In-vivo T2 Mapping and dGEMRIC of Human 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, T1 and T2, of articular cartilage have been proposed as imaging biomarkers for OA [1]. Cartilage T2 values increase with the increase of water content and collagen fiber fibrillation found during OA [2]. Cartilage T1 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 T1 and T2 values of hip cartilage separately [3,4,5]. To the best of our knowledge, no study has evaluated T1 and T2 values of hip cartilage in the same subjects in-vivo. Therefore, the purpose of this study was to evaluate T1 and T2 values of femoral cartilage in symptomatic OA subjects.

Materials and 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. Five patients have been enrolled to date (4F, 1M, 55.6±14.7 y.o., range 40-73). Data Acquisition: For T2 calculation, a series of coronal T2-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=16cm2, resolution=0.625 mm2. Following this acquisition, subjects were injected intravenously with a double dose (0.4 mL/kg) of the contrast agent Omniscan (Gd-DPTA- Amersham Health, USA) and performed low level exercises for 15 minutes. Subjects were then rescaned approximately 1.5 hours (1.7±0.4 hr) later. Coronal T1 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=16cm2, resolution=0.625 mm2. Data Analysis: T2 values of acetalubar and femoral cartilages were calculated on a pixel-by-pixel basis using the following equations:

\[ SI(T1) = So(1-2*a*exp(-TI/T1)+exp(-TR/T1)) \]

where \( SI(TE) = So*exp(-TE/T2) \) using a non-linear method (Matlab, Mathworks, Natick MA). Similarly, T1 values were calculated using the following equation for T1: 

\[ SI(T2) = So*exp(-TE/T2) \]

Results: The average bulk T2 value of femoral and acetalubar cartilage was 37.2±9.0ms and 38.4±10.6ms (mean±st.dev), respectively. The average bulk T1 value of femoral and acetalubar cartilage was 365.9±46.6ms and 345.6±53.0 ms, respectively. No differences of bulk T1 values (p=0.3) or bulk T2 values (p=0.7) were found. A representative femoral cartilage T1 and T2 map are shown below. No differences of T2 were found through the depth of femoral or acetalubar cartilages (p=0.05). However, T1 values of femoral cartilage significantly decreased in value from the articular surface to the subchondral bone surface. The T1 values of acetalubar cartilage reduced in value in a similar pattern through the depth of the tissue (Table 1).

Discussion: This study evaluated in-vivo T1 and T2 values of hip cartilage in subjects with symptomatic OA. The current T2 values are similar in magnitude to a previous study which examined patients with hip dysplasia [4]. Our acetalubar T2 values are also larger in magnitude when compared to a previous study of hip cartilage in healthy subjects [5]. The increase of T2 value likely indicates the presence of OA. Further more, the current T1 values tended to be similar in magnitude to patients with OA and less than T1 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 T1 and T2 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 T1 or T2 mapping alone would be sufficient 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.


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