

Clinical Feasibility of a new partial spoiling T2 Mapping approach after Cartilage Repair of the Knee

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Introduction: MRI imaging is well-established as a noninvasive method for diagnosis and therapy monitoring in osteoarthritis and after cartilage repair procedures. In addition to imaging of cartilage morphology for staging and grading of cartilage lesions, the use of parametric MR mapping techniques is becoming increasingly important (1). Quantitative T2 techniques use the relaxation constant as an indirect marker of cartilage structure, which provides information about the interaction of water molecules and the collagen network (2).

Although T2 mapping has shown reliable results, there are still limitations to this method in the clinical setting. Most studies use a 2D multi-slice, multi-echo, spin echo acquisition (MSME-SE) to acquire source images used to calculate the cartilage T2 maps. The 2D acquisition precludes reformatting the data into 3D surface maps and requires reliable positioning to achieve reproducible results. Because of the long echo trains needed to accurately characterize the cartilage T2 decay curve, image acquisition is rather long and the inherent variability in the 180° refocusing pulses leads to errors in T2 estimates as a result of the contribution from simulated echoes and magnetization transfer (3). Fast imaging sequences, such as steady state free precession (SSFP) techniques, have gained increasing interest for quantitative MRI and over the years several methods have been developed for rapid imaging of relaxation times based on SSFP protocols (4, 5). Recently, a new quantitative T_2 imaging approach was described based on partial RF spoiling (6) of the FID of a non-balanced SSFP sequence. Based on this approach, during an ongoing study, clinical data were collected in patients after cartilage repair surgery.

Hence the aim of this study was to evaluate the feasibility of this new quantitative T2 mapping using partial spoiling in a clinical background and to compare and correlate the results against the established methodology of T2 mapping with the MSME-SE technique.

Material and Methods: Thirty consecutive MR examinations were prospectively included in this study. MRI was performed during clinical routine standard follow-up intervals after matrix-associated autologous chondrocyte transplantation (MACT) of the knee joint. The 30 MR examinations were performed in 27 patients with a mean age of 34.7 ± 10.1 years and a mean follow-up of 41.0 ± 28.1 months after MACT. MR imaging was performed on a 3 Tesla MR scanner. The MR protocol was identical for all included MR measurements and consisted of a standard morphological protocol and both quantitative T2 methods: (i) standard MSME T2 with six echoes (12.9, 25.8, 38.7, 51.6, 64.5, 77.4 ms), TR of 1200ms, and an acquisition time of 4:46 minutes; (ii) new partial spoiling T2 with partial RF spoiling increments of 0.95° and 9.5°, TR of 9.5 ms, and an comparable acquisition time of 4:32 minutes. In plane resolution (320x320), field-of-view (160x160mm) and slice thickness (3mm) were kept identical for optimal comparability. A global and zonal (deep and superficial) region of interest (ROI) analysis was performed in the areas of cartilage repair and in the native surrounding control cartilage. Statistical comparison was performed by analysis of variance and correlation by Pearson correlation coefficient.

Results: The healthy reference cartilage showed a significant zonal increase ($p<0.001$) as a sign of hyaline cartilage ultrastructure for both, the standard MSME T2 measurements (deep: 51.6ms; superficial 59.2ms) and the new partial spoiling T2 measurements (deep: 37.5ms; superficial: 43.1ms). Comparable values could be found for the repair tissue sites, also with a significant increase from deep to superficial ($p<0.05$) as a sign for hyaline-like cartilage ultrastructure. The MSME T2 values were 54.2ms (deep) and 58.2 (superficial) and the partial spoiling T2 values 39.0ms (deep) and 44.4ms (superficial) respectively. For both quantitative T2 methodologies there was no significant different between repair tissue and control cartilage ($p\geq0.05$).

Although the new partial spoiling T2 measurements showed clearly lower quantitative T2 values compared to the standard MSME approach, there was a highly significant correlation ($p<0.001$) for both, the analysis of the deep and the superficial layer (Fig. 2). The Pearson correlation coefficient showed a moderate to high correlation for the deep cartilage layer with 0.661 and a high correlation for the superficial cartilage layer with 0.714.

Discussion: In the present study, a new quantitative T2 methodology was introduced showing promising results in its clinical feasibility in patients after cartilage repair surgery of the knee joint. The clearly lower T2 values in this approach, compared to standard MSME T2 mapping, have different reason. Besides B1 field inhomogeneities (requiring an underestimation of the actual flip angle), the low dispersion of T_2 values and hence different weighting (due to the echo-time) e.g. of cartilage hydration (water) might play a role. Nevertheless the high correlation, the clear stratification of the T2 values and the comparable results to the MSME T2 mapping, when comparing cartilage repair tissue and reference cartilage, shows strong similarities to standard T2 mapping techniques. The reported new partial spoiling T2 mapping technique shows additional benefits and possibilities in future approaches allowing for high resolution and three-dimensional, isotropic quantitative T2 mapping.

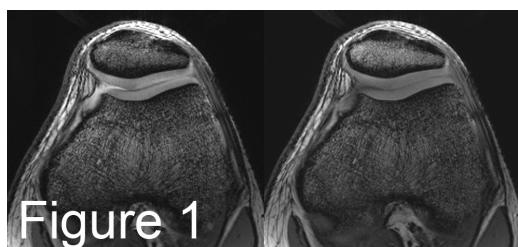


Figure 1

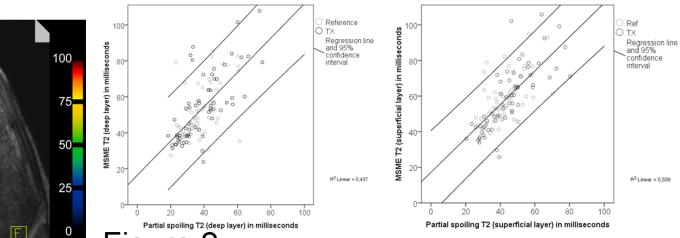


Figure 1: Both pFISP contrasts (left and middle) and the corresponding T2 map based on the new partial spoiling T2 mapping methodology. Figure 2: Significant correlations for the deep (left) and the superficial (right) cartilage layers with a regression line and the 95% confidence interval.

References: 1. H. Potter et al. Clin. Sports. Med. 2009., 2. T.J. Mosher et al. Semin Musculoskeletal Radiol. 2004., 3. C.F. Maier et al. J Magn Reson Imaging 2003., 4. K. Scheffler, J. Hennig. Magn. Reson. Med. 2004., 5. S.C. Deoni et al. Magn. Reson. Med. 2003., 6. O. Bieri et al. Proc. ISMRM 2010..