Texture Analysis of T1ρ Relaxation Times in Knee Osteoarthritis

J. A. Schooler[1], S. P. Yap[1], G. B. Joseph[1], X. Li[1], T. M. Link[1], and S. Majumdar[1]
[1]Musculoskeletal and Quantitative Imaging Research, Department of Radiology and Biomedical Imaging, UCSF, San Francisco, CA, United States

Introduction

The structural and biochemical compromise of hyaline articular cartilage significantly contributes to degenerative joint diseases such as Osteoarthritis (OA) (1). Quantitative magnetic resonance (MR) T1ρ relaxation time has been used to quantify biochemical changes of osteoarthritic cartilage in a non-invasive manner, specifically PG and GAG concentration along with hydration (2). Previous studies have demonstrated an elevation of T1ρ relaxation time with the progression of knee OA and T1ρ is believed to be a more responsive gauge of early cartilage degeneration than T2 relaxation time (3,4). The spatial distribution of T1ρ values is emerging as another metric of OA development and progression (5, 6). Haralick *et al.*(7) developed a method of texture analysis based on the grey-level co-occurrence matrix (GLCM) that can be used to evaluate spatial distribution of pixel intensities in an image. This study aims to characterize the spatial distribution of cartilage MR T1ρ values using GLCM texture parameters in OA patients and normal controls.

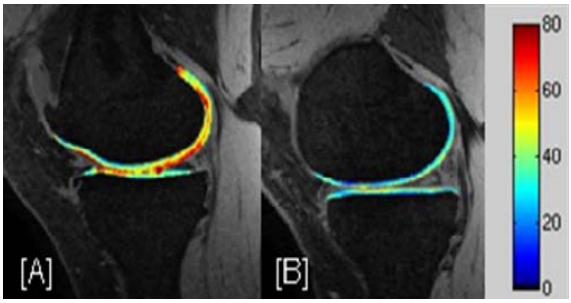

Figure 1 – Representative sagittal SPGR images with T1ρ relaxation times superimposed on articular cartilage as a color overlay of [A] OA patient, KL=3 and [B] control patient , KL=0.. Color scale (far right) spans from 0-80 ms.

Methods

18 OA patients and 14 controls were stratified using the radiographic Kellgren-Lawrence (KL) grading system (14 Control KL score = 0, OA; 12 KL score =1, 6 KL score =2).The mean age of the subjects was 47 years (± 11.8), mean BMI of 24.3 kg/m2 (± 4.14) and 38% of the subjects were female. Cartilage T1ρ maps were generated using a 3D T1ρ mapping technique based on an SPGR sequence (matrix 256x128, slice thickness=4 mm, time of spin lock (TSL) =0/10/40/80 ms, spin lock frequency =500 Hz)(4). Four cartilage knee compartments (lateral femoral condyle (LFC), medial femoral condyle (MFC), lateral tibia (LT), medial tibia (MT)) were segmented on a sagittal fat-saturated 3D SPGR sequence (matrix 512x512, FOV=16cm, slice thickness=1mm) using MATLAB (MathWorks, Natick MA) based in-house software. T1ρ maps were then registered to the SPGR images using an in house registration algorithm. Segmentations were then superimposed upon T1ρ maps to extract relaxation time mean values per compartment. GLCM texture parameters for the four compartments were defined using the same in-house MATLAB developed software. Eight GLCM texture parameters including Contrast, Dissimilarity, Homogeneity, ASM, Energy, Entropy, Mean, and Variance were calculated along four angles (0°, 45°, 90°, and 135°) and at one pixel offset. The differences in T1ρ parameters (mean T1ρ and GLCM measurements) between the controls and OA patients were assessed using mixed random effect regression models (independent variable: group, compartment and their interactions, dependent variable: T1ρ parameters), treating the subject as the random effect. All statistics were performed using JMP software version 8 (SAS Institute, Cary NC).

Results

Representative T1ρ maps in an OA patient and a control are illustrated in Figure 1. A significant correlation in mean T1ρ, GLCM mean, GLCM variance, and GLCM correlation was evident between OA patients and controls (Figure 2). GLCM variance is an indicator of the distribution of pixel values around the mean (8). GLCM mean values are a weighted measure of pixel frequency of occurrence with certain neighbor pixels and GLCM correlation is a gauge of linear dependency of grey levels on those of neighboring pixels. In areas of biochemically degraded cartilage we would expect elevated T1ρ relaxation times and in areas of especially high degradation it would be logical to expect GLCM variance, mean, and correlation values to fluctuate significantly from the mean.

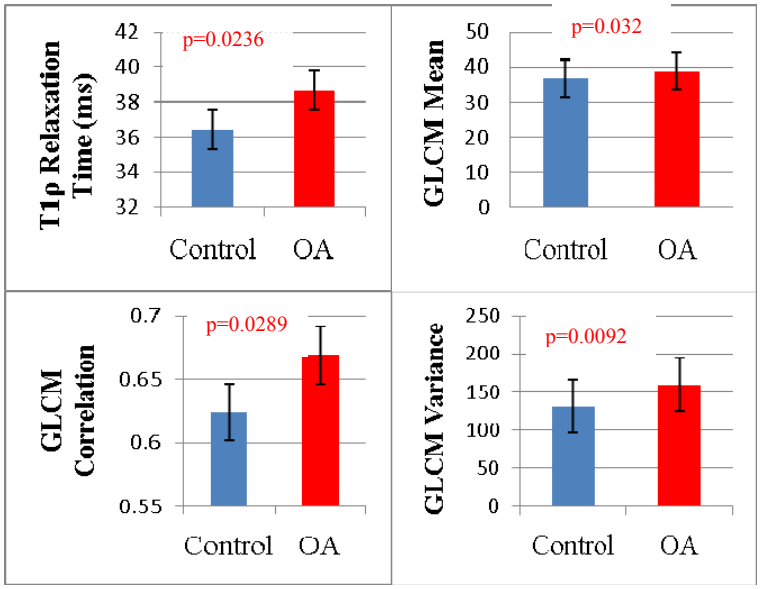

Figure 2 - T1ρ relaxation time and GLCM texture parameters found to have significant differences from OA patients vs. healthy controls. P-values for each GLCM measurement listed on graph in red.

Discussion

This study used GLCM texture analysis to quantify the heterogeneity of biochemical cartilage degeneration in OA patients compared to controls. Our results demonstrate that mean T1ρ as well as 3 of the 8 GLCM texture parameters (variance, mean, correlation) are elevated in OA patients compared to controls. These results are consistent with the findings Carballido-Gamio *et. al.* (7) with respect to T1ρ texture analysis of OA patients. Further investigation tracking a longitudinal OA cohort, of the remaining texture measurements warrants investigation and will be performed.

References

1) Brandt KD, et. al. Osteoarthritis. New York: Oxford University Press; 1998.
2) Akella et al, Magn Reson Med. 2001 Sep;46(3):419-23
3) Regatte et al, J Magn Reson Imaging. 2006 Apr;23(4):547-53
4) Li X, et. al. Osteoarthritis Cartilage. 2007 July ; 15(7): 789–797
5) Blumenkrantz G, et. al. Osteoarthritis Cartilage. 2008 May ; 16(5): 584–590.
6) Carballido-Gamio J, et al. Medical Physics, Vol. 36, No. 9, September 2009
7) Haralick RM, et al. IEEE Transactions on Systems, Man, and Cybernetics 1973;SMC-3(6):610-618.
8) Hall-Beyer M. GLCM Texture: A Tutorial. http://www.fp.ucalgary.ca/mhallbey/tutorial.htm

Acknowledgements

This research was supported by the NIH RO1 AR46905