Different distribution functions of Magnetization Transfer pulses for high resolution MT imaging of the knee at 3 Tesla

P. Martirosian[1], A. Boss[2], H. Graf[1], M. Deimling[3], B. Kiefer[3], and F. Schick[1]

[1]Section on Experimental Radiology, University of Tübingen, Tübingen, Germany, [2]Department of Diagnostic Radiology, University of Tübingen, Tübingen, Germany, [3]Department of Magnetic Resonance, Siemens Medical Solutions, Erlangen, Germany

Purpose

Magnetization Transfer Contrast (MTC) is an important contrast mechanism for tissue characterisation in MRI (1). At higher field strength, the implementation of the MT technique becomes more problematic because the specific absorption rate (SAR) increases with the square of the RF transmission frequency. This SAR restriction also appears to be a prohibitive barrier for translating pulsed MT to higher field strength. Recently, there have been several reports of methods to reduce SAR for MT imaging based on partial k-space application (2-4). However, the saturation of the macromolecular spins is dependent both on the MT pulse parameter (e.g. off-resonance frequency, duration and amplitude) and on the distribution and frequency of the MT pulse application in the imaging sequence itself (5). As the image contrast is predominantly determined by the data in the center of k-space, any distribution scheme should result in a high degree of saturation of the macromolecular pool. The purpose of this study is to assess several acquisition schemes for high resolution MT imaging of the knee at 3.0 Tesla, with regard to SAR efficiency.

Material and Methods

Measurements in six healthy volunteers were performed in a 3.0 T MR scanner (Siemens Medical Solutions, Erlangen, Germany) using a dedicated TX/RX (eight channel) knee coil. A spoiled gradient echo sequence using a Gaussian shaped MT saturation pulse was applied for 2D proton-density weighted imaging studies. In the sequence, the possibility to vary the distribution of the MT pulses in k-space was implemented. For each volunteer studied, three sets of images were acquired. The first set was acquired with no MT pulses. For the second set of images, MT pulses of constant amplitude were applied during the entire k-space (100%), and for the third set of images, the amplitude of the MT pulse was only nonzero for a small fraction of the k-space lines: 75%, 50%, 25%, 20%, 15%, 10%, 5%. The amplitude of each MT pulse was chosen as a function of the phase encoding index. A step function and a trapezoidal function with plateau and linear ramp were used. Two sets of experiments were performed: (a) the nominal flip angle of the MT pulse was kept constant at 500° (peak amplitude 7.1 μT) and (b) the flip angle of the MT pulse was adjusted to achieve the SAR value required in measurement with a 100% MT-fraction using a flip angle of the MT pulse of 500°. The SAR values were monitored using the SAR control unit from the manufacturer. In all measurements the duration of the MT pulse was 9472 μs (bandwidth 203 Hz) and the off-resonance frequency was 1500 Hz. The following sequence parameters were kept constant in all studies: TR = 25 ms, TE = 5 ms, flip angle = 15°, FoV = 154×154 mm^2, matrix size = 384×384, slice thickness = 5 mm, acquisition bandwidth = 260 Hz/Pixel. The MTR-maps were calculated on a pixel-by-pixel basis according to the equation $MTR = (M_0 - M_{Sat})/M_0$, where M_0 and M_{Sat} denote signal amplitude measured without and with the MT saturation pulse, respectively.

Results

MTR values for cartilage, muscle and meniscus as a function of the MT pulse fraction in k-space are plotted in Fig. 1a,b for the step distribution and in Fig. 1c,d for the trapezoidal distribution. Fig. 1a shows that nearly maximal tissue suppression occurs for all fractional amounts of MT applied, down to about 25% of k-space. Below 25%, the tissue MT suppression decreases rapidly back to the situation of no MT. Fig 1b shows that MT suppression increases by higher MT pulse amplitude for all fractional amounts of MT applied, down to about 10-25% of k-space. Similar results were found for the trapezoidal scheme, depicted in Fig. 1c,d. The calculated MTR maps of the knee obtained with MT pulse fraction of 10%, 25%, 50%, and 100% using the step amplitude modulation function are shown in Fig. 2. No significant degradation of image quality was found for MT pulse fractions down to 25%. Careful inspection of images acquired with MT pulse fraction of 25%-75% shows only slight ringing artifacts in the cartilage tissue due to point spread effect.

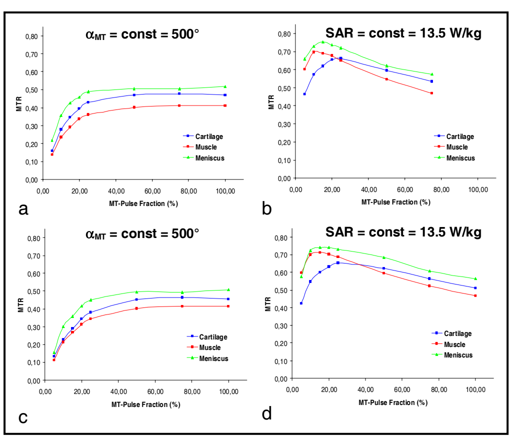
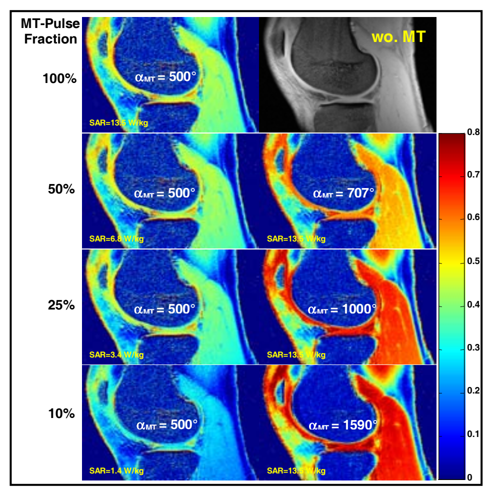


Fig. 1 (left). *MTR values for cartilage, muscle and meniscus as a function of the MT pulse fraction in k-space, using a step (a,b) and a trapezoidal (c,d) amplitude modulation function. The values were calculated for measurements with constant MT pulse amplitude of 500° (a,c) and with constant SAR of 13.5 W/kg (b,d).*

Fig. 2 (right). *Calculated MTR maps of the knee of a healthy volunteer obtained with MT fraction of 10%, 25%, 50%, and 100% using the step amplitude modulation function. The maps were calculated for measurements with constant MT pulse amplitude of 500° (peak amplitude 7.1 μT) and with constant SAR of 13.5 W/kg. The parameters of the applied sequence were: TR/TE = 25/5 ms, FA = 15°, FoV = 154×154 mm^2, matrix size = 384×384, SL = 5 mm, BW = 260 Hz/Pixel, NA = 6.*



Discussion

In the presented study, it was confirmed that the application of the MT pulses during a 25% fraction of k-space can achieve nearly the same MTC effect with significantly reduced SAR (approx. 75%) compared to MT pulsing throughout the entire imaging sequence. Keeping SAR constant, an increase of MT suppression at higher amplitude of the MT pulse was observed. The comparison of the step and the trapezoidal MT pulse amplitude modulation functions suggest that the MTC effect is not very sensitive to the shape function of the transition region (4). The results demonstrate that MTC applications for high resolution imaging of the knee at field strengths higher than 1.5 T are possible.

Literature

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