In-Vivo T_2 Mapping and dGEMRIC of Human Hip Cartilage at 1.5T

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INTRODUCTION

Magnetic resonance imaging (MRI) enables non-invasive diagnosis of diarthrodial joint pathology and is especially useful for detection of articular cartilage degeneration due to osteoarthritis (OA). Recently, the MRI longitudinal and transverse relaxation time constants, T_1 and T_2, of articular cartilage have been proposed as imaging biomarkers for OA [1]. Cartilage T_2 values increase with the increase of water content and collagen fiber fibrillation found during OA [2]. Cartilage T_1 values in the presence of gadolinium (delayed Gadolinium Enhanced MRI of Cartilage, dGEMRIC), decrease with reduction of proteoglycan content of cartilage which also occurs during OA [3]. Previous studies have evaluated T_1 or T_2 values of hip cartilage separately [3,4,5]. To the best of our knowledge, no study has evaluated in-vivo T_1 and T_2 values of hip cartilage in the same subjects. Therefore, the purpose of this study was to evaluate T_1 and T_2 values of femoral and acetabular cartilage in subjects with symptomatic hip OA.

METHODS

Following local institutional review board approval with informed consent, patients with symptomatic hip OA who were undergoing total hip replacement were enrolled in the study. Six patients have been enrolled to date (5F, 1M, 58.0±13.1 y.o., range 40-73). Data Acquisition: All data was acquired using a clinical 1.5T MR scanner (GE Healthcare, Milwaukee WI). For T_2 calculations, a series of coronal T_2-weighted fast spin-echo (FSE) images were acquired across 11 slice locations centered on the femoral head. Eight echo images were acquired at each slice location: TE=8.78ms-70.21ms, by 8.78ms, TR=1500ms, matrix= 256x160, slice thickness=4mm, slice spacing=1mm, FOV=16cm^2, resolution=0.625 mm^2. Following this acquisition, subjects were injected intravenously with a double dose (0.4 mL/kg) of the contrast agent Omniscan (Gd-DPTA^{2-}; Amersham Health, USA) and performed low level exercises for 15 minutes. Subjects were then rescanned approximately 1.5 hours (1.7±0.4 hr) later. Coronal T_1-weighted images were acquired at one slice location through the center of the femoral head using an inversion recovery sequence at five inversion time points: TE=8.35ms, TR=2000ms, TI=(50, 200, 400, 700,1600)ms, ETL=32, matrix=256x256, slice thickness=4mm, slice spacing=1mm, FOV=16cm^2, resolution=0.625mm^2. Data Analysis: T_2 values of acetabular and femoral cartilages were calculated on a pixel-by-pixel basis by fitting the echo time (TE) data and the corresponding signal intensity (SI) to the equation: $SI(TE)=So*exp(-TE/T_2)$ using a non-linear method (Matlab, Mathworks, Natick MA). Similarly, T_1 values were calculated by fitting the inversion time (TI) and the corresponding signal intensity to the equation: $SI(TI)=So(1-2*A*exp(-TI/T_1)+exp(-TR/T_1))$. Summary statistics were calculated using average bulk T_1 and T_2 values generated from all analyzed pixels. An automated program separated the cartilage into superficial, middle and deep zones for regional analysis of T_1 and T_2 values [6]. A paired t-test was performed to detect differences between bulk femoral and acetabular T_1 and T_2 values. A one-way repeated measures ANOVA was performed to detect any regional differences of T_1 and T_2 values. A post-hoc Student-Neuman-Keuls test was performed when significance was found in the ANOVA analysis.

RESULTS

The average bulk T_2 value of femoral and acetabular cartilage was 38.1±8.3ms and 39.3±9.7ms (mean ± st.dev.), respectively. The average bulk T_1 value of femoral and acetabular cartilage was 365.3±41.7ms and 349.0±48.1 ms, respectively. No differences between femoral and acetabular bulk T_1 values (p=0.3) or bulk T_2 values (p=0.7) were found. A representative femoral cartilage T_1 and T_2 map are shown below. No differences of T_2 were found through the depth of femoral (p=0.3) or acetabular (p=0.5) cartilage. However, T_1 values of femoral cartilage significantly increased in value from the articular surface to the subchondral bone surface (p=0.01). The T_1 values of acetabular cartilage increased slightly in value through the depth of the tissue (Table 1), but not significantly.

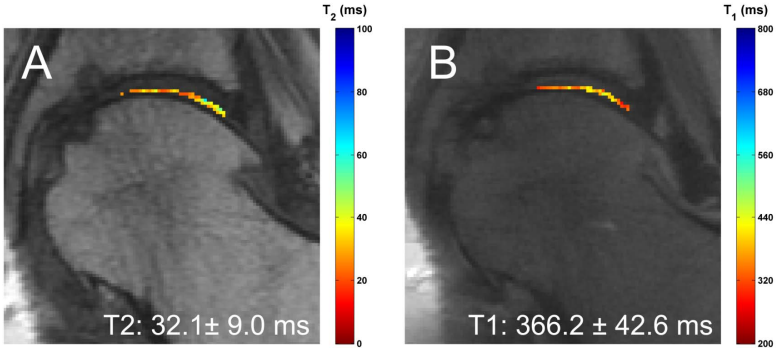

Figure 1. Representative time constant maps of load bearing femoral cartilage . (A) Pre-gadolinium injection T_2 map. (B) Post-gadolinium injection T_1 map.

DISCUSSION

This study evaluated in-vivo T_1 and T_2 values of hip cartilage in subjects with symptomatic OA. The current T_2 values are similar in magnitude to a previous study which examined patients with hip dysplasia [4]. Our acetabular T_2 values are larger in magnitude when compared to a previous study of hip cartilage in healthy subjects [5]. The increase of T_2 value likely indicates the presence of OA. The current T_1 values tended to be similar in magnitude to patients with OA and less than T_1 values found in healthy subjects [3], indicating reduced quantities of proteoglycans in the imaged articular cartilage. Two back-to-back scanning sessions were performed to acquire images for T_1 and T_2 mapping of hip cartilage. Although imaging and subject preparation time is longer than a normal clinical exam (approximately 3.5 hours), this scanning method enables a comprehensive quantitative analysis of the primary constituents of hip cartilage (water, collagen, proteoglycans). The combined scanning may be beneficial since it is unclear if T_1 orT_2 mapping alone would be sufficient for the diagnosis of OA or for examining changes of OA within a joint over time. Additional work evaluating the MR time constants of articular cartilage is needed to determine their applicability in a clinical setting.

Table 1. Zonal Analysis of T_1 Values of Hip Cartilage

Cartilage Depth	Femoral Cartilage (ms)	Acetabular Cartilage (ms)
Superficial	346.8 ± 32.4†	365.0 ± 48.3
Middle	378.1 ± 50.0	354.3 ± 57.9
Deep	387.3 ± 45.7	346.4 ± 48.0

Note: † - Superficial femoral cartilage had significantly reduced T_1 values compared to the middle and deep zones. All values reported as mean ± st.dev.

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