Reproducibility of Cartilage T2 Quantitation at 1.5 and 3.0T

T. Mendlik[1], S. Wagner[1], S. Wagner[1], W. Horger[2], M. Reiser[1], C. Glaser[1]

[1]Department of Clinical Radiology, Ludwig-Maximilians-University, Munich, Germany, [2]Siemens Medical Solutions, Erlangen, Germany

Introduction:

In terms of degenerative joint diseases such as osteoarthritis, magnetic resonance imaging (MRI) has proven a particularly powerful non-invasive technique for cartilage imaging. Within the last few years, research has been aimed at investigating the potential of MR parameters for quantifying alterations in the biochemical content and the structure of cartilaginous tissue. Prior studies have supported the assumption that T2 measurement of articular cartilage might be a promising tool to assess the tissue's condition quantitatively, especially at an early stage of disease progression [1,2]. Since 3.0T scanners are becoming more and more prevalent in clinical settings, the purpose of the present study was to compare the reproducibility of T2 quantitation by means of a recently developed multi-echo pulse sequence [3] at 1.5 and 3.0T.

Materials and Methods:

The patellar cartilage of the right knee joint of 6 healthy volunteers aged between 25 and 30 (mean = 26.5) years was examined on a 1.5T and 3.0T clinical MR scanner (Magnetom Sonata and Magnetom Trio, Siemens Medical Solutions, Germany) using a commercial transmit-receive extremity coil. The whole patella was covered by 20 axial slices (thickness = 3.0 mm), the in-plane resolution was chosen 0.31^2 mm^2 (interpolated from 256x256 to 512x512 matrix). The sequence parameters of the fat suppressed multi-echo sequence were: $TR/TE_{1.5T}$ = 3000/13.2-105.6 ms, $TR/TE_{3.0T}$ = 4500/13.2-105.6 ms, number of echoes = 8, bandwidth = 130 Hz/pixel. To assess the reproducibility of cartilage T2 measurement, the MR examination was repeated for 3 times for each volunteer at both field strengths, the knee joints being repositioned between the consecutive acquisitions. Cartilage segmentation was performed by a semi-automatic segmentation routine [4,5] within image data obtained from a 3D-FLASH water excitation sequence ($TR/TE_{1.5T}$ = 14.2/7.2 ms,$TR/TE_{3.0T}$ = 12.4/5.3 ms, flip $angle_{1.5T}$ = 15°, flip $angle_{3.0T}$ = 10°, bandwidth = 130 Hz/pixel). The delineated cartilage templates were superposed onto the corresponding multi-echo images. Cartilage T2 values were calculated on a pixel-by-pixel basis by a dedicated fitting algorithm implemented with AVS (Advanced Visual Systems, MA, USA). The intra-individual reproducibility was determined as coefficient of variation (CV, given in %) of the 3 consecutive measurements within 3 cross-sectional cartilage layers (lower, middle and upper layer) reaching from the cartilage-bone interface to the cartilage surface (Figure 1). The average reproducibility was determined as the root mean square average of the CVs of the 6 volunteers. Finally, the inter-individual variability of cartilage T2 was estimated by computing the mean value and the relative standard deviation across the 6 volunteers.

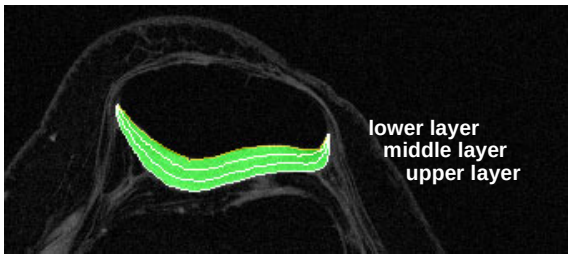

Figure 1: Evaluation of patellar cartilage T2 was performed within 3 cross-sectional cartilage layers, the lower layer being confined by the cartilage-bone interface and the upper layer being confined by the cartilage surface.

Results and Discussion:

Comparing the patellar cartilage transverse relaxation times averaged over each of the 3 cross-sectional layers, the T2 values varied from 27 to 41 ms (1.5T) / 21 to 36 ms (3.0T), increasing from the bone-cartilage interface (lower layer) up to the cartilage surface (upper layer).

The intra-individual reproducibility for the lower, middle and upper layer ranged from 0.9 to 7.5% (1.5T) / 0.7 to 5.0% (3.0T), from 1.3 to 5.1% (1.5T) / 2.5 to 7.5% (3.0T) and from 3.0 to 9.6% (1.5T) / 1.4 to 9.5% (3.0T), respectively. The average reproducibility was calculated 4.1, 3.8 and 6.3% (1.5T) / 3.7, 4.6 and 5.4% (3.0T), respectively. The inter-individual variability was determined 2.7, 4.7 and 7.2% (1.5T) / 7.2, 4.5 and 5.6% (3.0T), respectively.

Cartilage T2 values calculated from the 1.5T data were significantly higher than from the 3.0T data for all cartilage layers ($p_{lower\ layer}$ = 0.00002, $p_{middle\ layer}$ = 0.0009, $p_{upper\ layer}$ = 0.03) (Figure 2). Both the intra-individual as well as the average reproducibility were found to be similar at 1.5 and 3.0T. However, comparing the inter-individual (= biological) variability at both field strengths, a wide deviation could be detected in the lower cartilage layer where T2 values are the shortest. One possible reason for this result might arise from the field strength dependent shortening of the transverse relaxation time: probably, the minimal TE of 13.2 ms is too long to assess T2 values of about 20 ms reliably due to non-robust results in the fitting procedure.

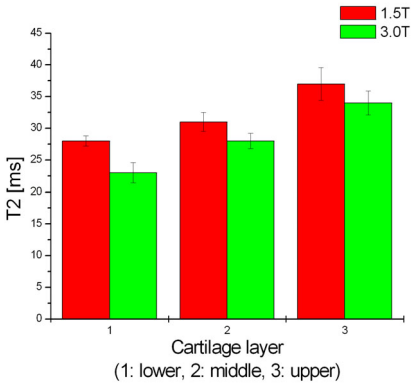

Figure 2: Mean cartilage T2 values and standard deviations (= inter-individual variability) for the 3 cartilage layers (see figure 1) at 1.5T (red) and 3.0T (green), averaged over the 6 volunteers.

Conclusion:

The reproducibility of T2 quantitation of articular cartilage was compared at 1.5 and 3.0T. Although the number of individuals included in the present study was rather small, in terms of reproducibility a field strength dependence could not be detected as far as the spatial resolution at both field strengths is kept equal. However, since the signal-to-noise ratio (SNR) at 3.0T is about twice the SNR at 1.5T, higher spatial resolutions would be feasible with increased magnetic field strength, making the use of 3.0T advantageous to 1.5T cartilage imaging. Especially the monitoring of disease progression and the evaluation of newly developed treatment strategies for cartilage repair would benefit exceedingly from turning to 3.0T-MRI.

References:

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