Cluster Analysis for T_2 and T_{1rho} Relaxation Times using 3D Projection Maps of the Femoral Condyle in a Healthy and ACL-injured Population

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PURPOSE: Over 50% of the ACL-injured population develops radiographic osteoarthritis (OA) 10-15 years after surgery[1]. Parametric MRI mapping (e.g. T_2 and T_{1rho}) of this population has demonstrated sensitivity to early degenerative changes such as proteoglycan loss and collagen disruption within the cartilage matrix[2,3,4]. Single slice[3,4,5] assessments of these features has shown general elevation of quantitative MRI parameters and focal defects[4,6], but this approach hampers sensitivity to focal cartilage lesions as it does not take the full cartilage plate into consideration. Instead, an approach for comprehensive 3D visualization and tracking can be achieved by creating a 2D projection image[7]. In this work, we apply this technique to demonstrate the use of difference maps between produced projections for tracking clusters of elevated T_2 and T_{1rho} relaxation times in an ACL-injured population.

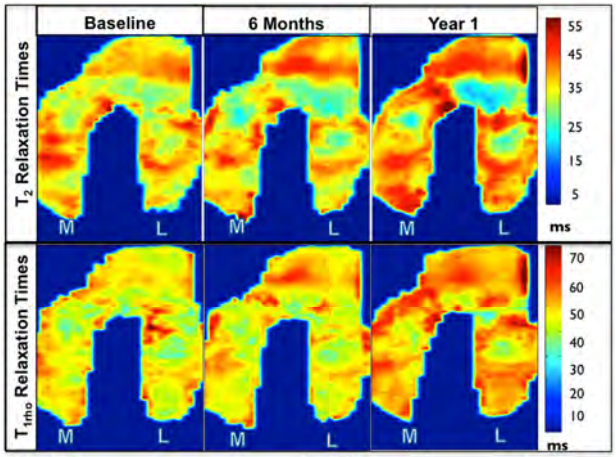

Fig 1*: Projection maps in a sample ACL-injured patient at 3 time points (Baseline, 6 months, 1 year) and for 2 quantitative values (T_2 and T_{1rho})*

METHODS:

Acquisition: Five healthy volunteers (scanned at baseline, day 2, and 1 year) and eight ACL-injured patients (scanned approximately 1 month post-surgery at baseline, 6 months and 1 year) were scanned at 3T using a transmit-receive 8-channel knee coil. Quantitative double-echo in steady-state (qDESS)[8] and CubeQuant T_{1rho}[9] imaging sequences were used to acquire the images. T_2 and T_{1rho} maps were generated in Osirix and projection maps were created[7] (Fig. 1).

Cluster Analysis: Areas of elevated quantitative values were identified by setting thresholds calculated from the difference maps between day 1 and year 1 in the healthy population. Using the absolute-mean-difference and standard deviation (σ) of each map, an elevation threshold was defined to be greater than +2 standard deviations from the healthy population's mean difference. The threshold was applied to the ACL-injured population difference maps (6 months to baseline and 1 year to baseline) (Fig. 2). A cluster was defined as a contiguous set of pixels above this threshold with a contiguous area greater than 9mm^2. To compare data between timepoints and subjects, the overall % cluster area (CA) was calculated (Fig. 3). A student's t-test was used to isolate differences between groups.

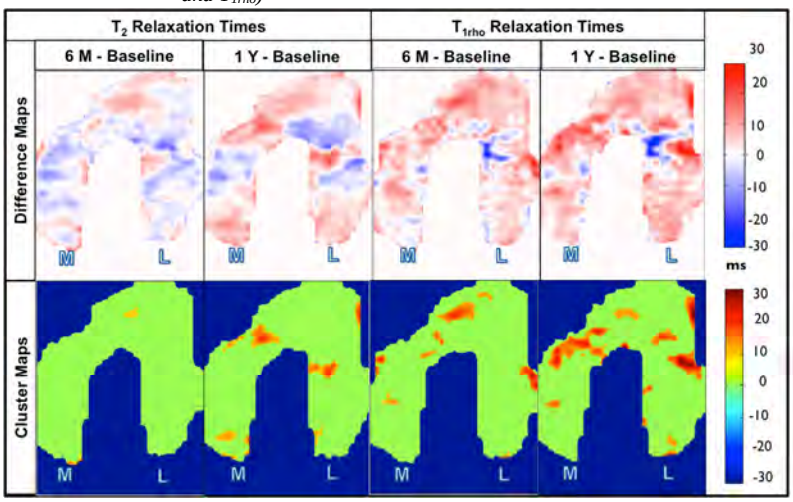

Fig 2: *Calculated difference maps and cluster maps for 2 time intervals. Shown are difference maps (top row) (6 M – Baseline and 1 Y – Baseline) within a sample patient for T2 and T_{1rho} and resulting cluster maps based on cluster threshold and size.*

RESULTS: The absolute mean ± σ for the 1 year difference maps within the five healthy volunteers was 1.1 ± 4.8 ms (T_2) and 1.9 ± 5.7ms (T_{1rho}). The cluster threshold was thus set to 2σ or 9.6 ms (T_2) and 11.4 ms (T_{1rho}). The average %CA covered within the healthy population was 0.8 ± 1% (T_2) and 2.1 ± 2.2% (T_{1rho}). Individual %CA within the ACL-injured population at the two time intervals ranged from 0.8-14.9% (T_2) and 0.9-25.6% (T_{1rho}). The average %CA at 6M/1Y was 4.7 ± 4.7%/6.6 ±2.7% (T_2) and 9 ± 8%/12.2 ± 5.5 (T_{1rho}) (Fig. 3). The %CA at 1 year in the ACL-injured population for both T_2 and T_{1rho} difference maps were significantly different (p = 0.0009 (T_2) and 0.0035 (T_{1rho})) from the %CA in the healthy population.

DISCUSSION: We observed greater sensitivity to change within the T_{1rho} difference maps as compared to T_2. The overall %CA in patients was much greater than in the healthy population, indicating that the proposed analysis approach may be useful in quantifying early changes in the OA disease process. This study is limited by the population size and additional investigations into regional thresholds, cluster sizes and cluster locations may help better differentiate between at-risk populations.

CONCLUSION: Through this cluster analysis of the full cartilage plate via projection maps, identifying and quantifying focal defects in cartilage over time may provide a useful biomarker for tracking early cartilage degeneration.

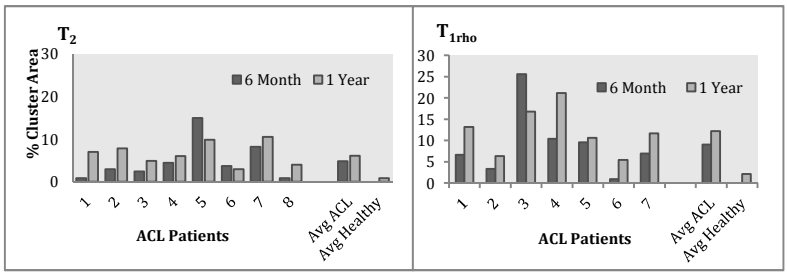

Fig 3: *% areas of projection maps covered by clusters in the ACL-injured population for both T_2 (n=8) and T_{1rho} (n=7).*

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