Detection and staging of acetabular cartilage damage in femoroacetabular impingement using dGEMRIC and T_2 mapping

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Introduction

Femoroacetabular impingement (FAI) has been recognized as one of the causes of hip osteoarthritis (OA) [1]. Surgery, including labral debridement/repair and osteotomies have been advocated to prevent the development of OA but these procedures are only successful in patients with limited damage of articular cartilage [2]. MR-based biochemical imaging techniques, such as delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC) [3] and T_2 mapping [4], have been proposed to detect cartilage damage in the hip. As dGEMRIC is sensitive to the earliest cartilage deterioration that occurs at the molecular level with loss of proteoglycans (PG) and T_2 mapping detects changes in collagen structure and water content that occur at a later stage of degeneration, in this study we propose to combine the two techniques to diagnose and stage cartilage damage in FAI. The aim of this work was to analyze the relationship of dGEMRIC and T_2 findings in the acetabular cartilage (AC) with the presence and severity of cartilage damage, assessed morphologically by indirect magnetic resonance (MR) arthrography.

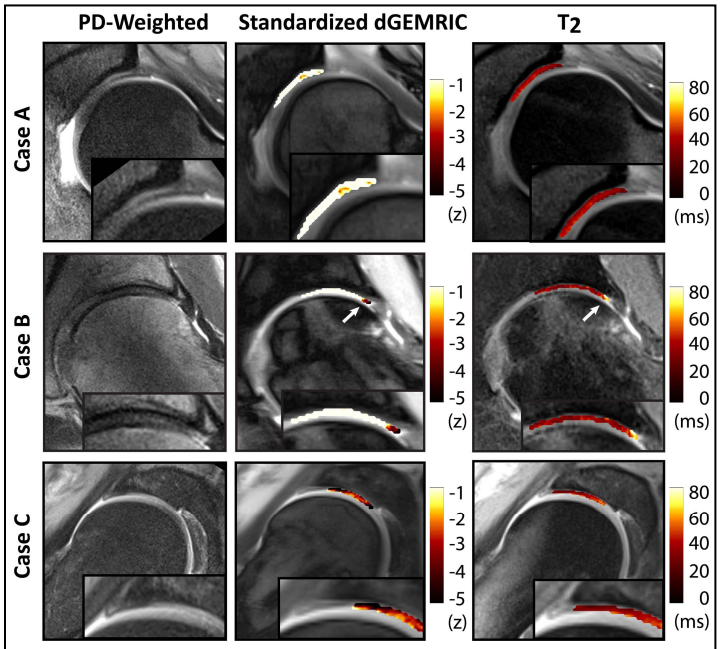

Figure 1. Combination of morphologic imaging, standardized dGEMRIC and T_2 mapping for cartilage assessment. Case A: the acetabular cartilage was reported as normal by arthroscopic evaluation. It is normal also in the PD-weighted image, in the standardized dGEMRIC map (i.e., high *z*) and in the T_2 map (i.e., low T_2). Case B: looking at the corresponding anatomic location, the surgeon reported "a small tear at the base of the labrum with mild irregularity in the adjacent cartilage. Remaining cartilage is preserved". The PD-weighted image shows indeed a partial thickness cartilage defect slightly medial to the chondrolabral junction. These arthroscopic findings were confirmed, and clearly highlighted, by the two parametric maps, which show low *z* and elevated T_2 only in the region corresponding to the damaged cartilage (white arrow). Case C: the radial section shows the acetabular cartilage in the anterior-superior region of a representative hip, which was reported as normal by morphologic assessment, is normal in the T_2 map, but it is abnormal according to the dGEMRIC map. Although it was normal also for arthroscopic evaluation, the surgeon reported extensive cartilage damage in the superior and posterior-superior regions, therefore the dGEMRIC map may indicate that the degenerative process has progressed to the adjacent cartilage at a biochemical level without macroscopic changes.

Table 1	Morphologic (reference)	dGEMRIC (z < -2)	T_2 (T_2 > 50 ms)
Accuracy (%)	< 50% damage	44.4% (20/45)	68.9% (31/45)
Accuracy (%)	> 50% damage	42.2% (19/45)	80.0% (36/45)
Specificity (%)	< 50% damage	32.3% (10/31)*	87.1% (27/31)
Specificity (%)	> 50% damage	34.2% (13/38)*	86.8% (33/38)
Sensitivity (%)	< 50% damage	71.4% (10/14)	28.6% (4/14)
Sensitivity (%)	> 50% damage	85.7% (6/7)	42.9% (3/7)

Table 1. Comparison of dGEMRIC and T_2 in the evaluation of cartilage damage reported by morphologic evaluation.
Significant differences ($p < 0.0001$) are indicated with a *.

Materials and Methods:

We performed a retrospective review of 45 hips (26 left, 19 right) in 44 subjects (29 females, 15 males) who received a dGEMRIC scan (age at MRI = 35 ± 10y) on a 3T MR system (Siemens Medical Solutions, Erlangen, Germany) at our institution for suspected FAI. After screening for the risk of Nephrogenic Systemic Fibrosis (NSF) using a questionnaire, patients received a double dose (0.2 mmol/kg) intravenous injection of Gd-DTPA^{2-} (Magnevist®, Bayer Healthcare) prior to imaging and walked for 15 min on a treadmill at controlled speed [5]. As part of the MR protocol, for each patient a morphologic proton-density-weighted (PD) image, a dGEMRIC T_1 map and a T_2 map were acquired for exactly the same radial section in the superior region of the hip AC. The PD image was acquired with a TSE pulse sequence, using 0.4 x 0.4 mm^2 in-plane spatial resolution, 4 mm slice thickness and TR/TE = 3110/25 ms. A rapid B_1-insensitive 2D T_1-mapping pulse sequence [6] was used for the dGEMRIC acquisition, with in-plane spatial resolution = 0.6 x 0.6 mm^2, slice thickness = 4 mm, TR/TE= 143/10 ms. The T_2 map was generated inline with a multi-echo spin echo sequence (Siemens syngo MapIt), using 0.6 x 0.6 mm^2 in-plane spatial resolution, 4 mm slice thickness, TR = 3000 ms and 7 echoes (TE = 12 ms to 96 ms). The dGEMRIC T_1 map was transformed into a standardized dGEMRIC map [7] using in-house developed software. The weight-bearing portion of the AC was segmented on both the standardized dGEMRIC and T_2 map (Fig. 1), assuming $z < -2$ [8] and $T_2 > 50$ ms, respectively, as thresholds between normal and abnormal AC. Using the PD image alone, an experienced musculoskeletal radiologist evaluated the AC near the chondrolabral junction as either normal, less than 50% damaged, or more than 50% damaged. A McNemar test was used to analyze the relationship between dGEMRIC and T_2 with morphologic assessment.

Results and Discussion

On morphologic assessment, the acetabular labrum was found to be torn or detached in 34 hips. Five hips did not have FAI, whereas 18, 7 and 15 cases were diagnosed as Cam, Pincer or Mixed FAI, respectively. There were no cases for which AC dGEMRIC was normal and T_2 was abnormal, in agreement with the fact that significant changes in T_2 occur only after the loss of PG shown by dGEMRIC. Table 1 summarizes the relationship between biochemical (dGEMRIC and T_2) and morphologic cartilage evaluation, using the latter as a reference. Overall, the results showed that dGEMRIC is very sensitive to AC damage, whereas T_2 is very specific to it. The former observation agrees with previous studies [7,8] and the latter suggests that damaged AC can be detected on morphologic assessment only at a later stage of degeneration, after T_2 becomes abnormal. Note that the relatively low specificity of dGEMRIC may be artifactual, as dGEMRIC may be detecting chondral abnormalities earlier than possible with morphologic assessment. The main limit of this study is that the results could not be validated against surgical findings. However, for few cases, arthroscopic reports were available and in agreement with dGEMRIC and T_2 values. Figure 1 compares morphologic images, dGEMRIC and T_2 maps for three representative hips, for which surgical findings are reported in the captions.

Conclusions

This study suggests that combining dGEMRIC and T_2 could allows detecting the earliest signs of hip articular cartilage damage and stage the severity of degeneration. Future work will include a prospective study to validate this hypothesis using surgical findings as a reference.

References

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