2017.12.16 磁振造影進階專業課程

# 回音平面與擴散加權影像

Echo Planar Imaging (EPI) & Diffusion weight

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## 本次課程內容

- 基本MR回顧與SE和GRE脈衝序列圖 (Pulse sequences diagram)
  - Slice selection encoding (Gz)
  - Frequency encoding (Gx)
  - Phase encoding (Gy)
- 回音平面造影(Echo Planar Imaging (EPI))
- 擴散加權造影原理(Principle of Diffusion Weighted Imaging (DWI))
- 擴散加權造影應用(Application of Diffusion Weighted Imaging (DWI))

**Reference:**
1.MRI The Basics (3rd) (Chapter 22: echo planar imaging)
2.MRI IN PRACTICE(4td) (Chapter5: pulse sequences)
(Chapter12: functional imaging techniques)
3. S Mori and J Zhang, Encyclopedia of Neuroscience, 2009.
4. S. Heiland, imaging decisions, 2003.

**Diffusion Tensor Imaging (DTI)**
S Mori and J Zhang, The Johns Hopkins University, Baltimore, MD, USA
© 2009 Published by Elsevier Ltd.

**Diffusion- and Perfusion-Weighted MR Imaging in Acute Stroke: Principles, Methods, and Applications**
S. Heiland





## 看圖說故事時間

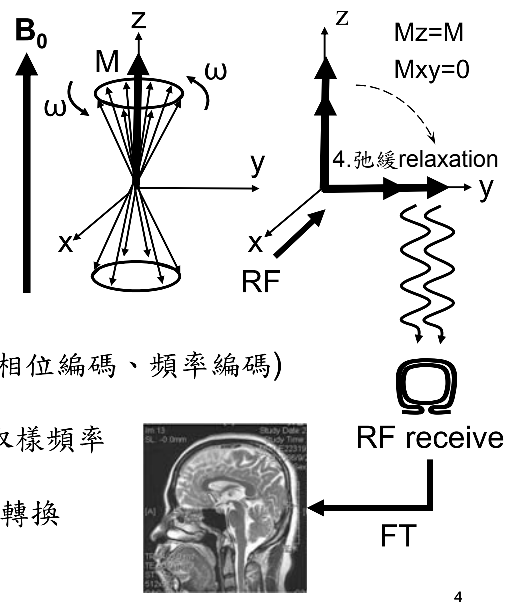
- 自願或抽簽請一位學員上台看影像, 並大聲地說出為什麼!!
  1.這些影像分別為那些加權影像?
  2. DWI影像中那個b-value最大?
  3. MRI影像中那一組是較新的梗塞?
- 你有兩次求救機會!!
  1. 你可以指名一位學員回答一個問題
  2. 你可以請全班學員舉手表決一個問題



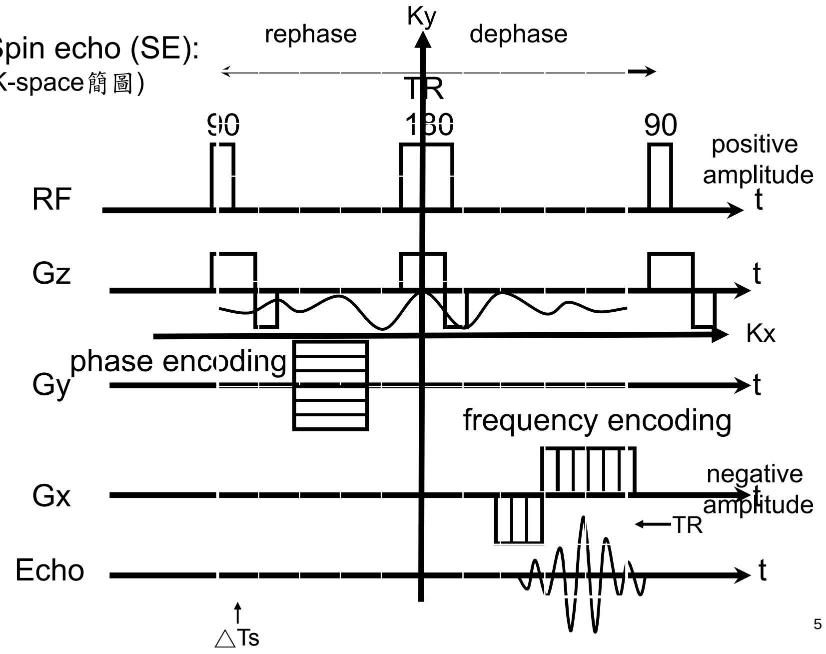


## MRI的成像過程

- 磁場 → 磁化現象
  1.排列alignment
  2.旋進precession
- RF脈衝 → 磁化量激發
  3.共振resonance
- 梯度磁場 → 切面選擇
  5.影像imaging
- 梯度磁場 → 空間編碼(相位編碼、頻率編碼)
  5.影像imaging
- 信號取號 → 接收線圈取樣頻率
  5.影像imaging
- 影像計算 → FOURIER轉換
  5.影像imaging



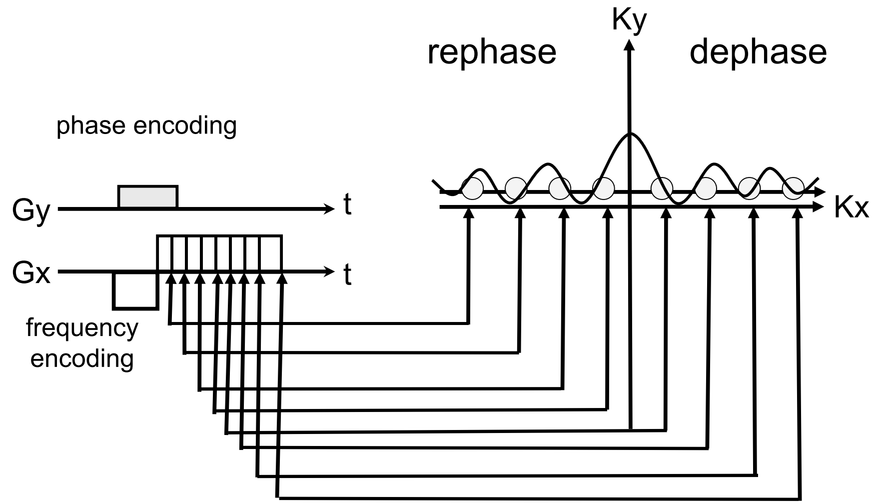
Spin echo (SE):
(K-space簡圖)







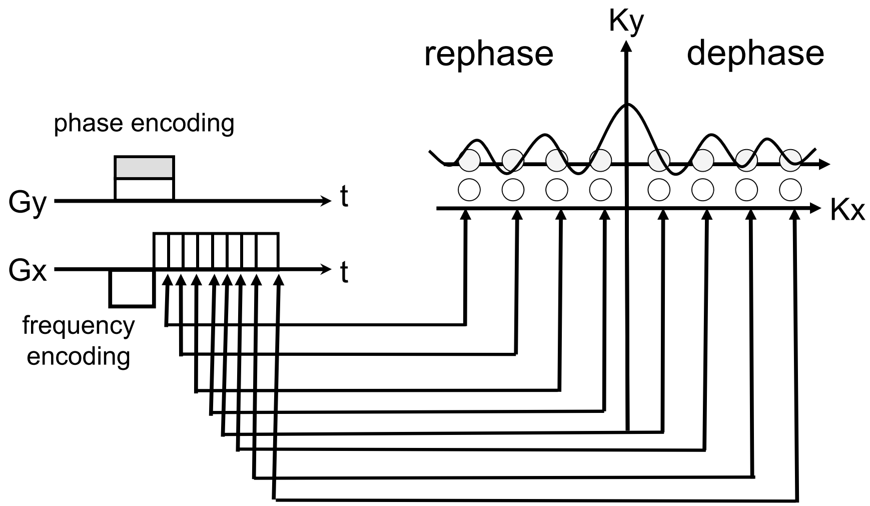

# Spin Echo K-space







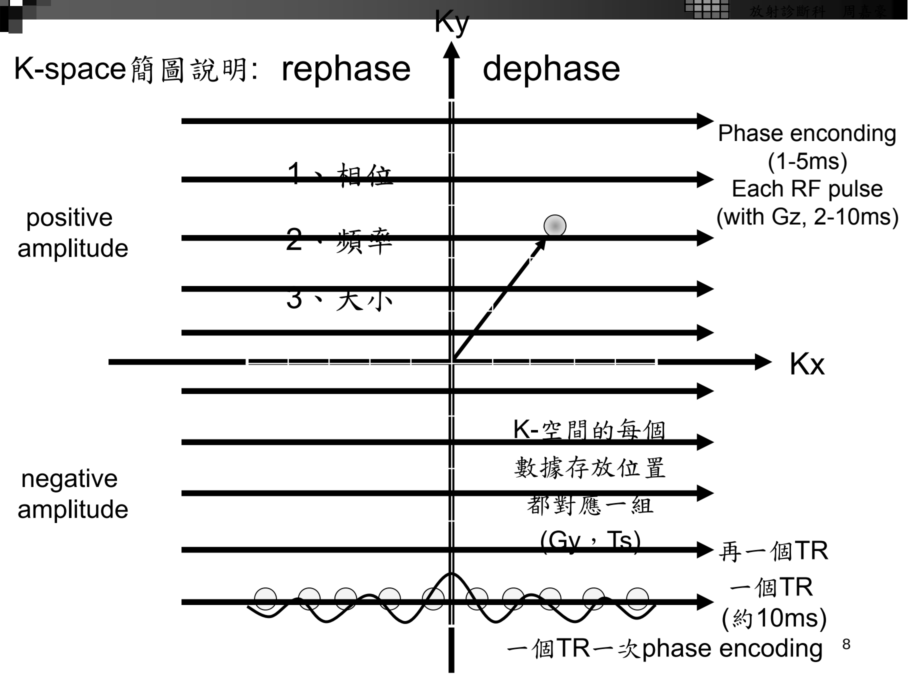

# Spin Echo K-space



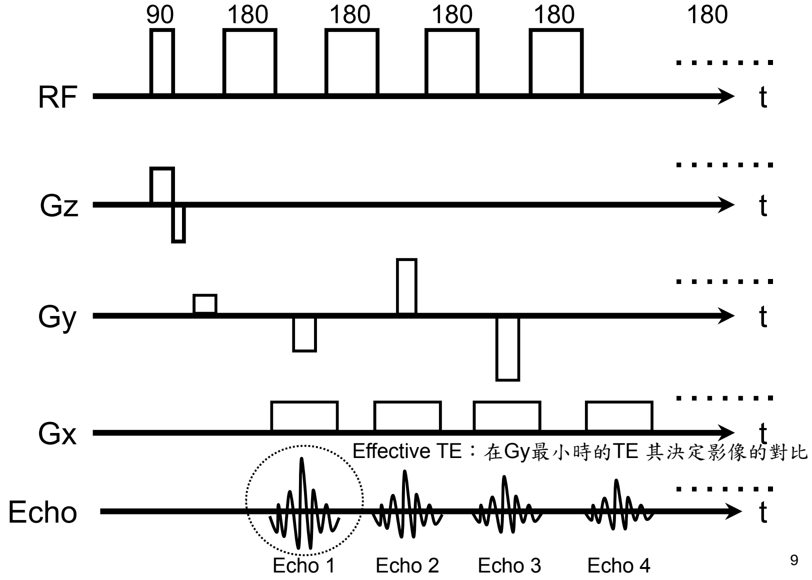





K-space簡圖說明:



# Fast Spin Echo (FSE)



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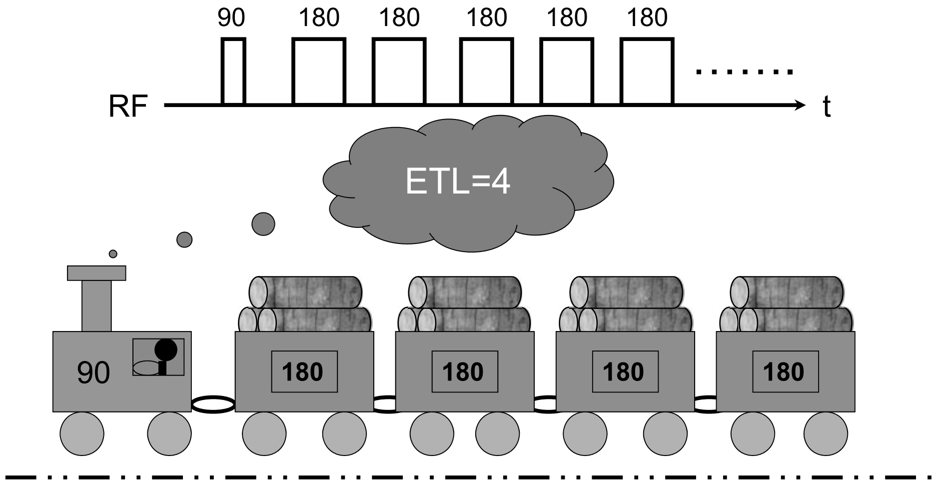
# Echo Train Length (ETL)





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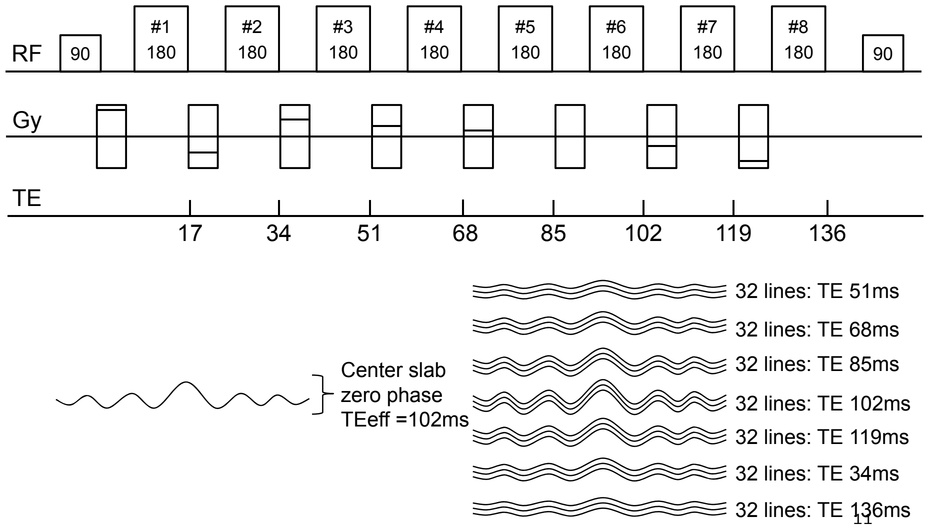
# Fast Spin Echo (FSE)



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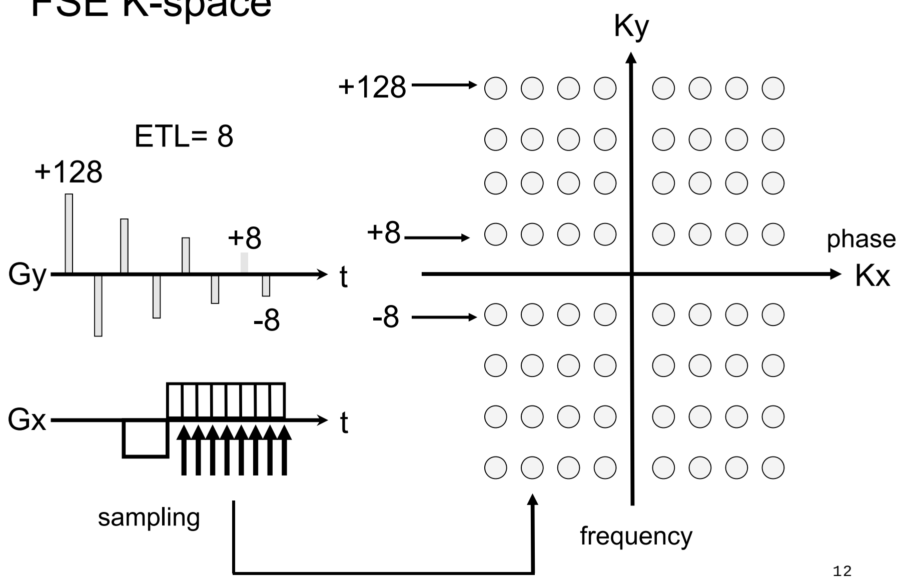
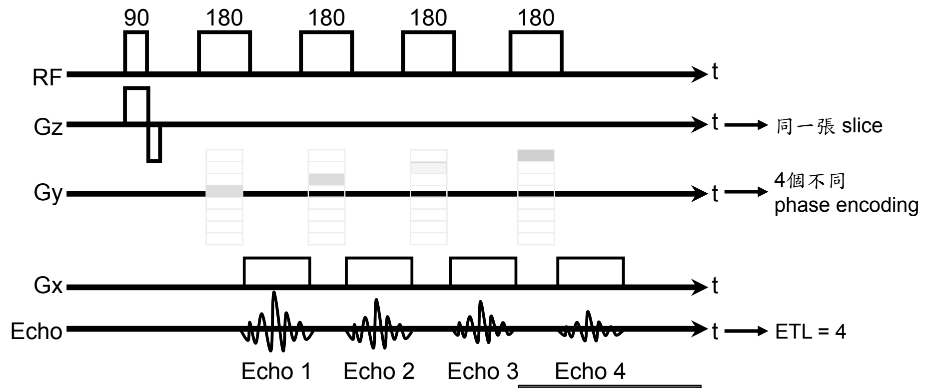
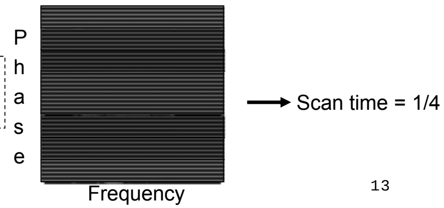
# FSE K-space



# Fast Spin Echo (FSE): 一個TR多次phase encoding




Scan time =
TR x phase encoding (Ny) / ETL x NEX




→ Scan time = 1/4





# Scan time of SE & GRE

Scan time = (TR) (Ny) (NEX)

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

↓ $SNR = volume\sqrt{\frac{(Ny)(Nx)(NEX)}{BW}}$ ↓ (未考慮FOV)

↑ pixel size= $\frac{FOV}{number\ of\ pixels}$ ↓

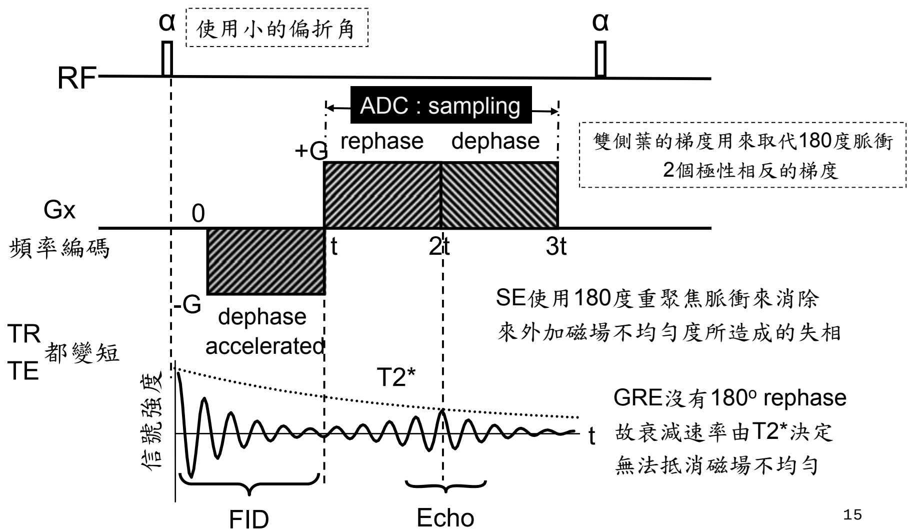
↓ Ny → poorer resolution → better SNR

- BW(receiver bandwidth)
- Ny is the number of phase-encoding steps
- NEX is the number of times we repeat the whole sequence

↑ $SNR = FOVx\ FOVy\ \Delta Z\sqrt{\frac{NEX}{(Ny)(Nx)(BW)}}$ (考慮FOV)



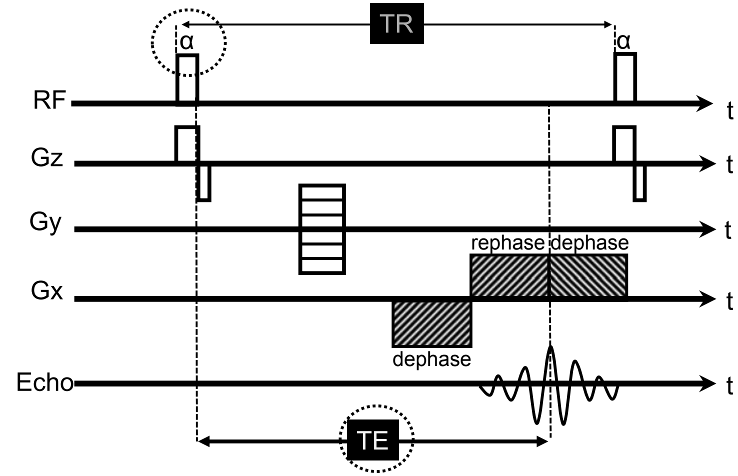
# 梯度重聚回音(Gradient Recalled Echo, GRE)






# GRE Pulse Sequence Diagram

- Three operator controlled parameters that affect the tissue contrast.



# Gradient echo: 2D & 3D acquisition time

- 因為TR很短, 所以一次scan只切一張
- 2D GRE 掃描時間 = (TR) (Ny) (NEX) (No. of slice)
- 3D GRE 掃描時間 = (TR) (Ny) (NEX) (Nz)

4.1 msec x 512 x 1 x 20 = 41 sec

……


共96張 ……

5.5 msec x 512 x 48 x 1 = 135 sec = 2 min 15 sec
再利用內插法, 由電腦計算組成96張影像



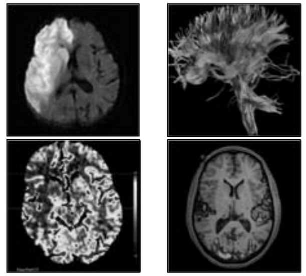


# 回音平面造影 Echo Planar Imaging (EPI)

- EPI : 目前最快的MRI掃描技術，平均完成一張影像可以在<u><100ms</u>
- 可以在一次TR的激發中將k-space填滿(during one T2* or T2 decay)

| 2D SE Scan time = (TR) (Ny) (NEX) ⟶ EPI Scan time = (TR) (NEX) |
|---|

- EPI運用:functional imaging
  - diffusion weight imaging (DWI)
  - diffusion tensor imaging (DTI)
  - perfusion imaging
  - functional MRI: BOLD & VASO



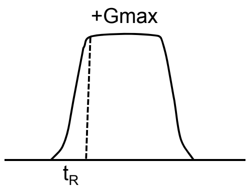




# Basic idea in Echo Planar Imaging (EPI)

- Requirements for high performance gradients:
  - Rapid on/off switching of the gradients
  - Gradient strength of 20~100 mT/m (Gmax)
  - Gradient rise times of less than 300μsec ($t_R$)

} high slew rate (mT/m/msec )




$$\text{Slew rate}=\frac{\text{Gmax}}{t_R}$$

Slew rate (SR)=迴轉速率
Gmax=最大梯度
$t_R$=上升時間(rise time)
單位:mT/m/msec

- Fast computers: fast digital manipulations and signal processing.
- Fast-sampling analog to digital converter (ADC):

$$\uparrow BW=\frac{1}{\Delta Ts\downarrow}=\frac{Nx}{Ts\downarrow}$$

$$\downarrow SNR = volume\sqrt{\frac{(Ny)(Nx)(NEX)}{BW\uparrow}}$$





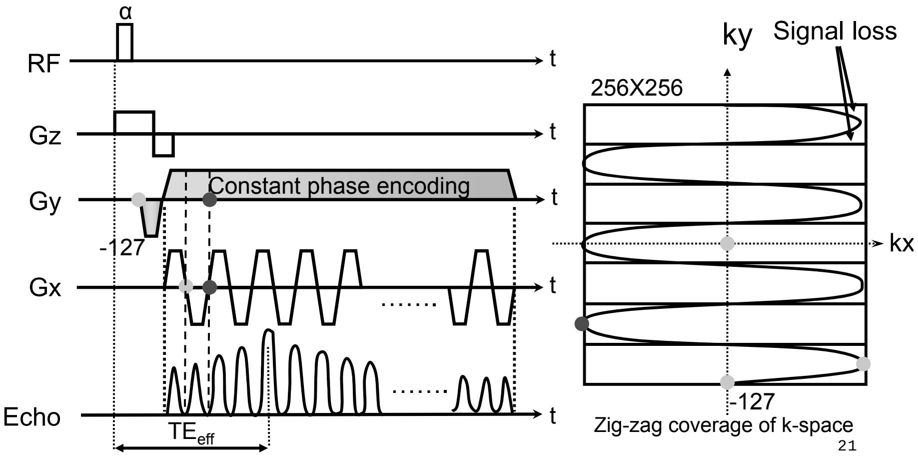
# Types of EPI: single-shot & multi-shot

single-shot EPI (單次激發)

- K-space中所有的線是在單一RF脈衝之後來進行填滿
- 利用許多個梯度(Gx)的反轉所產生的多個梯度回音來填滿
- 相位編碼次數Ny相當於讀出梯度的正向及負向葉片總數
- 單一一次T2*衰減中(<100ms)，讀出梯度必需快速的至最大正值到最大負值反轉Ny/2次 (256/2=128次)

# single-shot EPI (單次激發EPI)

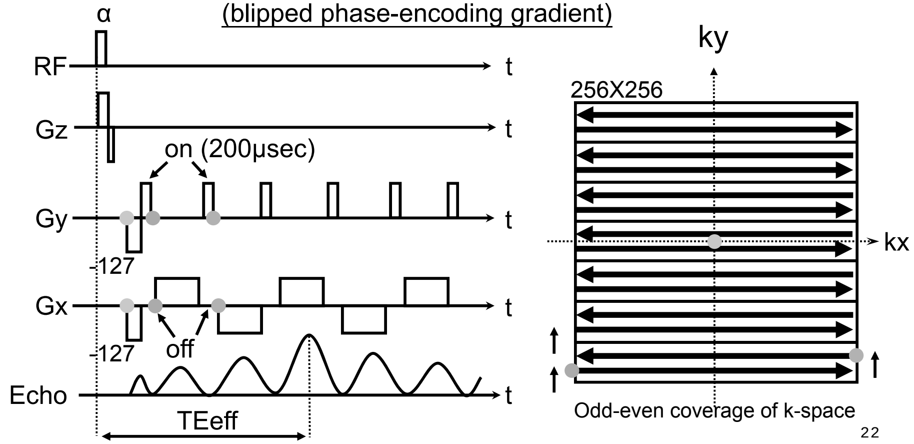
Original single-shot EPI: (constant phase-encoding gradient)






# single-shot EPI (單次激發EPI): blipped EPI

- blipped EPI: readout gradient為零的時侯，在k-space中kx軸的兩端短暫的施加phase encoding gradient(200μsec)(施加Ny次) (blipped phase-encoding gradient)

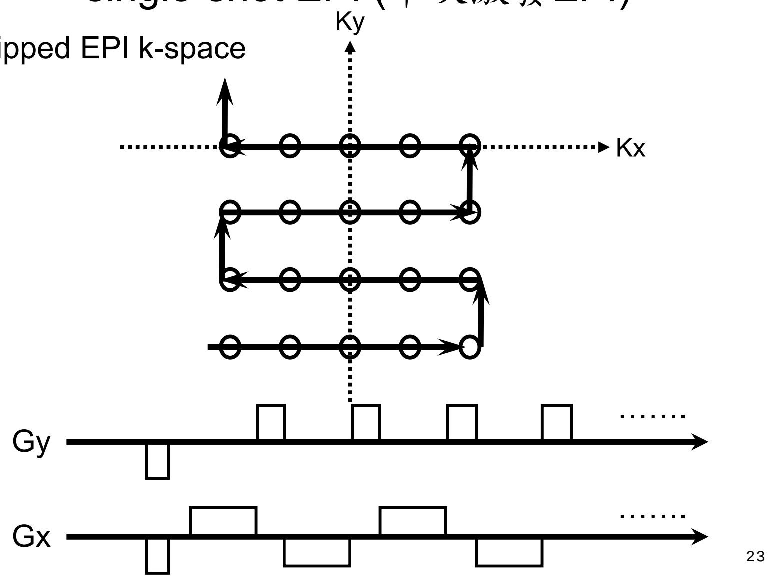







# single-shot EPI (單次激發EPI)

blipped EPI k-space



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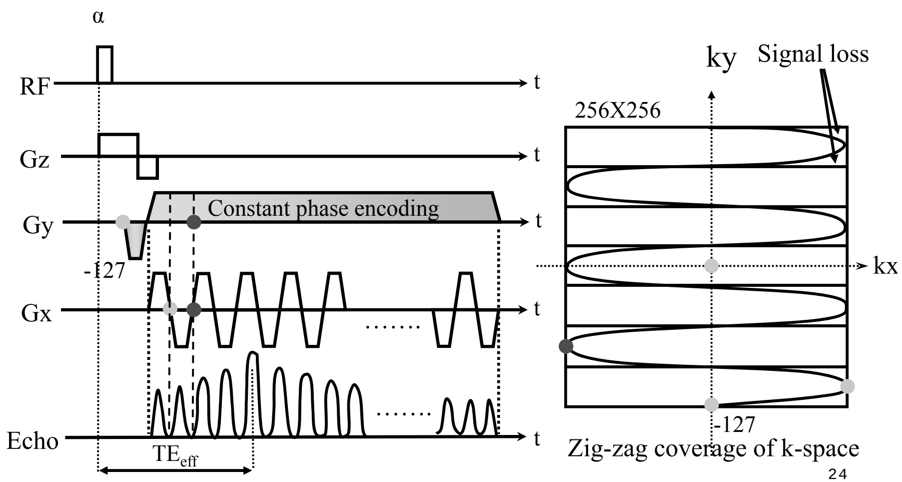

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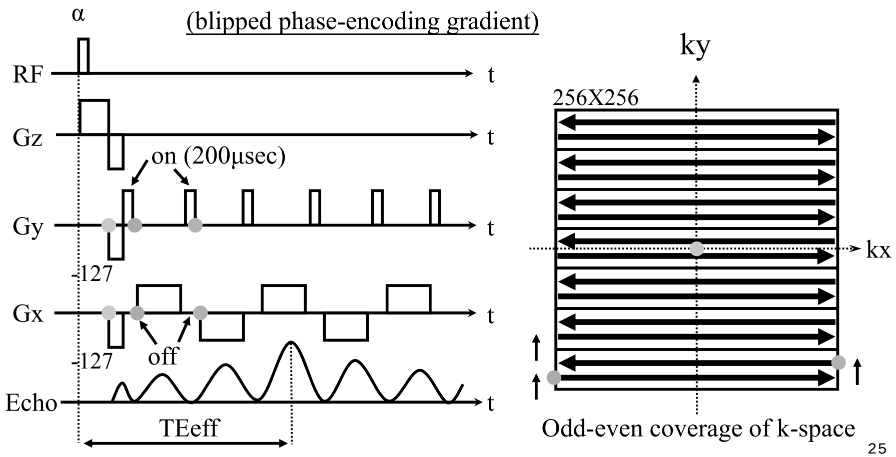
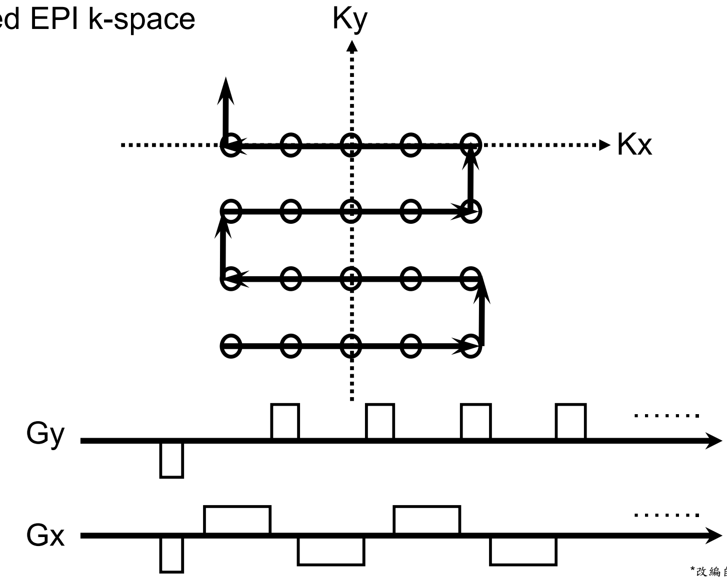



Odd-even coverage of k-space



# single-shot EPI (單次激發EPI)

blipped EPI k-space

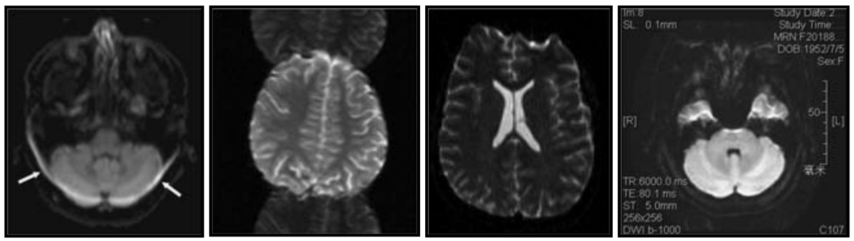





*改編自鐘敎文教授ppt

# single-shot EPI (單次激發EPI): artifacts

- 任何的相位錯誤會延伸到整個k-space
- Chemical shift artifacts:質子共振頻率的差異(fat & water)，造成沿著相位編碼的錯置 (remedy: apply fat suppression)
- N/2 Ghost artifacts: eddy currents、不完美的梯度、磁場的不均勻或odd-even回音之間時間不協調所造成 (remedy: proper tuning & shim)
- Magnetic susceptibility artifacts: paranasal sinuses附近空氣/組織的交界處 (remedy: apply multishot EPI)



mri-q.com/chemical-shift-in-phase mriquestions.com/nyquist-n2-ghosts humanconnectome.org/about/project/MR-preprocessingt

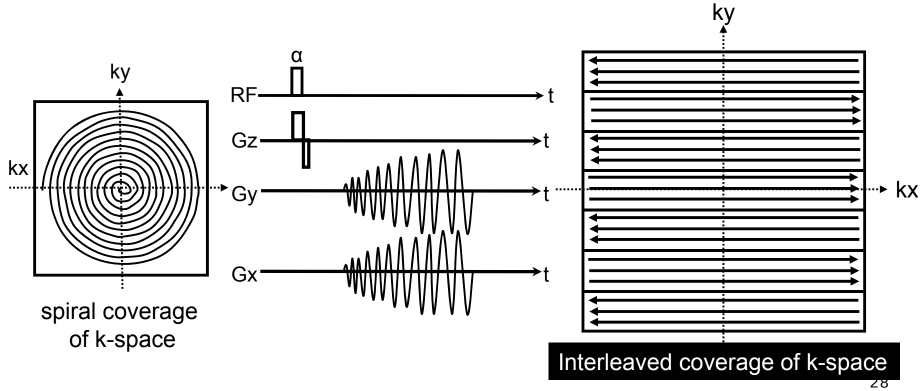


# Multi-shot EPI (多次激發EPI)

multi-shot EPI (多次激發) (also called segmental EPI)

- 讀出資料被劃分成多次激發或部分(Ns)，k-space分成多次的擷取

Ny = Ns x ETL (ETL: Number of lines in each segment)




spiral coverage of k-space

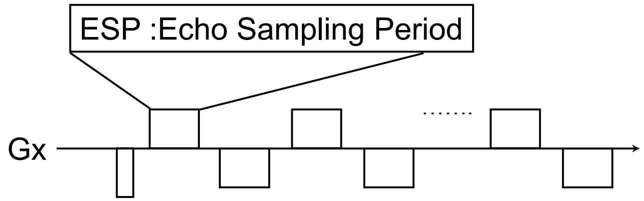
Interleaved coverage of k-space

# Scan time in EPI (single-shot & multi-shot EPI)

Scan time:

- T (single-shot EPI) = ESP x Ny x NEX
  = TR x NEX

- T (multi-shot EPI) = TR x Ns x NEX
  = TR x Ny/ETL x NEX








# Advantages of multi-shot EPI (compared with single-shot EPI)

Multi-shot vs. single-shot EPI

Advantages

- Less stress on the gradients
- Phase errors have less time to build up compared with single-shot EPI
- Reducing diamagnetic susceptibility artifacts

Disadvantages

- Multi-shot EPI takes longer to perform than does single-shot EPI
- Multi-shot EPI is more susceptible to motion artifacts





# Contrast in EPI

- EPI對比取決於「根」脈衝序列 (“root” pulsing sequence)
- MR影像的對比還是取決於TR、TE、α°

Contrast in EPI
- SE-EPI (90°-180°-EPI):提供T1與T2加權的對比
- GRE-EPI (α°-EPI):提供T2*加權的對比
- IR-EPI (180°-90°-180°) (inversion recovery):提供T1對比

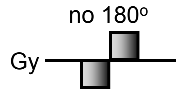
- EPI對影像的對比影響不大，but.......
  - Negative gradient開的強弱會影響TEeff
  - 類似FSE是個mix的訊號

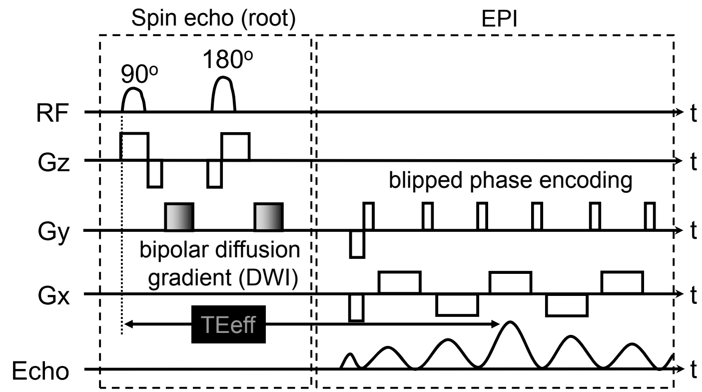




# SE-EPI (90°-180°-EPI)

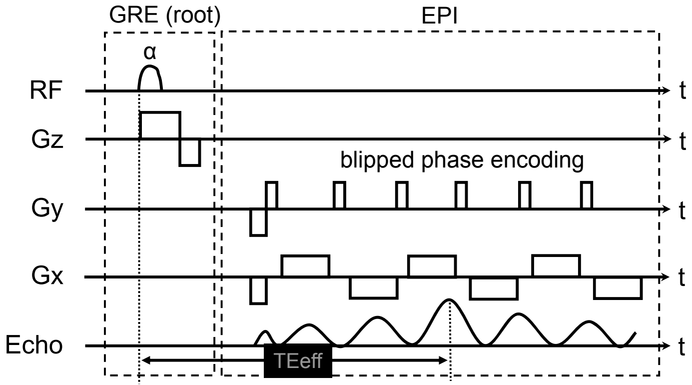
- 利用一個180° RF來克服外加磁場不均勻(inhomogeneities)
- 提供T1和T2加權
- SE-EPI的對比是由180° RF的rephase time取決
- DWI: “fixed position” proton no signal, diffusion & motion more dephaseing



# GRE-EPI (α-EPI)

- 沒有用到180° RF pulse (susceptibility effect & chemical shift effect存在)
- 提供T2*W影像，faster imaging speed > SE-EPI
- GRE-EPI的對比是由negative phase gradient 偏移和EPI readout 時間取決
- Dynamic imaging: perfusion imaging, cardiac cine imaging

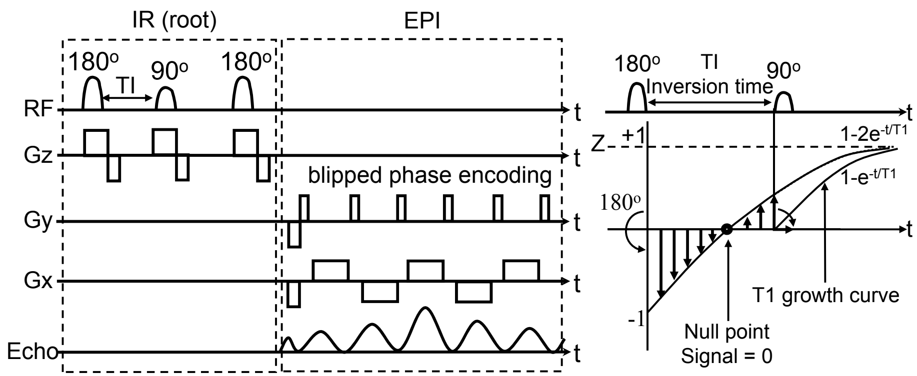







# IR-EPI (180°-90°-180°)

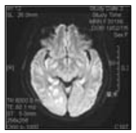
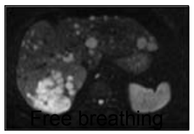
- 施加一個180°的反轉前置脈衝於SE之前(IR: inversion recovery)
- 提供T1加權對比(Heavy T1W)
- Suppression of tissue signal : STIR (for fat) & FLAIR (for water)








# Advantages & disadvantages of EPI

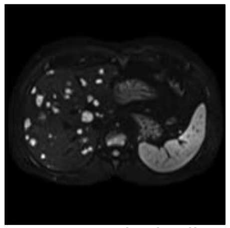

REVEAL + PACE

Advantages

- 100ms or (32~50ms)/slice
- 腦部DWI造影(觀察水分子擴散)，急性CVA的診斷很有幫助
- 運用在functional 、dynamic perfusion、Cardiac & respiratory motion等…
- 減少motion artifacts (motion free)的情況下獲得PDW、T1W、T2W和T2*W
- resolution能在有限的時間內去進行改善(256x256 ⟶ 512x512)

Disadvantages

- Fat suppression (減少chemical shift)
- 快速的梯度on/off可能造成"electric shock"
- phase error的產生(運用multi-shot EPI 來改善)
- 磁場的均勻度和軟硬體的設備都有較高的要求



metastases in the liver
(b=50sec/mm²)





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  - Frequency encoding (Gx)
  - Phase encoding (Gy)
- 回音平面造影(Echo Planar Imaging (EPI))
- 擴散加權造影原理(Principle of Diffusion Weighted Imaging (DWI))
- 擴散加權造影應用(Application of Diffusion Weighted Imaging (DWI))

**Reference:**
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(Chapter12: functional imaging techniques)
3. S Mori and J Zhang, Encyclopedia of Neuroscience, 2009.
4. S. Heiland, imaging decisions, 2003.


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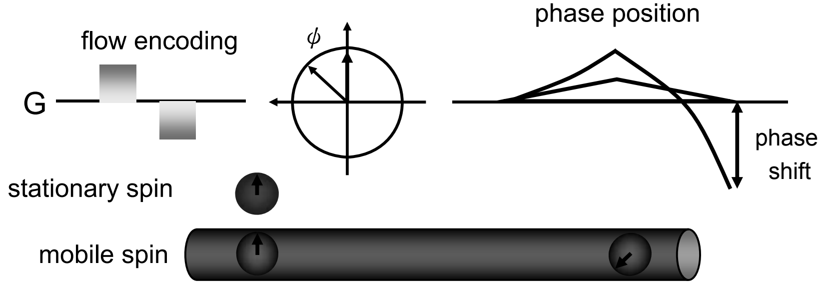
S Mori and J Zhang, The Johns Hopkins University, Baltimore, MD, USA
© 2009 Published by Elsevier Ltd.

**Diffusion- and Perfusion-Weighted MR Imaging in Acute Stroke: Principles, Methods, and Applications**
S. Heiland

# Review: Phase Contrast MRA (PC MRA)

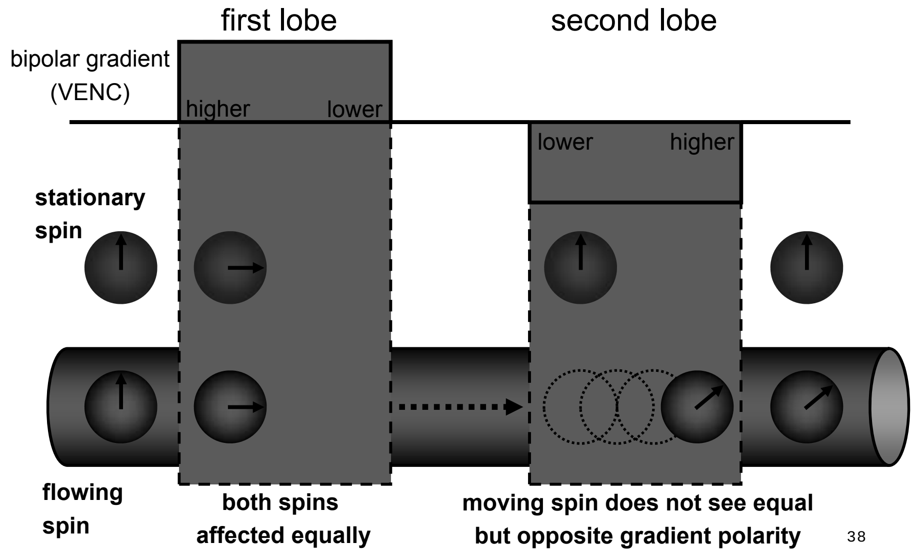
- Phase effects concern the transverse magnetization (血管有在流動→變黑)
- Bipolar flow-encoding gradient (strength and duration but opposite sign)
- Stationary spins = zero net phase shift
- Flowing spins = a non-zeros phase shift




phase shift $\phi = \int \omega\, dt = \int (\gamma Gvt)\, dt == \gamma Gv \int t\, dt = 1/2\, \gamma Gvt^2$

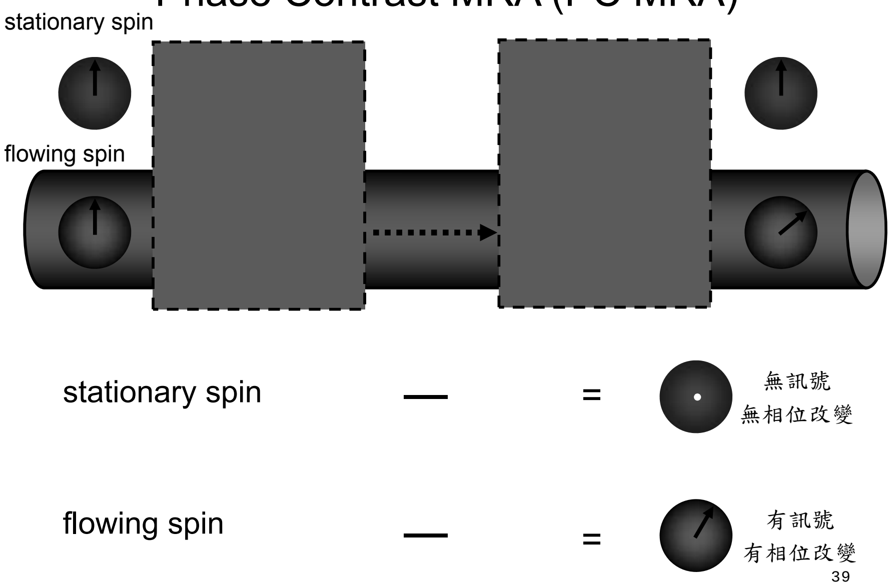


# Review: Phase Contrast MRA (PC MRA)





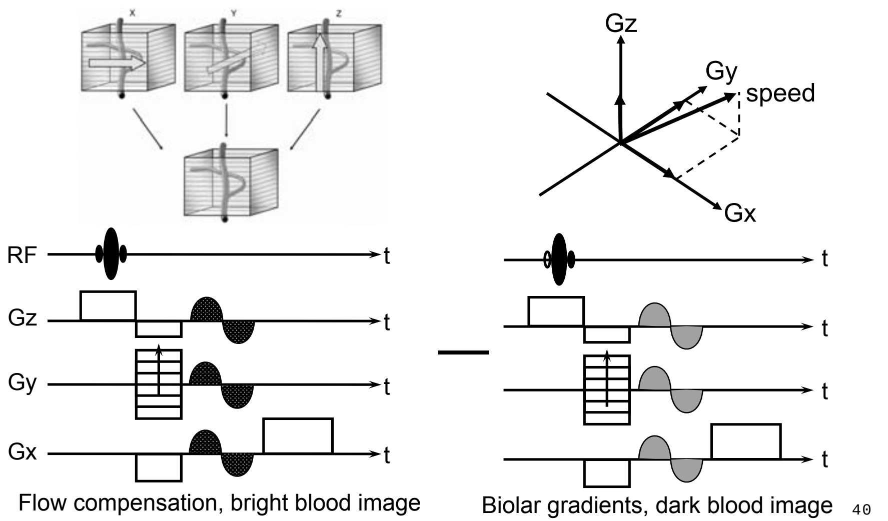

# Phase Contrast MRA (PC MRA)






# Magnitude & phase contrast method

整體流速 -- 重複三次 (Gx、Gy、Gz ) + 一次參考點(flow compensation)

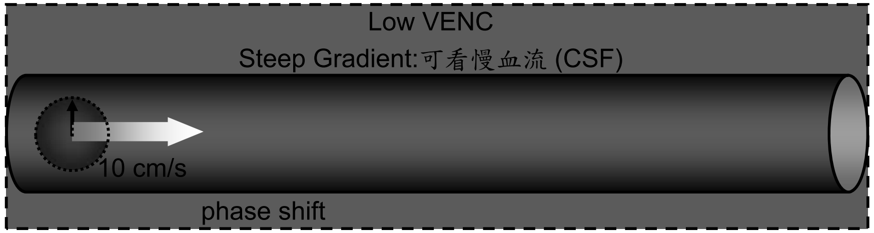




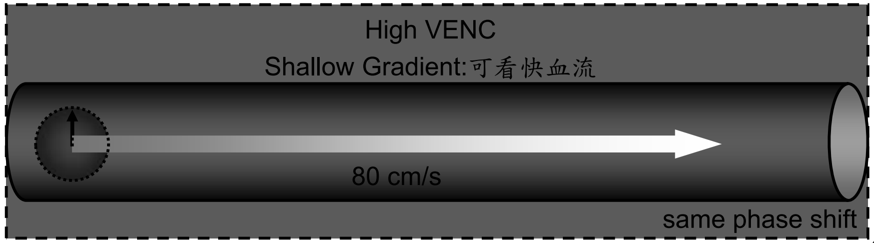

(部分圖檔來自於鐘孝文教授之ppt檔)

# Velocity encoding (VENC)

梯度愈強(弱)、VENC愈小(大)




水分子擴散是極慢的運動，只要梯度夠強也可以看到

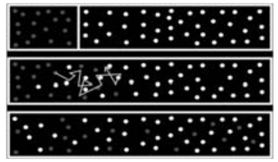




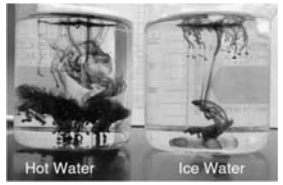



# 水分子的擴散

- Brownian motion:顯微鏡觀察懸浮於水中的花粉粒發現(1827)
- 擴散:高濃度往低濃度移動，直到分散均勻(隨機運動)
  同pixel或voxel中的水分子方向速度隨時都不同
- 移動速度↑: 環境溫度↑、粒子的質量↓、大小↓



- 擴散運動是非常慢的運動 (D Values)
  - 組織和高的擴散 = $3.0x10^{-3}$ $mm^2/sec$
  - White matter = $0.77x10^{-3}mm^2/sec$
  - Gray matter = $0.76x10^{-3}mm^2/sec$
  - 純水:$2.0x10^{-3}mm^2/sec$、0.06mm/sec、0.5mm/min

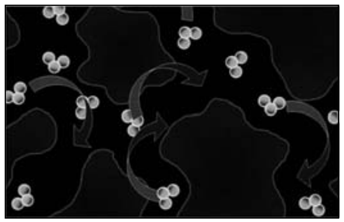




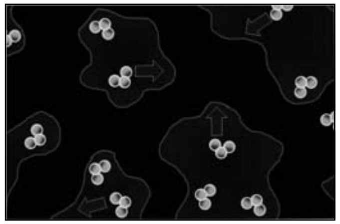



# MR Diffusion

- MR diffusion 用來描述細胞外間質(extra-cellular space)隨機的運動
- 人體內水分子會受到移動的阻礙物質造成diffusion變慢
  - ligaments, membranes, myelin, and macromolecules
  - 細胞的大小增加、細胞數量的增加、細胞外間質液改變



Freely diffusing water



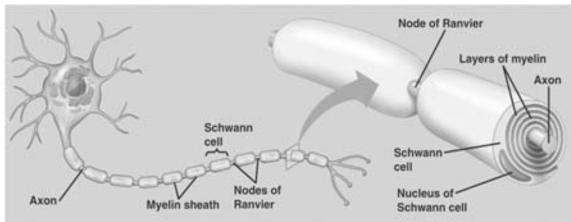
Restricted water

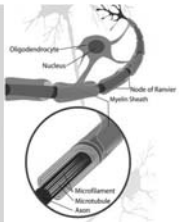


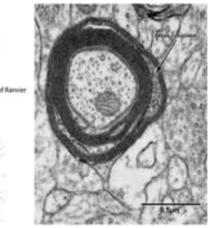


# Myelin sheath & axon (神經纖維)

- 髓鞘(Myelin sheath)的組成: Lipids 80%和 Proteins20%
- 細胞膜重複環繞軸突所形成的絕緣體，髓鞘約長1mm
- 髓鞘包覆處沒有離子通道；蘭氏結有動作電位
- 神經傳導速度可因有髓鞘增快5~7倍
- axon越粗，髓鞘越厚，傳導的速度越快
- 避免神經元間電訊號的干擾
- MR/diffusion也是一種對比，依diffusion好壞，找出去髓鞘化的病變



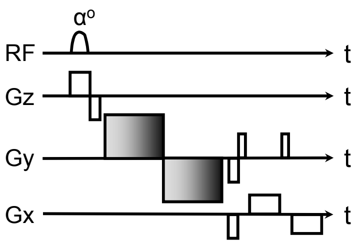





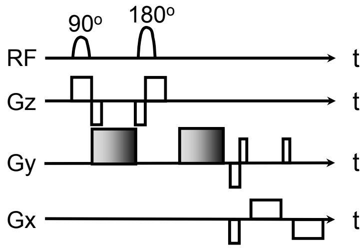
# 擴散加權造影原理
# Principle of Diffusion Weighted Imaging (DWI)

- 擴散運動是非常慢的運動(D value)
  - 組織和高的擴散 = $3.0x10^{-3}$ $mm^2$/sec
  - White matter = $0.77x10^{-3}mm^2$/sec
  - Gray matter = $0.76x10^{-3}mm^2$/sec
  - 純水:$2.0x10^{-3}mm^2$/sec、0.06mm/sec、0.5mm/min
  - sinus vein 、CSF、Peripheral veins = 5-10 cm/sec

bipolar diffusion gradient 強度增加




GRE-EPI: no 180ºRF / T2*/TEmin ↑




SE-EPI: 180ºRF / T2





# 擴散加權造影原理
# Principle of Diffusion Weighted Imaging (DWI)

- DWI的原理:
  - 類似PC MRA
  - 比較加入bipolar diffusion gradient前後信號差別
  - Bipolar diffusion gradient:強梯度、長時間 (TEmin↑)
  - diffusion factor=b factor=控制diffusion weighting
  - b value↑, diffusion contrast↑ ( b value↓, diffusion contrast↓)
  - b value臨床常用0, 600, 800, 1000sec/$mm^2$

$$\frac{S}{S_0} = e^{-bD}$$

Signal $=e^{-bD}=2.7^{-bD}$

$=2.7^{-b(1x10^{-3})}=37\%$

S =signal with the gradient application
$S_0$ =signal no gradient application
D =diffusion constant
b =diffusion weighting

White matter = $0.77x10^{-3}mm^2$/sec
Gray matter = $0.76x10^{-3}mm^2$/sec

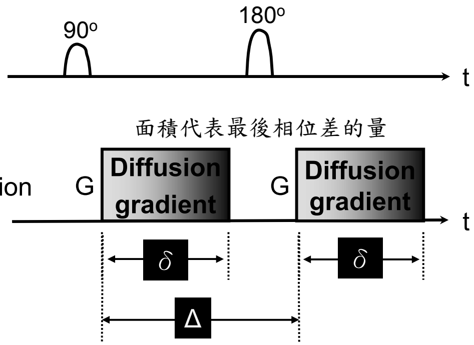




# Diffusion factor = b factor

- Diffusion signal loss by the gradient application

$$\frac{S}{S_0} = e^{-\gamma^2 G^2 \delta^2 (\Delta - \delta/3) D} = e^{-bD}$$




S =signal with the gradient application
$S_0$ =signal no gradient application
D =diffusion constant
$\gamma$ =gryomagnetic ratio
G =gradient strength
$\delta$ =gradient duration
$\Delta$ =time interval between dephasing and rephasing gradients



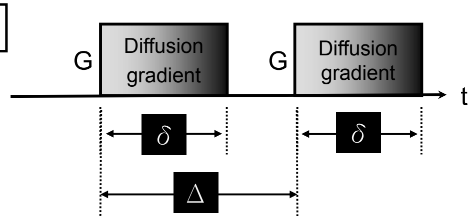


# Diffusion factor = b factor

- b factor = 0 no diffusion
- b factor = 500 mild diffusion weighted
- b factor =1000 more diffusion weighted

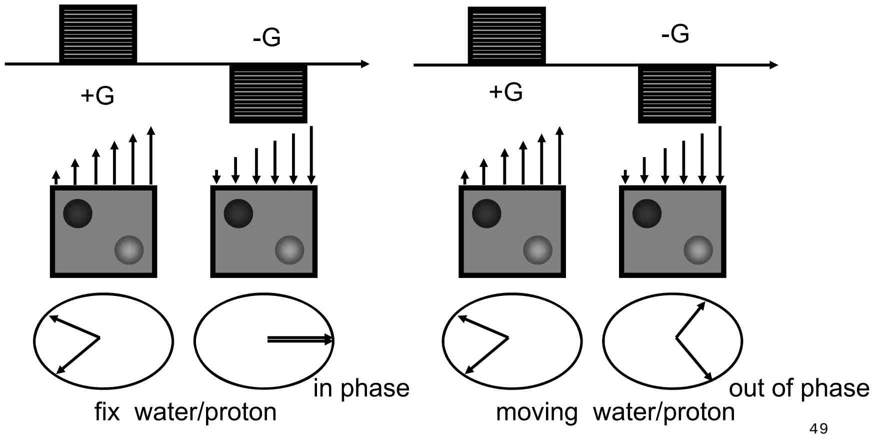
b factor = $-\gamma^2 G^2 \delta^2 (\Delta - \delta/3)$

D = diffusion constant
$\gamma$ = gryomagnetic ratio
G = gradient strength
$\delta$ = gradient duration



# Bipolar Diffusion Gradient

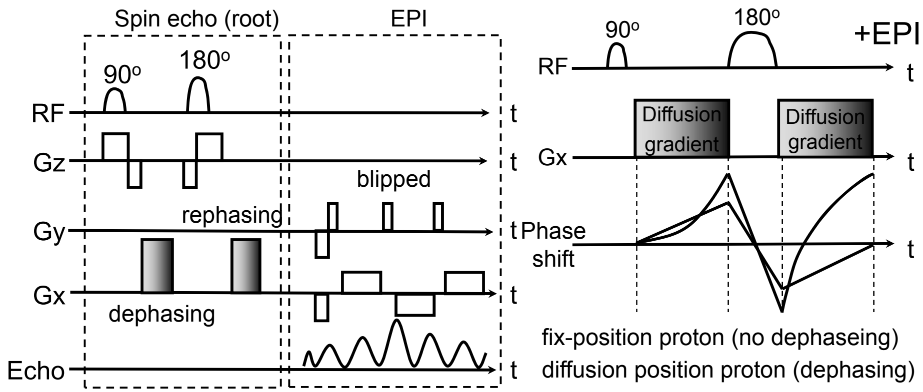
- Bipolar pair of diffusion gradietns is inserted between the RF excitation pulse and signal readout.






# Bipolar Diffusion Gradient SE-EPI (SE-EPI)

- Apply a pair of diffusion gradients before and after the 180$^o$ RF pulse (SE-EPI).






# 擴散加權造影原理 Principle of Diffusion Weighted Imaging (DWI)

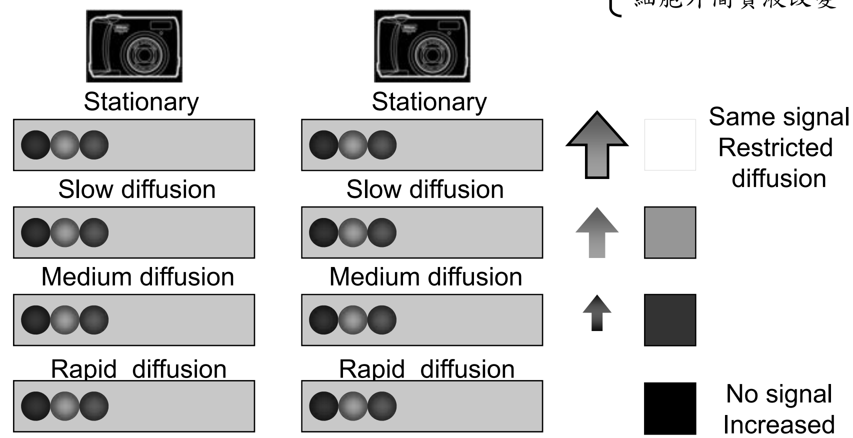
- Diffusion定義:物質分子會呈現隨機而且不規則狀的移動
  - Free: high diffusion along gradients ⟶ low signal
  - Restricted: low diffusion along gradients ⟶ high signal
- DWI目標:觀察水分子移動所造成影像上亮暗對比的差異
  - Diffusion gradients至少要開起三個方向 (Gx, Gy, Gz)
  - 不考慮水分子移動的方向性 (只考慮水分子有無restricted)
  - Diffusion magnitude (trace image): DTI
  - T2-weighted image: DWI: root + diffusion G+EPI，TR ↑ TE ↑



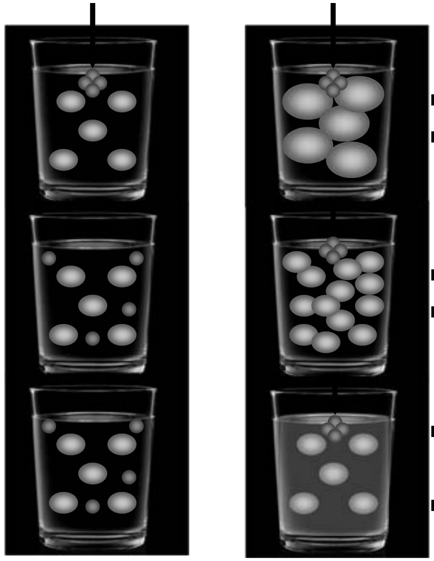
# Diffusion Moving vs. Signal Intensity

- Water/proton moving ↑ signal ↓

moving speed { 細胞的大小增加 / 細胞數量的增加 / 細胞外間質液改變



# Diffusion Moving vs. Restricted



- Increase in the size of cells
- Infarction :cytotoxic edema

- Increase in the number of the cells
- Tumors

- Increase in the viscosity of the extracellular fluid
- Abscess

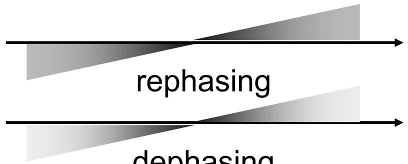


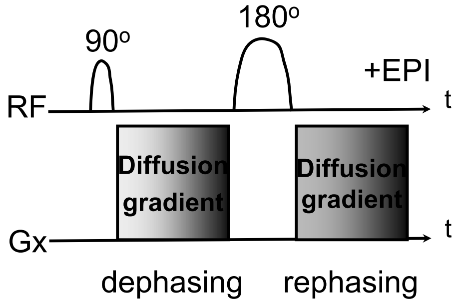


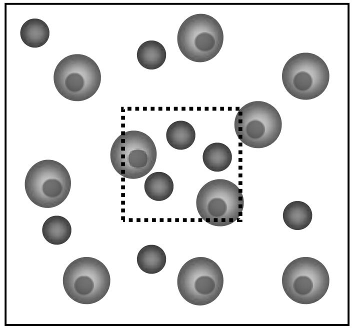
# Diffusion gradient and motion

Free water
CSF

Low signal



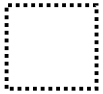





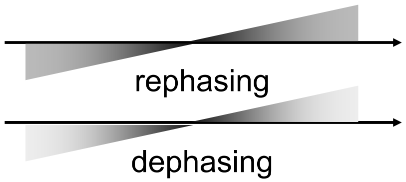


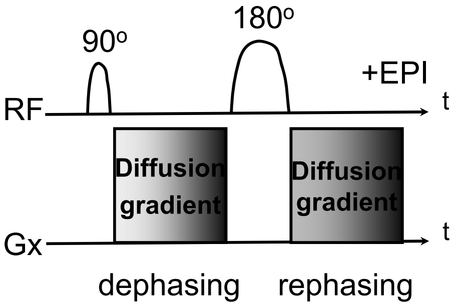
# Diffusion gradient and motion

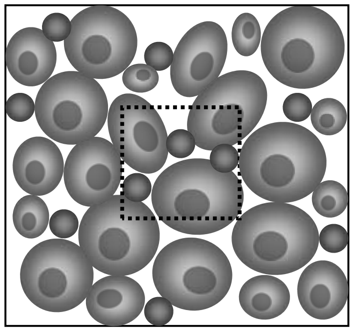
Restricted water
Tumors
Abscess
High cell density



high signal



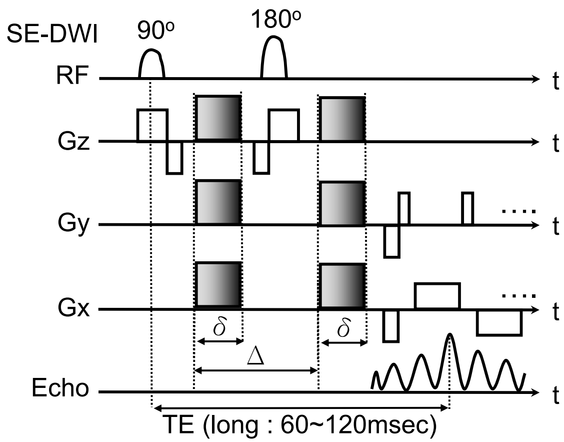



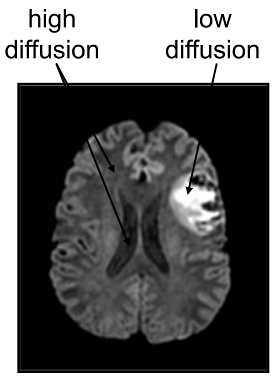




# 擴散加權影像
# Diffusion Weighted Imaging (DWI)

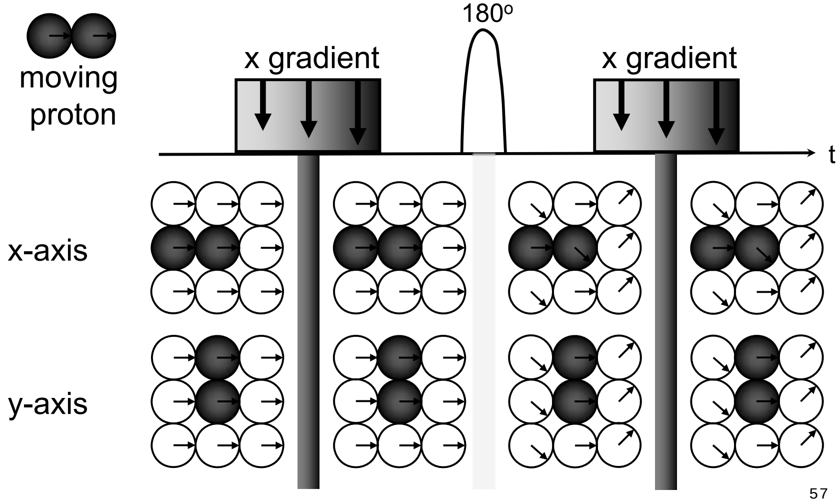
- Diffusion gradients至少要開起三個方向 (Gx, Gy, Gz)
- 等向性(isotropically)的DWI




DWI
擴散性:WM > GM

# 擴散加權影像
# Diffusion Weighted Imaging (DWI)

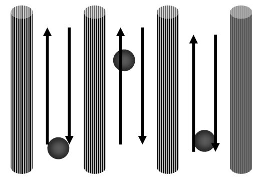







# Apparent diffusion coefficient, ADC

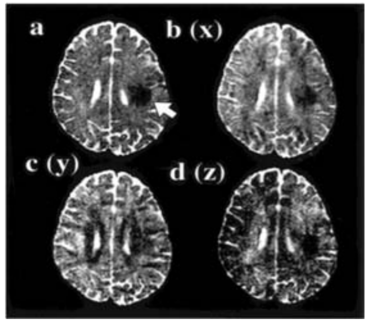
- Restricted diffusion & anisotropy
- 擴散在同一點內隨方向而不同
- DWI:梯度三個方向都開，各別取得Dx、Dy、Dz
- ADC is isotropic map (無關方向性)
- ADC ↓ for acute stroke infarction.




$$ADC = \frac{Dx+Dy+Dz}{3}$$

$$\frac{S}{S_0} = e^{-b\,D}$$

S =signal with the gradient application
$S_0$ =signal no gradient application
D =diffusion constant   b =diffusion weighting





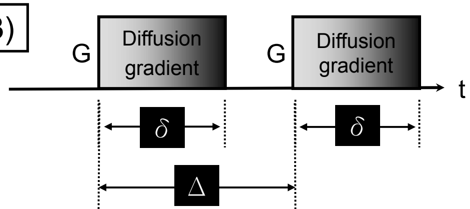



# T2 shine through effect

- 假如b=1000，diffusion gradient (G): 10~40mT/m(最大)
- b值需靠δ和Δ來提高
- δ和Δ提高，TE值就會提高 (TE : 60~120msec)
- TE值上提高，T2W就會提高
- 要有不同weighted影像來對比，求diffusion coefficient

$$b\ factor = -\gamma^2 G^2 \delta^2 (\Delta - \delta/3)$$

D =diffusion constant
γ =gryomagnetic ratio
G =gradient strength
δ =gradient duration








# T2 shine through effect

- *TR* value DWI sequences is long (8-10 sec) , so ($1-e^{-TR/T1}$) term may be disregarded.
- DW images both T2 and diffusion weighted (long TE: 60~120msec)
- Long T2 lesions can increase DWI signal mimicking restricted diffusion
- Clarified by reviewing ADC images

$$S_{DWI} = k[H] \cdot (1-e^{-TR/T1}) \cdot e^{-TE/T2} \cdot e^{-b \cdot ADC}$$

- K: is a scaling constant,
- *TR, TE*, and *b* are operator-selected parameters
- [*H*] is spin density
- ADC is the apparent diffusion coefficient (顯示純擴散訊息)

## T2 shine through effect

- DWI ↑, ADC ↓, T2 ↑ (正常狀況思考)
- DWI ↑, ADC ↑, T2 ↑
  (T2 ↑ effect > ADC effect)-"T2 shine through"

DWI → ADC → Restricted diffusion
DWI → ADC → T2 shine through

DWI ADC T2W





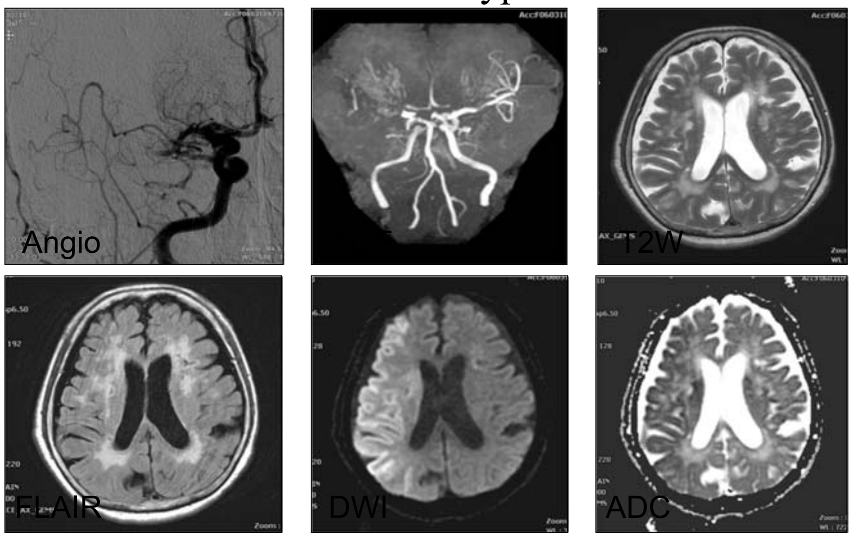
## 擴散加權造影應用
## Application of Diffusion Weighted Imaging (DWI)

- Ischemic stroke
- 偵測體內腫瘤
- 區別腫瘤的特性，以區別可能的病理型態
- 區別器官內腫瘤以及非腫瘤的區域
- 全身性擴散權重影像





## 擴散加權造影應用
## Ischemic stroke / 3hr / hyper acute stroke

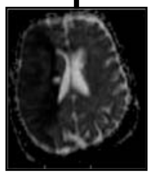




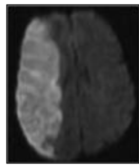



## 擴散加權造影應用
## Ischemic stroke

血管梗栓 血液供應不足 破壞內環境穩定 → energy deficit failure of Na+/K+ pumps → Intracellular Accumulation of Na+ → Glial and neuronal Swelling (intact BBB) (cytotoxic edema) / Reduction in extracellular space



ADC drop restricted

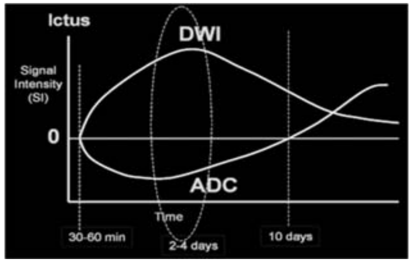


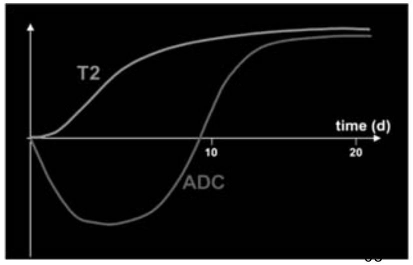
DWI hyperintensity

→ Eventual lysis(細胞溶解) edema → Vasogenic edema (cytolysis) (disrupted BBB) Tissue necrosis DWI low signal ADC high signal

# 擴散加權造影應用
## Ischemic stroke & T2, DWI, ADC

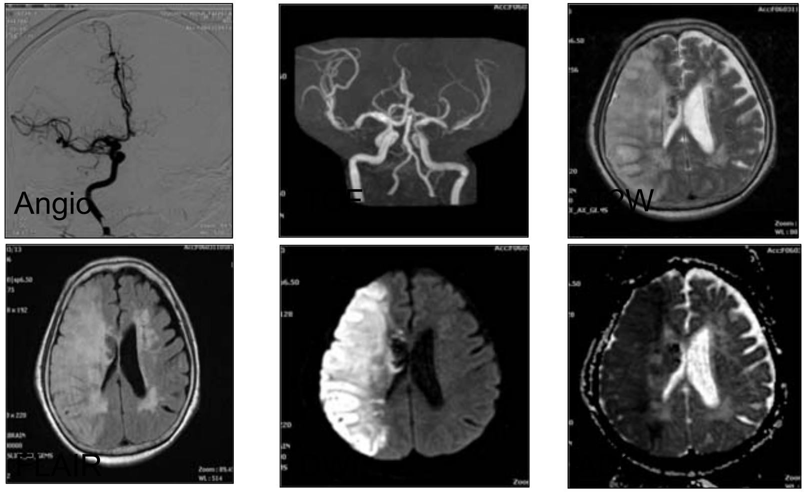
| | T2 | DWI | ADC |
|---|---|---|---|
| Hyperacute(<6hrs) | iso | high | low |
| Acute(6hr~7day) | high | high | low |
| Subacute(1~3weeks) | high | ios/high | Iso |
| Chronic(>3weeks) | high | iso/low | high |





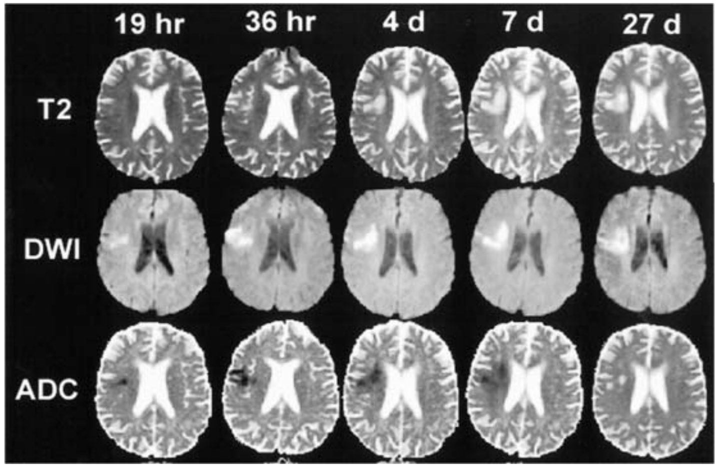

# 擴散加權造影應用
## Ischemic stroke / 3days / acute stroke








# 擴散加權造影應用
## Ischemic stroke

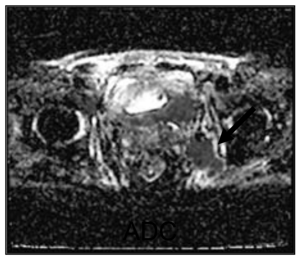


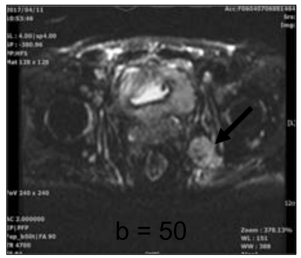

Maarten G. Lansberg. et al., **Evolution of Apparent Diffusion Coefficient, Diffusion-weighted, and T2-weighted Signal Intensity of Acute Stroke,** *AJNR Am J Neuroradiol* 22:637–644, April 2001

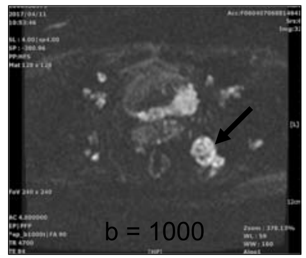


# 擴散加權造影應用
## 偵測體內腫瘤

- 腫瘤是細胞的異常增生，細胞密度會比正常組織高
- DWI上的訊號比正常組織高
- DWI將正常組織的訊號降低，腫瘤組織就可顯現
- ex: Prostate cancer & diffuse lymph nodes metastasis

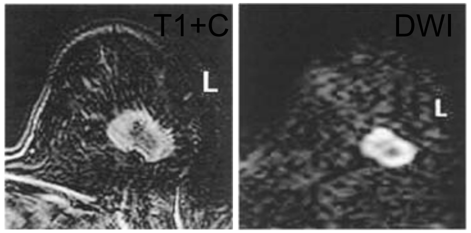



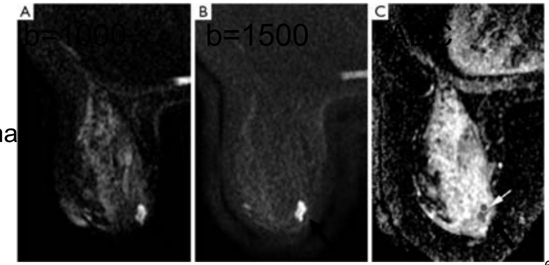

Prostate cancer with extracapsular and seminal vesicle invasions, diffuse lymph nodes metastasis, bone metastasis. stage T3N1M1

# 擴散加權造影應用
## 偵測體內腫瘤

Invasive ductal carcinoma




Invasive mammary carcinoma

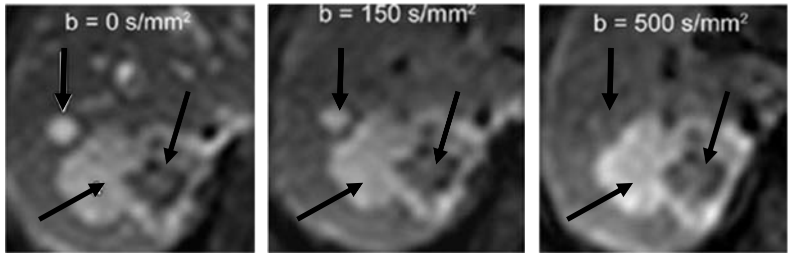







# 擴散加權造影應用
## 區別腫瘤的特性(良性/惡性)

- 區別腫瘤的特性，以區別可能的病理型態
- 良性腫瘤和惡性腫瘤有不同的組織型態以及細胞密度
- 擴散權重影像和表觀擴散係數(ADC)也完全不同
- ex: 肝臟內水泡和血管瘤的ADC比惡性腫瘤高(肝癌和轉移性腫瘤)
- 壞死性肝臟腫瘤的ADC也比感染性膿瘍高




肝臟的DWI顯示肝內水泡(白色箭頭)隨著b值增加，訊號明顯降低。
轉移性腫瘤(紅色箭頭)的訊號則無明顯改變，(藍色箭頭)則為壞死





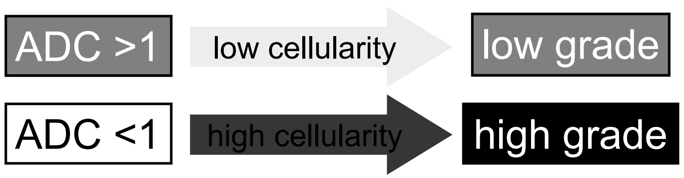
# ADC value & Tumor cellularity (細胞結構)

Tumors with high cellularity

- Medulloblastoma ( 髓母細胞瘤) → low ADC value (0.55-0.95)
- Lymphoma →ADC value (051-0.71)
- High grade glioma→ ADC value (058-0.89)
- Metastasis→ ADC value (< 1)

Tumors with low cellularity

- Ependymoma (室管膜瘤): low cellularity → high ADC value (1.01-1.3)
- Low grade glioma→ ADC value (>1.05)



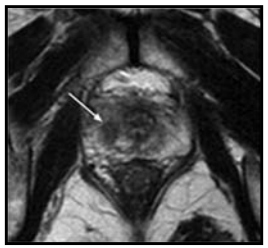



Faten Fawzy Mohamed et al. The Egyptian Journal of Radiology and Nuclear Medicine Volume 44, Issue 2, June 2013, Pages 349–355.



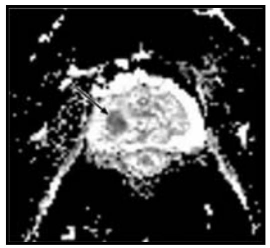
# 擴散加權造影應用
## 區別器官內腫瘤以及非腫瘤的區域

- 區別器官內腫瘤以及非腫瘤的區域
- 攝護腺癌和正常的攝護腺組織在傳統T2W影像上都是低訊號
- 界定腫瘤區域可能會產生困難
- 攝護腺癌有較低的ADC，以區別正常攝護腺組織



T2W

T2W:攝護腺癌和正常組織都是低訊號



ADC

ADC map:攝護腺癌明顯比正常組織低

# 擴散加權造影應用
# 全身性擴散權重影像

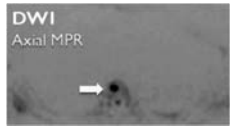
- 全身性擴散權重影像
- DWI可以同時作全身性的檢查，避免漏失病灶
- 罹患腫瘤的病患，可評估是否有轉移性腫瘤
- 特別是淋巴結，DWI可分析淋巴結內的組織結構

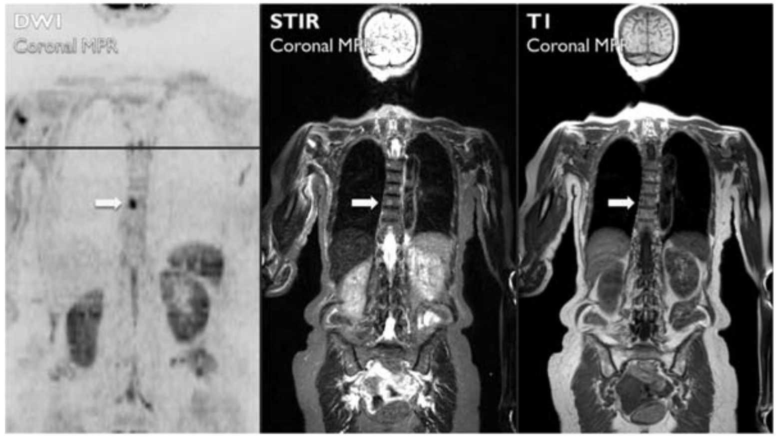
- DWI影像顯示右肺尖高訊號的腫瘤(星號)
- 左後腹膜腔有高訊號病灶(箭頭)，轉移性淋巴結





# 擴散加權造影應用
# 全身性擴散權重影像




Breast carcinoma: DWI helps detecting a small vertebral metastasis (arrow)





# Intracranial Hemorrhage on MRI

| Staging | Time | Component | T1 | T2 | FLAIR | DW image |
|---|---|---|---|---|---|---|
| Hyperacute | 1 day | | | | | |
| Acute | 1-3 days | oxyhemoglobin | B | A | A | B |
| Subacute _ early | 3-7 days | deoxyhemoglobin | C | B | A | A |
| Subacute _ late | 1-3 weeks | Methemoglobin (intracellular) | A | Inner:B Outer:A | A | A |
| Chronic_ early | 3weeks - months | Methemoglobin (extracelluar) | A | A | A | A |
| Chronic_ late | months - years | hemochrome | B | A or C | B | B |
| Remote | months - years | hemosiderin/ ferritin | B | A | | |

A: hyperintense B: hypointense C: Isointense





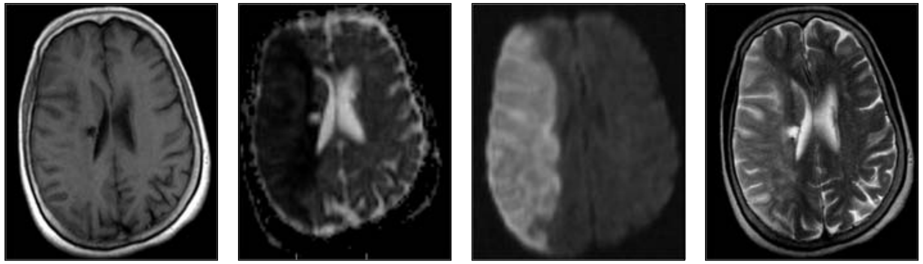
# 看圖說故事時間

- 自願或抽簽請一位學員上台看影像, 並大聲地說出為什麼!!
  1.這些影像分別為那些加權影像?
  2. DWI影像中那個b-value最大?
  3. MRI影像中那一組是較新的梗塞?

- 你有兩次求救機會!!
  1. 你可以指名一位學員回答一個問題
  2. 你可以請全班學員舉手表決一個問題

# 看圖說故事(一)
## 這些影像分別為那些加權影像?

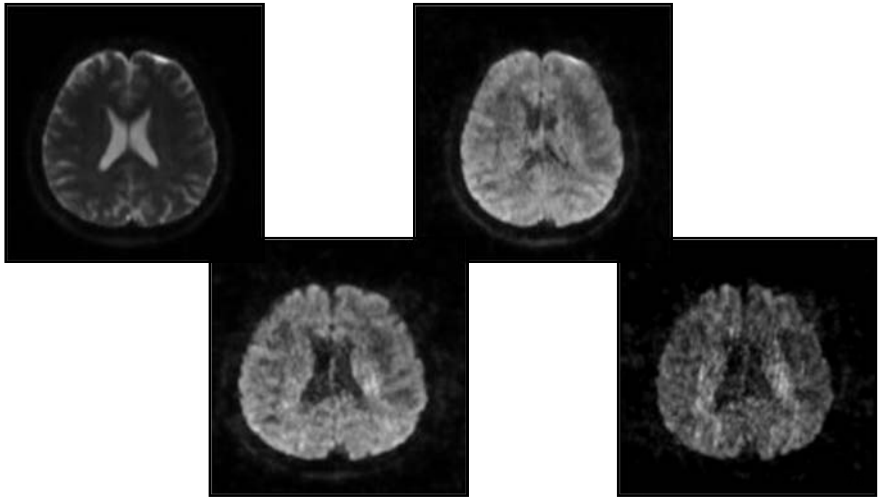
- 提示T1W、T2W 、 DWI、ADC





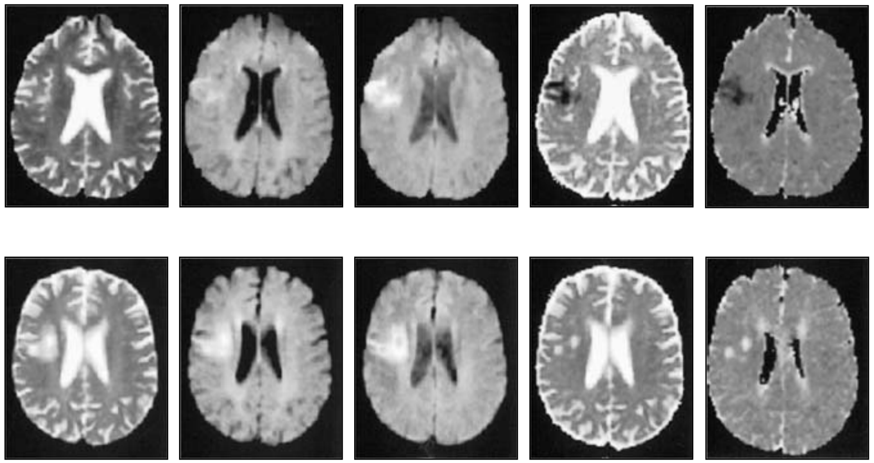


# 看圖說故事(二)
## DWI影像中那個b-value最大?





# 看圖說故事(三)
## MRI影像中那一組是較新的梗塞?



Maarten G. Lansberg. et al., **Evolution of Apparent Diffusion Coefficient, Diffusion-weighted, and T2-weighted Signal Intensity of Acute Stroke,** *AJNR Am J Neuroradiol* 22:637–644, April 2001





Thanks for your attention!