Parametric T2 and T2* mapping techniques to visualize intervertebral discs in patients with low back pain - initial results on the clinical use with 3.0 Tesla MRI

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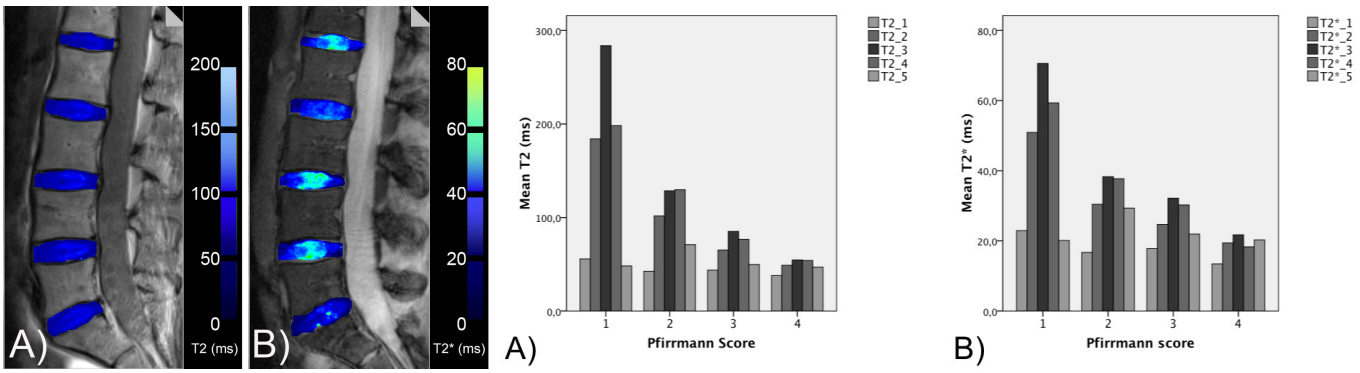
Introduction: Morphological magnetic resonance imaging (MRI) is a well-established method for the evaluation of intervertebral discs (IVDs) allowing for a grading of disc degeneration. Axial and sagittal T1 and T2-weighted sequences are standard diagnostic methods, however they are limited in detecting early signs of degeneration (3). The use of biochemical MRI and parametric mapping techniques is becoming increasingly important and may be capable to detect these early changes in the tissue ultrastructure. Although biochemical techniques like T2 relaxation time mapping are mainly used to assess the composition of articular cartilage (4), their use in the evaluation of the IVD is providing comparably promising results (5). Quantitative T2 provides information about the interaction of water molecules and the collagen network within the IVD. Besides classical spin-echo based T2 mapping, gradient-echo based T2* mapping was recently introduced in the description of articular cartilage (6, 7). T2* relaxation time mapping may theoretically also provide valuable information of the IVD ultrastructure, possibly comparable to standard T2, but with the additional benefit of three-dimensional acquisition capability together with high signal and high spatial resolution in a short scan time.
Aim of the study was to compare and correlate T2 and T2* relaxation in patients suffering from low back pain.
Material and Methods: Thirty patients with a mean age of 37.7 ± 9.9 years, suffering from low back pain were prospectively enclosed. All MR examinations were performed on a 3 Tesla MR unit (Magnetom Trio; Siemens Medical Solutions, Erlangen, Germany). Morphological (sagittal T1-FSE, sagittal and axial T2-FSE) and biochemical (sagittal T2 and T2* mapping; figure 1) MRI was performed covering the IVDs L1-L2 to L5-S1. 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, pixel matrix 256 x 256 and voxel size 0.9 x 0.9 x 5 mm; the bandwith was 228 Hz/pixel, with 12 slices, and a total acquisition time of 7:45 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 3:52 minutes. T2 and T2* relaxation times were obtained from on-line reconstructed T2 and T2* maps using a pixel-wise, mono-exponential non-negative least squares (NNLS) fit analysis. All IVDs were morphologically classified using the Pfirrmann score (8). Region-of-interest (ROI) analysis was performed on midsagittal T2 and T2* maps at 5 ROIs from anterior (ROI I) to posterior (ROI V) to obtain information on spatial variation between the annulus fibrosus (~ROI I and V) and the nucleus pulposus (~ROI 3). ROI Because there is a gradual transition from the annulus fibrosus to the nucleus pulposus and difficulties to define a clear border, ROIs were standardized in a reproducible way with five equally sized rectangular ROIs on two adjacent central slices (each ROI measured 20% of the disc diameter in the midsagittal plane). Statistical analysis of variance and Pearson correlation was performed.
Results: Altogether 150 IVDs were analyzed, including 1500 ROIs fot T2 and 1500 ROIs for T2*. According the Pfirrmann Score eight discs (5.3%) were classified as grade I, 90 (60.0%) grade II, 39 (26.0%) grade III, 13 (8.7%) grade IV and no discs had a collapsed disc space (grade V). Both, T2 and T2*, were able to clearly differentiate between all grades of IVD degeneration according to the Pfirrmann grading system ($p<0.05$) as visualized in figure 2, where T2 (A) and T2* (B) values (ms) are displayed relating to the Pfirrmann score. The spatial variation from the annulus fibrosus (ROI I) anterior to the nucleus pulposus (ROI II, III and IV) and to the annulus fibrosus (ROI V) posterior was significant ($p<0.05$) for Pfirrmann grade I between all 5 ROIs; for Pfirrmann grade II and III, the spatial variation, was only significant in between ROI I to ROIs II,III and IV to ROI V ($p<0.05$). For Pfirrmann grade V, there was still a significant anterior spatial variation in between ROI I and ROIs II, III and IV, whereas no spatial variation could be assessed between ROIs II, III and IV and the posterior ROI V ($p\geq0.05$). This spatial behavior of the T2 and the T2* values was identical, however the T2* evaluation showed comparably high values especially in the posterior ROI V at higher Pfirrmann grades. The assessed correlation between T2 and T2* was highly significant ($p<0.001$) with medium Pearson correlation coefficients of 0.380 (ROI I), 0.434 (ROI II), 0.376 (ROI III), 0.263 (ROI IV) and 0.251 (ROI V).
Discussion: In the presented initial study the use of T2 as well as T2* relaxation time mapping, demonstrates that all grades of IVD degeneration can be quantified and distinguished. Besides the established T2 methodology, T2* provides a fast and promising tool in the biochemical evaluation of IVDs. Interestingly especially T2* relaxation times in the posterior ROI V, representing the dorsal annulus fibrosus (where a disc herniation occurs), showed comparably high values in higher IVD degeneration. The presented preliminary results of the use of T2 and, to our knowledge for the first time, T2* mapping in the IVD, may present an interesting and valuable tool in the diagnosis and monitoring of patients with low back pain.



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