

Quantitative T2 mapping of knee cartilage: Initial results on the differentiation of healthy and altered articular cartilage of the knee by means of unloading

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Introduction: Relatively little is known about biomechanical behavior of articular cartilage. A study using rabbit knee joints in the evaluation of the recovery of cartilage after unloading sees the highest deformation of the collagen structure throughout all cartilage zones under static loading conditions (1). Completely recovery however of all deformations occurred after 30 minutes (1). Taking into consideration that walking and standing within the daily life is a kind of loading, hence deformation of collagen structure as well as water content changes after rest. Using MR imaging, the adequate approach for the evaluation of cartilage ultrastructure focusing on collagen structure and water content is quantitative T2 relaxation (2). Here a study on cartilage T2 mapping before and after 30 minutes of running shows a significant decrease in T2 values of the superficial zone within the weight bearing femoral cartilage supporting the hypothesis that cartilage compression changes the anisotropy of collagen fibers of articular cartilage (3). After cartilage repair however, cartilage ultrastructure is changed compared to healthy cartilage. Using T2 evaluation nevertheless in horses a hyaline like zonal variation from deep to superficial aspects of cartilage repair tissue was described (4). The aim of this study was to use cartilage T2 mapping and its zonal assessment for the evaluation of unloading during a one hour MR scan preoperatively in patients with a full thickness cartilage defect and in the post operative follow-up after matrix associated autologous chondrocyte transplantation (MACT).

Material and Methods: MRI was performed on a 3 Tesla MR scanner (Magnetom Trio, Siemens, Erlangen, Germany) using a dedicated eight channel knee coil. The image protocol consisted of a multi-echo spin-echo (SE) T2 acquisition with the following parameters: Repetition time (TR) 1.650 s; six echo times (TE) of 12.9 ms, 25.8 ms, 38.7 ms, 51.6 ms, 65.5 ms and 77.4ms; FoV of 160x160 mm, pixel matrix 320x320, voxel size 0.6x0.6x3.0mm; distance factor 0; bandwidth 230 Hz/pixel, averages 1; 6 slices, total acquisition time 3:50 minutes. T2 relaxation times were obtained from T2 maps using a pixel wise, mono-exponential non-negative least squares (NNLS) fit analysis. This SE-T2 sequence was, after a set of localizers, sagittal planned over the affected femoral condyle and was carried out at the beginning (pre-scan) and at the end (post-scan) of the clinical MR examination. The time gap between both T2 measurements was 45 minutes. In between a clinically used high resolution morphological MR scan was applied. The patients were asked to not to rest before the MR scan, so daily activity and walking to the MR ward was seen as a kind of loading. Now the supine knee was located with the joint space in the middle of the knee-coil. Time gap between lying down for the MR scan and the beginning of the first SE-T2 sequence could be held down to not more than 5 minutes.

Twenty-five patients were enrolled in this study. Eight patients pre-operatively with a single full-thickness cartilage defect on the femoral condyle (mean age 41.8±11.3 years, 5 female, 3male, 4 right, 4 left, all medial femoral condyle) and 17 patients (mean age 35.8±10.8 years, 4 female, 13 male; 6 right, 11 left, 12 medial, 5 lateral femoral condyle) 20.7±16.9 months after MACT within the knee. Regions of interest (ROI) analysis were manually done for image evaluation. ROIs were drawn by an experienced senior musculoskeletal radiologist in consensus with an orthopedic surgeon with special interest in musculoskeletal MR imaging. The areas of cartilage damage / cartilage repair and as internal control an area of healthy seen control cartilage were identified using the morphological images as well as the surgical reports. All areas of cartilage repair and cartilage damage and also all selected healthy seen cartilage sites were located within the weight bearing zone of the femoral cartilage. All ROIs had to cover the full thickness of cartilage repair / cartilage damage / control cartilage. For further evaluation on the zonal variation, the ROIs were divided into two equal sized deep and superficial regions. Statistical evaluation was done to compare T2 values of the pre- and post unloading scan using analyses of variance with a three way ANOVA with random factor. The trend between the deep and superficial cartilage layer was analyzed using a three way analysis of variance with random effects with two repeated measure factors. Differences with a P value less than 0.05 were considered as statistically significant.

Results: Within healthy seen cartilage sites, quantitative T2 values for the pre-unloading evaluation were 50.9±13.1ms for the deep zone and 56.0±10.9 ms for the superficial zone. 45 minutes later for the post-unloading evaluation, T2 values showed only a slight, not significant, increase to 51.2±13.3ms for the deep aspects and 57.7±12.8ms for the superficial aspect of articular cartilage. The increase between deep and superficial T2 values was significant. Concerning the pre-operative patients, the area of cartilage defect show initial significant lower T2 values with 41.5±6.0ms for the deep zone and 50.4±6.4ms for the superficial zone, however after unloading, values rise significantly to 52.6±14.3 for the deep aspect and 58.5±14.3 for the superficial aspect. The trend for the zonal variation from deep to superficial again was significant for both measurements. Finally the cartilage repair tissue after MACT showed pre-unloading values of 51.9±11.6ms for the deep cartilage zone and 55.9±14.1 for the superficial. Thus there was no significant difference from the healthy seen cartilage sites. However the post-unloading scan showed a significant increase in T2 values for deep (56.3±14.1ms) and even clearer for superficial (60.8±18.5ms) aspects of cartilage repair tissue. The trend from deep to superficial also within cartilage repair tissue was significant.

Discussion: Quantitative T2 relaxation can be used to assess pre- and post unloading values of articular cartilage in a clinical setup. Furthermore the presented approach of two SE-T2 scans at the beginning and the end of an MR scan might give additional information on the constitution of cartilage and might help to differentiate between healthy and affected articular cartilage. However it appears that changes in water content and anisotropy over time are different in healthy cartilage compared to altered cartilage. Larger patient groups have to elucidate a potential clinical impact of the presented approach.

References: 1. Kaab et al. Journal of Orthopaedic Research 2005;16(6): 743-751. 2. Mosher et al. Semin Musculoskelet Radiol 2004;8(4):355-368. 3. Mosher et al. Radiology 2005 Jan;234(1):245-9. 4. White LM et al. Radiology 2006;241(2):407-414.

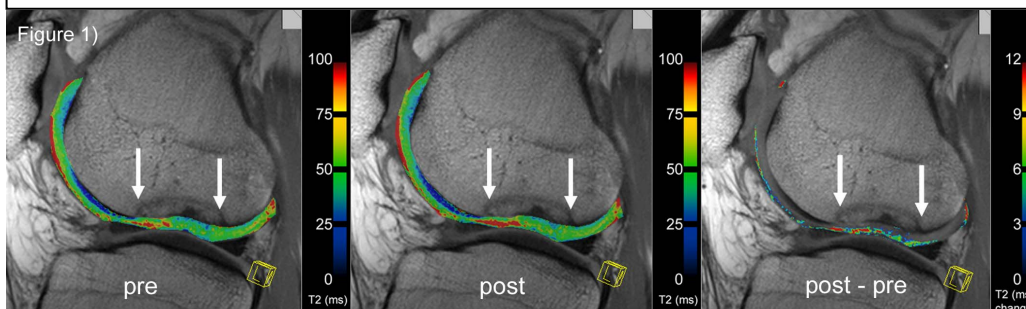


Figure 1: Quantitative T2 map of a patient after MACT. Left image shows the pre-unloading scan, the middle image the post unloading scan. The right image shows the subtracted T2 map (post - pre); for better visibility all T2 values < 3ms were removed. The remaining subtracted values (>3 ms) highlight the cartilage repair tissue.