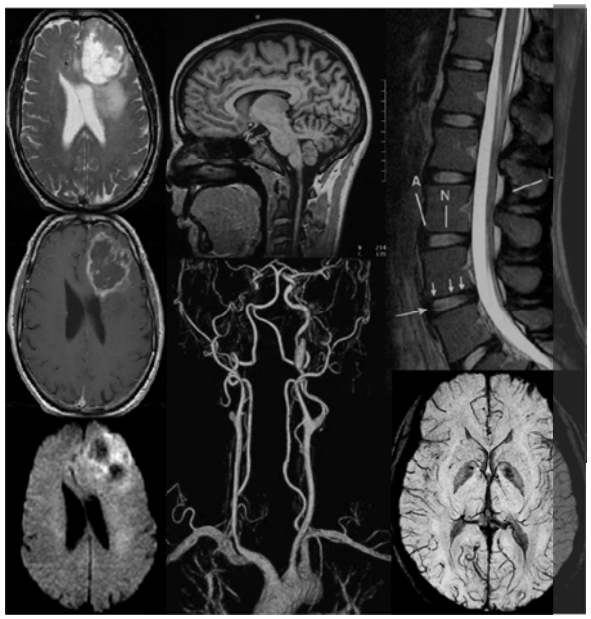

磁振影像學MRI
Gradient Echo – Part II

盧家鋒 助理教授

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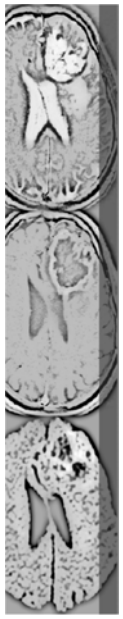
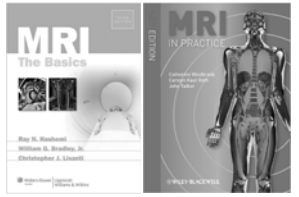
alvin4016@ym.edu.tw



本週課程內容 http://www.ym.edu.tw/~cflu

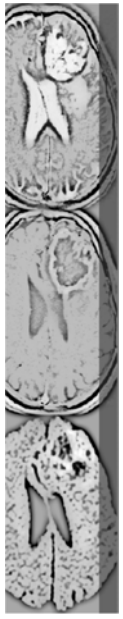
- 磁振造影流程
- 梯度回音種類
- 梯度回音應用

- **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

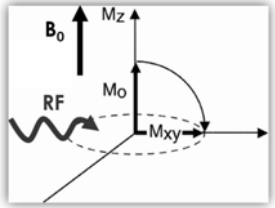


磁振造影流程

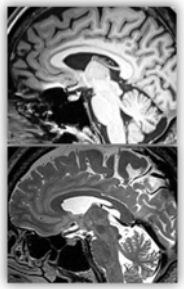
MRI Procedure



Procedure of MRI

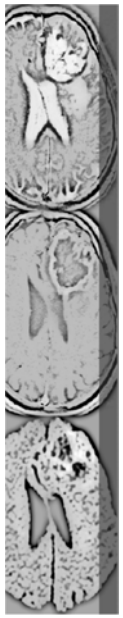


- ☑ Alignment (magnetization) B_0
- ☑ Precession $\omega_0 = \gamma B_0$
- ☑ Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- ☑ MR signal (EMF, relaxation time)
- ☐ Imaging (Pulse sequencing: SE, GRE, EPI)
  - ☑ Tissue Contrast: Image weighting
  - ☑ Spatial localization: Slice selection & Spatial Encoding
  - ☑ Data space/K space



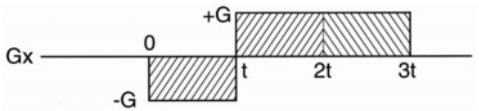
梯度回音類型

Echo formations of GRE

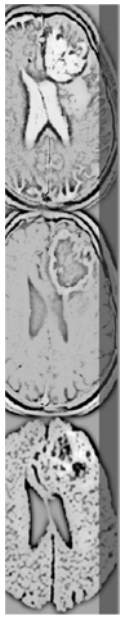


Properties of GRE

- 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.

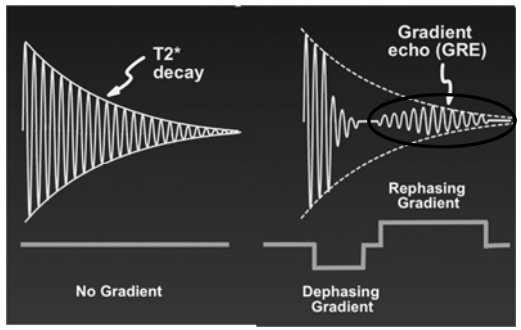


Negative lobe Positive lobe

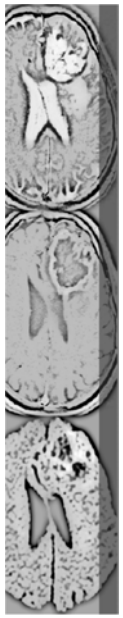


Bi-lobed Readout Gradient

- 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.

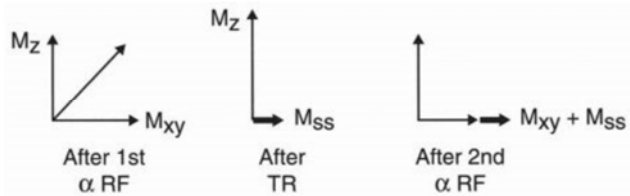


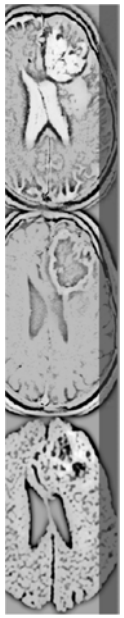
http://mri-q.com/gre-vs-se.html



Steady-state M_{ss}

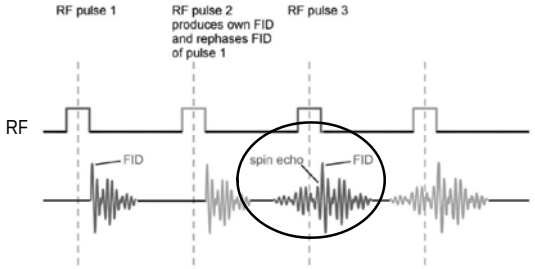
- The steady state of residual transverse magnetization.
- The steady state involves repeatedly applying RF pulses at time intervals less than the T2 (decay) and T1 (recovery) times of all the tissues.





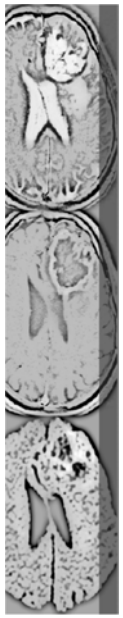
Echo formation in GRE

- Any two RF pulses produce a spin echo.
  - The first RF pulse excites the nuclei;
  - the second RF pulse rephases the FID and any residual magnetization present to produce a spin echo.



TR is similar to the TE/2 in CSE.

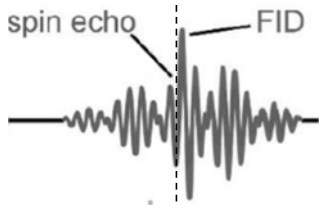
Mixture of 1st spin echo and 3rd FID

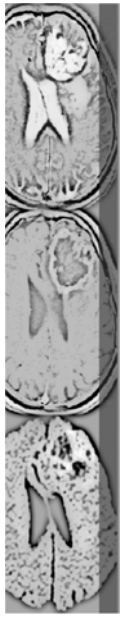


Signal weighting

- 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.

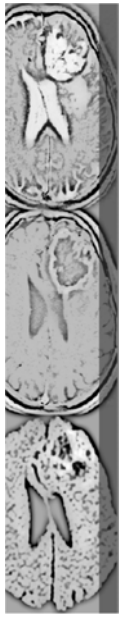
The spin echo is generated from both FID and M_{ss}.





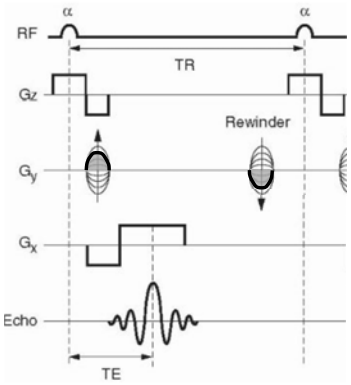
Formations of GRE

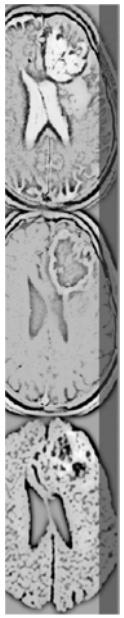
- Coherent gradient echo
  - The residual transverse magnetization is in phase
  - By applying a rewinder gradient
- Incoherent gradient echo
  - The residual transverse magnetization is out of phase
  - By applying a spoiler gradient



Coherent gradient echo

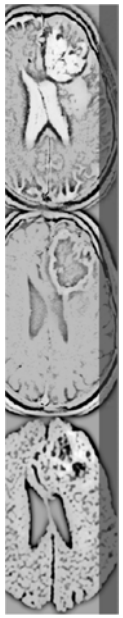
- A rewinder gradient is applied in the phase-encoding direction at the end of the cycle
  - to reverse the effects of the phase-encoding gradient applied at the beginning of the cycle
  - it "unwinds" the former dephasing effect.
  - insert T2* weighting
- GRASS and FISP





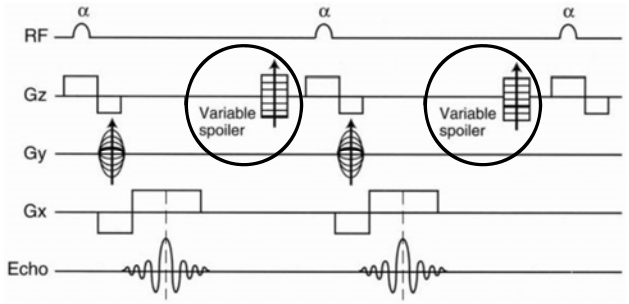
Incoherent gradient echo

- 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



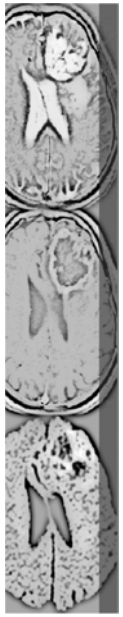
Gradient Spoilers

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



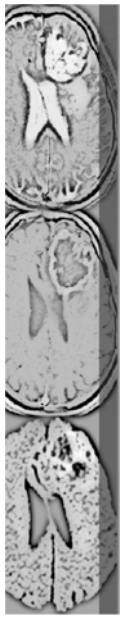
梯度回音應用

Applications of GRE



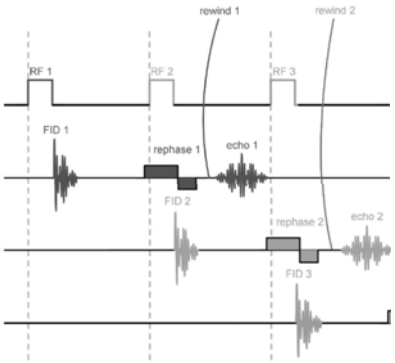
Steady-state free precession (SSFP)

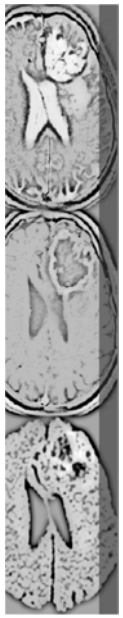
- About GRE in general…
  - Dominated by T2* effects and therefore true T2 weighting cannot be achieved.
  - TE is not long enough to measure the T2 time of tissues (as a TE at least 70 ms is required).
- The SSFP sequence obtains images that have a sufficiently long TE and less T2* than in other steady state sequences.



Steady-state free precession (SSFP)

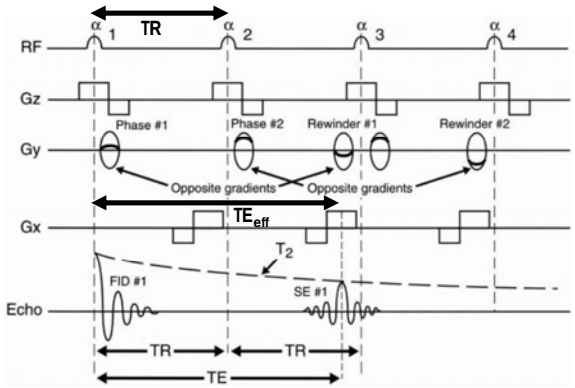
- Separate spin echo from FID
  - By applying a rewinder gradient to speed up the rephasing so that the spin echo occurs sooner.
- Rephasing has been initiated by an RF pulse rather than a gradient so that more T2 information is present.

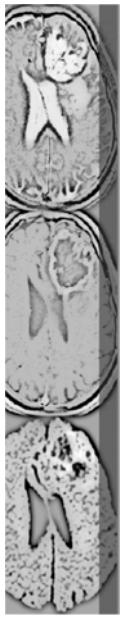




PSD of SSFP

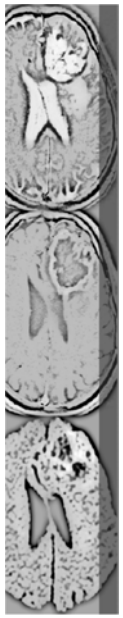
- Rewinder gradient is now used to speed up the rephasing of echo.





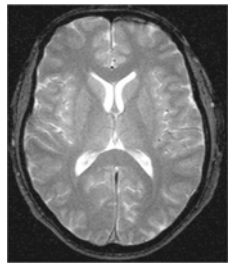
Steady-state free precession (SSFP)

- In SSFP, the effective TE is the time from the echo to the excitation pulse that created its FID.
  - The effective TE is longer than the TR.
- The resultant echo demonstrates more true T2 weighting than conventional GRE.



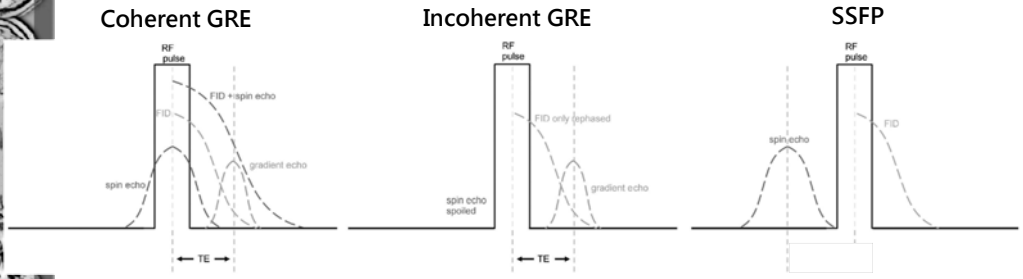
In practical…

- FSE has now largely replaced this sequence as it produces better T2 weighting in short scan times.
- However, the SSFP is used in sequences where rapid data acquisition and long TEs are required.
  - ex: Perfusion-weighted imaging



SSFP image

Comparison of echo formation



Comparison of echo formation

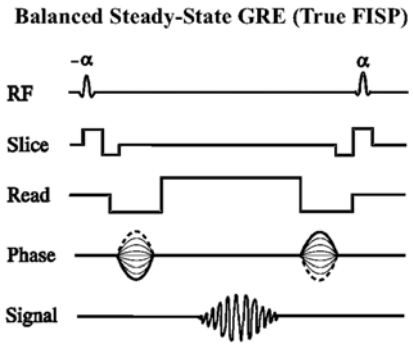
Table 21-3

GRE Technique	SNR	CNR	Comments
GRASS /FISP	Highest	Best possible T2*	Preserves steady-state component
SPGR /FLASH	Intermediate	Best possible T1 W	Spoils steady-state component
SSPF/PSIF	Lower	Provides T2W	Gradient-recalled SE ; TR < TE < 2TR

Balanced gradient echo

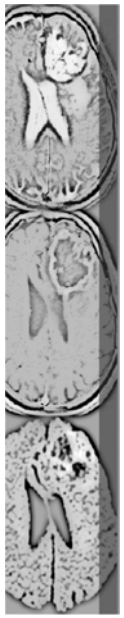
- This sequence is a modification of the coherent gradient echo sequence
- a balanced gradient system to correct for phase errors in flowing blood and CSF
- an alternating RF excitation scheme to enhance steady state effects.

http://mri-q.com/true-fispfiesta.html



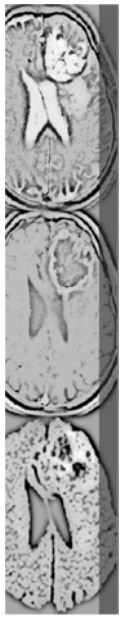
Multiplanar Techniques

- MPGR: multiplanar gradient recalled/GRASS
- MPSPGR: multiplanar SPGR
- Increase TR to perform multi-slice excitation
  → reduce (spoil) the steady-state component Mss
  - GRASS becomes similar with SPGR
- Use flip angle to adjust T1 weighting



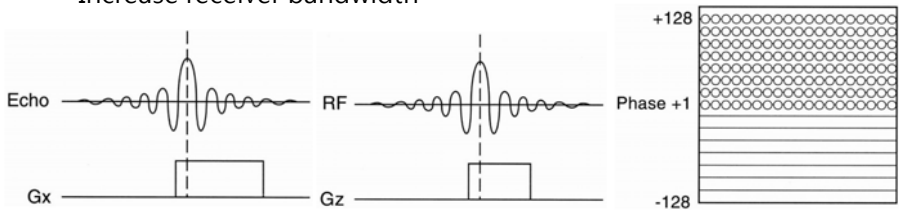
Multiplanar Techniques

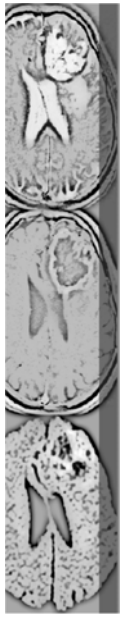
- Advantages
  - Long TR → increase SNR
  - Increase slice coverage
  - Possible for multi-echo imaging
  - Larger flip angle can be used → increase SNR



Fast gradient echo

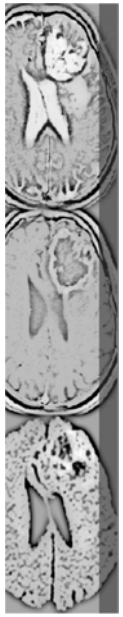
- Fractional echo
- Fractional RF
- Fractional number of excitation (NEX)
- Increase receiver bandwidth





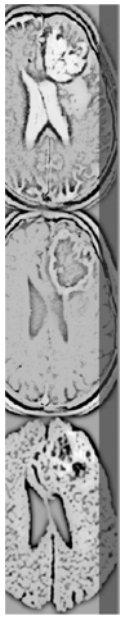
GRE acronyms http://mri-q.com/commercial-acronyms.html

Sequence	Siemens	GE	Philips	Hitachi	Toshiba
Generic Gradient Echo	GRE	GRE	FFE	GE	FE
RF-Spoiled GRE	FLASH	SPGR	T1-FFE	RSSG	T1-FFE
Coherent GRE with "FID" Refocusing	FISP	GRASS	FFE	SARGE (SG)	FE
Coherent GRE with "Echo" Refocusing	PSIF	SSFP	T2-FFE	TRSG	SSFP
Coherent GRE with Balanced "FID/Echo" Refocusing	True FISP	FIESTA	Balanced FFE	BASG	True SSFP
Coherent Balanced GRE using Dual-excitation	CISS	FIESTA-C	---	PBSG	---
Coherent Double GRE using Combined "FIDs" & "Echoes"	DESS	MENSA	---	---	---
Spoiled GRE using Combined Multiple FIDs	MEDIC	MERGE	M-FFE	---	---
Ultrafast GRE	TurboFLASH (2D) MP-RAGE (3D)	Fast GRE BRAVO (3D)	TFE 3D T1-TFE	RGE (2D) 3D-GEIR	Fast FE
Spoiled 3D GRE Variants	VIBE	FAME/LAVA	THRIVE	TIGRE	3D QUICK
GRE Plus SE with Combined Signal	TGSE	---	GRASE	---	Hybrid EPI

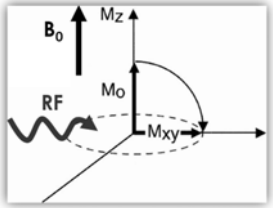


GRE acronyms

BASG	Balanced SARGE (Steady-state Acquisition Rewound Gradient Echo)
BRAVO	Brain Volume imaging
CISS	Constructive Interference in the Steady Steady State
COSMIC	Coherent Oscillatory State Acquisition for Manipulation of Imaging Contrast
DESS	Double Echo Steady State
FAME	Fast Acquisition with Multiphase Elliptical fast gradient echo
FE	Field Echo
FFE	Fast Field Echo
FIESTA	Fast Imaging Employing Steady State Acquisition
FIESTA-C	Fast Imaging Employing Steady State Acquisition - Constructive Interference
FISP	Fast Imaging with Steady Precession
FLASH	Fast Low Angle Shot
GE, GRE	Gradient Echo
GEIR	Gradient Echo Inversion Recovery
GRASE	Gradient And Spin Echo
GRASS	Gradient Recalled Acquisition in the Steady State
LAVA	Liver Acquisition with Volume Acceleration
MEDIC	Multi-Echo Data Image Combination
MENSA	Multi-Echo iN Steady-state Acquisition
MERGE	Multiple Echo Recombined Gradient Echo
M-FFE	Multiple Fast Field Echo
MP-RAGE	Magnetization Prepared Rapid Gradient Echo
PBSG	Phase Balanced SARGE
PSIF	Time-reversed FISP
RGE	Rapid Gradient Echo
RSSG	RF-Spoiled SARGE
SARGE (SG)	Steady-state Acquisition Rewound Gradient Echo
SSFP	Turbo Gradient Spin Echo
TGSE	Steady State Free Precession
THRIVE	T1-weighted High Resolution Isotropic Volume Examination
TIGRE	T1-weighted GRadient Echo
TRSG	Time-Reversed SARGE
VIBE	Volumetric Interpolated Breath-hold Examination



Procedure of MRI



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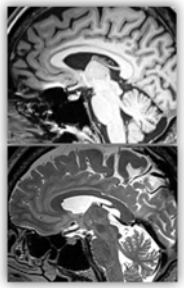
  - ☑ Data space/K space



THE END

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