

## **T1p MRI in Cartilage of Non-Osteoarthritic Knees With and Without Posterior Meniscus Lesions**

**Nathaniel E. Calixto**, Deepak Kumar, Karupppasamy Subburaj, Justin Singh, Joseph Schooler, Lorenzo Nardo, Xiaojuan Li, Richard B. Souza, Thomas M. Link, Sharmila Majumdar.  
University of California, San Francisco, San Francisco, CA, USA.

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**Introduction:** Responsible for shock absorption, load transmission, and joint lubrication, the meniscus plays an important role in knee health [1-3]. Baseline meniscus pathology is shown to precede joint space narrowing, an indication of osteoarthritis (OA), after 24 and 30 months [4-7]. The purpose of this study was to investigate the effect of meniscus lesions on knees with minimal to no radiographic OA (KL 0-1) and no focal morphological cartilage abnormalities. We used T1p MRI to assess proteoglycan changes at the macromolecular level in cartilage adjacent to torn and intact menisci.

**Methods:** Subjects recruited from the community underwent X-rays and 3-Tesla MRI. Two MR sequences were acquired: 1) a sagittal 3D high-resolution T2-weighted isotropic fast spin echo sequence (3D FSE CUBE) for segmentation and clinical grading 2) a sagittal T1p-mapping sequence for quantitative assessment. The Knee Osteoarthritis Outcome Score (KOOS) Survey was administered in all subjects. Radiographs were scored on the Kellgren-Lawrence (KL) scale, and cartilage and meniscus were graded on the 3D FSE images using modified Whole Organ MRI Score (mWORMS) scales [8]. Inclusion criteria for the study were minimal to no radiographic OA (KL < 2) and no focal defects in all tibiofemoral cartilage compartments (mWORMS < 2). Ten subjects had a meniscal tear (mWORMS ≥ 2) in at least one of the posterior meniscus horns and were termed "Cases." Ten healthy Controls with no meniscus tears were selected for comparison, matching age, gender, and BMI of Cases. After acquisition, the 3D FSE images were rigidly registered to the T1p images. Cartilage and meniscus regions of interest (ROIs) were manually segmented on the 3D FSE images using in-house software then overlaid onto T1p images for quality control; cartilage ROIs were also automatically divided into subregions based on loading and cartilage contact sites (Figure 1).

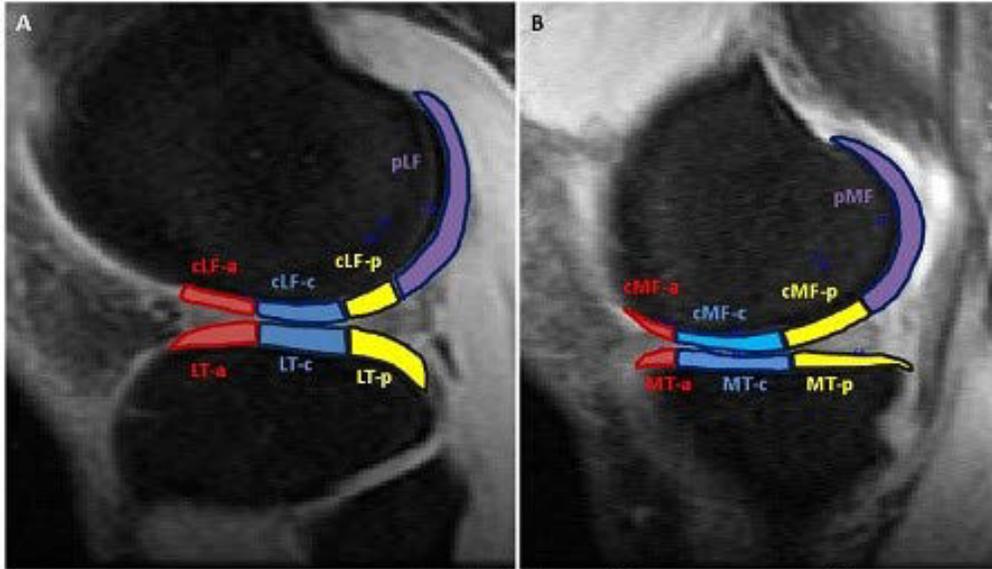


Figure 1a: Cartilage subcompartments of the lateral femur (LF) and lateral tibia (LT).

Figure 1b: Cartilage subcompartments of the medial femur (MF) and medial tibia (MT).

T1 $\rho$  relaxation times were calculated for whole cartilage ROIs as well as cartilage subregions. Student's t-test was used to compare survey scores and T1 $\rho$  values between Cases and Controls as well as between Cases with and without adjacent meniscus lesions, using an alpha level of  $P < 0.05$ .

**Results:** Five Cases had tears in the Lateral Posterior Horn (LPH) only, four had tears in the Medial Posterior Horn (MPH) only, and one had tears in both compartments. Cases had significantly lower KOOS Pain and Sports scores compared to Controls ( $p < 0.05$ ) and showed a trend toward lower Activities of Daily Living and Quality of Life scores than Controls ( $0.05 < p < 0.06$ ). T1 $\rho$  in the Lateral Tibia (LT) cartilage was significantly higher in Cases with LPH tears compared to lesions in other meniscus compartments ( $p = 0.02$ ), as was T1 $\rho$  in the Medial Femoral (MF) cartilage with MPH tears ( $p = 0.03$ ); there was a higher trend of T1 $\rho$  in the LT of Cases with LPH tears compared to Controls ( $p = 0.06$ ; Figure 2).

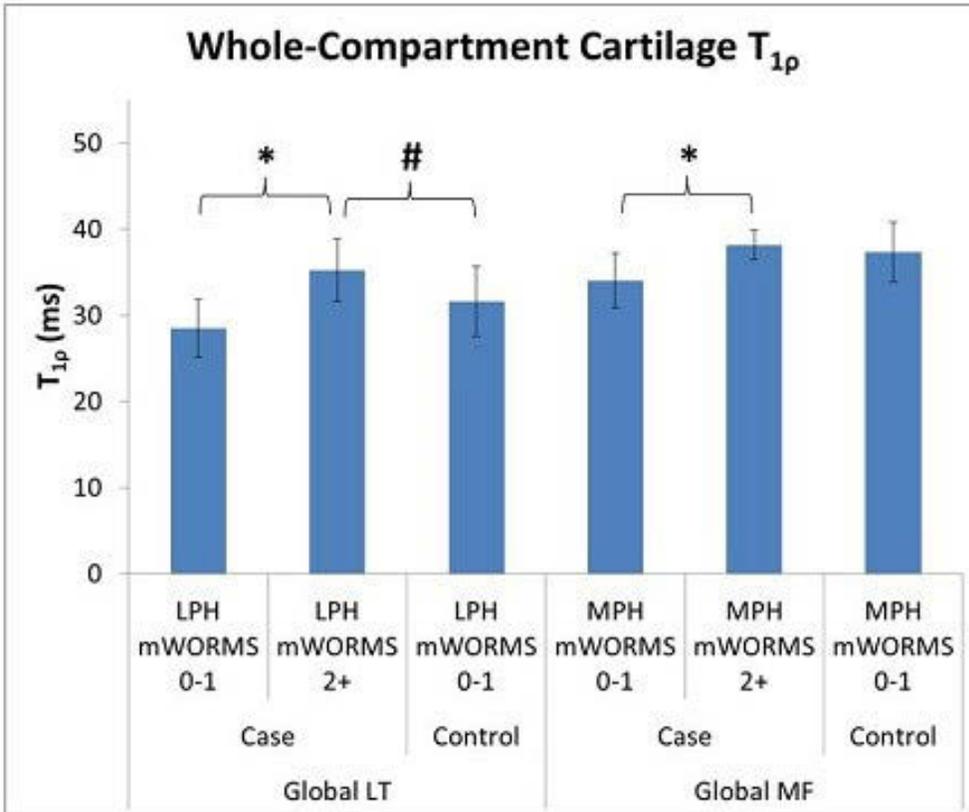


Figure 2: Whole-compartment T<sub>1ρ</sub> relaxation times of the LT and MF cartilage with and without adjacent posterior meniscus lesions.

\* signifies  $p < 0.05$ , # signifies  $0.05 < p < 0.10$ .

T<sub>1ρ</sub> in the subregion directly below the LPH (LT-p) was significantly higher in Cases with LPH tears than tears in other compartments ( $p=0.03$ ). Likewise, T<sub>1ρ</sub> in the subregion directly above the MPH (cMF-p) showed a higher trend with MPH tears ( $p=0.07$ ). T<sub>1ρ</sub> in the non-weightbearing posterior subregions of MF and LF cartilage (pMF and pLF) was elevated in Cases with adjacent posterior horn tears; this difference was significant in the pMF and approached significance in the pLF ( $p=0.002$  and  $p=0.08$ ; Figure 3).

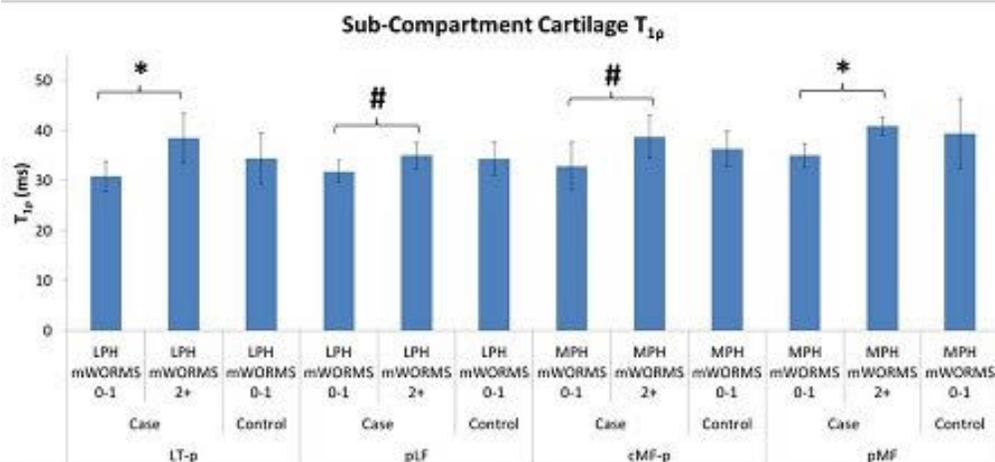


Figure 3: Sub-compartment T<sub>1ρ</sub> relaxation times of the LT, LF, and MF cartilage with and without adjacent posterior meniscus lesions. \* signifies p<0.05, # signifies 0.05<p<0.10.

**Discussion:** Healthy menisci are vital for knee health, and meniscus irregularities have been associated with progression of OA. Focusing upon subjects with no visible indications of OA, we investigated the effect of meniscus lesions on knee cartilage at the molecular level using quantitative MRI. Among subjects with meniscus lesions, T<sub>1ρ</sub> in cartilage adjacent to torn posterior meniscus horns is elevated relative to cartilage without adjacent meniscal tears. These differences were observed in whole compartments and subregions, indicating a degree of proteoglycan degradation in macroscopically healthy cartilage and marking the earliest changes in the OA disease process [9-10]. These differences were also observed in non-weightbearing posterior femoral cartilage; given the mobile nature of the femur, this region may slide adjacent to the torn meniscus and be affected in a similar manner to weightbearing cartilage. However, the data must be viewed in light of our small sample size (n=20). Since chondrocytes still have the potential to replace the depleted macromolecules [11], OA is potentially reversible at this early stage. We have also shown that non-OA patients with meniscus lesions reported diminished clinical outcomes. These individuals should be considered prime targets for interventions that can restore normal meniscal health, thus halting further cartilage damage and improving patient outcomes. Further work is necessary to follow disease progression from quantitative and morphological perspectives.

**Significance:** Individuals with macroscopically-intact cartilage but posterior meniscal tears showed elevated T<sub>1ρ</sub> relaxation times in adjacent cartilage, suggesting disrupted proteoglycan structure in these regions; these subjects also reported worse clinical outcomes than did their healthy counterparts.