3D metabolic mapping in the brain by 2D-GRAPPA accelerated FID-CSI at 7T

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Target Audience:
Scientists with interest in CSI sequence development at UHF

Purpose:
Recently, pulse-cascaded Hadamard Spectroscopic Imaging (HSI) was proposed for 3D-CSI at 7T to reduce the maximum B1 amplitude and therefore limit the specific absorption rate (SAR) and chemical shift displacement error (CDSE) in contrast to pulse superposition HSI [1, 2]. HSI allows 3D acquisition of few slices without PSF problems and increases the SNR compared to multi-slice CSI. In addition, different groups have shown that 2D-CSI can be performed by pulse acquire sequences with short acquisition delays at 7T with excellent quality [3, 4, 5], maximizing SNR and rendering J-coupling effects insignificant. This work presents the use of 2D GRAPPA [6] to accelerate pulse-cascaded HSI with four slices and acquisition of a free induction decay (FID) signal after a short acquisition delay (AD) at 7T.

Methods:
Pulse-cascaded HSI typically uses 4 or 8 consecutive Hadamard-encoded excitation pulses (Fig.1 A). Prior work [7] had established good slice localization properties even for adjacent slices. Phantom measurements and measurements of a healthy volunteer were conducted with a 7T Siemens Magnetom scanner (32 channel head coil, TR=600 ms, AD= 1.3/2.3/3.3/4.3 ms for slices 4/3/2/1, 64×64 matrix interpolated to 128×128, FOV 200mm, 6 mm slice thickness, ascending and adjacent slices, 20:14 minutes total measurement time) in array coil mode with gradient echo (GRE) image based coil combination [8]. 2D-GRAPPA acceleration [9] (Fig. 1 B) with an acceleration (R) of 3 in LR- and 2 in AP-direction was used for a total acceleration factor of 6. Auto-calibration signal data was obtained from the GRE images. The resulting spectra were processed with LCModel software.

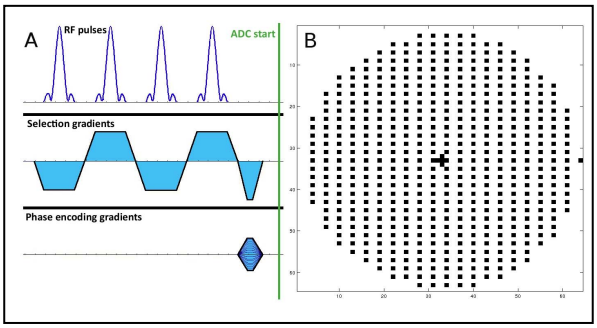

Fig.1: **A:** Pulse-cascaded HSI pulse and gradient structure; **B:** K-space excitation pattern for elliptically weighted 3x2 GRAPPA.

Results:
Metabolic maps with a 128x128x4 matrix were created for the major metabolites (NAA, Cho, CR, Ins, Glu). Individual spectra (Fig. 2) show that despite the R of six, there is still more than sufficient SNR for metabolite quantification. SNR values were calculated for the NAA signal, resulting in a mean SNR of 22.9±13.3 over all for slices.
CRLB values were below 20 for 97.5% of all voxels for tNAA, 97.2% for tCr and 95.2% for tCho. The respective CRLB mean values were 5.6±5.1 for tNAA, 6.4±5.5 for tCr and 7.7±6.5 for tCho.
A comparison of tNAA maps to anatomical T1w images (Fig.3) shows that anatomical structures such as gyri, the lateral ventricles, the corpus callosum and the longitudinal fissure are clearly visible due to the low NAA concentration in CSF and liquor.

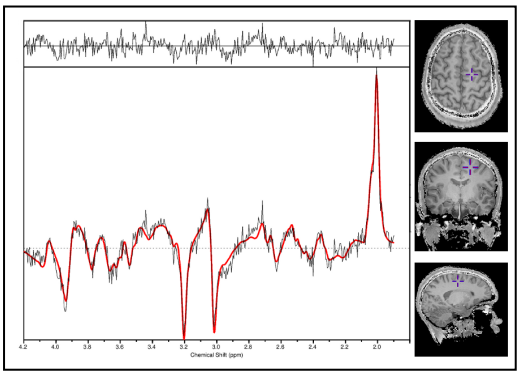

Fig.2: Spectrum of a white matter voxel, AD: 1.3 ms, nominal spatial resolution of 3.125×3.125×6 mm (58.6 mm^3).

Discussion/Conclusion:
2D-GRAPPA accelerated HSI allows fast 3D-CSI measurements of the brain *in vivo* using an FID acquisition scheme and can obtain a large matrix in ~20 minutes. However, B0 shimming at 7T is a difficult task and careful planning of the shim volume or significantly improved shim hardware [10] is a prerequisite for good data quality.
Our preliminary results indicate that even higher acceleration may be feasible while retaining enough SNR to obtain useful spectra while reducing the measurement times to clinically acceptable values.

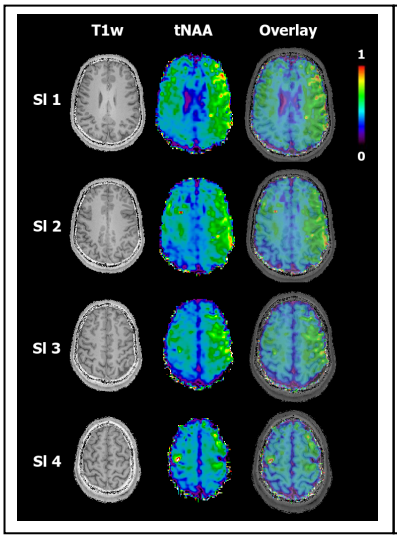

Fig.3: tNAA maps for all four HSI slices in comparison to T1w images. Varying signal intensity in LR direction due to AC mode B1- inhomogeneities.

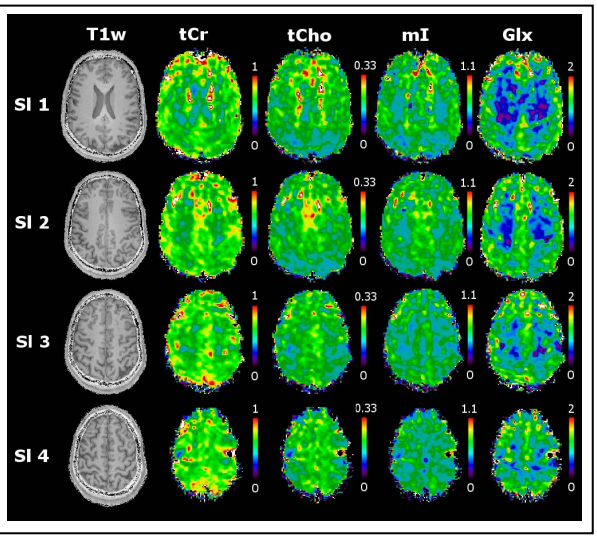

Fig.4: Metabolic ratio maps (all to tNAA) of important metabolites of all four HSI slices. Metabolic differences between GM and WM are clearly visible.

References:
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