Advanced MRI in the Clinic: MR Spectroscopy

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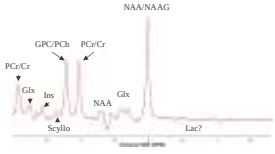
Declaration of Financial Interests or Relationships

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

MR Spectroscopy (MRS)

- MR spectroscopy (MRS) is a rapidly expanding clinical technique to quantify metabolites in vivo.
- This metabolic information may enable better diagnoses, personalized treatments, and rapid assessment of treatment response.
- After this talk, participants will know what these squiggly lines are and how to implement them in the clinic.



Information Encoding

Larmor equation

$\omega = \gamma B$

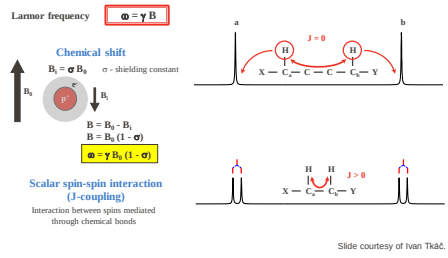
Magnetic interaction encoded in frequency

Fixed for a specific nucleus (^1H, ^{13}C, etc.)

Extrinsic effects on magnetic field
- B_0
- Magnetic field gradients
- Magnetic field inhomogeneity

Intrinsic effects on magnetic field
- Chemical shift
- J-coupling

Information Encoding



Slide courtesy of Ivan Tkáč.

Molecules of Interest

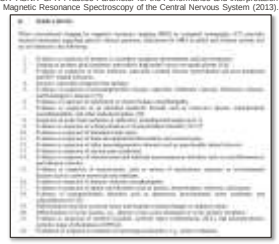
Primary peaks:
- Total NAA (2.0 ppm)
  - *N*-acetylaspartate and *N*-acetylaspartylglutamate
  - Neuronal marker
- Total Cr (3.0 ppm)
  - Creatine and phosphocreatine
  - Energy buffer
- Total Ch (3.2 ppm)
  - Choline, glycerophosphorylcholine and phosphorylcholine
  - Membrane turnover

Other peaks:
- Glx (glutamine, glutamate)
- γ-Aminobutyric acid
- Lactate
- Lipids
- Myo- and *scyllo*-inositol
- Citrate
- (D)-2-hydroxyglutarate (2HG)
- Taurine
- Glucose
- Ethanol
- Mannitol
- Acetate and succinate

Clinical Uses of MRS

- MRS is indicated for a variety of neurological conditions (right) and additionally under investigation in other body sites (breast, prostate, liver, etc.).
- Common (and potentially reimbursed) uses include:
  - Primary diagnosis of brain lesions.
  - Distinguishing recurrent brain tumor from radiation necrosis.
  - Diagnosis of inborn errors of metabolism affecting the CNS.

ACR–ASNR–SPR Practice Parameter for the Performance and Interpretation of Magnetic Resonance Spectroscopy of the Central Nervous System (2013).



Reimbursement

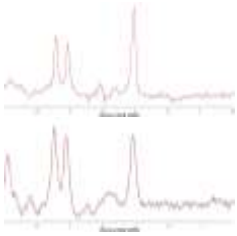
- MRS has an associated CPT code: 76390.
- Reimbursement for this code is inconsistent.
- The ACR is working for consistent reimbursement.

https://www.evicore.com/referenceguidelines/06_2018-head.pdf

MRS System Requirements

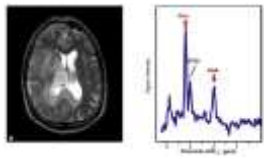
Hardware:

- Homogeneous magnetic field
- Linewidth desired < 0.1 ppm
  - 6 Hz @ 1.5 T; 12 Hz @ 3 T
- Field strength and bore size are not very important.
- Standard head coil (e.g. 8-channel brain array)



Single Voxel Spectroscopy (SVS)

- Most common technique
- Simple to acquire and interpret
- Excellent SNR efficiency
- Single, localized voxel allows for excellent shimming and, therefore, high-quality spectra



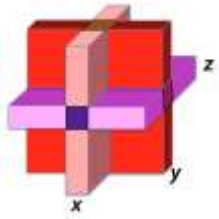
Courtesy of R. Jason Stafford

Clinical SVS Sequences

- ISIS
- STEAM
- PRESS
- LASER/semi-LASER

Most common

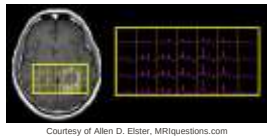
Often best results



Courtesy of Allen D. Elster, MRIquestions.com

Multi-Voxel Spectroscopy (MVS)

- A larger total coverage area takes the guesswork out of SVS voxel placement.
- Smaller individual voxels are possible, which leads to higher spatial resolution, but lower SNR and potential spectral contamination from adjacent voxels.
- Acquisition times are usually long.
- Difficulties obtaining a good shim over the entire region results in reduced quality.
- MVS sequences are usually just SVS sequences (e.g. PRESS) with phase encoding.



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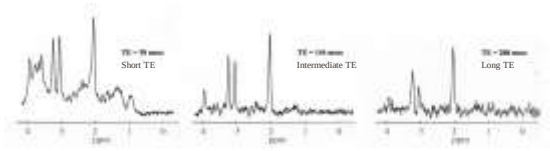
Choice of TE

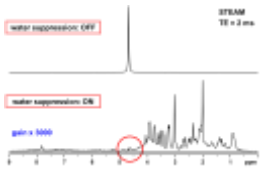


Courtesy of Allen D. Elster, MRIquestions.com

- Longer TE leads to nicer spectra and easier interpretation, but fewer metabolites are visualized.
- Short TE is usually recommended for evaluating metabolic and neurodegenerative disorders and intermediate TE is usually recommended for lesion assessment.
- Changing the TE (or TR) can dramatically change the appearance of/invert certain metabolites.

Clinical Water Suppression

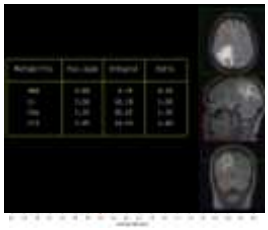
- Water signal is approximately 10,000 times more intense than metabolite signals.
- Clinical water suppression uses chemically-selective saturation (i.e. Fat Sat tuned to water).
- CHESS is most common.
- VAPOR is better.



Courtesy of Ivan Tkáč

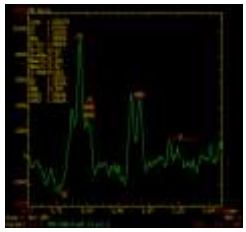
MRS Processing

- Vendor software usually only calculates peak heights/integrals and peak ratios.
- More advanced fitting software is available (e.g. LCModel, TARQUIN), but these are **not FDA approved**.



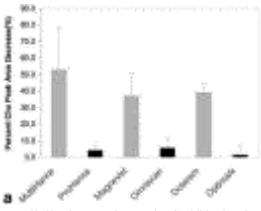
MRS Artifacts

- Artifacts in MRS appear very different from artifacts in MRI and are often less conspicuous.
- Kreis, Roland. "Issues of spectral quality in clinical 1H-magnetic resonance spectroscopy and a gallery of artifacts." *NMR in Biomedicine* 17.6 (2004): 361-381.



Contrast and MRS

- In clinical practice, the effect of gadolinium-based contrast agents (GBCAs) on non-quantitative MRS is usually insignificant, EXCEPT:
- Ionic GBCAs can decrease choline signal.



Lenkinski, Robert E., et al. "Interaction of gadolinium-based MR contrast agents with choline: Implications for MR spectroscopy (MRS) of the breast." MRM: 61.6 (2009).

MRS QA

- AAPM Report 78 (2002) details recommended MRS QA based on a simple phantom.
- AAPM Report 100 (2010) details recommended MRS acceptance testing using a phantom.
- Phantom-based MRS QA alone is insufficient since the simple phantom poorly emulates both the biochemical milieu and electromagnetic environment of the human brain.
- The ISMRM MRS Consensus Group (2014) recommends in vivo MRS QC.
- Performing MRS QC in vivo should produce more accurate and relevant results.
- Our institution is transitioning to real-time patient MRS QC for quality verification and longitudinal monitoring of scanner performance.

Non-Proton MRS

- Non-proton MRS is still in clinical trials with ^{13}C and ^{31}P closest to routine clinical use.
- ^{13}C and ^{31}P are primarily used for metabolic imaging.
- There is now a clinical hyperpolarizer available for ^{13}C that boosts the signal by 10,000x.

Nucleus	Natural abundance (%)	Gyromagnetic ratio (MHz/T)	Relative Sensitivity
^{1}H	99.98	42.58	100.00
^{13}C	1.11	10.71	1.59
^{19}F	100.00	40.05	83.30
^{23}Na	100.00	11.26	9.25
^{31}P	100.00	17.23	6.63
^{39}K	93.10	1.99	0.05

In conclusion, MR spectroscopy has a variety of clinical applications and is relatively simple to implement.

Thank you!

Questions?