Lipid Artifact Suppression for Detection of Cortical Metabolites in High-Resolution CTPRESS

Trina Kok[1], Berkin Bilgic[1], Borjan Gagoski[1], and Elfar Adalsteinsson[1,2]

[1]*Massachusetts Institute of Technology, Cambridge, MA, United States,* [2]*Harvard-MIT Division of Health Sciences and Technology, Cambridge, MA, United States*

Introduction: Changes in cortical metabolites e.g. Glu and Gln are complicated by the spatial proximity of the cortex to the subcutaneous lipid layer. Methods such as outer-volume suppression (OVS) [1] and inversion-recovery [2] effectively suppresses lipid signals but trade off outer cortical brain metabolite signals. Our work combines a recent lipid suppression technique [3] that exploits the approximate orthogonality between lipid and metabolite spectra, with a high-spatial-resolution CTPRESS acquisition in a spiral encoding. Here we demonstrate the successful recovery of cortical metabolites in a high resolution 0.51cc in vivo CTPRESS experiment with total scan-time of 20:32min (N_{avg} = 3).

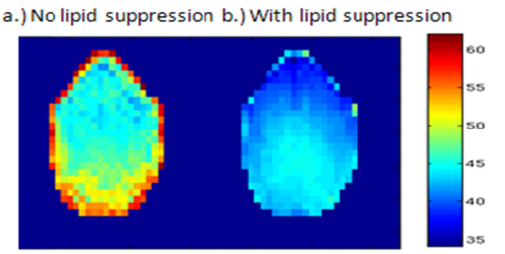

Fig 1a and b. Lipid maps in dB scale before and after the lipid suppression technique is applied

Methods: A healthy human subject was scanned on a 3.0 T MRI scanner (Siemens AG, Erlangen, Germany) using a 32-element receive coil, with a 17-step CTPRESS experiment for a voxel size of 0.71cm x 0.71cm x 1cm = 0.51cc in an FOV of 20 cm x 20 cm. The last 180° pulse of the PRESS-box was shifted in increments of 6.4ms to give a spectral bandwidth of 78.125Hz in f_1. Bandwidth in the f_2 dimension was 1.2 kHz. We chose average TE = 151ms for optimal SNR of Glu. The minimum scan time for this acquisition was 6:56min, but three averages were taken to improve SNR, yielding a total scan time of 20:32 min. Decoupled diagonal spectra from the 2D CTPRESS experiments were obtained by integrating the magnitude spectra along f_2 within ±13Hz along the 2D spectrum diagonal. CHESS water suppression pulses were applied but no additional RF pulses were required for lipid suppression, and the full axial slice was excited without PRESS localization within the brain.

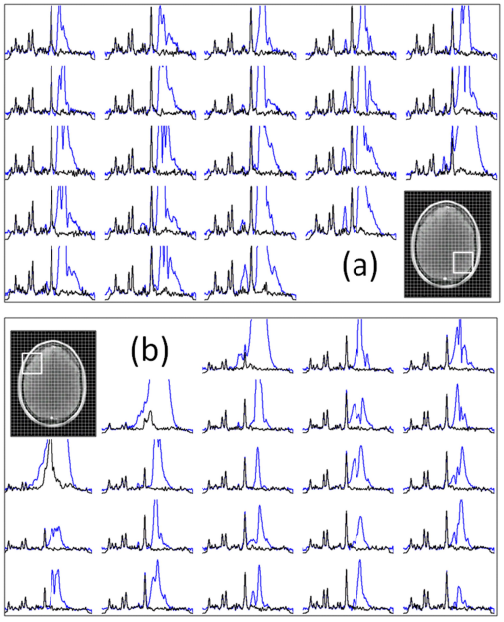

Fig 2a and b. Diagonal spectra extracted from spatially-resolved 2D CT spectroscopy at 0.51 cc resolution. Highlighted grid of voxels near the skull demonstrates excellent lipid suppression and high-quality cortical metabolite signals. Blue spectra are without lipid suppression and black spectra are after the lipid suppression algorithm is applied

For each of the 17 t_1 steps, lipid signals within the brain were suppressed by iteratively minimizing the cost function $||\mathbf{F}\,\mathbf{x}\text{-}\mathbf{y}||_2^2 + \lambda\,\Sigma_{i\in\mathbf{M}}||\mathbf{L}\cdot\mathbf{x}_i||_1$. **x** is the recovered spectral data with minimal lipid contamination within the brain and **y** is the FID in the t_2 dimension. **M** is a binary mask of the brain-only region in the FOV and **L** is the lipid spectra spectrally masked to exclude water signal. **F** is the Fourier operator and λ is an empirical regularization parameter. While the first term in the cost function maintains consistency between the measured data and the recovered metabolite signals, the second term ensures minimal lipid signals within the brain. The optimization took approximately 40min on a 12-core 64bit 3.07GHz Linux machine.

Results: Fig. 1a and b compares in dB scale, CSI images obtained without any lipid suppression and with the lipid suppression algorithm applied, by summing over the range of lipid resonance frequencies in the diagonal spectra. Fig. 2a and b maps the diagonal spectra from the 2D CTPRESS experiment for voxels in the vicinity of the skull, showing lipid suppression in these cortical voxels and the recovery of the dominant peaks of NAA at 2.0ppm. Fig. 3a and b further demonstrates the successful recovery of peaks of Glu, Gln and NAA between 2.25ppm-2.50ppm and 3.50-3.80ppm, which would otherwise be obscured by spectral lipid artifacts.

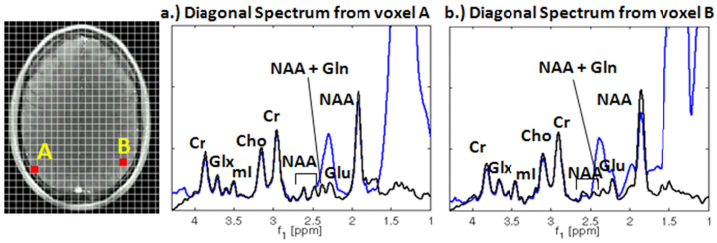

Fig 3a and b. Diagonal spectra from two cortical voxels, demonstrating successful recovery of Glu, Gln and NAA peaks (black), which without lipid suppression would suffer from severe lipid artifacts (blue).

Conclusion and Discussion: We implemented a high-resolution 0.51cc CTPRESS experiment with a lipid suppression technique that recovers peaks previously obscured by artifactual lipid signal in the metabolite spectrum. Major cortical metabolites of NAA, Cr, Cho, Glu, Gln and mI are successfully imaged in the cortex without the use of volume-selective excitation, outer-volume suppression or inversion recovery.

References: [1]Duyn et al; Radiology. 1993; 188(1):277-282 [2] BYdder et al; J Comput Assist Tomogr. 1985; 9(4):659-675 [3] Lee et al; ISMRM 2010; #965

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