Geometric Distortion in Diffusion-Weighted MR Imaging of the Prostate – Contributing Factors and Strategies for Improvement

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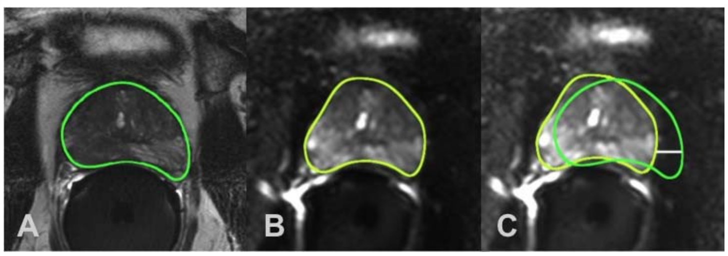
Target Audience: Radiologists, MRI Technologists, Prostate Imaging Researchers.

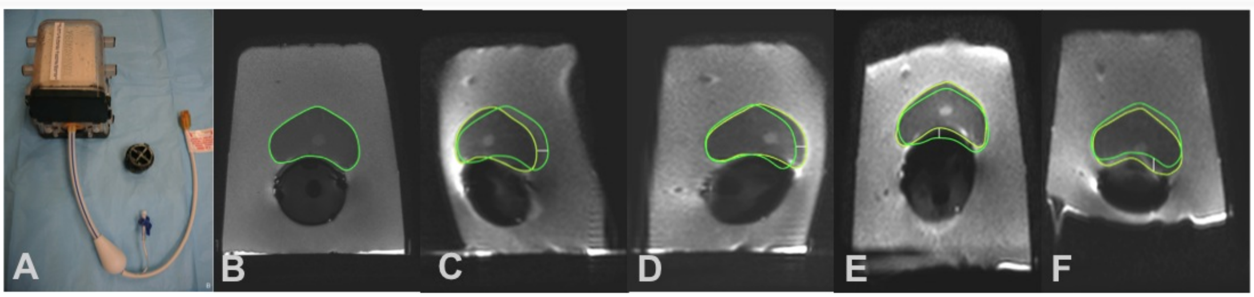
Purpose: To identify the causes and degree of geometric distortion observed in diffusion-weighted imaging (DWI) of the prostate and assess different acquisition strategies to mitigate distortion.

Methods: This IRB-approved, HIPAA-compliant study included 40 consecutive patients who underwent 3T magnetic resonance imaging (MRI) of the prostate with an endorectal coil (ERC) filled with air (n=20, air cohort) or barium (n=20, barium cohort). Geometric distortion was measured as the maximum displacement of the outer boundary of the prostate on single-shot echo planar DWI (b-values 0, 50, 1000, 1500 s/mm^2) relative to T2-weighted fast spin echo (T2-FSE) images. The effects of phase-encoding direction, receiver bandwidth, and parallel imaging on distortion in DWI were assessed in a prostate phantom on two different 3T MRI scanners from different manufacturers.

Results: The mean displacement of the prostate on DWI was not statistically different between the air cohort (1.8 ± 1.2 mm; range 0-4.2 mm) and the barium cohort (1.8 ± 2.1 mm; range 0-9.0 mm)($p>0.05$) and it was observed in the phase-encoding direction (i.e. right-left). Phantom experiments confirmed an averaged displacement of 6.0 mm in the phase-encoding direction, which decreased with the use of parallel imaging (4 mm) and higher bandwidth (2.9 mm). There was no statistical difference in the geometric distortion observed for all *b*-values ($p>0.05$) and across different manufacturers.



Geometric distortion on diffusion-weighted imaging (DWI) of the prostate in a patient MRI examination– The outer contour of the prostate in the T2-FSE image (**A**) and DWI image (**B**) was delineated manually. The prostate contour from the T2-FSE image of reference was saved and imported into the different b-value DWI images at the same anatomic level. After overlapping the prostate contour from the T2-weighted reference image (*green line*) on the DWI image (*yellow line*) the geometric distortion was estimated by measuring the displacement between the boundaries in the horizontal axis (*white line* in **C**).



Example of prostate phantom (A) experiment demonstrating that distortion occurs in the phase-encoding axis and direction. T2-FSE image (**B**) served as anatomical reference for the contour of the prostate (*green line*); When the phase-encoding direction on DWI was shifted from left-to-right (**C**) to right-to-left (**D**), and then to posterior-anterior (**E**) and anterior-posterior (**F**) direction, the axis and direction of the distortion consistently followed the phase-encoding orientation. *Yellow ROIs* indicate the outer contour of the prostate drawn on the DWI images; *white line* is the maximum distance between the borders and represents magnitude of displacement. This effect can also be inferred by assessing the shape of the signal void in the ERC balloon and the outer contour of the phantom.

Discussion: To our knowledge, this is the first investigation assessing parameters that may influence geometric distortion on DWI of the prostate. Our results confirm that geometric distortions on SE-EPI DWI of the prostate occur in the phase-encoding direction leading to a mismatch between DWI and T2-FSE images. In patients, the displacement ranged from 0 to 9.0 mm, which can have important implications when selecting lesions for targeted biopsy and/or therapy. Geometric distortions on DWI have been previously reported in brain MRI exams and attributed to the presence of variable *B*0 gradients leading to accumulation of phase error over the phase-encoding direction during the slice acquisition. We hypothesized that air inflation of the ERC balloon would be a primary source of B0 inhomogeneity. Although filling the balloon with barium has been reported to improve B0 gradients in prostate exams and spectroscopy acquisitions we did not observe improved geometrical distortion of the prostate on DWI in patients. The observation that geometric distortion was not dependent on the applied *b*-value lends further support for the use of ADC calculations in diagnostic characterization.

Conclusion: Geometric distortion in the phase-encoding direction is common on SE-EPI DWI of the prostate acquired using an ERC. Strategies to reduce this artifact include use of higher bandwidth and accelerated imaging. Awareness of this phenomenon and potential remedies may result in improved localization of prostate cancer, particularly important for situations demanding precise anatomy and tumor mapping such as targeted prostate biopsies or focal therapies. Inflation of the ERC balloon with barium did not improve the degree of distortion of the prostate on DWI images when compared to inflation with air in our study cohort.