A New Approach to Analyze dGEMRIC Measurements in Femoroacetabular Impingement

R. Lattanzi[1,2], A. Krigel[3], C. Petchprapa[2], A. V. Mikheev[2], K. Dunham[2], S. Gyftopoulos[2], T. C. Mamisch[4], Y. J. Kim[5], H. Rusinek[2], M. Recht[2], and C. Glaser[1,2]
[1]Center for Biomedical Imaging, New York University Langone Medical Center, New York, NY, United States, [2]Radiology, New York University Langone Medical Center, New York, NY, United States, [3]New York University School of Medicine, New York, NY, United States, [4]Clinical Research, University of Bern, Bern, Switzerland, [5]Orthopedic Surgery, Children's Hospital, Boston, MA, United States

Introduction

Careful assessment of articular cartilage (AC) in the hip is critical to discriminate between surgical decisions in patients with femoroacetabular impingement (FAI) [1]. Corrective surgical procedures, aimed at removing the bony abnormalities of FAI and treating the associated labral and cartilage abnormalities in order to delay osteoarthritis (OA), are less likely to be successful in patients presenting with extensive AC injuries [2]. Delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC) is used for the detection of early biochemical changes in AC [3]. A recent dGEMRIC study at 1.5 T [4] indicated T_1 = 500 ms as a threshold between healthy and damaged cartilage. However, the same study reported inter-subject variability in baseline cartilage T_1 values, suggesting that a threshold that on average is valid, may lead to erroneous assessment in particular cases. Other authors [5] have proposed to use the ratio between T_1 of the acetabular cartilage and T_1 of the entire joint (acetabular and femoral), in order to compensate for variations due to patient's age and sex, or diffusion of gadolinium contrast. In this work, we propose to use T_1 values in the femoral region of the hip AC, which can be assumed to be normal in the early stages of FAI [4,5], as a reference to standardize dGEMRIC measurements. We validated the proposed method against arthroscopic findings for a number of patients at 1.5 T.

Materials and Methods:

We performed a retrospective review of 10 hips in 10 patients (9 females, 1 male) with FAI, who received a preoperative dGEMRIC scan (< 4 months before surgery) and underwent hip arthroscopy (age at surgery = 20 ± 5y). A fast 2-angle T_1 mapping method [6] was used for the dGEMRIC acquisition on a 1.5 T MRI system (Avanto; Siemens, Erlangen, Germany). Relevant imaging parameters were: matrix size = 512 x 512, in-plane spatial resolution = 0.3 x 0.3 mm^2, slice thickness = 4 mm, TR/TE=20/4.86 ms, FA=6° and 20°. For each patient, we selected three coronal slices, showing the anterior-superior, superior and posterior-superior regions of the hip AC (30 slices in total). The weight-bearing portion of the hip AC, extending from the lateral bony edge, not including the labrum, to the edge of the acetabular fossa (Fig. 1) was segmented on the T_1 map corresponding to each slice. Within the segmented area, a region of interest (ROI) was defined over the central portion of the femoral cartilage, assumed to be healthy, and T_1 values (x) were transformed to standard scores (z, or z-values) using $z = (x - \mu)/\sigma$, where μ and σ are the mean and the standard deviation of T_1 in the femoral ROI. In the resulting standardized maps, z-values < 0 would indicate that the T_1 is low compared to normal. For the three regions of each patient, we assessed whether acetabular cartilage reported as damaged during arthroscopy (Outerbridge score I or greater) corresponded to z-values < 0.

Results

Table I reports T_1 values in the femoral cartilage for each case. Mean T_1 in the femoral (i.e. normal) cartilage was consistent (7 ± 4 % variation) for each patient among the anterior-superior, superior, posterior-superior regions. However, it varied among patients, ranging from 453 ms to 842 ms (mean/stdev = 598 ± 91 ms). Figure 1 shows standardized dGEMRIC maps for one representative patient. Standardized dGEMRIC maps assessed cartilage correctly in 20 slices out of 30. In 5 slices, cartilage with z-values > 0 was instead reported as damaged in the arthroscopic findings, whereas on 5 other slices the opposite occurred.

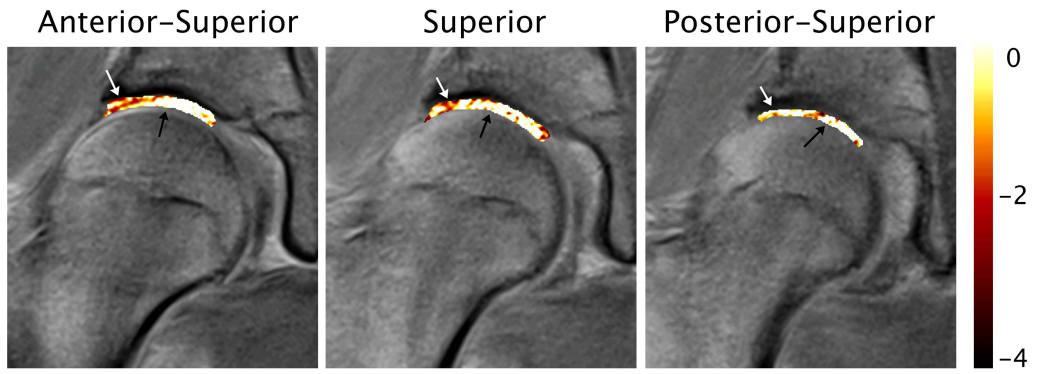

Figure 1. Standardized dGEMRIC maps of the weight-bearing portion of a representative hip articular cartilage, superimposed to coronal images. Pixel values smaller than zero indicate degenerated cartilage. The black arrows point to the central region of the femoral cartilage used to convert T_1 values into z-values. The white arrows point to the assessed (peripheral) region of the acetabular cartilage. The anterior-superior (left) and the superior (center) cartilage were damaged, whereas the posterior-superior cartilage (right) was intact, corresponding to the arthroscopic findings.

TABLE I.
T_1 (MS) VALUES IN THE FEMORAL CARTILAGE

Patient	Anterior-Superior	Superior	Posterior-Superior
1	629 ± 68	634 ± 50	677 ± 91
2	764 ± 102	704 ± 73	696 ± 113
3	557 ± 83	572 ± 64	522 ± 79
4	520 ± 96	538 ± 66	559 ± 52
5	639 ± 134	561 ± 106	481 ± 71
6	523 ± 66	523 ± 68	584 ± 76
7	562 ± 80	570 ± 90	571 ± 120
8	532 ± 76	480 ± 51	453 ± 72
9	627 ± 87	607 ± 64	595 ± 34
10	842 ± 137	777 ± 100	649 ± 84

Discussion and Conclusions

The range of T_1 values in dGEMRIC may vary substantially among patients [4,5] and our results suggest that using a single threshold T_1 value to separate abnormal from normal AC is not optimal in all cases. We proposed a new method to standardize dGEMRIC measurements on a patient specific basis. The range of colors in the standardized maps can be optimally adjusted to allow areas of abnormal cartilage to stand out. Comparison with arthroscopic findings showed that our method when using a cut off z-value of zero was accurate in 66% of the cases in discriminating normal from pathologic cartilage. Using a threshold of 500 ms (as suggested in Ref [4]) for all cases in the original dGEMRIC T_1 maps, accuracy drops to 46%. The validation study was limited in that arthroscopic evaluation may have missed small, localized cartilage lesions visualized by dGEMRIC. Also, the optimal threshold z-value is not clear yet. Future work will include a larger number of patients and dGEMRIC acquisitions at 3 T, where the border between femoral and acetabular cartilage layers can be delineated more accurately thanks to higher signal-to-noise ratio. Note that our method allows for direct comparison of dGEMRIC measurements at different field strengths. In conclusion, the proposed method has the potential to improve the clinical interpretation of dGEMRIC data in FAI, by removing the effect of inter- and intra-patient T_1 variability. This approach is expected to be less accurate for patients with advanced cartilage degeneration or other pathologies (e.g. dysplasia) for which the femoral cartilage is compromised.

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] Domayer SE et al, (2010) Osteoarthr. Catil. 18: 1421-28 [5] Pollard TCB et al (2010) J Bone Joint Surg Am. 92: 2557-69 [6] Sur S et al, (2009) JMRI 30: 896-900