Distortion Correction Method for Single Echo DTI at 7T MRI using Non-distortion and Distortion Dimension Combined PSF Mapping Technique

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INTRODUCTION

Diffusion tensor imaging (DTI) is a non-invasive MRI technique for in vivo measurement of the diffusion of water molecules, and with such information one can directly correlate the shapes and directions of nerve fibers or nerve bundles in the brain. However, especially in the case of high resolution (or long TE) at higher magnetic field imaging like 7T MR, the DTI images severely suffer from distortions due to B_0 field inhomogeneity, susceptibility, and chemical shift, as well as eddy current. In order to overcome aforementioned geometric distortion problems, we present a improved PSF mapping method which employs both the distortion dimension (y-dimension) and the non-distortion dimension (s-dimension) PSF mapping technique [3], instead of previously employed non-distortion [1] or distortion dimension PSF mapping technique [2].

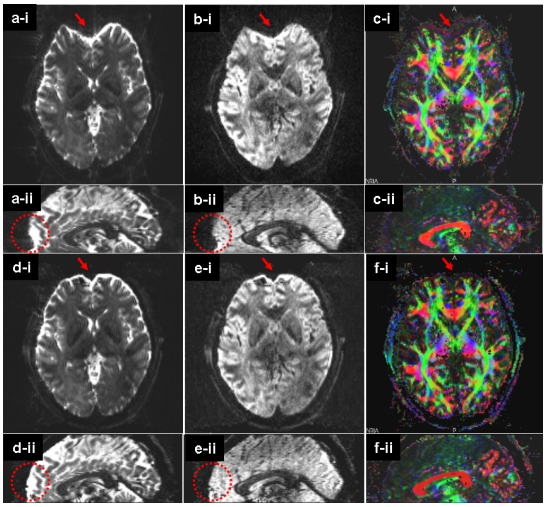

Fig.1. (a-c) Uncorrected images. (d-f) Corrected images. These images are corrected by s-y combined PSF correction method. (a,d) No diffusion weighted (b=0) images. (b,e) Diffusion weighted images (b=800). (c,f) Colored FA images.

MATERIALS AND METHODS

As the magnetic field strength increases the T_2 decay occurs faster. Therefore, to acquire high resolution and high SNR 7T DTI data, we should minimize TE. In order to minimize TE and to increase SNR, we modified EPI based double echo diffusion sequence with EPI based single echo diffusion sequence, which reduced 16ms from the double echo diffusion sequence. Then we made single echo diffusion PSF sequence. The single echo diffusion PSF sequence is based on no diffusion weighted (b=0 s/mm^2) single echo diffusion sequence readout with an added conventional gradient echo sequence with phase encoding steps before the start of blips. This sequence is based on PSF sequence developed by Zaitsev et al. [1]. With this PSF sequence we can derive the combined PSF pixel shift map [3]. Then we applied this combined shift map to with (b=800 s/mm^2) and without (b=0 s/mm^2) diffusion gradient data set to correct the geometric distortion. The experimental parameters are FOV = 224x224 mm, Thickness = 1.4 mm, Matrix = 160x160, TR = 10000 ms, TE = 68 ms, GRAPPA factor 2, b-value = 0 and 800 s/mm^2, 20 direction, 4 averages and 60 slices. To reduce eddy current, we used sinusoidal type readout gradient. All procedures are currently implemented using Matlab (MathWorks, Natick, MA). For data acquisition, 8-channel Tx/Rx home made coil was used for in-vivo human brain using 7.0T MRI (Siemens Medical System, Erlangen, Germany). The tractography images are reconstructed by using MedINRIA(http://www-sop.inria.fr)

RESULTS AND DISCUSSION

Fig.1 shows the results of diffusion weighted images corrected by non-distortion dimension and distortion dimension (s-y dimension) combined PSF mapping method [3] in human brain. Figure1 (a-c) images display three kinds of uncorrected images (no diffusion weighted (a), diffusion weighted (b) and colored FA (c) image) and (d-f) images show three kind of corrected images (no diffusion weighted (d), diffusion weighted (e) and colored FA (f) image). In uncorrected images (Fig.1 (a-c)), the frontal area is severely stretched along anterior and posterior direction because of susceptibility artifact (see the red circle in Fig.1 (a-ii) and (b-ii) and the red arrow in Fig.1 (a-i), (b-i) and (c-i)). The results of combined PSF corrected images (as shown in Fig.1 (d-f)), however, are completely corrected in the frontal area ((see the red circle in Fig.1 (d-ii) and (e-ii) and the red arrow in Fig.1 (d-i), (e-i) and (f-i)). Another corrected result is shown in Fig.2. In Fig. 2 we have segmented the corpus callosum based on uncorrected and corrected colored FA maps. To compare with uncorrected and corrected results, we overlaid segmented ROIs (see the red ROI) with T1 MPRAGE anatomy image. As shown in Fig.2(a) the genu of uncorrected corpus callosum is compressed along anterior and posterior direction compare with base T1 image (see the yellow arrow in Fig.2(a)). However after apply s-y combined PSF correction [3] method the corpus callosum is well matched with base T1 image. We display results of high resolution 7T single tractography images with four different ROIs were shown in Fig.3 ((a) Cortico spinal tract, (b) Corpus callosum, (c) Fornix, (d) Cingulum) and these results also match with base T1 image.

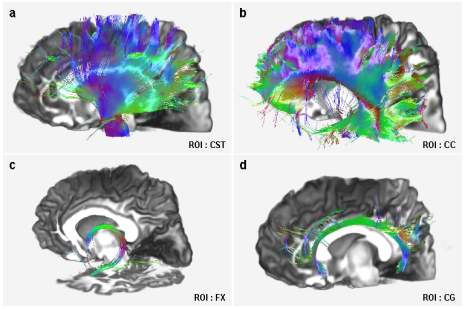

Fig.3. Results of 7T single tractography images. (a) Cortico spinal tract. (b) Corpuscallosum. (c) fornix. (d) Cingulum. All images are corrected by s-y combined PSF mapping method.

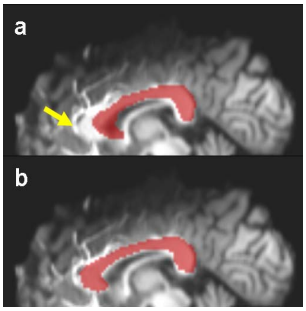

Fig.2. Result of diffusion weighted image corrected by s-y combined PSF mapping method. Red ROIs were drawn based on uncorrected (a) and corrected (b) colored FA images and overlaid this with T1 anatomy image.

CONCLUSION

By using single echo diffusion weighted sequence we can obtain high resolution and high SNR diffusion weighted image in 7T MRI. And by distortion and non-distortion dimensional combined PSF correction scheme [3], we can correct the geometric distortion both compressed and stretched area more accurately.

REFERENCES

[1] M. Zaitsev, et al., *MRM*, 2004; **52**:1156-1166 [2] M.H. In et al., ISMRM 18 (2010), submitted [3] S.H. Oh et al., ISMRM 18 (2010), submitted

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