Effects of correction of susceptibility distortion on DTI measures

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Introduction

Diffusion tensor imaging (DTI) has attracted great attention because of its potential use in studies of neurological disorders. Changes of fractional anisotropy (FA) and trace of tensor (Tr) have been used among other indices to indicate possible underlying pathological changes. For example, DTI parameters have been found to be important for early detection of Alzheimer's disease [1,2]. DTI data are mostly collected with Echo Planar Imaging (EPI), which suffers great geometric distortion (stretch, compress, or shear) and dropout due to field inhomogeneity induced by the susceptibility difference of different tissues [3]. These artifacts are more significant in phase encoding direction and they are worsened at higher magnetic fields. Although the geometric distortion and dropout is most severe at air-tissue interface such as temporal lobes and at surroundings of sinuses, small distortion and dropout in other areas such as surroundings of CSF can also cause misinterpreting and false value in DTI analysis. Distortion can also cause the inaccuracy of fiber tracking. Fiber tracking can even fail totally in areas with very severe distortions [4]. Because the diffusion tensor is calculated from voxel intensities of diffusion weighted images, changes in distribution of intensities in specific areas can affect the calculation of diffusion tensor and indices such as FA and Tr. To undistort EPI, utilization of field maps has been proved to be a successful method [3]. In this work, we examined quantitatively the effectiveness of the method by comparing the DTI results calculated with DWIs before and after susceptibility undistortion.

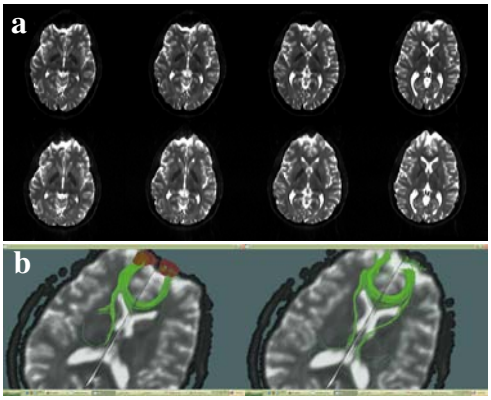

Figure 1. a) Upper row is the images before the correction, and the lower row is the images after the correction. b) Left image is the fiber tracking result before the correction. Right image is the fiber tracking result after the correction. The seeding ROI is selected at the frontal lobe.

Methods

Diffusion brain images of eight volunteers were acquired using a Siemens 3T Trio scanner. Phase encoding direction is from anterior to posterior. The first 4 sets had 6 diffusion-weighting directions while the second 4 had 12 directions. Image resolution was 128×128, voxel size was $1.79mm\times1.79mm\times8mm$. Field maps with exactly the same geometric settings with DW images were acquired using a double gradient echo sequence. The difference in 2 echo times was 2.36ms. Diffusion weighted images in 6 or 12 directions and b0 images were undistorted using the method described by Hutton et al. [3]. Another set of axial brain diffusion-weighted images with 60 diffusion directions was collected to show the effects of distortion correction on fiber tracking. The original and undistorted images were used for DTI calculation and fiber tracking with a home-built software, and DTI parametric maps were generated. Visual comparison of FA maps before and after undistortion was made. Four ROIs in different slices were selected in region of corpus callosum. FA values and corresponding variance were measured in these ROIs. The corpus callosum has white matter tract that connects the two cerebral hemispheres. FA value in corpus callosum is an important index in studies of early Alzheimer's disease [1,2]. These values can be affected by distortion because CSF surrounds it.

Results and Discussion

After the correction, the images show more fidelity as shown in Fig 1a. The compressed frontal lobe area is restored. With fiber tracking, we can observe extra symmetric fibers in corrected images that were missed in distorted images. The comparison of FA values (Fig. 2 left) and corresponding variance (Fig.2 right) in selected ROIs within corpus callosum are made. Paired t-test results show that, after undistortion, the FA values increase with a mean of 3.84% (p-value=0.006); variance of FA values reduces with a mean of 10.59% (p-value=0.005). The reduction of variance in FA value can be very useful because it means that the corrected values can be more sensitive in detecting early signs of diseases in patients.

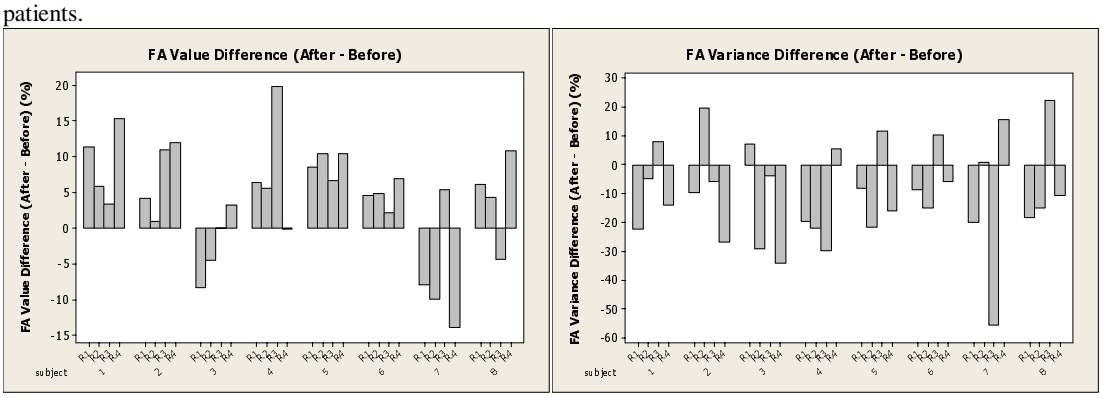

Fig 2. Comparison of the difference in FA value (left) and FA variance (right) between FA maps generated from DWIs before and after susceptibility undistortion. Eight groups of data are shown corresponding to 8 subjects. In each subject, four ROIs were compared. Results show significant increase in FA value and reduction in FA variance after correction.

Reference

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