Lipid suppression with variable-density spiral trajectory for volumetric brain CSI

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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 all the more challenging due to 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. Multiple methods of lipid suppression have been proposed, including outer-volume suppression (OVS) [1], widely used in CSI, and inversion-recovery [2], but both methods trade off some amount of metabolite signals for lipid suppression. Further, at high field strengths, spectrally-selective lipid-inversion has been proposed [3] to minimize the impact on metabolite signals while still achieving robust lipid suppression. Alternatively, by reducing spatial side lobes in the impulse response and using variable-density spiral trajectories that collect outer regions in k-space along with properly matched filtering, lipid signals can be bound spatially to reduce the amount of spatial signal leakage without SNR tradeoffs for the metabolites. This method places substantial requirements on the gradient hardware system and careful attention to the k-space trajectory and filter designs to achieve the required stringent transition- and stop-band characteristics. Here, we demonstrate an application direct filter design method of a three dimensional spherically symmetric filter [4]. By appropriately tuning the filter parameters, e.g. the extent in the k-space and stop-band placement, we can design a filter that has not only the desired voxel size, which supports the required metabolite SNR, but also provides sufficient spatial decay of the spatial side lobes of the impulse response.

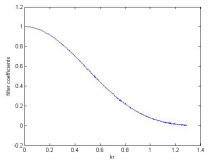


Fig. 1: Filter coefficients

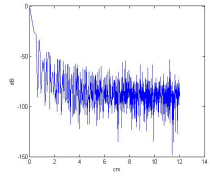
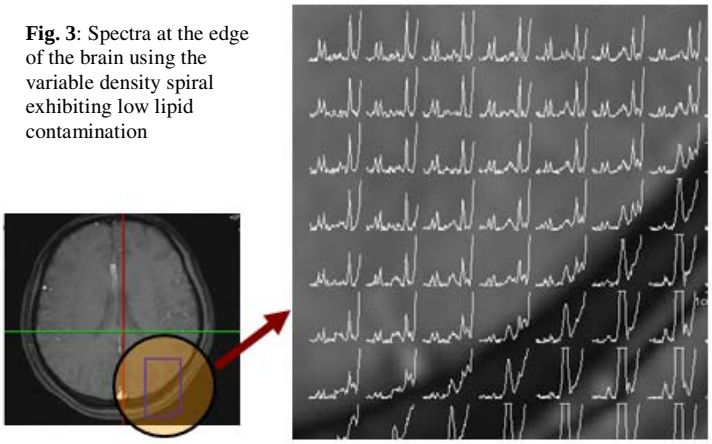


Fig. 2: Impulse response (dB)

Methods: We designed a three-dimensional, spherically-symmetric filter, f, (Fig 1, impulse response in Fig 2) and a corresponding 3D spiral-based k-space trajectory whose density, d, is approximately proportional to $|f|$, which is the SNR-optimal choice. The spiral trajectory was played on a 3T Siemens Trio scanner with a 12-channel Matrix head coil following a conventional PRESS excitation box that extended beyond the head in an axial section and 3-cm thick in z. The filter specifications included a voxel size of 0.726 cc, and the trajectory sampled k-space for FOV_{xy} = 24 cm, FOV_z= 6.2cm, in a scan time of 18 min. As a comparison, we scanned with the same subject with the same PRESS-box placement and a constant-density spiral trajectory with approximately the same voxel size (0.787cc) and scan time (17 min), but a larger FOV_z (14.8cm).

Fig. 3: Spectra at the edge of the brain using the variable density spiral exhibiting low lipid contamination



Results: Figure 3 shows representative spectra with the variable density spiral acquisition from the region in the blue rectangle, where we note the clear depiction of NAA, even in the periphery of the cortex. As expected, the leakage of lipids in the constant-density acquisition is *very* severe (Figure 4, dB scale).

Conclusion: A 3D filter and a matching variable-density spiral trajectory were designed and demonstrated for volumetric brain CSI in the absence of lipid suppression other than the designed rapid roll-off of side lobes in the spatial impulse response. Excellent lipid suppression was achieved via the filter function, and metabolite SNR was supported by maintaining the specified, required voxel size.

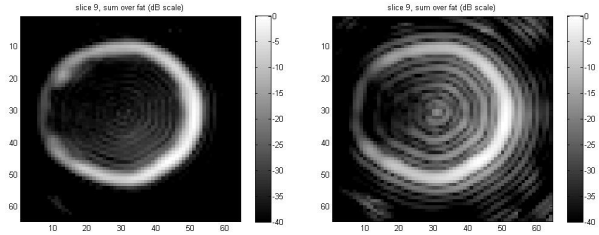


Fig. 4: lipid amount with variable density and constant density spiral (dB scale)

References

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[5] Parker et al, Medical Physics, 14(4), 640-645, 1987.