Distortion Free High Resolution in vivo Whole Brain Diffusion Tensor Image on 7.0T MRI

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INTRODUCTION: Diffusion-weighted imaging (DTI) is a non-invasive MRI technique for in vivo measurement of the diffusion of water molecules. Based on this, we are able to visualize *in vivo* nerve fiber or nerve bundles in the brain; we referred this technique as Diffusion Tensor Imaging (DTI). At the present time, single-shot echo planar imaging (EPI) is the most prevalent sequence for diffusion imaging due to its high acquisition speed and motion insensitivity. Diffusion pulse sequences based on single-shot EPI inherit virtually all of the artifacts associated with EPI. For example, distortion caused by magnetic susceptibility variations and B_0 field inhomogeneity is frequently observed in the frontal sinus. The susceptibility artifacts increase with the echo time (TE). Moreover, when high resolution at higher magnetic field imaging like 7.0T the TE increases, and then diffusion weighted images severely suffer from distortions due to susceptibility artifacts. Although the introduction of parallel imaging techniques to single-shot acquisition methods like EPI has reduced distortion artifacts, the net acceleration for EPI is currently limited to realistic values of 3 and 4, producing images that still suffer from distortion artifacts, especially at high field strengths or higher spatial resolution. So there are still significant residual problems. This is particularly true at higher field strengths where there is an increased level of susceptibility artifacts. Therefore, accurate geometric distortion correction is essential for obtaining high-resolution diffusion tensor image.

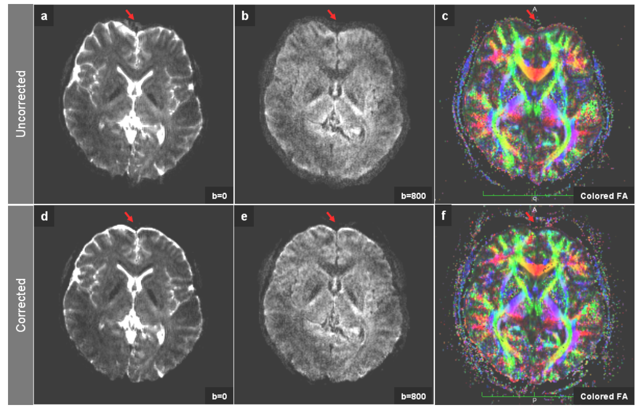

Fig.1. Comparison results of distortion correction method applied to diffusion weighted images in axial human brain. (a-c) Uncorrected images. (d-f) Corrected images. These images are corrected by combined dimension PSF correction method.

MATERIALS AND METHODS: MRI data were obtained on a 7.0T scanner (Siemens). The DWI sequence consisted of a single-echo (90°-180° RF) single-shot DW-EPI (TE/TR=68/9400ms, 1.0mm isotropic resolution, 20 DW-directions, b=0 and 800s/mm^2, GRAPPA 3, NEX 3 repeats and 80 slices). In order to reduce eddy current, we used sinusoidal type readout gradient. The DWI data were corrected for geometric distortions using a combined dimensional PSF mapping method [1]. Combined dimensional PSF mapping method, which takes into account both the distortion and the non-distortion dimensional PSF correction schemes, instead of previously employed singular method where either non-distortion [2] or distortion dimensional [3] correction are used. The 2D gradient echo sequence included the following parameters: TR/TE = 750/17.8 ms; flip angle = 45°; in-plane resolution = 0.25 mm; and the slice thickness was 2 mm. For data acquisition, 8-channel Tx/Rx home made coil was used. 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 combined dimensional PSF mapping method [1] in human brain. 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 arrows). The results of corrected images (as shown in Fig.1 (d-f)), however, are completely corrected in the frontal area (see the red arrows). To confirm results of distortion correction, we make tractography image of the Papez circuit. The Papez circuit of the brain is one of the major pathways of the limbic system and is chiefly involved in the cortical control of emotion. The Papez circuit plays a role in storing memory. The initial pathway was described as follows (Hippocampal formation→fornix →Mammillary bodies→mammillothalamic tract→Anterior thalamic nucleus→Cingulate gyrus→cingulum→ Parahippocampal gyrus→entorhinal cortex→hippocampus). Fig.2 shows the comparison results of PSF correction method applied to DTI of the Papez circuit. As shown in Fig.2(b) in uncorrected DTI image, anterior part of the Cingulum (green color, red arrow) is lost. The Fornix (blue color) and mamillothalamic tracts (red color, yellow arrow) reach improper anatomical termination. These tracts were particularly sensitive to distortions in A-P direction, which caused the majority of these tracts to reach anatomically incorrect regions of the brain. While the tracts of corrected DTI image (Fig.2(a)) reach the proper cortical regions. In corrected result, anterior part of the Cingulum (green color) is fully recovered, the Fornix (blue color) reaches the Mamillary body and mamillothalamic tract (red color) reaches the anterior thalamic region, which is its correct anatomical termination. We display series of high resolution 7.0T Papez circuit tractography image based on T_2*-weighted anatomy images were shown in Fig.3 and these results also match with base anatomical image. The Fornix (blue color) starts from hippocampal formation and goes through hippocampus and reaches to the Mamillary body. Mamillothalamic tract (red color) connects between Mamillary body and anterior part of thalamus. This pathway project Thalamus to cortical area (yellow color) and then finally go back to entorhinal cortex through Cingulum (green color). These results were well matcheded with the theory of Papez circuit and anatomy images.

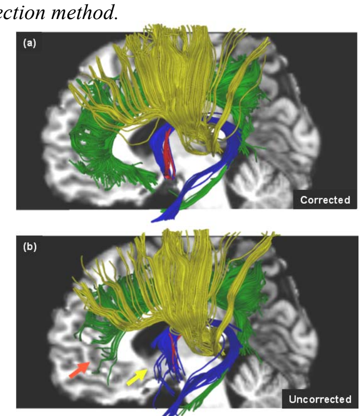

Fig.2. Comparison results of distortion correction method applied to diffusion tractography images of the Papez circuit. (a) Distortion corrected image and (b) Uncorrected image. (Blue: Fornix, Red: Mammillothalamic tract, Yellow: Thalamo-cortical projection fiber, Green: Cingulum)

CONCLUSION: These results show the efficacy of distortion correction for the anatomical accuracy of fiber tractography. With 7.0T distortion free high-resolution DWI data, we are able to visualize anatomically accurate fiber tractography image as well as small fiber tractography image such as mammillo thalamic tract, which not achievable at low field MRI (i.e. 1.5T or 3.0T).

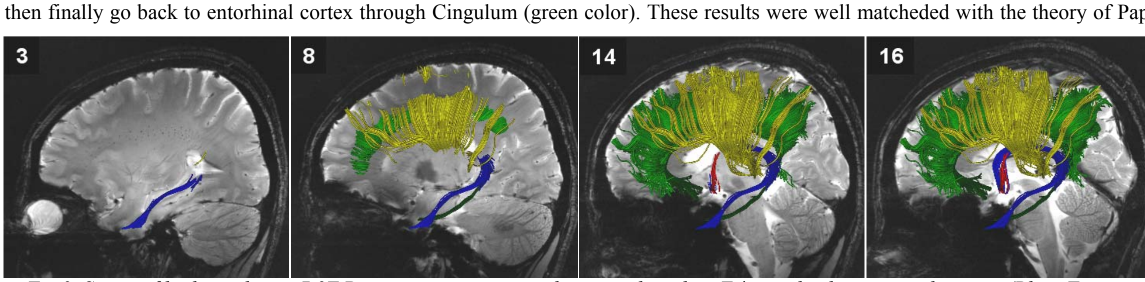

Fig.3. Series of high resolution 7.0T Papez circuit tractography image based on T_2-weighted anatomical images (Blue: Fornix, Red: Mammillothalamic tract, Yellow: Thalamo-cortical projection fiber, Green: Cingulum).*

REFERENCES [1] Oh SH, et al. Proc. ISMRM, 2010;18:1626. [2] Zaitsev M, et al. MRM 2004;52:1156-1166. [3] In MH et al. Proc. ISMRM, 2010;18:5070

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