Quantitative magnetization transfer ultrashort echo time imaging of the Achilles tendon.

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Introduction

Off-resonance radiofrequency saturation has been successfully used to improve contrast in ultrashort echo time (UTE) images of tendons. Typically the saturation pulse is applied around 1kHz from resonance where direct saturation effects will dominate in these short T2 species [1]. At higher offset frequencies direct saturation effects decrease and magnetization transfer between bound macromolecular and free protons may be important. Mathematical modeling of magnetization transfer in gradient echo images has proved useful in the brain, allowing estimation of the bound proton fraction, which is closely related to myelin concentration [2]. The aim of this study was to combine quantitative MT modeling with UTE imaging to model the effects of distant off-resonance saturation pulses in the Achilles tendon in normal subjects.

Methods

The Achilles tendons of 5 normal volunteers were studied. Single-slice axial UTE images were acquired at 1.5T (TR=115ms, TE=0.04ms, flip-angle=15º, 3mm slice thickness, 0.5mm in-plane resolution, 1min acquisition time). Gaussian saturation pulses were applied with flip angles of 250, 500, 1000 and 1400º at frequency offsets of 2, 5, 10, 20, 50 and 100 kHz from resonance. T1 was estimated from 3 saturation-recovery UTE images [3]. The total acquisition time was 1 hour.

Signal intensity was measured from regions of interest consisting of the entire Achilles tendon in the slice. Signal intensity as a function of flip-angle and frequency offset was fitted to the Henklemann model [4], modified by Ramani's approximation of the pulsed rf as equivalent power continuous wave saturation [5].

Results

Images showed saturation from off resonance irradiation consistent with magnetization transfer (fig 1). The model fitted the experimental data well (fig 2). A super-Lorentzian lineshape gave the best fit with a bound proton fraction of 23.3% ± 0.6% (mean ± standard deviation).

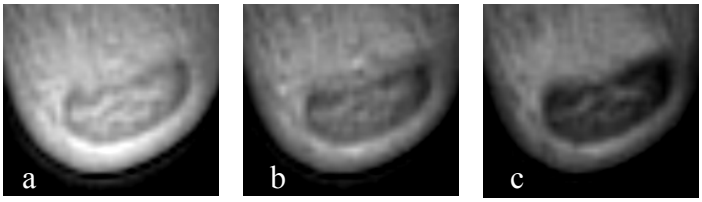

Figure 1: Examples of UTE images through the Achilles tendon of a normal volunteer.
(a) No off resonance saturation;
(b) 1400º pulse at 10kHz off resonance;
(c) 1400º pulse at 2kHz off resonance.

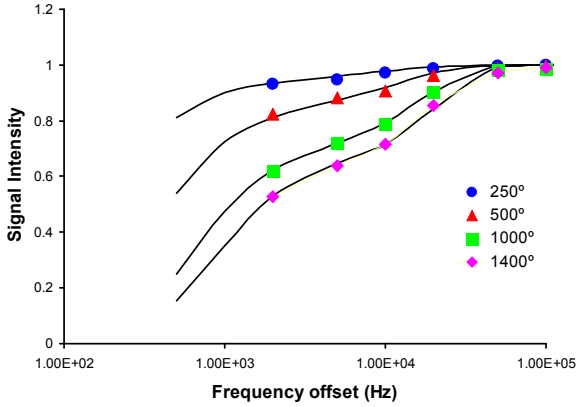

Figure 2: Signal intensity vs. Saturation pulse offset frequency for 4 different flip angles from a normal volunteer. Experimental data (points) and theory (lines)

Discussion

This study shows the feasibility of quantitative magnetization transfer using ultrashort echo time imaging in the Achilles tendon in clinically acceptable times. The model provided a good fit for saturation pulses of 250 to 1400º at 2 to 100 kHz off-resonance. The bound pool was best represented by a super-Lorenzian lineshape, as found for other tissues [5]. The bound protein fraction found in the Achilles tendon was higher than that previously reported in white matter of the brain [5], which may reflect the high collagen content closely bound to water in tendons [6]; similar values were obtained in all volunteers.

As the water content is known to increase relative to the collagen in Achilles tendonosis [7], this technique may be useful for quantitative assessment of tendon disease.

References

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