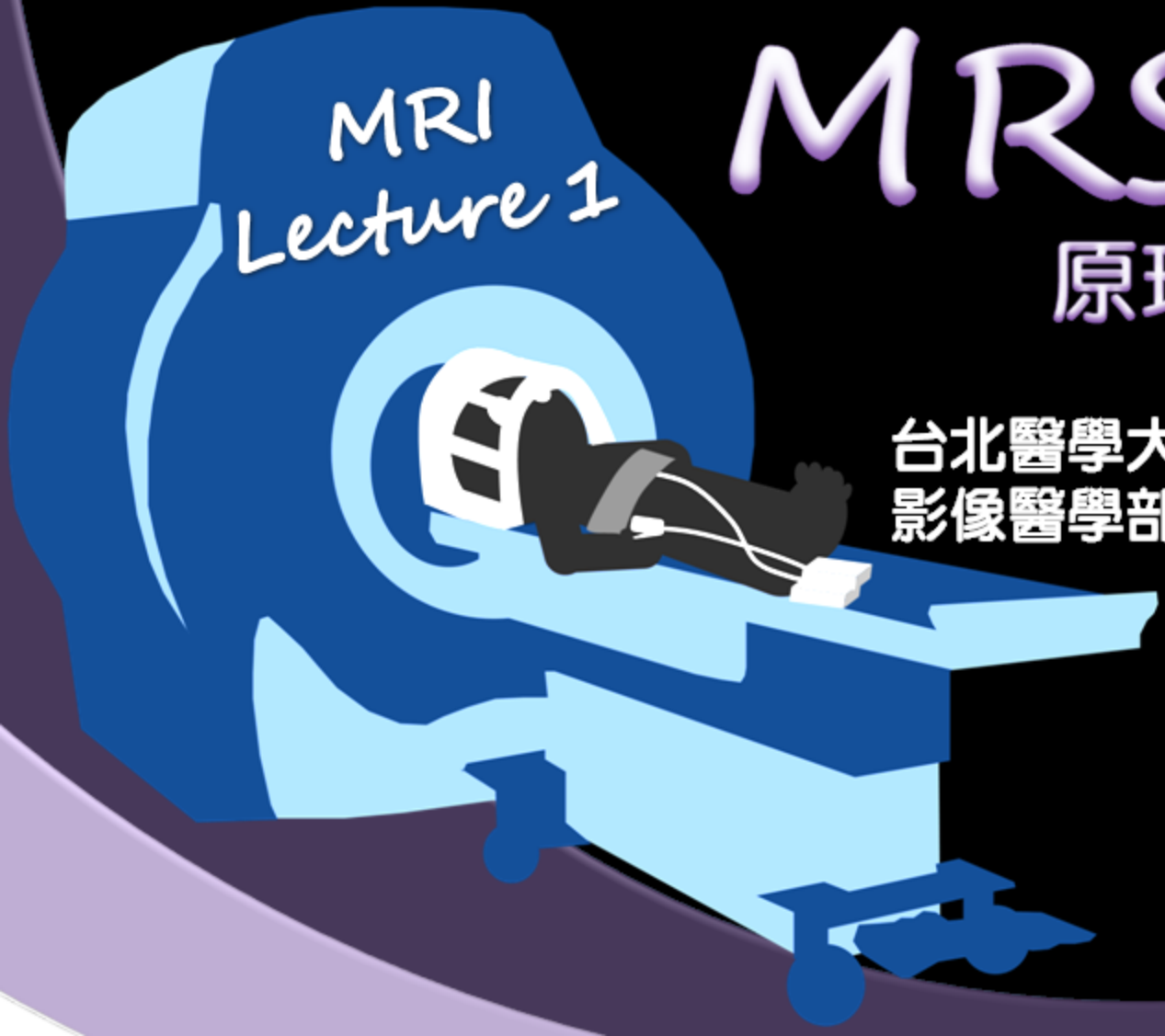
中華民國醫事放射學會

Taiwan Society of Radiological Technologists (TWSRT)



MRI Lecture 1

MRS

原理與臨床應用

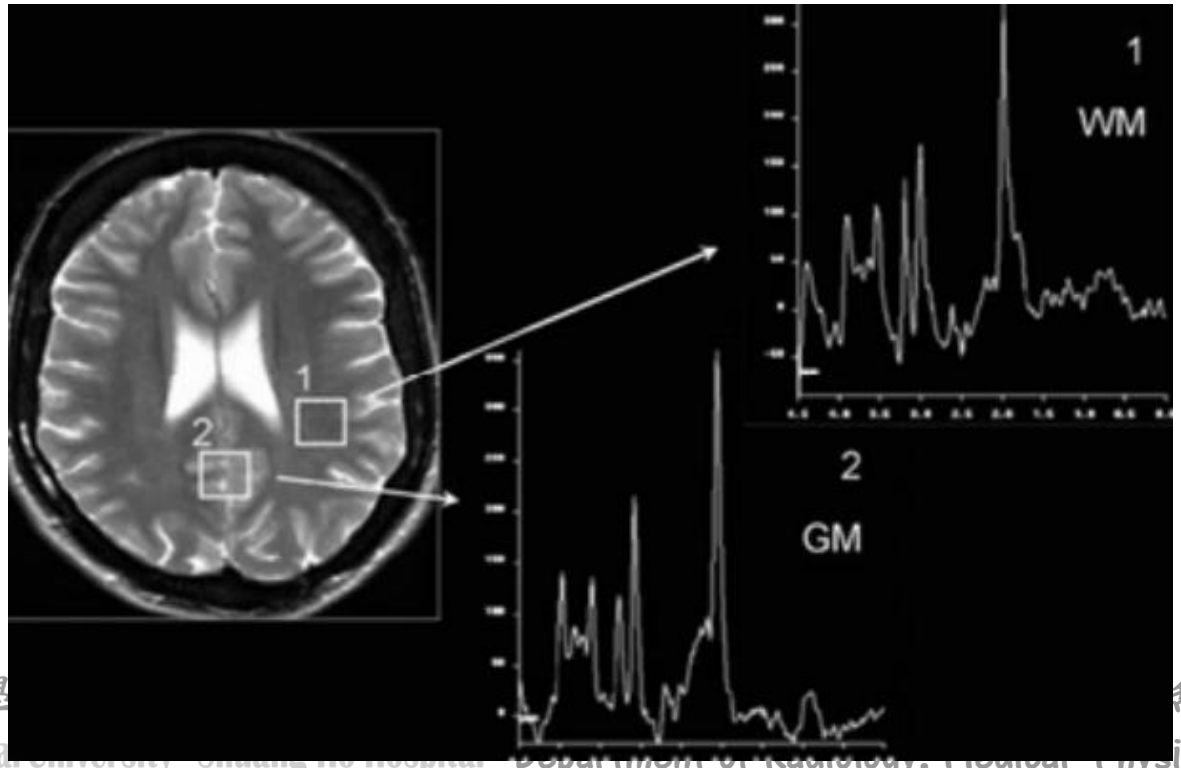
台北醫學大學 — 部立雙和醫院
影像醫學部 醫學物理師 李宜恬

2017.04.16

國泰

What's MR Spectroscopy?

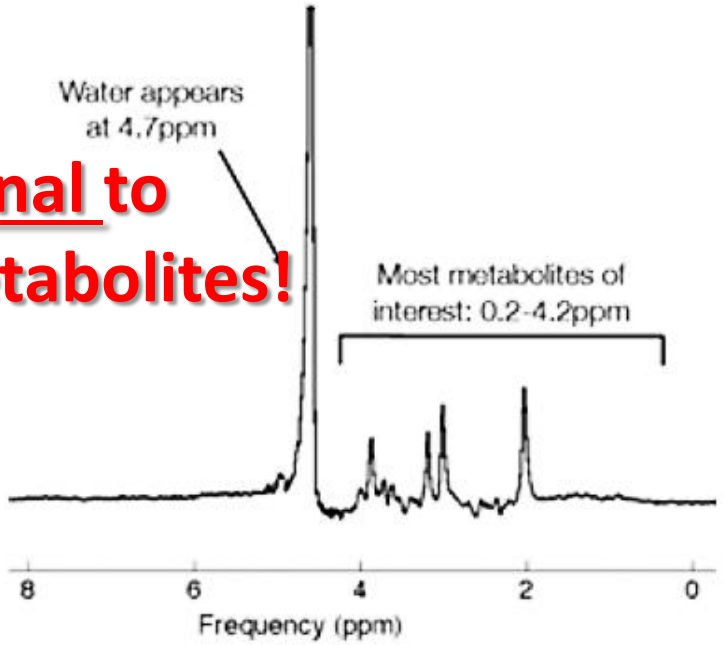
- Rather than providing images, it usually provides spectra consisting of individual peaks, the chemical shift of metabolites.
- Provide bio-chemistry information.



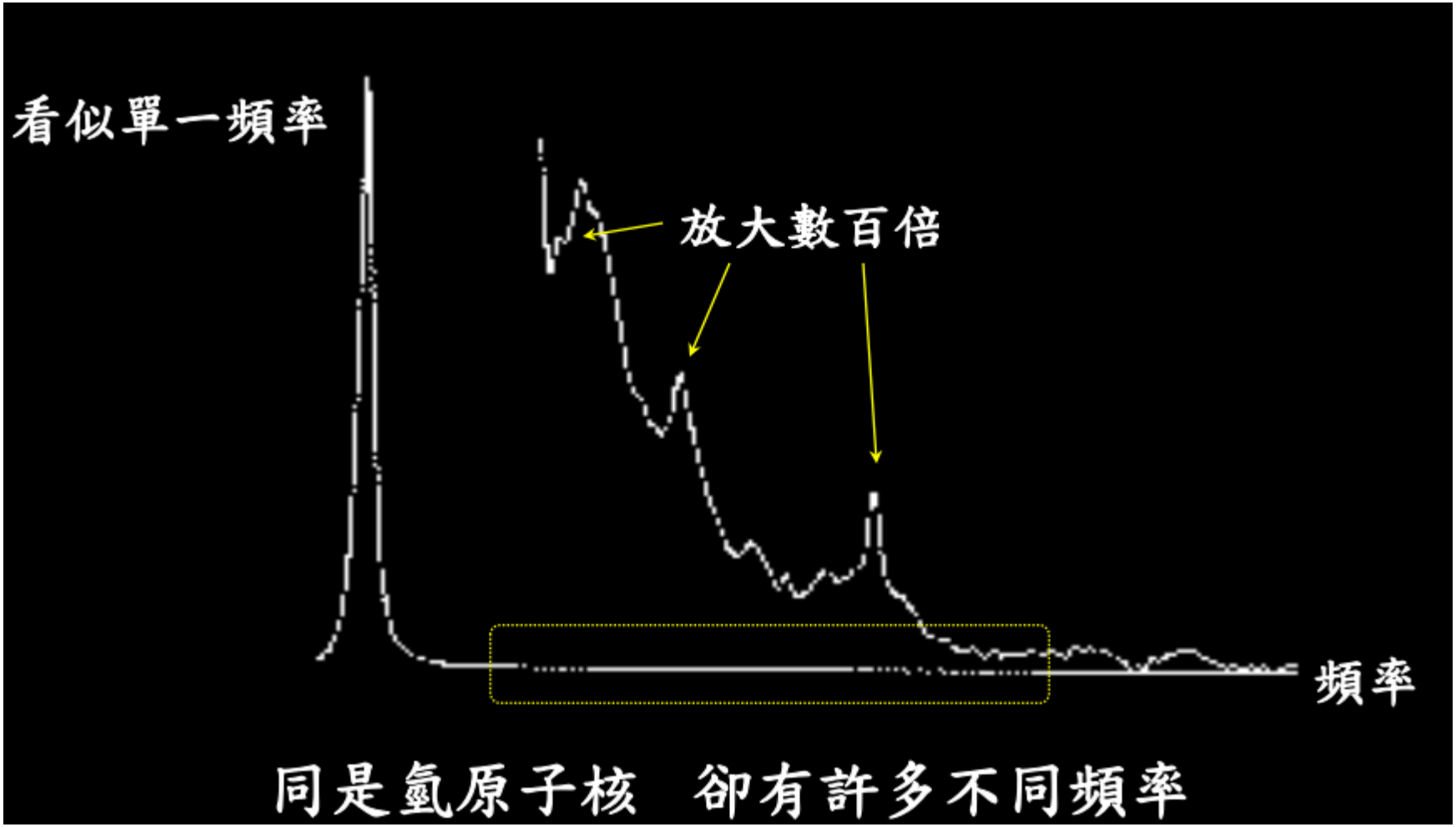
^{1}H (Proton) Spectroscopy

- Proton spectroscopy is easier to perform and provides much higher SNR than either sodium or phosphorus.
- Proton concentration in water ～100M
  Other metabolites: 1～10mM

✓ **Need to suppress the water signal to investigate the signals from metabolites!**

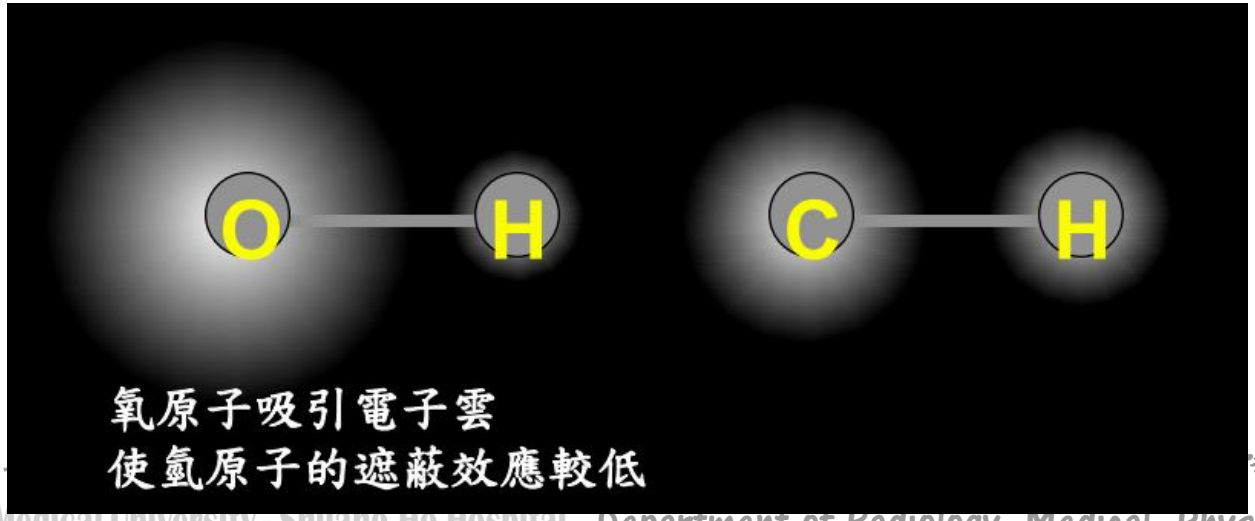


^{1}H (Proton) → Single Frequency?

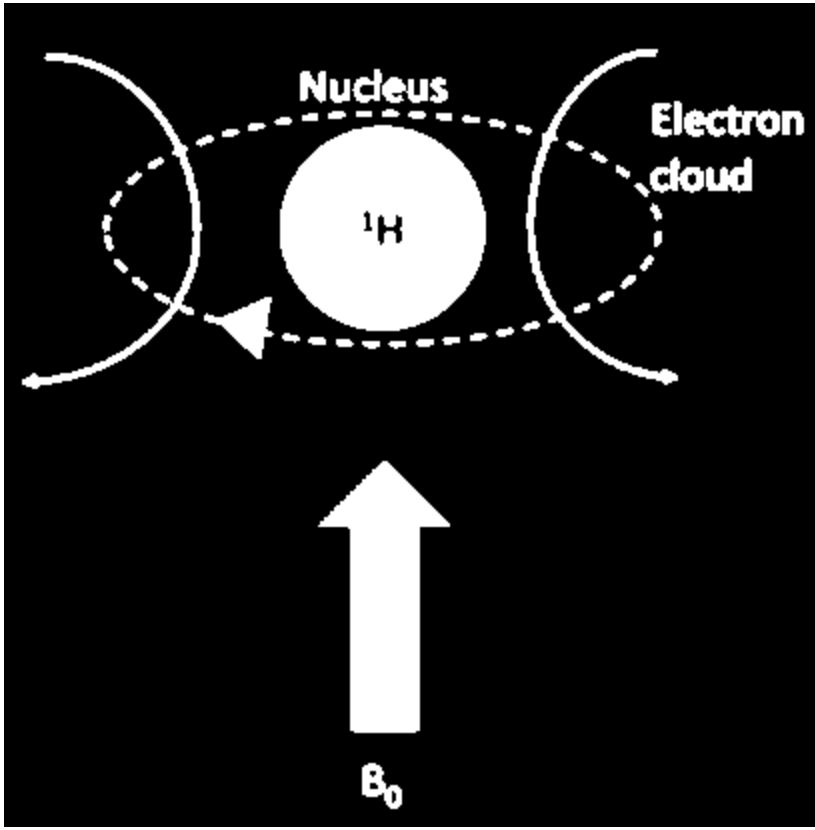


Different frequency?

- Different chemical environment.
- Different atom bonding.
- Electron screening effect (Shielding effect, 電子雲遮蔽效應)
  - Magnetic field weakened → frequency ↓
  - Chemical Shift



Chemical Shift & Shielding Effect

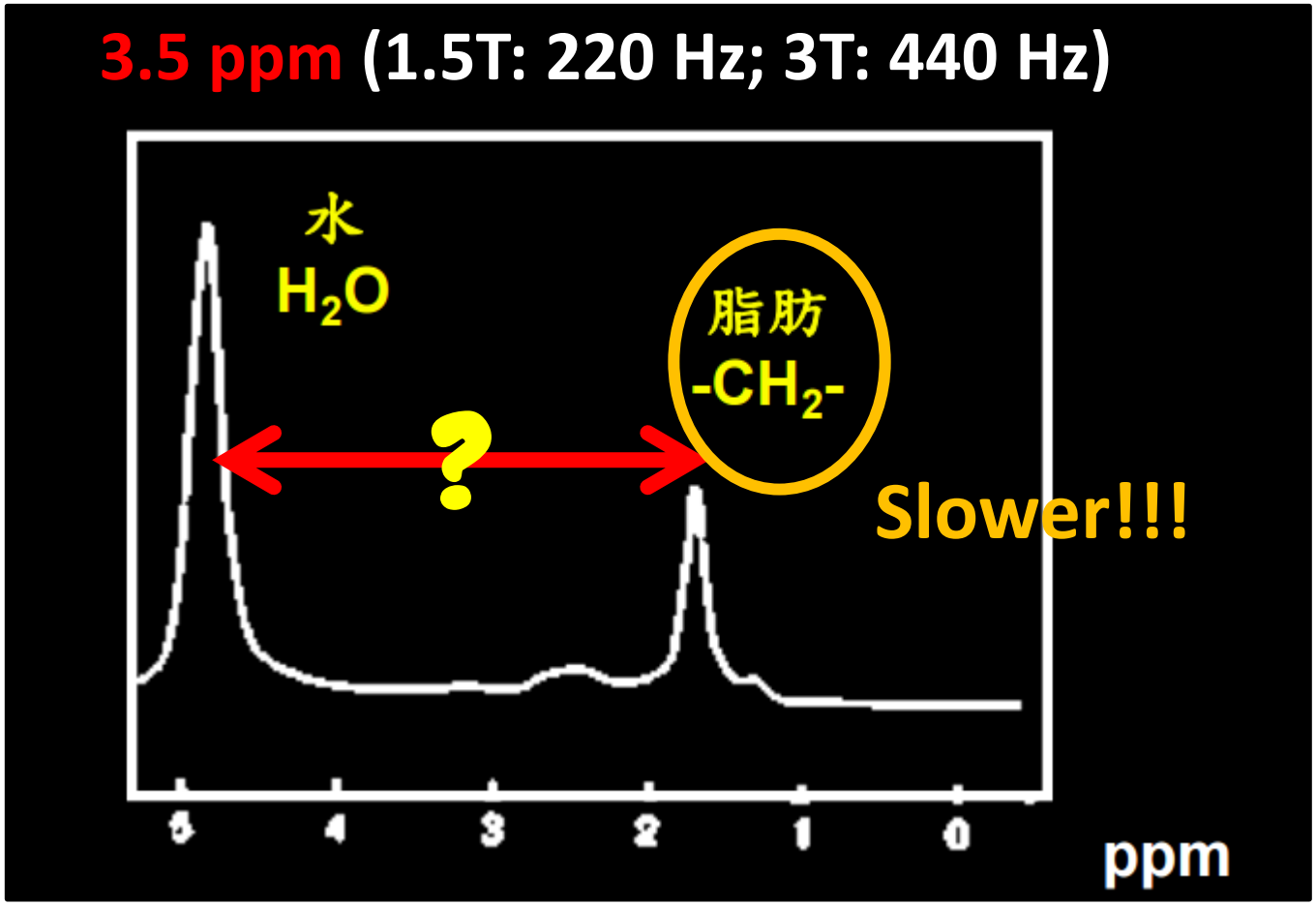


$$B_{local} = -\sigma B_0$$

$$\omega = \gamma B_0(1-\sigma)$$

σ = chemical shift shielding constant

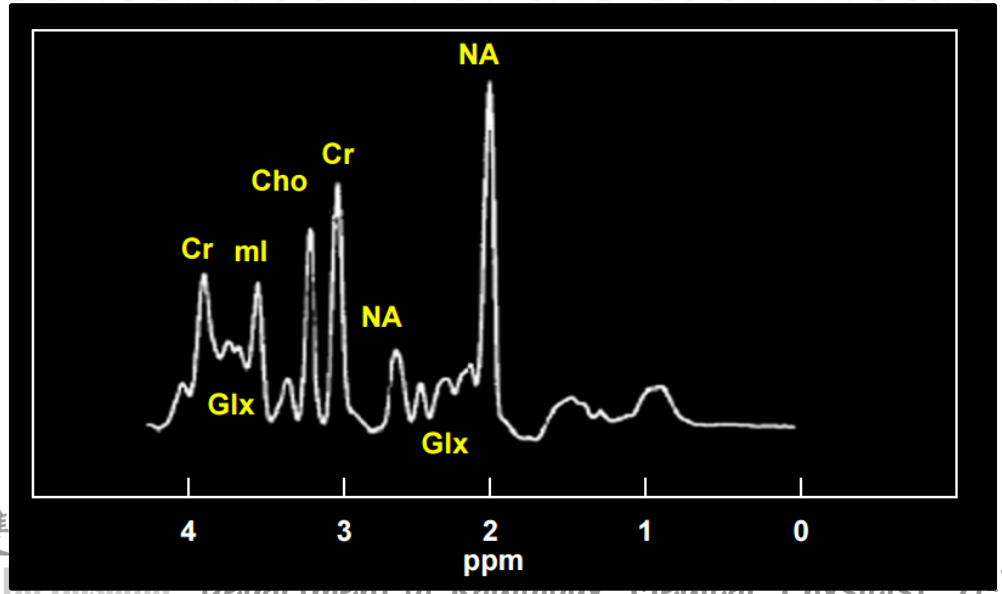
For example: Chemical Shift (Review)



Upper field **Lower field**

MR Spectroscopy

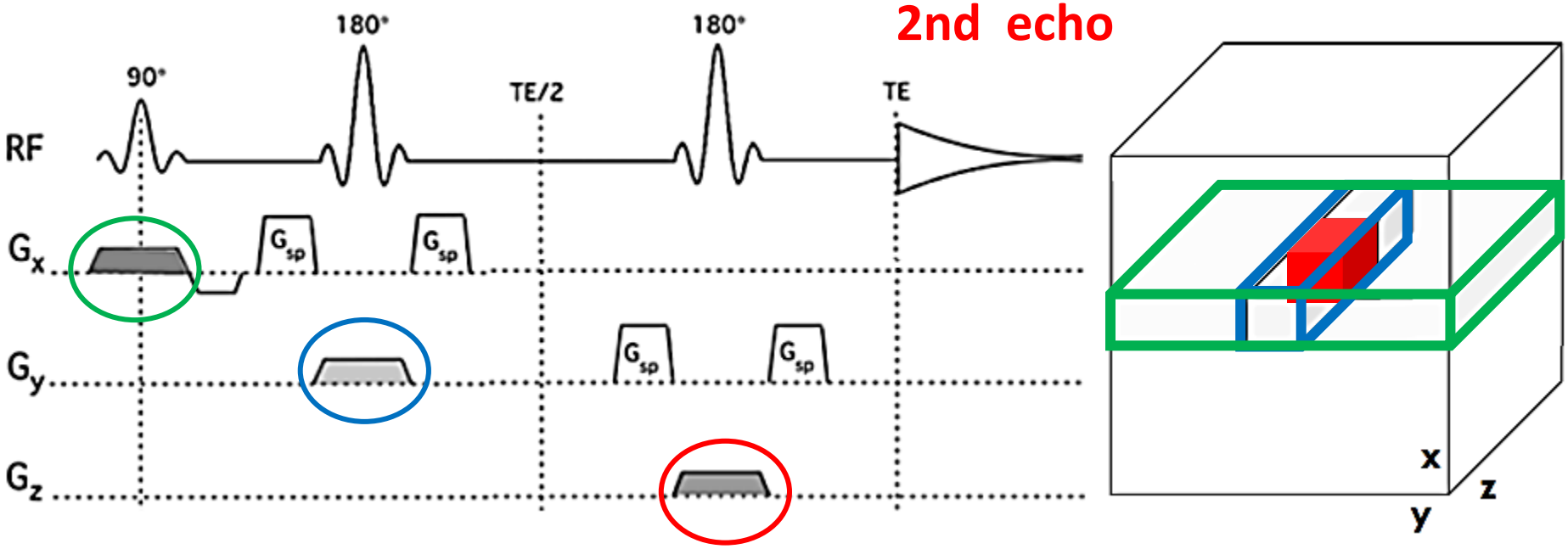
- The area under a given peak is proportional to the number of protons (concentration) contributing to the peak.
- MRS requires a species to be present in at least 1 mM concentration to be seen.
- Quantified the concentration of the each metabolites!



MRS pulse sequence

- **L**ocalization: Covering lesion and normal sites for comparison
- Two major sequences
- **P**oint-**Res**olved **S**pectroscopy, PRESS
- **St**imulated **E**cho **A**cquisition **M**ode, STEAM

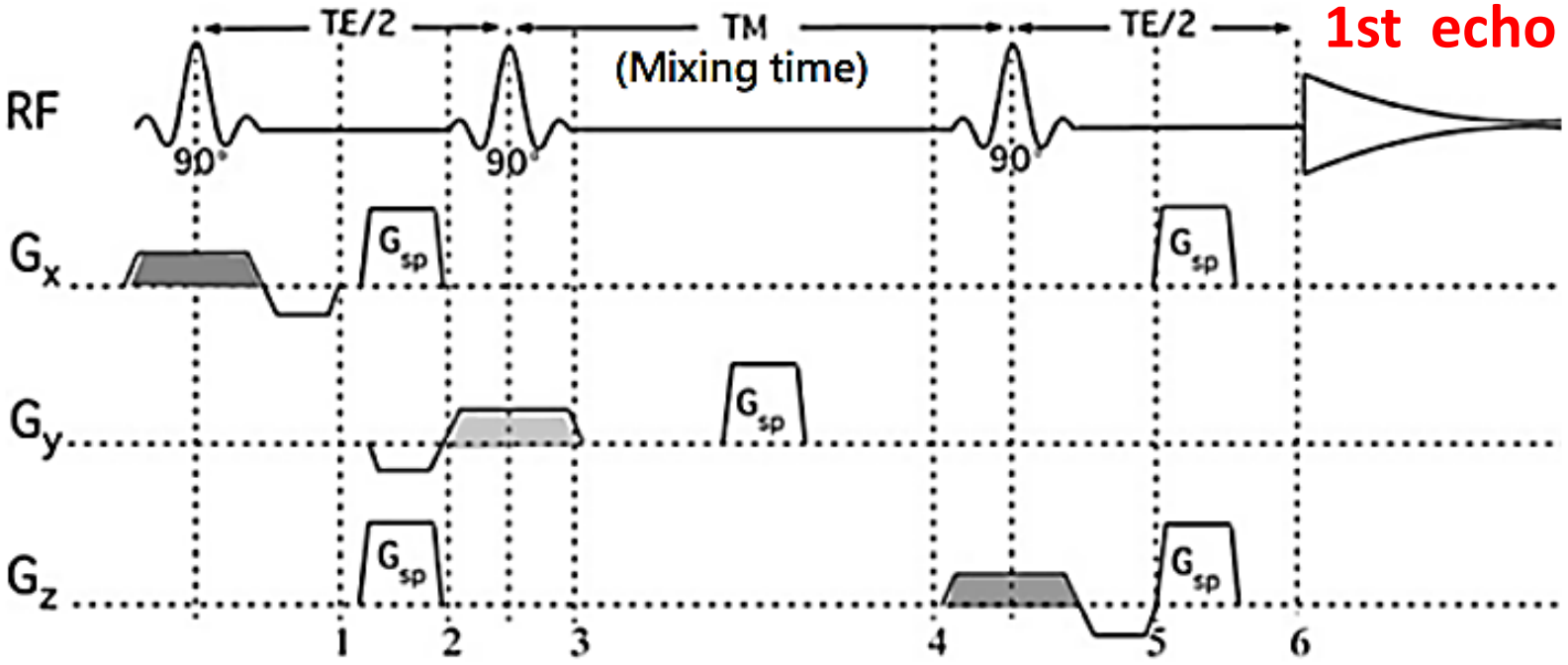
Point-Resolved Spectroscopy (PRESS)



- Dual spin-echo sequence consisting of 3 slice selective pulses in orthogonal planes (90-180-180)
- Signal comes from the intersection of the 3 planes!
- But….TE too long!! (Can't see short T_2 metabolites)

臺北醫學大學・部立雙和醫院 影像醫學部 醫學物理師 李宜恬
Taipei Medical University - Shuang Ho Hospital Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)

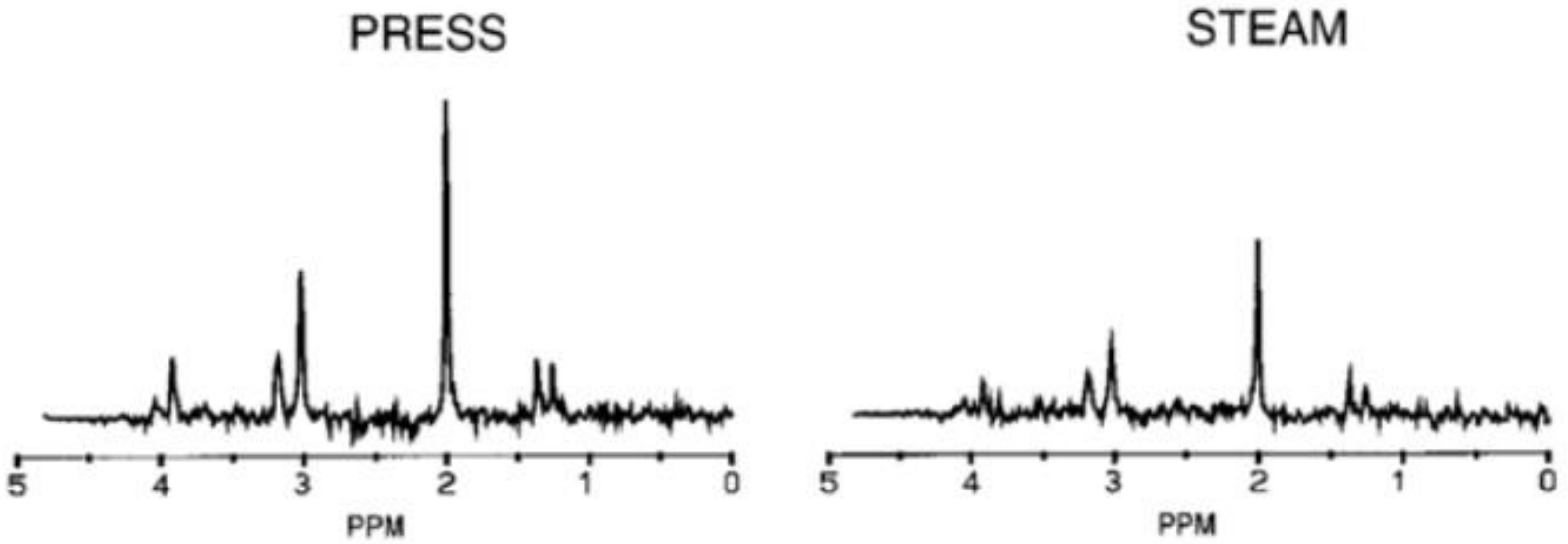
Stimulated Echo Acquisition Mode (STEAM)



- Consists of three orthogonally slice selective 90 pulses
- Separate 180 to 90 + 90 (90 -90-90)
- T_2 decay does not occur during TM
- But SNR decreased due to incompleted refocusing!!

PRESS vs. STEAM

- Stimulated echo amplitude is only half the size of a PRESS spin echo.



PRESS vs. STEAM

- Stimulated echo amplitude is only half the size of a PRESS spin echo.

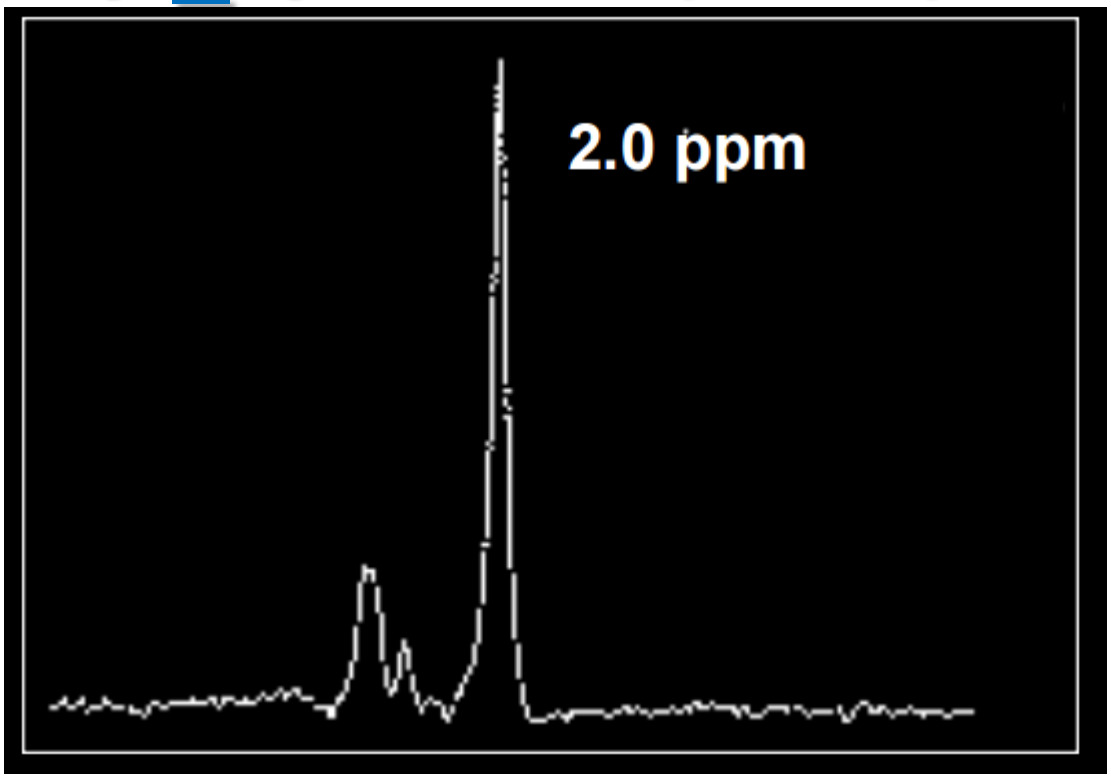
	PRESS	STEAM	Note
SNR	S	S/2	PRESS SNR 2x STEAM SNR
TE	Short TE difficult	Short TE possible	STEAM: Better for metabolites with short T2
SAR	High	Low	90 transmit lower power than 180
Location	Sharp	Sharper	90 pulses have sharper profiles than 180s

Short T_2 Metabolites

- Short T_2 → Wide Spectrum

- Wide spectrum → Wide bandwidth → dephasing faster → Short T_2

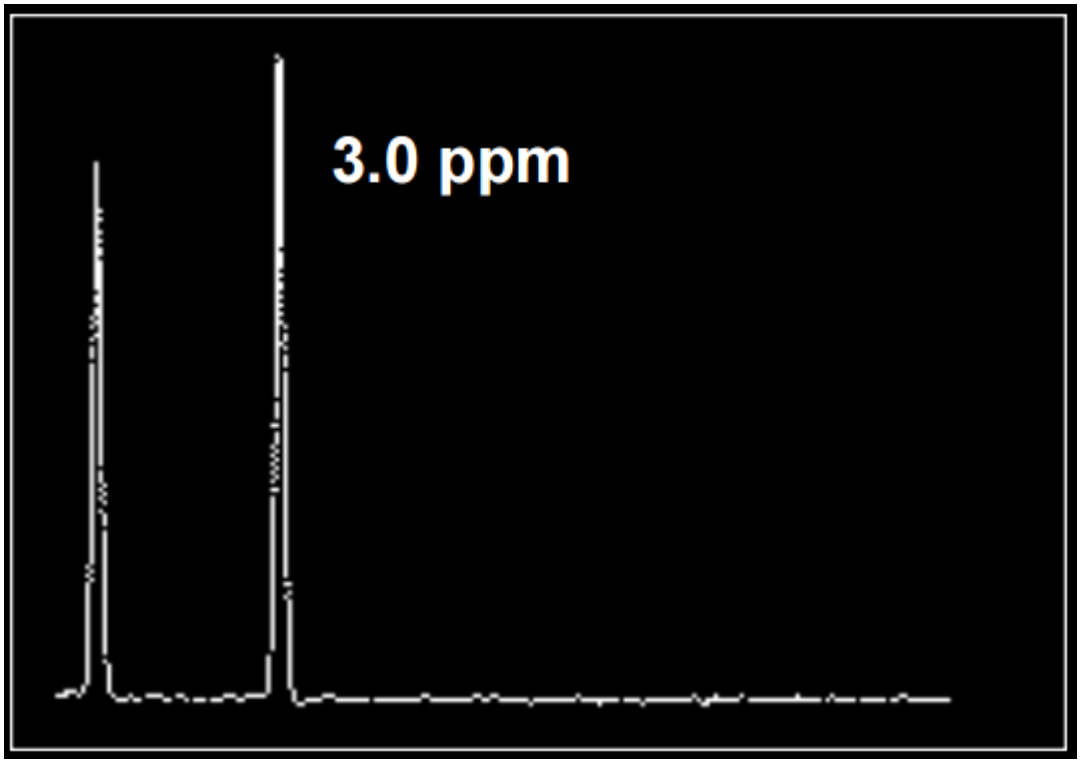
N-acetylaspartate (NAA) : Long T_2



- A neuronal marker
- Register marker: Adjust the frequency shift across subject and session.

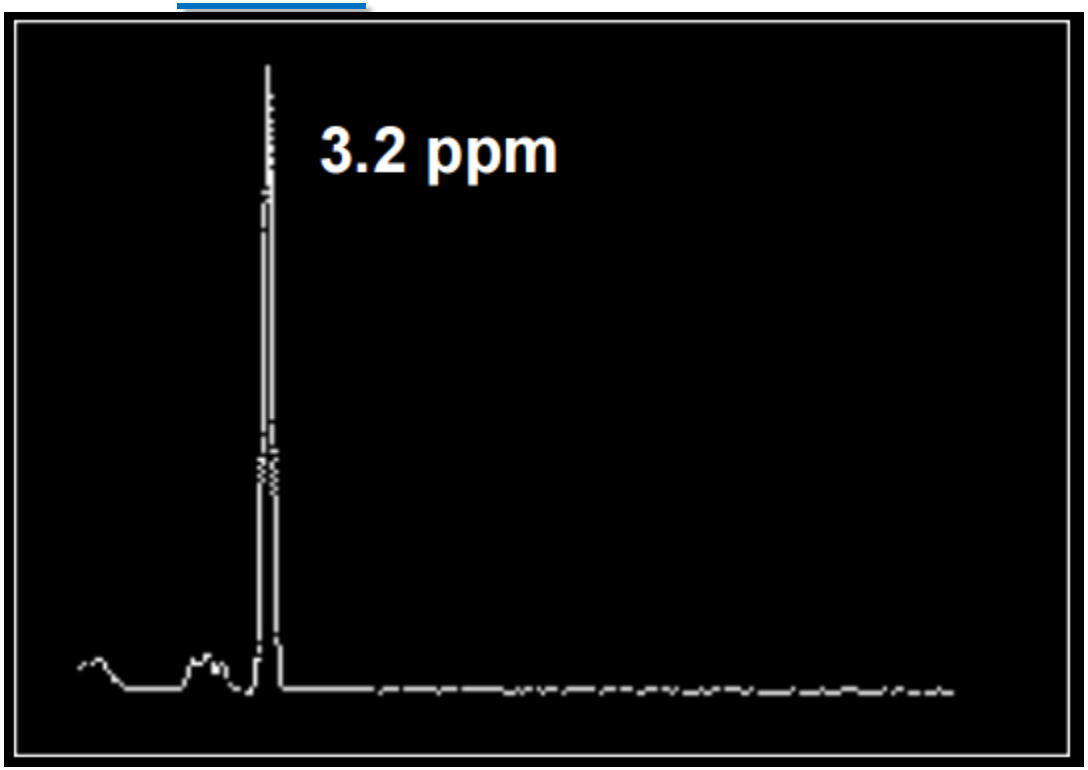
臺北醫學大學・部立雙和醫院 影像醫學部 醫學物理師 李宜恬
Taipei Medical University - Shuang Ho Hospital Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)

Cr/ PCr: Long T_2



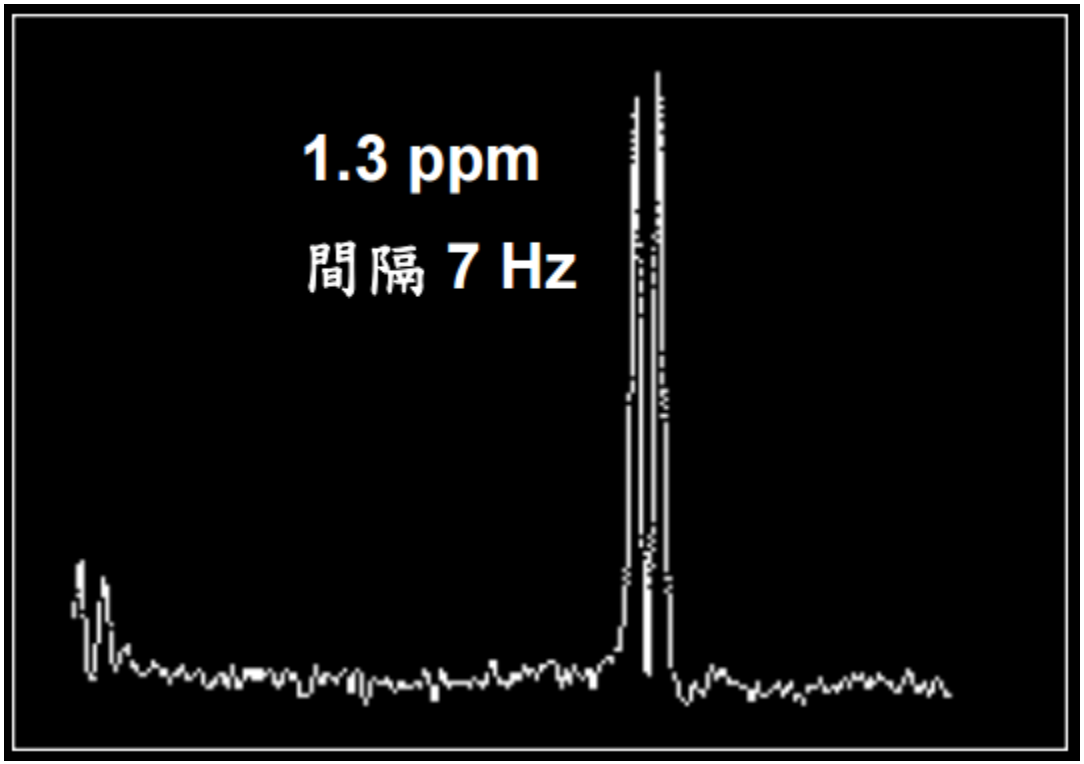
- Provide Phosphate

Choline: Long T2



- Neurotransmitter (Acetylcholine) and others.

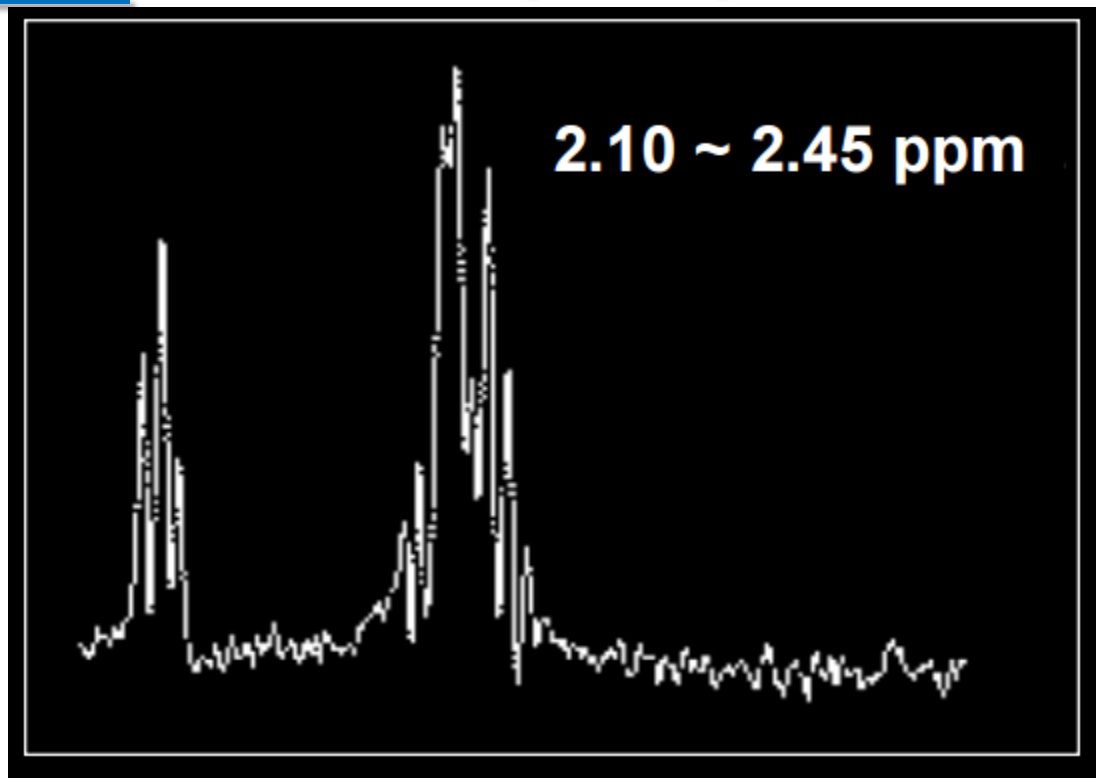
Lactate: Long T2



- Product of anaerobic metabolism
- **J-coupling**: methyl and methine share a bond → peak splitting (increase with TE)

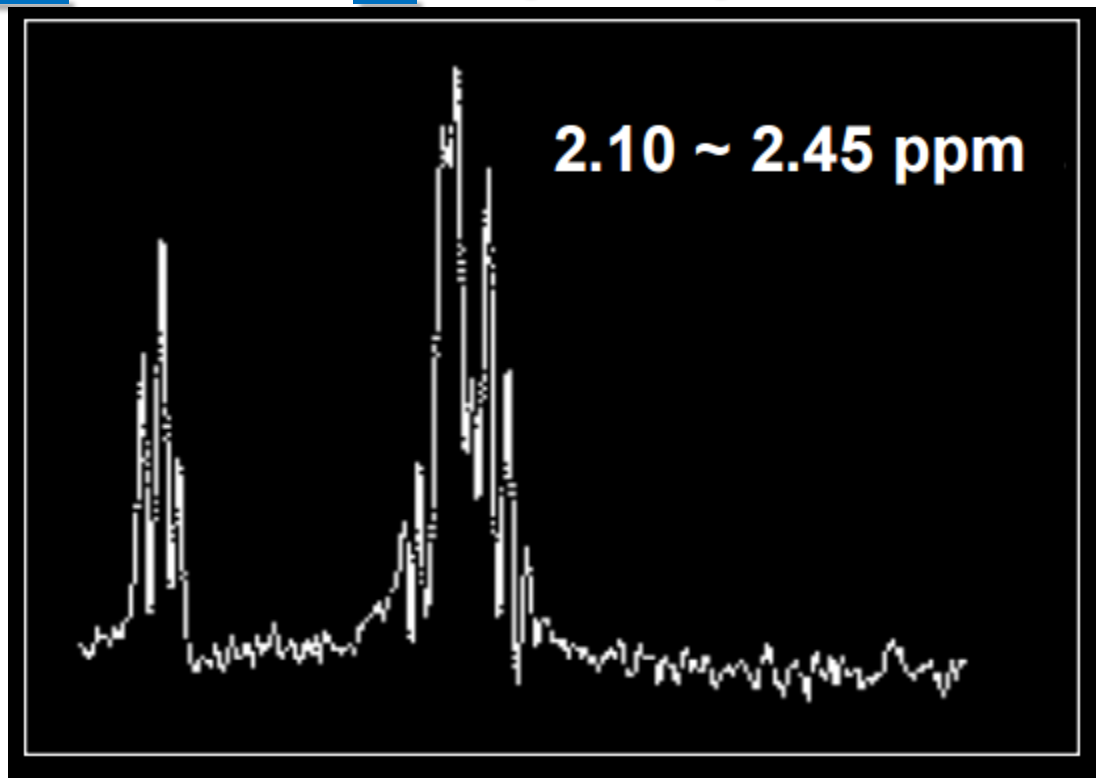
臺北醫學大學・部立雙和醫院 影像醫學部 醫學物理師 李宜恬
Taipei Medical University - Shuang Ho Hospital Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)

Glutamate (Glu): Short T_2



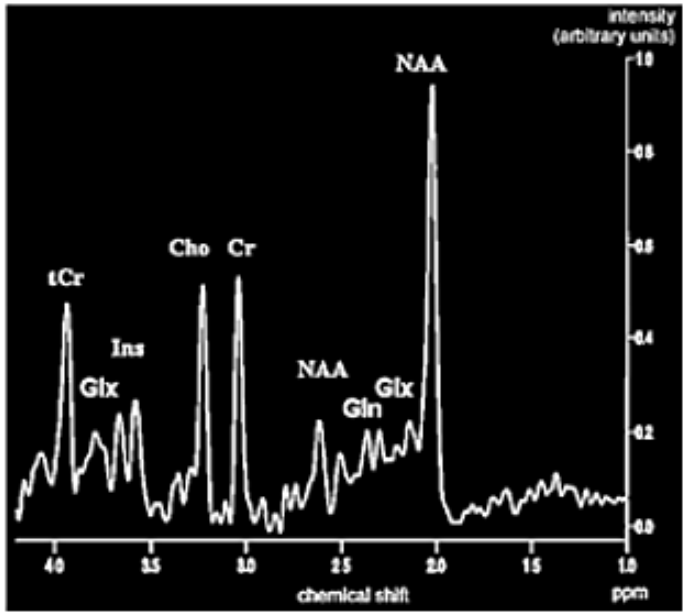
- Excitatory neurotransmitter

Glutamine (Gln): Short T_2



- Product of glutamate

MRS peaks in Brain



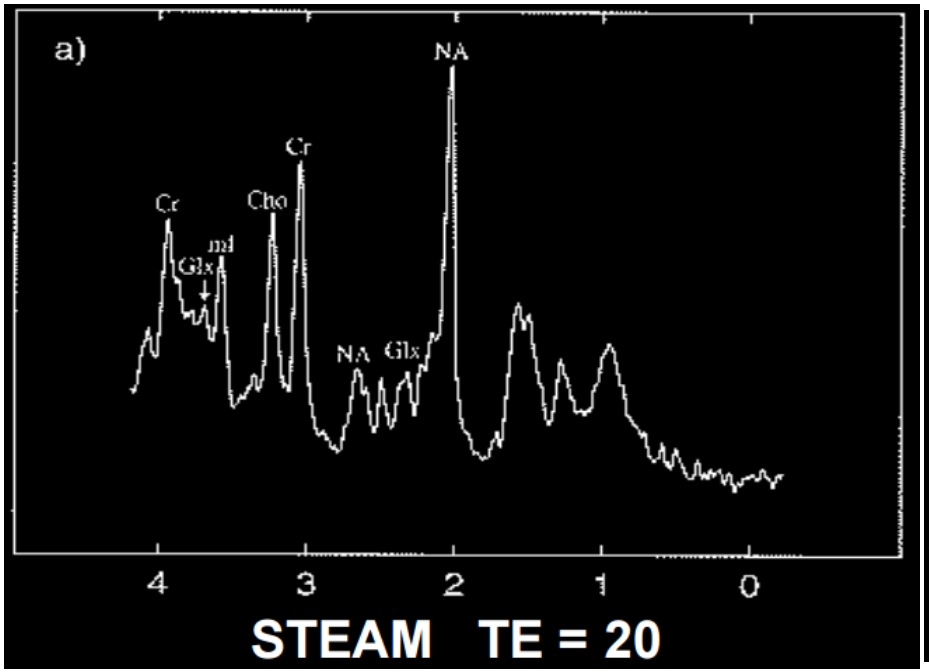
4.0 ppm ← 1.0 ppm

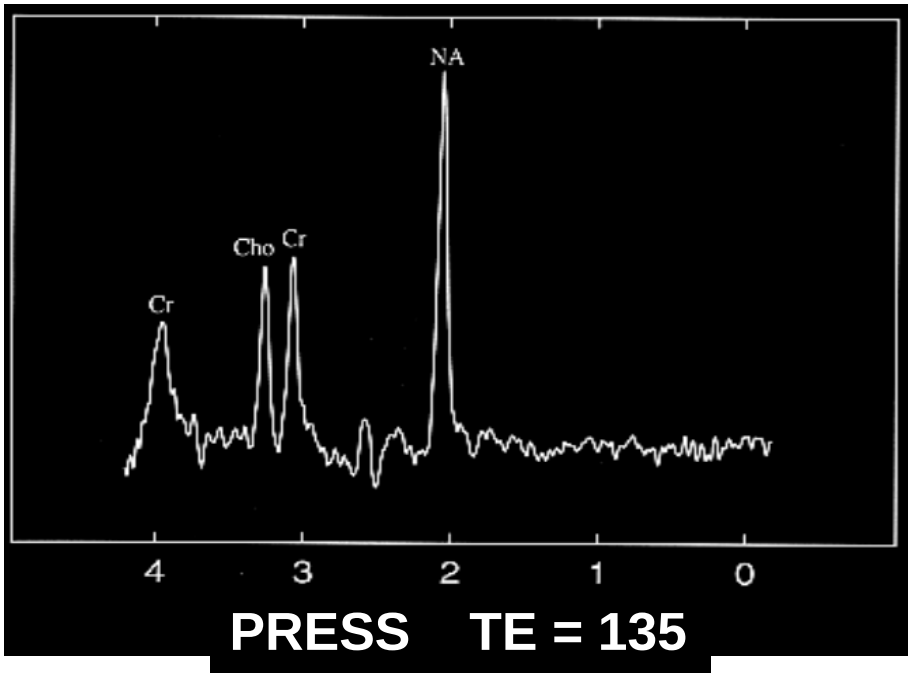
Metabolite	Major Resonance (ppm)	Effect	Visible only at short TE
Lipids (Lip)	0.9, 1.3	Breakdown of tissue	Y
Lactate (Lac)	1.3	Marker of anaerobic glycolysis	N
N-acetyl aspartate (NAA)	2.0	Marker of neuronal health	N
Glutamate/Glutamine (Glx)	2.1, 3.8	Excitatory neurotransmitter	Y
Choline (Cho)	3.2	Marker of membrane metabolism, cell proliferation	N
Creatine (Cr)	3.0	Marker of cellular energetics	N
Myo-inositol (MI or Ins)	3.5, 3.6	glial cell marker	Y

Short T_2 Metabolites

- Short T_2 → Wide Spectrum
- Wide spectrum → Peak Broadening → dephasing faster → Short T_2
- Looks like baseline drift??

Effect of TE





More information!

Specific!

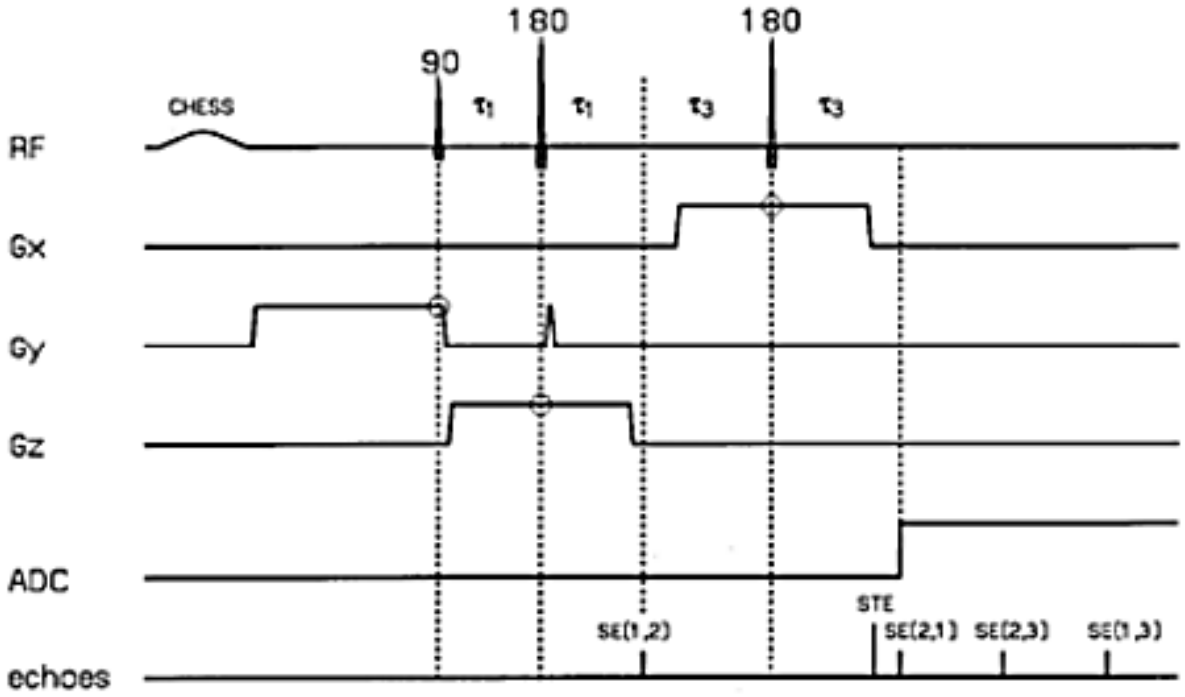
Use PRESS at long TE metabolites could achieve higher SNR!!

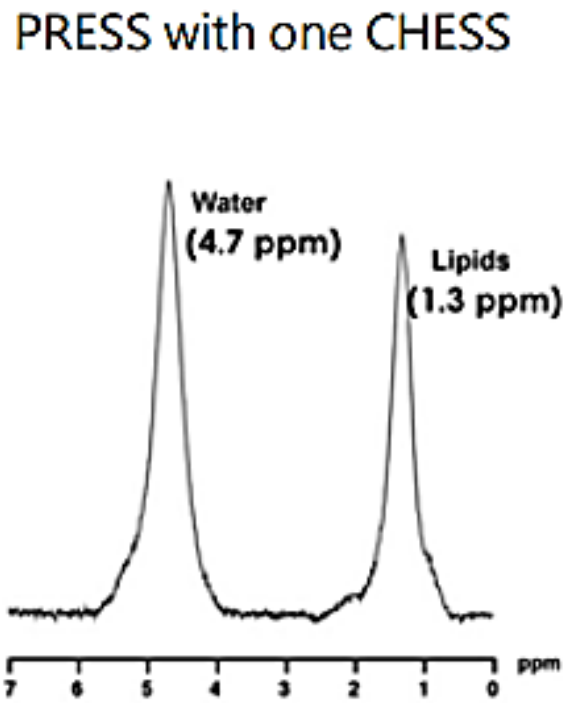
TR & TE in MRS

- Most institutions use a TR of 1500 msec and the shortest possible TE of 30 or 35 ms to **maximize the SNR**.
- This also allows the detection of short T_2 species (like myoinositol and lipid), which would otherwise have already decayed at longer TE.
- Peak width is proportional to $1/T_2$, thus short T2 species will lead to peak broadening.

Water Suppression

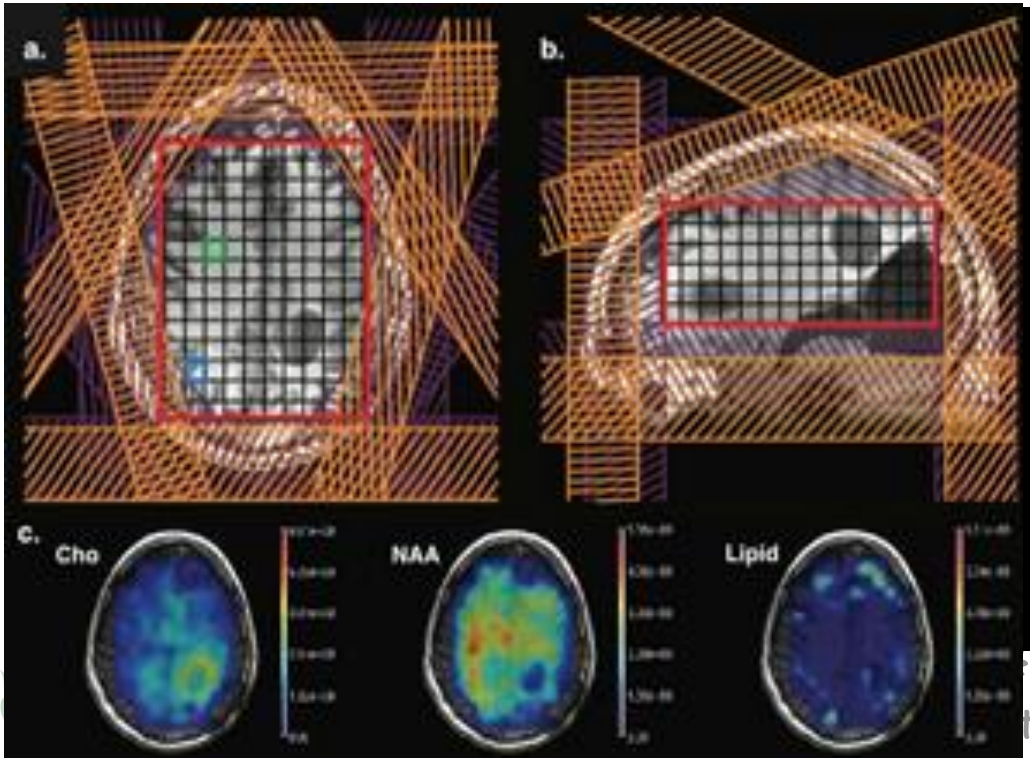
- **Che**mical **S**hift **S**election, CHESS
  - Frequency-selective presaturation pulse

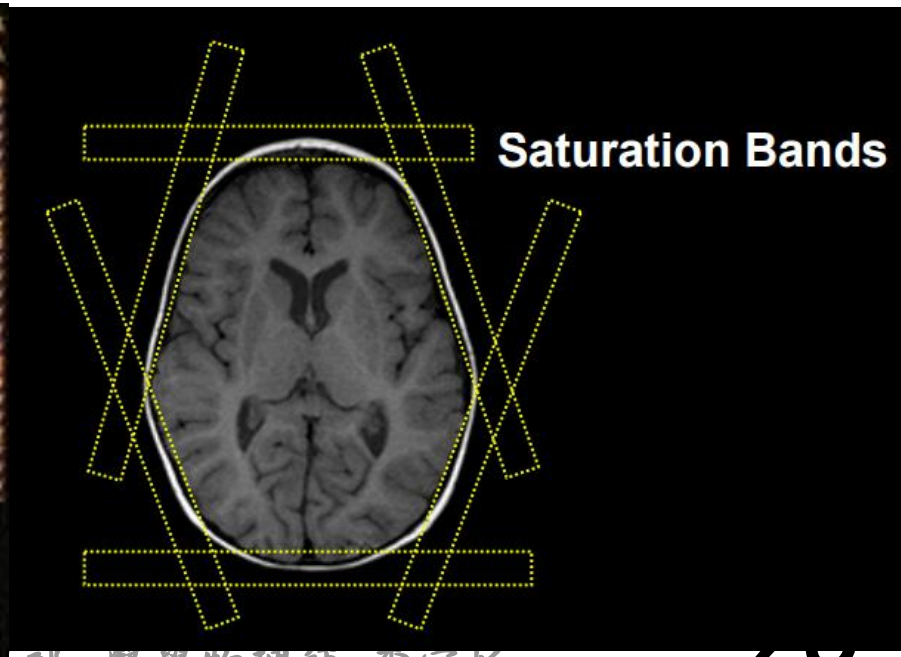




Fat Suppression

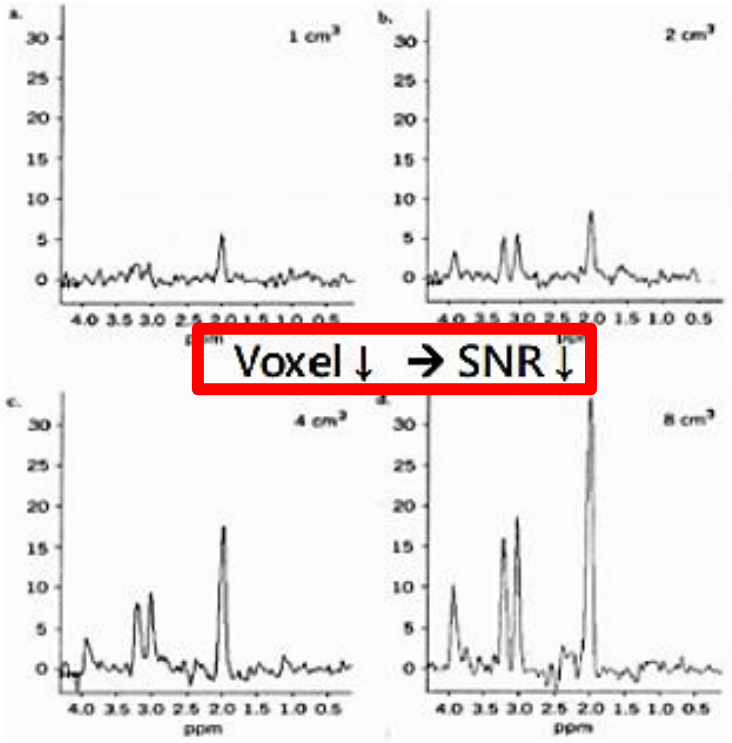
- Add spatial saturation bands
  - **O**uter **V**olume **S**uppression, OVS
- Why we didn't use frequency-selective saturation?





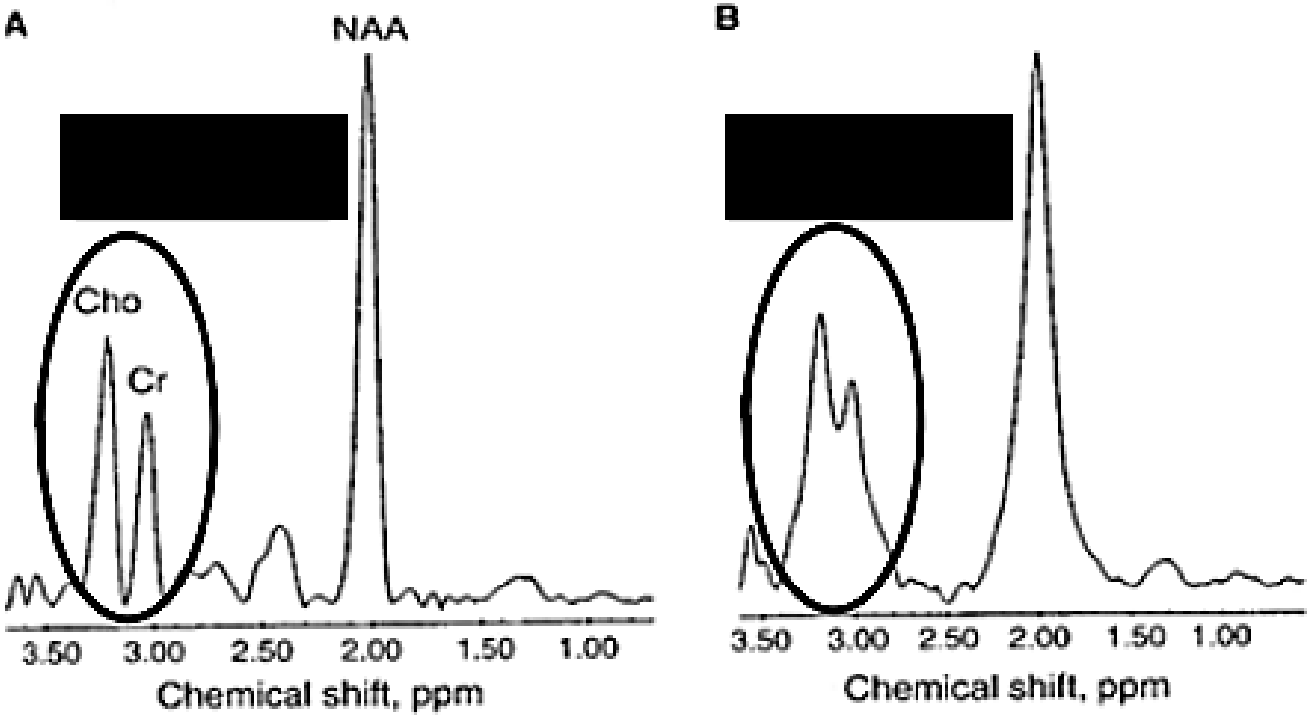
Voxel size of MRS

- MRS (6~15 min) in the brain is generally performed in conjunction with MRI.
- For single voxel techniques, a volume of 8 cc (2x2x2 cm3) is generally recommended at 1.5T.
- Peak height is generally proportional to field strength
  - a smaller voxel can be used at 3 T, reducing partial volume averaging.



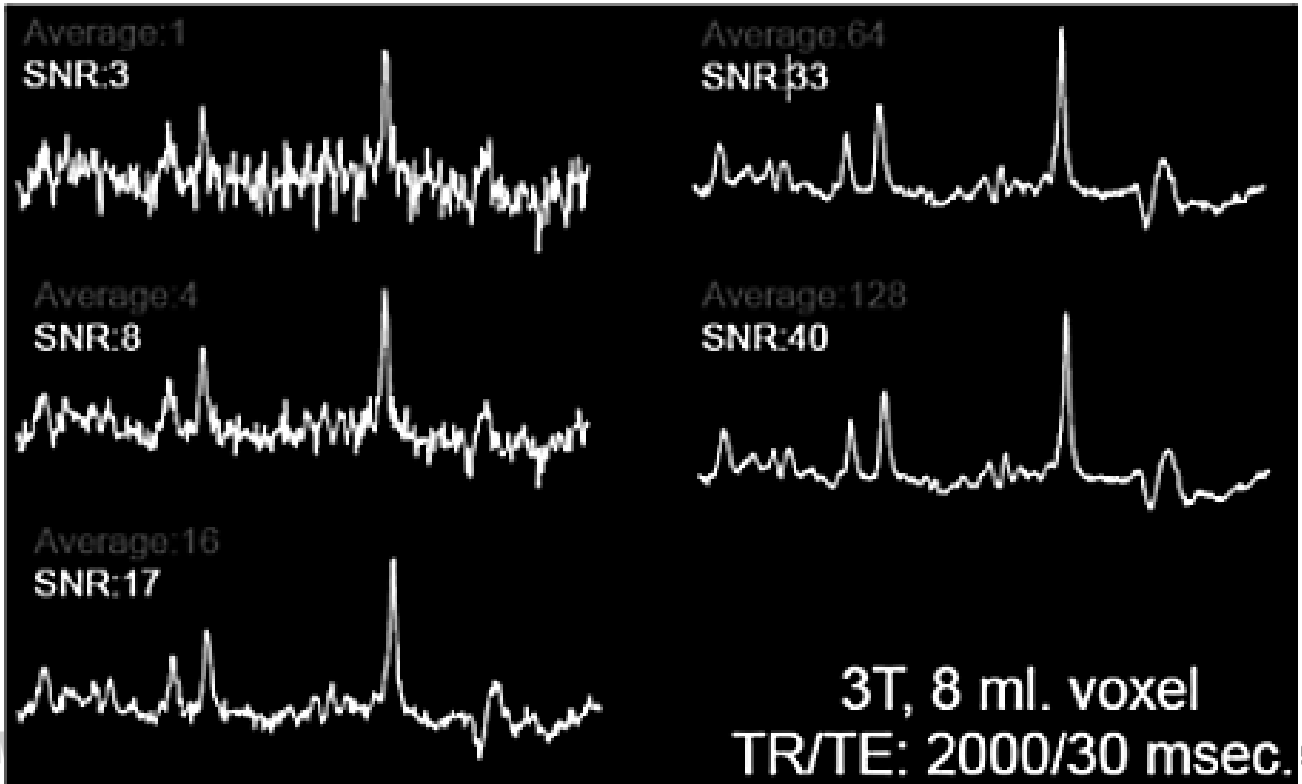
Shimming Requirement for MRS

- Shimming requirement for MRI is usually less than 5 ppm.
- For MRS, shimming results in improving the uniformity from 1 ppm in the main magnetic field to 0.1 ppm inside the voxel.



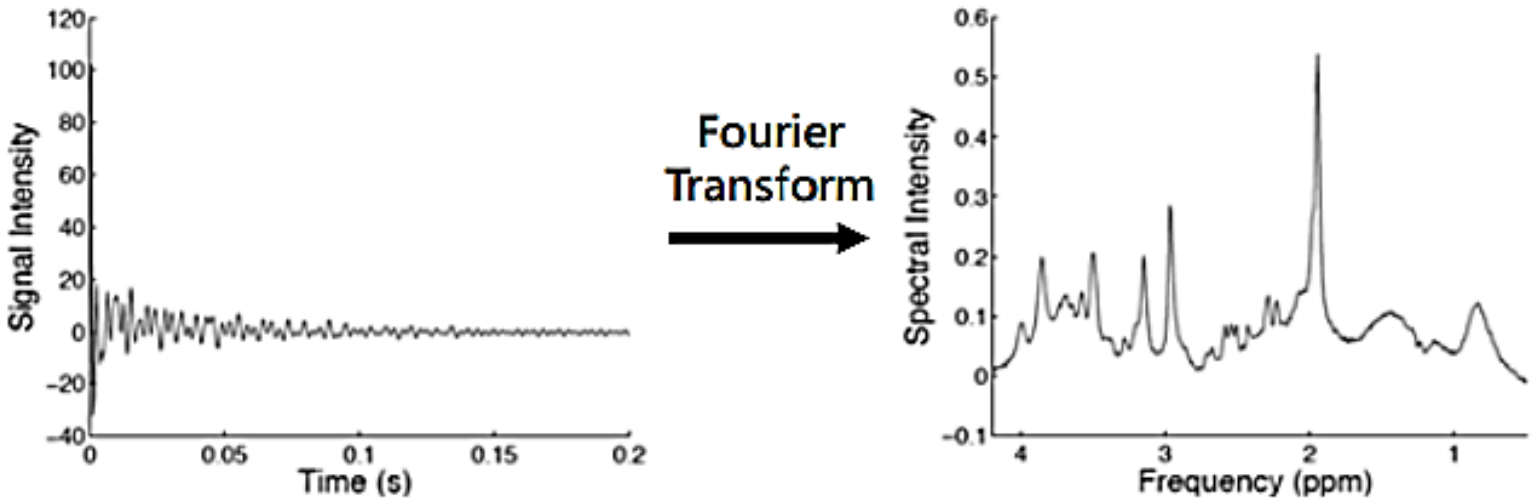
Average & SNR

- Another option to increase SNR is to increase the average (NEX)
- Typically, 64-128 averages are demanded to acquire sufficient SNR for short TE.



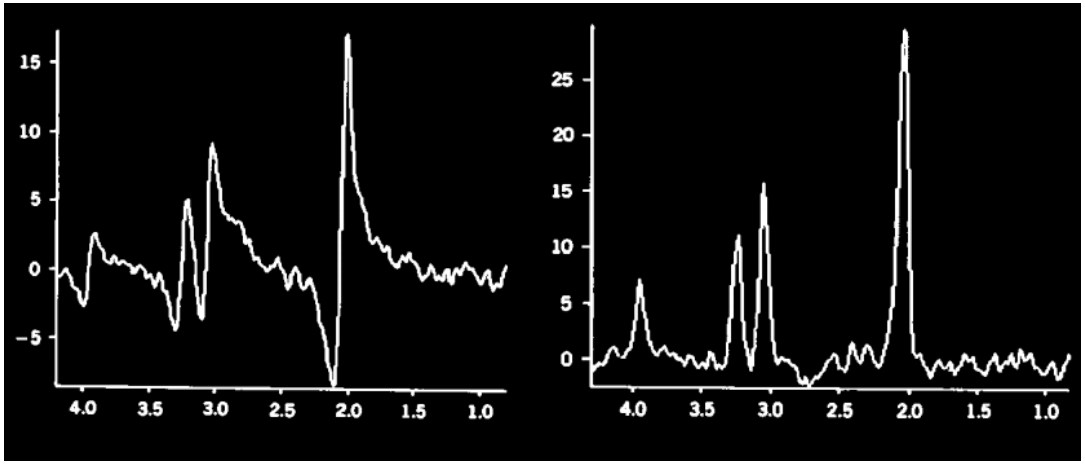
Fourier Transform

- In the simple MRS experiment, no frequency–encoding gradients are applied during the readout for spatial encoding.
- The signal does not contain spatial information, just information of the different resonance frequencies within the sample.



Post Processing

- FID signal processing
  - Water suppression (removing the 4.7 ppm signal)
  - Zero filling (Increase frequency resolution)
  - Apodization (Noise filter)
- Fourier Transform
- Spectrum processing
  - Phase Correction
  - Baseline Correction

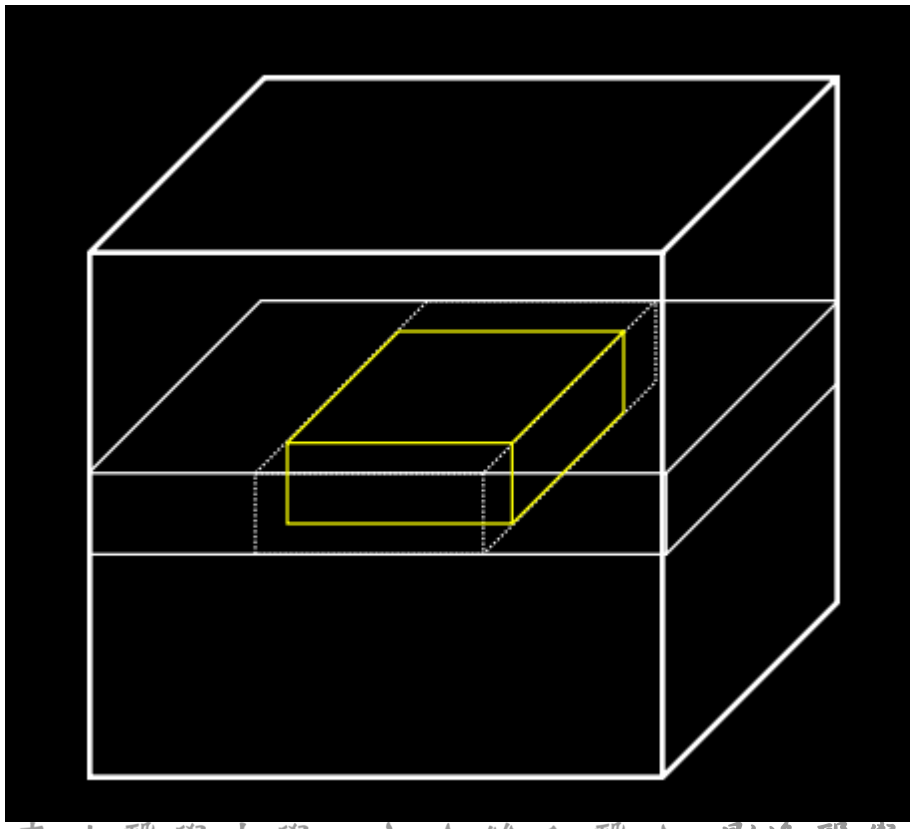


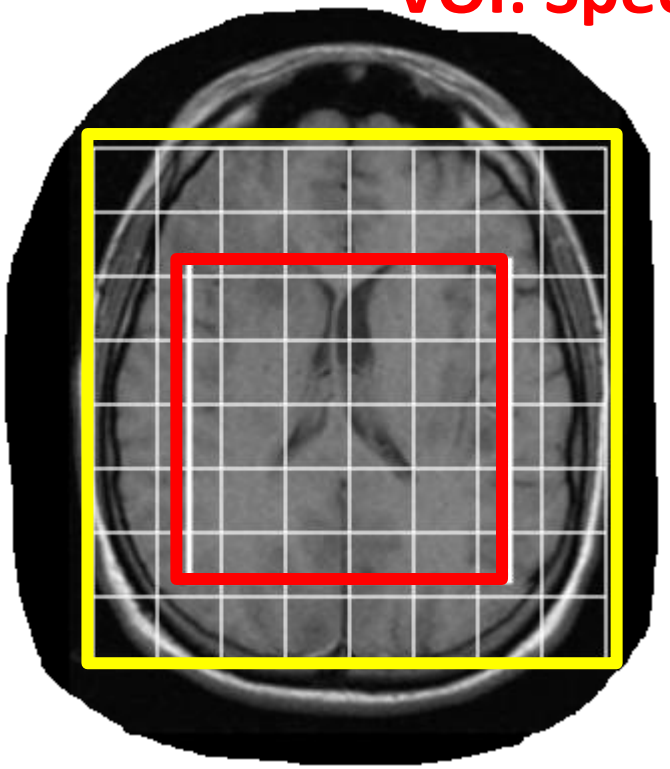
Spectroscopic Imaging (SI)

- Multi-Voxel
- Chemical Shift Imaging (CSI)

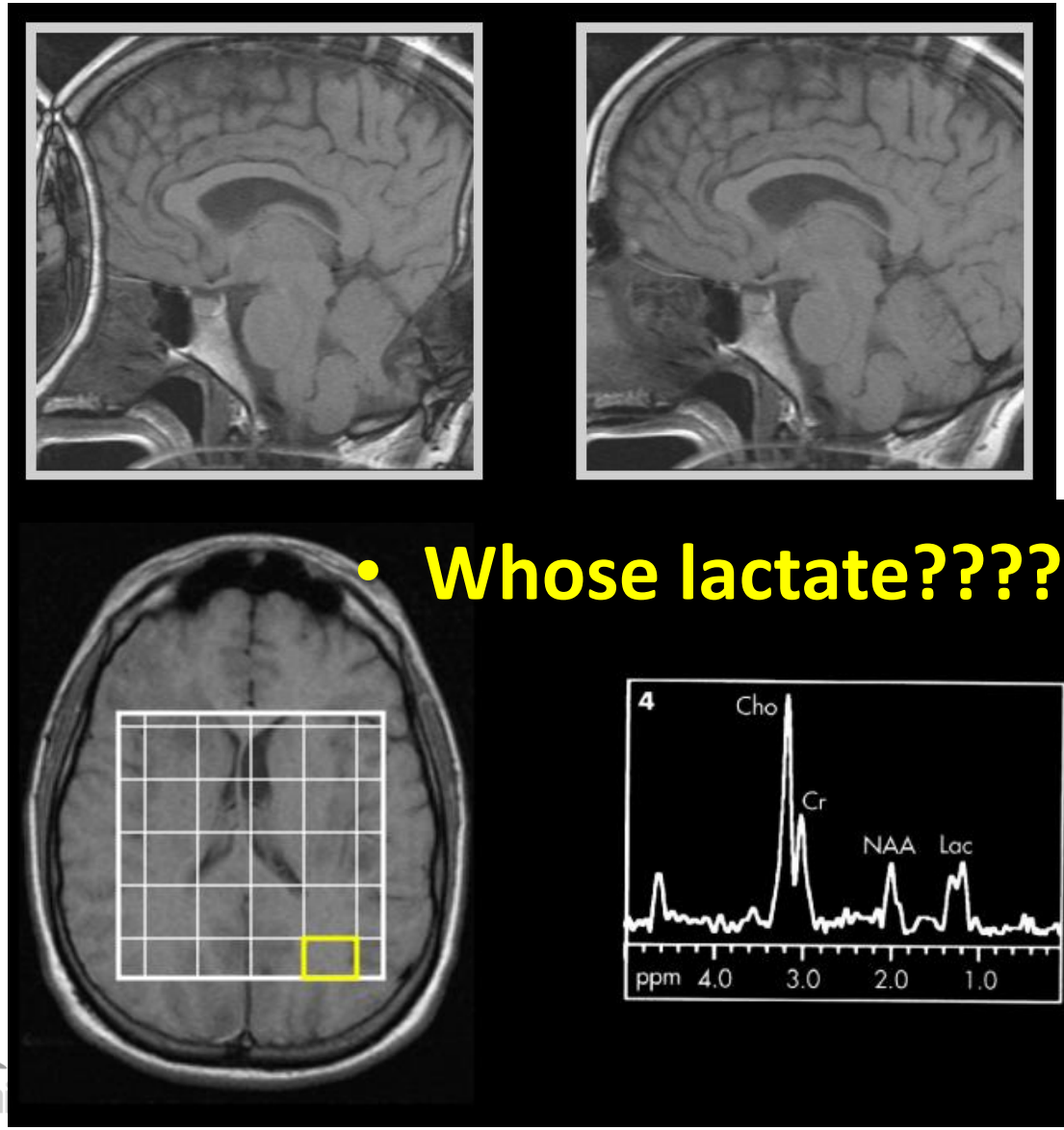
FOV: SNR ↑

VOI: Spectrum



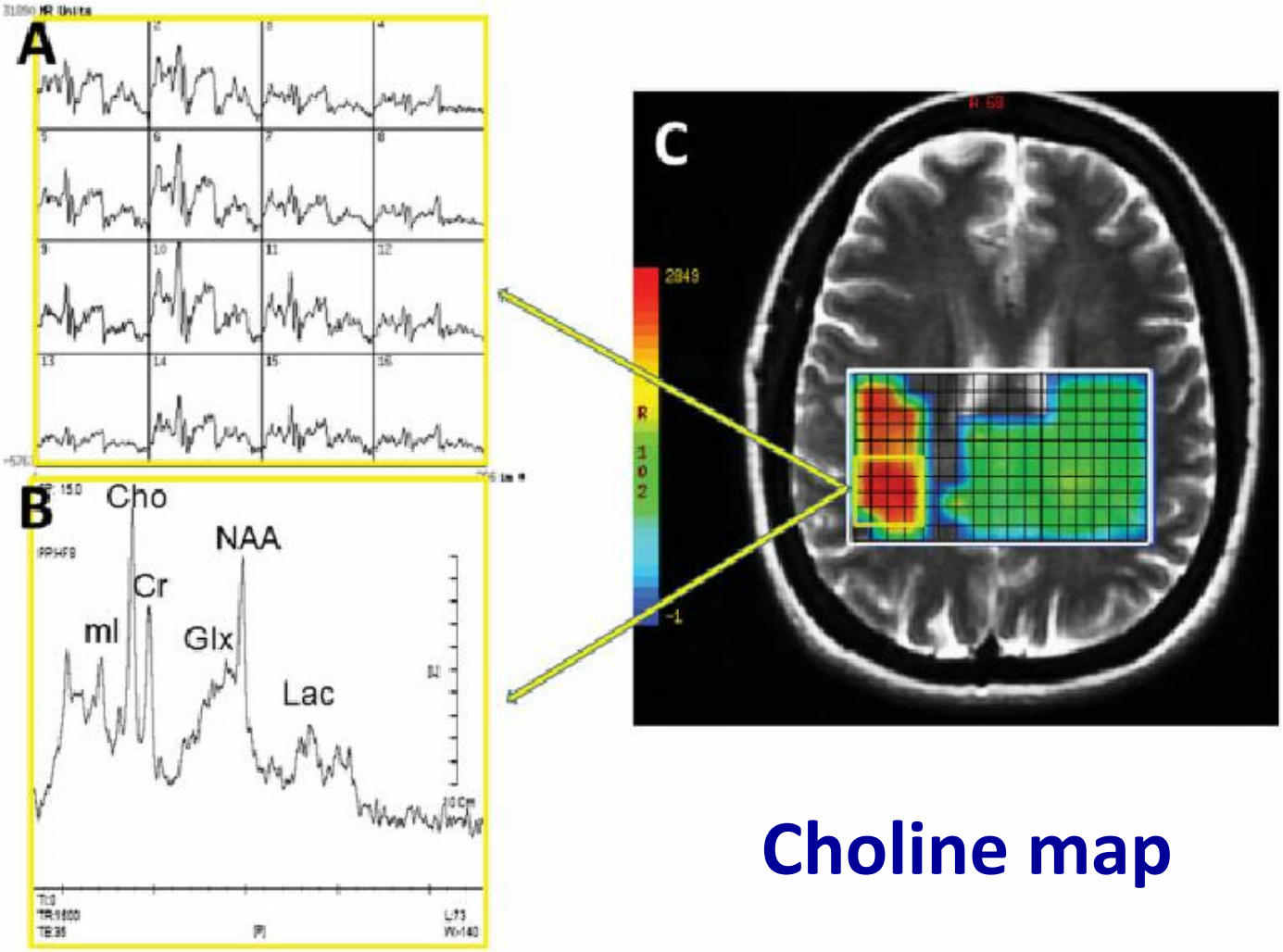


Aliasing Artifact



- Whose lactate????

Metabolite Concentration Map

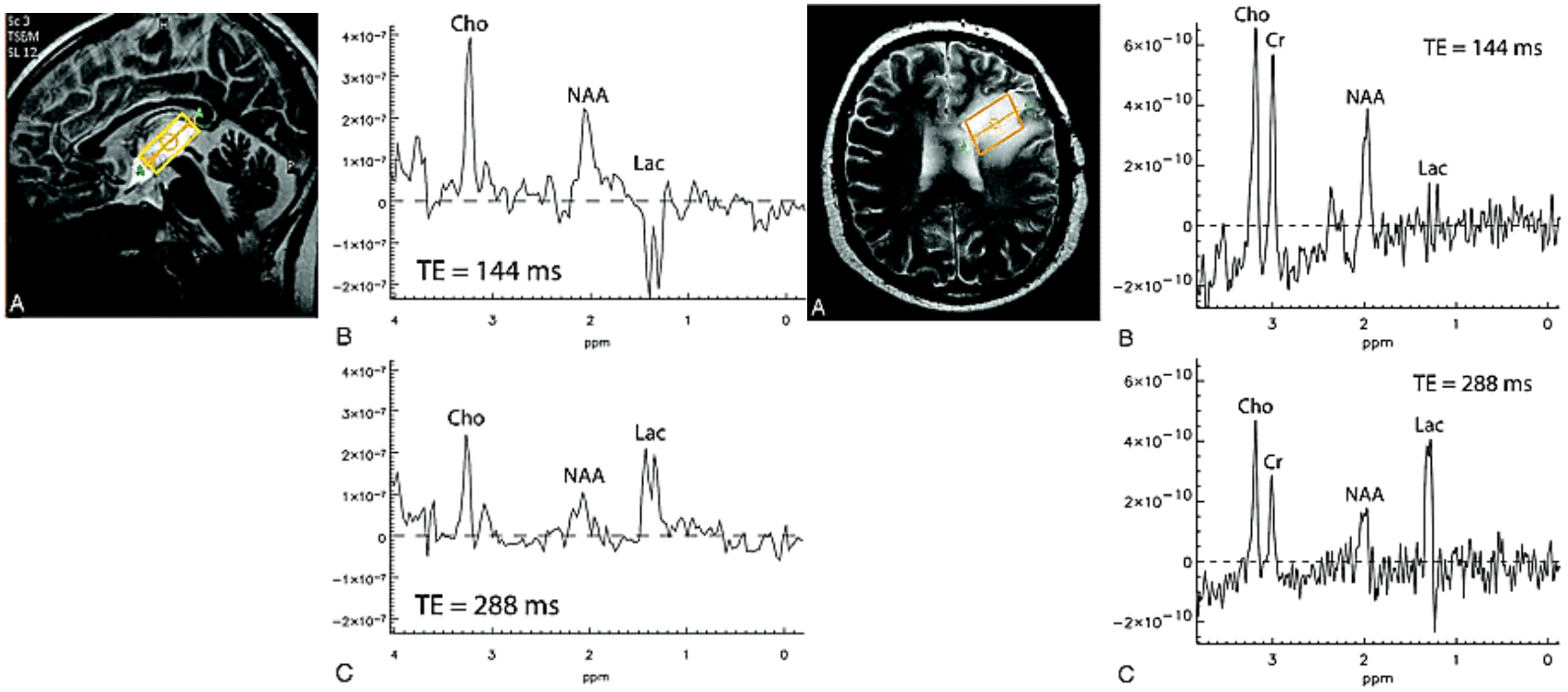


Choline map

臺北醫學大學・部立雙和醫院 影像醫學部 醫學物理師 李宜恬
Taipei Medical University - Shuang Ho Hospital Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)

Special Topic: Lactate

1. Inversion peak?
2. Nearly invisible at 3T short TE condition?

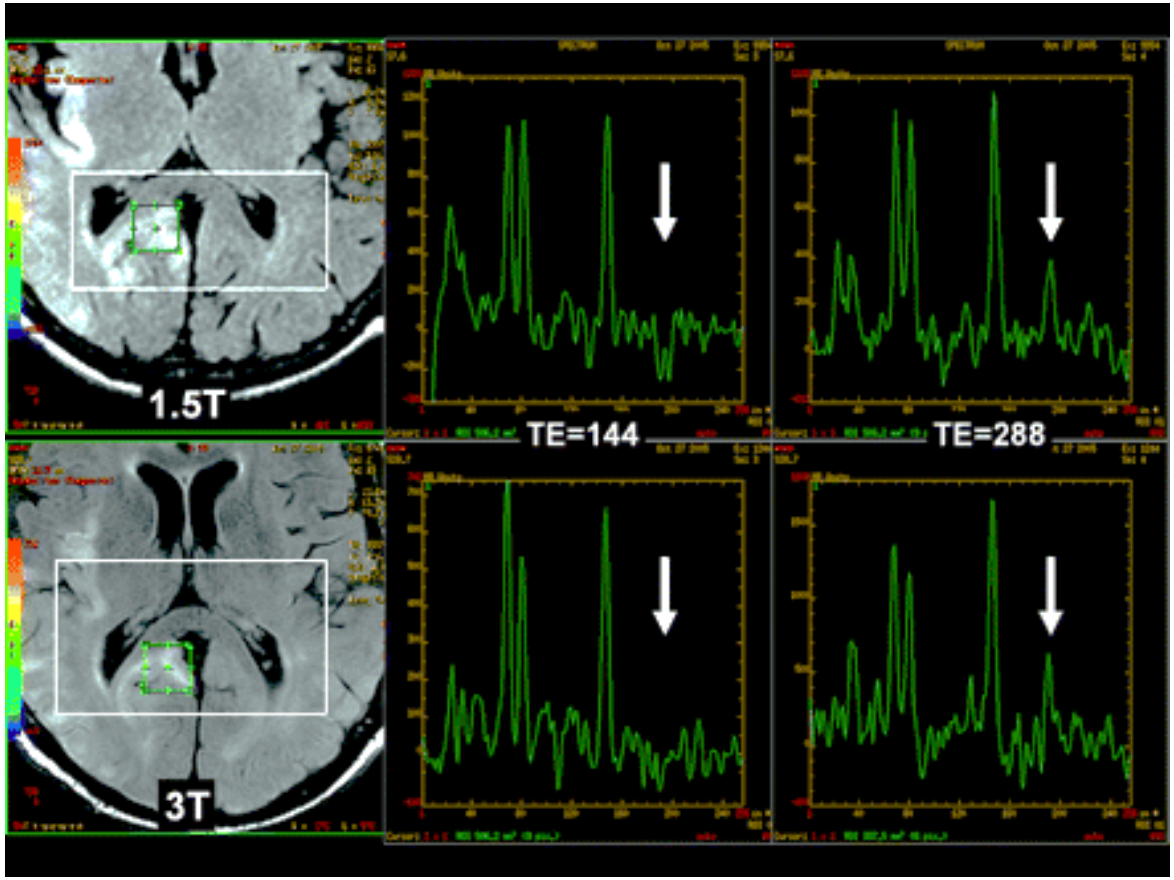


1.5T 3T

臺北醫學大學・部立雙和醫院 影像醫學部 醫學物理師 李宜恬
Taipei Medical University - Shuang Ho Hospital Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)

Special Topic: Lactate

1. Oppsite phase with NAA
2. Anomalous J-modulation



AJNR April 2006 27: 895-901

臺北醫學大學・部立雙和醫院
Taipei Medical University - Shuang Ho Hospital
Department of Radiology, Medical Physicist, Yi-Tien Li (MSc)