Non-water suppressed proton MR spectroscopy allows spectral quality improvement in the human cervical spinal cord

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Introduction: Magnetic resonance spectroscopy (MRS) is a valuable tool for non-invasive investigation of biochemical processes, as well as for differential diagnostics of various CNS pathologies such as cancer or multiple sclerosis, and would be even more benefiting in the spinal cord where performing a biopsy is perilous. However, spinal cord MRS has rarely been applied in clinical work due to technical challenges[1,2], including strong susceptibility changes in the region, as well as the pulsatile motion of the cord, and its finite diameter, all of which limit the attainable signal to noise ratio (SNR) and distort the lineshape. Hence, extensive signal averaging with long measurement times is required, which increase the likelihood of B_0 changes caused by patient motion, cord motion, and scanner drift, inducing frequency shifts between free induction decays (FIDs). To avoid incoherent signal averaging, it would be ideal to perform frequency alignment and phase correction before averaging. Unfortunately, frequency alignment of individual FIDs is not possible due to the low SNR of the metabolite peaks. Including the high SNR water peak in the FID would be ideal for frequency alignment, as well as for eddy-current correction, and would negate the need for extra water reference scans, but gradient sideband artifacts and the water tail baseline may distort the non-water-suppressed spectrum. To avoid these artifacts, previous studies have shown that applying an asymmetric adiabatic inversion pulse to alternately invert either the up- or down-field metabolites is effective to separate metabolite peaks from the water peak and sideband artifacts[3,4,5]. **Therefore, in this work**, ^{1}H non-water-suppressed MRS with the metabolite cycling (MC) technique was introduced in the spinal cord. It is expected that by using the high SNR water peak for frequency alignment, an improvement of the spectral quality of the metabolite peaks can be achieved.

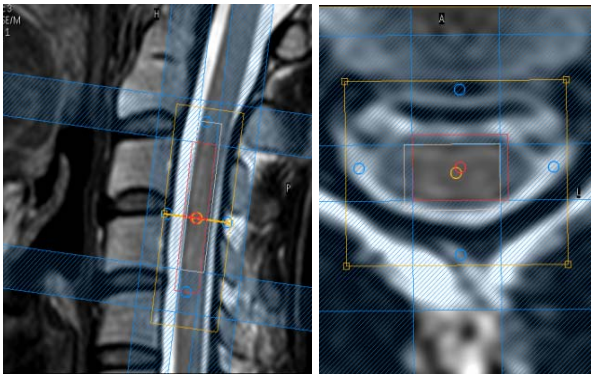
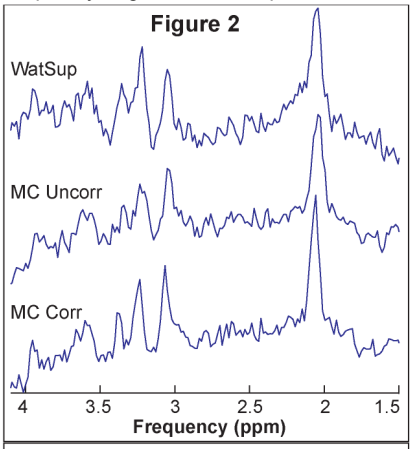
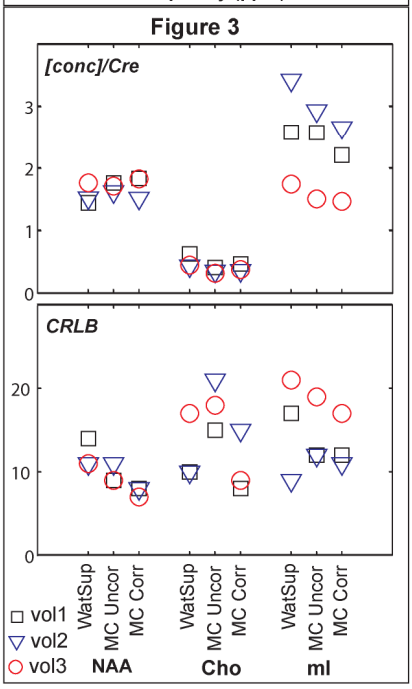


Figure 1. *Sagittal and axial image of the cervical spinal cord. Due to the chemical shift artifact the position of the NAA (red) and ml (white) voxel is shifted. Applying IVS bands (blue) minimizes this artifact. In addition, the shim box is displayed in orange.*





Methods: After the approval from the local ethics committee, 3 healthy adult volunteers were enrolled in the pilot study. MR experiments were performed on a 3T scanner (Achieva, Philips Healthcare, Best, The Netherlands) using the integrated body-coil (maximum B_1=13.5μT) for transmission and a Philips SENSE Neurovascular coil for reception (ring of 4 coils). ECG-triggered PRESS localization (voxel size: 6*9*35mm^3 shown in Figure 1, TR≥2500ms, TE=30ms, readout for 512ms, spectral bandwidth=2000Hz, 4*128 FIDs) was used for data acquisition, preceded by either the up- or down-field MC inversion pulse of duration 25ms. Inner volume saturation (IVS) was used to minimize the chemical shift displacement between metabolites (Fig. 1). With the finite size of the spinal cord, even small patient movements during the measurement lead to grossly incorrect measurement positions, thus, the voxel position was checked by acquiring axial T_2-weighted images after each block of 128 FIDs. If patient motion was identified, the voxel position was updated for the next block of 128 FIDs and the measurement was repeated. 2nd order FASTERMAP shim (ECG triggered[6]), power optimization, and center frequency were determined prior to each block. Four blocks of metabolite cycled and four blocks of VAPOR water-suppressed spectra were acquired interleaved for comparison. Individual FIDs were stored, for phase, frequency, and eddy-current correction prior to summation to yield the water spectrum, or subtraction of alternating FIDs to yield the metabolite spectrum. Each block of water-suppressed averaged spectra was eddy current, phase and frequency corrected prior to averaging. MRS data were quantified using LCModel[7] and a set of basis spectra simulated including 20 metabolites using GAMMA[8].

Results and Discussion: Fig. 2 shows the improvement in linewidth and SNR between the water-suppressed spectrum (WatSup) and metabolite cycled spectrum without (MC Uncorr) and with frequency alignment (MC Corr) in one volunteer (spectra zero-order phased and Gaussian filtered by 3Hz). By comparing the corrected and uncorrected MC spectra, a reduction of the linewidth (FWHM) can be observed in all volunteers from (mean ± SD) 9.0 ± 1.1Hz to 7.5 ± 1.5Hz, concurrent with in an increase of the SNR by ~12% from 5.7 ± 0.6 to 6.3 ± 0.6. VAPOR WatSup spectra achieved a FWHM of 7.8 ± 1.9Hz, and a SNR of 4.7 ± 0.6. Relative concentrations to creatine ([conc]/Cre) and Cramér–Rao lower bounds (CRLB) of the three major metabolites (NAA, choline (Cho), myo-inositol (mI)), are shown in Fig. 3. The prominent singlets of NAA and Cho exhibit consistent concentration ratios between the three methods, and lower CRLB in the MC case, whereas the lower SNR in the coupled spin system of mI exhibits a wider range of concentrations and CRLB.

Conclusion: Non-water-suppressed MRS via the MC technique offers the opportunity to perform frequency alignment of each FID even with the very low SNR available in the spinal cord. The results from 3 volunteers demonstrate that this technique improves spectral quality by increasing SNR and reducing the FWHM of the metabolite peaks, as compared to VAPOR. Future work will explore the reproducibility of this technique in a study with more volunteers.

References:
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