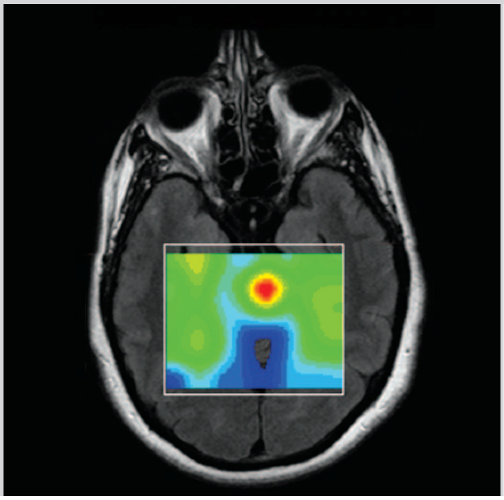
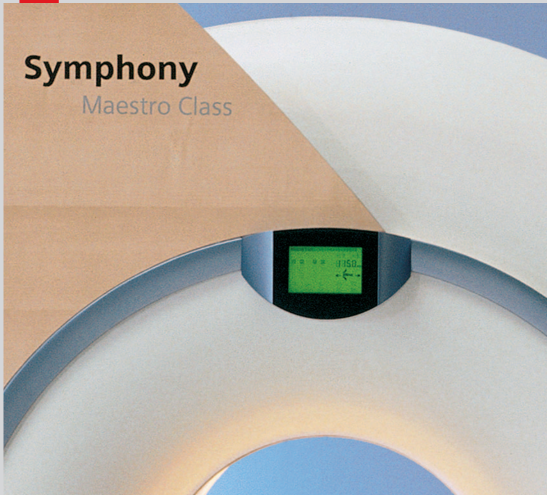
MRI Hot Topics





Clinical MR Spectroscopy: A Primer

SIEMENS
medical

Clinical MR Spectroscopy: A Primer

Nouha Salibi, Ph.D.
Siemens Medical Solutions USA, Inc.

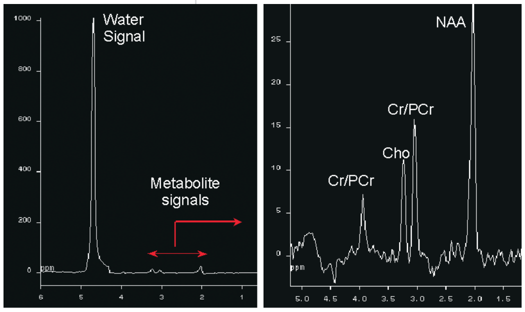


Figure 1: *Spectra from normal brain tissue. Small metabolite peaks are not visible in the presence of a large water peak (left spectrum). A water-suppressed spectrum on the right clearly displays the major brain metabolite peaks at TE=144 ms, namely N-acetyl aspartate (NAA), choline (Cho), and creatine/phosphocreatine (Cr/PCr).*

MR Spectroscopy as a Clinical Tool

Over the last few years, MR spectroscopy (MRS) has migrated beyond research laboratories to become an integral part of the clinical diagnostic routine. Although its main current application consists of proton MRS in the brain, there is a growing interest in using MRS for understanding disease states in the prostate, liver, muscle, breast, and heart. Multi-nuclear spectroscopy* promises to extend the clinical applications of MRS even further.

MR images are based on MR signals from water and fat, which are the two most abundant metabolites in the body and generate strong MR signals that dominate those from other metabolites. Apart from water and fat, MRS can detect metabolites that are indicative of disease states, and can help in evaluating the effectiveness of certain therapeutic approaches. In many instances, MRS is an attractive, noninvasive approach for resolving ambiguous findings seen on MR images and for monitoring the time course of certain diseases.

MRS Techniques

Clinical proton MRS techniques include single-voxel spectroscopy (SVS) and multi-voxel 2D and 3D chemical shift imaging (2D CSI and 3D CSI). SVS and some CSI sequences use volume-selective schemes that are based on either the SE (Spin Echo) technique or the STEAM (STimulated Echo Acquisition Mode) technique. Both SE and STEAM have three selective radiofrequency (RF) pulses to excite three orthogonal planes. A spectrum is collected from the volume defined by the intersection of the three excited planes. The SE sequence has one 90° pulse followed by two 180° pulses, whereas STEAM has three 90° pulses. While both sequences yield the same metabolic information, SE has twice as much signal.

Single voxel spectroscopy produces a single spectrum from a single voxel (Figure 2) that is typically 8 cm^3 in volume, whereas CSI measures spectra from multiple voxels that are typically 1 cm^3–1.5 cm^3 in volume. CSI data may be presented in a variety of displays including individual spectra, spectral maps, or colored metabolite images overlaid on anatomical images (Figures 3, 4). The two techniques are illustrated in Figures 2–4, where the same lesion has been examined with SVS (Figure 2) and CSI (Figures 3, 4). The two measurements yield comparable metabolic differences between spectra from the lesion and from the surrounding tissue. However, the relative changes among peaks are slightly different due to the difference in the relative amount of healthy tissue contained in the SVS (8 cm^3) and the CSI (1.5 cm^3) voxels.

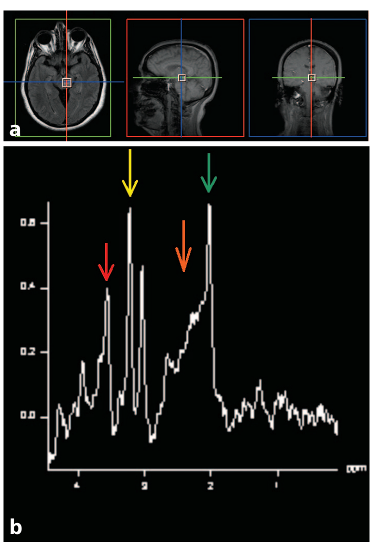


Figure 2: *(a), a single voxel is positioned to enclose a low-grade brain stem glioma. The voxel is 8 cm^3. The corresponding spectrum (b) is acquired with the SE sequence (TR=1500 ms and TE=30 ms). The spectrum shows reduced NAA (green arrow) with elevated choline (yellow arrow) and elevated myo-inositol (red arrow) and Glx (orange arrow).*

Which Technique When?

The choice of MRS technique should be tailored to each particular clinical case. In certain instances, SVS is a straightforward approach to collecting the desired MRS information (especially with metabolic brain disorders); it produces a single spectrum from a single volume of 2 cm^3 to 8 cm^3 in size. In other instances, however, SVS may not be optimal for investigating a lesion that is too large to be fully contained within the voxel, or a lesion that is too small to affect spectral peaks from a 2 cm^3 voxel.

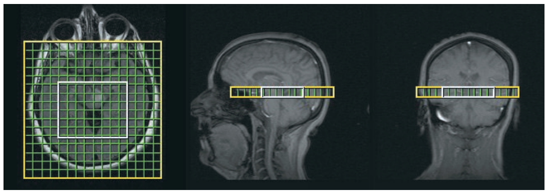


Figure 3: *Positioning of a 2D CSI slice including the low-grade brain stem glioma, as well as healthy brain tissue. Some CSI results are shown in Figure 4.*

2D or 3D CSI multi-voxel techniques allow better coverage of one large lesion or multiple lesions, and allow higher spatial resolution than SVS, which is needed for the investigation of regional variations within the VOI. Moreover, CSI measurement times are currently comparable to SVS measurement times. In the examples shown in Figures 2–4, the CSI approach allows examination of the lesion, as well as of the tissue surrounding the lesion, from the same CSI data set.

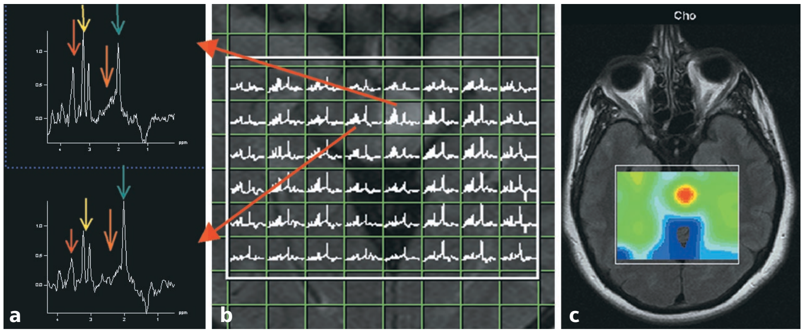


Figure 4: *2D CSI data set acquired with TR=1500 ms, TE=30 ms, and a spatial resolution of 1.5 cm^3. CSI results are shown as a spectral map (b), as spectra from the voxels indicated by red arrows (a), and as a choline metabolite image (c) generated from integral peak values. Elevated choline within the lesion is seen in the spectral map (b) and in the metabolite image (c) (red area). The upper spectrum in (a) is from the lesion and shows reduced NAA (green arrow), and elevated Cho (yellow arrow), mI (red arrow), and Glx, as compared to the lower spectrum in (a) which is from surrounding tissue.*

MRS at Various TEs

In MR spectroscopy, variable TE values provide the ability to control the "T2 contrast" of spectral peaks in the same way tissue T2 contrast is controlled in MR imaging. Short T2 metabolite signals decay faster, and the corresponding spectral peaks are not seen on long TE spectra. As illustrated in Figure 5, detection of such metabolites requires short TE measurements.

The major healthy brain metabolite peaks that are seen on long TE spectra include N-acetyl aspartate (NAA) at 2.02 ppm and 2.6 ppm, total choline (Cho) at 3.20 ppm, and total creatine (Cr) at 3.02 ppm and 3.9 ppm. Short TE spectra contain additional peaks, which include glutamine and glutamate (Glx) between 2.05–2.5 ppm and 3.65–3.8 ppm, scyllo-inositol (sI) at 3.36 ppm, glucose at 3.43 ppm and 3.8 ppm, and myo-inositol (mI) at 3.56 ppm and 4.06 ppm. Figure 5 also illustrates the dependence of peak metabolite ratios on TE. At TE=144 ms, the choline peak is higher than creatine, whereas at TE=30 ms, choline is lower than creatine due to the fact that creatine has a shorter T2 and decays faster than choline.

MRS and Magnetic Field Strength

MR spectroscopy is currently performed on clinical and research scanners at magnetic field strengths of 1 Tesla, 1.5 Tesla, and 3 Tesla. Spectroscopy at fields higher than 1.5T has been driven by the demand for improved sensitivity and better spectral resolution (i.e., chemical shift dispersion), which in turn allow for more reliable quantitation of MRS spectra. However, clinical MRS at higher fields presents new challenges, including increased chemical shift misregistration, and increased magnetic susceptibility effects that reduce resolution and sensitivity. New technical developments to overcome such challenges are currently being investigated and implemented in order to optimize the advantages of higher field MRS.

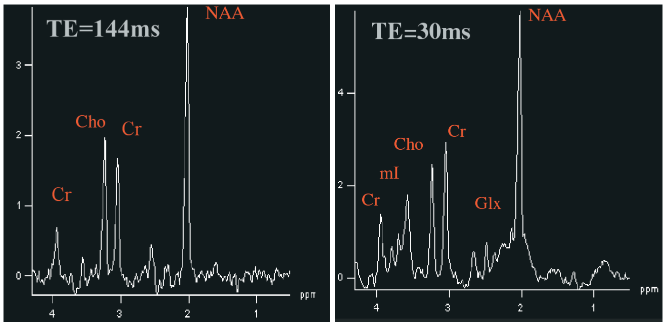


Figure 5: *Spectra from the same 8 cm³ single voxel in healthy brain tissue, acquired with the SE sequence at TE=144 ms (left) and TE=30 ms (right). Additional metabolite peaks are seen on the short TE spectrum. (Not all peaks are labeled for clarity).*

Conclusion

In recent years, considerable technological advances in MR scanner hardware and software have allowed the development of new and sophisticated approaches to MR spectroscopy. The currently available SVS and CSI techniques offer flexibility, automation, and a variety of features** that can be tailored to specific clinical MR examinations in order to make MR spectroscopy an integral part of your clinical MRI routine.

Visit the New MAGNETOM World Website

www.SiemensMedical.com/MAGNETOM-World

- Learn more about Siemens MRI users worldwide and about the broad range of clinical and research applications made possible by Siemens' MRI solutions.
- Download other MRI Hot Topics—including several on clinical applications of MRS.
- Find out why leading experts choose Siemens!
- Send us your questions and comments.
- Download Phoenixable images from leading Siemens MR users worldwide.

PHOENIX

* Multi-nuclear spectroscopy is now available with *syngo* MR 2002B.

** Please refer to the MRI Hot Topic "MR Spectroscopy with *syngo* MR 2002B: Automation with Flexibility".

Acknowledgements: Special thanks to Dr. E. Knopp and Dr. M. Law (NYU Medical Center) for the MRS data in Figures 2–4 and for their educational and clinical contributions.

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway
Malvern, PA 19355
Telephone: 610-448-4500
Internet: SiemensMedical.com

MAGNETOM World

Siemens **Medical Solutions** that help

Order No. 11006-137-3C
Printed in USA