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

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Introduction

Femoracetabular 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 (50 ± 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 B0-insensitive 2D T1-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 mm², 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 T1 values (s) were transformed to standard scores (z) using 

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z = (x - \mu)/\sigma,\]

where \(\mu\) and \(\sigma\) are the mean and standard deviation of \(T_1\) in the female ROI. The weight-bearing portion of the AC was segmented by a method recently proposed to normalize T1-mapping [4]. 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 mm² in-plane spatial resolution, 4 mm slice thickness and TR/TE = 310/25 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 on 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.

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 (acetalabular 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 slighter 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 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 increases. Inter- and intra-observer repeatability will also be evaluated for both dGEMRIC and morphologic cartilage assessment.

References