MRS of FAT

Robert E. Lenkinski, Ph.D.

Department of Radiology
Beth Israel Deaconess Medical Center
Boston MA 02215
rlenkins@bidmc.harvard.edu

There is renewed interest in determining the amount and composition of fat in a variety of organs, including liver and skeletal muscle. An example of a recently published NMR spectrum of subcutaneous fat in a human taken at is shown in Figure 1. A spectrum of peanut oil is shown for comparison.

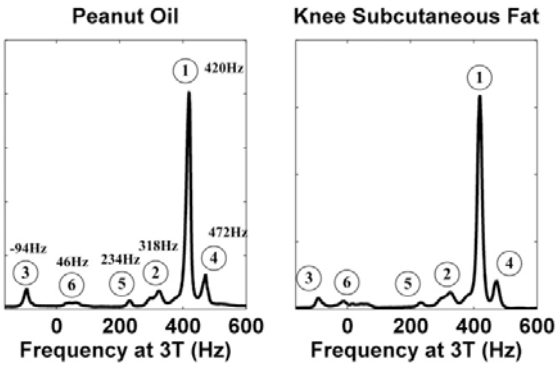

Figure 1. Two representative spectra collected in peanut oil and knee subcutaneous fat at 3T. The spectra were shifted and displayed such that the main fat peak is at 420 Hz relative to water. Both fat spectra show a very similar multi-peak pattern. Six peaks can be identified, and their chemical shift frequencies relative to the water resonant frequency at 3T are labeled. Peak 6 is at slightly different locations in the two spectra. Taken from (1).

The use of localized magnetic resonance spectroscopy (MRS) provides the most direct method for determining the amount and composition of fat *in vivo*. The relative amount of fat can be determined by determining its concentration relative to the water peak present. The composition of fat can be determined by identifying and quantifying the relative amounts of each of the six peaks labeled in Figure 1.

One of the interesting early observations made in comparing spectra obtained from fat in muscle to spectra obtained from fat in other organs was the observations of two lipid compartments in the spectra obtained from muscle (2,3). This observation and its explanation has provided the basis for quantitating intra-myocellular and extra-myocellular fat in muscle. The implications and utility of this approach will be discussed.

Poor shimming (adjustment of the local magnetic field homogeneity) may pose some problems for *in vivo* analysis. Physiological motion may also pose a problem if signal averaging is employed although there have been a variety of both navigator based methods (see for example (4)) as well as breath-holding methods (see for example (5)) employed *in vivo*. These may not be issues for "so-called" single voxel methods where only one localized region of tissue is sampled. There are applications where the

determination of the spatial distribution of fat content and composition may be important. In these cases there have been two distinctly different, but related approaches; multi-voxel MRS (see for example (6)) or MR image based methods. We will discuss the technical challenges and merits of both of these methods.

The image based methods are largely based on the Dixon approach (7) where a delay time is chosen such that MR images are acquired in which the relative phase evolution of the fat and water signals are either zero or 180 degrees. This simple approach has been extended to also account for the effects of the local magnetic field homogeneity (8,9). These simple Dixon based method have been combined with a variety of other features to deal with motion and reduce scan times (10,11).

This simple Dixon based approach is based on the assumption that there is a single predominant peak in the fat spectrum and that T2* relaxation effects are negligible. Neither of these assumptions is completely valid and there have been remedies proposed to deal with the results for both of these assumptions (1,12). As pointed out by Wehrli, in 1987, there are modulations observed in echo-trains generated by GRE images that can be used to provide spectral information (13). This approach as well as using a modification of the simple three point Dixon method, called the iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) (14) in combination with multi-peak estimation methods can be employed very well to image fat *in vivo* (1). We will discuss the basis for using this method as well as provide some results from the literature.

References

1. Yu HZ, Shimakawa A, McKenzie CA, Brodsky E, Brittain JH, Reeder SB. Multiecho Water-Fat Separation and Simultaneous R-2* Estimation With Multifrequency Fat Spectrum Modeling. Magnetic Resonance in Medicine 2008;60(5):1122-1134.
2. Kreis R, Boesch C. Spatially localized, one- and two-dimensional NMR spectroscopy and in vivo application to human muscle. Journal of Magnetic Resonance Series B 1996;113(2):103-118.
3. Schick F, Eismann B, Jung WI, Bongers H, Bunse M, Lutz O. Comparison of Localized Proton Nmr Signals of Skeletal-Muscle and Fat Tissue Invivo - 2 Lipid Compartments in Muscle-Tissue. Magnetic Resonance in Medicine 1993;29(2):158-167.
4. Tyszka JM, Silverman JM. Navigated Single-Voxel Short-Echo-Time Proton Spectroscopy of Moving Objects. J Magn Reson B 1996;112(3):302-306.
5. Katz-Brull R, Rofsky NM, Morrin MM, Pedrosa I, George DJ, Michaelson MD, Marquis RP, Maril M, Noguera C, Lenkinski RE. Decreases in free cholesterol and fatty acid unsaturation in renal cell carcinoma demonstrated by breath-hold magnetic resonance spectroscopy. American Journal of Physiology-Renal Physiology 2005;288(4):F637-F641.
6. Haase A, Frahm J, Hanicke W, Matthaei D. H-1-Nmr Chemical-Shift Selective (Chess) Imaging. Physics in Medicine and Biology 1985;30(4):341-344.
7. Dixon WT. Simple Proton Spectroscopic Imaging. Radiology 1984;153(1):189-194.
8. Glover GH. Multipoint Dixon Technique for Water and Fat Proton and Susceptibility Imaging. Jmri-Journal of Magnetic Resonance Imaging 1991;1(5):521-530.
9. Glover GH, Schneider E. 3-Point Dixon Technique for True Water Fat Decomposition with Bo Inhomogeneity Correction. Magnetic Resonance in Medicine 1991;18(2):371-383.
10. Ma JF. Breath-hold water and fat imaging using a dual-echo two-point dixon technique with an efficient and robust phase-correction algorithm. Magnetic Resonance in Medicine 2004;52(2):415-419.
11. Ma JF, Singh SK, Kumar AJ, Leeds NE, Broemeling LD. Method for efficient fast spin echo Dixon imaging. Magnetic Resonance in Medicine 2002;48(6):1021-1027.

12. Bydder M, Yokoo T, Hamilton G, Middleton MS, Chavez AD, Schwimmer JB, Lavine JE, Sirlin CB. Relaxation effects in the quantification of fat using gradient echo imaging. Magnetic Resonance Imaging 2008;26(3):347-359.
13. Wehrli FW, Perkins TG, Shimakawa A, Roberts F. Chemical Shift-Induced Amplitude Modulations in Images Obtained with Gradient Refocusing. Magnetic Resonance Imaging 1987;5(2):157-158.
14. Reeder SB, McKenzie CA, Pineda AR, Yu HZ, Shimakawa A, Brau AC, Hargreaves BA, Gold GE, Brittain JH. Water-fat separation with IDEAL gradient-echo imaging. Journal of Magnetic Resonance Imaging 2007;25(3):644-652.