An extended PSF mapping method for distortion correction in DW-EPI with both forward and reverse phase-encoding polarity at UHF

Myung-Ho In[1], Oleg Posnansky[1], Erik B Beall[2], Mark J Lowe[2], and Oliver Speck[1]

[1]Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Germany, [2]Radiology, Imaging Institute, Cleveland Clinic, Cleveland, OH, United States

INTRODUCTION

Echo planar imaging (EPI) is the most popular technique for diffusion tensor imaging (DTI). However, it suffers from geometric distortions that can locally either stretch or compress the image. Contrary to stretched areas, spatial information is lost in strongly compressed areas where multiple voxels collapse. Moreover, distortions are more severe at ultra-high field (UHF) such as 7T. To correct for geometric distortions, previous studies have acquired two diffusion weighted (DW) EPI sets with reversed phase-encoding (PE) polarity and combined after distortion correction (DiCo) [1-3]. The point spread function (PSF) mapping method has been shown to correct EPI distortions with high fidelity. However, it is time consuming when repeated for both PE polarities. In this study, an extended PSF method is proposed to correct distortions in DW EPI sets with forward and reverse PE polarities improving correcting fidelity.

MATERIALS AND METHODS

Single-shot spin-echo EPI scans with forward and reverse PE directions and a PSF reference scan, corresponding to EPIs with forward PE direction, were performed at 7T. The imaging protocols for EPI and PSF scans were: isotropic 2mm resolution, TR/TE=5910/56 ms, partial Fourier 6/8, Grappa factor 2, 52 slices, 4 homogeneously distributed scans with b-value=0, and 36 DW scans with non-collinear gradient directions with b=1000s/mm^2 (total 80 scans). The PSF data were acquired with an acceleration factor of 2 in the PSF dimension corresponding to 64 scans.

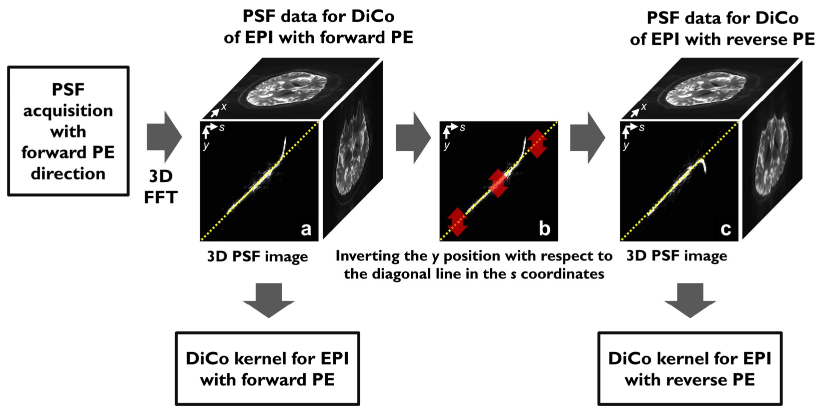

Fig. 1 The proposed reconstruction pipeline.

In order to correct distortions in EPIs with forward PE direction, a kernel was calculated from the measured PSF data as described in [4]. The measured PSFs were deviated from the diagonal along the distorted direction (*y*) in the non-distorted coordinates (*s*) (Fig. 1a). The corresponding PSFs leading to opposite image distortions were assumed to deviate from the diagonal with the opposite polarity direction along the *y* direction. Assuming that the PSF's shape is independent of the *y* direction, the corresponding PSF data were obtained using inverting the *y* position with respect to the diagonal line in the *s* coordinates (Fig. 1b) and used for calculating a kernel to correct distortions in EPI with reversed PE direction (Fig. 1c). Fractional anisotropy (FA) maps were calculated using FSL [5] after i) eddy current correction and registration [5] and ii) the proposed distortion correction. For comparison a reference image (Ref.) without distortions was calculated from the PSF data [4].

RESULTS AND DISCUSSION

Figure 2 shows the geometric agreement of the distortion corrected EPIs with forward and reverse PE polarities. The brain outline in the frontal areas and the geometry of both corrected EPIs agree very well with the reference image. Although the spatial resolution couldn't be fully recovered in strongly compressed areas for each individual EPI set, the resolution can be recovered from the corresponding EPI with reverse PE polarity as shown in the FA maps of Fig. 2 (see arrows). Both distortion-corrected EPIs may be combined with a suitable weighting into a final EPI without local loss of spatial resolution.

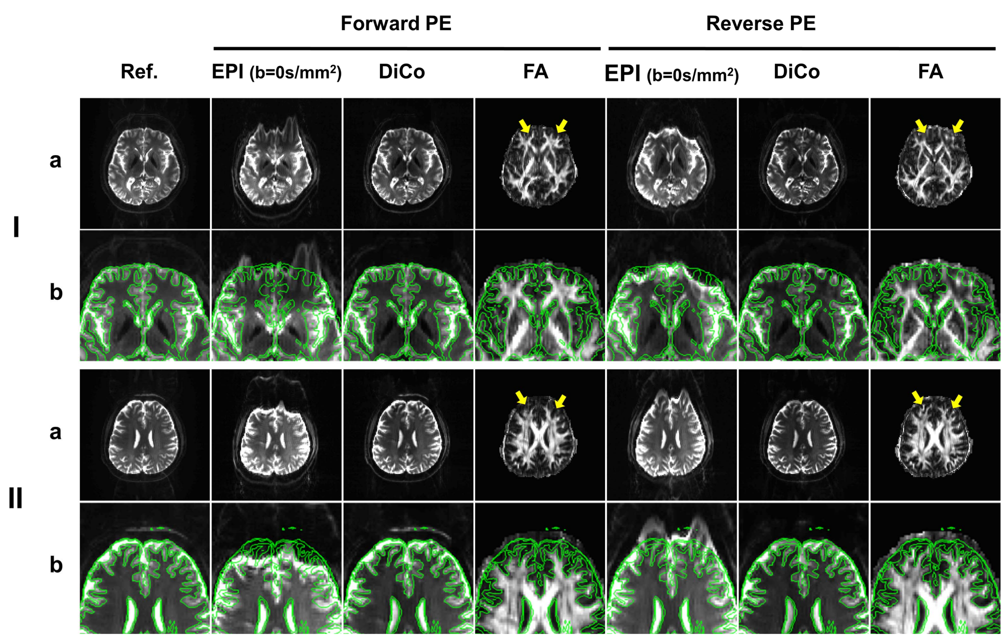

Fig. 2 The distortion corrected images and FA maps. Strong distortions appear to be either stretched (I) or compressed (II) depending on slice positions in EPI with forward PE direction and the effects are opposite in EPI with reverse PE direction. The green contours calculated from the reference image were overlaid onto the enlarged images (b) of the full FOV images (a).

CONCLUSION

The results demonstrate that the proposed method can correct distortions in EPIs with forward and reverse PE polarities with high fidelity and without repeated PSF scan for the reverse PE direction. In future work, an optimal weighting algorithm for the combination will be investigated.

REFERENCES

[1] JL Andersson et al., *Neuroimage* 2003; **20**:870-8
[2] D Holland et al., *Neuroimage* 2010; **50**:175-83
[3] KV Embleton et al., *HBM* 2010; **31**:1570-87
[4] MH In and O Speck, *MAGMA* 2012; **25(3)**:183-92
[5] FSL (http://fsl.fmrib.ox.ac.uk/fsl/)

ACKNOWLEDGEMENTS Grant support by DFG-grant (SP632-4).