Ghost artifact reduction in EPI (Echo Planar Imaging) with Sensitivity Encoding (SENSE)

S. Yun[1], S-S. Yoo[2], J. Chung[1], H. Park[1]

[1]Electrical Engineering, Korea Advance Institute of Science and Technology, Daejeon, Chung Cheong Nam Do, Korea, Republic of, [2]Radiology, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts, United States

Introduction

Nyquist ghosting artifacts degrade the quality of Echo Planar Imaging (EPI) due to the alternating offset of the k-space lines. Acquisition of separate reference image [1], modification of EPI sequences [2] or algorithmic correction schemes [3] have been applied to correct the artifacts. These artifacts do not appear in the most imaging sequence except the EPI because each line of k-space is traversed in the same direction and all k-space lines have nearly the same offset [3]. In order to reconstruct the images with a same traverse direction in k-space, we were motivated to use only even echoes or odd echoes of k-space in reconstruction, respectively. This type of approach reduces the field of view (FOV) to one-half in phase encoding direction, therefore is immune to Nyquist ghost artifacts inherently. Consequently, issues aliasing artifact associated with reduced-FOV approach can be effectively reduced by Sensitivity Encoding (SENSE) [4].

Methods

3 Tesla (Oxford) MRI scanner equipped with 4-channel phased array was used for the implementation of the algorithm. The schematics of the proposed algorithm are described in Fig.1.

1. EPI k-space data were acquired using phased-array coil (Fig.1a), and divided into two sets of k-space data,-one with even echoes (Fig.1b) and the other with odd echoes (Fig.1c). These k-space data (now reduced-FOV) were reconstructed for each phased array coil.
2. Gradient echo images (Fig.1d) were acquired from the same object using the same spatial resolution as the EPI images. These gradient echo images were used as the reference data for calculating sensitivity maps (Fig.1e).
3. These sensitivity maps were applied to reduced-FOV image sets (Fig.1b and 1c) using SENSE reconstruction algorithm to obtain aliasing artifact-free images (Fig.1f and 1g).
4. These aliasing artifact-free images were averaged to generate final image (Fig.1h).

The proposed method was applied to a phantom image and a human brain (24 year-old male, who gave informed consent).

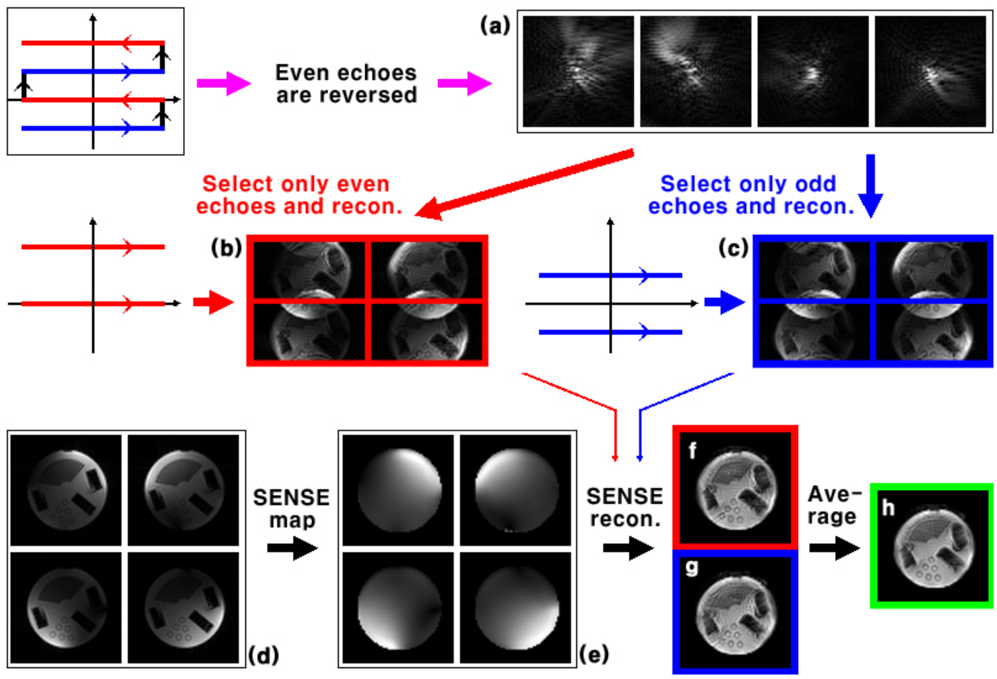

Fig. 1 **(a)** EPI k-space data, with even echoes reversed, **(b)** Even echo reconstructed images, **(c)** Odd echo reconstructed images, **(d)** Gradient echo reference images, **(e)** Sensitivity maps calculated from (d), **(f)** Alias-free image from (b) and (e) using SENSE, **(g)** Alias-free image from (c) and (e) using SENSE, **(h)** The average of (f) and (g)

Results

The performance of the proposed algorithm was measured by comparing the images with the original EPI images without any artifact correction. As evident from Fig.2, the algorithm effectively reduced the artifacts from both phantom and brain imaging. We averaged the two aliasing artifact-free images to attain the SNR comparable to the typical Nyquist ghost artifact reduction algorithms [2,3].

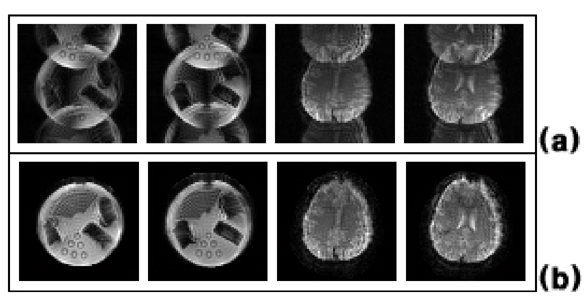

Fig. 2 **(a)** Original EPI images (2 slices of phantom and human brain), each image is obtained from sum-of-squares of phased-array images, **(b)** Ghost artifact removed images

Conclusion

In this study, we implemented an algorithm to reduce ghost artifacts in EPI using phased array data acquisition and SENSE reconstruction. The proposed algorithm does not require calculation of the phase maps or modification of the EPI pulse sequence. We believe the algorithm of this kind can be effectively deployed for reconstructing EPI data in parallel imaging techniques (such as SENSE, SPACERIP) to accelerate the temporal resolution of, for example, functional MRI studies.

Acknowledgement

This work was supported by the 02-PJ3-PG6-EV07-0002, Korean Ministry of Health and Welfare.

References

[1] Bruder H et al., "Image reconstruction for EPI with non-equidistant k-space sampling", Magn Reson in Med. 1992;23;311-323.
[2] Nau-Kuei Chen et al., "Removal of Nyquist Ghost Artifacts with Two-dimensional Phase Correction", Magn Reson in Med. 2004;51;1247-1253.
[3] Michael H. Buonocore et al., "Ghost Artifact Reduction for Echo Planar Imaging Using Image Phase Correction", Magn Reson in Med. 1997;38;89-100.
[4] Klaas P. Pruessmann, "SENSE: Sensitivity Encoding for Fast MRI", Magn Reson in Med, 1999;42;952-962.