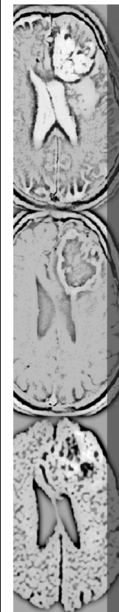




磁共振影像學MRI Spin Echo

盧家鋒 副教授

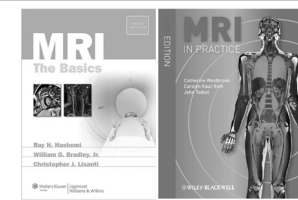
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生物醫學影像暨放射科學系
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本週課程內容 <http://cflu.lab.nycu.edu.tw>

- 自旋回音 (spin echo)
- 快速自旋回音 (fast spin echo)

- MRI The Basics (3rd edition)
 - Chapter 8: Spin echo
 - Chapter 19: Fast spin echo
- MRI in Practice, (4th edition)
 - Chapter 5: Pulse sequences



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

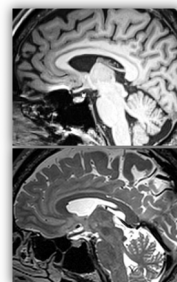
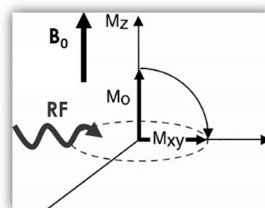
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Procedure of MRI

- 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



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自旋回音

Spin echo (SE)
Conventional spin echo (CSE)

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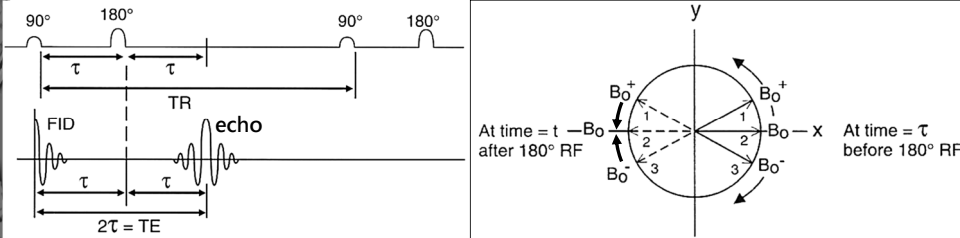
Rephasing 180° RF

- T2* decay depends on both
 - External magnetic field
 - Spin-spin interactions

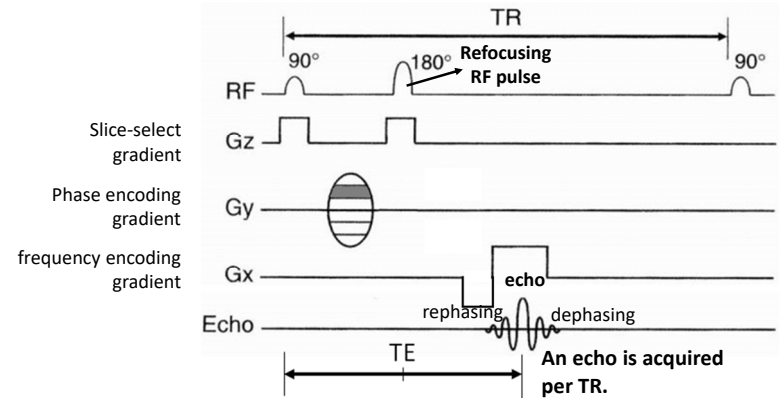


- T2 decay depends only on
 - Spin-spin interactions

Eliminate the effects of ΔB_{ext}

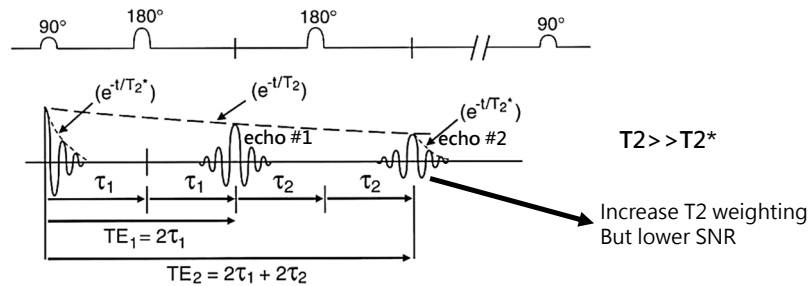


Spin-echo pulse sequence diagram



Dual-echo spin echo

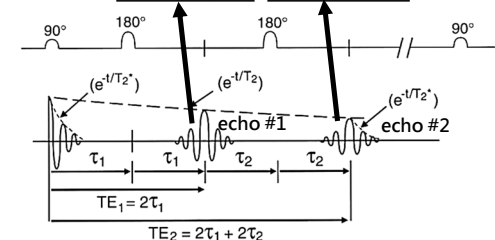
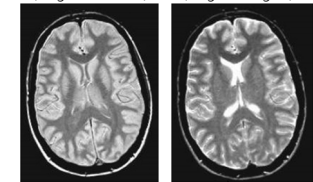
- A second 180° pulse applied at time τ_2 after the first echo will allow the spins to rephase again at time $2\tau_2$ after the first echo and a second echo is obtained.



Dual-echo spin echo

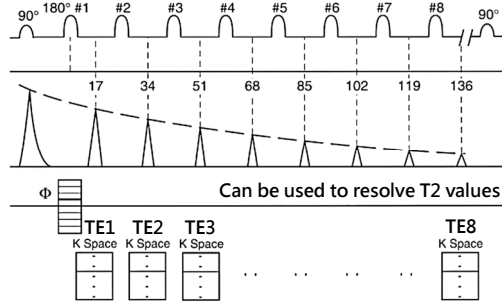
- The proton density images can be acquired with T2-weighted images without using another sequence.

Proton density (long TR, short TE) T2-weighted (long TR, long TE)



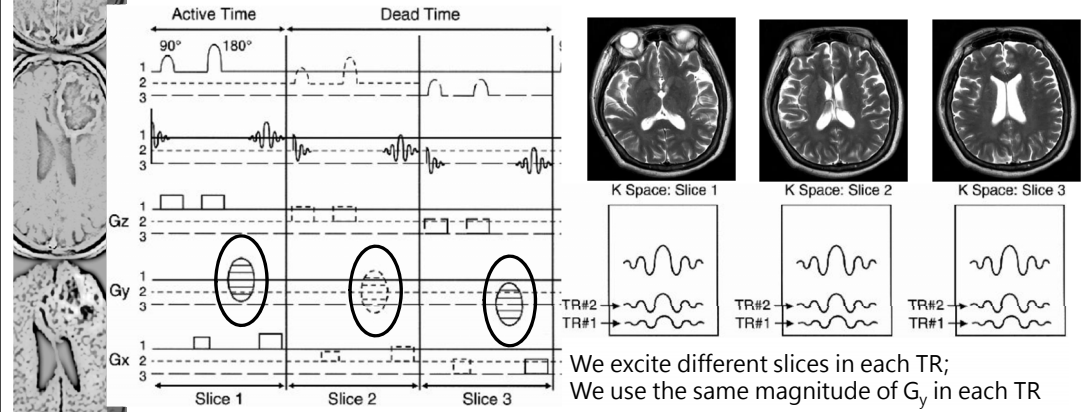
Multi-echo spin echo

- Fill each echo into the distinct k-space.
- For an eight-echo train, we get eight different images.



Only with a single phase-encoding step

Multi-slice Acquisition in a TR



Multi-slice & multi-echo spin echo

(C) 5. 磁振造影傳統自旋回聲 (conventional spin echo) 脈衝序列中，若在一個 TR 內選擇 4 個切面，每個切面有 2 個回聲 (echo)，則在一個 TR 內，有幾個相位編碼梯度？

- A.1
- B.2
- C.4
- D.8

(A) 2. 磁振造影傳統自旋回聲 (conventional spin echo) 脈衝序列中，若在一個 TR 內選擇單一切面，4 個回聲 (echo)，則在一個 TR 內，有幾個相位編碼梯度？

- A.1
- B.2
- C.4
- D.8

(B) 1. 磁振造影傳統自旋回聲 (conventional spin echo) 脈衝序列中，若在一個 TR 內選擇 2 個切面，4 個回聲 (echo)，則在一個 TR 內，開啟幾次相位編碼梯度？

- A.1
- B.2
- C.4
- D.8

(103 年第二次放射線器材學第 45 題)

Multi-echo procedure doesn't increase the phase-encoding steps.

快速自旋回音

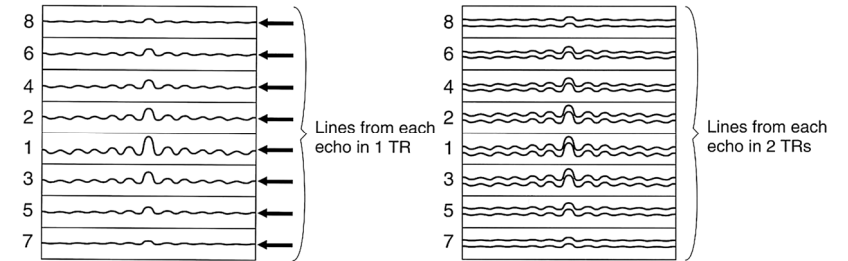
Fast spin echo (FSE)

Terminology of FSE

Manufacturer	Name
Bruker	Rapid acquisition with relaxation enhancement (RARE)
GE, Hitachi, Toshiba	Fast spin echo (FSE)
Siemens, Philips	Turbo spin echo (TSE)

Fast spin echo (FSE)

- FSE is a very elegant way of manipulating the CSE technique to save time.
- We will only have one k-space. We'll fill this k-space eight lines (eight-echo train) at a time.



Echo Train Length (ETL)

- ETL refers to the number of echoes used in FSE.
- The time interval between successive echoes (or between 180° pulses) is called the echo spacing (ESP).
- A typical ESP is on the order of 16 to 20 msec.

Fast spin echo

- In FSE, before each 180° pulse, we place a different value of the phase-encoding gradient.
- For the 180° pulse before the echo we choose as the TE_{eff} (in this case, 102 msec), we use a phase-encoding gradient with the lowest strength.

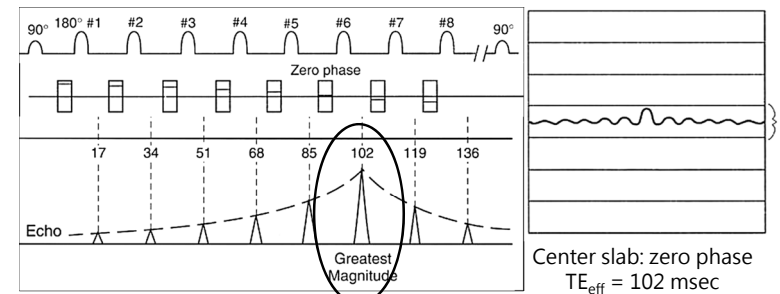
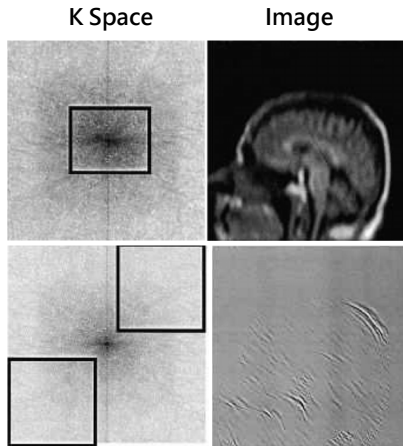


Image of K-Space

- The center of k-space contributes to the primary information of image (e.g. **contrast**).
- The periphery of k-space provides information regarding fitness of the image and clarity at sharp interfaces



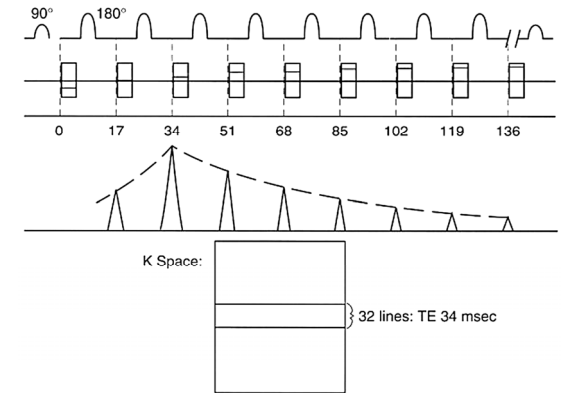
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Change TE_{eff} to adjust T2 weighting

- Long TR, short TE
→ Proton density
- Long TR, long TE
→ T2-weighted



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Scan Time

- *Scan time (CSE)* = $(TR)(Ny)(NEX)$
- *Scan time (FSE)* = $\frac{(TR)(Ny)(NEX)}{ETL}$

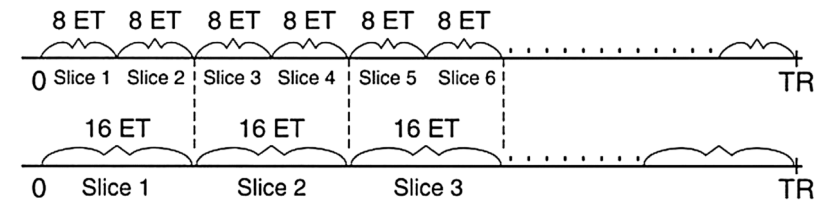
<http://cflu.lab.nycu.edu.tw>, Textbook: MRI The Basics, Hashemi et al.

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Trade-off: slice coverage

- Increasing the ETL causes a reduction in coverage (number of slices) within a TR.
- ETL ↑ → speed ↑ → slice coverage ↓



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Phase-encoding step

- Please compare to the conventional spin echo.
- Depends on both ETL and slice number in a TR.

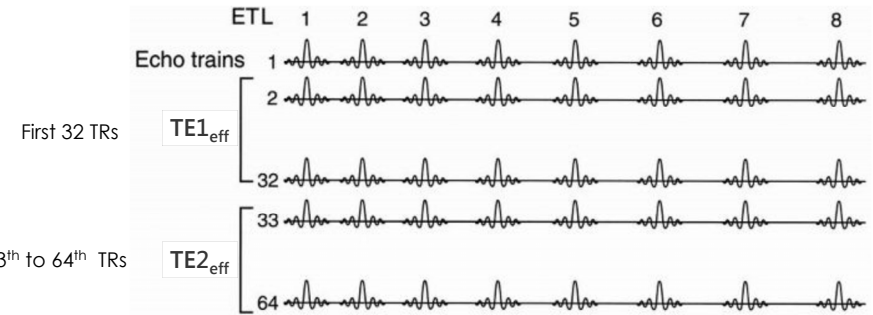
(D) 4. 磁共振造影快速自旋回聲 (fast spin echo) 脈衝序列中，若在一個 TR 內選擇單一切面且回聲列長度 (echo train length) 為 8，則在一個 TR 內，有幾個相位編碼梯度？

- A.1
- B.2
- C.4
- D.8

(98 年第一次放射線器材學第 48 題)

Multi-echo FSE

- Full echo trains: the entire echo train is completed for a TE_{eff} .



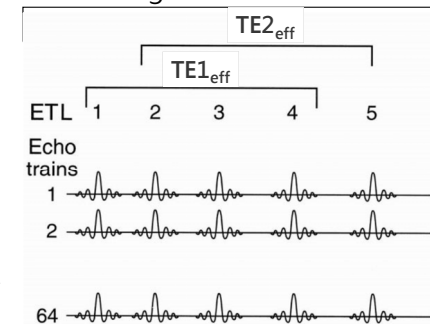
Multi-echo FSE

- Split echo trains: the first half of the echo train contributes to the image with $TE1_{eff}$ and the second half to $TE2_{eff}$ (thus, two k-spaces are created).



Multi-echo FSE

- Shared echo trains: the first and last echoes in the train are emphasized for $TE1_{eff}$ and $TE2_{eff}$ respectively, and the echoes in between are shared for both images.

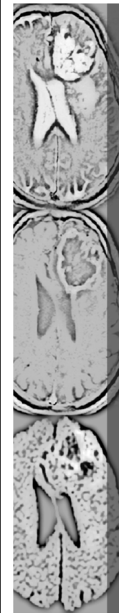


Can save more time for multi-slice.



Properties of FSE

- Advantages
 - The scan time is decreased (which allows faster scanning).
 - The signal-to-noise ratio (SNR) is maintained because we still have 256 phase-encoding steps.
 - The increased speed allows for high resolution imaging in a reasonable amount of time.
 - Motion artifacts will be less severe. Because the 180° pulses are evenly spaced, there is a natural even-echo rephasing effect. For instance, cerebrospinal fluid (CSF) motion artifacts are much less severe on FSE than on CSE images.
 - The rephasing from the multiple 180° pulses leads to less distortion from metallic objects (magnetic susceptibility) on FSE images.
 - Similarly, FSE images are much more tolerant of a poorly shimmed magnet than are CSE images.



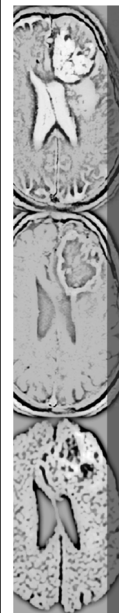
Properties of FSE

- Disadvantages
 - Reduced coverage, that is, decreased number of slices.
 - Contrast averaging (k-space averaging) so that
 - CSF is brighter on proton density-weighted FSE images.
 - To alleviate this problem, either use a shorter ETL (to exclude longer TEs) or a higher BW (to decrease ESP and the minimum TE_{eff}).
 - Magnetization transfer (MT or MTC) effect in FSE. MTC is inadvertently present in FSE. This is caused by the presence of multiple, rapid 180° pulses containing off-resonant frequencies.



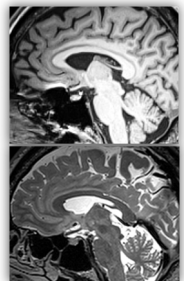
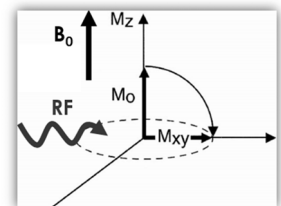
Properties of FSE

- Disadvantages (continue~)
 - Magnetic susceptibility effects will be less than with CSE. Therefore, T2-weighted FSE images are less sensitive to magnetic susceptibility effects such as metal or hemorrhage (e.g., deoxyhemoglobin and hemosiderin) than are T2-weighted CSE images (Fig. 18-47).
 - Fat is bright on T2-weighted FSE images. This is due to suppression of diffusion-mediated susceptibility dephasing caused by the closely spaced 180° pulses. You could do a fat-saturated FSE to decrease the intensity of fat.



Procedure of MRI

- Alignment (magnetization) B_0
- Precession $\omega_0 = \gamma B_0$
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 - 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
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THE END

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