PROPELLER EPI with Reversed Gradient Method for High Resolution DTI at 3.0T without Field-map Correction

H-C. Chang[1], T-C. Chuang[1], T-Y. Huang[2], H-W. Chung[1,3], C-Y. Chen[3], F-N. Wang[1], K. K. Kwong[4]

[1]Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, [2]Department of Electrical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan, [3]Department of Radiology, Tri-Service General Hospital, Taipei, Taiwan, [4]MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, Massachusetts, United States

Introduction

The PROPELLER EPI (periodically rotated overlapping parallel lines with enhanced reconstruction using EPI as signal readout) has been shown useful for diffusion tensor imaging (DTI) applications [1]. Since susceptibility-induced geometrical distortions in EPI could lead to blurring in PROPELLER EPI images, a series of correction schemes need to be employed to reduce blurring effects, especially for high-resolution imaging at large matrix size [1]. Field map correction [2] and parallel imaging acquisition [3] are both effective means to achieve such a goal. In this work, we propose another option using a modified reversed gradient method (RG) [4-5], which is compatible with parallel imaging, to generate high-resolution DTI without the need for field map correction.

Theory

The RG method relies on two EPI acquisitions, each using phase-encoding gradients with reversed polarity such that the distortions are in opposite directions [4,5]. Information on the difference in spatial displacements is then used to correct for both the geometric distortions and signal intensities, hence to reconstruct the image. In PROPELLER EPI, the use of the RG method reduces distortions for each single-blade image, thereby reduces blurring after PROPELLER reconstruction in the k-space. To achieve data acquisition that fills the entire circular k-space and with opposite phase gradient polarity, the rotating angles of the blades cover a total of 360°, in contrast to the original version of PROPELLER EPI with single signal average which only needs 180° coverage [1]. The RG method thus uses each pair of blades that are symmetric to each other in k-space trajectory (i.e. 1° to 180° vs. 181° to 360°). This property means that for imaging techniques that need multiple signal averages, such as DTI, no extra modifications on the PROPELLER EPI acquisition sequence need to be performed except the post-processing steps for the RG method.

Material and methods

We collected human brain PROPELLER EPI data with diffusion tensor weighting on a 3.0T MRI scanner (Philips Achieva, Best, the Netherlands). The single-shot spin-echo EPI for data readout in each rotating blade consisted of the following parameters: blade size (15%*256)*256 (ETL=37), rotating angle 15°, NEX 4, TE 90ms, TR 1200ms, slice thickness 3mm, b-factor 1000 s/mm^2, 24 blades for 360° k-space coverage (which became 12 after applying the reversed gradient method). The final reconstructed image had 256*256 matrix at 0.86mm resolution. The computation algorithm for the RG method in our study employed a modified scheme using the concept of displacement map to achieve accurate correction, the details of which are discussed in another abstract.

Results

The results of PROPELLER EPI using reversed gradient method to reduced image blurring are shown in Fig.1 for one single blade of data. Compared to non-corrected blade in Figs.1a and 1b, the corrected blade image in Fig.1c showed greatly reduced distortions and better signal homogeneity. The RG-corrected PROPELLER EPI images acquired near the skull base (Fig.2, bottom row) exhibited much less blurring than those without RG correction (Fig.2, top row). The resolution improvements from the RG correction method could be appreciated by the colored FA map in Fig.2f.

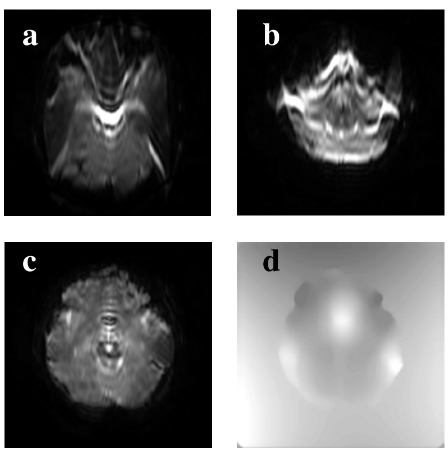

Figure 1. Single blade images acquired with opposite phase gradient polarities showing distortions along opposite directions (a,b), RG corrected blade image (c), and its displacement map (d).

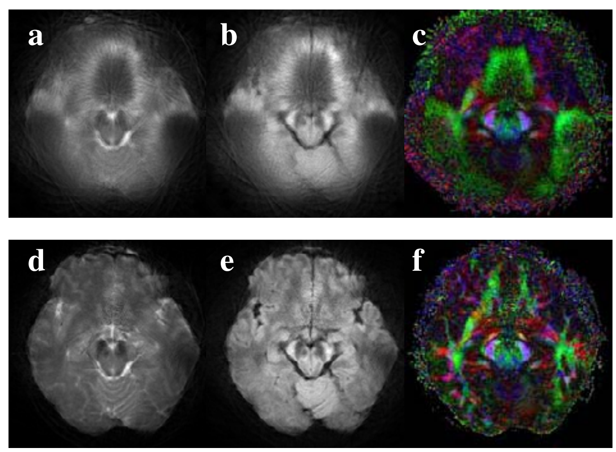

Figure 2. PROPELLER EPI images *without* (a-c) and *with* RG correction (d-f), showing prominent difference in blurring effects on the b = 0 images (a,d), diffusion-weighted images (b,e), and colored FA maps (c,f).

Discussion

The results from our study show that high-resolution DTI using PROPELLER EPI acquisition indeed benefits from the RG method. The RG method is compatible with parallel imaging in principle, hence could be used in combination with PROPELLER EPI with SENSE [3]. Compared with field map correction, the RG method does not need extra acquisitions to obtain accurate field maps for correction. The RG method is also computationally economic [4,5], therefore does not increase image reconstruction time substantially. Another important advantage of the RG method is that it also corrects EPI distortions arising from eddy current effects, as long as the distortions are opposite in directions when the phase encoding gradient is reversed in polarity. In contrast, the eddy current distortions would not be correctable by field map methods, because a field map does not include information on eddy currents.

Conclusion

The RG method reduces EPI distortion, therefore helps reducing image blurring for PROPELLER EPI acquisition. Combining the advantages of SENSE compatibility, less computing time, and eddy current correction capability, the reversed gradient method is an effective approach for high-resolution diffusion tensor imaging with PROPELLER EPI acquisition using large matrix size at high fields.

Reference

[1] Wang FN, et al, MRM, 54:1232 (2005). [2] Jezzard P, et al, MRM, 34:65 (1995). [3] Chuang TC, et al, 12th ISMRM, 2004. [4] Chang H, et al, IEEE Trans. Med. Imag, 11:319 (1992). [5] Morgan PS, et al, JMRI, 19:499 (2004).