Impact of different coils on biochemical T2 and T2* relaxation time mapping of articular cartilage

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Introduction: In the evaluation of articular cartilage, cartilage repair and OA, biochemical magnetic resonance imaging (MRI) plays an important role. Different biochemical methods are exploited for their potential use at 1.5 Tesla and 3.0 Tesla in various studies and recently in clinical routine protocols (1). Advances in coil-technology significantly improve their ability for the diagnosis of cartilage disorders (2). While delayed gadolinium enhanced MRI of cartilage (dGEMRIC) focuses on the visualization of the glycosaminoglycan content of cartilage, techniques like T2 and T2* relaxation time mapping are more likely to be influenced by the orientational behavior of collagen and tissue hydration (3,4,5). Crucial for all biochemical methodologies however is a high reproducibility and to interpret changes e.g. in follow-up examinations. Perhaps the most widely implemented biochemical MR parameter is T2. Quantitative T2 has been the subject of numerous studies, nevertheless the T2 relaxation times in the depiction of healthy or altered articular cartilage differ, most probably due to different study protocols and different employed sequences. When looking at the hardware components, besides the magnet also the utilized coil has to be taken into consideration.

There are different solutions in the market for the technical implementation of coils. These different solutions are emphasizing different aspects in clinical application as well as in technical realization. The impact of coil design on the contrast-to-noise ratio, precision, and consistency of morphological MRI has already been shown (6). Furthermore, differences due to multichannel coils, parallel imaging techniques, and reconstruction filters have been addressed for morphological signal- and contrast-to-noise evaluations with very interesting results (7). The impact of different coils on quantitative T2 or T2* relaxation times however has, to our knowledge, not been investigated before.
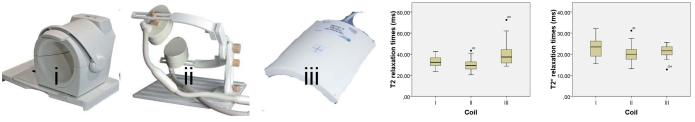
The aim of the present initial study was to assess T2 and T2* relaxation time values of patella cartilage in healthy volunteers using three different coils at 3.0 Tesla MRI.

Material and Methods: Fifteen healthy volunteers with a mean age of 26.3 ± 4.8 years were enclosed. All MR examinations were performed on the same 3 Tesla MR unit (Magnetom Trio; Siemens Medical Solutions, Erlangen, Germany) and at the same time of the day. All volunteers were scanned in the supine position after at least half an hour of rest to minimize changes in between the coils due to different loading conditions before the MR examination. Furthermore the three coils were used in random order for all volunteers. One knee of each volunteer was analyzed using one coil after the other.

The following coils were used: i) a dedicated eight-channel knee phased-array coil (In vivo, Gainesville, FL, USA), ii) an eight-channel multi-purpose coil (Noras, Wuerzburg, Germany), and iii) a double tuned (1H, 13P – used 1H) surface coil (Rapid Biomedical, Rimpar, Germany). T2 and T2* relaxation times were obtained from on-line reconstructed T2 and T2* maps (MapIt, Siemens, Germany) using a pixel-wise, mono-exponential non-negative least squares (NNLS) fit analysis. Region-of-interest (ROI) analysis was performed on the patellar cartilage for mean as well as zonal (deep and superficial) T2 and T2* values. T2 relaxation time measurements were prepared by a multi-echo spin-echo sequence with a TR of 1200 msec, TE 13.8, 27.6, 41.4, 55.2, 69.0 and 82.8 msec, a field of view of 160 x 160 mm; a matrix size of 320 x 320 and with a slice thickness of 3 mm. The bandwidth was 240 Hz/pixel, with12 slides and an acquisition time of 4:03 minutes. T2* relaxation time measurements were prepared by a multi-echo gradient-echo sequence with a TR of 600 msec, TE 5.7 , 9.8, 14, 18.1, 22.2 and 26.4. FoV, matrix and slice thickness were kept consistent for the T2 and the T2* sequences to guarantee comparability; the bandwith was 260 Hz/pixel, with 12 slices, and a total acquisition time of 2:02 minutes. Statistical analysis of variance was performed to compare the quantitative T2 and T2* values of the different coils.

Results: The mean (full-thickness) quantitative T2 values (ms) were 32.9 ± 4.7 for the i) eight-channel knee coil; 30.0 ± 5.4 for the ii) eight-channel multi-purpose coil and 39.9 ± 10.9 for the iii) surface coil. The differences in between the three coils were statistically significant: i) versus ii) ($p=0.031$); i) versus iii) ($p=0.001$); ii) versus iii) ($p<0.001$). The differences between the mean (full-thickness) quantitative T2* values (ms) as assessed by the different coils were slightly less pronounced compared to the T2 evaluation. The T2* values were 32.2 ± 4.4 for the i) eight-channel knee coil; 20.2 ± 3.7 for the ii) eight-channel multi-purpose coil and 21.4 ± 2.8 for the iii) surface coil. The differences in between the three coils were statistically significant in two comparisons: i) versus ii) ($p=0.008$); i) versus iii) ($p=0.043$); ii) versus iii) ($p=0.127$). When looking at the zonal T2 and T2* values, again the T2 evaluation ($p=0.001$ to $p=0.249$) revealed clearer differences due to the respective coil compared to the T2* evaluation ($p<0.001$ to $p=0.202$).

Discussion: In the presented initial study, T2 as well as T2* relaxation times could be assessed in the patella cartilage of healthy volunteers using three different commercial available coils. The mean as well as the zonal T2 and T2* values revealed, in most of the cases, significant differences in between the respective coils. These differences were a little less pronounced in the T2* measurements, compared to the T2 evaluations. The present results demonstrate that biochemical T2 and T2* mapping is highly dependent on the utilized coil. Hence when performing studies on biochemical cartilage T2- or T2*-imaging, and especially in longitudinal studies or multi-center studies, always the same coil has to be used to ensure comparability. Furthermore the present study might, besides many other reasons, provide some explanations on the large differences of T2 relaxation times of cartilage in literature.

The three different coils are depicted: i) eight-channel knee coil; ii) eight-channel multi-purpose coil; iii) surface coil. The Box-Plots visualize the differences in between the T2 (left) and T2* (right) relaxation times as assessed by the different coils i), ii) and iii).

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