High angular resolution diffusion imaging with B0 distortion correction at 7T

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Introduction: Recently 7T in vivo data have been used to demonstrate the feasibility of DTI (1) and Q-Ball imaging (2) for improved visualization of white matter anatomy with parallel imaging (1,2) and higher order shimming (2). However, increased B0 inhomogeneity at 7T, due to magnetic susceptibility variations in the head, complicates accurate analysis of diffusion weighted images (3). Up to this point there have been no detailed studies demonstrating the feasibility of B0 inhomogeneity corrections at 7T using HARDI data from EPI acquisitions. In this study, the effect of B0 inhomogeneity correction is investigated using B0 field maps and measurements of the spatial accuracy of fiber orientation distribution functions (FODs) calculated using the FORECAST (4) model.

Methods: Data were acquired on a 7T Philips Achieva whole body scanner (Philips Medical System, Cleveland, USA) using a 16 channel receiver SENSE head coil. Diffusion weighted SE-EPI and field map images were acquired with FOV = 240x240mm, voxel size = 2.5mm isotropic with no gap, 30 slices, image matrix = 96x96, TR/TE = 5500/72ms, SENSE reduction factor = 2, ΔTE = 1ms and b-value = 0 and 2000 s/mm^2 with 32 diffusion weighting directions and one T2 weighted image. Image distortions were corrected using the field map (5) and diffusion weighted images (both corrected and non-corrected) were registered to corresponding T2 weighted images. The FOD was calculated using Tikhonov regularization, penalizing negative values in the FOD (6), with a 4th order spherical harmonic expansion for each voxel in the ROI (Fig. 1).

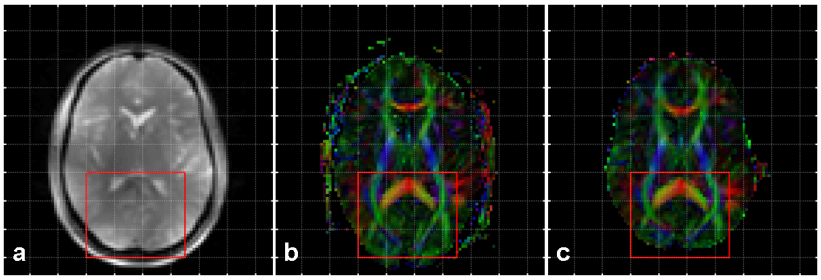

Figure 1. Gradient echo (a), FA before (b) and after (c) field inhomogeneity correction with ROI (red square).

Results: Figure 1 shows one of the gradient echo images (Fig. 1a) used to calculate the field map and FA maps before (Fig. 1b) and after (Fig. 1c) inhomogeneity correction. After the correction, the morphology of the brain anatomy (Fig. 1c) is much closer to the relatively distortion free gradient echo image (Fig. 1a), as can be verified visually using the grid lines overlaid on each image. Figure 2 shows FOD function plotted for each voxel in the ROI before (Fig. 2a) and after (Fig. 2b) correction (FA > 0.15). As shown in Fig. 2b, fibers are better aligned with anatomical structure after the correction.

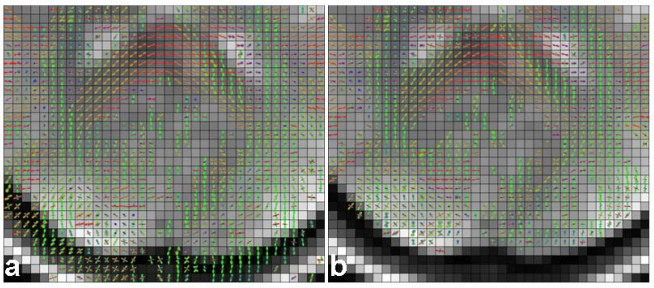

Figure 2. FOD plot before (a) and after (b) field inhomogeneity correction for the ROI in Fig. 1. FODs are shown superimposed on the multishot gradient echo image.

Discussion: This initial study confirms that HARDI measurements in ultra high field strengths involve serious field-related distortions. However, it shows that inhomogeneity correction using a static field map can provide more accurate delineation of anatomy and corresponding fiber structures. Though we made use of one phase-encoding direction in this study, using an optimized SENSE factor (3), reverse phase-encoding gradient (7) and RF inhomogeneity correction could provide further improvements in 7T HARDI image quality..

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