New Technique for Metabolite Cycled Non-Water-Suppressed Proton Spectroscopy in the Human Brain at 7T

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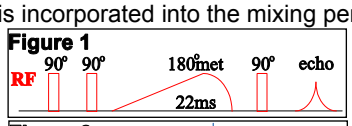
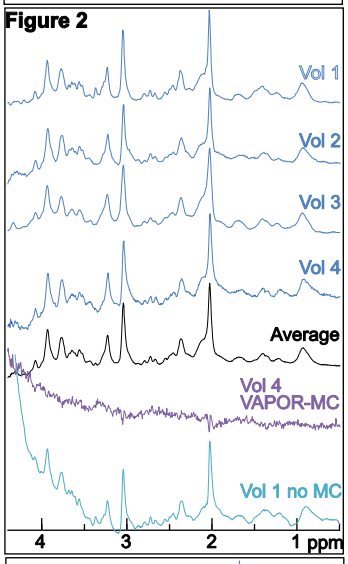
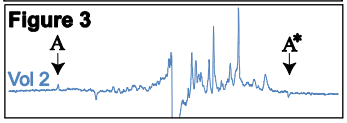
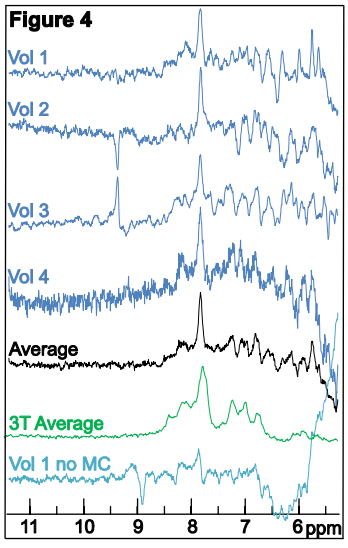
Introduction

Non-water-suppressed magnetic resonance spectroscopy (MRS) can improve the signal to noise ratio (SNR), as well as the robustness of MRS in the presence of B_0 fluctuations or subject motion, by enabling optimal coil channel summation, as well as automatic phase, frequency, and eddy-current correction of individually acquired FIDs prior to averaging. However, the presence of the large water peak in the spectrum may cause baseline distortions, digitization noise, and/or gradient sideband artifacts. A recent study[1] at 3T demonstrated the effectiveness of the metabolite cycling (MC) technique[2,3] to achieve non-water-suppressed MRS with sufficient cancellation of sideband artifacts, as well as clear detection of exchangeable peaks in the region downfield of water otherwise unseen in conventional water-suppressed spectra. Yet, assignment of the downfield peaks is hampered by exchange broadening and overlapping peaks. **Thus, the goals of this study were to:** 1) apply the MC technique at 7T to improve the peak identification profiting from both greater spectral resolution, and increased absolute frequency distance between water and exchangeable resonances; and 2) minimize the time available for exchange, **by introducing a new implementation of metabolite cycling**, in which the metabolite inversion pulse is incorporated into the mixing period of STEAM, as shown in Figure 1.









Methods

Fifteen healthy volunteers ("Vol") were scanned on a Philips 7T whole body MRI system with a half-volume quadrature surface coil (max B_1=44μT; RAPID Biomedical). A midline occipital gray matter voxel (12mL for Vol 1 to 3; 8mL for Vol 4) was prescribed, the flip angle was optimized over this volume[4], and FASTESTMAP 2nd order shimming was performed. Spectra were acquired with the MC technique, which was altered from previous implementations[1,2,3] to include the metabolite inversion pulse in the mixing period of STEAM (TE/TM/TR = 11/36/4000 ms; frequency modulated RF pulses to minimize chemical shift displacement; metabolite inversion pulse duration 22ms, which was optimized for sufficient bandwidth; see Fig 1). Incorporating the metabolite inversion pulse into TM both reduces the effective time between separation of water and metabolite magnetizations and the measured echo, as well as capitalizes on the slight increase in T_1 relaxation times observed with higher fields since signal decay during the mixing period is – neglecting exchange – solely due to T_1 relaxation[3]. Individual FIDs were stored for DC offset, phase, frequency, and eddy-current corrections with the water peak obtained from the sum of all traces. Subsequent subtraction of alternating FIDs yielded the metabolite spectrum.

Results

Fig. 2 shows metabolite cycled upfield spectra from 4 volunteers with 512 FIDs each, demonstrating that the sideband artifacts and water baseline are reduced to below the level of most upfield features in comparison to the non-MC spectra shown in the bottom trace. The purple trace labeled "VAPOR-MC" shows the difference between a VAPOR water suppressed scan with 64 FIDs and the MC spectrum of Vol 4, where it is evident that in this implementation MC offers the same information as the water suppressed spectra. However, some artifacts remain, such as antisymmetric sidebands that are not fully canceled out, an example of which is shown in Fig 3 at ~9.3 and ~0 ppm. Fig. 4 shows the downfield region, with a comparison to the MC spectrum acquired with PRESS (TE 20ms) at 3T[1] averaged over 11 volunteers. It is clear that the NAA peak at 7.9 ppm is better resolved at 7T, and the 7T MC spectra hint at more peaks in this region, however, the between-volunteer variability of the remainder of the downfield region (possibly due to not fully canceled sidebands or instabilities of the receive chain electronics) makes peak identification difficult at this stage.

Conclusions

These results demonstrate that non-water-suppressed MRS via metabolite cycling at 7T yields upfield spectra with the same information content as water-suppressed spectroscopy. Moreover, performing metabolite cycling at 7T profits from increased spectral resolution, which aids in the identification of downfield peaks, as demonstrated by the sharper downfield NAA peak at 7T versus 3T. Though continued effort is needed to further reduce small artifacts, there is strong motivation to take advantage of the benefits MRS with metabolite cycling in the mixing period of STEAM, such as the ability to perform corrections on individual FIDs to increase SNR, and to investigate fast exchanging protons. In addition, chemical shift imaging with metabolite cycling would provide an inherent water reference in each spectrum for a quantitation standard, eddy-current correction reference, and guide to optimize signal combination in multi-channel coils, when acquiring an additional non-water suppressed scan would be prohibitively long.

References

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