[1]H-MRSI in Human Calf Muscles at 3T: Ordering Effects and Intra-myocellular Lipids

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Introduction

Intramyocellular lipids (IMCL) have been measured extensively by [1]H-MRS in diabetes and physiology, mostly employing single voxel spectroscopy methods at 1.5T [1,2]. However, the strong spectral overlap between IMCL and lipids from bulk fat (extra-myocellular lipids, EMCL) frequently renders reliable IMCL estimation impossible, especially in obese subjects. In addition, dipolar coupling effects have been shown for a number of metabolites leading to spectral patterns that depend on muscle fiber orientation [3]. This effect can be used to map muscle fiber orientations and is important for metabolite quantification. Only few studies have used MRSI methods for acquisition of proton muscle spectra [4-7], and a detailed analysis of residual dipolar coupling in different muscles at higher field strength has not been performed, yet. In this study we performed MRSI studies in human calf muscles at 3T, 1) to compare the separation of IMCL and EMCL with 1.5T, 2) to investigate residual coupling in muscles with different fiber orientations, 3) to determine the impact of different sampling strategies (low resolution for fast scanning versus high resolution and prolonged scanning) on possible applications, e.g. for the complicated separation of IMCL and IMCL in adipose subjects.

Methods

Eighteen measurements were performed in 9 healthy subjects on a 3T MR scanner (Siemens, Trio) using a 2D MRSI sequence in transverse orientation with PRESS volume pre-selection. For fast acquisitions (scan time: 10 min) spectra were acquired with TR 1.6s, TE 30 ms, Matrix: 24×24 (circular sampling) over a FOV of 14 cm. High resolution spectra (scan time: ~40 min) were acquired with TR: 0.53–0.8s, Matrix: 64×64–80×80 (circular sampling). For most measurements saturation bands were used to reduce signal contributions from subcutaneous and/or bone marrow. Postprocessing included moderate spatial apodization and lipid extrapolation.

Results and Discussion

MRSI spectra demonstrated good spectral quality in the range between 2.5-4.3 ppm (Cr, Tau region) across large parts of the excited volume and sufficient IMCL/EMCL separation at least in some regions of the calf in all measurements with high and low spatial resolution. Compared to 1.5T a much more detailed analysis of residual dipolar coupling is possible. Fig. 1 clearly shows the different patterns depending on the fiber orientation. The downfield satellite of the Cr methylene triplet, which can-not be observed at 1.5 T, is separated from the TMA resonance. The dipolar splitting (in addition to J-coupling) of the Tau resonance becomes visible depending on the fiber orientation, and TMA broadens along with increasing splittings of the other resonances, also suggesting residual dipolar coupling for TMA.

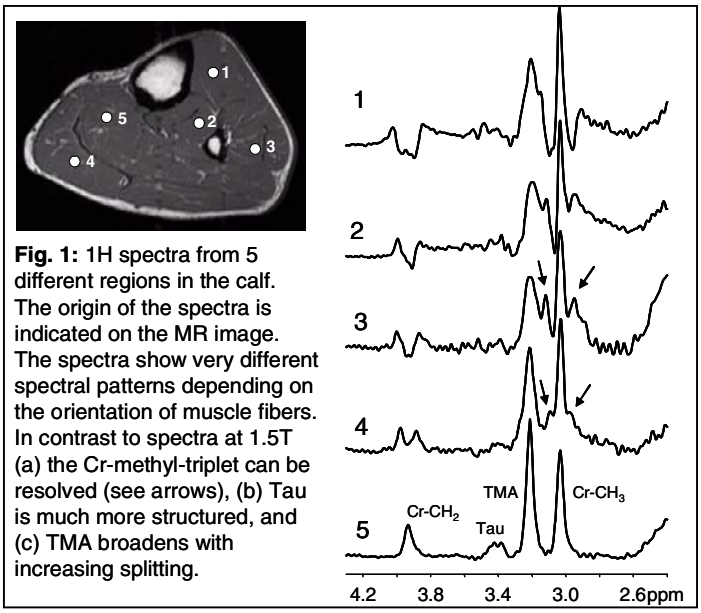

Fig. 1: 1H spectra from 5 different regions in the calf. The origin of the spectra is indicated on the MR image. The spectra show very different spectral patterns depending on the orientation of muscle fibers. In contrast to spectra at 1.5T (a) the Cr-methyl-triplet can be resolved (see arrows), (b) Tau is much more structured, and (c) TMA broadens with increasing splitting.

The separation between IMCL and EMCL was clearly improved compared to 1.5T. In tibialis anterior an almost complete separation was observed (Fig. 2), and the splitting is sufficient for reliable IMCL estimation by fitting at least in parts of soleus, which shows generally the smallest IMCL/EMCL separation for parallel muscle alignment (Fig.2). This confirms previous results [6]. The measurements at lower resolution acquired within 10 min offer a possibility to obtain IMCL, Cr, TMA, Tau concentrations as well as fiber orientations in different muscles very quickly. The spectra at higher resolution did not improve spectral quality of individual voxels and did not reveal substantial differences within muscles. However, the much smaller voxel size is likely to improve the success rate for measurements in obese subjects, which fail often because of insufficient IMCL / EMCL separation, especially in single voxel measurements.

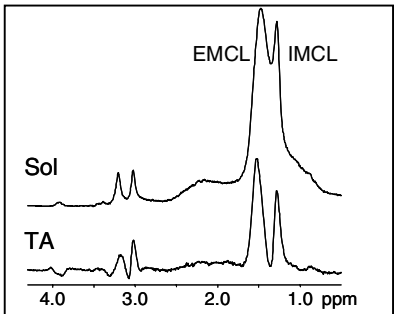

Fig. 2: [1]H spectra from tibialis anterior (TA) and soleus (Sol). In contrast to 1.5T, EMCL and IMCL are much better separated , with complete separation in some MRSI spectra of TA or tibialis posterior (not shown).

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Acknowledgment

This work was supported by Swiss National Foundation 3100A0-105815