Correlating Muscle Structure and Function with MRS and DTI

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Introduction

MR can provide metabolic and structural information about muscle using spectroscopy and diffusion tensor imaging (DTI). Such information can aid in the diagnosis, staging and treatment of a wide range of muscle pathologies such as chronic compartment syndrome, peripheral vascular disease and peripheral effects of chronic obstructive pulmonary disease (COPD). The directional nature of muscle fibers influence the appearance of metabolites, with creatine, lactate and taurine exhibiting dipolar coupling which varies with angle to the main field[1,2]. To establish a normal control population, we examined the proton MR spectra of several human calf muscles (anterior tibialis, medial gastrocnemius, peroneus longus and soleus), fractional anisotropy and volume ratio in ten individuals.

Methods

The calves of ten (10) healthy adult volunteers were scanned using the standard quadrature knee coil on a 3T Signa scanner (GE Healthcare, Waukesha, WI, USA), software version 12. The MR exam consisted of the following sequences: MRS (probe-p, TR=2000ms, TE=30ms, 64 acquisitions, 15mm^3 voxel located in each of the 4 muscles studied, scan time=2:08), DTI (SE-EPI, TR=6s, TE=67.1ms, b=500, 6 directions, 64^2 acquisition matrix, 25-3mm contiguous slices, 8 averages, scan time=5:48), and an axial T1W scan (3D-FSPGR, TR=5.8ms, TE=1.4ms, flip=15^o, 76-1mm slices, 16cm FoV, 256^2 acquisition matrix, 2 averages, scan time=3:26).

MRS data were analyzed using LCModel[3] with the standard simulated muscle basis set (muscle-1), which fits extramyocellular lipids (EMCL), intramyocellular lipids (IMCL), creatine (Cr), choline (Cho) and taurine (Tau). The -CH_2- group of creatine at about 3.9ppm, which exhibits angular-dependent dipolar splitting, is not fit with LCModel. Mean fractional anisotropy (FA) and volume ratio (VR) were computed for the MRS voxel using the Diffusion Tensor analysis package supplied with FuncTool2 (GE Healthcare, Waukesha, WI, USA). ANOVA, followed by Duncan's test were used to test for statistically significant differences in metabolites fit by LCModel between different muscles. This was similarly done to test for differences in FA and VR between the four muscles.

Results and Discussion

The MRS results with Cramer-Rao bounds less than 20% were analyzed (Figure 1; * indicates significance at $P < 0.05$ level). The IMCL and choline concentration in soleus were significantly greater than that of any other muscle, while the creatine level in anterior tibialis was significantly lower. Measurable taurine was only found in soleus (mean 22.33 +/- 25.6). Figure 2 shows the mean FA for each muscle group; the FA for soleus was significantly lower than all other muscles, except medial gastrocnemius. There was no significant difference in VR between muscles (Table 1), although all muscles exhibit very non-isotropic diffusion. A linear fit was done to determine if there exists a relationship between FA and metabolite concentration for the various muscles and metabolites. A significant correlation was found only for anterior tibialis between FA and IMCL (R=0.49), Cr (R=0.45) and Cho (R=0.64), as shown in Figure 3.

Conclusions

Normal metabolite concentrations, FA and VR have been established for four muscles in the human calf. The relationship between metabolite concentration and FA found only in anterior tibialis suggests a structure-composition interaction, in particular the nature of the anisotropy and how it relates to dipolar coupling and the main magnetic field. Since this relationship was only observed in one muscle, a correction for fiber orientation may not always be required.

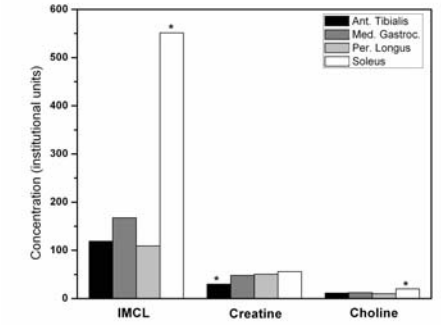

*Figure 1. Metabolite concentration for various muscles. P<0.05 significance between muscles indicated by *.*

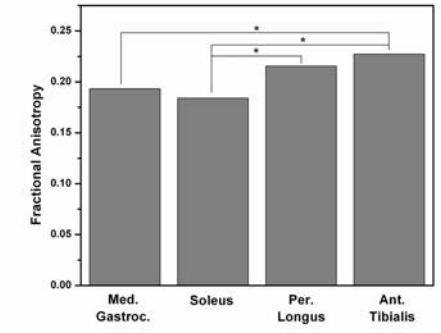

*Figure 2. Mean Fractional anisotropy for various muscles. P<0.05 significance indicated by *.*

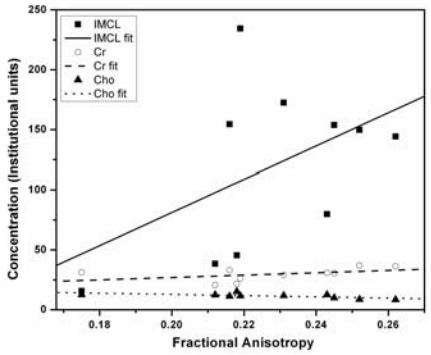

Figure 3. Relationship between FA and metabolite concentration for anterior tibialis.

	MG	Sol	PL	AT
Mean FA	0.193	0.184	0.215	0.227
Std FA	0.041	0.024	0.027	0.025
Mean VR	0.043	0.036	0.049	0.052
Std VR	0.024	0.009	0.013	0.010

Table 1. Mean and standard deviation of FA and VR for all muscles studied.

References

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