CEST MRI Using Golden-Angle Cartesian Acquisition with Compressed Sensing Reconstruction

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INTRODUCTION:

We propose a new 3D dynamic CEST MRI technique which involves saturation transfer preparation, a gold-angle rotated, variable-density signal acquisition and compressed sensing (CS) reconstruction. The approach offers improved signal detection sensitivity and motion artifacts reduction, enables a continuous signal acquisition and retrospective reconstruction with flexible temporal resolution.

METHODS:

The sequence framework combines golden-angle rotated, variable-density spiral-centric Cartesian acquisition[1, 2] and low-rank based multi-coil CS reconstruction.[3] Following the preparation pulses, one shot, which includes a number of phase-encoding steps predefined in the ky-kz Cartesian grid, is acquired. Following shots are rotated by a golden angle to allow for a uniform and continuous coverage of k-space. 400 k-space lines were acquired per shot after the CEST preparation within an imaging matrix of 96x96x20. For each frequency offsets, 5 shots were acquired corresponding to the time required for a fully-sampled k-space. The CEST preparation uses a train of 20 Gaussian pulses, 50 ms each, with inter-pulse delay of 0.5 ms, and B1 power was 1.6 μT. The sampling trajectory was rotated by 137.5° between different shots. For image reconstruction, first, images were reconstructed by CS reconstruction with spatiotemporal constraints using all 5 shots (Fig. 1a). Then "shots" were retrospectively removed from the k-space and CS reconstruction was applied to the first 2 shots (Fig. 1b) and the first shot alone (Fig. 1c). The PLOF[4] method was used for extracting the NOE contrast at -3.5 ppm from a posterier white matter ROI and genertaing the NOE maps.

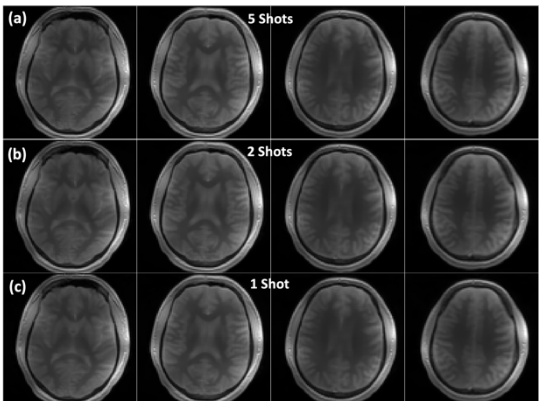

Fig. 1. images reconstructed using (a) 5 shots, (b) 2 shots and (c) a single shot.

RESULTS:

The CS reconstruction was able to generate artifact-free images with just 2 shots or a single shot, which correspond to acceleration factors of 4.8 or 9.6 and a temporal resolution of 10s or 5s per 3D volume per frequency offset. The Z-spectral features from multiple exchange pathways were well preserved (Fig. 2). Fitting results showed almost identical NOE contrast from images reconstructed from 5, 2 and even a single shot (Fig.3). The NOE maps showed slight blurring at the tissue boundaries when using a single shot for reconstruction (Fig.3).

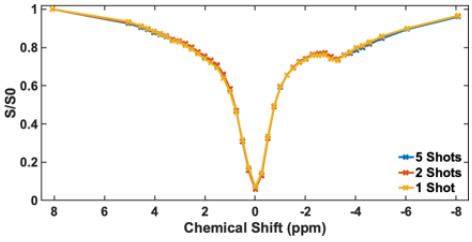

Fig. 2. Z-spectra of an ROI from images reconstructed using 5, 2 and 1 shot(s).

DISCUSSION:

Combining the advantages of our variable density spiral-centric Cartesian acquisition and CS reconstruction, we demonstrated that the CEST contrast can be well preserved with 4.8-fold acceleration rate. The choice of further acceleration depends on the application. For dynamic imaging, e.g., repeated observation at a certain frequency offset, the current sequence framework offers flexibility of retrospectively combining different number of shots to achieve arbitrary temporal resolution.

CONCLUSION:

We proposed a 3D CEST imaging method using a golden angle rotated and variable-density Cartesian acquisition in combination with multi-coil compressed sensing reconstruction. It is possible to obtain whole brain CEST maps well under 5 min with this method, making it applicable to clinical applications.

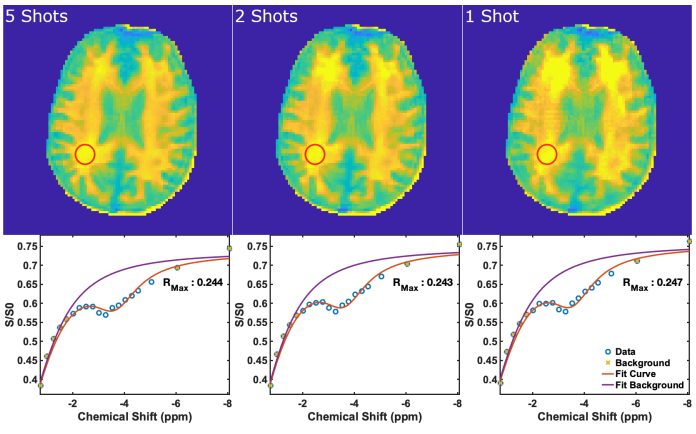

Fig. 3. Top: NOE maps calculated from images reconstructed using 5, 2 and 1 shot(s). Bottom: corresponding Z spectra and the PLOF fittings for a white matter ROI.

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