Systematic comparison of Magnetization Transfer Contrast in human subjects at 3.0, 1.5, and 0.2 Tesla

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Purpose

Magnetization Transfer Contrast (MTC) is an additional contrast to standard MR imaging yielding information concerning the composition of tissues, which cannot be achieved by other methods relying solely on spin density and tissue relaxation behaviour (1). Within outlined body regions, the value of magnetization transfer imaging has been demonstrated for the assessment of white matter diseases (e.g. multiple sclerosis [2]), breast assessment [3], diseases of the cartilage [4] and the musculoskeletal apparatus [5], tissue ischemia [6], and the improvement of tumor delineation [7] and grading [8]. The saturation of the macromolecular and the free water spins is dependent on many imaging parameters, e.g. the off-resonance frequency, bandwidth and amplitude of the MT pulse, and the imaging sequence itself. The goal of this study is to evaluate MTC effects for a wide range of tissues (white and grey matter, liver, kidney, spleen, muscle, and articular cartilage) in human subjects at field strengths of 0.2, 1.5, and 3.0 Tesla. Magnetization transfer ratios (MTR) were calculated using a set of varying MTC pulse parameters.

Material and Methods

In-vivo measurements in three healthy volunteers were performed in 0.2 T, 1.5 T, and 3.0 T MR scanners (Siemens Medical Solutions, Erlangen, Germany). MTC MR imaging studies of the head, knee, and abdomen were performed using a multiple magnetization transfer contrast (mMTC) sequence. The mMTC sequence is a modification of a proton-density weighted spoiled gradient echo sequence using a 9472 µs (bandwidth 203 Hz) Gaussian shaped MT saturation pulse. The new module allows for a flexible design of the MT pulse, regarding the flip angle and the off-resonance frequency. Furthermore, multiple MTC imaging is possible: consecutive measurements could be performed with variable flip angle or variable off-resonance frequency, while keeping other MT pulse parameters constant. In mMTC studies with variable flip angle, 11 measurements were performed with flip angles between 0° and 1000° (peak amplitude B_1 = 14.2 µT) and an increment of 100°. Off-resonance frequency was kept constant to 1500 Hz in these measurements. In mMTC studies with variable off-resonance frequency, 11 measurements were performed with off-resonance frequencies between 750 Hz and 2250 Hz and an increment of 150 Hz. The flip angle was kept constant to 500° in these measurements. Relaxation pause after measurements was 10 s. The following sequence parameters were kept constant in all studies: TR = 100 ms, TE = 8 ms, flip angle = 25°. FoV / matrix size were 256×192 mm^2 / 192×144 in the head, 160×160 mm^2 / 192×192 in the knee, and 400×400 mm^2 / 192×192 in the abdomen, respectively. Slice thickness, number of averages, and acquisition bandwidth were adjusted to compensate the leakage in signal-to-noise ratio at lower field strengths. The MTR-maps were calculated on a pixel-by-pixel basis according to the equation $\mathbf{MTR = (M_0 - M_{Sat}) / M_0}$, where $\mathbf{M_0}$ and $\mathbf{M_{Sat}}$ denote signal amplitude measured without and with the MT saturation pulse, respectively.

Results

Fig. 1 shows the calculated MTR maps of the cortical brain region, of the knee, and of the abdomen of a healthy volunteer obtained at 3 T (top), 1.5 T (middle), and 0.2 T (bottom) with MT pulse flip angle of 1000° and off-resonance frequency of 1500 Hz. MTR values for white matter and articular cartilage as a function of the flip angle and off-resonance frequency of MT pulse are plotted in Fig. 2a, 2b. Fig. 2c shows MTR values for liver, spleen, and kidney as a function of the flip angle obtained at 1.5 T and 3.0 T. As expected, MTR increases at larger flip angle. Furthermore, these results indicate that MTR values are larger at higher magnetic field strengths, e.g. using MT pulse with flip angle of 1000° and off-resonance frequency of 1500 Hz, the MTR values for white and grey matter of 0.35 and 0.3 at 1.5 T increased by 21 % and 17 % at 3.0 T.

Discussion

In the presented study, the MTR values were calculated for a wide range of tissues at 0.2 T, 1.5 T, and 3.0 T using mMTC imaging sequence. Quantitative MTR maps could be calculated. MTR values were found to be increasing at higher magnetic field strength using a density weighted gradient echo sequence in combination with an MT prepulse. The increased ratio might partly compensate the SAR (specific absorption rate) related problems in MTC applications at higher field strengths.

Literature

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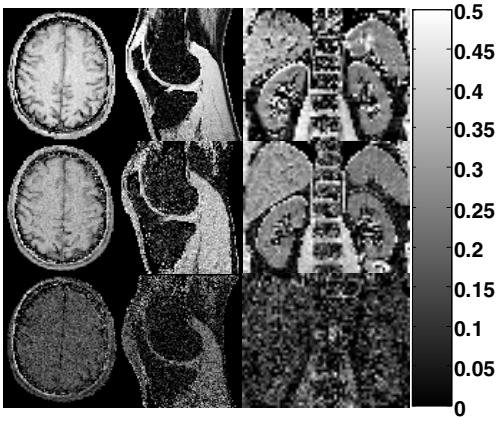

Fig. 1. Calculated MTR maps of the cortical brain region, of the knee, and of the abdomen of a healthy volunteer obtained at 3.0 T (top), 1.5 T (middle), and 0.2 T (bottom) using an MT pulse with a flip angle of 1000° (peak amplitude 14.2 µT) and an off-resonance

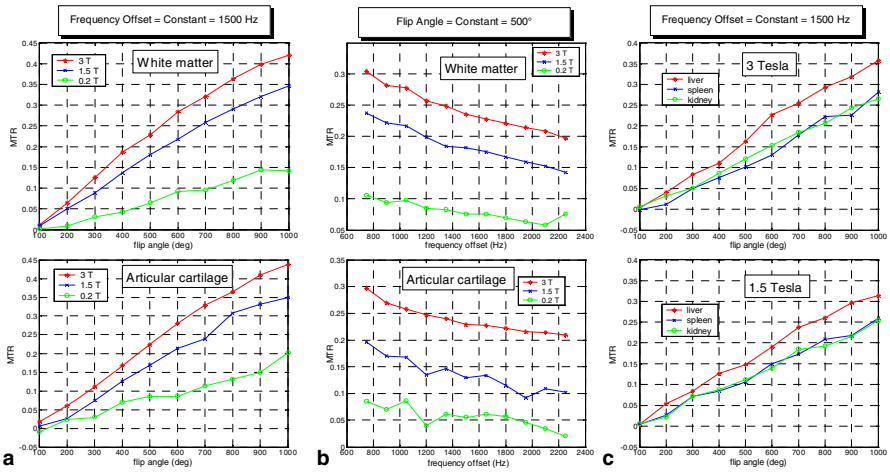

Fig. 2. MTR values for white matter and articular cartilage as a function of the flip angle **(a)** and off-resonance frequency **(b)** of MT saturation pulse obtained at 0.2 T, 1.5 T, and 3.0 T. **(c)** MTR values for liver, spleen, and kidney as a function of the flip angle obtained at 1.5 T and 3.0 T.