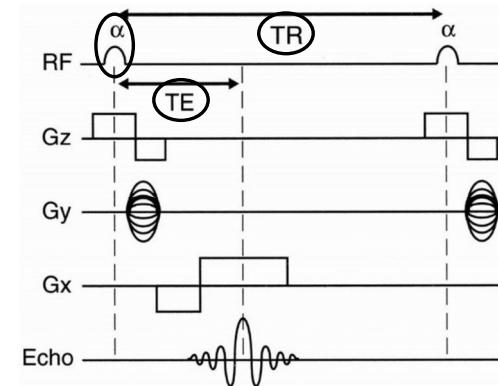
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## GRE Pulse Sequence Diagram

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



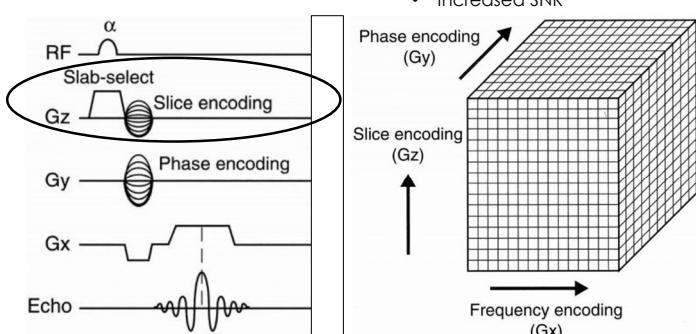
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## 3D GRE imaging

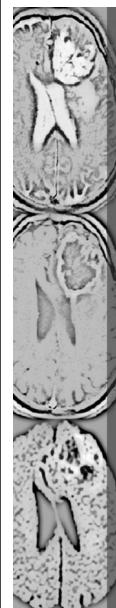
- $\text{Scan time} = (\text{TR})(N_y)(\text{NEX})(N_z)$



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## 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!

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## Disadvantages of GRE

- Decreased SNR caused by small  $\alpha$ , 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.

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## 梯度回音類型

Different formations of GRE

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## 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.

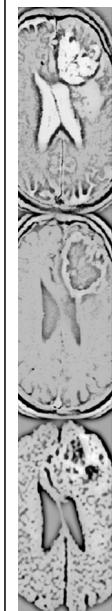
The steady state is a term describing the stable condition that does not change over time.

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

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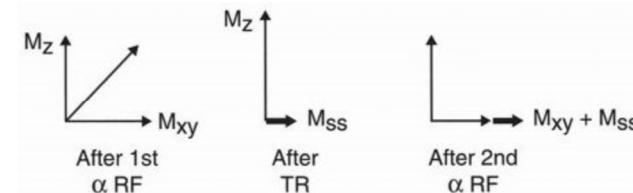
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## Steady-state $M_{ss}$

- 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.



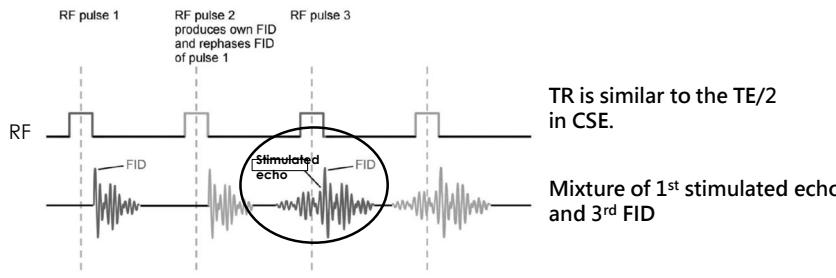
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## Echo formation in GRE

- Two or more RF pulses produce a 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.



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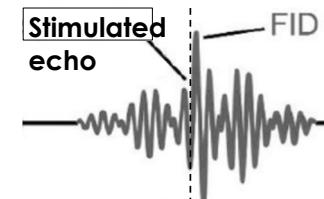
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## Signal weighting

- an *FID*, which occurs as a result of the withdrawal of the previous RF pulse and, contains either T2 \* or T1 information
- a *stimulated 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  $M_{ss}$ .



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## 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

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## 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

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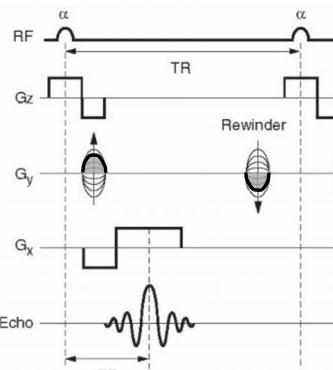
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## Coherent gradient echo

- 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

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## Parameters of coherent GRE

To maintain the steady state:

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

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## 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

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## 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

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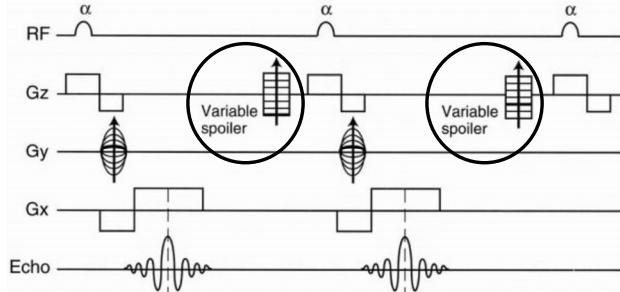
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## Gradient Spoilers

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



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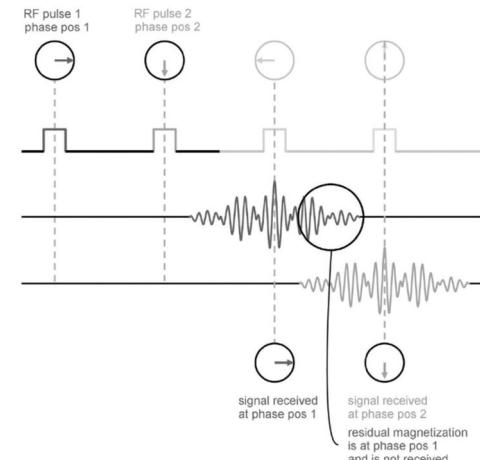
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## RF spoiling

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



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## 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

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## 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

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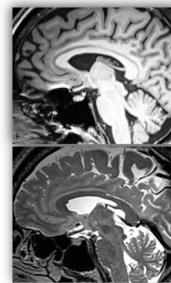
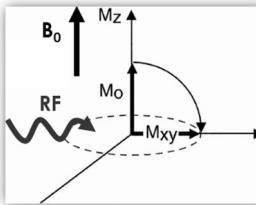
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  - The most effective resonance is produced when  $\omega_0 = \omega_2$
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- Imaging (Pulse sequencing: SE, GRE, EPI)
  - Tissue Contrast: Image weighting
  - Spatial localization: Slice selection & Spatial Encoding
  - Data space/K space



THE END

[alvin4016@ym.edu.tw](mailto:alvin4016@ym.edu.tw)