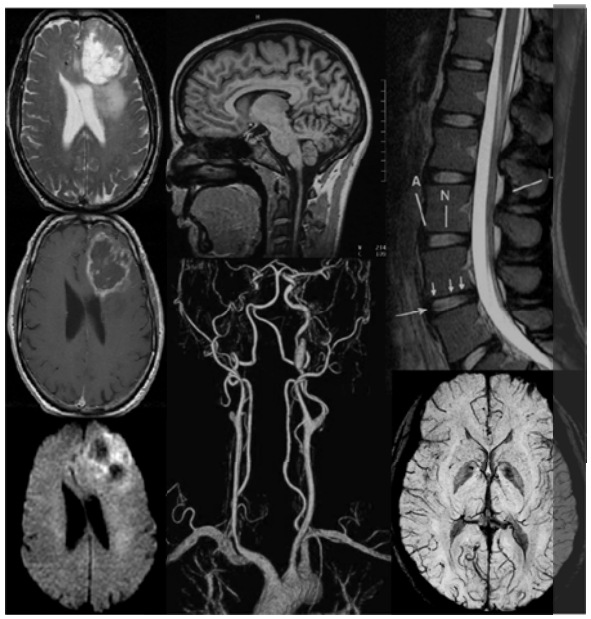

醫用磁振學MRM
磁振原理複習II

盧家鋒 助理教授

國立陽明大學 生物醫學影像暨放射科學系
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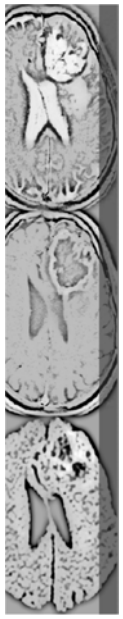
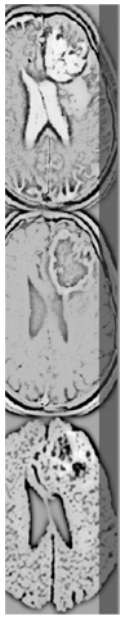


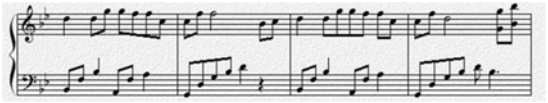
Pulse Sequencing

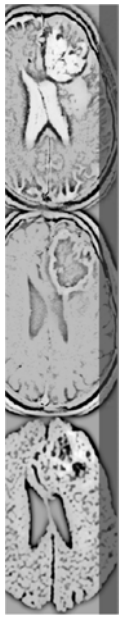
- Spin Echo**自旋回音 (SE)**
- Fast Spin Echo**快速自旋回音 (FSE)**
- Gradient Echo**梯度回音 (GRE)**
- Echo Planer Imaging**回音平面造影 (EPI)**



Pulse Sequence Diagram, PSD

- The sheet music (樂譜) of MRI
  - Arranging the tone, timing, and duration for each component.
- The instruments (樂器) in MRI are…
  - Transmitting RF coil (transmit RF pulse)
  - Slice-selective gradient coil
  - Phase-encoding gradient coil
  - Frequency-encoding gradient coil
  - Receiving RF coil (receive echoes)





The goal of PSD

- Just like that the sheet music aims to form a beautiful melody for the concert.
- PSD aims to fill out a full K-space for MR imaging!

K-Space properties

- Each of the signals has its maximum signal amplitude in the center column.
- The maximum amplitude occurs in the center row because this line is obtained without additional dephasing.

1 K-Space matrix → 1 MR image

Conventional way

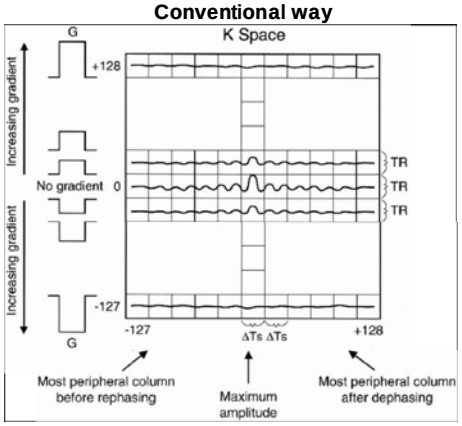
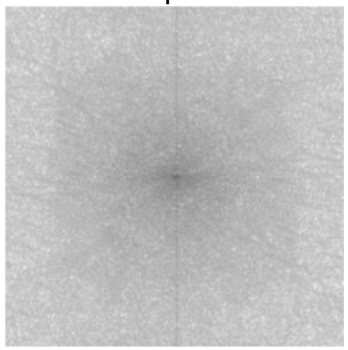


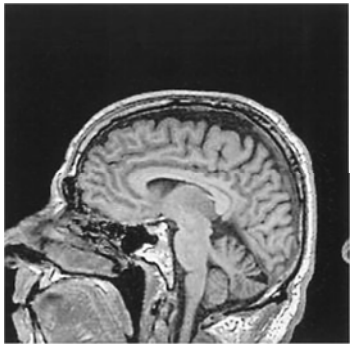
Image of K-Space

K Space



2D FFT →

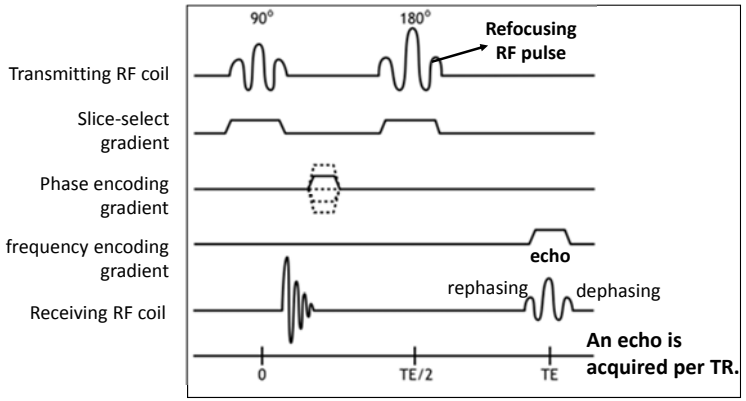
Reconstructed Image



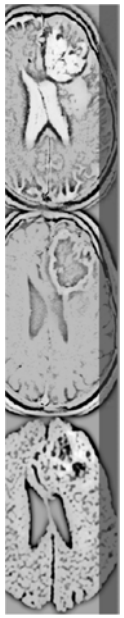
The Question now is …

- How to fill out the K-space matrix…
  - Control frequency-encoding gradient for the x-axis (columns) of K space.
  - Control phase-encoding gradient for the y-axis (rows) of K space.
  - The image contrast is determined by TR, TE, and flip angle.

Spin-echo pulse sequence diagram

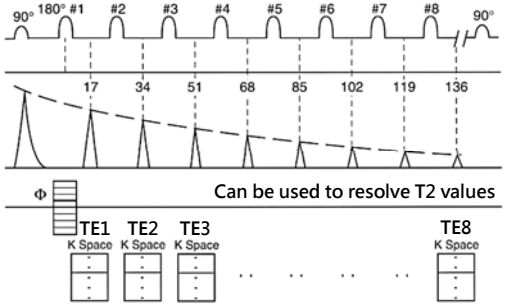


One row of K space!



Multi-echo spin echo

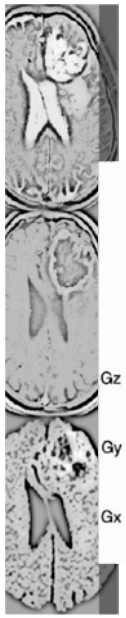
- Fill each echo into the distinct k-space.
- For an eight-echo train, we get eight different images.



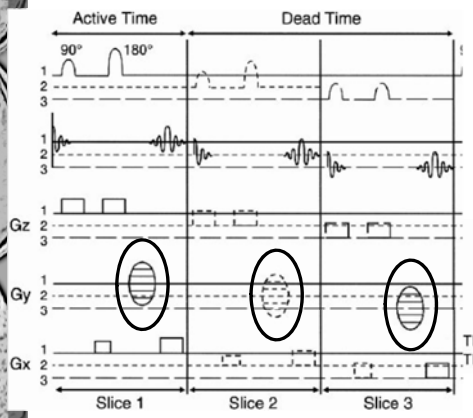
Only with a single phase-encoding step

Can be used to resolve T2 values

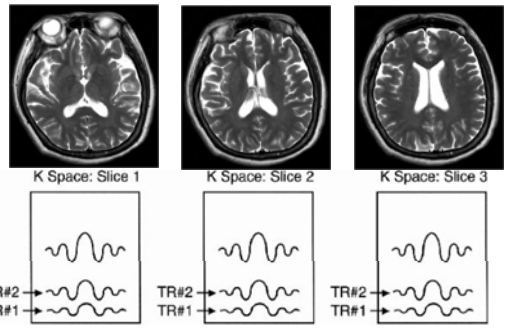
Same image slice with different T2 weighting



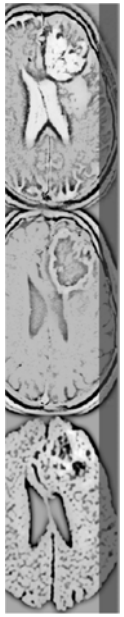
Multi-slice Acquisition in a TR



We excite different slices in each TR;
We use the same magnitude of G_y in each TR

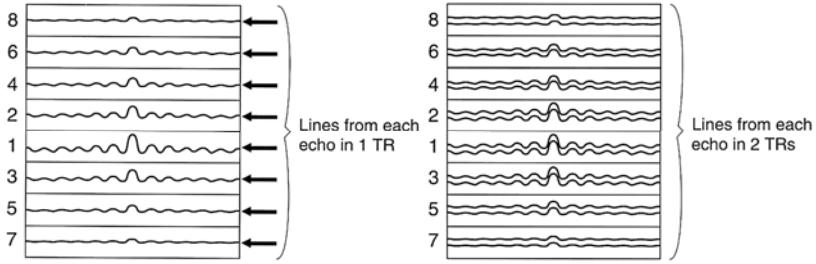


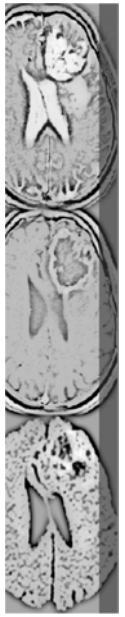
Different image slices with the same image contrast



Fast spin echo (FSE)

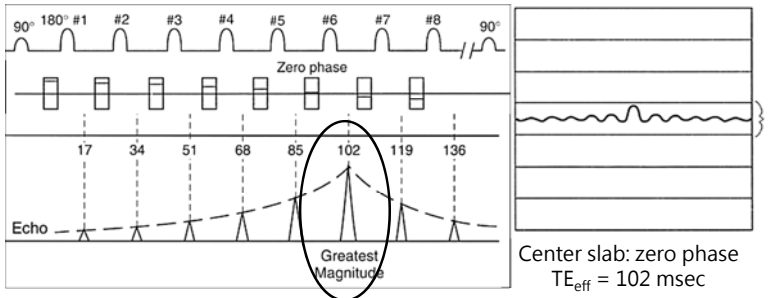
- We will only have one k-space. We'll fill this k-space eight lines (eight-echo train) at a time with eight different phase-encoding strengths.





Fast spin echo

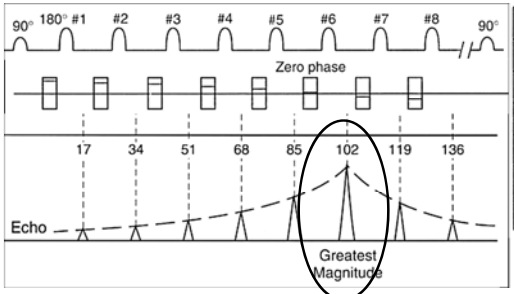
- In FSE, before each 180° pulse, we place a different value of the phase-encoding gradient.
- For the 180° pulse before the echo we choose as the TE_{eff} (in this case, 102 msec), we use a phase-encoding gradient with the lowest strength.

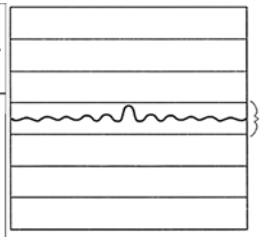


Center slab: zero phase
TE_{eff} = 102 msec

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.





Center slab: zero phase
TE_{eff} = 102 msec

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.

Phase-encoding step

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

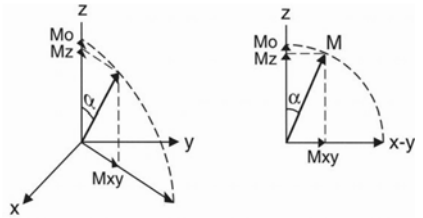
(D) 4.磁振造影快速自旋回聲（fast spin echo）脈衝序列中，若在一個 TR 內選擇單一切面且回聲列長度（echo train length）為 8，則在一個 TR 內，有幾個相位編碼梯度？
A.1
B.2
C.4
D.8

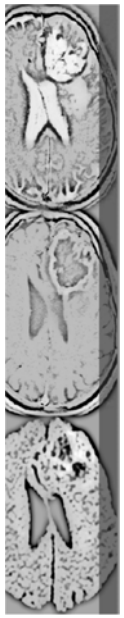
(98 年第一次放射線器材學第 48 題)

The purpose of Gradient Echo

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

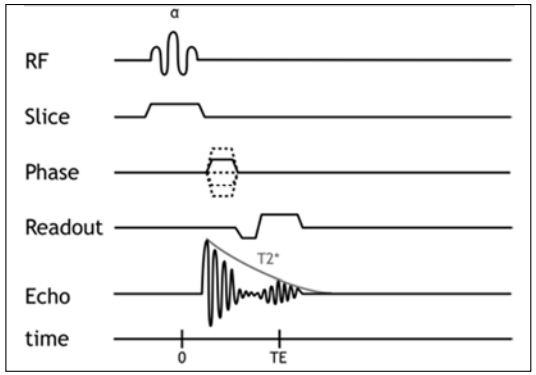
Number of excitation (SNR)
Number of phase encoding (spatial resolution)
Repetition time: can be controlled to minimize the scan time.

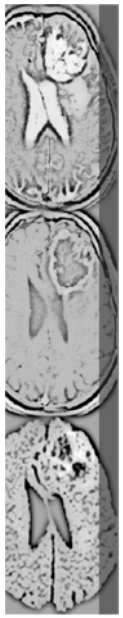




GRE Pulse Sequence Diagram

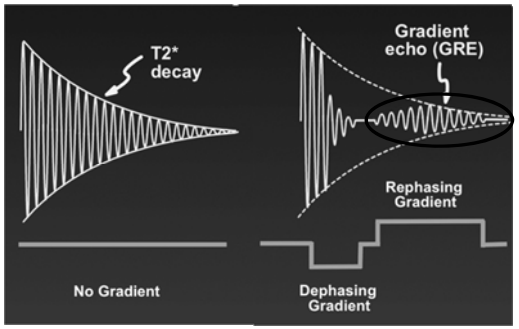
- Three operator-controlled parameters that affect the tissue contrast.



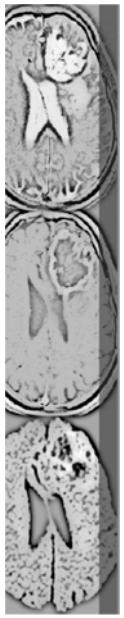


Bi-lobed Readout Gradient

- 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.

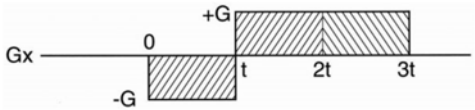


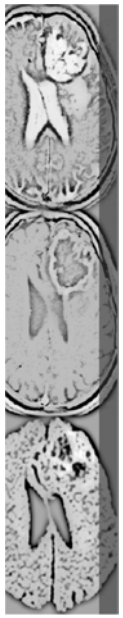
http://mri-q.com/gre-vs-se.html



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.

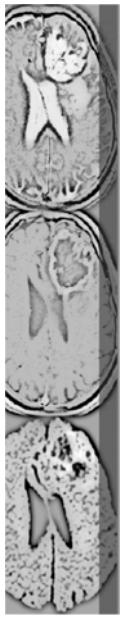




Tissue contrast in GRE

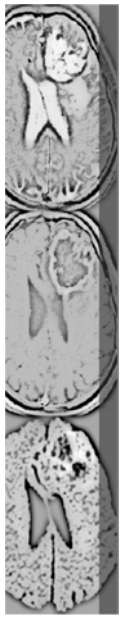
	T1 weighting	Proton density	T2* weighting
Flip angle	Large (70~110°)	Small (5~20°)	Small (5~20°)
TR	Short (< 50 ms)	Long (> 200 ms)	Long (> 200 ms)
TE	Short (1~5 ms)	Short (5~10 ms)	Long (15~25 ms)

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.



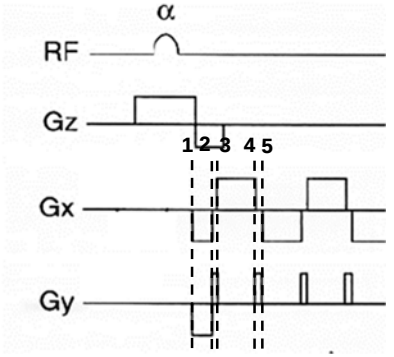
The Purpose of EPI

- Even the GRE can shorten TR, we still need several TRs to fill out one K space matrix.
- Can we fill out one K space matrix within a TR?
  - To do so, we need to manipulate the phase-encoding and frequency-encoding gradient.

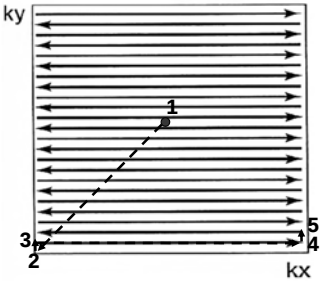


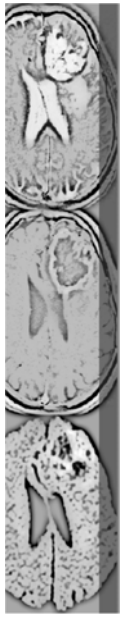
Single-shot EPI

- The phase-encode gradient is subsequently applied briefly during the time when the readout gradient was zero (200 μsec).



An odd-even coverage of k-space





Single-shot EPI

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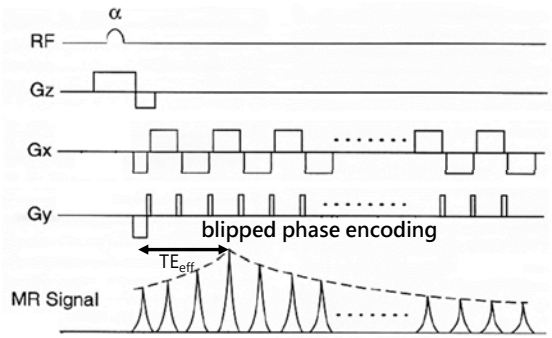
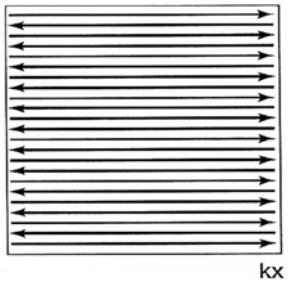
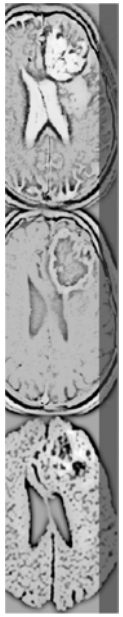


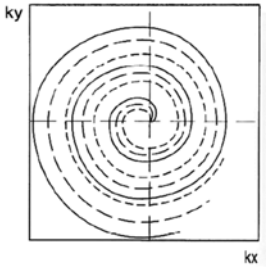
An odd-even coverage of k-space





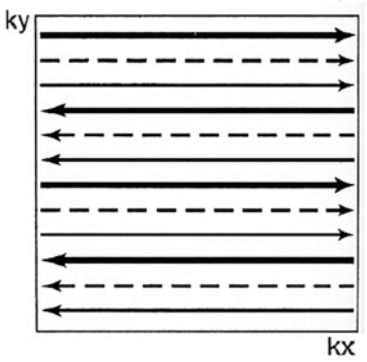
Multi-shot EPI

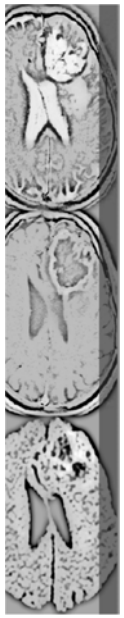
- Also called segmental EPI
- The readout is divided into multiple shots or segment (N_s)
  - $N_y = N_s$ x ETL



A spiral coverage (using oscillating G_x and G_y)

An interleaved coverage of k-space

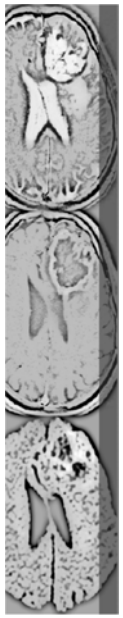




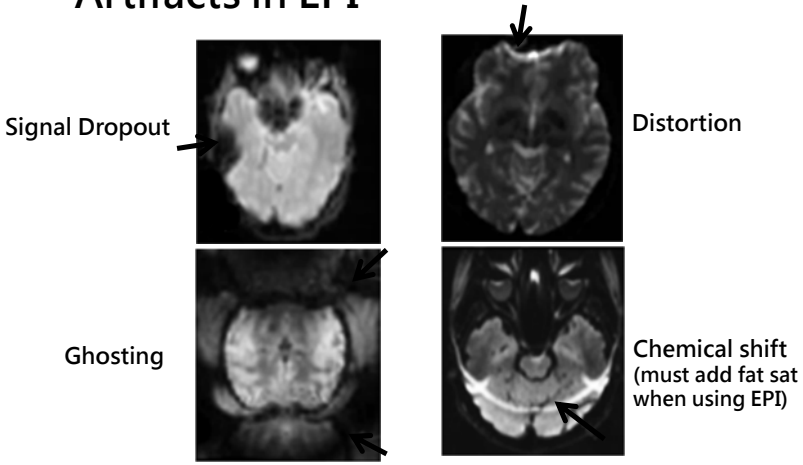
Contrast in EPI

- Contrast in EPI depends on the "**root**" pulsing sequence

- SE-EPI (90^o-180^o-EPI)
- GRE-EPI (α^o-EPI)
- IR-EPI (180^o-90^o-180^o-EPI)
  - inversion-recovery (IR)



Artifacts in EPI



THE END

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