How Does Cartilage T2 Change After Selective Enzymatic Degradation?

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Introduction:

Degenerative joint diseases cause a high socio-economic burden. Especially for diagnostic work up of cartilage degeneration in osteoarthritis, MRI has evolved to an important tool within the last decade. However, for monitoring the course of disease and assessing therapeutic effects on the internal structure of cartilage a quantitative evaluation method is essential. Particularly cartilage T2 might be a promising quantitative parameter for detecting early pathologic findings [1,2] which are characterized by variations of the biochemical structure of articular cartilage such as loss of proteoglycans [3]. Therefore, the purpose of this study was to evaluate the changes of cartilage T2 in human patellar cartilage after enzymatic treatment with hyaluronidase (inducing a loss of proteoglycans) in a widely accessible clinical setting at 1.5T.

Materials and Methods:

8 human patellae without any visible macroscopic lesions of the cartilage surface were harvested within 48 hours of death (male, aged from 19 to 37 (mean = 26.1) years). The MR measurements were performed on a clinical 1.5T whole-body imager (Magnetom Symphony, Siemens Medical Solutions, Germany) using a commercial transmit-receive extremity coil. The whole patellar specimen was covered by 20 axial slices (thickness = 3.0 mm), the in-plane resolution was chosen 0.63^2 mm^2. For determination of cartilage T2 a recently developed fat suppressed multi-echo pulse sequence was applied (TR/TE = 3000/13.2-105.6 ms, number of echoes = 8, bandwidth = 130 Hz/pixel) [4]. For comprehensive anatomical depiction of cartilage tissue a 3D-FLASH water excitation sequence was used (TR/TE = 17.6/8.8 ms, flip angle = 15°, bandwidth = 130 Hz/pixel). During the measurements the patellae were fixed on a home-built device and stored in 0.9% NaCl solution in order to prevent the cartilage from dehydration. Two series of images were acquired, one before and one after exposition of the medial patellar facet to a solution containing 330 u/ml hyaluronidase for six hours at 37°C. After segmentation of the cartilage in the anatomical images and superposition of the segmented areas on the corresponding multi-echo images T2 values were calculated on a pixel-by-pixel basis by a dedicated fitting algorithm implemented with AVS (Advanced Visual Systems, MA, USA). Within 5 consecutive central slices the cartilage was subdivided automatically into 7 equally sized sections (Figure 1) and T2 values of the non-treated part (lateral facet: section 1, 2) and the enzymatically treated part (medial facet: section 4, 5) of the cartilage were compared separately for a lower, middle and upper layer (Figure 1).

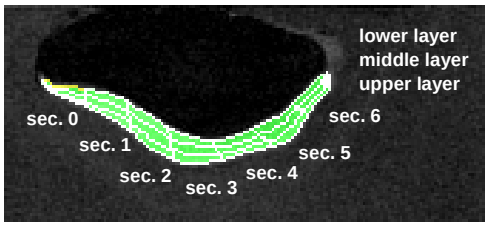

Figure 1: The cartilage was subdivided automatically into 7 sections (sec. 0-6) and 3 layers (lower, middle, upper layer). Sections 1 and 2 were evaluated representatively for the lateral, sections 4 and 5 for the medial (= enzymatically treated) patellar facet's cartilage.

Results and Discussion:

The patellar cartilage T2 relaxation time ranged from 30 to 53 ms in the medial facet and from 29 to 55 ms in the lateral facet, showing a zonal distribution with increasing T2 values from the cartilage-bone interface (lower layer) up to the cartilage surface (upper layer). After digestion by hyaluronidase the T2 values of the enzymatically treated part of the cartilage (medial facet) decreased by averaged 8.2% in the lower layer, by 21.7% in the middle layer and by 18.5% in the upper layer. Within the non-treated part of the cartilage (lateral facet), the T2 values were reduced by averaged 1.5%, 9.3% and 16.8%, respectively. Especially in the medial patellar facet's cartilage (enzymatically degraded) the cross-sectional zonal appearance of the transverse relaxation time seemed almost lost (Figure 2).

Enzymatic treatment of articular cartilage with hyaluronidase showed a significant decrease of T2 values in the 3 examined layers of the medial facet ($p_{lower\ layer}$ = 0.03, $p_{middle\ layer}$ = 0.0002, $p_{upper\ layer}$ = 0.0005). T2 loss was particularly pronounced in the middle layer, affecting the zonal distribution of the T2 time. The observed reduction of cartilage T2 might be explained by alterations of water content due to a decrease of the electronegative force corresponding to the enzymatically induced decrease of proteoglycans. However, there was also detected a reduction of cartilage T2 in the non-treated lateral facet, increasing from the lower to the upper layer. Probably, the storage of the specimen in saline solution during the MR measurements might have induced some additional change of water content, thus influencing also the T2 values of the lateral patellar facet's cartilage.

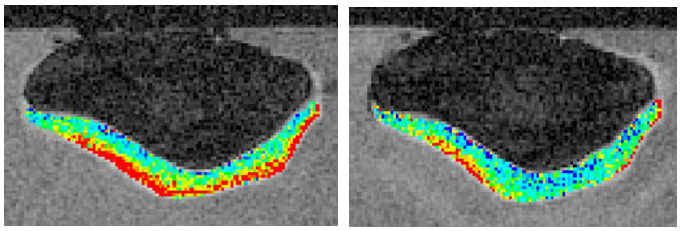

Figure 2: T2-map before (left) and after (right) enzymatic treatment. Especially the medial patellar facet's cartilage shows a decrease of T2 as well as a loss of the zonal appearance of T2 after digestion by hyaluronidase.

Conclusion:

The current study demonstrates that proteoglycan depletion induced by enzymatic treatment with hyaluronidase leads to a decrease of human cartilage T2, measurable at 1.5T in a clinical setting. Although the detected loss of cartilage T2 might also be attributable to the incubation of the specimen in 0.9% NaCl solution - at least to a certain extent - the cross-sectional pattern of T2 loss was completely different in the enzymatically degraded facet (pronounced T2 reduction in the middle layer) as compared to the non-treated facet (decreasing T2 reduction from the cartilage surface to the bone-cartilage interface). In order to improve the understanding of the mechanism behind and to assess the potential of T2 quantitation in patients suffering from osteoarthritis, present work is focused on histological and biochemical analysis of the proteoglycan and water content of the specimen.

References:

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