Image Reconstruction using Dynamic EPI Phase Correction

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Introduction

Magnetic resonance imaging (MRI) studies using echo planar imaging (EPI) employ data acquisition techniques in which data is collected on both positive and negative polarity lobes of readout gradient waveforms. Phase errors are inherent in this data collection scheme and must be corrected for during image reconstruction. One technique used for EPI phase correction is to acquire a set of non-phase encoded data during an EPI reference scan, computing phase correction coefficients to be used during image reconstruction of the subsequent EPI scan(1,2). If phase characteristics change during EPI scans with longer durations, such as functional magnetic resonance imaging (fMRI), diffusion tensor imaging (DTI) and multi-phase EPI scans, increased Nyquist ghosting and image translation in the phase direction may result (3,4,5). We propose a method of dynamic EPI phase correction in which phase characteristics are monitored during an EPI scan, and the original phase correction parameters determined prior to the scan are adjusted to insure consistent image fidelity is maintained throughout the duration of the scan.

Methods

Data was collected using a 3.0 T General Electric (GE) Signa MR scanner (GE Healthcare, Waukesha, WI, USA) equipped with a high bandwidth (1MHz) data acquisition subsystem and a TwinSpeed gradient coil capable of 40 mT/m at a maximum slew rate of 150T/m/s. Conventional gradient recalled echo (GRE) and spin echo (SE) EPI scans were performed with a standard GE single channel head coil as well as an 8-channel head coil (MRI Devices, Waukesha, WI, USA). Raw data from each experiment was saved and re-processed off-line to show the effects of the new algorithm.

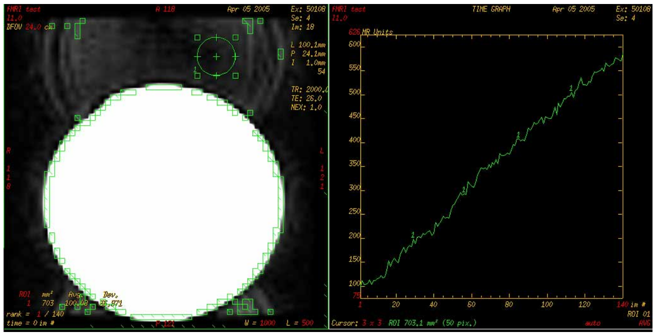

Fig. 1. Single-channel 3T fMRI ghosting levels without dynamic EPI phase correction.

Results

EPI-GRE and EPI-SE pulse sequences were modified to collect extra non-phase-encoded reference data during the EPI scan. During image reconstruction, the non-phase-encoded reference frames of data are Fourier transformed, and phase subtraction is performed to compare the phase of each frame of data to a corresponding frame from the start of the scan. This phase difference data is then row-subtracted from neighboring frames of data, and a magnitude-weighted least-squares fit is used to estimate first-order phase correction coefficients from the phase difference data. These estimates are temporally filtered with a low-pass filter, and then used to adjust the original phase correction coefficients obtained prior to a scan. Fig. 2 shows the results of applying this technique to data obtained with the following parameters: single channel head coil, EPI-GRE, TE=26 msec, TR=2000, FOV=24cm, slice thick=3mm, 36 slices, 140 phases. Fig. 3 shows results of this technique for a human volunteer.

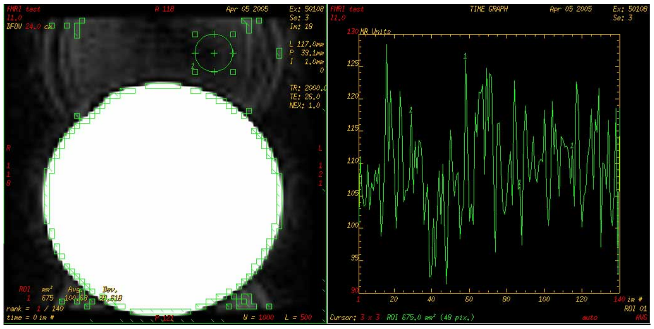

Fig. 2. Single-channel 3T fMRI ghosting levels with dynamic EPI phase correction using the same raw data as shown in Fig. 1.

Discussion and Conclusion

Dynamic EPI phase correction provides a robust and efficient means of adjusting linear phase correction coefficients to insure that Nyquist ghosting levels remain consistent during the course of a scan. In addition, image translation in the phase direction due to B_0 drift is eliminated by adjusting a constant phase term that increments from echo to echo. Collecting extra reference data during an EPI scan may reduce the maximum number slices that can be acquired within a TR.

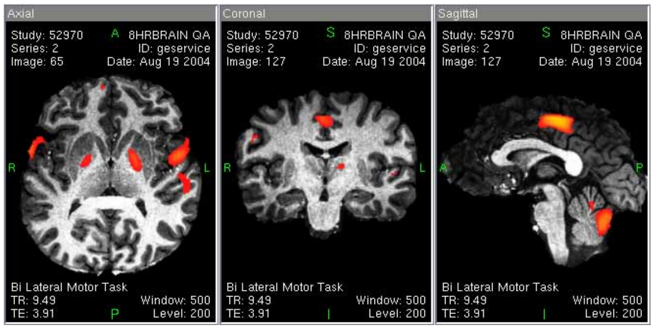

Fig. 3. fMRI results from a human volunteer using dynamic EPI phase correction with an 8-channel coil.

References

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