

Orientation dependent effects in spectra of human skeletal muscle recorded at 1.5 and 3 T

J. Machann¹, G. Steidle¹, G. Helms¹, F. Schick¹

¹Department of Diagnostic Radiology, Section on Experimental Radiology, Tuebingen, Germany

Introduction

Proton MR spectra of human skeletal muscle show distinct orientation dependent features. Main reasons for frequency shifts occurring in different muscle groups are anisotropic susceptibility distribution (intramyocellular (IMCL) and extramyocellular lipids (EMCL) [1,2]), and residual dipolar coupling effects, which make the splitting of the creatine signals – methyl (Cr_3 , triplet) at 3.05 ppm and methylene (Cr_2 , doublet) groups at 3.95 ppm [3]. Furthermore, taurine signals (Tau) show orientation dependent signal characteristics [4]. Increasing magnetic field strength leads to increasing signal to noise ratio, but increasing susceptibility effects are expected as well. Dipolar coupling effects remain constant. Aim of the study was to compare signal patterns of spectra recorded from different skeletal muscles in order to evaluate (1) whether there is an improved separation of IMCL and EMCL at 3.0 T, and (2) whether and how signal characteristics of Cr and TMA/Tau are changing.

Material and Methods

Comparative spectroscopic examinations were performed on whole body imagers at 1.5 T (Magnetom Sonata, Siemens, Germany) and 3 T (Magnetom Trio, Siemens/Bruker, Germany). Volunteers were in supine position with the most extended part of the lower leg in the center of the extremity coil. For volume selection in the tibialis anterior muscle (TA, fusiform muscle with nearly parallel fibres) and the soleus muscle (SOL, feathered muscle with tilted fibre orientation) a single voxel STEAM technique was applied. Measurement parameters: TE=10ms, TR=2s, 40 acquisitions. Voxel size was chosen to $11 \times 11 \times 20 \text{ mm}^3$ on both units. At 3.0 T, additional spectra were recorded with smaller voxel sizes of $9 \times 9 \times 18 \text{ mm}^3$ (48 Acq.), $7 \times 7 \times 14 \text{ mm}^3$ (64 Acq.), and $5 \times 5 \times 10 \text{ mm}^3$ (80 Acq.).

Results

Exemplary spectra recorded from TA and SOL of a male volunteer at 1.5 T (b) and 3.0 T (c) are depicted in Fig. 1. In TA (left row) as well as in SOL (right row) IMCL and EMCL are clearly better distinguishable at 3 T. Methylene resonance of IMCL shows clearly smaller natural linewidths and the separation between EMCL and IMCL is constant (in ppm scale). However, due to susceptibility effects, methylene signal of EMCL remains with broader lines in both muscles. In SOL, Cr_3 and TMA/Tau signals are better resolved at 3 T and the Cr_2 resonance remains as a single peak (magic angle of muscle fiber orientation). In TA, the Cr_3 triplet is resolved and TMA/Tau resonances are split in four signals at 3 T, probably due to orientation dependent dipolar coupling effects [5] as shown in Fig. 2. Separation of Cr_2 peaks is halved (in ppm-scale) as dipolar coupling effects are independent of field strength. Spectra from smaller voxels with careful positioning were shown to provide a clearly decreasing EMCL signal contamination, resulting in improved quantification of IMCL in SOL at 3.0 T (Fig. 3).

Discussion

Examinations on lipid metabolism requiring selective assessment of IMCL clearly benefit from the higher field strength, as clearly narrower IMCL resonances and nearly unchanged susceptibility based broad EMCL signals occur in spectra of skeletal muscles at 3.0 T. Due to the higher signal yield (SNR is increased by a factor of 1.7-1.8) reduction of voxel size is feasible at 3.0 T leading to a separate depiction of IMCL with reduced contamination by EMCL in an acceptable measuring time. Dipolar coupling effects in the TMA/Tau complex of TA have been described from examinations of mouse gastrocnemius muscle on a 7 T NMR spectrometer [5]. As the splitting does not occur at 1.5 T a valid explanation of this effect can not be given up to now, and further examinations are required.

References

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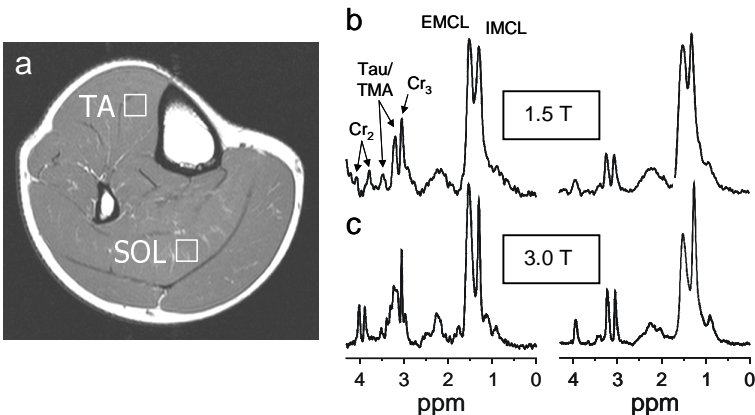


Fig. 1: Proton spectra of skeletal muscle recorded at 1.5 T (b) and 3.0 T (c). Left row: tibialis anterior muscle (TA), right row: soleus muscle (SOL)

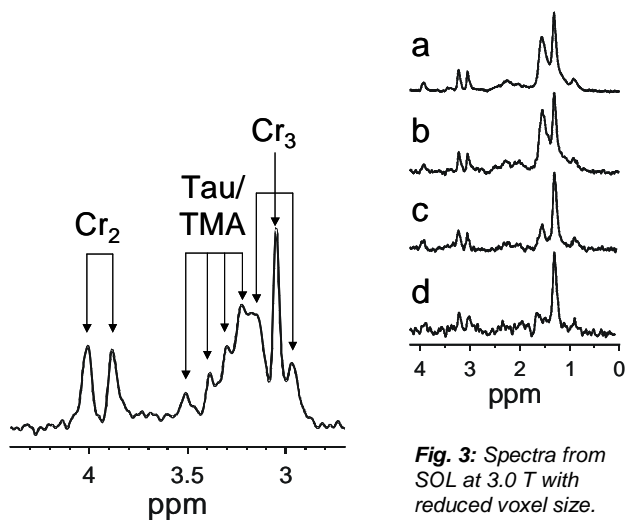


Fig. 2: Signal splittings in Tau/TMA complex of TA at 3.0 T.

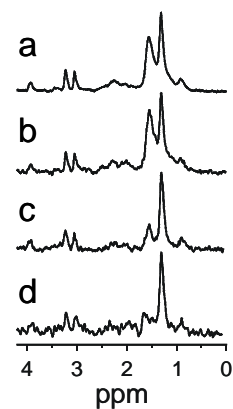


Fig. 3: Spectra from SOL at 3.0 T with reduced voxel size. (a) $11 \times 11 \times 20 \text{ mm}^3$ (b) $9 \times 9 \times 18 \text{ mm}^3$ (c) $7 \times 7 \times 14 \text{ mm}^3$ (d) $5 \times 5 \times 10 \text{ mm}^3$