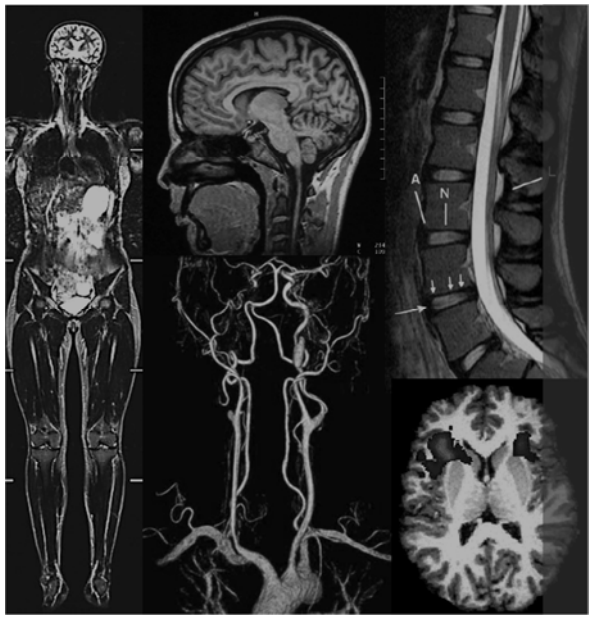

組織對比
A Course of MRI

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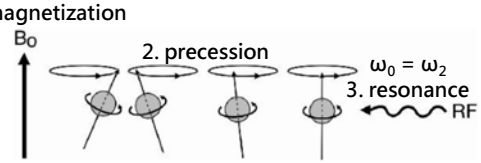
本週課程內容

- TR, TE與組織對比
- 組織對比之臨床應用

Procedure of MRI



- 1. Alignment (magnetization) B_0
- 2. Precession $\omega_0 = \gamma B_0$
- 3. Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
- 4. MR signal (EMF, electromotive force)
- 5. Relaxation time
  - T1 (recovery rate of M along B_0),
  - T2 (decay rate of transverse M),
  - T2* (consider both T2 and B_0 inhomogeneities)
- The most effective resonance is produced when $\omega_0 = \omega_2$

TR, TE與組織對比

Repetition Time, Time to Echo, and Tissue Contrast

T1, T2 vs. TR, TE

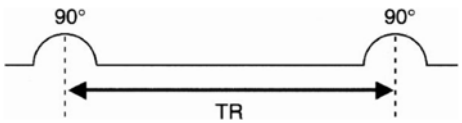
- T1 and T2 are inherent properties of the tissue and therefore fixed.
- TR (repetition time), and TE (time to echo) can be controlled and adjusted by the operator.
- By appropriate setting of TR and TE, we can put more "weight" on T1 or T2.

T1 and T2

- T1 is defined as the time when 63% of the longitudinal magnetization has recovered (with 3*T1=95% recovery).
- T2 is defined as the time when 63% of the transverse magnetization has decayed (with 3*T2=95% decay).

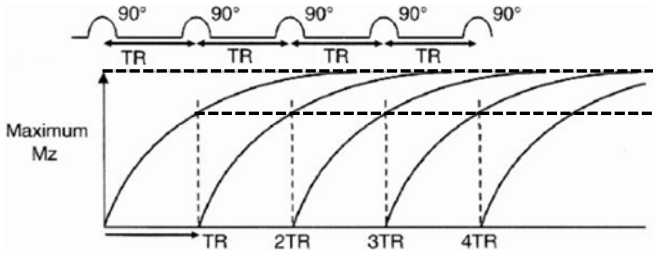
TR (Repetition Time)

- To spatially encode the signal, 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 90º Pulses

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

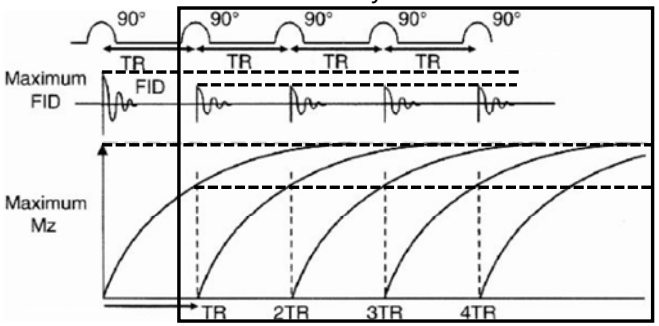


FID During Successive 90º Pulses

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

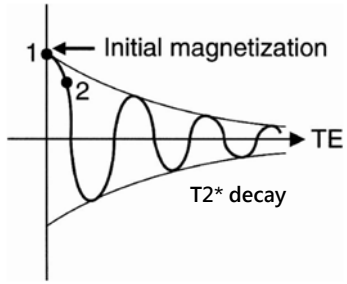
$$N(H)(1-e^{-TR/T1})e^{-TE/T2^*}$$

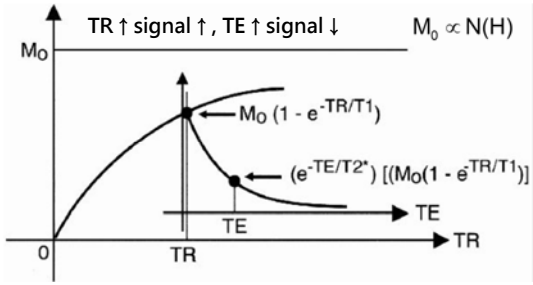
Only use the FIDs after 1*TR for imaging



TE (Time to Echo or Echo Delay Time)

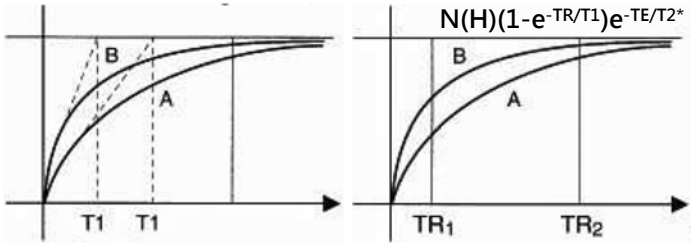
- We wait a short period of time (TE) after RF pulse and then make the measurement.
- The T2* decay curve starts out at the value of $M_0(1-e^{-TR/T1})$ on the T1 recovery curve and then decays very quickly.





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 effect (contrast).**



$$N(H)(1-e^{-TR/T1})e^{-TE/T2^*}$$

Tissue Contrast (T1 weighting)

- **Longer TR reduces the T1 effect (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.
- If TR is close to zero, then $1-e^{-TR/T1}=0$.
- Ideally, we use TR≒T1 for T1-weighted imaging.

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* effect (contrast).**

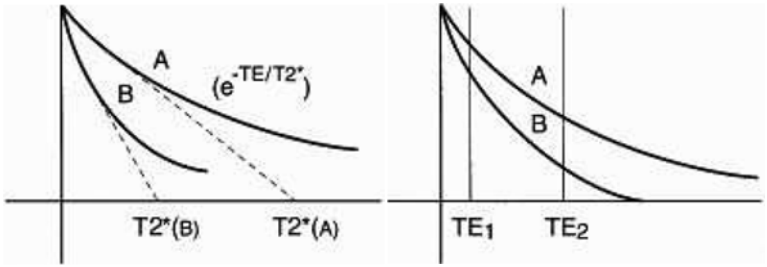


Image Contrast

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

組織對比之臨床應用

Clinical Applications of Tissue Contrast

T2 Characteristics

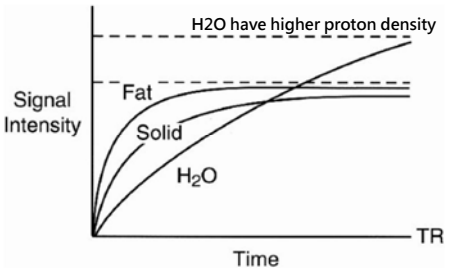
- Determined by how fast the proton spins in that tissue dephase.
- If they dephase rapidly, we get a short T2.
- If they dephase slowly, we get a longer T2.

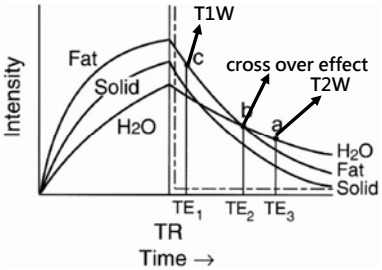
T1 Characteristics

- Determined by how well the protons can give off their energy to the surrounding lattice.
- The most efficient energy transfer occurs when the **natural motional frequencies (ω)** of the protons are at the **Larmor frequency (ω_0)**.
- If the efficiency of energy transfer from the protons to the lattice is increased, the T1 becomes shorter.
- $\omega(H_2O) >> \omega_0$, $\omega(solids) < \omega_0$, $\omega(fat) \fallingdotseq \omega_0$

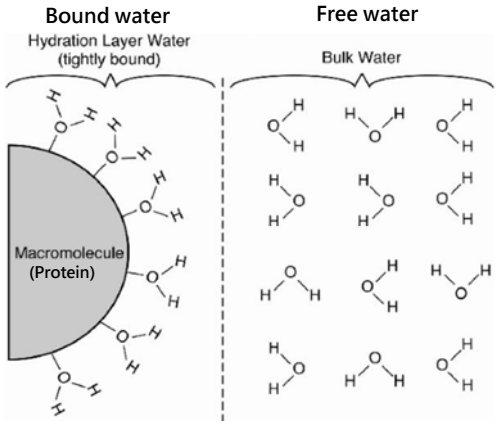
T1 and T2 Characteristics

- T1 (longer T1, slower M_z recovery)
  - **H_2O > Solid tissue > Fat**
- T2 (longer T2, slower M_{xy} decay)
  - **H_2O > Fat > Solid tissue**





Water



T1: 10~100 ms
T2: 5~10 ms

T1: 2000~3000 ms
T2: 1000~2000 ms

Although the hydration layer water has much shorter T1 than bulk water, it also has shorter T2 (fast signal decay).

T1 and T2 Characteristics: Brain Tissues

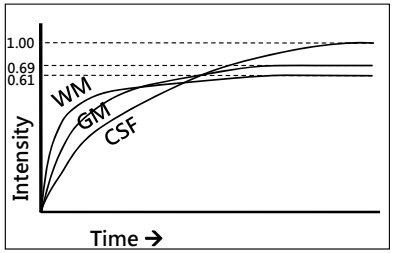
- T1 (longer T1, slower M_z recovery)
  - **Cerebrospinal fluid (CSF) > Gray matter (GM) > White matter (WM)**
- T2 (longer T2, slower M_{xy} decay)
  - **CSF > GM > WM**

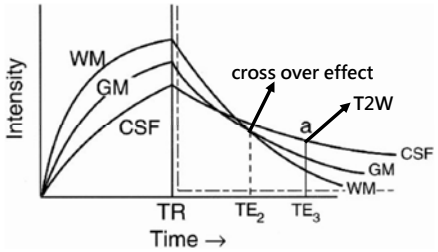
Table 6-1 T1, T2, and Proton Density of Brain Tissues at 1.5 T*

	T1 (msec)	T2 (msec)	N(H)
White matter	510	67	0.61
Gray matter	760	77	0.69
Edema	900	126	0.86
CSF	2650	180	1.00

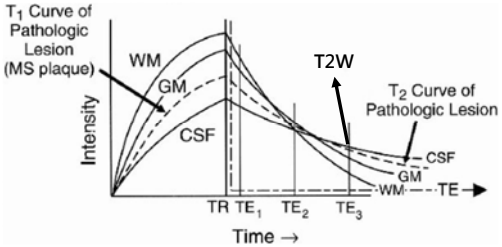
*Stark and Bradley, p. 44.

T1 and T2 Characteristics: Brain Tissues



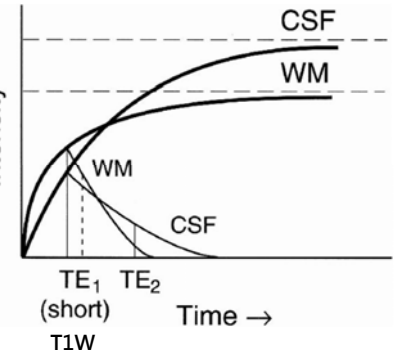


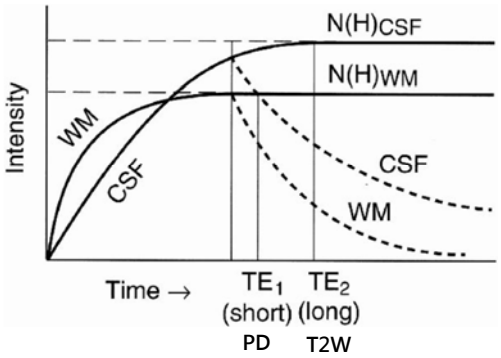
- The pathologic lesions (vasogenic edema) have a slow T1 recovery and a long slow T2 decay.



Tissue Contrast

- Shorter TR vs. Longer TR

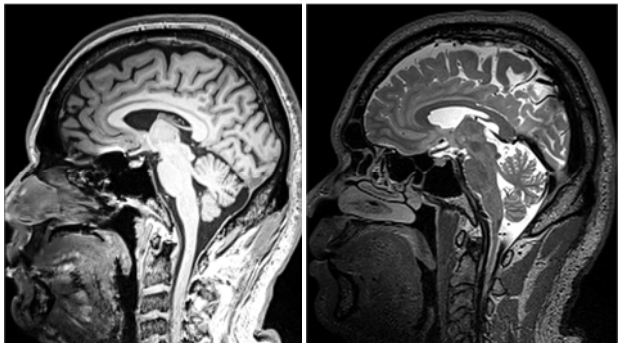




Sagittal Brain images – Normal case

TR=2530 ms
TE=3.03 ms
T1W(TR↓ TE↓)

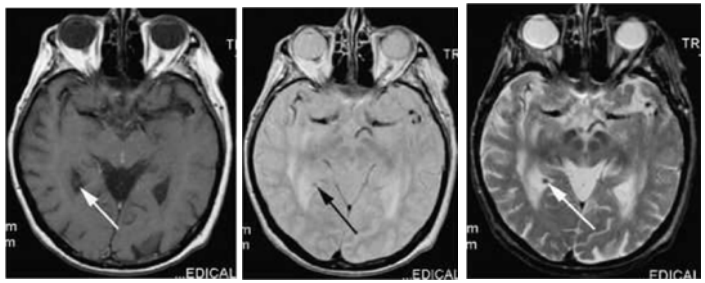
TR=3200 ms
TE=403 ms
T2W(TR↑ TE↑)



Axial Brain Images

- Arrow: a small intraventricular meningioma that has typical signal close to GM

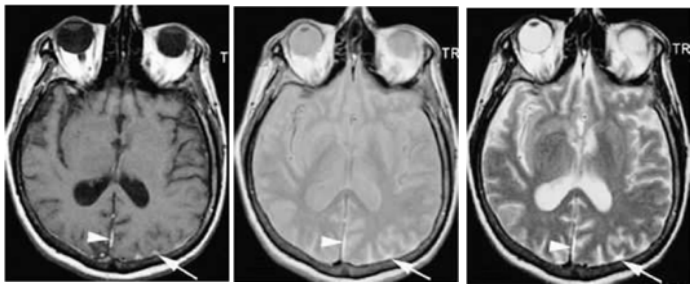
T1W(TR↓ TE↓) **PD(TR↑ TE↓)** **T2W(TR↑ TE↑)**



Axial Brain Images

- Arrow: a subarachnoid hemorrhage
- Arrowhead: a small subdural hemorrhage

T1W(TR↓ TE↓) PD(TR↑ TE↓) T2W(TR↑ TE↑)

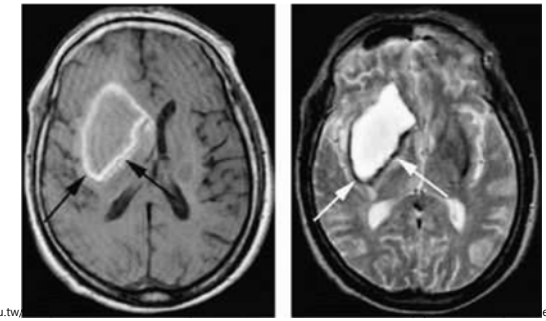


T2-FLAIR is a better choice

Axial Brain Images

- A right basal ganglia acute hypertensive hemorrhage (isointense on T1 and birght on T2-oxyhemoglobin)
- Arrows: a rim of bright T1 and dark T2 represents a more temporally advanced intracellular methemoglobin

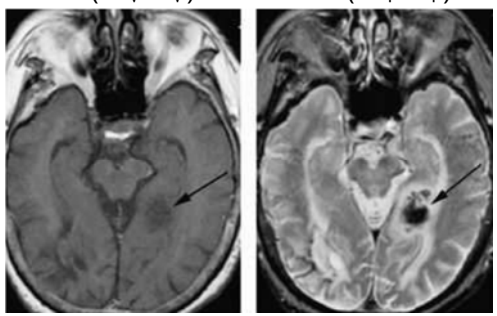
T1W(TR↓ TE↓) T2W(TR↑ TE↑)



Axial Brain Images

- An acute left medial temporal intraparenchymal hematoma (dark on T1 and T2-deoxyhemoglobin).

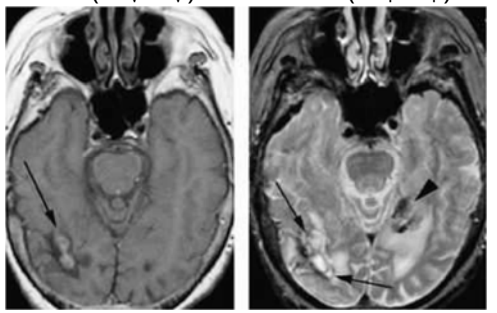
T1W(TR↓ TE↓) T2W(TR↑ TE↑)



Axial Brain Images

- A late subacute right occipital hematoma (bright on both T1 and T2-extracellular methemoglobin).

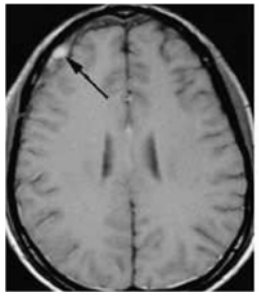
T1W(TR↓ TE↓) T2W(TR↑ TE↑)



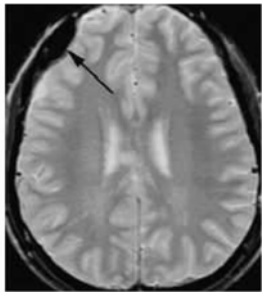
Axial Brain Images

- An early subacute epidural hematoma along the right frontal lobe (bright on T1 and dark on T2-intracellular methemoglobin).

T1W(TR ↓ TE ↓)



T2W(TR ↑ TE ↑)



THE END

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