

Localized Cartilage Assessment with Three-Dimensional dGEMRIC and Quantitative MRI in Patients with Femoroacetabular Impingement

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Introduction

Femoroacetabular impingement (FAI), in which femoral deformities lead to localized damage of the labrum and/or cartilage, has been proposed as a mechanism explaining idiopathic osteoarthritis in non-dysplastic hips (2). Further tests of this hypothesis and associated surgeries to prevent osteoarthritis will rely on identifying a noninvasive method for assessing localized cartilage degeneration at the hip. Delayed gadolinium enhanced MRI of cartilage (dGEMRIC) permits inference of glycosaminoglycan (GAG) distribution in articular cartilage from measurements of the tissue T1 value after injection of the MRI contrast agent gadolinium (1). Application of dGEMRIC to study clinical hip problems has focused on a single summary index describing the entire joint (3). Quantitative MRI (qMRI) assessment of cartilage morphology has been validated in joints with thin cartilage plates (6) but has not been used to describe local acetabular and femoral cartilage morphology. Our objectives were to assess the feasibility of a three-dimensional (3D) dGEMRIC protocol to assess localized GAG distribution in articular cartilage of patients with hip impingement and to determine the feasibility of assessing cartilage morphology of both the acetabular and femoral cartilage in those same patients.

Methods

We performed qMRI and 3D-dGEMRIC scans on four patients diagnosed with FAI (hip pain, positive impingement test) and four controls matched for age and body mass index. We used a Philips Intera 3T scanner with a flexible surface coil around the hip. Subjects first underwent the qMRI scan and, after exiting the scanner, were intravenously injected with 0.2 mM/kg gadolinium (Magnevist, Berlex Labs) and asked to perform hip rotations for 10 minutes followed by 20 minutes of walking to facilitate diffusion of the contrast agent into the cartilage. dGEMRIC imaging started 75 minutes after injection.

qMRI Protocol: 3D sagittal fast gradient echo with selective water excitation (ProSet), TR/TE/flip = 18.5 ms/6.3 ms/15°, FOV = 160 mm, matrix: 512 x 512, 1.5 mm slice thickness, 50 slices, 6:45 minutes.

qMRI Analysis: Femoral head and acetabular cartilage plates were manually segmented with commercially available software (Chondrometrics, Ainring, Germany). 19 slices of the femoral head cartilage and 17 slices of the acetabular cartilage plates were segmented for each subject. We determined volume and mean/maximum thickness.

dGEMRIC Protocol: sagittal 3D IR-TFE, TR_{ref}/TE/flip = 4.7ms/1.6ms/15°, inversion time TI = 1600, 1200, 800, 400, 200, 150, 100 ms, FOV = 220 mm, matrix: 256 x 256 (interpolated to 512 x 512), 3 mm slice thickness, 20 slices. Scan time was approximately 35 minutes. To attain sufficient signal-to-noise at the short TIs, TR_{shot} was held constant at 1700 ms for each TI.

dGEMRIC Analysis: All 3D scans were volume registered prior to analysis to compensate for any subject movement during the examination. Quantitative T1 maps were generated with custom programs (IGOR, Wavemetrics, USA) through pixel-based curve fitting of the magnitude signal intensities versus inversion times (Figure 1). The geometric center of the femoral head was identified and used to divide the cartilage surface into anterior and posterior regions. Regions of interest (ROIs) were manually segmented on the four middle slices for each subject and the average of all pixels within the four-slice ROI defined the dGEMRIC index (T1-value) for that region.

Results

In seven out of eight cases the volume of patient cartilage was less than the control but, for the most part, within the expected measurement variation (6). Mean and maximum cartilage thicknesses were consistent between the two groups (Tables 2 and 3). In all but one of the eight subjects the anterior dGEMRIC index was lower than that in the posterior region (Table 1). Two of the four symptomatic subjects had both anterior and posterior dGEMRIC indices that were more than 145 ms lower than corresponding regions in their matched controls and fell in the range of values for subjects with osteoarthritis in a previous study (4).

Discussion

We have shown that it is possible to perform comprehensive *in vivo* morphological measurements for both articular and femoral cartilage plates from the same high resolution dataset. Local measurements of cartilage morphology, which may be pertinent in studies of FAI, can be made from these data (although we have presented only global measurements here). Previous *in vivo* qMRI studies in the hip have evaluated only a single cartilage plate and measured either volume or thickness (5, 7). Our images at 3.0T were acquired in approximately half the time and with improved in-plane resolution as compared to those previous studies at 1.5T.

Our results show that there are local differences in cartilage dGEMRIC index that are substantial in some subjects and some controls. This approach may yield more information about cartilage health than a single score for the entire joint, particularly when cartilage degeneration may be localized, such as in FAI.

References 1) Burstein D, et al. MRM. 2001; 45:36-41. 2) Ganz R, et al. Clin Orth. 2003; 417:112-120. 3) Kim Y, et al. JBJS Am. 2003; 85:1987-1992. 4) McKenzie C, et al. Proc. ISMRM 13 (2005). 5) Nishii T, et al. Osteo & Cart. 2004; 12:650-657. 6) Vanwanseele, B. et al. MRM. 2004;51:1026-1030. 7) Zhai G, et al. Arth. & Rheu. 2005; 52:4:1069-1076.

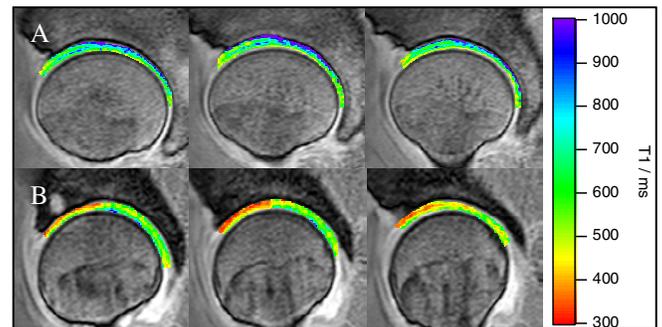


Figure 1: Slices 10-12 for the matched control (A) and patient #2 (B).

Table 1: Average T1 for symptomatic subjects and matched controls.

Average T1 for Four Slices					
		Anterior T1 (ms)		Posterior T1 (ms)	
No.	Sex/Age	Control	Patient	Control	Patient
1	F-19	779	630	F-24	792
2	M-36	726	453	M-34	793
3	M-40	614	624	M-35	725
4	M-36	691	692	M-34	751

Table 2: Femoral head cartilage volume and thickness measurements.

Femoral Head Cartilage						
		Volume (ml)		Mean Thickness (mm)		Max Thickness (mm)
No.	Control	Patient	Control	Patient	Control	Patient
1	3.6	3.4	1.4	1.3	2.3	2.2
2	3.3	3.2	1.2	1.2	2.3	2.4
3	4.5	3.8	1.4	1.3	2.7	2.2
4	3.2	3.1	1.2	1.1	2.1	1.9

Table 3: Acetabular cartilage volume and thickness measurements.

Acetabular Cartilage						
		Volume (ml)		Mean Thickness (mm)		Max Thickness (mm)
No.	Control	Patient	Control	Patient	Control	Patient
1	3.3	3.4	1.7	1.7	3.3	3.0
2	2.9	2.7	1.5	1.6	3.7	2.7
3	4.3	3.1	2.1	1.7	3.5	3.5
4	2.3	2.0	1.4	1.2	2.6	2.8