Quantitative evaluation of image-based distortion correction in diffusion tensor imaging of the breast

Cheng-Liang Liu[1], Matthew L Olson[1], Peixian Liu[1], Marko K Ivancevic[2], Constance D Lehman[1], and Savannah C Partridge[1]
[1]*Department of Radiology, University of Washington, Seattle, Washington, United States,* [2]*Philips Healthcare, Best, Netherlands*

Introduction:

Diffusion-weighted imaging (DWI) has shown promise for characterizing breast lesions based on the apparent diffusion coefficient (ADC)[1], and diffusion tensor imaging (DTI) measures of fractional anisotropy (FA) may further improve cancer detection and diagnosis[2,3]. A known challenge of DWI is that strong diffusion gradients in combination with echo-planar imaging (EPI) acquisition sequences cause directionally-dependent (eddy-current-based) distortions in diffusion-weighted images[4]. Resulting misregistration within the DWI sequence between the b=0 and different diffusion gradient images reduces the accuracy of computed DWI and DTI parametric maps. Our goal was to assess the utility of image-based distortion correction for improving spatial alignment and measurement accuracy in DTI of breast cancer.

Materials and Methods:

In this IRB approved study, 21 patients with invasive breast malignancies underwent DTI on a 3T Philips Achieva scanner with a 16-channel breast coil. DTI was acquired using a diffusion-weighted spin echo EPI sequence with TR/TE = 5336ms/61ms; SENSE = 3; NSA = 2; matrix = 240x240; field of view = 36x36 cm; slice thickness =5 mm; gap = 0. Diffusion gradients were applied in six directions with b values of 0 and 800 s/mm^2. Each DTI sequence was registered using a commercially-available automated 3D affine transformation algorithm (Diffusion Registration tool, Philips Healthcare)[5,6] that aligns each b=800 s/mm^2 image to the corresponding b=0 s/mm^2 image. Spatial alignment was quantified before and after registration as the percentage of overlap between lesion contours defined on the on the b=0 and six b=800 s/mm^2 images. DTI maps were computed from both the unregistered and registered datasets. Lesion DTI values, including: mean lesion contrast to noise ratio (CNR) on the combined DWI (geometric mean of the six b=800 s/mm^2 DWIs), ADC, FA, and eigenvalues (λ_1, λ_2, λ_3) were measured by region-of-interest (ROI), and compared between datasets by Wilcoxon signed-rank test. Effect of lesion type (mass vs. nonmass) and size (≤1cm vs. >1cm) were evaluated by Mann-Whitney U test.

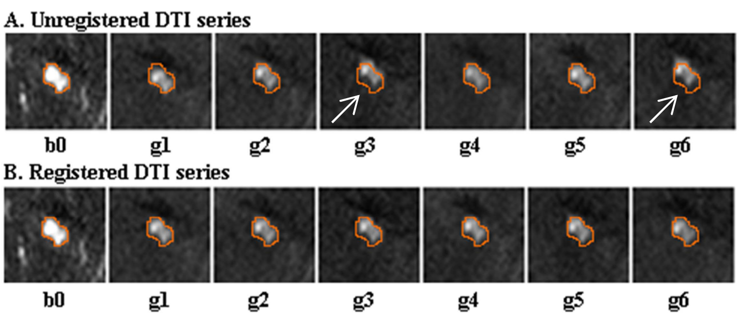
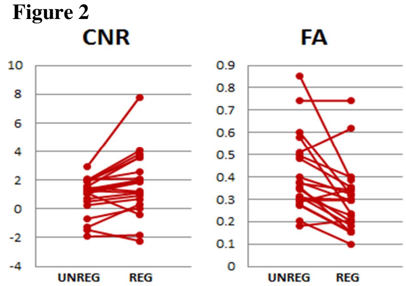


Figure 1: Comparison of lesion location on unregistered (A) and registered (B) DTI series. Lesion ROI was defined on the reference b0 image and propagated to each of the six diffusion gradient (b=800 s/mm^2) images (g1-g6). Significant misalignment of lesion location in g3 and g6 images (A, arrows) with respect to b0 boundary is mostly corrected by the registration algorithm (B).

Figure 2



Results:

The study included 21 lesions (n=15 mass, n=6 nonmass), ranging 5-105mm (median, 15mm) in diameter. Mean spatial alignment between the b=0 and b=800 s/mm^2 images increased from 78% to 90% (p=0.02), Fig 1. With registration, mean lesion CNR increased from 0.92 to 1.72 (p=0.002), Fig 2. Lesion eigenvalues converged: mean λ_1 decreased from 1.71 to 1.52×10^{-3} mm^2/s (p=0.004), λ_2 decreased from 1.28 to 1.16×10^{-3} mm^2/s (p=0.007), and λ_3 increased from 0.68 to 0.85×10^{-3} mm^2/s ($p < 0.001$). Mean lesion FA decreased from 0.41 to 0.30 (p=0.0002), Fig 2. Mean lesion ADC also decreased from 1.22 to 1.18, but did not reach statistical significance (p=0.07). Effects of registration on DTI measures were not different for mass vs. nonmass (p>0.05), but effects on FA and λ_3 tended to be greater for larger (>1cm) lesions than for smaller lesions (p=0.06, p=0.03, respectively).

Discussion:

Registration improved lesion alignment between DWIs, which agrees with a prior report in four patients[5]. Furthermore, registration increased lesion CNR, a measure of conspicuity, and decreased anisotropy. This is consistent with misalignment in the DTI series producing elevated anisotropy measures, particularly at structural boundaries. Lesion ADC values also decreased slightly with registration, but were less affected by misalignment than other DTI measures. In conclusion, image-based distortion correction can improve lesion conspicuity and may be essential for quantification of DTI parameters beyond ADC. While our study evaluated a single registration algorithm, similar tools are commercially-available through other manufacturers and CAD software vendors.

References: **1.** Partridge SC, et al. Am J Roentgenol 2009; 193(6):1716-22. **2.** Partridge SC, et al. JMRI 2010; 31(2):562-70. **3.** Eyal E, et al. Invest Radiol 2012; 47(5):284-91. **4.** Le Bihan D, et al. JMRI 2006;24(3):478-488. **5.** Arlinghaus LR, et al. JMRI 2011; 33(5):1063-70. **6.** Netsch T, et al. IEEE Trans Med Imaging 2004; 23(7):789-98.

Acknowledgements: Funding support provided by NIH R01 CA151326.