Proton Spectroscopy of Humans Skeletal Muscle at 7T

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Single-voxel ^{1}H NMR spectroscopy of human skeletal muscle has attracted considerable interest because it allows measurement of the concentration of di- and triglycerides inside skeletal muscle cells (intramyocellular lipids, IMCL). Typically at 1.5 or 3.0 T, IMCLs are quantified from the dominant methylene resonance $(-CH_2-)_n$ compared to a reference signal (1,2). This approach works well for the tibialis anterior where extracellular fatty septa are presumably oriented parallel to Bo, but resolution of intra-and extracellular methylene signals is more difficult in the gastronemius and soleus, large muscle groups with oblique fiber orientation (1,2). The limited chemical shift dispersion also restricts the use of information from the methyl hydrogens, methylene hydrogens from unsaturated fats, and the hydrogens α and β to C1. Since the resonance frequency shift, about 0.2 ppm, is due to susceptibility effects, we evaluated chemical shift dispersion in volume-localized ^{1}H NMR spectra in human skeletal muscle at 7T.

Seven adult subjects (6 male, 1 female, none with obesity, type 2 diabetes or peripheral vascular disease) were studied supine on a 7T Achieva (Philips Medical Systems). The left calf was placed in a partial-volume quadrature T/R imaging and spectroscopy coil with a z-axis coverage of about 140 mm. TSE images were acquired and STEAM (10x10x10 mm, TR 2000, TE 16, TM 22, NA 80) was used for spatial localization. Apparently lean voxels in the gastrocnemius were studied, except as noted.

The study was well-tolerated by all subjects. Typical spectra with chemical shift assignments are shown in the left panel for subject 1. Creatine (a and d) and carnitine (c) were observed in all spectra (assignments from 1 - 3). Taurine (b) was detected in 5/7 subjects. The characteristic methylene signal from conjugated double bonds at 2.9 ppm was not detected. Four additional resonances were observed between 1.6 and 2.6 ppm and were assigned as follows: extramyocellular triglyceride (EMCL) hydrogens α to the carboxyl (e); IMCL hydrogens α to unsaturated bonds overlapped with EMCL hydrogens α to unsaturated bonds (f); IMCL hydrogens α to unsaturated bond (g); EMCL hydrogens β to unsaturated bonds (h). Since the chemical shift difference between the IMCL and EMCL hydrogens was ~0.2 ppm, the EMCL methylene resonance at 1.5 ppm must be overlapped by IMCL hydrogens β to the carboxyl. Resonances i, j, k and l were assigned to EMCL methylenes, IMCL methylenes, EMCL methyl, and IMCL methyl. Moving the voxel from lean tissue to a region with obvious fat (Figure 1, subject 2, lower panel) caused an increase in resonances e, f and h, (but not g) consistent with assignment to EMCL. Chemical shift imaging data were analyzed by curve-fitting individual spectra. The IMCL resonance from the fitted spectra was used to generate an IMCL image (Figure 2).

^{1}H NMR spectroscopy and CSI of human calf muscle is straightforward at 7T and offers improved chemical shift resolution.

References: 1) Boesch C, *et al.* NMR Biomed. 2006; 19: 968-88. 2) Machann J, *et al.* Diabetes Obes Metab. 2004; 6: 239-48. 3) Szczepaniak LS, *et al.* Magn Reson Med. 2002; 47: 607-10.

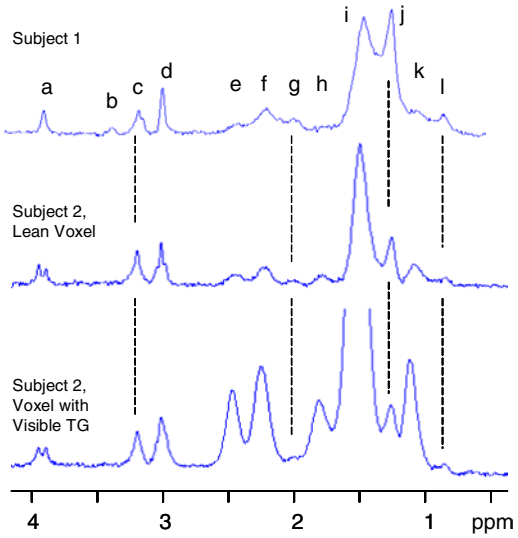

Figure 1. Volume Localized ^{1}H NMR Spectra from the Gastrocnemius. Chemical shift assignments are described in the text.

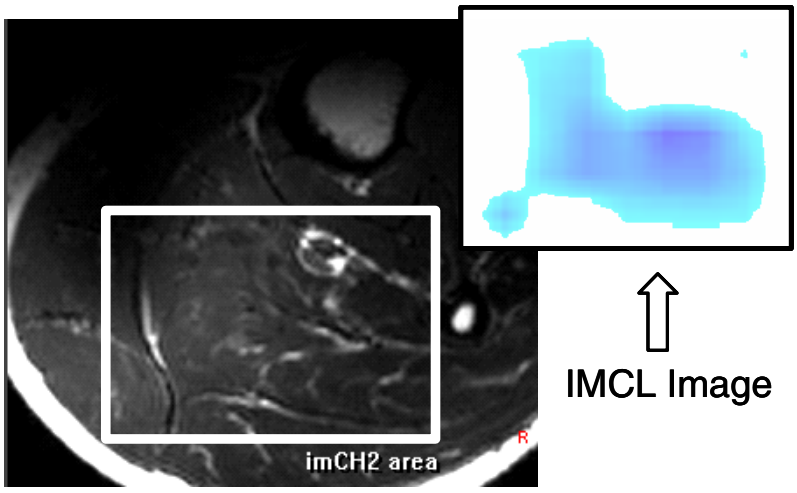

Figure 2. Axial Image of the Left Calf. A chemical shift image of intracellular lipids in the volume of interest (white box) is shown in the inset. Note the absence of signal in the CSI from regions with obvious adipose tissue.