31P DWS of different muscles in the lower leg

Melissa Hooijmans[1], Ece Ercan[1], Robert Brandt[1], Andrew Webb[1], Hermien Kan[1], and Itamar Ronen[1]

[1]Radiology, Leiden University Medical Center, Leiden, Zuid-holland, Netherlands

Target audience: Researchers and physicians interested in microstructural characteristics of human skeletal muscle.

Purpose: To use ^{31}P diffusion weighted spectroscopy (DWS) to determine if there are differences in PCr diffusion between different lower leg muscles, possibly indicative of muscle fiber type composition in the two muscles . Diffusion weighted imaging has been applied to skeletal muscle before [1], but the information content of these results is limited by the lack of compartment specificity of water. In addition, in skeletal muscle, adipose tissue can lower the diffusion coefficient estimations in skeletal muscle [1,2].

Methods: 31P DWS was performed in the lower leg of 4 healthy volunteers (18-50 years). All measurements were performed on a 7T MR scanner (Philips Achieva, Netherlands, Best) with a custom built birdcage coil tuned for both ^{31}P and ^{1}H.T1-weighted axial images were obtained with the following scan parameters (TR/TE 260/5ms; spatial resolution 0.9x0.9x7.0mm), followed by a STEAM based 2D-DW CSI data-set (matrix size 8x8; TR/TE/TM 3000/60/240ms; readout bandwidth 4kHz; 1024 sample points, voxel size 20x20x50mm;) in which diffusion weighting was applied in six (n=2) or 3 (n=2) standard semi-orthogonal directions (b=2000s/mm^2). A bipolar gradient scheme was used to reduce eddy current effects. Apparent diffusion coefficients (ADC) values of the phosphocreatine (PCr) signal were determined for two different muscles, known to be different in both fiber type composition and muscle cell size; the soleus muscle (SOL) and the medial head of the gastrocnemius muscle (GC). Differences in ADC between the individual lower leg muscles were assessed with a paired sampled t-test and considered significant at p< 0.05.
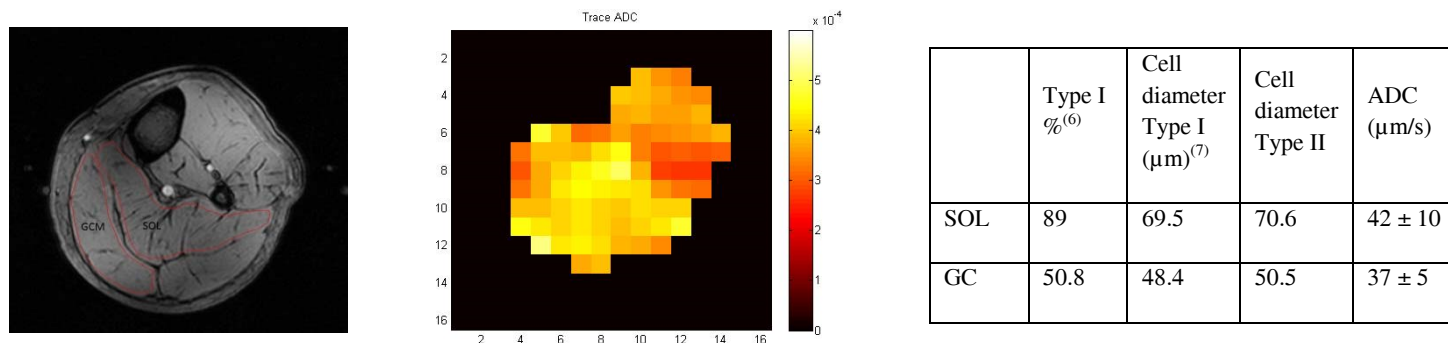

	Type I %[6]	Cell diameter Type I (μm)[7]	Cell diameter Type II	ADC (μm/s)
SOL	89	69.5	70.6	42 ± 10
GC	50.8	48.4	50.5	37 ± 5

Figure 1. T1-weighted image with the selected leg muscles (left) and an ADC map of the lower leg (right)

Results: In all subjects, the SNR of the PCr signal was sufficient to be able to determine the ADC for a number of voxels situated in the two different lower leg muscles (fig 1). Using paired t-tests a significant difference was found in ADC values between the SOL and GC muscle(p=0.024) (table 1).

Discussion & conclusion: Our results show that it is feasible to determine ADC values of the PCr signal at the individual skeletal muscle level in the human lower leg at 7T and that PCr diffusion is higher in the SOL compared to the GC muscle. By probing PCr instead of water, as would be done in DWI, we were able to obtain values for diffusion of the strictly intra-cellular metabolite PCr. Diffusion of PCr within the cellular compartment is likely to be limited by the amount of mitochondria in combination with the sarcoplasm reticulum. As Type I fibers contain more of both structures, it could be expected that in muscles containing predominantly type I fibers, such as the SOL muscle[3](table 1), the diffusion of PCr would be hindered the most. On the other hand, muscle cells also vary in diameter between different muscles, and cell size will logically also have a major effect on intra cellular diffusion. As the SOL muscle has been shown to have a larger cellular diameter compared to the GC muscle[4] (table 1), apparently, PCr diffusion seems to be affected more by cell size than fiber type distribution. While our results still need to be confirmed by probing more muscles, the difference between these two muscles clearly shows the potential of ^{31}P DWS to probe intra-cellular properties of skeletal muscle.

References: [1]. Zaraiskaya T et al. *J Magn Reson Imaging* 24: 402-408, 2006. [2]. Kan JH et al. *J Magn Reson Imaging* 29: 663-670, 2009. [3] Johnson et al. *J. Neurol Sci* 18: 111-129, 1973. [4] Polgar et al. *J Neurol Sci 19:307-318*, 1973