Magnetic field-dependent magnetisation transfer contrast MRI with fast field-cycling

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Introduction

Magnetisation transfer contrast (MTC) is a standard MR technique to characterise the immobile macromolecular protons using an off-resonance pre-saturation pulse (or MT pulse). MTC is normally implemented at a fixed magnetic field (B_0) but not at a range of B_0 because of the limitations of available MRI scanners. Only a few research groups have tried to investigate the field-dependent MT effect using two or three independent MRI scanners [1,2]. In order to conduct field-dependent MTC experiments with a single instrument, we needed techniques which enable both B_0 and the resonance frequency of the RF coil (f_0) to shift simultaneously during the pulse sequence. Fast field-cycling (FFC) is a novel technique that affords the ability (rapidly switching B_0 between levels) to study the MT effect over a range of B_0 [3-5]. Switching of f_0 can also be attained by means of a special multi-tunable RF coil [5]. In this work, we measured the MR ratios of test samples at five different B_0 values utilising FFC in order to evaluate the MT effects.

Methods

Experiments were carried out using a home-built field-cycling MRI scanner with detection at 58.7 mT (proton Larmor frequency of 2.5 MHz) [6]. An interleaved (with and without MT irradiation) FFC-MTC pulse sequence was implemented (Fig.1) showing that both B_0 and f_0 are concurrently shifted into the corresponding values during MT irradiation but returned to the original B_0 during MR data acquisition. This sequence enabled collecting ten images during a single scan. The 1st and 2nd images were acquired at the 1st B_0 with and without MT irradiation, and the 3rd and 4th images were obtained at the 2nd B_0 field strength, and so on. A multi-sample phantom which consisted of 1%, 2%, and 4% agarose samples was utilised and a sample only containing 0.04 mM $MnCl_2$ solution (without agarose) was used as a control. In order to evaluate the MT effect, regions of interest within the images were manually drawn and MT ratios of each sample were calculated using the equation of MT ratio or MTR = $(M_0 – M_s)/M_0$, where M_s and M_0 are the signal intensities of the free protons measured with and without applying the MT saturation pulse, respectively. MTR images were also acquired by pixel-by-pixel based image processing using MATLAB.

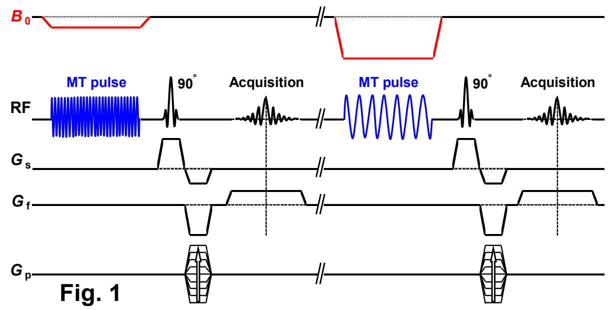

Fig. 1

Results

MT irradiation was employed at the uniformly-distributed five desired B_0 fields (49.3, 51.6, 54.0, 56.3, and 58.7 mT), with MR signal detection always at 58.7 mT. The MT pulse conditions were: 5 μT RF magnetic field strength (B_1), 1 kHz offset, and 3 s MT pulse duration, and the imaging parameters were: 6.2 s TR, 20 ms TE, 20 ms B_0-switching time, 85 ms delay after B_0-switching and before applying 90º pulse for MR data acquisition, 145 × 145 mm field of view, 64 × 64 pixel image matrix size, 30 mm slice thickness, NEX = 4. The parameters were identical at all pre-determined B_0 fields. Fig. 2 shows the phantom images without and with MT pulse irradiation and the MTR image (from left to right) at five different B_0 (49.3 to 58.7 mT, from top to bottom). Fig. 3 shows MTR values over a range of B_0 strengths. Since the bound pool did not exist in the control sample, the MT effect was almost zero, as expected, whilst the MT effects of the other samples increased with increasing concentration of agarose at each field. Furthermore, the results of this experiment presenting MTR values for the given MT pulse parameter were larger at the higher B_0, and more contrast between samples was also seen at the higher field.

Discussion

We have demonstrated field-dependent MTC experiments by evaluating the MT effects of 1%, 2% and 4% agarose gel samples at five different fields around 58.7 mT, showing that higher MT effects occurred at higher field.

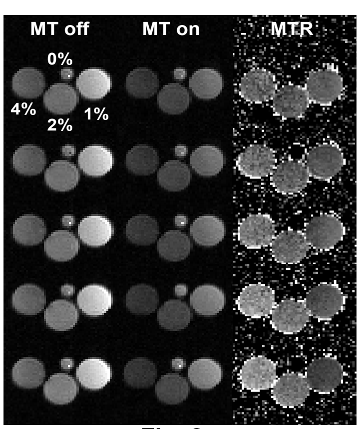

Fig. 2

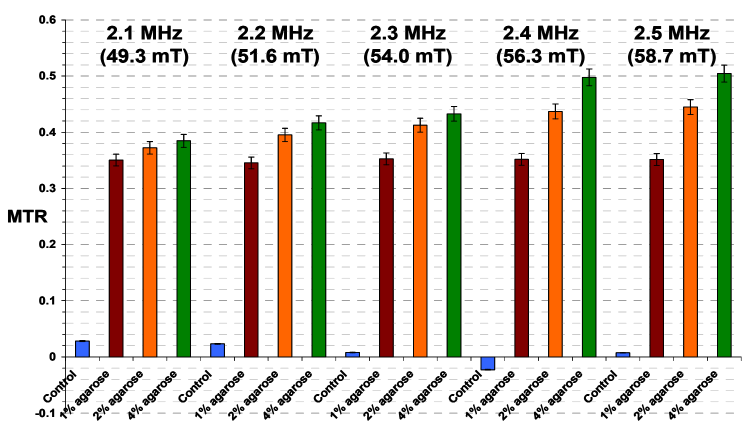

Fig. 3

References

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