Improved Estimation of Muscle Water Diffusion Properties Using Dixon Imaging

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Introduction

Recently, it has been shown that elements of the diffusion tensor, and in particular those reporting on diffusion transverse to the longitudinal axis of the fibers, may reflect muscle damage in a manner distinct from T_2 (1,2). However, severe and chronic muscle damage, such as that occurring in Duchenne muscular dystrophy and polymyositis, may result in necrosis of muscle fibers. Consequently, fibrosis and replacement of muscle tissue by fat may occur, and the latter process lowers the diffusion coefficient estimates of muscle tissue (2,3). Therefore, in those patients in whom it may be most important to quantify muscle damage, the data may be most confounded by the presence of non-muscle tissue.

Fat-water separation methods may allow improved estimates of water diffusion properties under these conditions. In this work, we combine asymmetric spin-echo (ASE) Dixon imaging with diffusometry, and show proof of the principle that this approach provides more consistent estimates of muscle water diffusion than non-lipid suppressed diffusometry. We refer to this approach as lipid suppressed acquisition with diffusometry (LISA-D).

Methods

Samples: Six hamburger portions having varying nominal fat percentages (4, 8, 10, 15, 20, and 25%) were purchased and then further homogenized in a food processor. Each ~1 gram sample of each portion was measured and the sample was placed into a 2 ml centrifuge tube. In addition, a 2 ml sample of aqueous $MnCl_2$ was studied.

MRI Acquisition: MRI procedures were performed on a 31 cm bore, 4.7T Varian Direct Drive MR imager/spectrometer at room temperature. The samples were placed in the center of a 63 mm birdcage resonator and introduced into the center of the magnet. Global shimming was performed until the full width at half maximum of a ^1H peak obtained from the entire sample was <40 Hz. ASE data were obtained using TR/TE=2000/36.6, matrix =64×128, FOV=40×80 mm, slice thickness=1 mm, and ASE offsets (τ) of 0 and 714 μs. For each value of τ, images were obtained with and without a diffusion weighting (*b*) value =660 s/mm^2 along a single axis.

Data Analysis: Imaging processing was performed using Matlab v. 7.6.0. Complex images were formed from the ASE data for each value of τ and *b*. To form maps of water distribution, the images were added and the magnitude calculated. Also, magnitude images of the τ=0 images were calculated to form a combined (water + fat) image. In both combined and water images, the apparent diffusion coefficient, ADC, was calculated as

$$ADC = \frac{\ln \frac{S(b=0)}{S(b=660)}}{b} \qquad [1]$$

The mean and standard deviation (SD) of the ADC for all meat samples in water and combined images were determined.

Results

Figure 1 shows the ADC measured for regions of interest specified in the water-only and combined images, with the point at a fat percentage=0 corresponding to the water sample. For the $MnCl_2$ sample, the ADC measured form the water-only and combined images was similar (1.9×10^{-5} cm^2/s). For the meat samples, the mean (SD) of the ADC for the water-only images was 1.1 (SD 0.005) $\times10^{-5}$ cm^2/s and for the combined images 0.91 (SD 0.13) $\times10^{-5}$ cm^2/s.
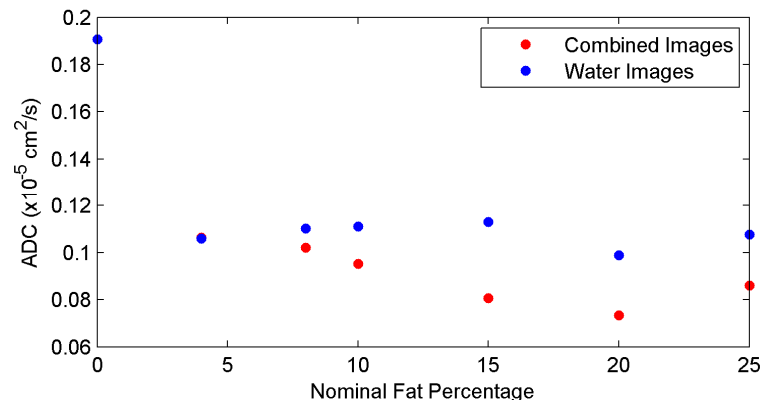

Figure 1. ADC estimated from water-only and combined images in meat samples of varying fat content.

Discussion

Qualitatively consistent with the predictions from a study simulating the effects of fat-muscle partial volume artifacts on muscle diffusion measurements, the ADC from combined water-fat images decreased with increasing fat content. However, more consistent and precise estimates of ADC were obtained using water-only images. These data suggest that improved measurements of muscle water diffusion may be obtained by using LISA-D or similar combined diffusion/fat suppression methods.

References
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