Iterative CSI Reconstruction with High-Resoluiton Spatial Priors for Improved Lipid Suppression

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Introduction

Estimates of cortical brain metabolites using chemical shift imaging (CSI), especially those of NAA, are severely hampered by strong, subcutaneous lipid signals. This problem is compounded by both the narrow spectral separation between lipids components in the 0.9-1.3ppm range and the dominant NAA resonance at 2.0ppm, as well as the spatial proximity of the cortex to the source of the undesired signals. Receive arrays with small, sensitive coils in close proximity to the subcutaneous fat further increase the challenge of this problem. Due to low SNR of brain metabolites and scan time limitations, high resolution CSI, although favorable from a lipid-suppression view, is not feasible. Dual-density approach [1] and extrapolation methods [2~4] have been proposed to estimate the high spatial-resolution lipid spectra and reduce truncation artifacts and undesired signal leakage into the brain. We present an iterative reconstruction method that exploits the fact that the source of the strong, undesired signal is limited to the subcutaneous outer tissues, but with no lipids arising from the brain itself.

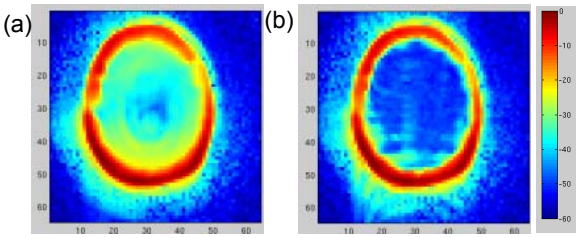
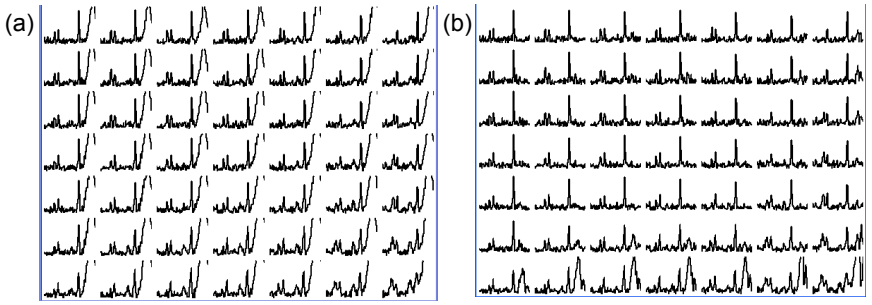


Fig. 1. (a) Conventional Reconstruction, (b) Iterative reconstruction with spatial priors

Methods

We demonstrate the method with a low spatial resolution single-slice, variable-density, single-slice spiral CSI [5] on a healthy volunteer (FOV= 24 cm, resolution= 0.7cc, TE=144ms, TR=2s, imaging time = 2 min, no lipid suppression) on a Siemens 3T Tim Trio, 32ch head coil. To condition the CS reconstruction and impose spatial sparsity, we sample additional image data with a high-resolution gradient echo image (512^2, 10mm slice thickness, imaging time 51s) and one turbo-flash image (64^2, imaging time 1s) with the same resolution as the CSI. The high resolution GRE image provides high-quality *a priori* for spatial localization of skull, subcutaneous fat and brain. We process this image and generate a lipid mask, i.e. of skull + subcutaneous fat, and a brain mask. The receive coil profile is determined from the turbo-flash image and is used for optimal coil combination in CSI. The spectroscopic reconstruction is iterative, and is initialized with conventional gridding, zero-padding, apodization, IFFT, and coil-combinations. The CSI data are then iteratively reconstructed by minimizing the cost function: $\sum_k \left\| F_u I_k - d_k \right\|_2^2 + \lambda \sum_{x,y \in M_b} \sum_l \left\| s_l ' s_c(x,y) \right\|_1$, where I_k is the image from coil k, F_u is Fourier operator on the sampled CSI extent, d_k is gridded raw data from coil k, M_b is the brain mask, s_l are lipid spectra collected from the lipid mask, and s_c are the spectra in the combined CSI image. The first term in this expression enforces data consistency, while the second term minimizes lipids inside the brain mask. With the initial estimate of the CSI image and the lipid spectra, we iterate this minimization process by the steepest-descent algorithm. The iterative image reconstruction time was approximately 10 minutes.



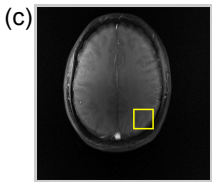


Fig. 2: Spectra of NAA, Cre, Cho, lipid (1.2 ~ 3.8 ppm) inside the ROI (yellow rectangle in (c)) : (a) Conventional Reconstruction, (b) Iterative Reconstruction with spatial priors, (c) Structural image of the slice.

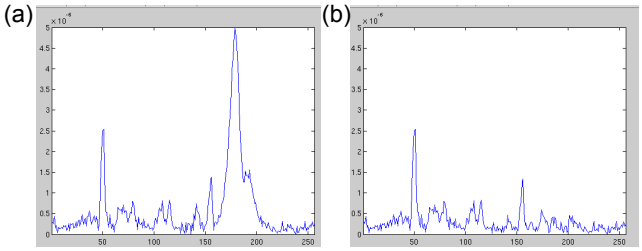


Fig. 3: A spectrum at one voxel in the cortex (the 6th raw and the 7th column in Fig. 2): (a) Conventional Reconstruction, (b) Iterative Reconstruction with spatial priors

Results

Fig. 1 compares the lipid map (sum of absolute spectra from 0.90 to 1.66 ppm) by conventional reconstruction (zero-padding and IFFT) to the iterative reconstruction in dB scale. Fig. 2 shows the spectra by the conventional reconstruction and iterative reconstruction. Fig. 3. shows a spectrum of 800Hz at one voxel in the cortex. By doing the iterative reconstruction, we gain a factor of ten more lipid suppression at the voxel.

Conclusion

We have developed and demonstrated an iterative reconstruction with spatial priors for improved lipid suppression. By imposing the spatial locality constraint on the lipid spectra inside the brain, we are able to substantially improve lipid suppression from the subcutaneous fat into the brain.

References : [1] Sarkar S, Magn Reson Imag., 2002, [2] Plevritis SK, MRM 1995, [3] Haupt CI, MRM 1996, [4] Metzger G, Magn Reson Imag.,1999, [5] Lee, ISMRM 2009, p. 2378.
Acknowledgements: Siemens Medical Solutions, NIH R01EB007942, HST Martinos Catalyst Fund