Geometric Distortion Correction of DTI using Accelerated PSF Mapping based Reconstruction at 7 Tesla

M-H. In[1], and O. Speck[1]
[1]Biomedical Magnetic Resonance, Otto-von-Guericke-University, Magdeburg, Germany

INTRODUCTION

Although diffusion tensor imaging (DTI) allows the observation of molecular diffusion in tissue, it severely suffers from distortions due to B_0 field inhomogeneity, susceptibility, and chemical shift, as well as eddy currents induced by the diffusion encoding gradients, especially at ultra high field such as 7T. These cause geometric and intensity distortions in MR image formation. Moreover, the distortions vary according to the diffusion encoding direction. Ideally, a correction method should take these direction-dependent distortions into account. However, reference data based methods are very time consuming when repeated for all diffusion encoding directions. In this study, a point spread function (PSF) mapping based reconstruction with an improved acceleration technique is proposed for the correction of direction-dependent distortions in diffusion tensor imaging.

THEORY

In the PSF method, integration of the 3D PSF data $I(x,y,s)$ along the distorted dimension (s) yields an undistorted image $I_{undistorted}(x,s)$ [1-4]:

$$I_{undistorted}(x,s) = \int I(x,y,s)\,dk_y \qquad (1)$$

MATERIALS AND METHODS

In order to allow fast acquisition of the PSF, two acceleration methods along the PSF dimension are employed. A high reduction of the field of view (rFOV factor 16) combined with only 3 acquisitions with low rFOV (factor 4) in the center of the PSF dimension (low resolution). Despite the sparseness of the PSF data, strong FOV reduction leads to fold-over effects. The low resolution data are used to resolve this ambiguity. The reconstruction for the proposed method is illustrated as flowchart in Fig. 1. Two shift maps with and without wrapping effects are calculated from the 1st and 2nd part of the PSF data, respectively. The wrapped shift map is unwrapped using the shift map without fold-over effects and the final shift map is obtained after smoothing and weighted linear extrapolation of the shift map to the areas outside of the mask region [6]. The integral of the unwrapped 3D PSF data along the distorted dimension (y) yields an undistorted image as described in Eq. (1).

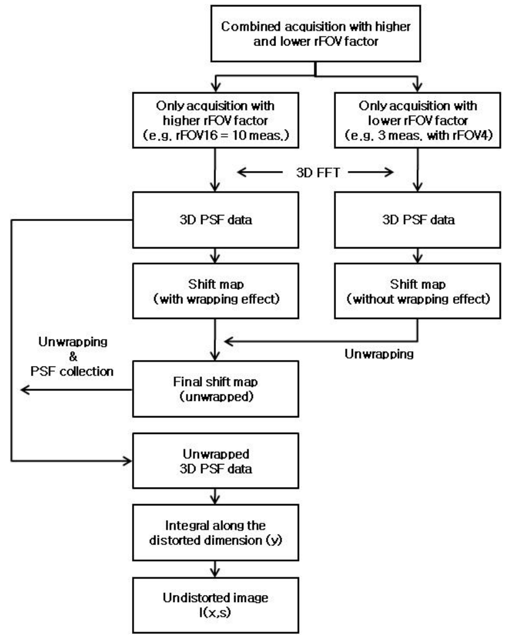

Fig. 1 The proposed reconstruction pipeline.

For experimental verification, axial single-shot spin echo EPI DTI was used on a partially filled oil phantom at 7T (Siemens Healthcare, Erlangen, Germany). A diffusion sequence was modified in order to acquire the PSF data in all directions. The experimental parameters were TR/TE = 1000/69 ms, Matrix size = 160×160, FOV = 224×224 mm, Thickness = 1.4mm, GRAPPA factor 3, partial Fourier 5/8, b-value = 0 and 1000 s/mm^2, 6 directions and 3 slices.

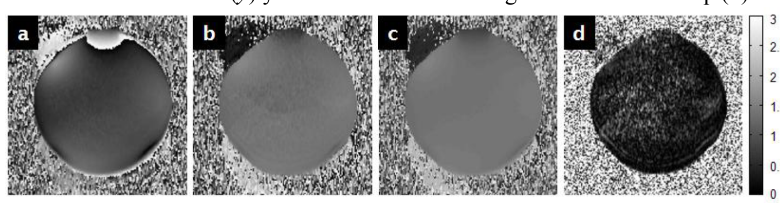

Fig. 2 The shift map with (a) and without (b) fold-over effect calculated from each 3D PSF data. (c) combined high fidelity shift, and (d) shows the difference between (b) and (c)

RESULTS AND DISCUSSION

Figure 2 shows the unwrapping procedure which can be performed robustly since the differences between two shift maps with (Fig. 2a) and without fold-over effects (Fig. 2b) are localized and continuous. Figure 3 displays undistorted image in comparison to the original. Due to different diffusion gradient eddy current effects, distortions are represented differently as shown in Fig 3a, 3b and pronounced differences occur (Fig. 3c). In contrast, the proposed method corrects the direction-dependent distortions robustly (see Fig. 3d, 3e and 3f). Moreover, the proposed method yields higher SNR due to the multi-shot nature of the PSF method (similar to 3D acquisitions). Since DTI acquisitions frequently use multiple averages due to their low SNR, the proposed method can be used with a corresponding reduction of averages. Thereby, the SNR and scan time are maintained while the distortions are largely corrected.

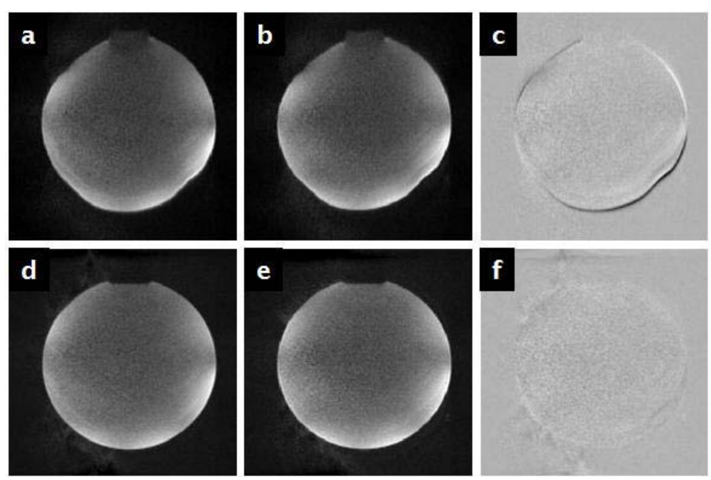

Fig. 3 The distortion correction results in a phantom image. (a) and (b) distorted EPI images with different diffusion gradient directions, (c) a difference map between (a) and (b), (d) and (e) corrected results of (a) and (b) by the proposed method, and (f) shows the difference map between (d) and (e).

CONCLUSION

The results demonstrate that the proposed method can correct direction-dependent distortions in diffusion tensor imaging without loss in SNR per unit time. Opposed to image based retrospective correction methods is allows a model free determination of distortions in geometry and intensity with high fidelity.

REFERENCES

[1] Matthew D. Robson, et al., *MRM*, 1997; **38**:733-740
[2] Huairen Zeng, et al., *MRM*, 2002; **48**:137-146
[3] M. Zaitsev, et al., *MRM*, 2004; **52**:1156-1166
[4] Joseph W. Stevick, et al., *MRM*, 2008; **59**:598-606
[5] O. Speck, et al., MAGMA, 2008; 2008; 21(1-2): 73-86
[6] M.H. In, et al., ISMRM, 2010

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