Metabolite Cycled Non-Water-Suppressed Spectroscopy Offers Increased Spectral Quality In Cases of Physiologic and Subject Motion

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Introduction

Efforts to improve magnetic resonance spectroscopy (MRS) measurements in the presence of motion have focused on three general approaches, separately or combined, namely: A) gating, i.e. synchronization of signal acquisition to physiologic motion (respiratory or cardiac), B) motion tracking, via either an optical motion sensor[1] or navigator images[2]; and C) phase and frequency correction, via the "under-suppressed" water[2] or an interleaved water spectrum[1]. The latter category endeavors to increase the signal to noise ratio (SNR) of the acquired spectra through post-processing to improve phase correction, frequency alignment, and characterization of the lineshape. However, the "under-suppressed" water signal inherently offers a lower SNR reference than the full water signal, and additional non-water suppressed spectra are still needed for lineshape correction. With interleaved water scans, motion can occur between the water-suppressed and unsuppressed acquisitions. Hence, we propose that the metabolite cycling method[3,4] of non-water suppressed MRS sufficiently addresses these drawbacks by offering the full SNR water signal in the same acquisition, and would ideally compliment any motion tracking scheme to improve spectral quality in cases of subject motion or in organs affected by physiologic motion.

Figure 1 (Liver)

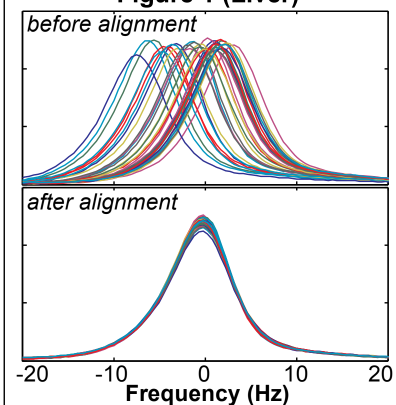


Figure 2 (Brain)

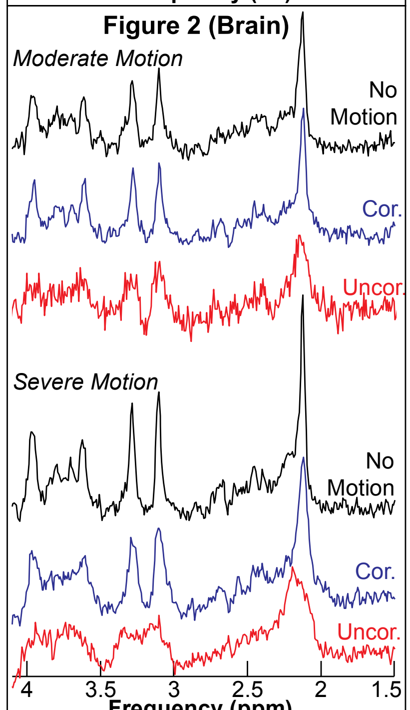
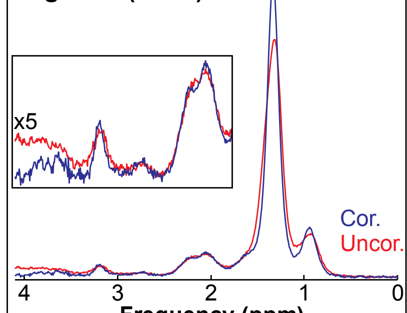


Figure 3 (Liver)



Methods

Two healthy volunteers were examined to study correction of brain motion and 17 subjects (5 lean, 12 obese), underwent MRS of the liver. Informed consent was obtained prior to scanning on a Siemens TRIO 3T MRI system. For brain MRS, a 4 cm^3 voxel in the frontal white matter was prescribed. Spectra were obtained without deliberate motion, as well as after the volunteer had been instructed to continuously and randomly rotate their head to the left or right by either >4 cm ("severe motion"), or ~1.5 cm ("moderate motion"). To determine lipid content in the liver, a 19 cm^3 volume was localized, and volunteers were instructed to breathe in the rhythm of the scanner (TR 5 s) so as to be in a short breathing pause in expiration during data acquisition. All spectra were acquired using a PRESS sequence (TE 20ms) preceded by an RF pulse to invert the up- or down-field metabolites in alternating acquisitions[5]. Individual spectra were stored, and each acquisition was frequency and phase corrected prior to Fourier transformation. Pure metabolite and water spectra were obtained from either summation or subtraction. To improve spectral quality further, FIDs in which the water peak frequency before alignment was more than 10 Hz from the mean were rejected, as they represent cases of extreme motion with grossly altered ROI composition. Finally, brain spectra were eddy current corrected using the first FID, while the liver spectra were eddy current corrected using the averaged pure water spectrum.

Results and Discussion

Spectra from the liver show significant fluctuations of the water peak frequency in spite of cooperative efforts of all subjects to time data acquisition within expiration (particularly for obese subjects), motivating the need for alignment of FIDs prior to averaging to correct these frequency offsets, as shown in Fig. 1 (one subject, water peak, all 32 spectra included). Examples of both moderate and severe deliberate head motion from two healthy volunteers is shown in Fig. 2 to demonstrate the increase in SNR and decrease in linewidth of metabolite peaks following frequency alignment (spectra acquired during motion are labeled "Uncor." for prior to correction, and "Cor." for following correction). For liver, the median water peak full width at half maximum over all 17 subjects prior to alignment was 18 Hz (range: 13 - 36 Hz), and after alignment was 15 Hz (13 - 22), highlighting how the frequency and eddy current corrections available with the metabolite cycling technique perform particularly well with decreasing quality of the originally measured spectra. Finally, an example of the linewidth improvements achievable with liver spectra is shown in Fig. 3, documenting crucial refinement of lipid and metabolite resonances.

Conclusions

These results demonstrate that the metabolite cycling technique greatly decreases linewidth and improves SNR of the final spectra in cases of organ or subject motion. The ability to robustly align shifted frequencies, reject severely mispositioned FIDs, and perform eddy current correction with the metabolite-removed water spectrum increases spectral quality, which – particularly in conjunction with a motion tracking scheme to prevent changes in voxel composition – will help make MRS more applicable in clinical practice.

References

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Supported by the Swiss National Science Foundation (#320030-120324 and 310000-118219)