Abnormal Tibiofemoral Kinematics Following ACL Reconstruction are Associated with Early Cartilage Matrix Degeneration Measured by MRI T1rho

Introduction: Previous large long-term studies suggested that subjects with anterior cruciate ligament (ACL) injury had a high risk of developing post-traumatic osteoarthritis, even after ACL reconstruction. (1) Abnormal kinematics following ACL reconstruction are hypothesized to contribute to cartilage damage by altering the native loading patterns in the reconstructed knee. Proving a connection between altered kinematics and the development of cartilage damage has proven difficult, as the latent period between surgical reconstruction and cartilage degeneration, as shown in radiographs, is long. We have developed MR methods to quantify knee kinematics and MR T1rho to detect early cartilage matrix degeneration prior to morphological changes in the cartilage. Our study aimed to assess whether altered kinematics following ACL reconstruction are associated with early cartilage degeneration as measured by T1rho MRI.

Methods: Eleven patients (7 women and 4 men, age: 33 ± 9 years) underwent 3Tesla MR imaging (GE Healthcare) 18 ± 5 months following ACL reconstruction using an 8-channel knee coil. All patients were reconstructed using an anteromedial drilling technique. Patient had both knees scanned during one visit using a previously described custom loading device (Figure 1). High resolution fat-suppressed spoiled gradient echo (SPGR) and 3D T1 rho sequences (FOV = 14 cm, matrix = 256 x 192, slice thickness = 4 mm, time of spin-lock = 0/10/40/80ms, spin-lock frequency = 500 Hz) were acquired in an unloaded fully extended position. T2-weighted fast spin-echo (FSE) (TR/TE = 4000 ms / 50.96 ms, FOV = 16cm, 512 x 256 matrix, slice thickness of 1.5 mm) images were obtained at knee extension and 30° flexion under simulated loading (125N).

Anterior tibial translation (ATT) and tibial rotation (TR) between flexion and extension, and T1rho relaxation times of the knee cartilage were quantified using methods previously developed in our lab. (2,3) Previous studies showed high reproducibility of both T1 rho and kinematics quantification. The cartilage was divided into five compartments: medial and lateral femoral condyles (MFC/LFC), medial and lateral tibias (MT/LT), and patella. A sub-analysis of the weight-bearing (wb) region of the femoral condyles -- the area overlying and between the meniscal horns as well as the regions overlying the meniscal body -- was also performed.

Percentage change in cartilage T1 rho relaxation time was determined between the injured and contralateral uninjured knees across all compartments of the knee. Patients were categorized as having “abnormal” kinematics – either ATT or TR – if difference between injured and uninjured contralateral knees for the kinematic variable in question was outside one standard deviation from the mean (defined as the group standard deviation of the contralateral uninjured knees). Intra-subject differences were analyzed with paired t-tests, while inter-group differences were analyzed with unpaired t-tests.

Results: T1rho relaxation times of MFC compartment and MFC-wb region were significantly elevated in the injured knees compared to contralateral control knees (Table 1).

Table 1 Comparison of T1rho relaxation times (ms) in the MFC and MFC-wb regions between the Injured (ACL-reconstructed) and Control (contralateral) knees.

<table>
<thead>
<tr>
<th></th>
<th>MFC</th>
<th>MFC-wb</th>
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<tbody>
<tr>
<td>Injured</td>
<td>42.6 ± 3.7</td>
<td>42.2 ± 5.9</td>
</tr>
<tr>
<td>Control</td>
<td>39.8 ± 3.3</td>
<td>38.5 ± 4.0</td>
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<tr>
<td>p-value</td>
<td>0.04*</td>
<td>0.01*</td>
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Based on kinematic MRI, seven patients were defined as having “restored” ATT, while only 3 had “restored” TR. There were statistically significant (p<0.05) percentage increases in the percentage change of the T1rho relaxation times of the MFC-wb, MT, patella and overall average cartilage in the “abnormal” ATT group compared to “restored” ATT group. (Figure 2) No statistically significant differences between “restored” and “abnormal” TR groups were observed, however the percentage change of the MFC cartilage T1 rho approached significance (p = 0.08).

Conclusions: Quantitative MRI T1rho allows us to detect early cartilage matrix damage in the ACL reconstructed population. Utilizing our novel loading device in conjunction with T1rho MRI, we were able to, for the first time, quantify the relationship between altered tibiofemoral kinematics and early changes in cartilage matrix. Our results suggested that kinematic changes, particularly in the anterior-posterior plane, following ACL reconstruction may predispose patients to cartilage matrix degeneration as early as 18 months following surgery. The medial femoral condyle, and in particular the weight-bearing region, is more sensitive to changes in loading patterns and therefore more prone to early degeneration. Our results indicate that restoring native knee kinematics following ACL injury may help to prevent progression of cartilage damage.

References:

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