RF Power Dependence of Human Brain CEST, NOE and Metabolite MT Effects at 7T

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Introduction:

Magnetization transfer (MT) is a well-known MRI technique that can indirectly detect macromolecules and other solutes in the tissue. Early MT studies at low magnetic fields generally involve two pools: bulk water and solid-like macromolecular protons. Both pools have symmetry absorption lineshapes. MT effects at ultrahigh fields have yet not been well investigated, but a few recent studies show significant asymmetry effects around the water resonance (1,2). The main sources of this asymmetry may be attributed to amide protons transfer (APT) at 3.5 ppm, and nuclear Overhauser enhancement (NOE) and various metabolite MT effects at upfield (3), all of which seemingly become more apparent at 7T than 3T. In this work we investigate the RF saturation power dependence on the asymmetry of these MT signals at 7T. We also evaluate the two-pool MT model through data fitting.

Method:

An MT-TFL (Turbo-Flash) pulse sequence was implemented on a 7T Siemens MRI scanner using a home-made 8-channel phased-array transmit/receive head coil (5). A train of eight Hanning-windowed RF saturation pulses is used to saturate the protons associated with solutes or macromolecules. Each pulse lasted 99 ms and had an mean amplitude of B1sat shown in Fig. 1. The interval between them was set to 1 ms. A TFL readout was applied to acquire a single slice of 8 mm, TR/ TE=1,000/2.73 ms, BW of 130 Hz for a resolution of 1.7×1.7×8 mm^3. 36 frequency offsets varied between -6 ppm and 6 ppm were acquired. The normalized signal intensity as a function of RF frequency offset was plotted as a z-spectrum. In this work the saturation RF pulse had a total length of 800 ms, which may not be long enough for the system to reach a steady state. So the fitting was done by solving the modified Bloch equations with exchange terms (4). The residues were calculated to evaluate the two-pool model and the APT, NOE and metabolite MT effects.

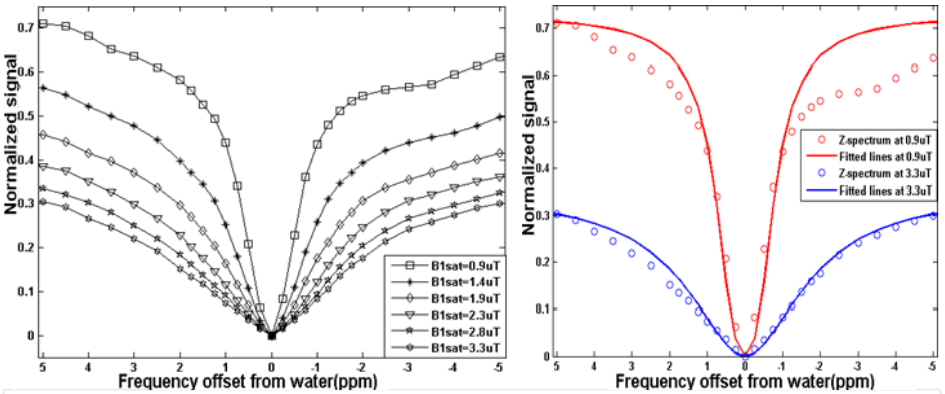

Figure 1: (a) Z-spectrum of MT data at varying saturation B_1 from 0.9 μT to 3.3 μT and (b) z-spectrum and fitted lines at 0.9 μT and 3.3 μT.

Results and discussion:

Figure 1 shows the z-spectrum at six different B_{1sat} levels (a) and the fitting result of min (0.9 μT) and max B1 (3.3 μT) (b). The possible NOE and/or metabolite MT signals appear at upfield (-5 – 0 ppm) of z-spectrum, which are large at low B_{1sat}. Figure 2 shows the fitting residues at +3.5 ppm (namely, APT) and -3.5 ppm (NOE and/or metabolite MT) as a function of B_{1sat}. At low B_1, the NOE and metabolite MT effects are the dominant source of MT asymmetry. However, at higher B_1, the APT effect becomes stronger and finally reverses the asymmetry plot. This phenomenon suggests that compared to NOE and metabolite MT, APT requires a higher B_1 for adequate transfer efficiency. Fig. 3 shows asymmetry maps calculated by subtracting the saturation image of -3.5 ppm from +3.5 ppm at B_{1sat} of 0.9 μT (a), and by subtracting the image of +3.5 ppm from -3.5 ppm at B_{1sat} of 2.8 μT (b) (ventricles masked). At low B_{1sat} where the NOE and metabolite MT effects dominate, the asymmetry of MT is much more apparent in white matter than grey matter ($p<0.0001$). This suggests that the NOE and metabolite MT effects at the offset of -3.5ppm may be mainly caused by the lipid signal which resonates at about-3.5ppm from the water signal and is much more abundant in WM than in GM. The APT map (Fig. 3b) is more homogeneous across brain pixels. We also tried four-pool model fitting(bulk water, macromolecule, NOE and metabolite MT, and APT). The data show that the four-pool model performed well at all B_{1sat} levels.This suggests that at least four pools are needed to accurately model the MT effect at 7T.

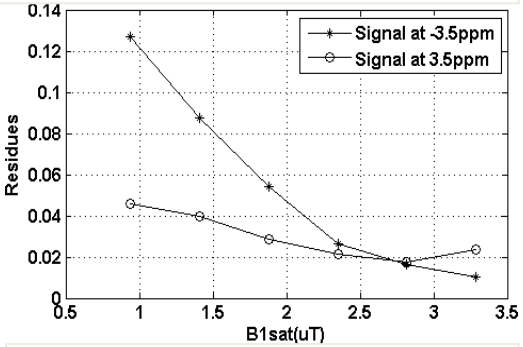

Figure 2: Fitting residues at +3.5ppm (APT effect) and -3.5ppm (NOE/metabolite MT) as a function of B_{1sat}.

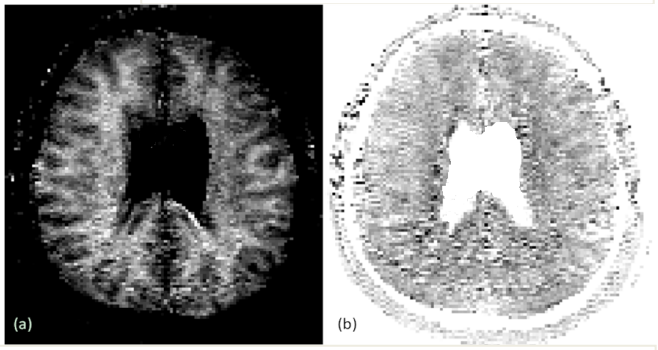

Figure 3: MT asymmetry maps. (a) Subtracting the saturation images at -3.5ppm from +3.5ppm at B_{1sat} of 0.9 μT.(b) Subtracting the images at +3.5ppm from -3.5ppm at B_{1sat} of 2.8 μT.

Our results suggest that at 7T, MT asymmetry at high B_{1sat} may be considered for CEST imaging and MT asymmetry at low B_{1sat} may provide an approach for in vivo imaging of brain lipid (e.g., myelin). The possible mechanism of these NOE and metabolite MT signals needs to be explored further.

References:

(1) Ling et al. PNAS 105(2008)2266. (2) Jones et al. ISMRM 2011. (3) Graaf et al. MRM 41(1999)1136. (4)Woessner et al. MRM 53(2005)790. (5) Zuo et al. CSR-ISMRM branch meeting Beijing 2011.This work was sponsored by CAS Knowledge Innovation Important Direction Grant KSCX2-YW-R-259.