An EPI Sampling Trajectory with ACS Lines in Each Shot

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Target audience: Researchers interested in EPI reconstruction.

Purpose: Echo planar imaging (EPI) is a widely used technique in many MRI applications due to its high sampling efficiency. Calibration-less imaging is advantageous since no external scan is required to estimate coil sensitivities, and separate calibration scans may adversely affect consistency between coil sensitivities and undersampled data. There are two main categories of calibration-less reconstruction methods, based on the domain of the regularization term (SAKE in k-space, and CLEAR in image space). However, these methods do not work well for uniformly undersampled data such as EPI. In this work, we modify the EPI trajectories to acquire extra ACS lines, and demonstrate that a small ACS region (4 lines) considerably improves CLEAR reconstructions over a standard uniform EPI acquisition.

Methods: The proposed trajectory is shown in Fig. 1. In the modified trajectory, outer lines are sacrificed to sample an ACS region with 4 ky lines. To keep ky velocity (which determines off-resonance distortion in the blip direction) constant, the proposed EPI trajectory has additional dead time between kx readouts outside of the ACS region.

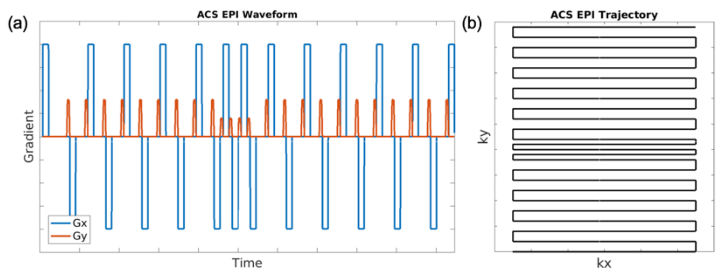

Figure 1. The modified EPI waveform (A) and acquisition trajectory (B) with ACS region.

One fully sampled 8-channel brain dataset was retrospectively undersampled for simulation. Under IRB approval, one volunteer was scanned using the conventional and modified EPI sequence with number of shots = 2, TR/TE = 4000/110 ms, matrix size = 128x128, FOV = 22 cm, readout BW = +/-125 kHz, slice thickness = 4 mm, echo train length = 55 ms for conventional EPI, 110 ms for modified EPI, four ACS lines for the modified EPI scan. CLEAR was applied to one shot data after linear odd-even phase correction with a regularization parameter of 0.002.

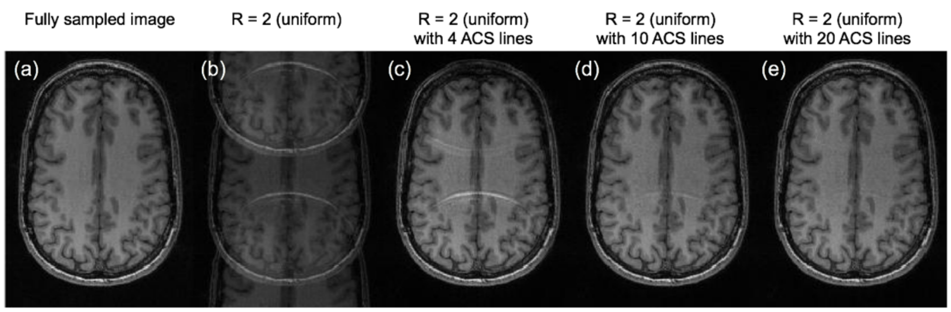

Figure 2. Fully sampled image (a) and CLEAR reconstruction results on retrospectively undersampled data with different trajectories (b-e).

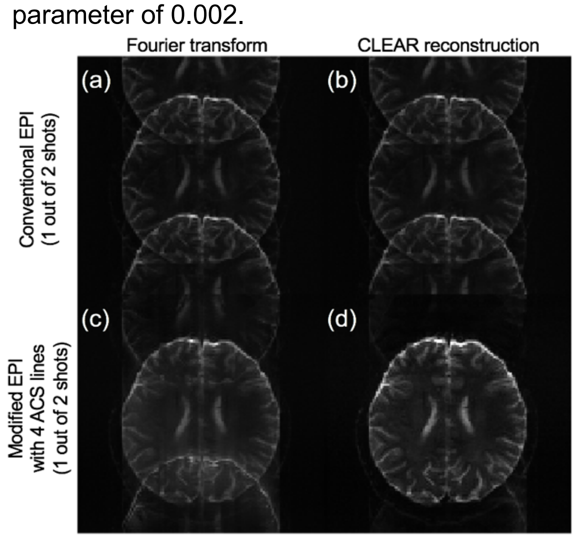

Figure 3. One shot image from 2-shot acquisition using conventional EPI (a) and modified EPI sequence (c), and CLEAR reconstruction results (b, d).

Results and Discussion: Figure 2 shows the fully sampled image and reconstruction results with CLEAR on retrospectively undersampled data. CLEAR fails to reconstruct uniformly undersampled data (Fig. 2b). With 4 ACS lines in the center, ghosting artifacts are considerably reduced (Fig. 2c). Ghosting artifacts decrease as the ACS region grows (Fig. 2c, d). Similarly, CLEAR reconstruction of the data acquired using the modified EPI trajectory shows substantial improvement (Fig. 3d).

A limitation of the proposed trajectory is that the ky velocity is constrained by the ky velocity at the ACS region. In this preliminary study, the EPI train is lengthened with considerable dead time to accommodate this. The ky velocity could be increased with partial kx readouts in the ACS region to reduce echo spacing. The proposed trajectory may enable variable density undersampled EPI. This technique may also be beneficial to other EPI-related applications and reconstruction methods.

Conclusion: Acquiring more ACS lines in each shot of EPI could enable better calibration-less reconstruction.

References: [1] Shin PJ et al. MRM. 2014. [2] Trzasko JD et al. ASILOMAR, 2011.