# Gradient nonlinearity Correction on ADC measurement: A multi-platform study on Diffusion weighted imaging

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**Purpose:** Diffusion weighted imaging (DWI) has been used in clinical body applications where ADC measurement at off iso-center locations is performed [1,2]. It is known that gradient non-linearity can introduce an error in the measured ADC value off isocenter [3]. In this work, we studied off isocenter effect on the measured ADC values in different types of scanners from a single vendor and investigated the possibility of correcting ADC error using gradient field map.

**Methods:** A RSNA QIBA phantom containing three water vials and two sets of polymer polypropylene vials with different concentrations immersed in ice water to maintain temperature at 0°C was used for ADC measurements. DWI was performed using an EPI sequence with 3 scan trace mode, bipolar diffusion encoding gradients; TR/TE=5000/136ms; b-values=0, 500,1000,2000 s/mm$^2$; FOV= 400×400; acquisition matrix= 256×256; 5 slices with slice thickness= 5 mm, at isocenter (X0Z0), with 10cm displacement (R/L) along X axis (X10Z0), with 10cm displacement (H/F) along Z axis (X0Z10) and also with the combination of 10cm displacements in both X and Z axis (X10Z10). The same measurement was repeated on eight different scanners (Siemens Medical Solutions, Erlangen, Germany), including four 3T scanners (Prisma, Trio, Skyra, Verio) and four 1.5T scanners (Area, Ananto, Symphany, Espress) with different gradient coils. To measure the ADC value, ROIs were placed on ADC maps generated by the scanner software. ADC errors due to gradient nonlinearity at each off isocenter locations (X10Z0, X0Z10 and X10Z10) was predicted by calculating diffusion encoding gradient errors based on the gradient coil specific field maps expressed as a set of spherical harmonics [5,6]. A statstical analysis is conducted to estimate difference between long bore system and short bore system.

**Results**: The average water ADC value measured at isocenter is 1120±69 ($10^{-6}$ mm$^2$/s). As shown in figure 1, the 1.5T long bore scanners have less off isocenter effect, which is consistent with gradient nonlinearity. While the X offset produces elevated ADC values, they are reduced after correction of gradient error. An opposite deviation in measured ADC with Z offset was also compensated after correction. The gradient nonliearity correction provides a corrected ADC value closer to water value in most of the scanner. Significant differences in gradient nonlinearty error were found between long bore scanner and short bore scanner in x10z0 (p=0.01), x0z10 (p=0.009) and x10z10 (p=0.001).

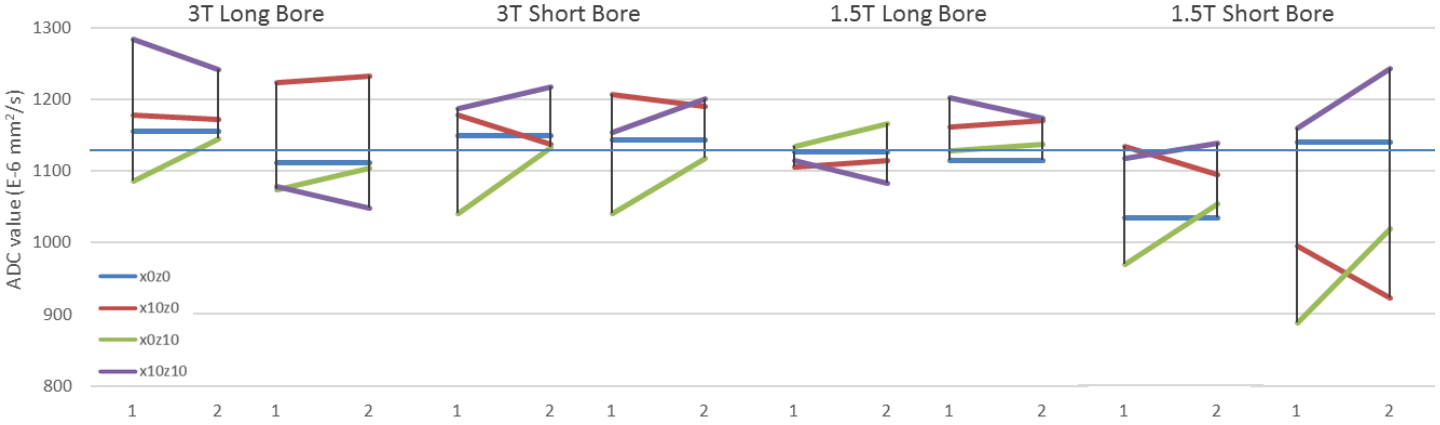


**Fig.1.** A figure shows ADC values (y axis) before gradient nonlinearity correction (shown as group 1 on x axis) and after the correction (shown as group 2) for 8 scanners. From left to right are two 3T long bore scanners, two 1.5T long bore scanners, two 3T short bore scanners, and two 1.5T short bore scanners. Values were colorized to represent ADC measurement at different position settings (blue:x0z0, red:x10z0, green:x0z10 and purple: x10z10). The average of water ADC values from 8 scanners (1120 μm$^2$/s) was marked as a blue solid line. The 1.5 long bore displayed the smallest bias from off-positioning effect but the most efficient correction was found in 3T long bore scanner.

**Conclusions:** Our study revealed that the error of measuring ADC value is significantly greater at non-center region in short bore scanners compare to long bore scanners and the error can be reduced by correcting gradient errors at off isocenter locations. Such correction could improve the results of ADC measurement in longitudinal study involving multiple scanners.

**Ref:** 1.Mori and Barker et al. 1999, Anato.Record. 257:102-9 2. Padhani et al. 2009, Neopplasia, 11:102-25. 3.Malyarenko,et al. 2013, jMRI 37:1238-46. 4.Chenevert et al.2011, jMRI 34:983-7. 5.Tan et al. 2013, jMRI 38:448-53. 6. Bammer at el. 2003, MRM. 50:560-9.