Pulsed Magnetization Transfer SENSE Imaging in the Brain at 3T

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Introduction

Magnetization transfer (MT) imaging has been used as an early detector of white matter degeneration, e.g. in Multiple Sclerosis (1,2-4). Pulsed MT has been used in clinical experiments only using head-coil excitation at field strengths at or below 1.5T, operating close to maximum SAR (3.2 W/kg for the brain) To improve SNR, transition to higher field is beneficial, but because power deposition is proportional to B_o^2, this seems difficult. In addition, with new parallel imaging technology, one would like to perform MT imaging with the body coil, exacerbating the problem. Here, employing the fact that the lengthened T1 at high field prolongs the presence of MT saturation, we show that it is possible to acquire high resolution, rapid, whole brain, pulsed MT images at 3T with body-coil excitation. The initial data show several new image features, previously not appreciated at lower field.

Methods

Three healthy adults were scanned after written informed consent. Studies were performed on a 3T Philips Intera (Philips Medical Systems, Best, The Netherlands). Quadrature body coil was used for transmission, SENSE head coil for reception. MT-weighted images at offset frequency ω, S(ω), were acquired using a 3D-Spoiled Gradient Echo, TR / TE /α = 65 ms / 15 ms / 9°, with a 20 ms non-selective MT pre-pulse (peak amplitude = 10.5 μT) and multi-shot echo planar imaging. To maintain SAR within the FDA guidelines, fewer MT pulses were performed per slice. However, speed was achieved by acquiring high frequency k_y lines early when the saturation is incomplete. Simulation (4) using the Bloch equations shows that steady state is reached within in 1.5 seconds, still well before the center lines of k_y space were acquired. Visually, the best contrast in the MTR images was at ω = 1.5 kHz. Other parameters were: whole brain field of view = 204x204x90 mm (ap, rl, fh), acquired resolution = 1.4 x 1.4 x 1.5 mm, total scan time 1min 41s. SENSE factor 2 was used to minimize EPI-related susceptibility artifacts at the air-tissue interface and to reduce the total scan time. Total SAR = 3.0 W/kg. The MTR was calculated voxel by voxel: MTR = 1-S(ω)/S_o. A similar MT acquisition was performed at 1.5T (Intera NT, Philips Medical Systems) using conventional pulse sequence parameters and the SNR was compared to the 3T. Simulation of the coupled Bloch equations including exchange was performed to calculate the effect of T1 on the MT build-up and maintenance of steady-state given the increased TR at 3T compared to 1.5T.

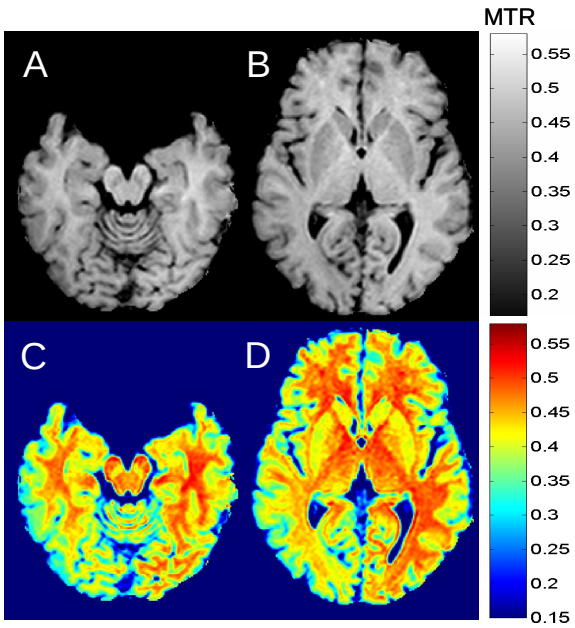

Figure 1: 3T MTR images at 1.5 kHz off resonance at the inferior colliculi (A, C) and lateral ventricles (B, D). Arrows: gray matter not conventionally seen in MTR imaging: substantia nigra (C) and globus pallidus (D).

SNR	Gray	White
1.5	8.7	17.3
3.0	23.0	37.1

Table 1: SNR at each field strength for internal gray and frontal white matter

Results and Discussion

The results indicate the possibility of performing high-quality MT imaging at 3T using body coil excitation and SENSE detection. Figure 1 shows example MTR images at the level of the inferior colliculi (A,C) and lateral ventricles (B,D). Visual discrimination between grey and white matter is seen in all slices. Note that the underlying mechanism of MTR causes the highly myelinated white matter to be bright, grey matter darker, and CSF, darkest. Typical MTR values found in each type of tissue are: CSF (0.01 ± 0.02), putamen (0.40 ± 0.01) and frontal white matter (0.48 ± 0.01). Several anatomical features can be appreciated in the color images, figure 1 C,D. Figure 1C: discrimination between the substantia nigra and the cerebral peduncles (arrow). Figure 1D: distinction between the putamen and globus pallidus (arrow) can be seen. An advantage of MT imaging at 3T is the increased SNR, which is compared to 1.5T MTR images in Table 1. The possibility of performing MTR imaging at 3T was facilitated strongly by the elongation of T1. To maintain the SAR at regulated levels, it was necessary to also lengthen the TR, but as shown in figure 2, the lengthened T1 allows the saturation to remain for a longer period of time. The red line indicates the MTR build-up over successive TR's given the standard tissue parameters found for 3T (T1 WM = 700 ms; T2 = 70 ms). Similarly, the blue curve shows the MTR build-up for tissue parameters indicative of 1.5 T (T1 = 550 ms, T2 = 80ms) but using the sequence described above at 3T. It can be seen that due to the increase in T1, the MTR effect is greater at 3T than would have been expected for T1 values observed at 1.5T. The black curve represents the expected MTR build-up at 1.5T if we used the same MT pulse as was used at 3T (duration and amplitude) but with shorter TR. The green curve is the expected MTR result at 1.5T if we allow the SAR value of 3.0 W/kg at 1.5T. While the MT effect is greater at 1.5T (due to shorter TR and larger amplitude MT pulse), the SNR is compromised. The relationship between T1 and the MT effect has often been taken for granted, but these results indicate a necessary condition for whole brain pulsed MT to be adequately performed at 3T is that the T1 is long enough to account for the increase in TR.

Conclusion

Elongation of T1 at higher fields allowed pulsed MT to be performed while maintaining acceptable SAR and fast acquisition. Due to higher SNR,he MTR images showed a high degree of distinction between dense and less dense white matter with concomitant discrimination of grey matter. This technique should be very useful in quantifying varying degrees of pathology in diseases such as multiple sclerosis.

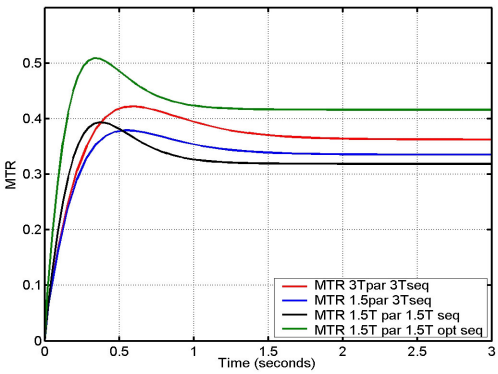

Figure 2: MTR build-up curves for 3T (red) and 1.5T (green, blue, black) tissue parameters: SAR=3.0 at 1.5T (green), SAR = 3.0 at 3T (red), 3T pulse sequence with 1.5T tissue parameters (blue) and 3T pulse sequence applied at 1.5T with longer TR using 1.5 T tissue parameters (black).

References

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