2017.04.16 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 weighted imaging (DWI)

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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
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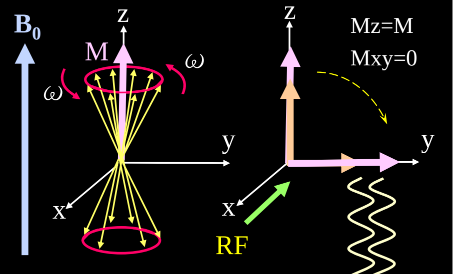
Diffusion- and Perfusion-Weighted MR Imaging in Acute Stroke: Principles, Methods, and Applications

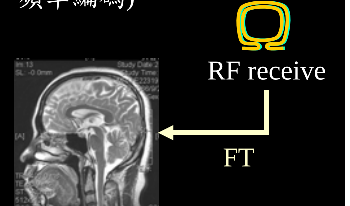
看圖說故事時間

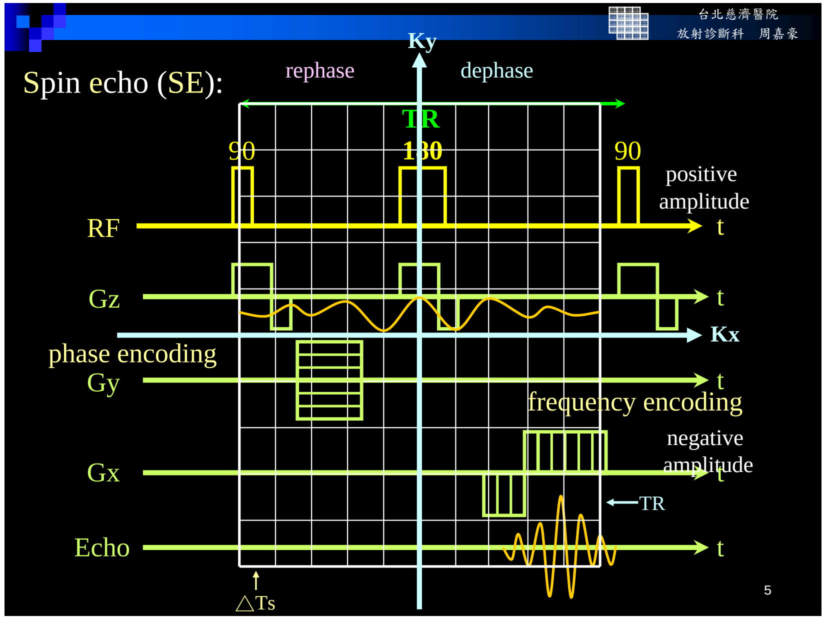
- 自願或抽簽請一位學員上台看影像,並大聲地說出為什麼!!
  1.這些影像分別為那些加權影像?
  2. DWI影像中那個b-value最大?
  3. MRI影像中那一組是較新的梗塞?
- 你有兩次求救機會!!
  1. 你可以指名一位學員回答一個問題
  2. 你可以請全班學員舉手表決一個問題

基本MR回顧:

- 磁場 → 磁化現象
- RF脈衝 → 磁化量激發
- 梯度磁場 → 切面選擇
- 梯度磁場 → 空間編碼(相位編碼、頻率編碼)
- 信號取號 → 接收線圈取樣頻率
- 影像計算 → FOURIER轉換



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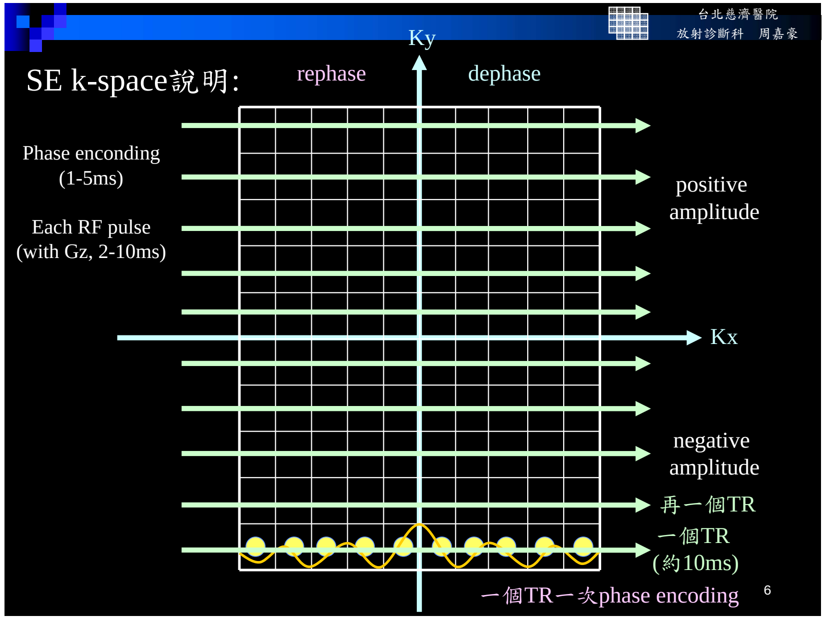
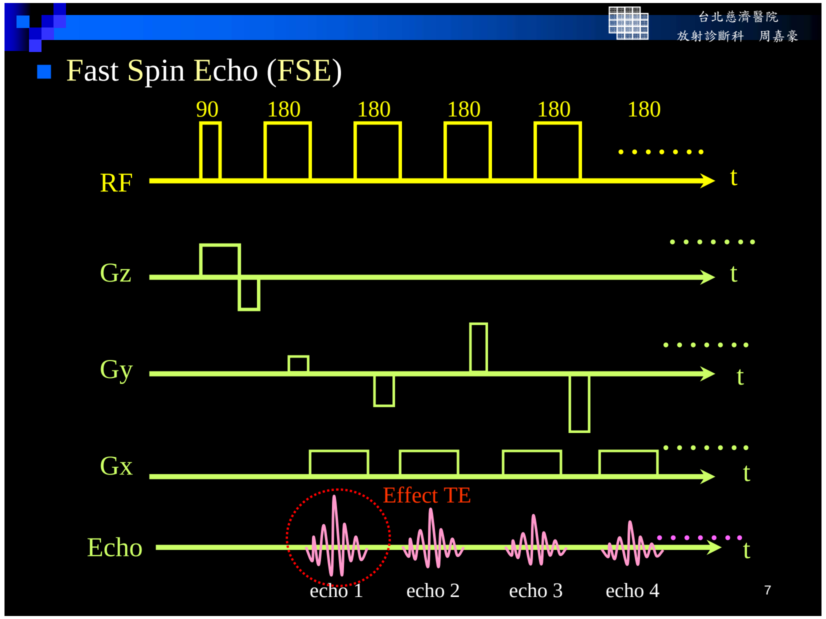
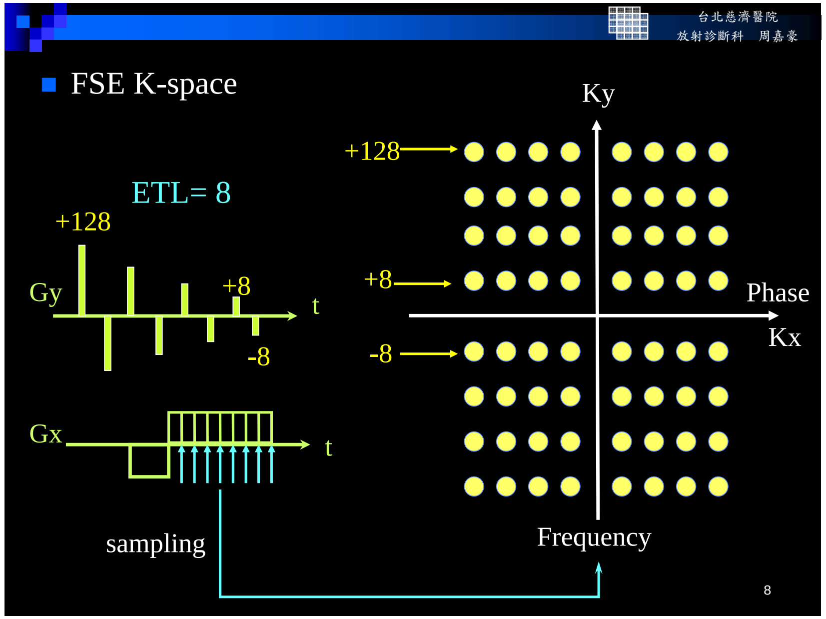
放射診斷科 周嘉豪
Spin echo (SE):
rephase
Ky
dephase
TR
90
180
90
positive amplitude
RF
t
Gz
t
Kx
phase encoding
Gy
t
frequency encoding
negative amplitude
Gx
t
TR
Echo
t
△Ts
5


台北慈濟醫院
放射診斷科 周嘉豪
SE k-space說明:
rephase
Ky
dephase
Phase enconding (1-5ms)
Each RF pulse (with Gz, 2-10ms)
positive amplitude
Kx
negative amplitude
再一個TR
一個TR (約10ms)
一個TR一次phase encoding
6


台北慈濟醫院
放射診斷科 周嘉豪
Fast Spin Echo (FSE)
90
180
180
180
180
180
RF
t
Gz
t
Gy
t
Gx
t
Effect TE
Echo
t
echo 1
echo 2
echo 3
echo 4
7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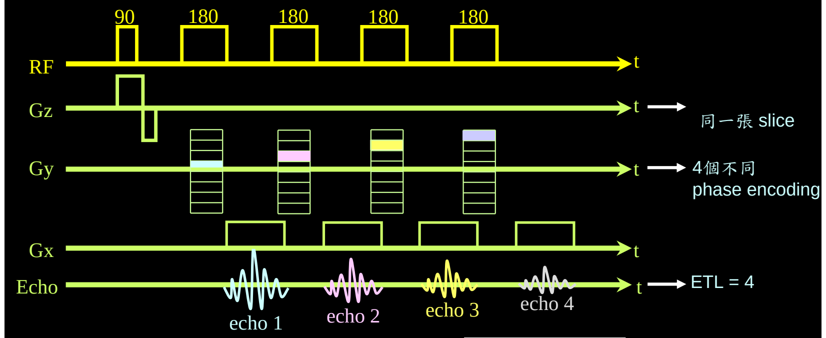
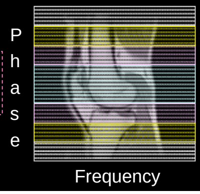
放射診斷科 周嘉豪
FSE K-space
ETL= 8
+128
Gy
+8
-8
t
Gx
t
sampling
Ky
+128
+8
-8
Phase
Kx
Frequency
8

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



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



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.

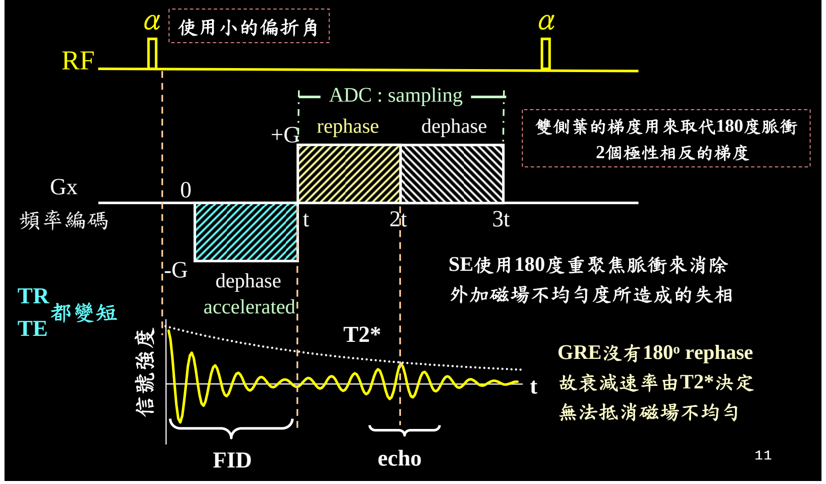
↓SNR=volume $\sqrt{\frac{Ny \times Nx \times NEX}{BW}}$ ↓

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

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

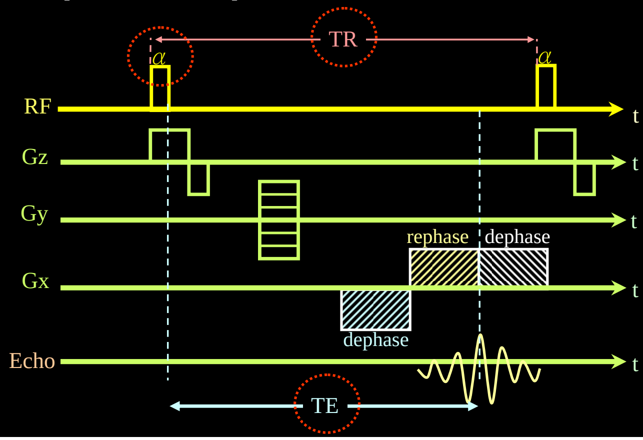
↓Ny → poorer resolution → better SNR

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)

20 張

4.1 msec x 512 x 1 x 20 = 41 sec

……

x48

共96張 ……

5.5 msec x 512 x 48 x 1 = 135 sec = 2 min 15 sec

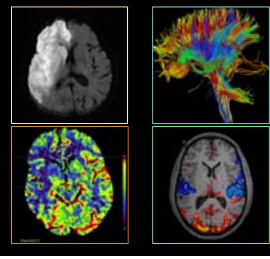
再利用內插法, 由電腦計算組成96張影像

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<100ms
- 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)

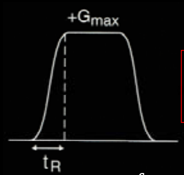
- EPI運用:functional imaging
  - diffusion weight imaging (DWI)
  - diffusion tensor imaging (DTI)
  - perfusion imaging
  - functional MRI: BOLD & VASO



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 300 μ sec (t_R)

  } High slew rate (mT/m/msec)



$$\text{Slew rate} = \frac{G_{max}}{t_R}$$

Slew rate=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):

$$\uparrow BW = \frac{1}{\Delta Ts\downarrow} = \frac{Nx}{Ts\downarrow} \qquad \downarrow SNR = \text{volume}\sqrt{\frac{(Ny)\ (Nx)\ (NEX)}{BW\uparrow}}$$

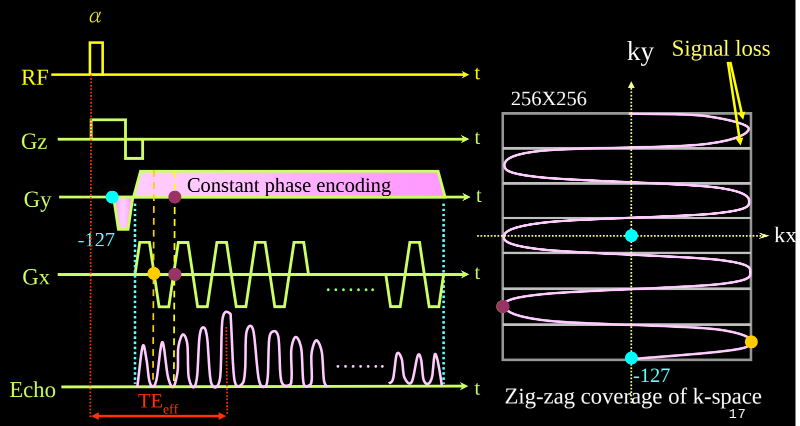
Types of EPI: single-shot & multi-shot

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自最大正值到最大負值反轉Ny/2次 (256/2=128次)

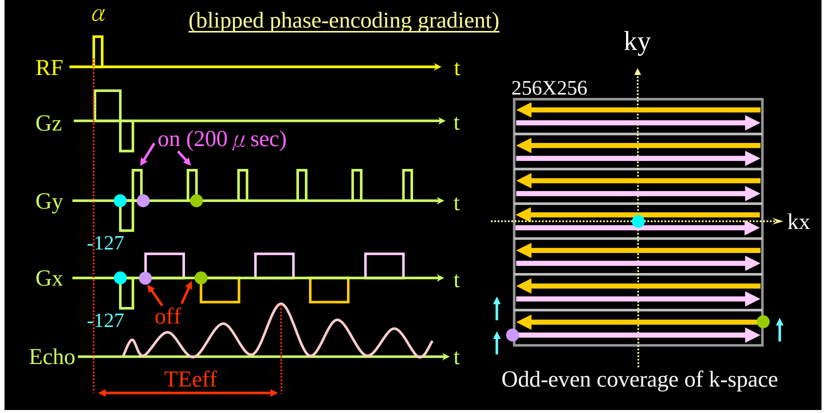
single-shot EPI (單次激發EPI)

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



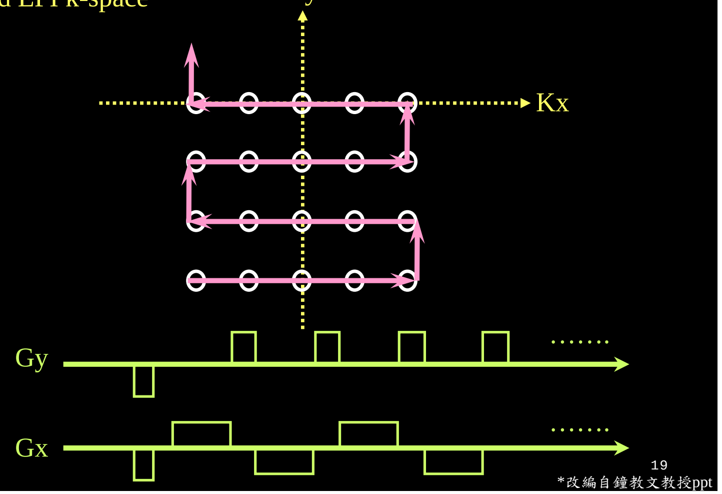
single-shot EPI (單次激發EPI): blipped EPI

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



single-shot EPI (單次激發EPI)

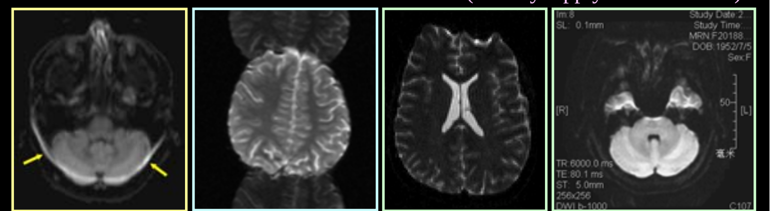
blipped EPI k-space



*改編自鐘教文教授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)



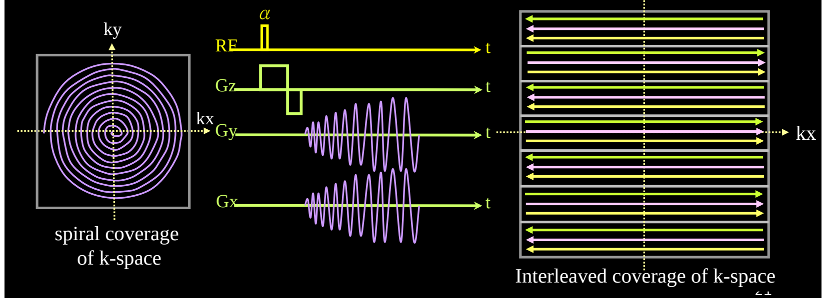
mri-q.com/chemical-shift-in-phase　mriquestions.com/nyquist-n2-ghosts　humanconnectome.org/about/project/MR-preprocessingt

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)

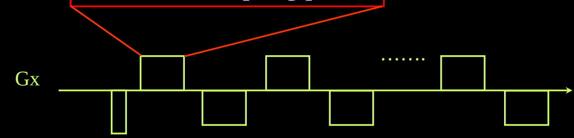


Scan time in EPI (single-shot & multi-shot EPI)

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

ESP :echo sampling period



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

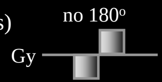
- EPI對比取決於「根」脈衝序列 (“root” pulsing sequence)
- MR影像的對比還是取決於TR、TE、α^o

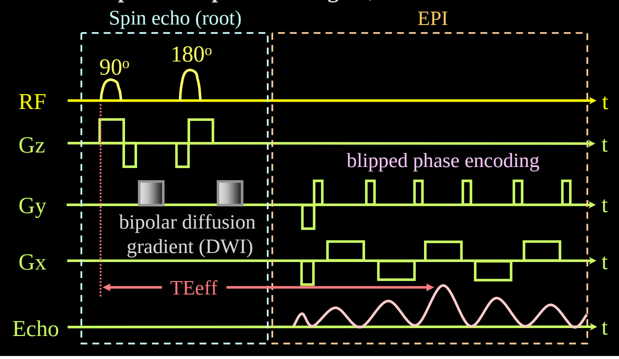
Contrast in EPI:
- SE-EPI (90^o-180^o-EPI):提供T1與T2加權的對比
- GRE-EPI (α^o-EPI):提供T2*加權的對比
- IR-EPI (180^o-90^o-180^o) (inversion recovery):提供T1對比

- 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 (90º-180º-EPI)

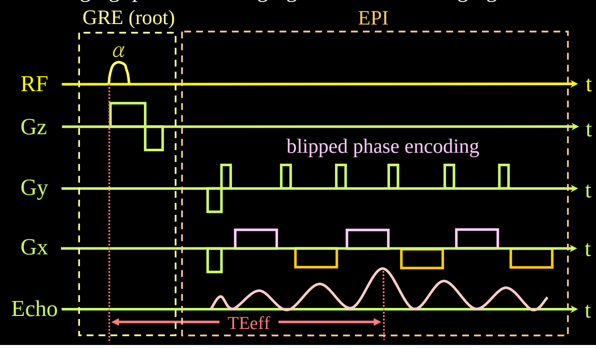
- 利用一個180º RF來克服外加磁場不均勻(inhomogeneities)
- 提供T1和T2加權
- SE-EPI的對比是由180º RF的rephase time取決
- **DWI: "fixed position" proton no signal, diffusion & motion more dephaseing**





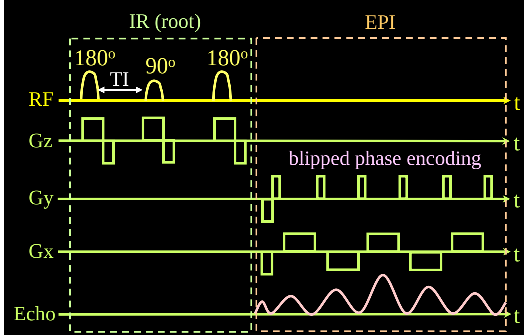
GRE-EPI (α-EPI)

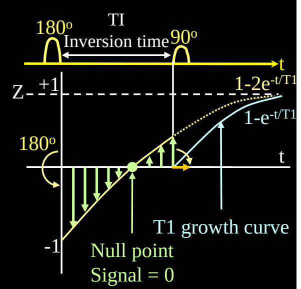
- 沒有用到180º RF pulse (susceptibility effect & chemical shift effect存在)
- 提供T2*W影像，faster imaging speed > SE-EPI
- GRE-EPI的對比是由negative phase gradient 偏移和EPI readout 時間取決
- Dynamic imaging: perfusion imaging, cardiac cine imaging



IR-EPI (180º-90º-180º)

- 施加一個180º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

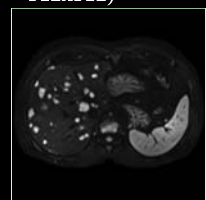
REVEAL + PACE

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)

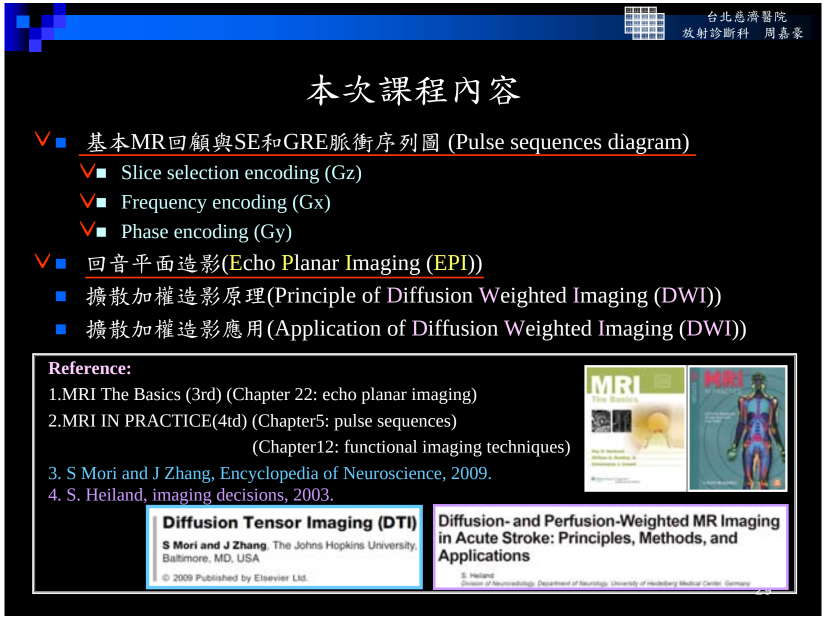
Disadvantages

- 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/mm^2)

From:www.healthcare.siemens.com/magnetic-resonance-imaging/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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.
MRI The Basics
MRI IN PRACTICE
Diffusion Tensor Imaging (DTI)
S Mori and J Zhang, The Johns Hopkins University, Baltimore, MD, USA
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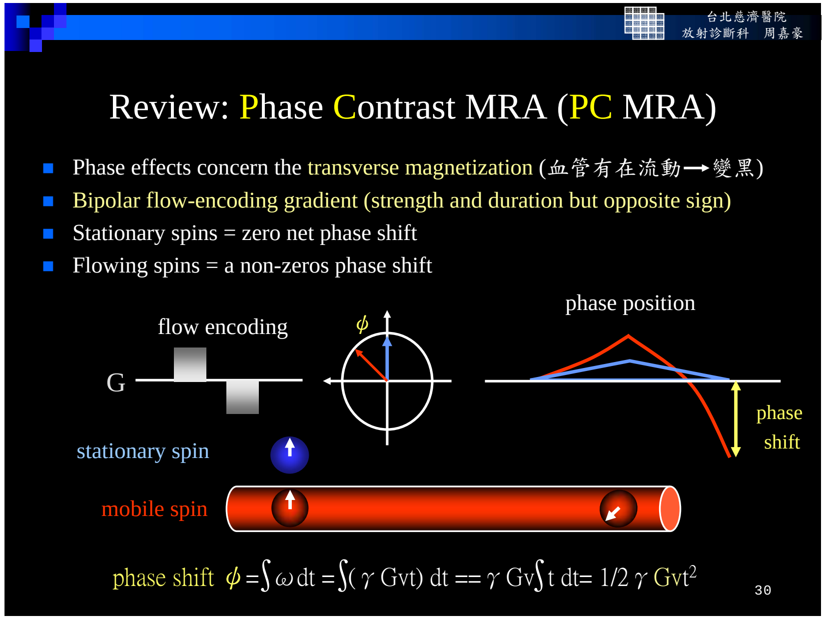
Diffusion- and Perfusion-Weighted MR Imaging in Acute Stroke: Principles, Methods, and Applications
S. Heiland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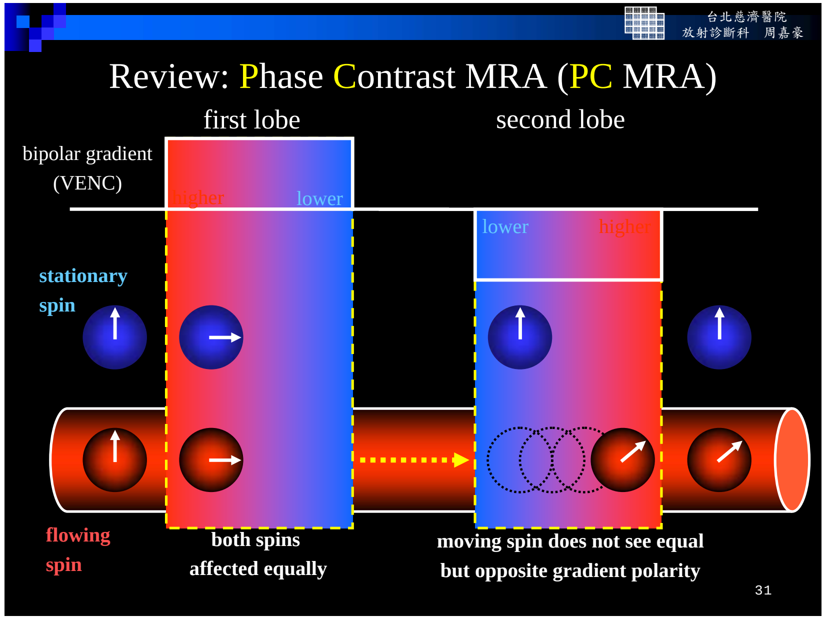
放射診斷科　周嘉豪
Review: Phase Contrast MRA (PC MRA)
Phase effects concern the transverse magnetization (血管有在流動→變黑)
Bipolar flow-encoding gradient (strength and duration but opposite sign)
Stationary spins = zero net phase shift
Flowing spins = a non-zeros phase shift
flow encoding
G
ϕ
phase position
phase shift
stationary spin
mobile spin
phase shift $\phi = \int \omega dt = \int (\gamma Gvt) dt == \gamma Gv \int t dt = 1/2 \gamma Gvt^2$
30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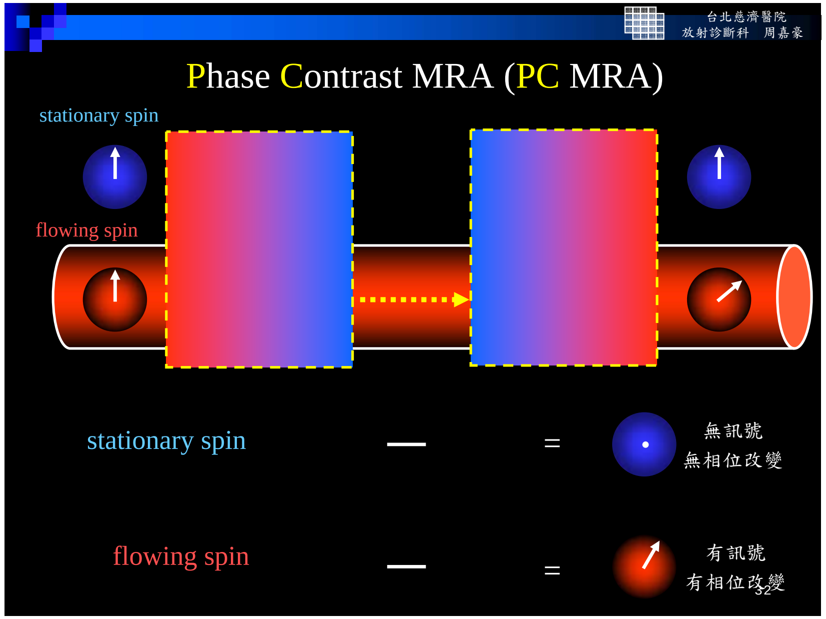
放射診斷科　周嘉豪
Review: Phase Contrast MRA (PC MRA)
first lobe
second lobe
bipolar gradient
(VENC)
higher
lower
lower
higher
stationary
spin
flowing
spin
both spins
affected equally
moving spin does not see equal
but opposite gradient polarity
31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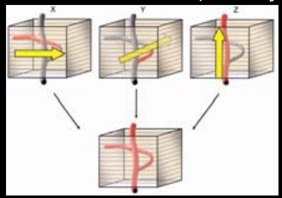
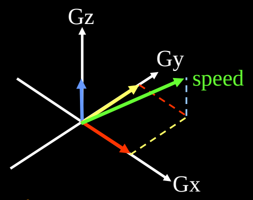
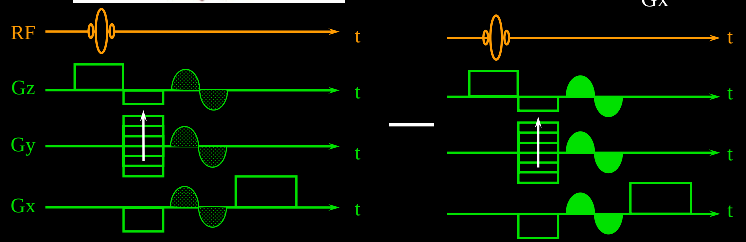
放射診斷科　周嘉豪
Phase Contrast MRA (PC MRA)
stationary spin
flowing spin
stationary spin
—
=
無訊號
無相位改變
flowing spin
—
=
有訊號
有相位改變
32

Magnitude & phase contrast method

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







Flow compensation, bright blood image

Biolar gradients, dark blood image

(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)

Low VENC

Steep Gradient:可看慢血流 (CSF)

phase shift

水分子擴散是極慢的運動，只要梯度夠強也可以看到

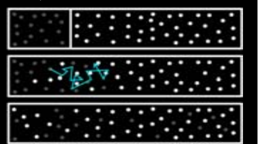
High VENC

Shallow Gradient:可看快血流

same phase shift

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↓

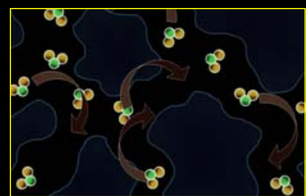


- 擴散運動是非常慢的運動 (D Values)
  - 組織和高的擴散 = 3.0x10^{-3} mm^2/sec
  - White matter = 0.77x10^{-3}mm^2/sec
  - Gray matter = 0.76x10^{-3}mm^2/sec
  - 純水:2.0x10^{-3}mm^2/sec、0.06mm/sec、0.5mm/min

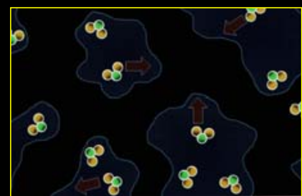
https://zh.wikipedia.org/wiki/

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

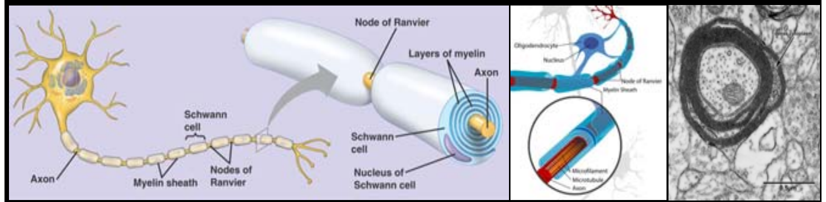


Restricted water

MRI IN PRACTICE(4td):ch12: functional imaging techniques.

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



https://smallcollation.blogspot.tw/2013/05/myelin-sheath.html

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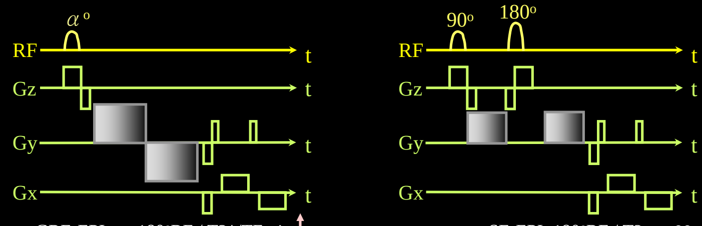
擴散加權造影原理 Principle of Diffusion Weighted Imaging (DWI)

- 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 180°RF / T2*/TEmin↑

SE-EPI: 180°RF / T2

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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

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

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

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

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

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

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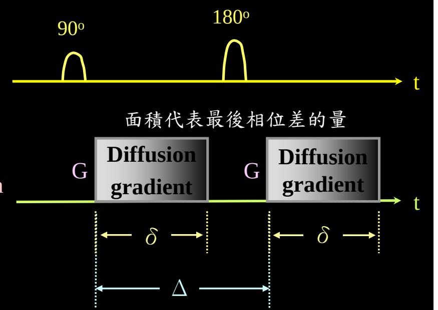
Diffusion factor = b factor

- Diffusion signal loss by the gradient application

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



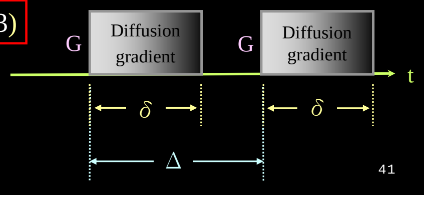
S =signal with the gradient application
S_0 =signal no gradient application
D =diffusion constant
γ =gryomagnetic ratio
G =gradient strength
δ =gradient duration
Δ =time interval between dephasing and rephasing gradients

Diffusion factor = b factor

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

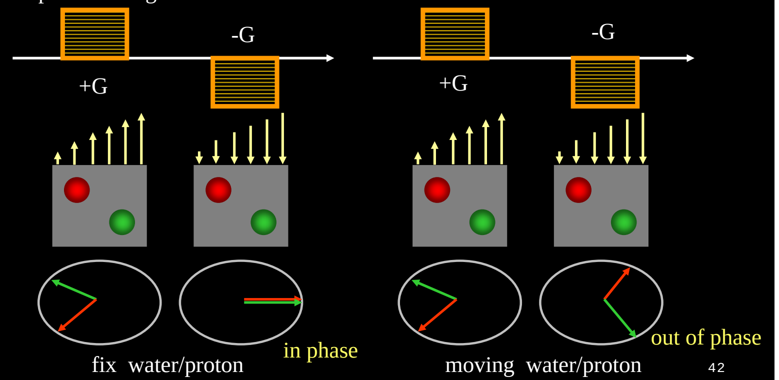
b factor = $-\gamma^2 G^2 \delta^2 (\Delta - \delta/3)$

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



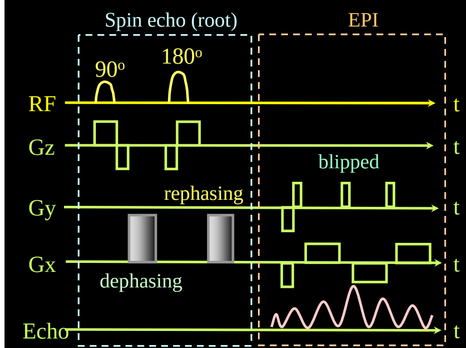
Bipolar Diffusion Gradient

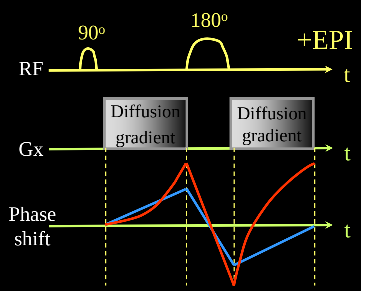
- Bipolar pair of diffusion gradietns is inserted between the RF excitation pulse and signal readout.



Bipolar Diffusion Gradient
SE-EPI (SE-EPI)

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

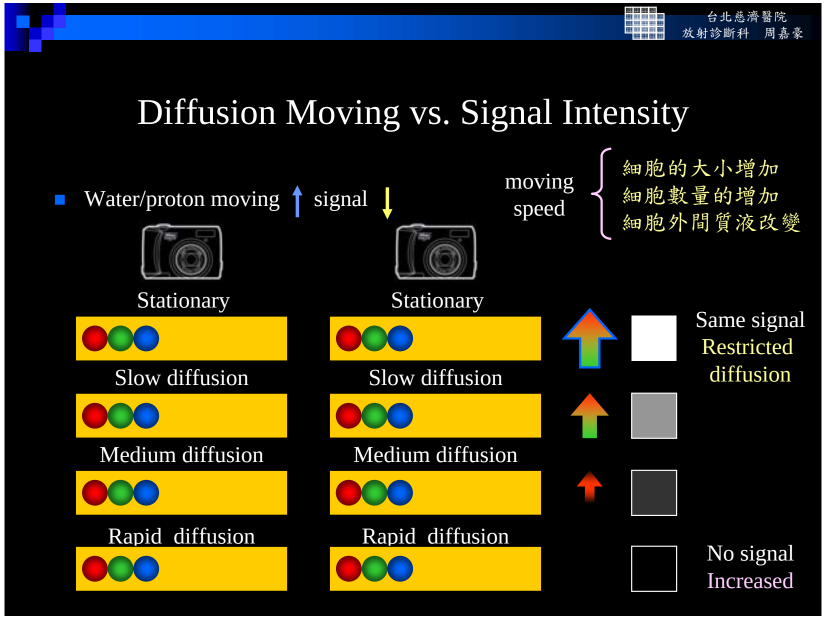




fix-position proton (no dephaseing)
diffusion position proton (dephasing)

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↑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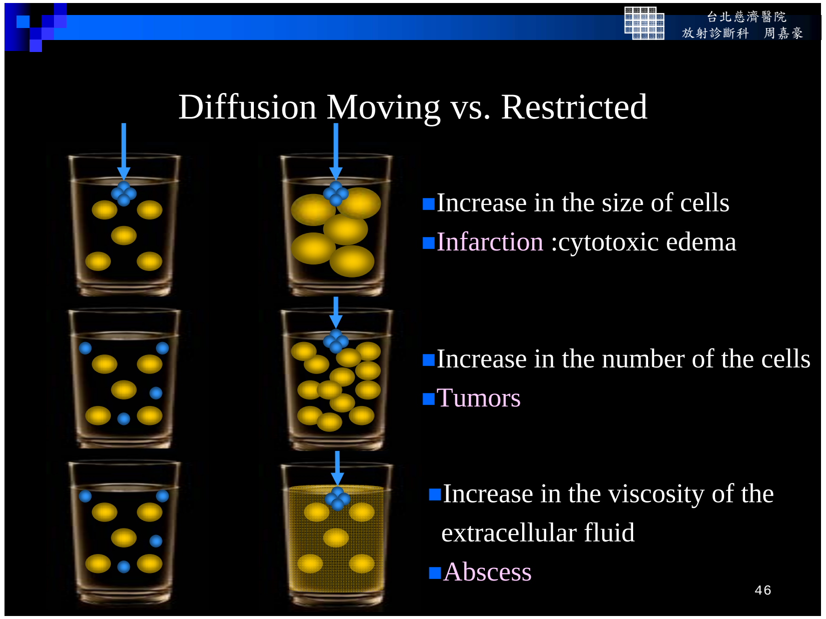
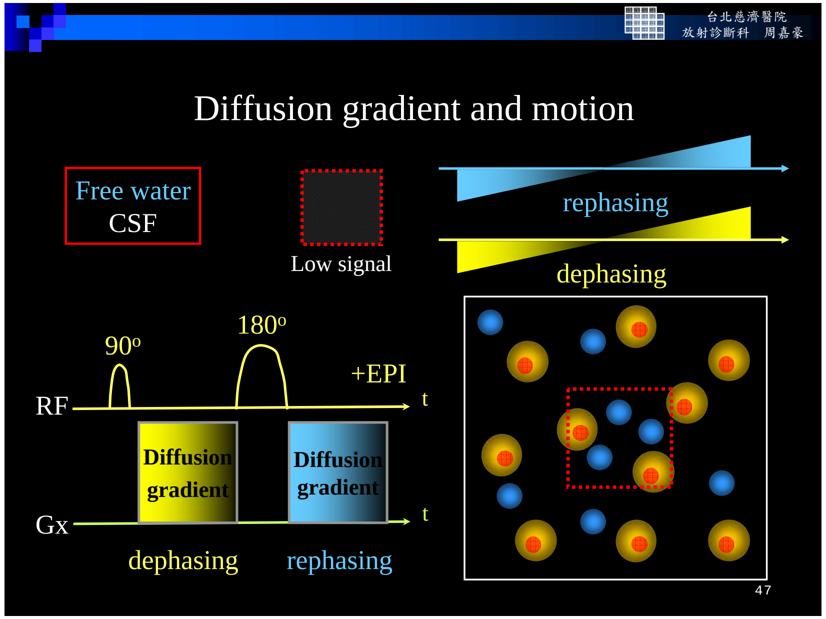
放射診斷科 周嘉豪
Diffusion Moving vs. Signal Intensity
Water/proton moving ↑ signal ↓
moving speed
細胞的大小增加
細胞數量的增加
細胞外間質液改變
Stationary
Stationary
Slow diffusion
Slow diffusion
Medium diffusion
Medium diffusion
Rapid diffusion
Rapid diffusion
Same signal
Restricted diffusion
No signal
Increased


台北慈濟醫院
放射診斷科 周嘉豪
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
46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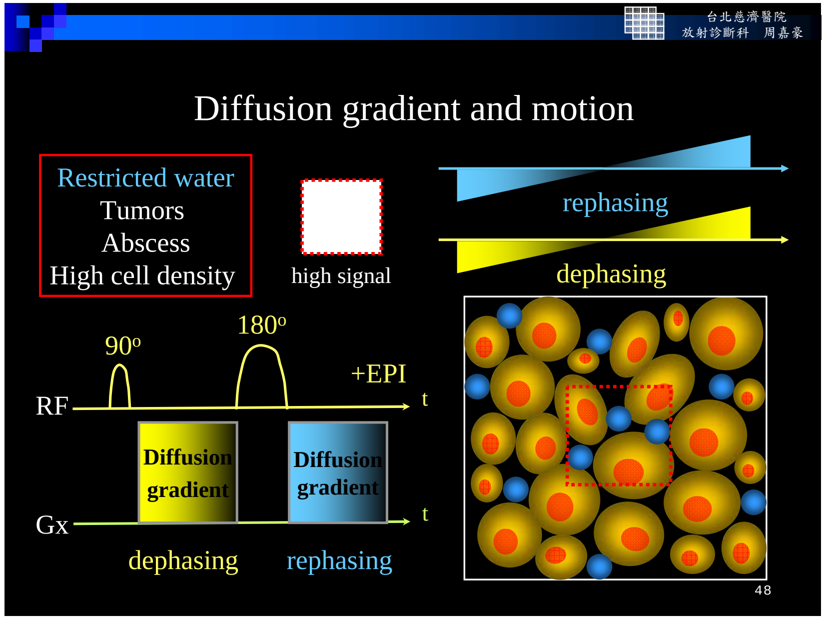
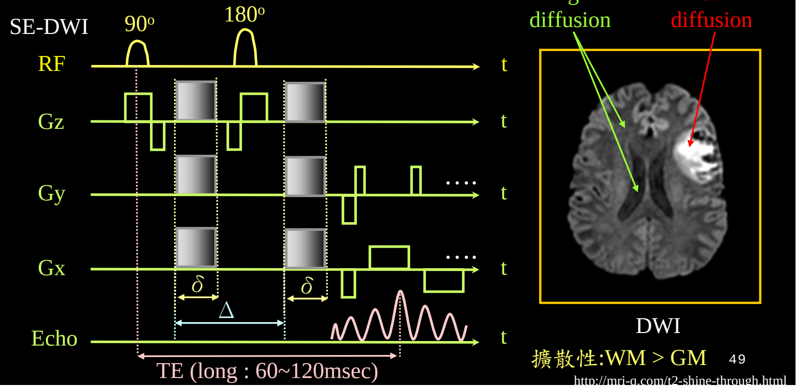
Diffusion gradient and motion
Free water
CSF
Low signal
rephasing
dephasing
90°
180°
+EPI
RF
t
Diffusion gradient
Diffusion gradient
Gx
t
dephasing
rephasing
47


台北慈濟醫院
放射診斷科 周嘉豪
Diffusion gradient and motion
Restricted water
Tumors
Abscess
High cell density
high signal
rephasing
dephasing
90°
180°
+EPI
RF
t
Diffusion gradient
Diffusion gradient
Gx
t
dephasing
rephasing
48

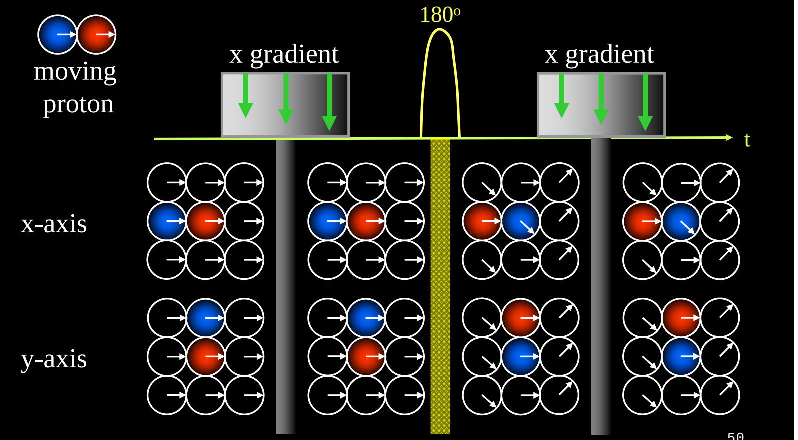
擴散加權影像 Diffusion Weighted Imaging (DWI)

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



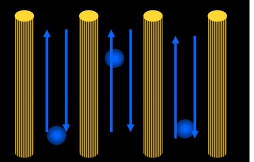
http://mri-q.com/t2-shine-through.html

擴散加權影像 Diffusion Weighted Imaging (DWI)



Apparent diffusion coefficient, ADC

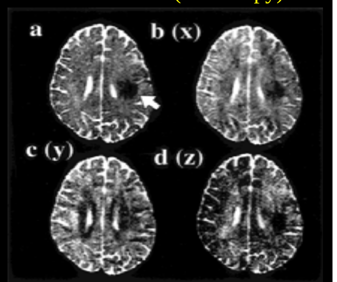
- Restricted diffusion & anisotropy
- 擴散在同一點內隨方向而不同
- DWI:梯度三個方向都開，各別取得Dx、Dy、Dz
- ADC is isotropic map (無關方向性)
- ADC ↓ for acute stroke infarction.



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

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

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



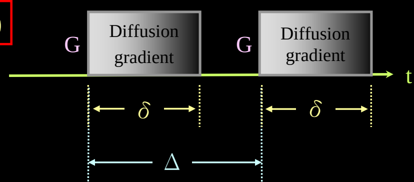
SUSUMU MORI et al. THE ANATOMICAL RECORD (NEW ANAT.) 257:102–109, 1999

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)

http://mri-q.com/t2-shine-through.html

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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

http://mri-q.com/t2-shine-through.html

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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

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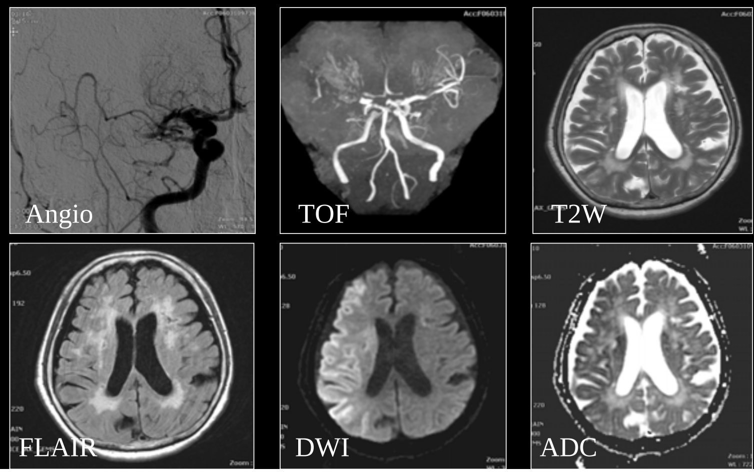
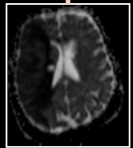
擴散加權造影應用
Ischemic stroke / 3hr / hyper acute stroke

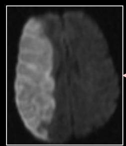


擴散加權造影應用
Ischemic stroke

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

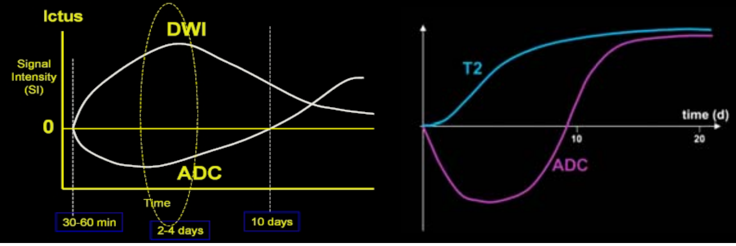
Eventual lysis(細胞溶解) edema
→ Vasogenic edema (cytolysis) (disrupted BBB) Tissue necrosis DWI low signal ADC high


ADC drop restricted

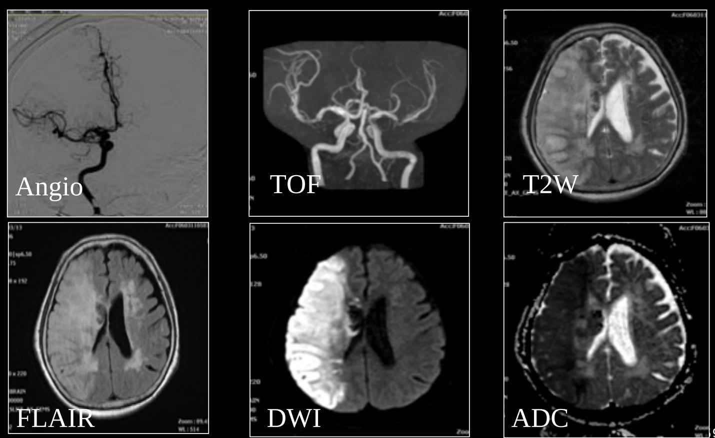

DWI hyperintensity

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

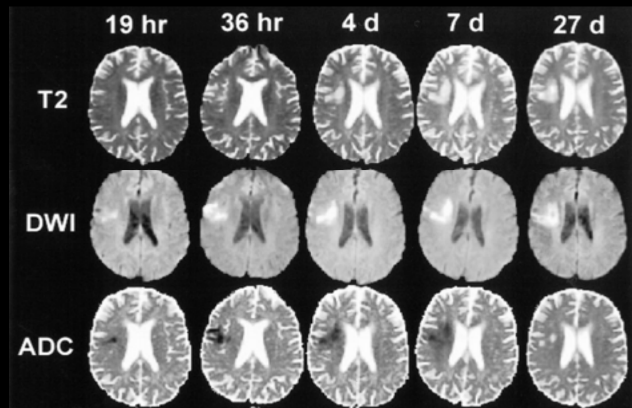
	T2	DWI	ADC
hyperacute(<6hrs)	iso	high	low
Acute (6hrs~7day)	high	high	low
Subacute (1~3weeks)	high	iso/high	iso
Chronic(>3 weeks)	high	iso/low	high



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



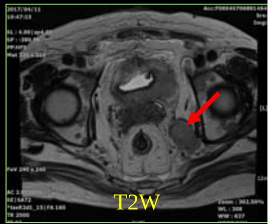
擴散加權造影應用
Ischemic stroke

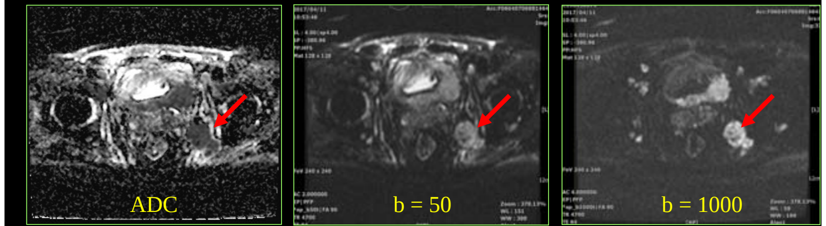


Maarten G. Lansberg. et al., **Evolution of Apparent Diffusion Coefficient, Diffusion-weighted, and T2-weighted Signal Intensity of Acute Stroke,** *AJNR Am J Neuroradiol* 22:637–644, April 2001

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

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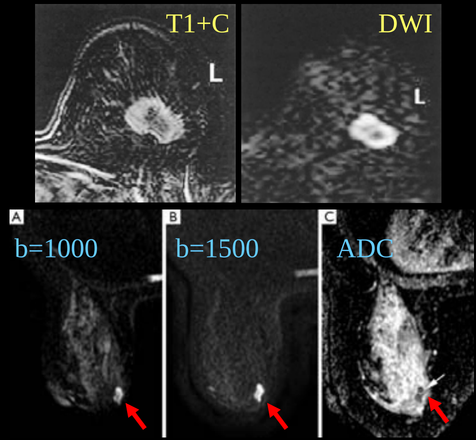
擴散加權造影應用
偵測體內腫瘤

Invasive ductal carcinoma

Invasive mammary carcinoma



Kuroki,2004 /Mohammad Eghtedari1, et al, 2016

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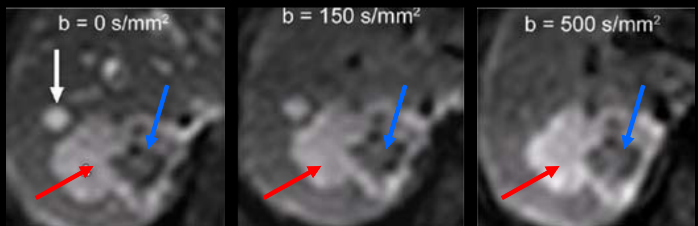
擴散加權造影應用
區別腫瘤的特性(良性/惡性)

- 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(箭頭)隨著b值增加，訊號明顯降低。
轉移性腫瘤(星號)的訊號則無明顯改變

http://depart.femh.org.tw/medical_image/tw/science_c.html

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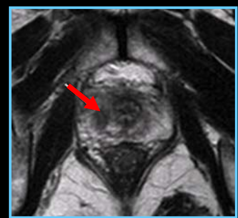
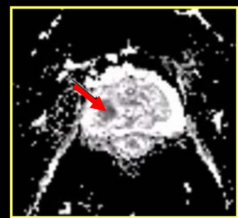
擴散加權造影應用
區別器官內腫瘤以及非腫瘤的區域

- 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

http://depart.femh.org.tw/medical_image/tw/science_c.html

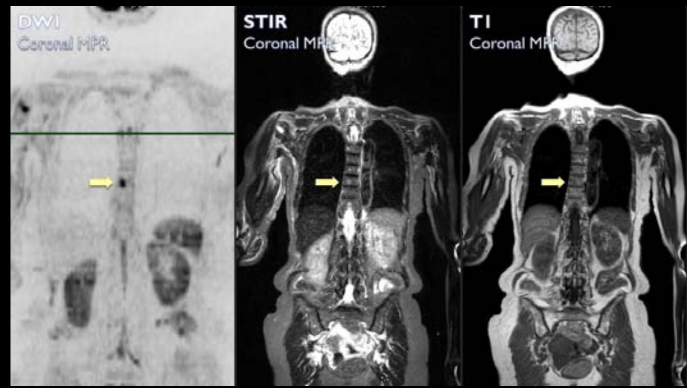
擴散加權造影應用
全身性擴散權重影像

- 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

http://depart.femh.org.tw/medical_image/tw/science_c.html

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)

C. de Bazelaire et al., Let's diffuse diffusion , ECR 2009.

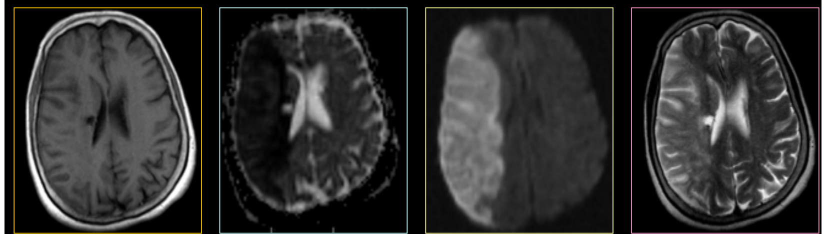
看圖說故事時間

- 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?

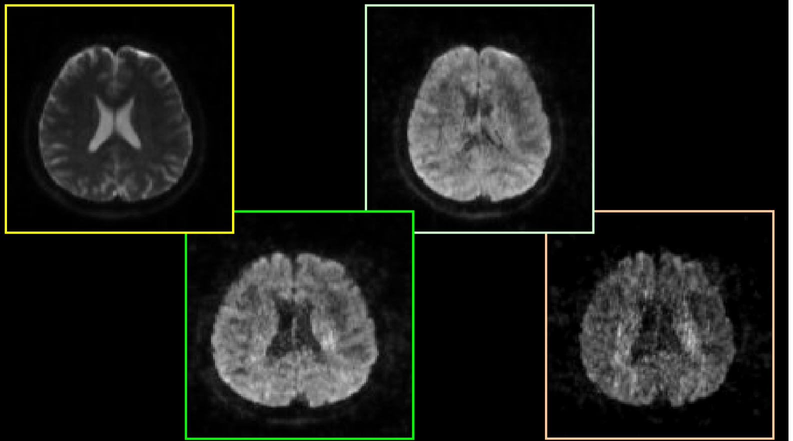
- 你有兩次求救機會!!
  1. 你可以指名一位學員回答一個問題
  2. 你可以請全班學員舉手表決一個問題

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?



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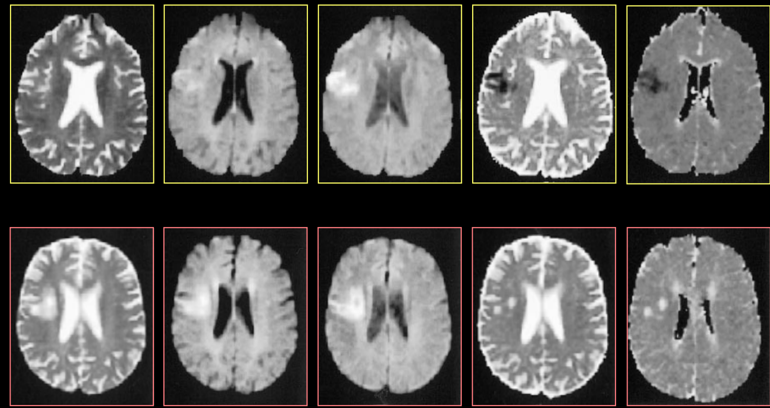
看圖說故事(三)
MRI影像中那一組是較新的梗塞?



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

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Thanks for your attention!