Quantitative Magnetization Transfer Analysis of In-Vivo Human Patellar Cartilage at 3.0T

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Introduction: Quantitative magnetization transfer (qMT) may provide new cartilage biomarkers obtained through the magnetization transfer effect [1]. qMT can be used to measure the concentration of protons bound to macromolecules (f), the exchange rate between mobile protons and macromolecular bound protons (k), and the T2 relaxation time of macromolecular bound protons (T2b). Previous studies have measured f and k in bovine cartilage samples and human cadaveric knee joints using a fixed T2b in the qMT analysis [2-4]. We have developed a MR protocol for measuring qMT parameters of human patellar cartilage in vivo at 3.0T with an acquisition time of 30 minutes which is robust enough to fit f, k, and T2b. This study was performed to compare qMT parameters of patellar cartilage in young sedentary volunteers and older volunteers who perform regular strenuous physical activity.

Method: Two groups of 6 asymptomatic volunteers each were identified based on age and level of regular physical activity: 6 younger sedentary males between 23 and 33 years of age (group 1) and 6 older males between 41 and 47 years of age who performed regular strenuous physical activity (group 2). All 12 volunteers underwent an MR examination of the knee on a 3.0T scanner (Discovery MR750, GE Healthcare, Waukesha, WI) using an 8-channel phased-array extremity coil (In Vivo, Orlando, FL). For each volunteer, 2 SPGR volumes were acquired for B1 error correction using AFI [5], 4 SPGR volumes were acquired for T1 mapping using VFA [6], one SPGR volume was acquired with no MT effect, and 8 SPGR volumes were acquired with MT effects at four MT offset frequencies (3, 9, 15, 21 kHz) and two MT powers (890°, 500°). Besides the AFI volumes, all scans were acquired with a 14cm field of view, 0.54mm x.0.54mm in-plane resolution, and 4mm slice thickness. The AFI volumes were acquired at a quarter of this resolution since B1 effects vary smoothly across the field of view. Total scan time was 30 minutes. Image reconstruction and analysis was performed within MATLAB with FSL's FLIRT software providing co-registration between each scan series. The qMT parameters f, k, and T2b were calculated with a non-linear iterative regressive least-squares fitting methods using a model previously described by Yarnykh [7]. qMT parameters were measured in regions of interest placed around the entire patellar cartilage and within the superficial and deep halves of the cartilage. Student t-tests were used to compare qMT parameters in the superficial and deep layers of cartilage and to compare cartilage qMT parameters for both groups of volunteers.

Results: Patellar cartilage qMT values in younger sedentary volunteers (group 1) and older physically active volunteers (group 2) are shown in Table 1. For both groups of volunteers, f was significantly higher ($p<0.05$) in the deep layer than the superficial layer of cartilage, while T2b was significantly higher ($p<0.05$) in the superficial layer than the deep layer of cartilage. There was no significant ($p=0.80$) depth dependent variation in k. Older physically active volunteers had similar ($p=0.49$-0.96) global cartilage f and k values as young sedentary volunteers. However, older physically active volunteers had significantly higher ($p<0.05$) global cartilage T2b values when compared to younger sedentary volunteers. In order to appreciate qualitative differences between younger sedentary volunteers and older physically active volunteers, one slice from the f and T2b maps of a subject in groups 1 and 2 are shown in Figure 1.

Global ROI				Deep Layer (Top) ROI				Superficial Layer (Bottom) ROI			
Group	Value	Mean	SD	Group	Value	Mean	SD	Group	Value	Mean	SD
1	f	18.17%	4.02%	1	f	22.97%	6.46%	1	f	13.94%	2.12%
1	k	8.77	4.03	1	k	8.64	5.09	1	k	8.89	3.27
1	T2b	6.87	0.13	1	T2b	6.36	0.51	1	T2b	7.32	0.47
2	f	16.83%	2.40%	2	f	21.89%	2.86%	2	f	12.25%	3.63%
2	k	8.89	3.28	2	k	8.57	3.01	2	k	9.10	4.50
2	T2b	7.44	0.43	2	T2b	6.70	0.51	2	T2b	8.12	0.92

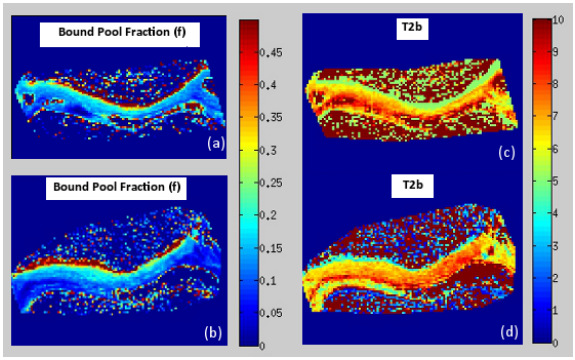

Figure 1. Comparison of f [%] and T2b [μs] between a younger sedentary volunteer (a, c) and an older physically active volunteer (b, d). Notice that the f is lower and the T2b is higher in the older subject (b, d) when compared to the younger subject (a, c).

Discussion: Our study has documented the feasibility of performing comprehensive qMT assessment of human patellar cartilage at 3.0T in a 30 minute scan time. The f and k values in our study are similar to those reported previously in the literature [2-4]. A depth-dependent variation in cartilage f and T2b was noted. Since previous studies have shown that f correlates with cartilage proteoglycan content, the higher f values in the deep layer of cartilage are most likely due to increased proteoglycan content in this region [2]. The etiology for the depth dependent variation in T2b is currently unknown. Patellar cartilage T2b was significantly higher in older physically active volunteers than younger sedentary volunteers which suggest that T2b is the most sensitive qMT parameter for detecting early cartilage degeneration due to aging and extended periods of strenuous physical activity. Additional studies are needed to compare qMT parameters in asymptomatic volunteers and patients with osteoarthritis and to investigate the factors that lead to alterations in qMT parameters during various stages of cartilage degeneration.

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