Fast, Regional 3D Hybrid (1D-Hadamard 2D-Rosette) Proton MRSI in The Human Brain

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Introduction

Fast 3D ^{1}H-MRSI methods cover large regions to full brain, at ‹1 cm^3 spatial resolution, in ‹20 minute (1). However, sometimes, only regional coverage is desired. *e.g.*, in lower brain regions, near the air-filled sinuses, where 1-2 ppm/cm local $\mathbf{B_0}$ variations are encountered (2), undermining water suppression and SNR. Their removal requires shim orders not found on clinical scanners (3), but they can be mitigated by: *(a)* shimming only the structure(s) sought (3); *(b)* small voxels to sample less $\mathbf{B_0}$ variations (4); and *(c)* thin VOI in the susceptible direction (5). The problem with these is that if CSI is used to localize in the thin direction, its spatial response (PSF), will: *(a)* contaminate the VOI with extraneous signals from the imperfect slice profile; *(b)* bleed-in signal between slices; and *(c)* bleed-out up to 13%, lowering the SNR (6). All three, we show, can be addressed with cascaded transverse Hadamard spectroscopic imaging (cT-HSI) for localization along the slice-selection direction (7). Unlike CSI, cT-HSI PSF can be improved to a nearly ideal “boxcar” with high BW optimized RF pulses, minimizing both bleeds, maximizing the VOI SNR (8). Here we demonstrate these advantages by comparing ×2 cT-HSI with ×8 CSI, both with in-plane 2D 20×20 rosette-spectroscopic-imaging (RSI) (9), for fast, ‹10 minute, 3D ^{1}H-MRSI in a phantom comprising partitions of different metabolites, to identify bleeds and localize their sources and in the human hippocampus.

Methods

Human and phantom data were acquired on a 3 T MR scanner and 20-channel head-coil. Two 3D ^{1}H-MRSI sequences were compared. One defined the 2 cm thick VOI (to avoid local susceptibility inhomogeneities too strong or varying to shim, *e.g.,* in the temporal lobes) with a 3 ms, 18 μT peak $\mathbf{B_{1+}}$ Shinnar-Le Roux (SLR) 90° pulse, using ×8 CSI to localize in that direction. The other uses a cascade of two of the same SLR 90°s for ×2 cT-HSI encoding under ×2 fold stronger gradients. For both, the other two directions were localized with 2D 20×20 rosette spectroscopic imaging (RSI).

Results

cT-HSI is shown both (a) in simulations; (b) a structured phantom; and *(c) in vivo* in the human temporal lobes, to dramatically reduce the signal bleed within the VOI slices from the ~26% in CSI to ‹1% in simulations; and from ~›50% down to 5-8% in a phantom. The cT-HSI SNR is improved by 10-15% compared with the ×8 CSI, reflecting the former’s commensurate reductions in signal bleed out.

Discussion

Since in MRSI spatial and spectral localizations are the *raison d’être*, it is shown that CSI spatial and spectral localization shortcomings, can be dramatically reduced to negligible fractions, using high BW cT-HSI RF pulses (7). This advantage, however, comes at the costs of increased SAR from the RF pulses, progressively larger T_2 weighting for earlier pulses in long, ›4, cascades and loss of acceleration in the HSI direction(s). Nevertheless, hybrids of cT-HSI in the VOI narrow direction(s) with RSI in-plane, *e.g.,* as shown here, can be conceived to take advantage of each method’s advantages, while minimizing the impact of their weaknesses.

Conclusion

Compared with CSI, cT-HSI hybrid with in-plane RSI, facilitates fast 3D multivoxel encoding 20×20×2 voxels at sub 1 cm^3 spatial resolution over the bilateral human hippocampus, in under 5 minutes at negligible spectral and spatial contamination and ~15% SNR gains compared with the customary CSI.

References

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Acknowledgements

Supported by NIH Grants EB011639, NS090417, NS081772, NS097494 and EB017183. A. Tal is supported by the Monroy-Marks Career Development Fund, the Carolito Stiftung Fund, the Harold Perlman Family and Minerva foundation from the Federal German Education and Research Ministry.