Gradient nonlinearity correction to improve ADC accuracy and standardization in breast cancer clinical trials

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Introduction:

Gradient nonlinearity (GN) is a significant source of error for MRI diffusion measures [1]. This presents confounding effects when comparing measurements across different MR scanners and configurations in multi-center clinical trials. GN generally increases with increasing distance from magnet isocenter, and thus is of great concern in breast imaging where large spatial offsets are common. Study purpose: To determine the improvement in ADC accuracy resulting from GN correction (GNC) at typical breast imaging positions for multiple scanner configurations, and to measure the effect of GNC on ADC measurement in human subjects.

Materials and Methods:

Dual ice-water phantoms developed for a multi-center breast cancer trial were imaged at 3 sites using the configurations shown in Table. 1. The FOV was set to cover both right (R) and left (L) breast positions. A normal volunteer (Female, 22y) and a subject with breast cancer (F, 38y) were imaged with the Site1-Z configuration. A GNC program (GE Global Research, Niskayuna, NY)[2] utilizing 5th order spherical harmonics was used to retrospectively generate ADC maps for phantom and human subject scans. Correction was done on 3-direction data (site 1) and trace data (sites 2 and 3). Uncorrected and corrected ADC values were compared as a function of anterior-posterior (AP) and superior-inferior (SI) positions for both R and L breast coil offsets.

Table 1: Configurations for HDxt Scanners (GE Healthcare, Waukesha, WI)

Config.	Grad Mode	b val. (s/mm^2)	TE	ESp	Rx Coil
Site1-W	Whole (WGM)	0,100,600,800	95	912	8ch, Sentinelle
Site1-Z	Zoom (ZGM)	0,100,600,800	68	664	8ch, Sentinelle
Site2	N/A	0,800	98	748	8ch, Sentinelle
Site3	N/A	0,800	98	884	8ch, GE
Common values: 1.5T; Axial; 3-axis DW-single shot EPI; FOV=32cm.					

Results:

Figure 1a,b show phantom ADC maps (Site1-WGM, Site1-ZGM), Figure 1c shows the variation in the AP direction for original and GNC-ADC for these two configurations as percent error from 1.1×10^{-3} mm^2/s. In ZGM the GNC reduced errors to <5% over this AP range for both R and L phantoms. In WGM the uncorrected errors were much smaller, but residual errors after GNC were larger. Imaging artifacts appeared much more significant in WGM as seen at the less anterior positions in Figure 1a,c. Figure 1d shows the results for left phantom ROI analysis of scans from the 3 sites. GNC significantly improved the accuracy at sites 1 and 2. Site 3 showed a small improvement, but had inherently good linearity with uncorrected errors <4% due partially to using a breast coil that placed the phantoms closer to isocenter. Figure 2 shows a breast with 3 areas of decreased ADC indicative of cancer. GNC reduced the measured mean ADC in ROI1,2,3 by 6.5%, 8.0%, and 10.7% respectively, consistent with known bias error that increases with RL and AP distance from isocenter. In 2 scans of a volunteer at table SI positions 2.8cm apart, GNC slightly reduced the mean absolute change in anatomically matched ROIS from 5.7% to 4.4% over a 16 slice (5.6cm) SI range.

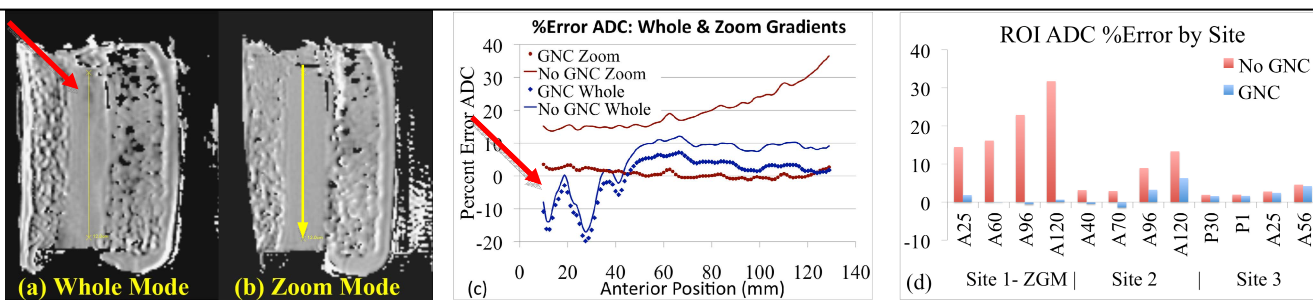

Figure 1. ADC maps from left ice-water phantom for (a) Site1-W and (b) Site1-Z; (c) Variation in ADC accuracy along the yellow line drawn in 1(b) from A10 to A130 in the left breast phantom. Oscillations at A10-A40 resulted from a reproducible EPI artifact in whole gradient mode (red arrows); (d) Reduction of ADC error with GNC for 3 different imaging systems.

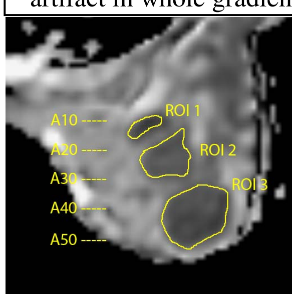

Figure 2. ROI analysis of multiple tumor regions.

Conclusions:

GNC greatly reduces ADC bias errors in typical breast imaging positions. This can be used to reduce inter- and intra-scanner variations. On dual-gradient mode scanners GNC allows maintaining ADC accuracy while using a gradient mode with significantly shorter TE and echo spacing (ESp), and improved image quality.

References:

1. Malyarenko D, Galban CJ, Londy FJ, et al. Multi-system repeatability and reproducibility of apparent diffusion coefficient measurement using an ice-water phantom. Epub: J Magn Reson Imaging. 2012
2. Ek T. Tan, Luca Marinelli, Zachary W. Slavens, et al. Improved Correction for Gradient Nonlinearity Effects in Diffusion-Weighted Imaging. J Magn Reson Imaging. 2012 (in press)

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