Quantitative T2* Mapping of Meniscus Before and After Meniscal Repair

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INTRODUCTION: The meniscus is crucial to the long-term maintenance and function of the knee joint. It provides joint stability, shock absorption and a barrier for articular cartilage to glide on. Strong forces that exceed the maximum tensile strength of the menisci or knee twisting can cause meniscal tears. Meniscal root tears in particular can lead to meniscal extrusion and increased contact stresses on articular cartilage resulting in altered weight-bearing capacity of the knee joint and ultimately contributing to the development and acceleration of knee osteoarthritis[1]. Unrepaired medial meniscus root tears did not allow patients to fully heal in 87% of patients[2]. Magnetic resonance imaging (MRI) is the most effective and noninvasive tool for assessing the condition of the meniscus[3]. Recent studies have shown the correlation between MRI T2 relaxation times and healing of meniscus[4-5]. The goal of this longitudinal study is to evaluate T2* values in the menisci of patients before repair (baseline) and six months after the meniscal repair (follow up). We hypothesize that infiltration of fluid caused by the meniscal repair procedure (sutures) will increase the T2* values in the repaired region at follow up MRI.

METHODS: This study is an IRB approved and HIPPA compliant longitudinal study. In this study, seven female patients with a unilateral posterior root tear of the medial meniscus (mean age: 54 years; age range: 43-62 years; mean body mass index: 29 kg/m2) underwent 7T MRI before the repair of the root attachment (baseline) and six months after the repair (follow up). The MRI protocol included T1- and T2-weighted turbo-spin echo sequences with fat suppression and a T2-weighted 3D SPACE with fat suppression for morphological assessment of the knee joint. For quantitative evaluation, a 3D multi-echo gradient recalled echo (GRE) sequence with an array of seven echo times (TE) between 3.1 and 21.4 ms was acquired to calculate T2* relaxation times in both menisci. The T2* maps were calculated by fitting a mono-exponential signal decay of the multi-echo T2* data with a two-parametric least-square fitting routine in Matlab. To evaluate the fitting accuracy, the root mean square error (RMSE) was normalized to the estimated signal intensity at the echo time of 0 ms. The 3D-structure of the medial and the lateral menisci was manually segmented from the anterior attachment to the posterior attachment and mapped onto the T2*-weighted images using ITK-SNAP (**Fig. 1**). Each meniscus was divided into four regions, including anterior horn (0°- 45°), anterior body (45°- 90°), posterior body (90°- 135°), and posterior horn (135°-180°). The median T2* values and the corresponding RMSE were measured in the four meniscal regions. Additionally, the number of pixels within the segmented 3D-structure was used to estimate the volume of each meniscal region. A linear mixed effect model was used to compare the T2* values of the meniscal regions and the volume between the baseline and follow up MRI.

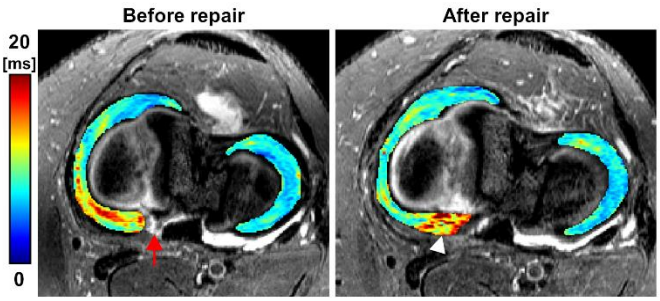

Figure 1. Representative axial T2* maps overlaid on the fat-suppressed SPACE images of the medial (arrowhead) and the lateral menisci of a patient (age 43 years, female) with root tears in the posterior horn of the medial meniscus (PHMM) (arrow). The segmented T2* maps show increased T2* values in the PHMM (arrowhead) after the repair.

RESULTS SECTION: Significantly longer T2* values (p=0.02) were found in the posterior horn of the medial meniscus at six months after the meniscal repair when compared to the same region at baseline (**Figs. 1-2**). The posterior horn of the medial meniscus was the region where the repair was performed. The differences in other regions as well as the regions in the lateral meniscus did not reach statistical significance (p>0.05). Comparing the volume, no statistical difference was found between the baseline and follow up MRI in the lateral and the medial menisci. The mean normalized RMSE was below 4.3% for all regions, which demonstrates a good reliability of the fitting results.

DISCUSSION: Elevated T2* values in the posterior horn of the medial meniscus six months after the root tear repair in the region reflect increased hydration or infiltration of fluid due to the suture fixation. A previous study has also shown increased T2 values in the healing menisci[4]. These findings indicate that it takes a longer period of time (> 6 months) for the menisci to start the healing process. However, the quality of the meniscal tissue in these patients have to be closely monitored following the repair to avoid the risk of postsurgical failure.

SIGNIFICANCE/CLINICAL RELEVANCE: The findings are highly significant for patient management since the success of surgical root repair relies on the longitudinal assessment of the menisci and the presence of healthy tissue at the repair site. Suture fixation in highly abnormal tissue might increase the risk of postsurgical failure. Activity modification might be needed longer than 6-month post surgically to allow tissue to heal. Quantitative follow up of meniscal composition with T2* mapping might therefore be useful indicator of the healing progression in repaired meniscus.

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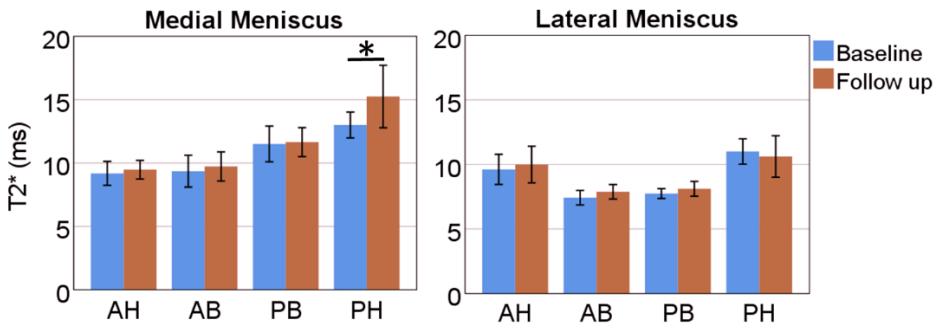

Figure 2. Plots of the median T2* values from meniscus anterior horn (AH), anterior body (AB), posterior body (PB) and posterior horn (PH) of seven patients with root tears in the posterior horn of the medial meniscus (PHMM) before meniscal repair (baseline) and six months after the repair (follow up). The T2* values were significantly longer (*p =0.02) in the PHMM at the follow up.