Quantitative evaluation of image-based distortion correction in diffusion tensor imaging of the breast
Cheng-Liang Liu1, Matthew L Olson1, Peixian Liu1, Marko K Ivancevic2, Constance D Lehman1, and Savannah C Partridge1

1Department of Radiology, University of Washington, Seattle, Washington, United States, 2Philips 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 diagnosis2,3. 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 images4. 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/mm². 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/mm² image to the corresponding b=0 s/mm² 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/mm² 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/mm² DWIs), ADC, FA, and eigenvalues (λ₁, λ₂, λ₃) 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.

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/mm² 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 λ₁ decreased from 1.71 to 1.52×10⁻³ mm²/s (p=0.004), λ₂ decreased from 1.28 to 1.16×10⁻³ mm²/s (p=0.007), and λ₃ increased from 0.68 to 0.85×10⁻³ mm²/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 λ₃ 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 patients5. 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.


Acknowledgements: Funding support provided by NIH R01 CA151326.