Simultaneous acquisition of morphological images and functional T2 values: A feasibility study in patients after cartilage repair in the knee using a Double Echo Steady State (DESS) approach at 3 Tesla

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Introduction:

Different qualitative and quantitative MRI techniques have been proposed for probing the structure and the molecular composition and structure of cartilage. Especially cartilage repair procedures demand for advanced MR sequences. Regarding therapy monitoring morphological sequences are important to assess defect filling, integration, surface and structure. Here a fast Double Echo Steady State (DESS) sequence with water excitation (we) permits accurate and precise analysis of cartilage morphology in the knee joint at 3T[(1)]. However improve monitoring after cartilage repair procedure, quantitative mapping techniques seem to be useful[(2)]. Based on the theory of Bruder et al.[(3)] the simultaneous acquisition of both SSFP signals allows the formation of two MR images with clearly different contrasts: S+ = FISP (Fast Imaging Steady Precession) and S- = PSIF (reversed FISP) . The DESS sequence combines these signals into one by the application of the sum of squares. The PSIF part of the sequence leads to the high T_2 contrast, whereas the FISP part provides representative morphological images. In principle the T_2 values in the image can be calculated from the combination of the first and second images.

In this study we used those combined possibilities of the DESS sequence and compared it to a standard T_2 multi-echo spin echo (SE) sequence in patients after cartilage repair procedure using microfracture technique (MFX).

Material and Methods:

Eleven patients, mean age 39.64 ± 14.68 years, with a follow up period of 31.73 ± 17.74 months after MFX therapy underwent MR imaging on a Siemens TRIO scanner (Siemens Medical Solutions, Erlangen, Germany). Ethical approval for this study was provided by the Medical University of Vienna. Isotropic 3D DESS imaging was performed with a field of view (FoV) of 200x200mm, pixel matrix 320x320 and voxel size of 1.00x1.00x1.00mm. Echo time (TE) was 4.2ms for the S+ echo and 18.6 ms for the S- echo, repetition time (TR) 11.4ms, flip angle 33° (optimized after measurements of healthy controls) and acquisition time 7:18minutes. Following the methodology setout in Bruder[(3)] the T_2 values can be calculated as $T_2 = -(2TR) / \ln(PSIF/FISP)$, they are approximatively valid for $\alpha \leq 90$ degree. It is possible to calculate the theoretical error for this T_2 formula and plot this as a function of the flip-angle as shown in Figure 1. Examination of this graph shows that for the imaging parameters chosen here and with the assumption that T_1 is approx. 1000ms, this method is reasonably robust down to angles of 35 degrees (giving a 15% error). There exists a tradeoff within this method whereby higher flip-angles deliver higher accuracy but at the expense of the signal to noise ratio and T_2 accuracy. For T_2 comparison a standard 2D multi-echo (six) SE sequence with FoV 200x200mm, pixel matrix 320x320 and voxel size of 0.63x0.63x1.0mm was performed. TEs were 12.9, 25.8, 38.7, 51.6, 65.5 and 77.4 ms, TR 1.650 s and acquisition time was 8:46minutes. T_2 maps were calculated using a pixel wise, mono-exponential non negative least square (NNLS) fit analysis.

Results:

Mean T_2 values [ms] in MFX areas compared to sites with healthy cartilage were significantly decreased using our new T_2 DESS approach and the standard T_2 SE technique. MFX repair tissue showed T_2 values of 51.6 ± 9.7 in T_2 DESS and 48.0 ± 12.0 in T_2 SE, normal cartilage at control sites showed T_2 values of 61.8 ± 13.2 in T_2 DESS and 55.9 ± 10.7 in T_2 SE ($p < 0.05$). By correlating the raw T_2 values, generated by T2 DESS approach and standard T2 SE calculations, we found a significant correlation on the coefficient level of Pearson for both, the healthy (<0.05) and the MFX (<0.01) areas. One exemplary patient data set of the described DESS sequence is shown in figure 2: The PSIF and FISP contrasts; posterior are the ROIs within normal/healthy cartilage, inferior the ROIs within the microfracture area (arrow).

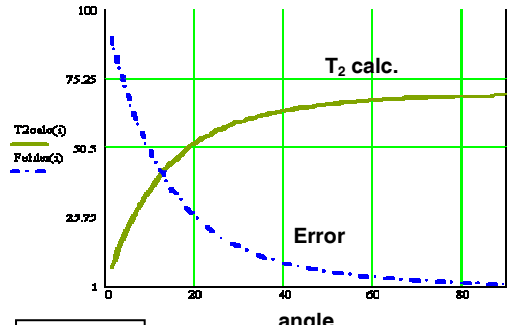

Figure 1

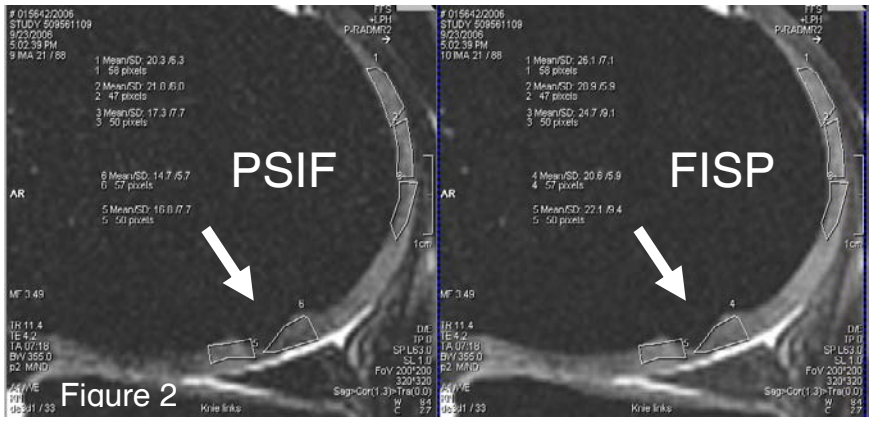

Figure 2

Discussion:

T_2 mapping based on an isotropic, high resolution DESS sequence correlates fairly good with standard SE T_2 mapping. Hence the presented DESS option gives the opportunity to combine morphological and functional imaging in one clinical sequence to assess cartilage and cartilage repair tissue.

References:

1. Eckstein et al. Ann Rheum Dis. 2006 Apr;65(4):433-41. 2. White et al. Radiology 2006;241(2):407-414. 3. Bruder et al. Magn Reson Med. 1988 May;7(1):35-42.