

Longitudinal Evaluation of Meniscal T1ρ Relaxation Times From 1-2 to 2-3 Years With and Without Applied Load In Patients Following ACL Reconstruction With Meniscal Surgery

Divya Pradip Roy¹, Sadegh Khodabandloo¹, John C. Ramsdell^{1,2}, Bruce D. Beynon¹, Mathew J. Faila¹, Jiming Zhang¹, Matthew Geeslin¹, Mickey I. Krug¹, Michael DeSarno¹, Niccolo Fiorentino¹

¹University of Vermont, Burlington, VT, ²New York Mets, New York City, NY, Email: divya-pradip.roy@uvm.edu

Disclosures: The authors do not have any conflict of interest to disclose.

Introduction: Anterior cruciate ligament (ACL) injury combined with meniscus tears increases the risk of developing early onset post-traumatic osteoarthritis (PTOA) compared to ACL injury in isolation. The increased risk of PTOA in this population has been attributed to several factors, including altered joint biomechanics and elevated articular cartilage contact stress resulting from meniscal resection and/or meniscectomy in addition to ACL reconstruction. However, the underlying mechanism for the onset and progression of PTOA in subjects with ACL reconstruction and meniscal surgery (ACLR+M) are not well understood. Advanced imaging modalities such as quantitative MRI (qMRI) capture the microstructural and compositional alterations in soft tissues such as the meniscus and have the potential to be used as early biomarkers of PTOA progression. In addition, qMRI can be used to study the behavior of the meniscus in response to loading which provides insight into the load transmission capabilities of the surgically repaired/ resected meniscus. Therefore, the purposes of this study were to 1) evaluate the longitudinal changes in meniscal composition from 1-2 years after ACLR+M surgery to 2-3 years after ACLR+M surgery using a qMRI parameter T1ρ relaxation time, and 2) assess the difference in the loading response of the meniscus between the two timepoints using the changes in T1ρ relaxation times in response to an applied load of 50% body-weight (BW). We hypothesize that the surgically repaired/ resected limb's meniscus will exhibit 1) increased T1ρ relaxation times compared to the contralateral limb from 1-2 to 2-3 years, and 2) that there will be a different response to compressive loading of the ACLR+M limb between the two timepoints.

Methods: This study was approved by the University of Vermont institutional review board (IRB) and all participants provided written informed consent prior to participation. Fifteen patients were recruited for the study 1-2 years (16.5 ± 3.6 months) post ACLR+M surgery. Among the initial 15 patients, five were excluded from the study due to structural damage found in the contralateral knee, scheduling conflicts, a contralateral ACL injury between timepoints, and an ACL graft tear between timepoints. Thus, this study includes data from N=10 (7 males and 3 females) ACLR+M subjects. Of these, seven underwent ACLR with an ipsilateral bone-patellar tendon-bone (BPTB) autograft, one had a quadriceps tendon autograft, one received a BPTB allograft, and one had an ipsilateral BPTB autograft with lateral extra-articular tenodesis. The contralateral knee of all patients was verified as uninjured through MR scanning and assessment by a board-certified, fellowship-trained musculoskeletal radiologist. Out of the 10 patients, six had medial meniscus injuries, two had lateral meniscus injuries, and two had medial and lateral meniscus injuries. Meniscal injuries were either repaired or repaired and partially resected. Prior to MR imaging, the patient's knees were non-weight bearing for 15 minutes. Subsequently, T1ρ images were acquired with the subject in a supine position, with the left knee imaged first followed by the right knee. Then, T1ρ images were obtained with a compressive load of 50% of their BW applied to the plantar aspect of their foot using a MR-compatible loading device. The same process was then repeated for the right limb. T1ρ relaxation time colormaps of the meniscus were generated on five sagittal slices centered at 20% and 80% of the medial-lateral directed width of the tibial plateau (Figure 1). Only the posterior horns of the medial and lateral meniscus were evaluated to assess longitudinal composition and the response to applied compressive loading. Results are reported as (least square mean ± standard error, p-value). Linear mixed model analysis was performed with random effects of subject and fixed effects of timepoint and limb to evaluate statistically significant difference.

Results: Elevated T1ρ relaxation times were found in the contralateral limb's meniscus from 1-2 to 2-3 years (19.6 ± 0.7 vs 21.7 ± 0.7 ms, p = 0.008), whereas the ACLR+M limb's meniscus did not show a significant increase (21.4 ± 1.2 vs 23.7 ± 1.2 ms, p = 0.14) (Figure 2). Neither the ACLR+M (2.4 ± 1.1 vs 1.2 ± 1.2 ms, p = 0.46) nor contralateral limb's (0.8 ± 0.8 vs 0.9 ± 0.8 ms, p = 0.92) meniscus showed significantly different response due to applied load from 1-2 to 2-3 years (Figure 3).

Discussion: Progressive elevation of T1ρ relaxation times over 2-year period after surgery in the posterior horn of the meniscus has been reported in ACL-injured patient cohort and is thought to be associated with the depletion of proteoglycan content in the tissue matrix, indicating microstructural alterations. Contrary to our hypothesis, the ACLR+M limb's meniscus in our patient population did not show significant elevation from 1-2 to 2-3 years post-ACLR+M, however, the contralateral limb's meniscus demonstrated a significant longitudinal elevation in T1ρ relaxation times. We speculate that the longitudinal increase in T1ρ in the contralateral side may be due to favoring the contralateral limb during post-surgery recovery period which continues during and after rehabilitation. Similarly, the effects of compressive loading (loaded-unloaded T1ρ values) was not significant in both limbs when compared between 1-2 and 2-3 years, which is in contrast to what we hypothesized. However, only assessing difference between timepoints and interactions with limbs might not capture the complex relationships between individual compartments (medial/lateral and injured/uninjured), loading, and knee surgical status.

Significance: To our knowledge, this is the first study reporting the short-term compositional alterations and effect of compressive load in the meniscus of the ACLR+M patient population. Future work includes additional statistical analysis of injured/uninjured compartment(s) and load.

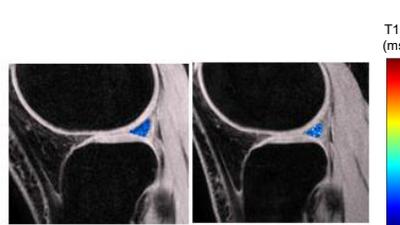


Figure 1: Example T1ρ colormap from an uninjured lateral posterior meniscal compartment of a patient at 1-2 (left) and 2-3 (right) years post ACLR+M without loading

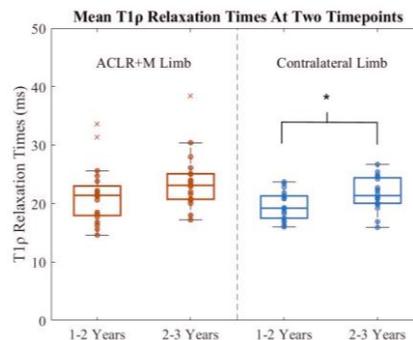


Figure 2: Longitudinal changes of meniscal posterior horn T1ρ

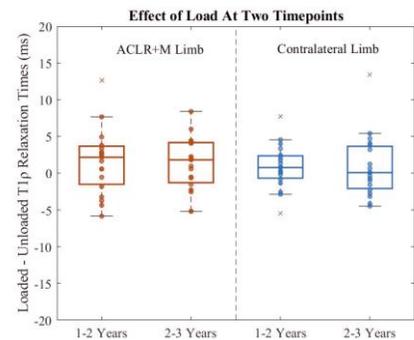


Figure 3: Effect of load on meniscal posterior horn T1ρ at two timepoints