

中華民國醫事放射學會  
Taiwan Society of Radiological Technologists (TWSRT)

MRI Lecture 2

MRS

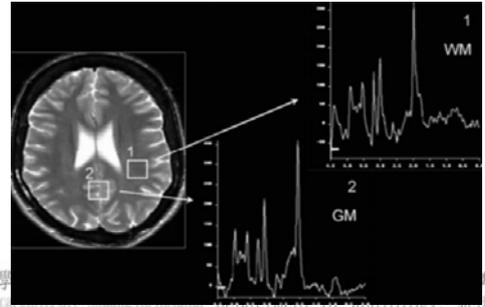
台北醫學大學一部立雙和醫院  
影像醫學部 醫學物理師 李宜恬  
2016.11.19



2016/11/18

## What's MR Spectroscopy?

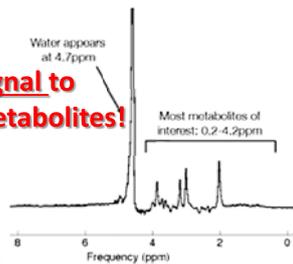
- Rather than providing images, it usually provides spectra consisting of individual peaks, **the chemical shift of metabolites**.
- Provide **bio-chemistry information**.



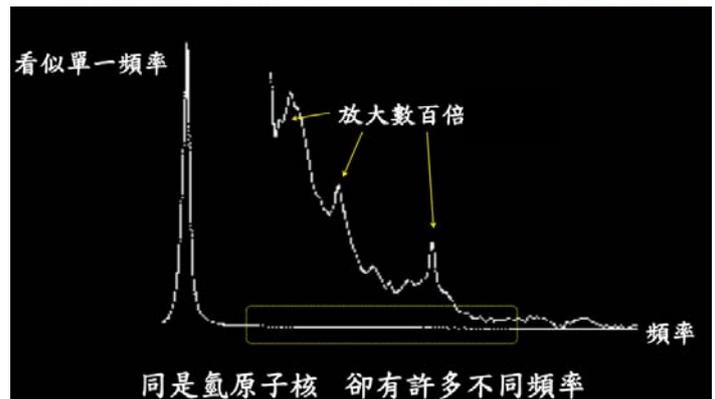
## <sup>1</sup>H (Proton) Spectroscopy

- **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!**

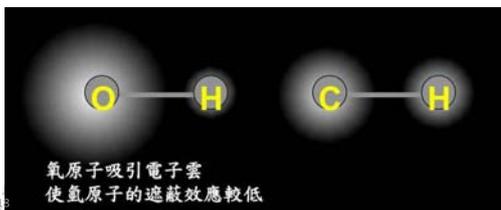


## <sup>1</sup>H (Proton) → Single Frequency?

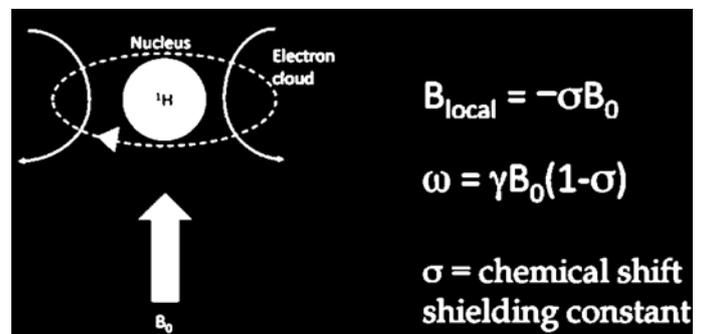


## Different frequency?

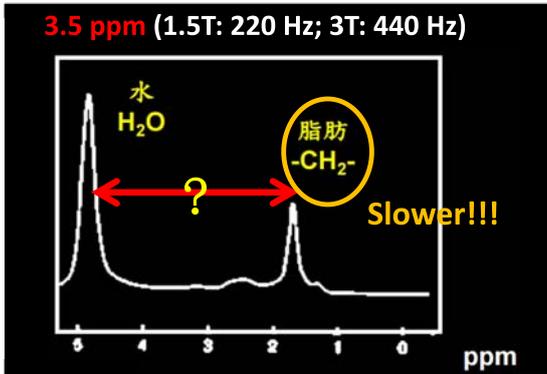
- Different chemical environment.
- Different atom bonding.
- Electron screening effect (**Shielding effect**, 電子雲遮蔽效應)
  - Magnetic field weakened → frequency ↓
  - **Chemical Shift**



## Chemical Shift & Shielding Effect



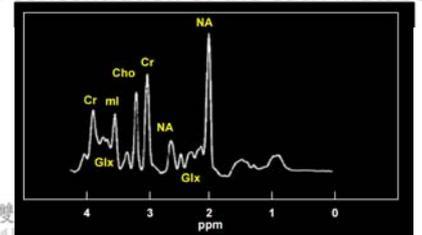
## For example: Chemical Shift (Review)



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

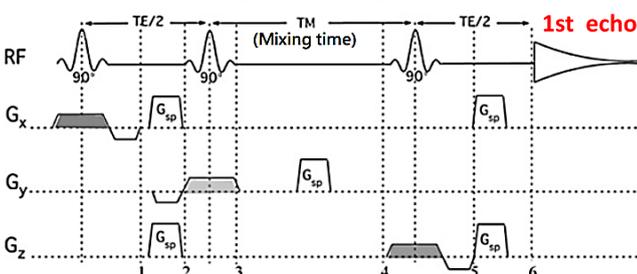
- Localization**: Covering lesion and normal sites for comparison
- Two major sequences
- Point-Resolved Spectroscopy**, PRESS
- Stimulated Echo Acquisition Mode**, STEAM

## 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 T2 metabolites)

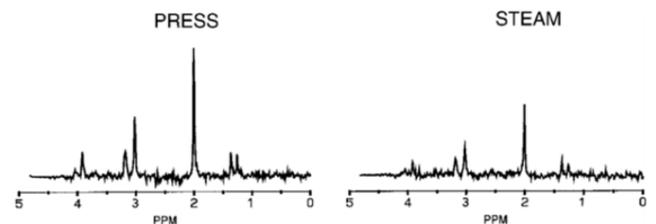
## Stimulated Echo Acquisition Mode (STEAM)



- Consists of three orthogonally slice selective 90 pulses
- Separate 180 to 90 + 90 (**90-90-90**)
- T2 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

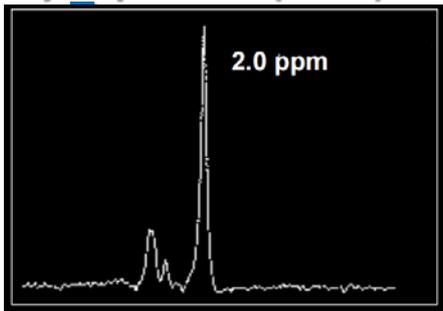
- Stimulated echo amplitude is only half the size of a PRESS spin echo.

	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 T2 Metabolites

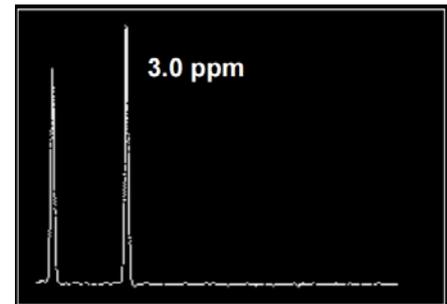
- Short T2 → Wide Spectrum
- Wide spectrum → Wide bandwidth → dephasing faster → Short T2

## N-acetylaspartate (NAA) : Long T2



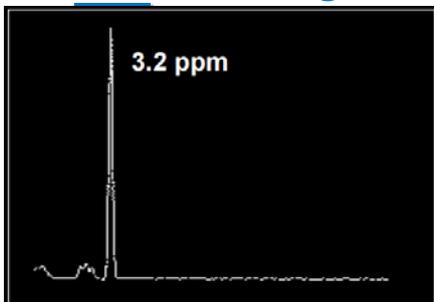
- A neuronal marker
- Register marker: Adjust the frequency shift across subject and session.

## Cr/ PCr: Long T2



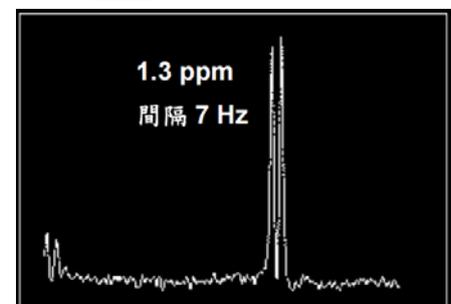
- Provide Phosphate

## Choline: Long T2



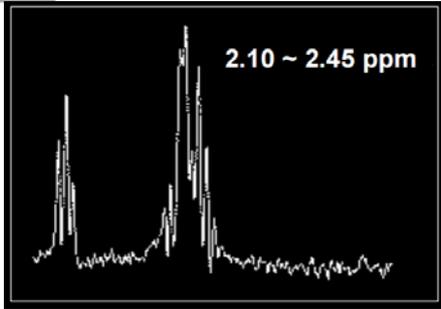
- Neurotransmitter (Acetylcholine) and others.

## Lactate: Long T2



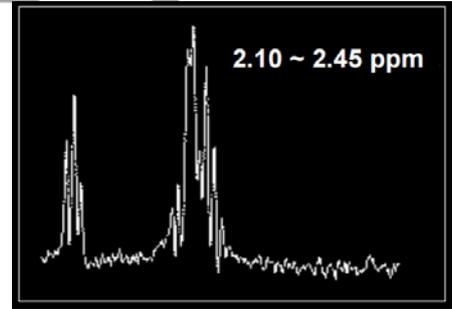
- Product of anaerobic metabolism
- J-coupling: methyl and methine share a bond → peak splitting (increase with TE)

## Glutamate (Glu): Short T2



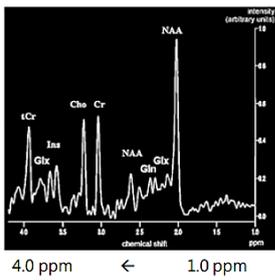
- **Excitatory** neurotransmitter

## Glutamine (Gln): Short T2



- Product of glutamate

## MRS peaks in Brain

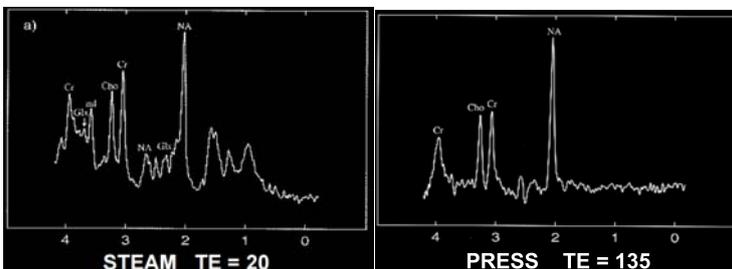


Metabolite	Major Resonance (ppm)	Effect	Visible only at short TE
Lipids (Lip)	0.9, 1.3	Breakdown of tissue	Y
Lactate (Lac)	1.3	Marker of anaerobic glycolysis	N
N-acetyl aspartate (NAA)	2.0	Marker of neuronal health	N
Glutamate/Glutamine (Glx)	2.1, 3.8	Excitatory neurotransmitter	Y
Choline (Cho)	3.2	Marker 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 T2 Metabolites

- Short T2 → Wide Spectrum
- Wide spectrum → Peak Broadening → dephasing faster → Short T2
- Looks like baseline drift??

## Effect of TE



**More information!**

**Specific!**

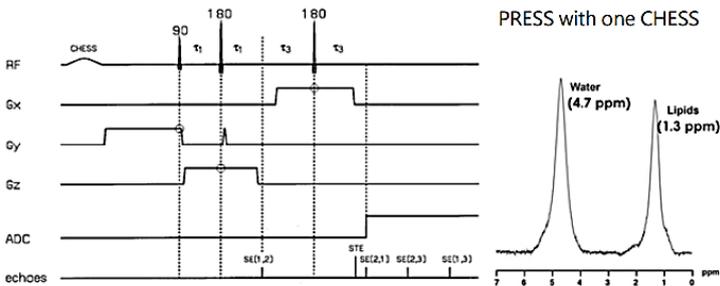
Use **PRESS** at **long TE** metabolites could achieve **higher SNR!!**

## 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 T2** 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.

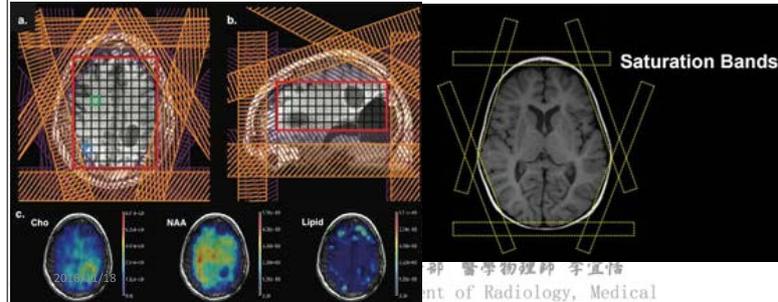
## Water Suppression

- **Chemical Shift Selection, CHES**
  - **Frequency-selective presaturation** pulse



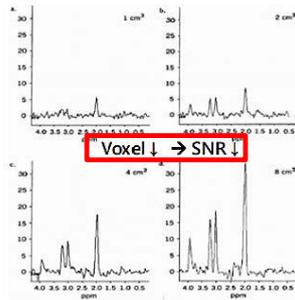
## Fat Suppression

- Add **spatial saturation** bands
  - **Outer Volume Suppression, OVS**
- Why we didn't use frequency-selective saturation?



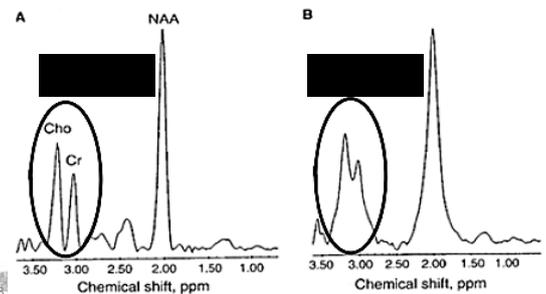
## Voxel size of MRS

- MRS (6~15 min) in the brain is generally performed in conjunction with MRI.
- For single voxel techniques, a volume of 8 cc (2x2x2 cm<sup>3</sup>) 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.



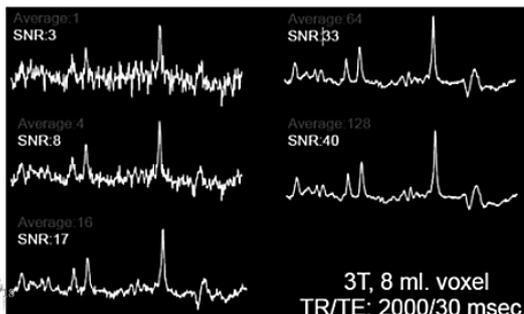
## Shimming Requirement for MRS

- 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.



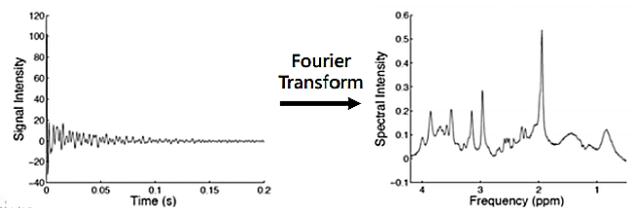
## Average & SNR

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



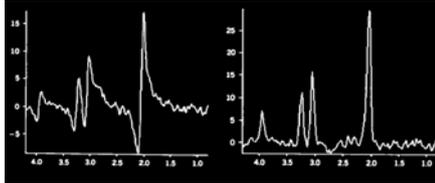
## Fourier Transform

- 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

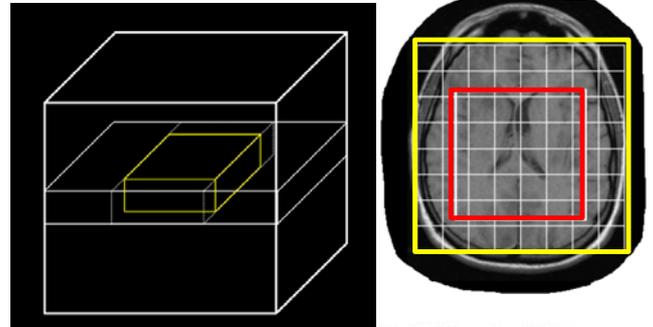


## Spectroscopic Imaging (SI)

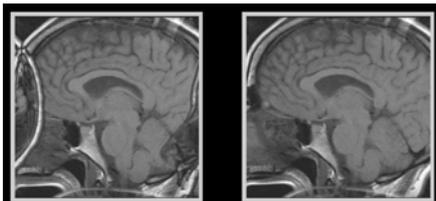
- Multi-Voxel
- Chemical Shift Imaging (CSI)

FOV: SNR ↑

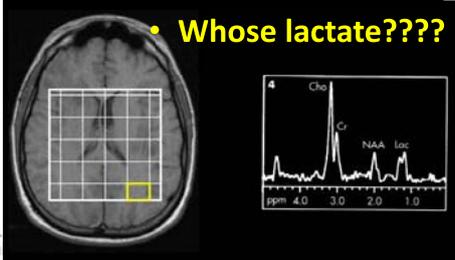
VOI: Spectrum



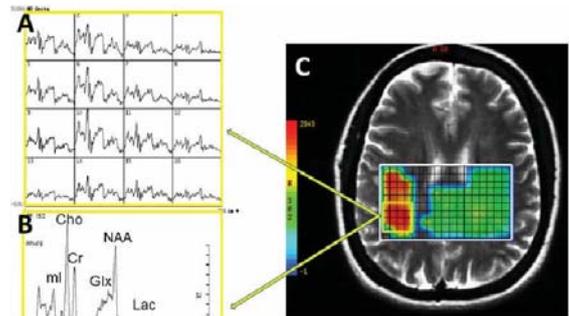
## Aliasing Artifact



Whose lactate????



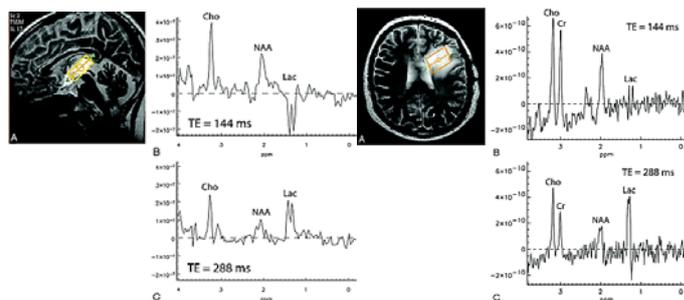
## Metabolite Concentration Map



Choline map

## Special Topic: Lactate

- Inversion peak?
- Nearly invisible at 3T short TE condition?



1.5T

3T

## Special Topic: Lactate

- Opposite phase with NAA
- Anomalous J-modulation

