Effects of gradient nonlinearity correction on DTI ADC and FA measurements for assessing breast cancer treatment response

David Newitt[1], Ek Tsoon Tan[2], Lisa Wilmes[1], Hee Jung Shin[3], Luca Marinelli[2], and Nola Hylton[1]

[1]*Radiology and Biomedical Imaging, UCSF, San Francisco, CA, United States,* [2]*GE Global Research, Niskayuna, NY, United States,* [3]*Radiology, Asan Medical Center, University of Ulsan, Korea*

Introduction:

Gradient nonlinearity (GN) is a significant source of error for MRI diffusion measures [1] and presents confounding effects when comparing measurements between patients, between visits for the same patient, and between contra- and ipsi-lateral measurements within a single study. GN results in spatially-varying diffusion-encoding b-values, and generally increases with increasing distance from magnet isocenter. It is thus of great concern in breast imaging where large imaging FOV (>30cm) and large spatial offsets from isocenter of the tissue of interest (>8cm) are common. Recent work [2] indicates that diffusion tensor imaging (DTI) of the breast may provide important information for characterizing breast cancers.

Study purpose: Determine the effects of GN correction (GNC) on ADC and FA absolute and % change measurements in a study of breast cancer.

Materials and Methods:

40 patients with biopsy confirmed locally advanced breast cancer (LABC) receiving neoadjuvant chemotherapy (NAC) and enrolled in an institutional review board-approved, HIPAA compliant, clinical trial at our institution were imaged on a GE Signa 1.5T scanner. All patients gave informed consent. DTI (EPI, 6 directions, b=0,600s/mm^2) was acquired pre-NAC (V1) and after 3 cycles of treatment (V2). A GNC program (GE Global Research, Niskayuna, NY)[3] utilizing 5th order spherical harmonics was used to retrospectively generate ADC and FA maps. Tumor ROI encompassing regions hyperintense on b=600 s/mm^2 combined images and hypointense on corresponding ADC maps were defined by a radiologist on a single representative slice (Figure 1). Tumor ROI varied in area from 0.16 – 19.2 cm^2 (mean=3.2cm^2). Reference ROI (1cm^2 circles) were defined in normal appearing breast tissue in the contra-lateral breast. GN corrected and uncorrected mean ADC and FA values were calculated, along with percent change from V1 to V2 (ΔADC, ΔFA).

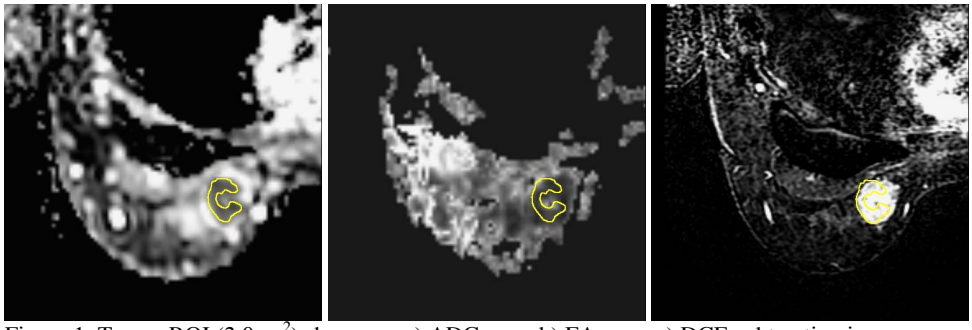

Figure 1. Tumor ROI (3.0cm^2) shown on a) ADC map; b) FA map; c) DCE subtraction image.

	ADC (10^{-3} mm^2 / s)		FA	
Correction	Tumor	Normal	Tumor	Normal
None	1.15 (.14)	2.05 (.23)	0.18 (0.06)	0.21 (0.07)
GNC	1.02 (.13)	1.79 (.19)	0.17 (0.06)	0.19 (0.06)
% GNC Change	-11.2 (3.2)	-12.6 (4.4)	-5.5 (10.9)	-9.2 (18.5)
	ΔADC		ΔFA	
None	32.8 (19.6)	-0.39 (7.5)	13.5 (22.8)	6.69 (24.3)
GNC	33.5 (19.4)	-0.24 (7.0)	20.8 (30.3)	2.38 (31.5)

Table 1. Mean (SD) of diffusion parameters with and w/out GNC for V1 (ADC, FA) and % change V1 to V2 (ΔADC, ΔFA), and mean change with GNC for V1.

Results: Mean and SD of the diffusion parameters are shown in Table 1. On average GNC reduced the measured V1 tumor ADC by 11.2% and normal tissue ADC by 12.6%, this difference due to the ROI for normal tissue being on average slightly further from isocenter (10.7cm v 9.9cm in x-y plane). The percent change in ADC from V1 to V2 (ΔADC) mean was not appreciably changed with GNC (32.8% v. 33.5% for tumor, -0.4% v -0.2% normal, without v. with GNC), but for individual patients GNC resulted in a difference in the ΔADC ranging from -5% to 8% (RMS change = 3%). This difference was strongly correlated (R^2=0.86) with changes in the ROI position between visits as shown in Figure 2. FA was also generally reduced by GNC, 6% in tumor and 9% in normal (V1). Little correlation (R^2=0.13) was observed for change with GNC in ΔFA with change in ROI x-y centroid position.

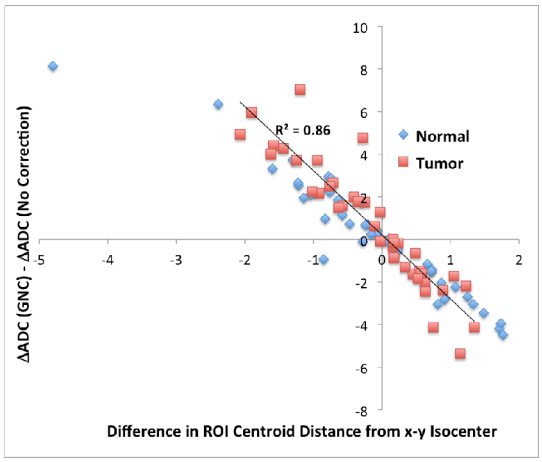

Figure 2. Change in ΔADC with application of GNC plotted against the difference in off-axis position of the ROI centroid, showing positional dependence of correction size..

Discussion: At typical breast MRI positions GNC corrected errors of up to 10-15% in ADC. While GN effects may be reduced by measuring changes such as ΔADC, errors up to 6% were still observed in individual cases, with an RMS error of 3%. FA showed comparable changes. GNC will not affect the many other potential sources of errors; including EPI-distortion, diffusion-distortion, motion artifacts, and B1-inhomogeneity.

Conclusion: GNC can correct errors that may be significant against typical changes of MRI DTI parameters with treatment.

References:

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