

Influence of Foot Orientation on the Appearance of ^1H Muscle Spectra Obtained from Soleus and Vastus Lateralis

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Introduction

In vivo ^1H spectroscopy in skeletal muscle has been more frequently performed in the lower leg than the thigh. It has been shown at 3 T that ankle orientation alters bulk susceptibility and residual dipolar couplings of protons in the calf skeletal muscle (1). With *in vivo* ^1H MRS, changes in the residual dipolar couplings have been observed on CH_3 and CH_2 groups of creatine and trimethyl ammonium (TMA) containing molecules with ankle orientation. Additionally, changes in ankle orientation also affected the separation of intramyocellular and extramyocellular lipids (1). In this project, we investigate the influence of ankle orientation on ^1H spectra from the thigh, specifically the vastus lateralis muscle.

Methods

Normal volunteers ($n = 4$) were studied after giving informed consent according to the procedures approved by the Institutional Review Board. *In vivo* ^1H NMR spectra were obtained using a previously described LASER sequence (2). MR experiments were performed using a 4-T (90-cm horizontal bore) magnet (Oxford Magnet Technology, Oxford, UK) equipped with Varian INOVA console (Varian, Palo Alto, CA) to localize an 8 cm^3 voxel placed in soleus and vastus lateralis at different foot positions (neutral (0°), foot dorsiflexion (-20°), and foot planar flexion ($+45^\circ$)). Custom-made quadrature RF surface coils were used to transmit and receive signals from the calf and the thigh (Figure 1). The orientation of the foot was controlled using wooden wedges of different angles.

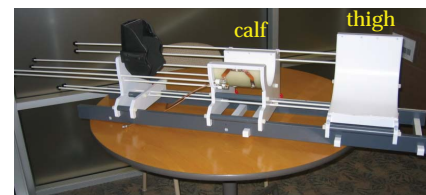


Figure 1. A custom made holder with two quadrature RF surface coils.

Results

Figure 2 demonstrates the impact of ankle orientation on the ^1H NMR spectra from the calf muscle (soleus) with consequent effects on the concentration and separation of IMCL and EMCL. The splitting patterns change for CH_3 group of creatine (Cr_3) from a singlet at $+45^\circ$ to a triplet at -20° . The CH_2 group of creatine (Cr_2) changes from a singlet at $+45^\circ$ to a doublet at -20° . The residual dipolar coupling is around 12 Hz, and the expected splitting patterns were discussed previously in relation to the orientation of the leg to the magnetic field (3). The linewidth of TMA signal changes from 9.7 Hz at $+45^\circ$ to 17.8 Hz at 0° and to 21.7 Hz at -20° . The taurine signal is only observed at $+45^\circ$ when there is no residual dipolar coupling. The carnosine signals are also affected by ankle orientation with observed changes in the linewidth and splitting.

The spectra obtained from vastus lateralis (Figure 2) illustrate that the ankle orientation does not have a big impact on the appearance of the spectra. The observed splitting of the Cr_2 peak (~ 12 Hz) suggests that overall there is a fair amount of dipolar coupling. The linewidth of TMA signal is 12 ± 1 Hz for spectra obtained at different ankle positions.

Discussion and Conclusions

In the soleus, the effects of ankle orientation on the appearance of ^1H spectra are very similar to the effects of changes in leg orientation relative to the magnetic field (3). Ankle orientation affects the ^1H spectra in the soleus more significantly than the ^1H spectra in the vastus lateralis. Consequently, variability in ankle orientation can impede comparison of spectroscopic measurements in the soleus between individuals and across institutions. Performing spectroscopic measurements in the vastus lateralis appears to minimize the effect of ankle orientation allowing for more uniform quantitation and reproducibility.

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References: 1. Velan, S. *et al.*, *Proc Intl Soc Magn Reson Med* **16**: 2597 (2008). 2. Garwood, M. *et al.*, *J Magn Reson* **153**:155 (2001). 3. Vermathen, P. *et al.*, *Magn Reson Med* **49**:424 (2003).

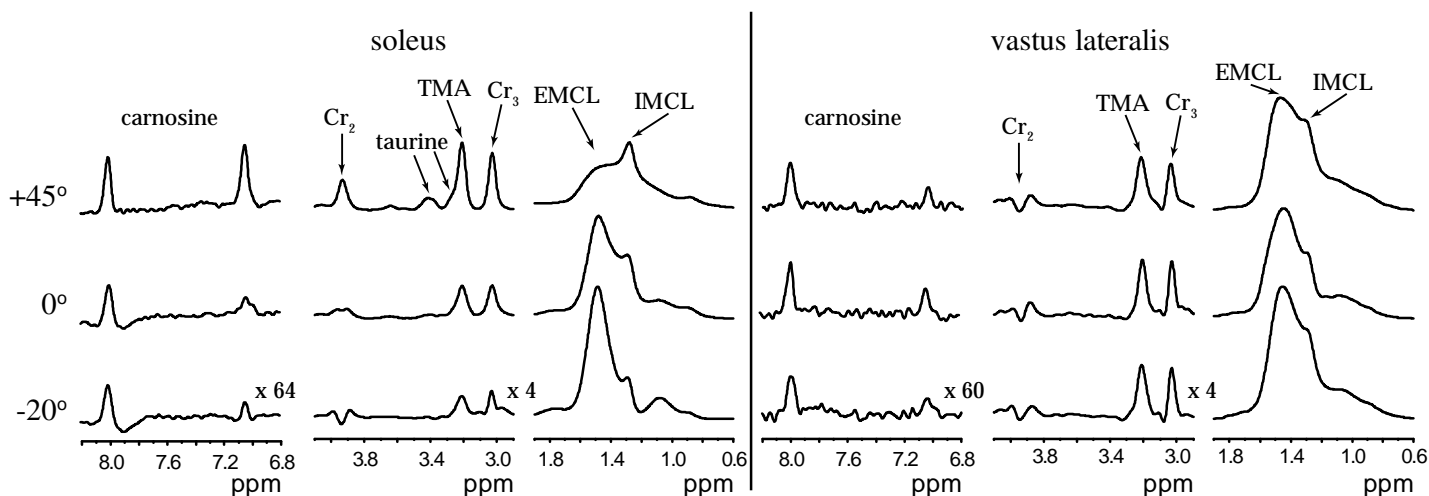


Figure 2. ^1H spectra obtained with LASER sequence from 8 mL voxels from the soleus ($\text{TR} = 4$ s, $\text{TE} = 37$ ms, 64 scans) and vastus lateralis ($\text{TR} = 4$ s, $\text{TE} = 52$ ms, 64 scans) from three different ankle orientations, 45° , 0° , -20° . The spectra are shown processed with 2 Hz Lorentzian to Gaussian line broadening and no baseline correction. The vertical scale was adjusted between different parts of spectra. IMCL = intramyocellular lipids, EMCL = extramyocellular lipids, Cr_3 = CH_3 group of creatine, TMA = trimethylammonium containing compounds, Cr_2 = CH_2 group of creatine