In-Vivo T1 and T2 Measurements of Muskuloskeletal Tissue at 3T and 1.5T

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Abstract

T1 and T2 values of muskuloskeletal tissues were measured in 5 normal volunteers at 1.5T and 3T. Look-Locker and T2 preparation methods were used to acquire images at different points on the T1 and T2 relaxation curves. A mono-exponential fit of the sampled points yielded T1's and T2's that were in the range of published values. Knowledge of 3T relaxation time constants is critical for the development of optimized muskuloskeletal imaging protocols at the higher field strength.

Introduction

A promised boost in SNR drives the growing popularity of the 3T whole body scanner in the clinical setting. In order to leverage this SNR for faster and/or higher resolution imaging, new imaging protocols must properly account for different T1 and T2 values at 3T. As an important step towards the development and optimization of 3T muskuloskeletal imaging protocols, T1 and T2 values of muscle, cartilage, synovial fluid, bone marrow, and fat were measured at 3T in five healthy volunteers. For reference and comparison, 1.5T values were measured in the same subjects.

Methods

The right knees of 5 healthy volunteers (2 male, 3 female, ages 27-38) were imaged at both 1.5T (GE Signa TwinSpeed) and 3T (GE Signa VH/i). Using a T/R extremity coil, sets of images at a single axial location containing muscle, cartilage, synovial fluid, marrow, and subcutaneous fat were acquired at different points on the T1 and T2 relaxation curves. T1 or T2 of a given tissue was calculated by performing a mono-exponential fit of the mean pixel intensities of a selected ROI at the different sampling times.

T1 Measurement Protocol Image sets for the T1 calculation were obtained using a Look-Locker method [1]. 10° alpha pulses were used to acquire eight images representing 8 equidistant samples along the T1 recovery curve. The sampling period was tailored to provide echo times with adequate coverage of the T1 recovery curve for each tissue of interest (Table 1). Acquisitions with the inversion pulse are subtracted from non-IR steady-state acquisitions yielding an understood asymptote of zero [2]. Because the asymptote of the exponential is known, acquiring the last sample at a time approximately equal to the T1 of the tissue is sufficient. A TR of 5000 was selected to provide adequate longitudinal recovery.

T2 Measurement Protocol Image sets for the T2 calculation were obtained using a T2 preparation sequence [2,3,4]. The T2 preparation sequence consists of a 90° tip-down pulse, a train of equally-spaced 180° pulses, and a 90° tip-up pulse. Different T2 echo times are generated by varying the number of 180's during the train of 180's and/or by varying the space between those 180's (Table 1). Images were acquired at 6 different echo times with a TR of 3 seconds.

Acquisition Both T1 and T2 image sets were acquired using a spectral spatial excitation with spiral readout – 4096 points, 8 arms, FOV 18 cm, slice thickness 3mm, 4 averages for T1 and 2 averages for T2. For fat and marrow measurements, the spectral spatial excitation was centered on the lipid resonance.

Post-Processing Using a custom software tool, ROI's were placed on each tissue of interest and a mono-exponential fit was calculated for each ROI [5]. To preserve the integrity of the fit, points in or near the noise floor were discarded. Relaxation times were averaged across all subjects and the standard deviations of the measurements were calculated (Table 2).

Tissue	T1 Echo Times (ms)	T2 Echo Times (ms)
muscle, cartilage	5.4, 206, 406, 606, 806, 1006, 1206, 1406	5.4, 17, 27.6, 38.3, 54.3, 102
synovial fluid	5.4, 506, 1006, 1506, 2006, 2506, 3006, 3506	5.4, 53, 99.6, 193, 390, 774
marrow, subcutaneous fat	5.4, 106, 206, 306, 506, 606, 706	5.4, 25, 43.6, 81, 166, 326

Table 1: Echo times for T1 and T2 protocols

Results

Measured T1's and T2's fall in the range of published values [6,7,8]. As is generally accepted, T1 values increase when moving from 1.5T to 3T, while T2 values decrease slightly, or remain roughly the same. The sharp decrease of the measured T2 for synovial fluid was also observed at 4T [7]. The T2's of fat and marrow are longer than the values reported by Duewell [7], but similar values were reported by Bottomley [8]. Cartilage and synovial fluid relaxation times had relatively high standard deviations which may be due to small voxel sizes, individual variations, or pathology [9].

Tissue	T1 (ms)		T2 (ms)	
	1.5T	3T	1.5T	3T
muscle	1130 ± 91.7	1420 ± 38.1	35.3 ± 3.85	31.7 ± 1.90
cartilage	1060 ± 155	1240 ± 107	42.1 ± 7.05	36.9 ± 3.81
synovial fluid	2850 ± 279	3620 ± 320	1210 ± 140	767 ± 48.8
marrow	288 ± 8.42	371 ± 7.94	165 ± 5.50	133 ± 4.43
subcutaneous fat	288 ± 5.27	365 ± 9.0	165 ± 4.96	133 ± 6.14

Table 2: *In-vivo* T1 and T2 measurements at 1.5T and 3T in milliseconds (value ± std deviation)

Conclusion

Knowledge of the increased T1 and decreased T2 relaxation times at 3T will allow intelligent design of new muskuloskeletal imaging protocols. For example, T1 values can be used to optimize inversion times for inversion recovery imaging. These relaxation times will also help determine the optimum repetition and echo times that maximize the benefit of increased SNR at 3T.

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