Characterization and Correction of B0-Susceptibility Distortion in SENSE Single-Shot EPI-based DWI Using Manual Landmark Placement

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Introduction

Image distortion by B0-susceptability is one of the most significant problems of DTI, which is based on single-shot echo planar imaging (EPI). The degree of distortion can be drastically reduced by employing parallel imaging [1,2], but a significant amount of distortion still remains around sinus areas. In order to perform group analyses or volumetric studies based on DTI, it is of great importance to quantify the amount of distortion. Although various automated correction methods have been postulated, there are no widely accepted methods especially for parallel-imaging data, in which correction based on a phase map is not straightforward. In this paper, we applied manual landmark-based mapping and correction of the distortion. There are three purposes of the study. First, the amount of distortion in DWI using SENSE (r = 2.5) and a 1.5T magnet was characterized three-dimensionally. Second, we used the tool to identify areas with large distortion quantitatively, which will be later used to judge the confidence levels of group analyses. Third, the distortion map was used to correct the distortion.

Methods

Data acquisition: *In vivo* adult human data were acquired using A 1.5 T Philips Gyroscan NT system. A single-shot EPI sequence with the SENSE parallel imaging scheme (SENSitivity Encoding, reduction factor R = 2.5) was used for DTI data acquisition, with an imaging matrix of 96× 96 and a field of view of 240 × 240 mm (nominal resolution 2.5 mm), which was then zero-filled to a 256 × 256. Axial slices thickness was 2.5 mm parallel to the anterior–posterior commissure line. A total of 50 to 55 slices covered the entire brain and brainstem leaving no gap. The diffusion weighting was encoded along 30 independent directions and the b-value was 700 mm^2/sec. Five additional images with minimal diffusion weighting (b= 33 mm^2 /sec) were also acquired. Co-registered magnetization-prepared rapid gradient echo (MPRAGE) images of the same resolution were also recorded for anatomical guidance. **Distortion Characterization:** After overlaying the 25 by 25 grids (each grid has 10 by 10 pixels) on an isotropic diffusion weighted (ISO) image and corresponding MPRAGE image, we placed 30 to 40 landmarks for each slice on the correspondent anatomical features. The landmarks were restricted to move only along the phase-encoding axis on axial plane. A three dimensional (3D) vector field was acquired by linear interpolation from the landmark information. The landmark placement took typically 2.5 hours for one dataset. Distortion-corrected images were computed by third order B-spline interpolation [3] based on the 3D vector field. All the interpolation computation was performed with custom made software coded with Visual C++.

Results and Discussion

Fig. 1 shows the vector field overlaid with the T_1-weighted images. It clearly shows geometric distortions in the frontal and temporal lobes. The color bar indicates quantitatively the distortion amount in pixels. The positive (red) and negative (purple) values represent distortion in anterior and posterior directions, respectively. Fig. 2 shows the corrected ISO images in comparison with the original ISO images and a MPRAGE image. This study shows that the distortion in the SENSE-DWIs is mostly concentrated in the frontal and temporal lobes. The majority of the distortion is low frequency and within 5 pixels, which can be corrected simply by applying the inverse of the determined vector field. The results also specified concentrated areas with large and high-frequency distortion. While these areas can not be accurately corrected due to difficulties in placing landmarks for corresponding areas, this method can label such problematic areas with a large displacement. Compared with conventional automated methods, our approach is more time and labor consuming, but has more flexibility to properly identify and label the high-frequency distortion regions. For the future DTI-based quantitative studies, this 3D vector map can be used to exclude problematic brain regions.

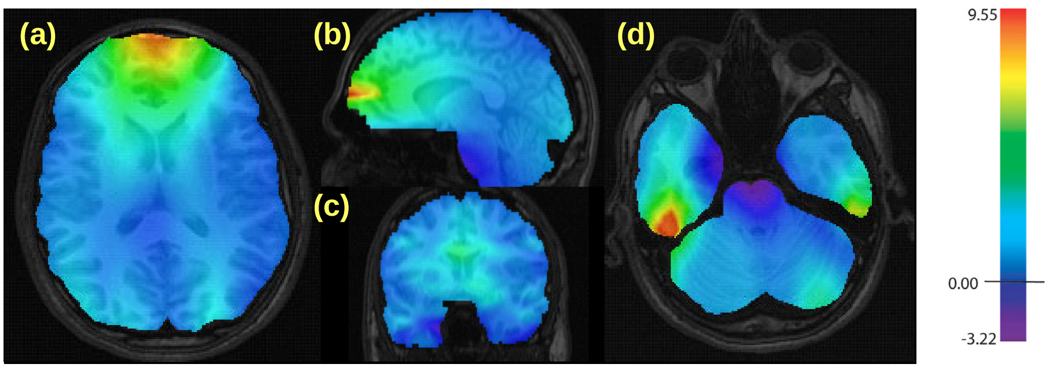

Fig. 1 Vector field overlaid with the T_1-weighted image. (a) upper axial plane, (b) sagittal plane, (c) coronal plane and (d) lower axial plane.

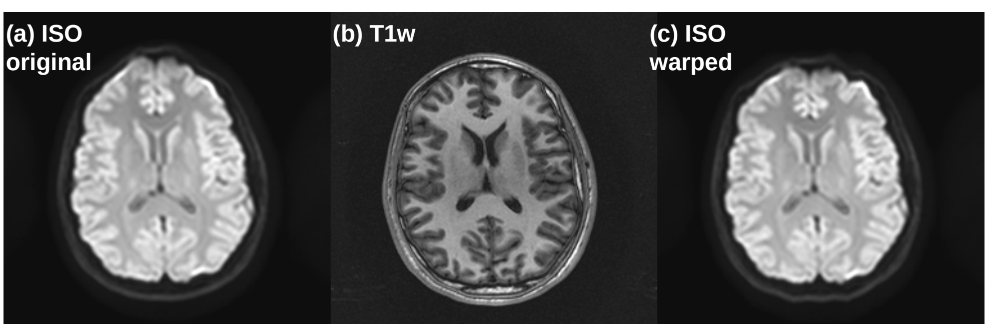

Fig. 2 ISO images before (a) and after (c) the correction and MPRAGE (b), used as an anatomical template

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Reference

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