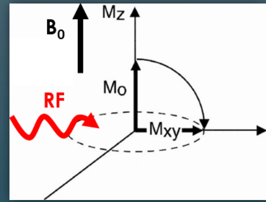
磁振影像學MRI
重複時間與回波時間
TR & TE

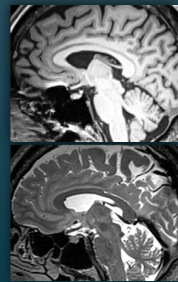
盧家鋒 教授

國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw

Procedure of MRI



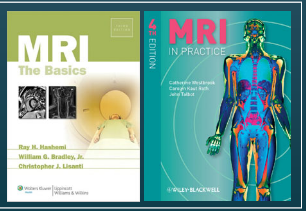
- ☑ Alignment (magnetization) B_0
- ☑ Precession $\omega_0 = \gamma B_0$
- ☑ Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- ☑ MR signal (EMF, relaxation time)
- ☐ Imaging (Pulse sequencing)
  - ☐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



本週課程內容 http://cflu.lab.nycu.edu.tw

- 重複時間與回波時間(TR & TE)
- TR&TE綜合效應(T1/T2權重)

- MRI The Basics (3rd edition)
  - Chapter 5: TR, TE, and Tissue Contrast
- MRI in Practice, (4th edition)
  - Chapter 2: Image Weighting and Contrast

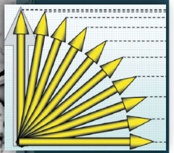


重複時間與回波時間TR, TE

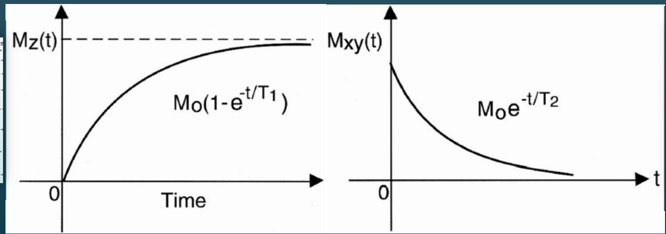
Time of Repetition (TR) & Time of Echo (TE)
Repetition Time (TR) & Echo Time (TE)

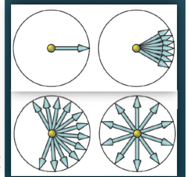
T1 & T2 Relaxation Time

T1:	T2:
The longitudinal relaxation time	The transverse relaxation time
The spin-lattice relaxation time	The spin-spin relaxation time
$M_z(t)=M_0(1-e^{-t/T1})$	$M_{xy}(t)=M_0e^{-t/T2}$



recovery



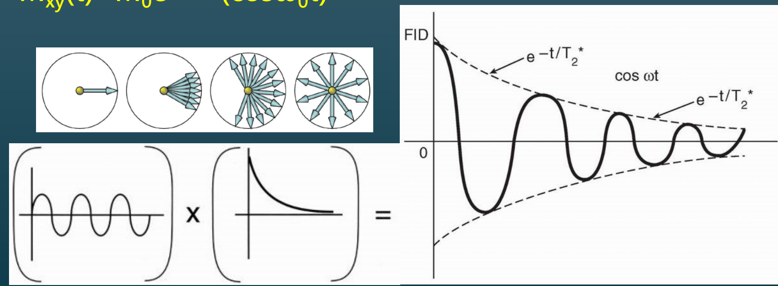


dephasing

T1>T2>T2*

Received Signal: Free Induction Decay

- The oscillating, decaying signal is called an FID.
- $M_{xy}(t)=M_0e^{-t/T2^*}(\cos\omega_0 t)$



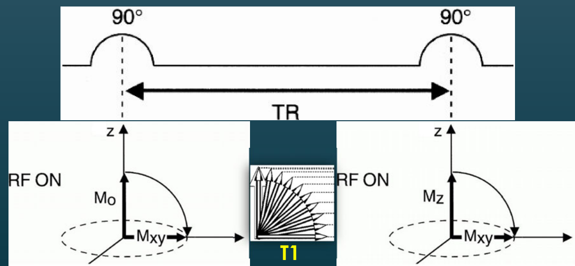
The frequency of the received signal is also ω_0.

T1, T2 ⇔ TR, TE

- T1 and T2 are inherent properties of the tissue and therefore fixed.
- TR and TE can be controlled and adjusted by the operator.
- By appropriate setting of TR and TE, we can put more "weight" on T1 or T2.

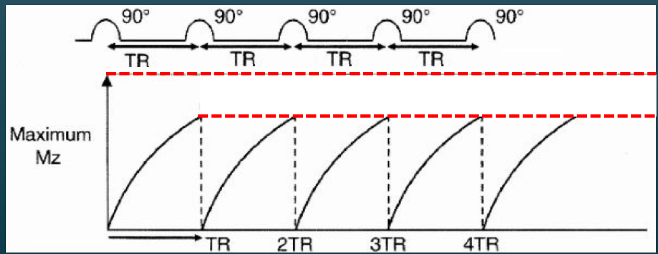
TR (Repetition Time)

- To spatially encode the signal and to increase the signal-to-noise ratio, we have to apply the RF pulse *multiple times* while varying the gradients.
- The time interval between RF pulses is called TR.



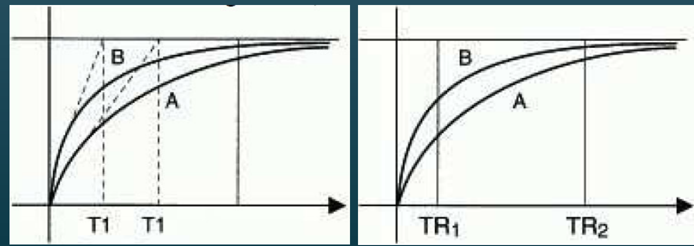
T1 Recovery During Successive 90° Pulses

- $M_z(TR)=M_0(1-e^{-TR/T1})$
  - If TR → ∞, $M_z(TR) = M_0$
  - Otherwise, $M_z(TR) < M_0$



Tissue Contrast (T1 weighting)

- If tissue A has a longer T1 than tissue B, it takes longer to recover M_z.
- Shorter TR (TR_1) offers better T1 tissue contrast (difference) between tissues A and B.
- **Longer TR reduces the T1 weighting(contrast).**

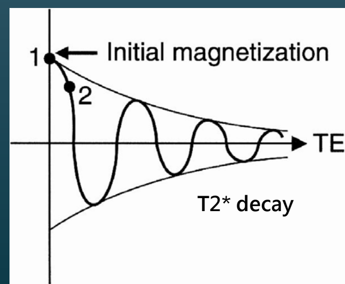


Tissue Contrast (T1 weighting)

- **Longer TR reduces the T1 weighting(contrast).**
- We can certainly minimize the T1 effect with a TR of 2000 to 3000 msec.
- In general, if TR is 4 to 5 times T1, then the T1 effect becomes negligible.
- Ideally, we use TR≒T1 for T1-weighted imaging.

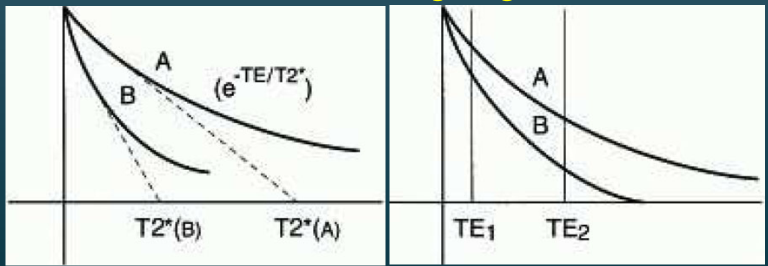
TE (Time to Echo or Echo Delay Time)

- We wait a short period of time (TE) after RF pulse and then make the measurement.
- The T2* decay curve (FID) starts out at the value of $M_0(1-e^{-TR/T1})$ on the T1 recovery curve and then decays very quickly.



Tissue Contrast (T2* weighting)

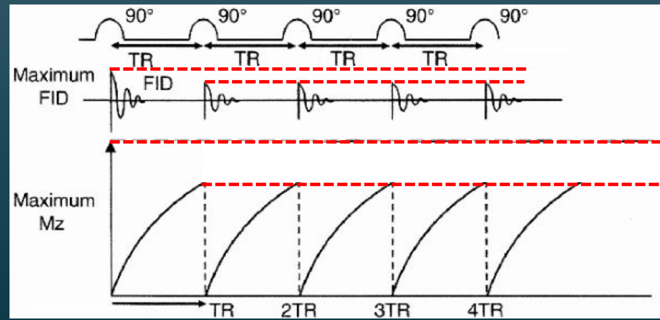
- If tissue A has a longer T2* than tissue B, it takes longer to decay M_{xy}.
- Longer TE (TE_2) offers better T2* tissue contrast (difference) between tissues A and B.
- Shorter TE reduces the T2* weighting(contrast).



FID During Successive 90° Pulses

- The FID signal (the voltage of EMF) would be proportional to

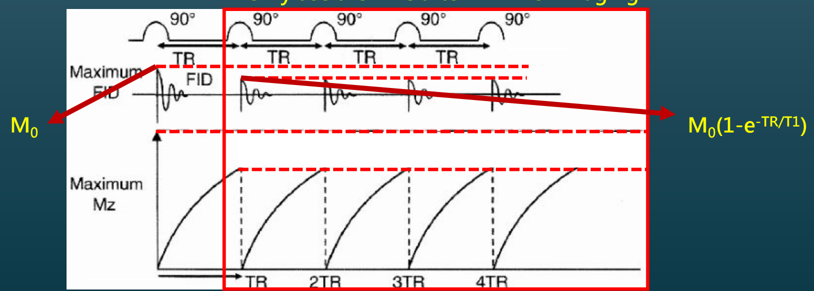
$$M_0(1-e^{-TR/T1})\, e^{-TE/T2^*}$$



Dummy Scans

- Each dummy scan contains all of the RF pulses, delays and gradients used in the pulse program.
- But the receiver is not turned on to collect data.
- To ensure that the spin system is in a steady state.

Only use the FIDs after 1*TR for imaging



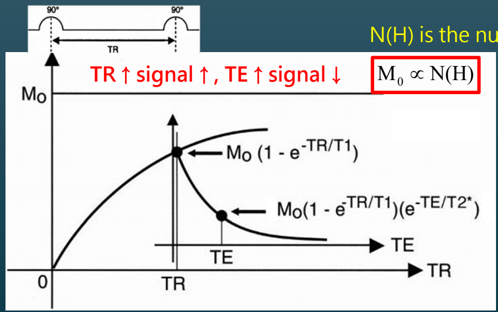
TR&TE綜合效應(T1/T2權重)

T1 or T2 Weighting

Combination of TR and TE

- Don't forget that the FID is originated from M_{xy}.

N(H) is the number of mobile protons



Generally, TE < TR

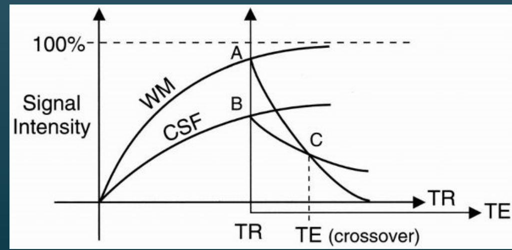
Exercise 5-1

- (a) For a TR = 2000 msec, find the relative signal intensities for WM and CSF (i.e., points A and B on the graph).

Assume...

	T1 (msec)	T2 (msec)	N(H)
WM	500	100	100
CSF	2000	200	100

WM: $100(1-e^{-2000/500})$
$=100(1-0.018) = 98.2$
CSF: $100(1-e^{-2000/2000})$
$=100(1-0.368) = 63.2$



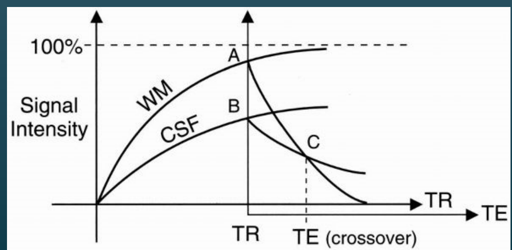
Exercise 5-1

- (b) Calculate the crossover TE where WM and CSF have identical T2 weighting (point C).

Assume...

	T1 (msec)	T2 (msec)	N(H)
WM	500	100	100
CSF	2000	200	100

$$98.2(e^{-TE/100})=63.2(e^{-TE/200})$$
$$\frac{98.3}{63.2}=\frac{e^{-TE/200}}{e^{-TE/100}}$$
$$\ln(1.55)=(-TE/200)-(-TE/100)$$
$$0.4407=TE/200$$
$$TE=88.14$$



Exercise 5-1

- (c) Now, calculate the signal ratio of CSF/WM for TE = 25 (first echo) and TE = 100 msec (second echo).

Assume...

	T1 (msec)	T2 (msec)	N(H)
WM	500	100	100
CSF	2000	200	100

WM: $100(1-e^{-2000/500})(e^{-25/100})$
$= 98.2 \times 0.78 = 76.6$
CSF: $100(1-e^{-2000/2000})(e^{-25/200})$
$= 63.2 \times 0.88 = 55.6$
CSF/WM = 0.72

WM: $100(1-e^{-2000/500})(e^{-100/100})$
$= 98.2 \times 0.37 = 36.3$
CSF: $100(1-e^{-2000/2000})(e^{-100/200})$
$= 63.2 \times 0.61 = 38.6$
CSF/WM = 1.06

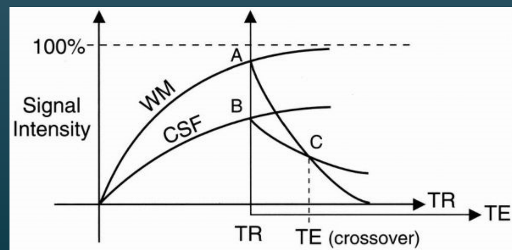


Image Contrast

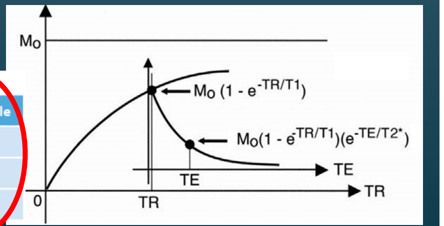
- Long TR, short TE ➔ proton density
- Long TR, long TE ➔ T2*-weighted
- Short TR, short TE ➔ T1-weighted
- Short TR, long TE ➔ no signal

Example:

Long TR	2000 ms
Short TR	300–700 ms
Long TE	60 ms+
Short TE	10–25 ms

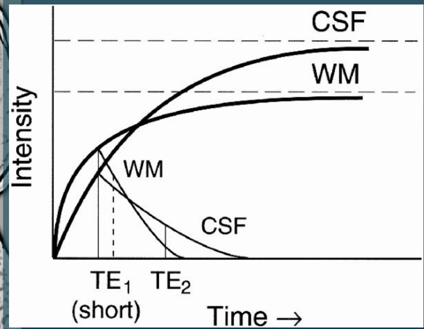
Table 2.3 Parameters used in gradient echo.

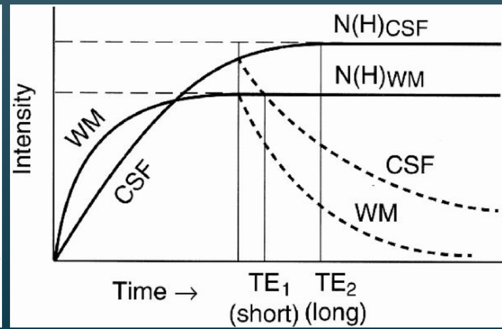
Weighting	TR	TE	Flip angle
T1	short	short	large
T2	long	long	small
Proton density	long	short	small



Tissue Contrast

- Shorter TR vs. Longer TR

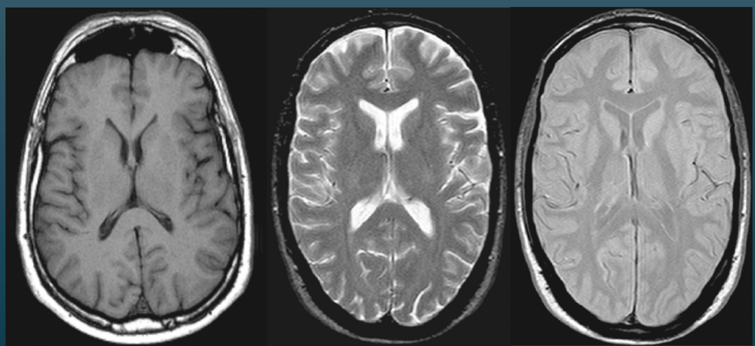




T1W PD T2W

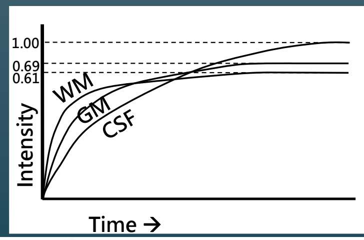
T1/T2/PD weighted Images

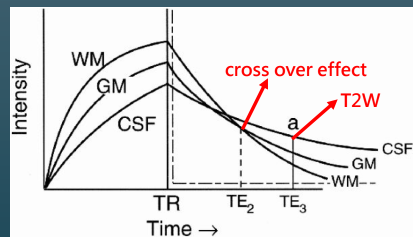
T1W T2W PDW

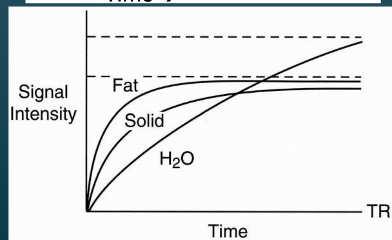


CSF > edema > GM > WM

Adjust T1 and T2 weighting





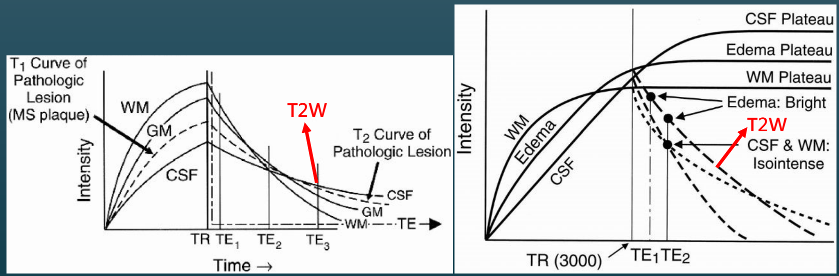


T1: **CSF>GM>WM**
T2: **CSF>GM>WM**
N(H): **CSF>GM>WM**

T1: **H_2O > Solid tissue > Fat**
T2: **H_2O > Fat > Solid tissue**
N(H): **H_2O > Fat > Solid tissue**

Differentiate abnormality

- Adjust T1/T2 weighting to enhance abnormalities.

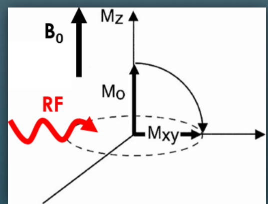


Intracranial Hemorrhage on MRI

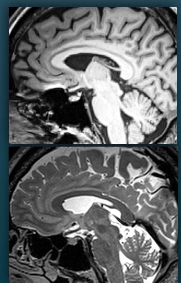
Staging	Time	Component	T1W	T2W
Hyperacute	1 day			
Acute	1-3 days	oxyhemoglobin	hypointense	hyperintense
Subacute _ early	3-7 days	deoxyhemoglobin	isointense	hypointense
Subacute _ late	1-3 weeks	methemoglobin(intracellular)	hyperintense	inner :hypointense outer : hyperintense
Chronic_ early	3weeks - months	methemoglobin(extracelluar)	hyperintense	hyperintense
Chronic_ late	months - years	hemochrome	hypointense	hyperintense or isointense
Remote	months - years	hemosiderin/ferritin	hypointense	hyperintense

http://lib.yeezen.com.tw/lb/Radiology/gloo/n-mrihemorrhage.html

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)
  - ☑ Tissue Contrast: Image weighting
  - ☐ Spatial localization: Spatial Encoding



THE END

alvin4016@nycu.edu.tw