GRE reference scan for robust reconstruction of high resolution slice and in-plane accelerated 2D GE EPI at 7T

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Target Audience: Clinicians and researches interested in high resolution slice accelerated 2D EPI at 7T.

Purpose: To improve motion sensitivity and reconstruction quality of high resolution slice and in-plane accelerated 2D EPI.

Introduction: Acquiring high temporal, high spatial resolution 2D EPI requires acceleration along both the in-plane phase encode and slice directions. For such acquisitions, not only do small motions become large relative to the voxel size but the reference scans also become very long (~30-120 secs) enhancing the motion sensitivity already inherent in in-plane segmented multi-shot reference scans [1]. Previous work has shown that alternative reference scans can reduce motion sensitivity in low resolution (3mm) in-plane accelerated 2D EPI [2]. In this study we show the advantage of the GRE FLASH [3] reference scan for high resolution slice and in-plane accelerated 2D GE EPI.

Methods: High resolution, whole brain gradient-echo EPI was acquired at 1.5, 1.25 and 0.9 mm isotropic resolutions. For repeatability testing, each resolution was acquired three times per reference scan type: SEG ref (standard segmented EPI), SS ref (single shot EPI), GRE ref (GRE FLASH). These reference scans were used for in-plane unaliasing while single-band in-plane under-sampled scans were used for MB slice unaliasing. In-plane (GRAPPA) and slice (multiband, MB) acceleration factors were both 3 with a ¼ FOV shift in the PE direction using blipped-CAIPIRINHA [4]. Echo spacings were minimized and TE was ~19ms requiring 7/8, 6/8, and 5/8 partial Fourier; 1300, 1900, and 3600ms TR for each resolution respectively. Z-coverage was ~135mm. For the 0.9mm data, this required 150 slices and a custom modification to both pulse sequence and reconstruction code to overcome the vendor specific 128-slice limit. A 32 channel receive and quadrature transmit coil (Nova Medical, Wilmington, MA) was used on a Siemens Magnetom 7T system. The subject was instructed to be as still as possible throughout the session.

Results and Discussion: Fig 1 shows that even in the presence of minimal head motion, in-plane acceleration combined with slice accelerated EPI can result in dark/bright alternating slice intensities (or "horizontal stripes"; top left) as well as increased ghosting and reconstruction noise (bottom left). Although the SS ref provided shorter reference scan times, it resulted in significantly increase noise and ghost levels for the GRAPPA3xMB3 acquisition (Fig 1, bottom middle). Use of the GRE ref significantly improved image quality (contrast homogeneity), while reducing both the dark/bright slice artifact and reconstruction noise. Average SNR across the brain in three separate acquisitions also showed significant improvements at higher spatial resolutions with the GRE ref (Fig 2, top). The improvement over a standard SEG ref increased with spatial resolution (Fig 2, bottom), reaching a factor of 140% for the 0.9mm (equivalent to two averages of SEG ref data).

Conclusion: Prior studies reported that the above artifacts tend to appear when there is relatively large head motion during the reference scan [3, 5]. However, with motion prone subjects and/or higher spatial resolutions (<1.25mm) a more robust reference scan like a GRE ref is required. Future work will evaluate the GRE ref under task, resting-state, and diffusionn MRI.

References: [1] Moeller et al. Proc Int Soc Magn Reson Med 2008; [2] Griswold et al. NMR in Biomed 2006; [3] Polimeni et al. Proc ISMRM 2013; [4] Setsompop et al. MRM 2012; [5] Ugurbil et al. NeuroImage 2013.

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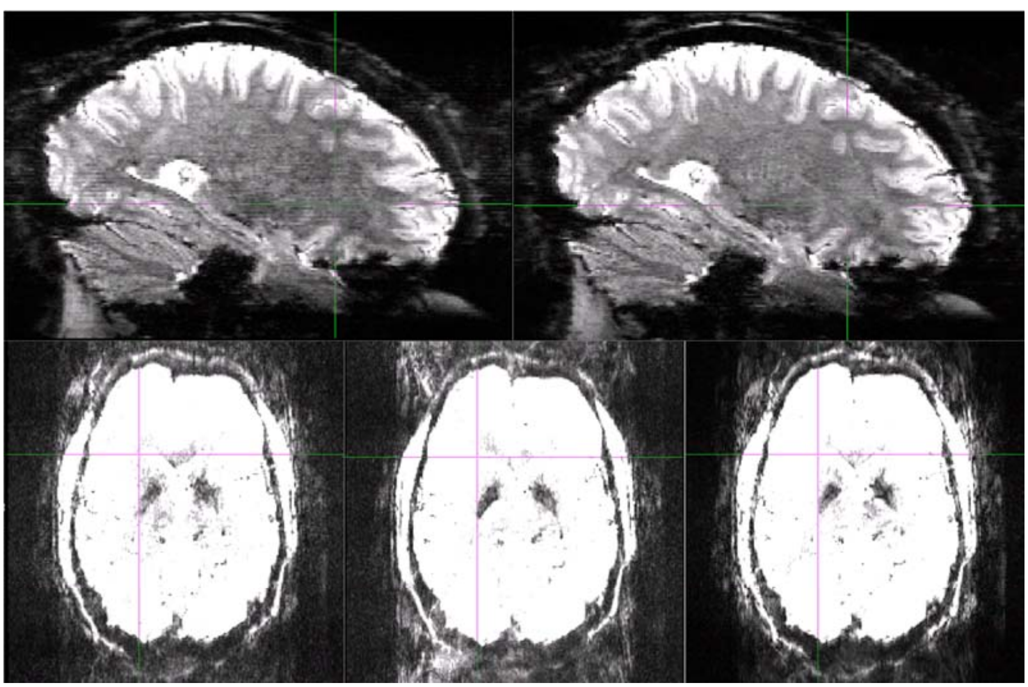

Figure 1: Image quality from a still subject using various reference scan types at 0.9mm
Sagittal slices (top row): SEG ref shows dark/bright pattern can be seen alternating slices (left), GRE ref improves image quality substantially (right). Axial slices windowed to view noise (bottom row): SEG ref (left), SS ref adds additional ghosting (middle), GRE ref greatly reduces noise (right).

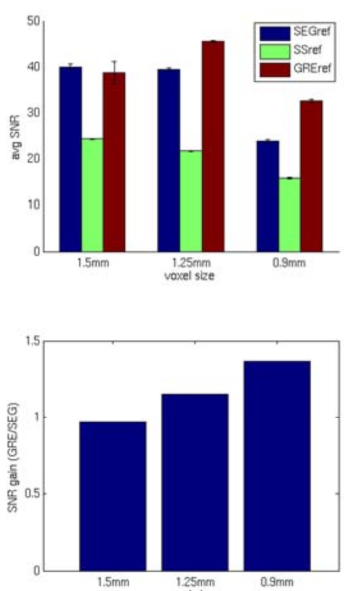

Figure 2: SNR comparison
Average SNR is worst for SS ref at all resolutions (top). GRE ref has largest improvements for highest spatial resolutions (bottom)