

T2-star Relaxation as a means to differentiate Cartilage Repair Tissue after Microfracturing Therapy

T. Hughes¹, G. H. Welsch², S. Trattnig², L. Brandi², S. Domayer³, and T. C. Mamisch⁴

¹Medical Solutions, Siemens AG, Erlangen, Bayern, Germany, ²MR Center, Department of Radiology, Medical University of Vienna, Vienna, Austria, ³Department of Orthopedic Surgery, Medical University of Vienna, Vienna, Austria, ⁴Department of Orthopaedic Surgery, University Bern, Bern, Switzerland

Introduction

MR imaging of cartilage is widely accepted as a tool in the evaluation of cartilage. Originally such studies were limited to morphological sequences, but increasingly MR imaging is being used to produce parameter maps (i.e. relaxation or diffusion constants) which allows a biochemical evaluation of the cartilage. One such parameter which has been extensively used is the T2 relaxation value, where the T2 value of the cartilage is a function of collagen content, concentration and water content [1-4]. T2 maps are created using a multi-echo spin echo technique. However some problems with this technique have to be considered such as stimulated echoes create a fluctuation in the signal within the echo train, crosstalk issues and relatively long scan time. We present here the T2-star relaxation constant as an alternative to the T2 relaxation constant in a preliminary cross-sectional study of patients after cartilage repair using Microfracturing technique (MFX).

Material and Methods

The measurement of eleven patients after MFX therapy (follow up interval 31.73 ± 17.74 months) were performed on a Siemens TRIO Scanner. Ethical approval for this study was provided by the Medical University of Vienna. Two protocols were prepared (i) a 2D six echo GRE with FOV 200x200mm, voxel size 0.63mmx0.63mmx1.5mm, TE 4.52, 8.5, 12.5, 16.5, 20.5, 24.5 ms, acquisition time 3:46 minutes and (ii) a standard 2D six echo SE with FOV 200x200mm, voxel size 0.63mmx0.63mmx1mm, TE 12.9, 25.8, 38.7, 51.6, 64.5, 77.4ms, acquisition time 8:46 minutes. From these measurements a pixel wise, mono-exponential linear least-squares analysis was undertaken to obtain T2-star (GRE) and T2 (SE) maps (shown in Figure 1). ROI were then prepared in microfracture cartilage regions and in healthy appearing cartilage regions on the posterior condyle. These ROI were analysed using a multi-exponential non negative least squares (NNLS) analysis (all ROIs exhibited mono-exponential behavior) and the results are shown in Figure 2.

Results and Discussion

Figure 1 shows that the T2-star map delineates the micro-fracture area much more clearly than the T2 map. The results from the T2-star and T2 analysis for 11 patients are shown in Figure 2. The mean T2-star value in healthy cartilage was 37.03 ± 4.29 ms and the micro-fracture cartilage 27.03 ± 8.10 ms. These values compare with the T2 values in healthy cartilage 55.91 ± 10.66 ms and microfracture cartilage 47.97 ± 12.04 ms. A close examination of the data reveals that the T2-star values show a much greater difference in values between healthy and repair tissue ($p=0.00$ vs $p=0.05$). Furthermore we found a statistical significant linear correlation of the relative difference between normal and repair cartilage sites ($p<0.05$). The sensitivity of the T2-star method to the underlying microstructure can be understood when one remembers that the T2-star relaxation is a measure of the local de-phasing caused by the microscopic magnetic fields produced by the microstructure (i.e. local susceptibility effects and local diffusion dephasing). This is in contrast to the T2 SE technique where the local de-phasing is rewound by the refocusing pulses. This means that the T2 parameter is partly a function of the water content. Not only may T2-star be an indicator of underlying microstructure, but the analysis required to fit the parameter to the signal evolution in the echo train is considerably simpler and less error prone than for the T2 SE technique. With the T2 technique the echoes within the SE echo train are influenced by stimulated echoes (arising from the non-perfect pulse profile and cross-talk issues) resulting in a fluctuation in the signal intensity along the echo train. These fluctuations can bias the fitting used to obtain the T2 value. Within the GRE echo train there is no such fluctuation which makes the fitting of the data more robust. Additionally the T2-star method is considerably faster than the T2 method allowing a greater spatial resolution to be measured or a faster scan time. In conclusion the preliminary results for the patients after MFX therapy show the possible value of T2* as an alternative for T2 measurement for assessment of different cartilage composition.

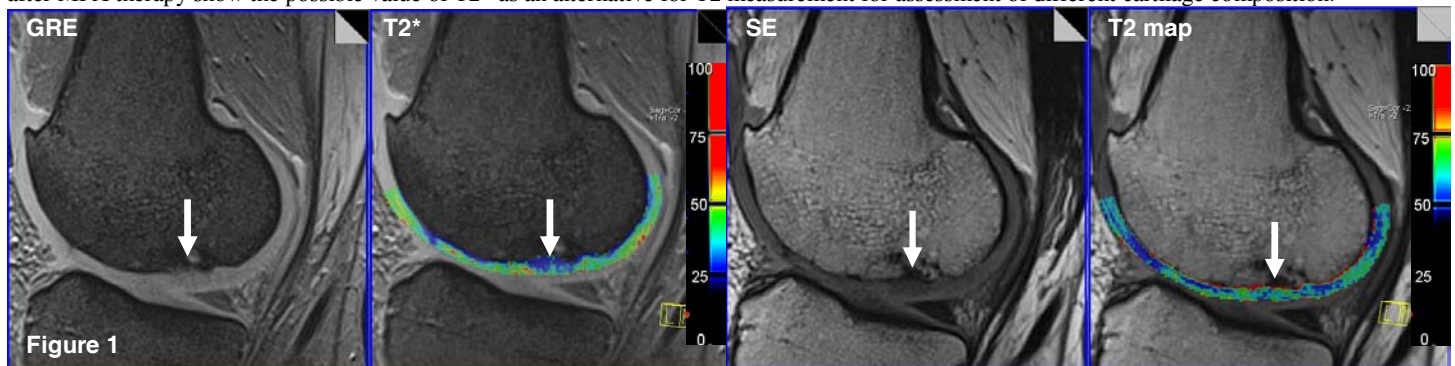


Figure 1. The T2* and T2 maps are shown for a representative patient along with the corresponding morphological images. Arrows denote the micro-fracture region.

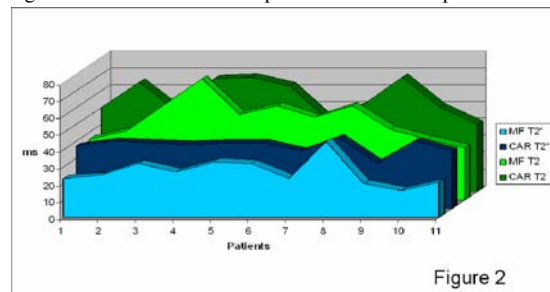


Figure 2. The T2* values for healthy cartilage (CAR T2*) and microfracture cartilage (MF T2*) are compared with the corresponding T2 values (CAR T2) and (MF T2)

References

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