CORRECTING FOR CENTER FREQUENCY VARIATIONS IN MRSI DATA USING THE PARTIALLY SUPPRESSED WATER SIGNAL

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Introduction: Several authors have reported using interleaved acquisition of navigators to dynamically estimate the center frequency throughout a spectroscopic acquisition and correct raw data to minimize spatial and spectral artifacts that would otherwise occur [1,2]. In these methods, a short acquisition without water suppression was used to acquire data for the center frequency estimation. In preliminary work reported here, we explored using a self-navigated approach with phase-encode reordering, in which raw phase-encoded data from a MR spectroscopic imaging (MRSI) acquisition with partial water suppression was used to estimate the center frequency variations, thereby allowing data correction without the need for special navigators.

Methods: We detected significant (random) center frequency variations with time on one of our 1.5T GE MRI scanners. These variations, if uncorrected, produced significant phase-encoding artifacts in reconstructed MRSI data. In post-processing, we estimated the center frequency shift from the linear phase ramp of the raw FIDs in the phase-encoded data itself. In principle this should be possible because the effect of a center frequency shift is to add a phase ramp to the FID regardless of phase encoding. MRSI datasets with 16x16 or 24x24 phase encoding steps were acquired from an MRS phantom using PRESS localization (TE/TR = 30/1000 msec.) with solvent suppression up to 99%. Each FID was processed to determine if a linear phase ramp could be detected over 100 ms at the beginning of the FID. The slope of the ramp was used to estimate the time-varying center frequency shift.

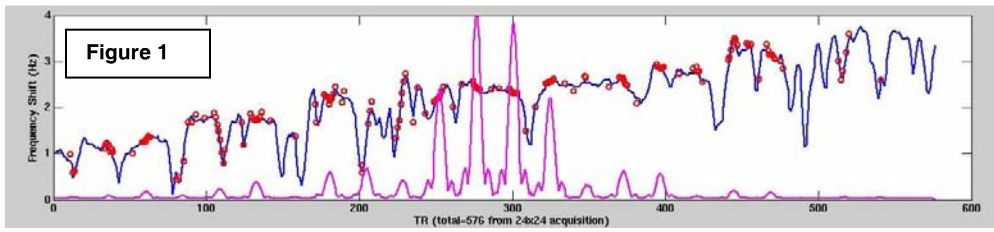
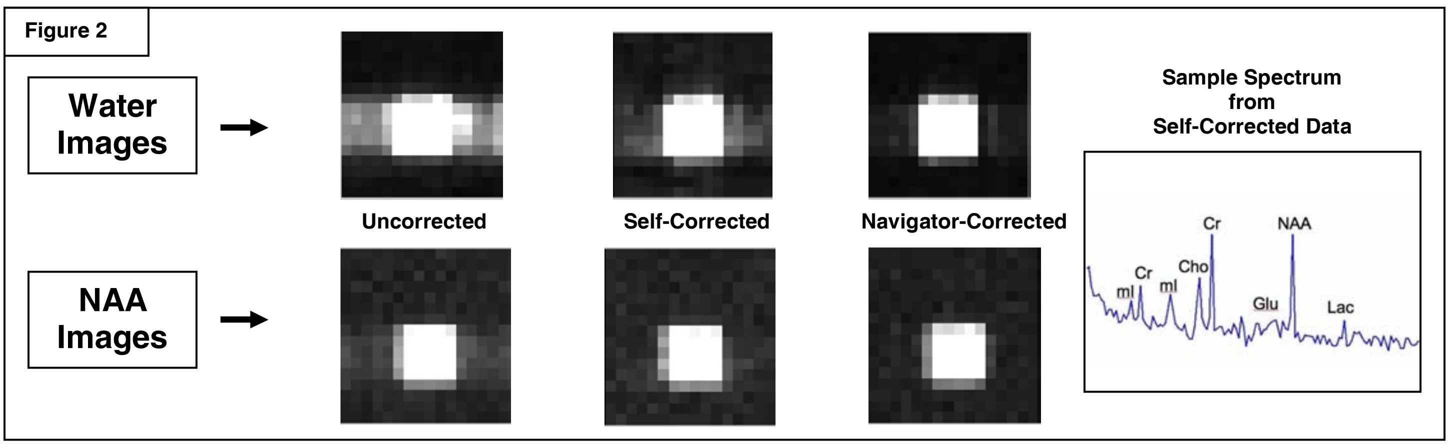


Figure 1 shows a comparison of the center frequency shift for each TR estimated from the linear phase of interleaved FID navigators acquired without phase encoding (in blue) compared with the frequency shift estimated from the phase-encoded FIDs for acquisitions where the difference between the two estimates was small (in red). Also shown is a representation of the maximum signal level of each k-space acquisition (in magenta). Note that the frequency shift parameters estimated from the phase-encoded FIDs agree with those from the navigators for acquisitions with high signal levels, i.e. those nearer the center of k-space. This motivated us to reorder the phase-encoded acquisitions so that the most robust shift parameter estimates were best placed to interpolate the frequency shift over the full time of a MRSI acquisition. The frequency shift parameters were then used to apply a first-order phase correction to the consecutively acquired MRSI FIDs before reconstruction.



Results: Figure 2 shows 16x16 images reconstructed from an MRSI acquisition using the GE MRS phantom. The horizontal is the longtime phase encoding direction (16 TRs between each phase encoding step). The images are of a 5x5x1 cm PRESS voxel in a 16 cm FOV. Images were obtained by integrating the magnitude spectra under the water peak (top set) and the NAA peak (bottom set). All water images were windowed identically to exaggerate artifact, as were the NAA images. The images on the left were obtained by directly reconstructing the MRSI data without any correction. Note that there is significant artifact in the longtime phase encoding direction due to the significant variation of the center frequency between phase encoding steps. The self-navigated correction substantially reduces the artifact (center images). There is still phase encoding artifact evident in the water images but it is below the noise floor in the NAA image. For comparison, on the right we show the result when the shift parameter is calculated using interleaved navigator FIDs (doubling acquisition time). The sample spectrum on the far right comes from a voxel near the center of the PRESS voxel.

Discussion and Conclusions: We have demonstrated that it is possible to significantly reduce spatial artifacts encountered in MRSI data that result from variations in the center frequency that occur during data acquisition. These variations may be due to instrumentation, environmental, or physiological factors. In this work, the raw data itself was used to determine parameters used in the correction. This self-navigated correction approach is feasible when there is strong enough signal from water present in the raw data, either because residual water is intentionally left to provide a reference [3] or because the data is acquired without solvent suppression [4].

References:
[1] Thiel et al. Magn Reson Med. (2002)47:1077. [2] Ebel and Maudsley. Magn Reson Med. (2005)53:465. [3] Schricker et al. Magn Reson Med. (2001)46:1079 [4] Clayton et al, Concepts Magn Reson (2001)13:260.

Acknowledgements: This work was supported by NIH U41-RR019703 ,NIH R21-CA11092, and NIH 5R25-CA089017.