Cartilage assessment in femoroacetabular impingement using dGEMRIC with radial imaging planes at 3 Tesla: preliminary validation against intra-operative findings

Riccardo Lattanzi[1,2], Catherine Petchprapa[1], Daniele Ascani[1], Roy I Davidovitch[3], Thomas Youm[3], Robert J Meislin[3], and Michael Recht[1]

[1]*Radiology, New York University Langone Medical Center, New York, NY, United States,* [2]*The Bernard and Irene Schwartz Center for Biomedical Imaging, New York University Medical Center, New York, NY, United States,* [3]*Orthopedic Surgery, New York University Hospital for Joint Diseases, New York, NY, United States*

Introduction

Femoroacetabular impingement (FAI) has been recognized as one of the causes of hip osteoarthritis (OA) [1]. Joint-preserving surgeries, aimed at correcting the bony abnormalities associated with FAI and repair labral injuries, are likely to prevent or delay hip OA only in patients with limited degeneration of the articular cartilage (AC) [2]. Accurate pre-operative evaluation of AC is therefore critical in FAI. Delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC) is a biochemical imaging technique that is sensitive to the earliest degenerative changes in cartilage [3]. A pulse sequence was introduced in recent years for dGEMRIC of the hip at 3 T on radial imaging planes [4], which have been advocated for morphologic evaluation of the acetabular labrum and AC in FAI, as they allow orthogonal display of the whole acetabular rim. The aim of this work is to validate radial dGEMRIC at 3 T against arthroscopic findings, employing a method recently proposed to standardize dGEMRIC measurements in order to remove the effects of patient's age, sex and diffusion of gadolinium contrast [5].

Materials and Methods:

We performed a retrospective review of 17 hips (10 left, 7 right) in 17 patients (10 females, 7 males) who received a pre-operative dGEMRIC scan (age at MRI = 34 ± 10y) and underwent hip arthroscopy (52 ± 34 days after MRI) at our institution. All patients had FAI and either torn or detached labrum. Location of tears and AC injuries/defects were documented on a post-operative descriptive hip form. A rapid B_1-insensitive 2D T_1-mapping pulse sequence [4] was used for dGEMRIC acquisition on a 3 T MRI system (Verio; Siemens Medical Solutions, Erlangen, Germany). Relevant imaging parameters were: in-plane spatial resolution = 0.6 x 0.6 mm^2, slice thickness = 4 mm, TR/TE= 143/10 ms, receiver bandwidth = 161 Hz/pixel, acquisition time ~1 min 40 s per slice. For each patient, six radial dGEMRIC maps were acquired covering the anterior-superior (AS) and posterior-superior (PS) regions of the hip AC. Due to wrapping and motion artifacts, the number of usable slices varied among patients, ranging from 2 to 6 for a total of 77, with at least one AS and one PS in each case. For all slices, a region of interest (ROI) was defined over the central portion (near the fovea) of the femoral cartilage, assumed to be healthy, and T_1 values (x) were transformed to standard scores (z) using $z = (x - \mu)/\sigma$, where μ and σ are the mean and standard deviation of T_1 in the femoral ROI. The weight-bearing portion of the AC was segmented on the new standardized dGEMRIC maps and results were validated against arthroscopy findings, using $z < -2$ as a threshold between normal and abnormal AC. Image processing was performed using in-house developed software. Six proton-density-weighted (PD) images were acquired with a TSE pulse sequence (total acquisition time = 2 min 20 s) along the same radial planes using 0.4 x 0.4 mm^2 in-plane spatial resolution, 4 mm slice thickness and TR/TE = 3110/25 ms. For each radial plane, an experienced musculoskeletal radiologist evaluated the cartilage using the PD images alone. Sensitivity, specificity and accuracy were assessed for both dGEMRIC and morphologic evaluation.

Results

Fig. 1 shows the average T_1 value in the femoral cartilage ROI (i.e. healthy cartilage) for each patient, with the age of the patient in the x-axis label. Error bars indicate intra-patient variability, which ranged from 15 to 60 ms. Fig. 2 shows standardized dGEMRIC maps and the corresponding PD images for radial planes through the AS and PS cartilage regions of one representative patient. Overall sensitivity and specificity for dGEMRIC were 86% and 55%, compared to 59% and 61% for morphologic assessment. Accuracy was 73% and 60%, respectively. Table 1 shows that the performance improves considerably for dGEMRIC by looking at the AS cartilage alone.

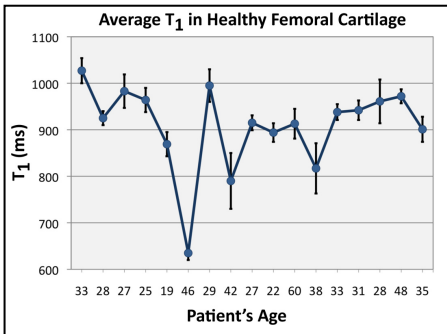

Fig. 1. Average T_1 values for the 17 patients in the region of the femoral cartilage used to standardize dGEMRIC maps. The error bars indicate intra-patient variability.

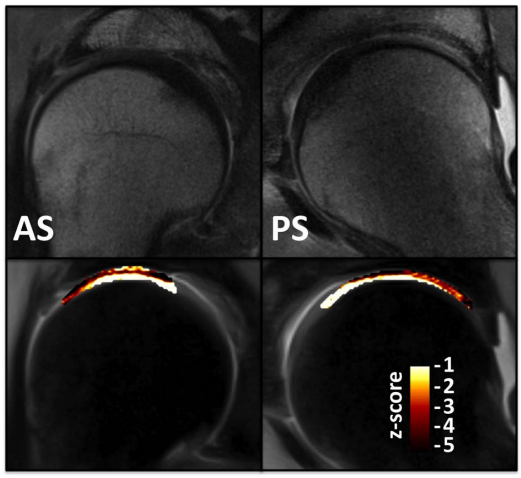

Fig. 2. PD-weighted radial images (top row) depicting the anterior-superior (left) and posterior-superior (right) articular cartilage for a representative hip. Corresponding standardized dGEMRIC maps of the weight-bearing portion of the hip cartilage are shown in the bottom row, superimposed to lower-resolution images used for T_1 mapping [4]. In both cases, z values are large in the central region of the femoral cartilage, assumed as healthy, and low in the acetabular cartilage, where lesions were confirmed by arthroscopy.

Discussion and Conclusions

Baseline cartilage T_1 values vary among patients (Fig. 1), confirming the need to standardize dGEMRIC values on a patient specific basis. Other authors have proposed to normalize T_1 values in the acetabular cartilage by the average T_1 of the total cartilage (acetabular and femoral), showing that they can discriminate healthy subjects from FAI patients [6]. However, the difference was on average only 15%, suggesting that the method might be less effective for individual cases. This is the first study that validates dGEMRIC at 3 T against arthroscopic findings for FAI patients. Our results show that, by using central femoral cartilage as internal reference to standardize T_1 values in the entire AC, dGEMRIC can predict cartilage abnormalities with high sensitivity and accuracy. The relatively low specificity may be due to reasons intrinsic to the technique, as dGEMRIC can detect biochemical changes in the AC before macroscopic effects occur, as well as to the fact that radial imaging planes allowed a comprehensive evaluation of the whole joint, whereas intra-operative arthroscopic assessment is more limited. Since hip arthroscopy is routinely performed via an anterior and anterolateral portal, findings in the AS region are more reliable as they are directly visualized by the surgeon. This suggests that the actual overall dGEMRIC performance could be as high as that associated with the AS region (Table 1). This study shows that dGEMRIC improves cartilage assessment compared to morphologic imaging. Slightly higher sensitivity and specificity (75% and 72% on average between 2 readers) were reported for hip cartilage evaluation using PD images in a previous study [7], although a fair comparison is not possible because intra-articular gadolinium injection, coronal imaging planes and open surgeries were used. The performance of dGEMRIC improved at 3 T using radial imaging planes, compared to other results reported for 1.5 T and coronal imaging planes [5]. The main limit of this study is that all patients had a damaged acetabular labrum, likely corresponding to some level of cartilage degeneration. As discussed above, that may have affected the specificity of dGEMRIC, therefore future work will include healthy volunteers to assess the reliability of the specificity reported in this work. The dGEMRIC protocol is routinely performed on FAI patients at our institution and we expect to improve the statistical analysis as the number of cases increase. Inter- and intra-observed repeatability will also be evaluated for both dGEMRIC and morphologic cartilage assessment.

Table 1

	dGEMRIC			Proton Density		
	Overall	AS only	PS only	Overall	AS only	PS only
Sensitivity (%)	86	94	81	59	65	56
Specificity (%)	55	65	44	61	59	63
Accuracy (%)	73	79	67	60	62	58

References

[1] Ganz R et al. (2003) Clin Orthop Relat Res 417:112-20 [2] Beck M et al. (2004) Clin Orthop Relat Res 418:67-73 [3] Bashir A et al. (1996) MRM 36(5):665-73 [4] Lattanzi R et al. (2011) MRM 66(2):348-355 [5] Lattanzi et al. (2011) ISMRM p.3221 [6] Pollard TCB et al. (2010) J Bone Joint Surg Am. 92: 2557-69 [7] Knuesel PR et al. (2004) AJR 183: 1729-35