

Regional Analysis of Hip Cartilage MR Relaxation Times in Subjects with and without Femoroacetabular Impingement

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INTRODUCTION: Over the past decade, conditions such as femoroacetabular impingement (FAI) (1-2) and acetabular dysplasia (3-4) have been identified as pertinent causes of premature osteoarthritis (OA) of the hip joint in young and middle-aged patients. Early detection of cartilage degeneration could help identify patients with hip pain who may benefit from early surgical intervention. Quantitative magnetic resonance imaging (qMRI) techniques such as $T_{1\rho}$ and T_2 relaxation time mapping have recently emerged as potential markers of early biochemical cartilage degeneration (5). These measures are highly sensitive to alterations in composition and structural integrity of collagen in the cartilage extracellular matrix *in vivo*. However, evaluation of the articular hip cartilage with MRI is extremely challenging, because of the thinness of the cartilage and spherical surface geometry of the femoral head and acetabulum (9). Due to the thin, adhesive nature of the two articular hip cartilage layers, morphological and relaxometry analysis of this tissue has generally considered the two layers (femoral and acetabular) as a single unit. However, the biomechanical loading of the hip joint and thus the degenerative changes in cartilage may vary locally, depending on the anatomy of the joint, physical activities, and the composition of the cartilage (8,1-2), thus emphasizing the need for regional analysis of healthy and degenerated hip cartilage. The objective of this study was to perform a sub-regional analysis of MR relaxation times ($T_{1\rho}$ and T_2) measurements in the hip joint for early assessment of cartilage defects in patients with FAI.

METHODS: Twelve healthy volunteers (Age = 29.9±10.9 years, range= 22-60 years; BMI = 23.5±2.8 kg/m², range = 17.9–28.1 kg/m²) and 9 patients who presented with symptomatic FAI based on clinical examination and plain radiographic findings (1) (Age = 36.6±9.7 years, range = 23–52 years; BMI = 26.2±6.9 kg/m², range = 18.8–38.4 kg/m²) were recruited as a part of a large cohort study approved by the IRB of our institution. All imaging was performed with a 3T GE MR750 MR Scanner and a cardiac coil (GE Healthcare). Participants were positioned supine, with the knees extended and the feet held together by adhesive tape for standardizing the hip and knee angles, positioning aids were used to immobilize and support patients. The imaging protocol included sagittal and coronal T_2 -weighted fat-saturated fast spin-echo (FSE) images for clinical grading, oblique axial T_2 -weighted FSE images for alpha angle (α) measurement, high resolution, fat-suppressed, sagittal 3D fat-suppressed spoiled gradient echo (SPGR) images for cartilage morphology assessment, and a concatenated $T_{1\rho}/T_2$ quantification sequence (7), allowing post-processing creation of $T_{1\rho}$ and T_2 maps. All but one of the FAI patients had cam-type deformity. Both femoral and acetabular cartilage layers in each joint were semi-automatically segmented on sagittal 3D high-resolution spoiled gradient echo (SPGR) images. These segmented regions of interest (ROIs) were automatically divided radially into twelve equal sub-regions (30° intervals) based on the fitted center of the femur head (figure 1), thereof only 9 sub-regions (R2–R10) contained cartilage. For acetabular cartilage analysis, only sub-regions R2 to R8 contained cartilage. The mean value of $T_{1\rho}/T_2$ was calculated in each sub-region after superimposing the divided cartilage contours on the MR relaxation ($T_{1\rho}/T_2$) maps to quantify the relaxation times. ANOVA was performed to identify whether the differences in MR relaxation times between healthy and FAI subjects differed between the sub-regions of the cartilage. The ability of mean values of global ROIs and different sub-regions of the cartilage to discriminate between healthy and FAI subjects was assessed using the area under the curve (AUC) of the receiver operating characteristic (ROC) curve analysis.

RESULTS: $T_{1\rho}$ and T_2 relaxation times of the femoral cartilage were significantly higher in FAI subjects compared to healthy controls (39.9±3.3 msec in FAI vs. 35.4±2.3 msec in controls for $T_{1\rho}$ (P=0.0020); 33.9±3.1 msec in FAI vs. 31.1±1.7 msec in controls for T_2 (P=0.0160)). Sub-regional analysis showed significantly different $T_{1\rho}$ and T_2 relaxation times in the anterior-superior region (R9) of the hip joint cartilage between subjects with FAI and healthy subjects (Figure 2). ROC analysis showed that sub-regional analysis in femoral cartilage was more sensitive in discriminating FAI joint cartilage from that of healthy joints than global analysis of the whole region ($T_{1\rho}$: area under the curve (AUC)=0.981, P=0.0001 for R9 sub-region; AUC=0.901, P=0.002 for whole region; T_2 : AUC=0.976, P=0.0005 for R9 sub-region; AUC=0.808, P=0.0124 for whole region).

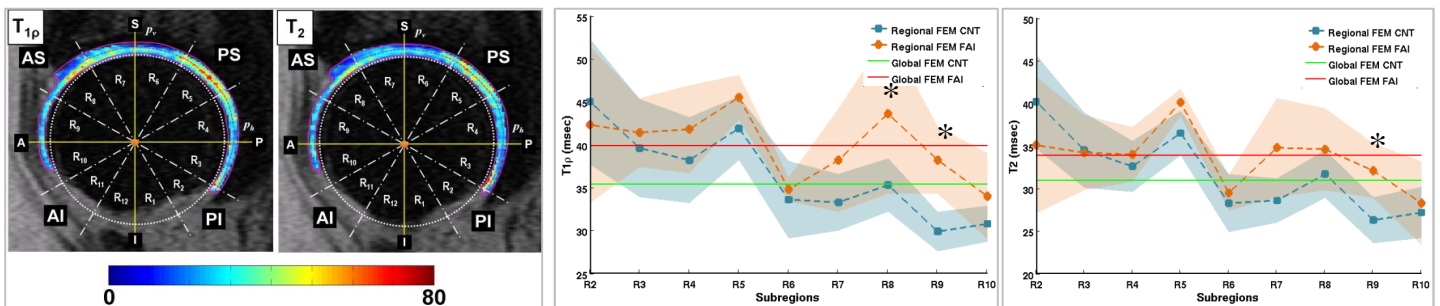


Figure 1: (a) Color-coded $T_{1\rho}$ and T_2 relaxation time maps of hip cartilage overlaid on the first echo MR images and sub-regions are superimposed on them. The bar represents the color specific $T_{1\rho}$ and T_2 values in msec. (b-c) $T_{1\rho}$ and T_2 values in sub-regions of the femoral cartilage of healthy and FAI subjects. (*) represents significant difference between healthy and FAI subjects

DISCUSSION: This study results clearly suggest that the damage due to FAI pathologic deformities appears to be region-specific (impaction of the head) and the surrounding cartilage regions are less affected (showing less or no change in biochemical composition) (2,4,9). These findings are consistent with previous studies in literature on location of hip joint cartilage lesions in FAI patients (8-9). ROC analysis results suggest that the analysis of individualized (femoral and acetabular) regions of interest gives better insight on region-specific degeneration and allow us to exclude joint fluid with high signal intensity between the acetabular and femoral cartilage layers during quantification. In conclusion, this study demonstrated (a) variations in regional composition at the hip cartilage using MR relaxation times ($T_{1\rho}$ and T_2), (b) analysis based on local regions is more sensitive than global measures of hip cartilage composition, and (c) that cartilage degeneration in subjects with and without FAI may be region-specific.

References: [1] Clohisy et al., JBJS, 2008;90:2267, [2] Leunig et al., CORR,2009;467:616. [3] Beck et al., JBJS,2005;87(7):1012. [4] Jacobsen Acta Orthop, 2006;77(324):1. [5] Li et al., MRM, 2009;61(6):1310-1318; [6] Lievens et al., Ann Rheum Dis 2004;63(6):621-626. [7] Li et al., ISMRM 2011:19; [8] Sampson, Clin Sports Med 2011;30(2):331-348; [9] Bittersohl et al., Osteoarthritis Cartilage 2009;17(10):1297-1306.

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