T1ρ relaxation time of lateral meniscus and its relationship with T1ρ of adjacent cartilage in knees with acute ACL injuries at 3T

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INTRODUCTION: Patients with anterior cruciate ligament (ACL) injury tend to develop osteoarthritis (OA) even after ACL-reconstruction [**1**]. In OA, cartilage and meniscal changes are preceded by damage of the collagen-proteoglycan (PG) matrix [**2**]. In a recent study, using the dGEMRIC technique, significant correlations between T1(Gd) of meniscus and T1(Gd) of articular cartilage were found, potentially demonstrating associated degenerative processes in knee joint [**3**]. Typical changes in knees with ACL injuries (i.e. bone marrow edema like lesion – BMEL, meniscal tears) are predominantly located at lateral side of the joint [**4**]. T1ρ mapping has the ability to reflect changes in biochemical composition of cartilage with early OA (i.e. PG loss) [**5,6**]. The aim of this study was to study T1ρ relaxation time in lateral meniscus and its relationship with adjacent cartilage T1ρ in knees with acute ACL injuries using 3T MRI.

MATERIAL and METHODS: Fifteen healthy volunteers (4 female, 11 male, mean age = 30.1 ± 8.6) without any clinical symptoms of OA and 16 patients (5 female, 11 male, mean age = 32.5 ± 5.8) with ACL tears were studied using a 3T GE MR scanner and a quadrature knee coil. All ACL injured patients were imaged prior to surgery. Sagittal $T_{1\rho}$-weighted images were acquired using a previously developed sequence based on a 3D-SPGR sequence [**7**] (FOV = 12 cm, slice thickness = 3 mm, TR/TE = 10/5.8 ms, TSL = 0/10/40/80 ms, spin lock frequency = 500 Hz). The protocol also included sagittal 3D high-resolution water excitation spoiled gradient-echo (SPGR) imaging, and fat-saturated T2-weighted fast spin-echo (FSE) images. T1ρ maps were generated by fitting the T1ρ-weighted images $S(TSL) \propto \exp(-TSL/T1\rho)$ pixel-by-pixel. T1ρ maps and T2-weighted images were then aligned to SPGR images. The meniscus and the cartilage were segmented semi-automatically in SPGR images using an in-house spline-based developed program. Lateral meniscus was divided into anterior horn and posterior horn regions. Cartilage weight-bearing regions of lateral femoral condyle (LFC) and lateral tibia (LT) were partitioned in 3 regional compartments, similarly to a previous method [**8**]: anterior, central and posterior (**Figure 1, A**). The coefficients of variation (CV) characterizing the reproducibility of meniscus T1ρ measurements were assessed in 4 control subjects based on 2 repeated scans. T-tests were applied in order to compare ACL patients with controls, and Spearman's rank correlations were performed between cartilage and meniscus.

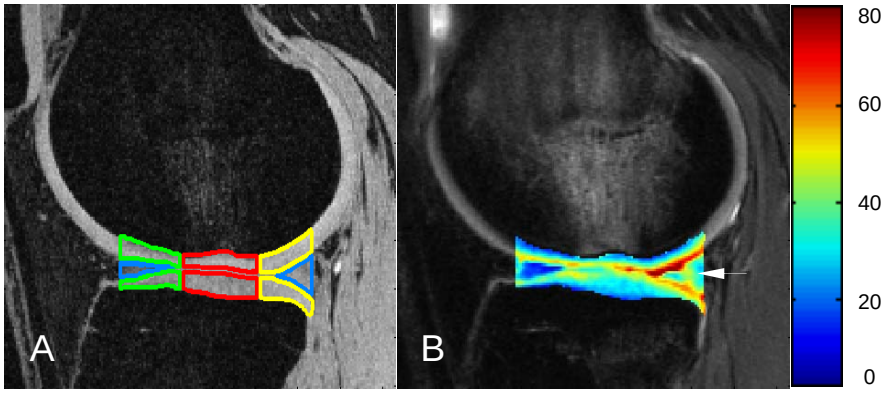

Figure 1 - Meniscus (blue) and cartilage segmented compartments - anterior (green), central (red) and posterior (yellow) - displayed on a SPGR image (A). T1ρ color map overlaid on a fat-sat T2-FSE image obtained in a patient (B); a partial meniscal tear (arrow) can be observed at the posterior horn of meniscus.

RESULTS: Among the ACL injured patients 12 (75%) had meniscal tears. The computed CVs showed good measurement precision: 4.6% for anterior horn and 3.3% for posterior horn. T1ρ data for meniscus and cartilage are plotted in **Figure 2**. In controls, the meniscus T1ρ mean values were 14.71 ± 1.80 ms for the anterior horn, and 14.69 ± 2.31 ms for the posterior horn, whereas in patients, 17.49 ± 3.01 ms for the anterior horn and 21.13 ± 5.00 ms for the posterior horn. Significantly elevated T1ρ values for meniscus were found in patients compared with controls in both anterior (P=0.004) and posterior horn (P<0.001) of the meniscus (**Figure 1, B**). Significantly higher T1ρ values were found at the posterior horn compared with anterior horn of patients' meniscus (P=0.005) (**Figure 2**). The cartilage T1ρ values ranged from 31.00 ms to 40.10 ms in controls, whereas in patients from 32.03 ms to 44.18 ms. At the LFC, there was no significant difference between patients and controls in each compartment; however, significant elevations were noticed over all subjects between compartments (**Figure 2**). At the LT, significantly increased T1ρ values were found in patients compared with controls at the posterior compartment only (P=0.002). A significant correlation (R^2=0.47, P=0.007) was found between T1ρ values in posterior horn of meniscus and T1ρ values in posterior LT cartilage.

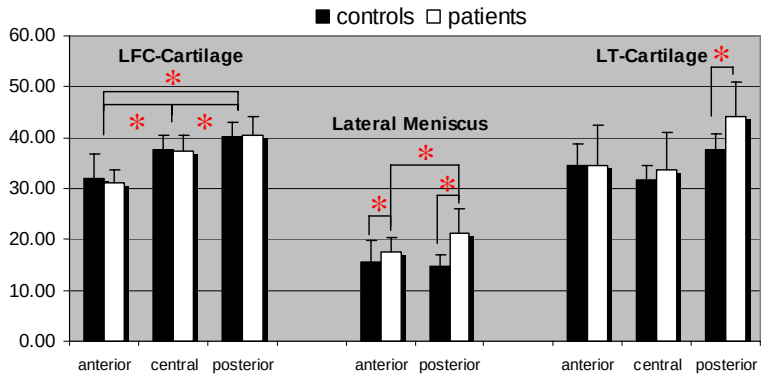

Figure 2 - T1ρ data for lateral meniscus and articular cartilage in ACL injured patients vs. controls; *P<0.05.

DISCUSSION: T1ρ quantitative assessment of lateral meniscus in ACL injured patients was demonstrated with good reproducibility. Significantly increased T1ρ values were found in meniscus in patients compared with controls. Significant T1ρ elevation was also found in patients' posterior horn compared with anterior horn. This T1ρ elevation in posterior horn of meniscus was significantly correlated with cartilage T1ρ elevation in posterior compartment of LT, which demonstrated a strong injury-related relationship between meniscus and cartilage biochemical changes. Overall, lower T1ρ values were found in meniscus compared with cartilage, consistent with previous study [**9**] indicating lower GAG in meniscus than in cartilage. These patients will be followed longitudinally to determine any meniscal changes progression and the relationship with cartilage changes and OA development.

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