

3D metabolic mapping of the brain at 7T by pulse-cascaded Hadamard encoding with short acquisition delay

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Target Audience:

Scientists in MRSI/CSI sequence development

Purpose:

Recently, pulse-cascaded Hadamard Spectroscopic Imaging (HSI) was proposed for 3D-CSI at 7T to reduce maximum B1 amplitude and therefore limit the specific absorption rate (SAR) in contrast to pulse superposition HSI [1]. This enables shorter slice selective pulses with higher RF bandwidth, reducing chemical shift displacement errors compared to standard Hadamard encoding [1]. 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 [2, 3, 4]. This maximizes SNR and renders J-coupling effects insignificant. This work compares spectra and metabolic maps of pulse-cascaded HSI with four slices and single slice CSI, both with short acquisition delays FIDs at 7T to confirm these advantages. Further, the achieved practical SNR-increase due to the HSI's intrinsic 4× averaging is investigated.

Methods:

Instead of pulse superposition in conventional HSI, pulse-cascaded HSI encoding requires the use of four consecutive Hadamard-encoded excitation pulses (Fig.1). Localization profile and contamination measurements in phantoms were conducted to investigate HSI slice properties.

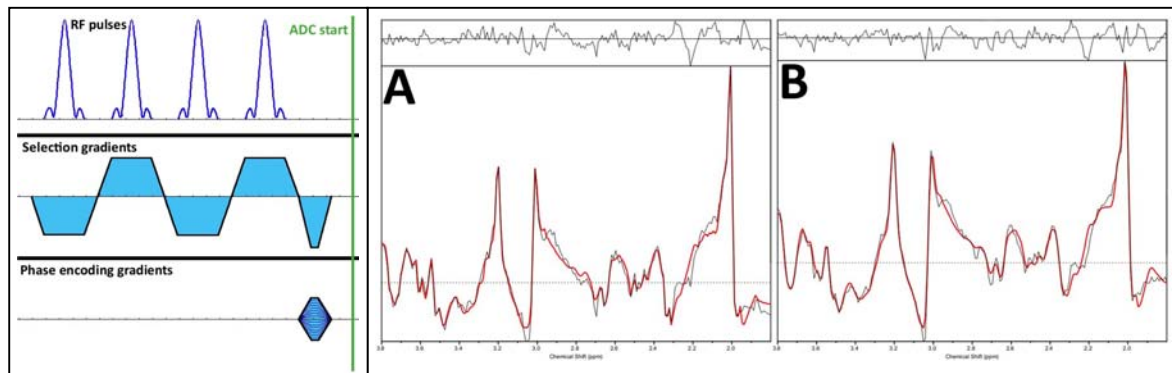


Fig.1: Pulse-cascaded HSI sequence structure

Fig.2: Spectra of a male volunteer central white matter voxel with a nominal spatial resolution of 5.2×5.2×6 mm for A) standard CSI and B) HSI-CSI

Six healthy volunteers were measured with standard CSI and HSI-CSI (32 channel head coil, TR=400 ms, TE= 1.3

ms, matrix 42×42, FOV 220mm, 6 mm slice thickness, adjacent slices, 8:24 minutes measurement time per slice, third or fourth ascending slice was chosen for comparison). Two volunteers were measured in VC mode, the other four in AC mode with gradient echo image based coil combination [5]. The resulting spectra were processed with LCModel software.

Results:

Slice localization and contamination properties of HSI slices were approximately equal to standard CSI values. HSI Volunteer brain voxel spectra displayed good comparability to standard CSI while featuring a better SNR (Fig.2). Absolute SNR per unit time (SNRt) derived from NAA peaks to background amounts to 117.83±35.28 for HSI and 82.25±24.40 for CSI over all AC mode volunteer voxels. SNRt ratio HSI to CSI maps for three volunteers are shown in Fig.3, the mean SNRt ratio was 1.45±0.30 over all volunteer voxels. The acquired metabolic ratio maps for HSI in the center regions of the brain were consistent to CSI while enhancing artifacts at the brain rim (Fig.4). No differences in the resulting HSI/CSI ratios between AC and VC mode could be found.

Discussion:

The current results show that pulse-cascaded HSI-CSI provides results that are well comparable to standard CSI while offering a significant SNR increase over conventional multi-slice CSI. The SAR reduction allows multi-slice excitation at short TRs. The achieved mean SNR increase of 1.45±0.30 is lower than the theoretically expected factor of 2. A possible reason lies in the imperfect SNR computation for high signal values that can be distorted by background and artifacts. Probable causes are movement-induced extra-cranial lipid artifacts due to the long measurement time.

Conclusion:

Pulse-cascaded HSI-CSI has a high potential for future 3D CSI brain measurements at 7T with 4-8 slices. Improvements of water and lipid suppression as well as better in-plane localization will enhance spectral quality. Implementation of parallel imaging and advanced readout trajectories trading off HSI's SNR increase can address the current measurement time limitations and lead to higher spatial resolutions.

References:

- [1] Goelman et al., *MRM* 2007; 58 (1):167–173
- [2] Henning et al., *NMR Biomed* 2009; 22(7):683-96
- [3] Boer et al., *NMR Biomed* 2011; 24(9):1081-8
- [4] Bogner et al., *NMR Biomed* 2012; 25(6):873-82
- [5] Strasser et al., *Proc. Intl. Soc. MRM* 20 (2012):1746

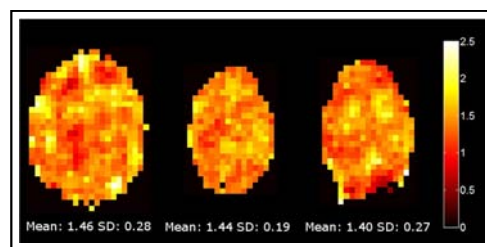


Fig.3: SNR ratios HSI to CSI for three volunteers

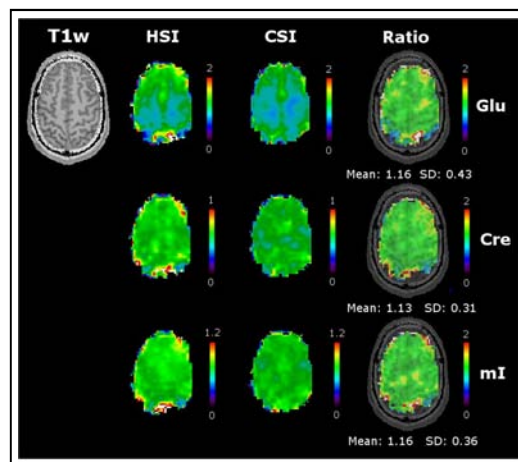


Fig.4: Comparison of metabolic ratio maps (all to NAA+NAAG) for HSI and Standard CSI