

# Assessment of the Radial Distribution of Glycosaminoglycans (GAG) in Arthritic Hips using Delayed Gadolinium Enhanced MRI of Cartilage (dGEMRIC)

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## Introduction:

Delayed Gadolinium Enhanced MRI of Cartilage (dGEMRIC) is used to assess cartilage integrity by measuring its glycosaminoglycan (GAG) content. Until recently, most dGEMRIC studies have employed quantitative T1 mapping based on single slice two-dimensional inversion recovery fast spin-echo sequences. The limitations of 2D IR-FSE acquisition are clear: single slice sequences provide limited coverage and IR-FSE sequences require long scan times, making them susceptible to motion artifacts. Although a 3D Look-Locker acquisition dGEMRIC technique has been used for imaging of knee cartilage, the spherical bone structure of the hip joint leads to partial volume errors and therefore requires increased resolution and special imaging planes to assess the entire joint. This has led us to implement a 3-D fast 2 angle T1 mapping technique [1] to assess the radial pattern of glycosaminoglycan (GAG) distribution in articular and femoral cartilage of the hip.

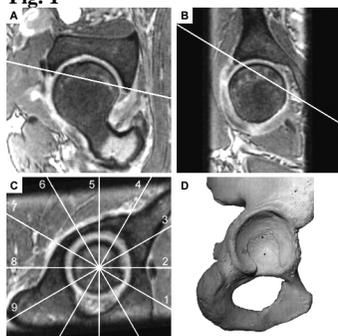
## Materials and Methods:

Thirty-five hips in 35 patients showing radiographic evidence of femoroacetabular impingement or developmental dysplasia of the hip were imaged using a 3D isotropic fast T1 mapping dGEMRIC sequence (TR 15 msec, TE 3.27 msec, flip angles of 4.1 and 23.5 deg., matrix size 192/192, 16 cm FoV, voxel size 0.8 x 0.8 x 0.8 mm, acquisition 30 min. post contrast agent injection). All patients were imaged with a previously validated fast T1 mapping dGEMRIC sequence (voxel size 0.6 x 0.6 x 4 mm) for comparison. For each patient, 3D image data was reconstructed into 9 radial slices spaced 30 deg. apart and oriented orthogonally to the acetabular opening (excluding the fossa). In each slice, a dGEMRIC index was calculated as the mean T1 relaxation time of the acetabular and femoral cartilage between the vertical center and peripheral edge of the joint, excluding the labrum. Patterns of dGEMRIC index distribution, corresponding to GAG content, across the 9 radial positions (from anterior-inferior to posterior-inferior) were compared for hips with varying amounts of arthritis.

## Results:

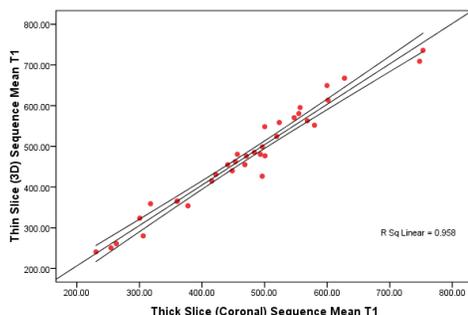
The 3D fast T1 mapping sequence measurements correlated extremely well to previously validated sequence measurements (Pearson regression coefficient  $R^2 = 0.958$ ). Radial data was stratified by overall dGEMRIC score (mean of 9 radial dGEMRIC indices) into 4 arthritis grades: grade 0 (n = 10, mean = 597 ms), grade 1 (n = 10, mean = 488 ms), grade 2 (n = 10, mean = 380 ms), and grade 3 (n = 5, mean = 293 ms). A consistent pattern of the highest dGEMRIC index occurring in the superior regions of the joint cartilage was observed in the grade 0-2 hips: mean superior and superior-posterior dGEMRIC indices were significantly greater than overall dGEMRIC scores ( $p < 0.05$ ). In grade 3 hips, an inverted pattern of GAG distribution was observed: superior regions displayed significantly lower dGEMRIC indices in comparison to overall dGEMRIC scores ( $p < 0.05$ ).

Fig. 1



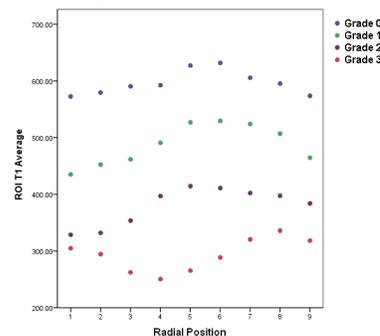
**Figure 1:** Selection of radial slices for reconstruction (white lines indicate plane selection). The plane is positioned across the acetabular opening in the sagittal view (A) and the coronal view (B), then rotated at 30 degree intervals around the joint in the axial view (C). The bone structure of the acetabulum is displayed (D) for reference.

Fig. 2



**Figure 2:** Correlation between the T1 from high and low resolution F2T1 techniques, Pearson regression coefficient  $R^2 = 0.958$ .

Fig. 3



**Figure 3:** Radial distribution of dGEMRIC indices. The superior regions of less severe hips (grades 0-2) exhibited the highest dGEMRIC indices. The same regions had the lowest dGEMRIC indices in hips with severe OA (grade 3).

## Discussion:

This study supports previous data illustrating the clinical applicability of the 3D fast T1 mapping dGEMRIC method to assess the GAG content in cartilage. dGEMRIC indices acquired using this method show a radial distribution of proteoglycan concentration around the hip joint that is consistent with previous histological findings (higher GAG content in superior regions of hip joint cartilage) [2]. An inverted distribution pattern is observed in patients with severe OA, representing the degeneration of cartilage in the weight bearing regions. These results demonstrate the viability of using high resolution 3D scans to analyze the full hip joint in any orientation. The potential for errors in T1 from noise artifacts was a major concern for the development of thin slice acquisition; however, the strong correlation between dGEMRIC indices calculated using the high and low resolution F2T1 techniques diminishes these concerns. We therefore conclude that the 3D dGEMRIC is a powerful diagnostic tool that will allow future researchers and clinicians to characterize the patterns of cartilage damage in early OA in vivo.

## References:

[1] Mamisch TC et al., Magn Reson Med 2008 60(4):768-773. [2] Maroudas et al., Ann Rheum Dis 1973 32(1):1-9.