Quantitative Magnetization Transfer of Entire Human Patellofemoral Joint in 30 Minutes

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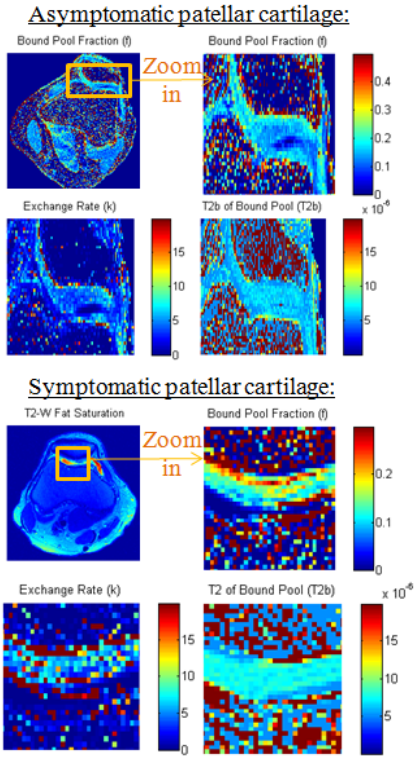
Purpose: Direct imaging of macromolecules is difficult in MRI due to their ultra-short T2 relaxation time. Quantitative magnetization transfer (qMT) imaging provides quantitative information about macromolecular interactions with water. qMT can measure the concentration of protons bound to macromolecules (f), the exchange rate between mobile protons and bound protons (k), and the T2 relaxation time of bound protons (T2b). Since articular cartilage has a high macromolecular concentration consisting primarily of collagen and proteoglycan, qMT of cartilage may be sensitive to its macromolecular content and structure. As qMT requires the acquisition of multiple MT-weighted images, extremely long scan times are a limitation. Thus, most joint studies to date have involved ex vivo cartilage samples (1) and human cadaveric cartilage specimens (2). Here we investigate methods for qMT imaging of the entire human patellofemoral joint in less than 30 minutes.

Method: Beyond MT-weighted imaging, qMT requires T1 maps, as well as flip angle and B0 maps to avoid confounding factors. All imaging techniques used a 2D radial "stack of stars" trajectory designed to cover the entire patella with 3mm slices with two echoes per TR. While we use enough excitations to fully sample the radial space here, later implementations using compressed sensing could exploit the radial trajectory for further acceleration.

Actual flip angle (AFI) source data was acquired using SPGR images (α=55°, 30 ms TR_1, 150 ms TR_2) and calculated using a simple relation (3). Source images for calculating DESPOT T1 maps (4) were obtained using SPGR images acquired at TR=23ms and 4 different flip angles (4°, 10°, 20°, and 30°). The T1 maps were generated using an iterative least squares linear fit of these images (4). MT preparation was done prior to SPGR imaging (α=10°, 34 ms TR) at 9 offset frequencies (3 kHz, 9 kHz, 15 kHz, 21 kHz) and 2 powers (500°, 850°). All MT-weighted images were reconstructed with a simultaneously acquired B_0 correction map. qMT images were calculated using a non-linear least squares 3-point fit in MATLAB (5). While the AFI scans were acquired in 4 minutes, all other SPGR scans were acquired in 2 minutes, resulting in a 28 minute total scan time. The method was performed on a 23 year old asymptomatic volunteer and 46 year old symptomatic subject with early cartilage degeneration on a GE MR 750 3T scanner (GE Healthcare, Waukesha, WI) using a 8 channel extremity coil.



Results: Figure 1 shows the f, k, and T2b maps of the patellar cartilage for both the asymptomatic volunteer and the volunteer with early cartilage degeneration. There was a depth dependent variation in the qMT parameters of cartilage with higher f, k, and T2b values in the deeper layers and lower values near the articular surface. Table 1 shows the measured qMT parameters for patellar cartilage and skeletal muscle and compares them to values reported previously in the literature (7). Although the T_1 value for cartilage in the asymptomatic volunteer was slightly lower than previously reported values, the f, k, and T_{2b} values for cartilage and skeletal muscle were similar to those reported in the literature. The qMT values for muscle were similar for the asymptomatic volunteer and the symptomatic patient. However, the f value was lower and the k and T2b values were higher for patellar cartilage in the symptomatic patient than the asymptomatic volunteer.

Discussion: This study documents the feasibility of performing qMT imaging of the human patellofemoral joint in less than 30 minutes. For both the asymptomatic volunteer and the symptomatic patient with early cartilage degeneration, the qMT parameters were convincing compared to the literature. Depth dependent variations in cartilage qMT parameters were also observed similar what was previously reported by Gold et. al. using patellar cadaveric specimens (2). While our study included only 2 subjects, the differences between the asymptomatic volunteer and the symptomatic patient in cartilage qMT parameters but not muscle qMT parameters is encouraging. Additional studies are needed to understanding of how qMT parameters change during cartilage degeneration and which factors are responsible for changes in qMT parameters during various stages of the disease process.

Cartilage	Asymptomatic	Abnormal	Literature (7)
T1	1069±111 ms	1367±142 ms	1168±18 ms
f	16.6±3.9%	15.1±4.5 %	17.1±2.4 %
k	5.1±3.2	7.6±5.1	9.7
T2b	6.6±1.7 µs	7.4±0.7 µs	8.3±0.1 µs

Muscle	Asymptomatic	Abnormal	Literature (7)
T1	1293±150 ms	1180±118 ms	1412±13 ms
f	13.9±3.5%	12.3±2.7 %	7.4±1.3 %
k	7.51±5.6	8.9±5.6	4.5
T2b	6.4±0.9 µs	6.6±0.7 µs	8.7±0.1 µs

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