Prostate Diffusion Distortion Correction with Restriction Spectrum Imaging

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Target Audience: Radiologists and scientists who read and process prostate diffusion images.

Purpose: Diffusion imaging often increases the conspicuity of prostate cancers and detects them with greater accuracy than T2 or perfusion imaging[1,2]. Diffusion imaging in the prostate is susceptible to distortion from B0 inhomogeneity. Distortion correction in prostate imaging is not routinely performed, resulting in diffusion images without accurate localization of tumors. Restriction spectrum imaging (RSI-MRI) is a diffusion imaging technique that incorporates distortion correction[3] .

Methods: 28 patients underwent pre-operative multiparametric MRI that included T2 and diffusion-weighted (b=0,800 s/mm^2) imaging, and diffusion tensor (0, 800, 1500, 4000 s/mm^2 at 30 directions) imaging for restriction spectrum imaging cellularity index (CI) maps. CI Z-score maps, standardized across the sample, are distortion-corrected. To correct for distortion, forward and reverse trajectories were collected at b = 0 s/mm^2. The distortion-correction algorithm [4] for the RSI-MRI sequence utilizes the symmetry of the distortion from B0 inhomogeneity. By collecting images at b = 0 s/mm^2 in both the forward and reverse phase encode trajectories, a deformation field map was calculated and used to correct the entire diffusion data set. Distortion maps were generated to reflect the offset of the collected data versus the corrected data. Whole-mount histology, and Gleason scores were available for correlation.

Results: Across the 27 included patients (excluding one patient due to data collection error), the average root mean square distortion distance of the prostate was 3.1 mm (standard deviation, 2.2 mm; maximum distortion, 12 mm). When specifically looking at the tumor regions, the average root mean square of the distortion distance of the tumors was similar at 3.1 mm (standard deviation, 2.3 mm; maximum distortion, 13 mm). Nine of the 27 patients demonstrated histologically proven extracapsular extension. Standard diffusion MR of the prostate only identified one tumor as definitively demonstrating extracapsular extension. The distortion correction RSI-MRI maps demonstrated extracapsular extension in eight of the nine patients.

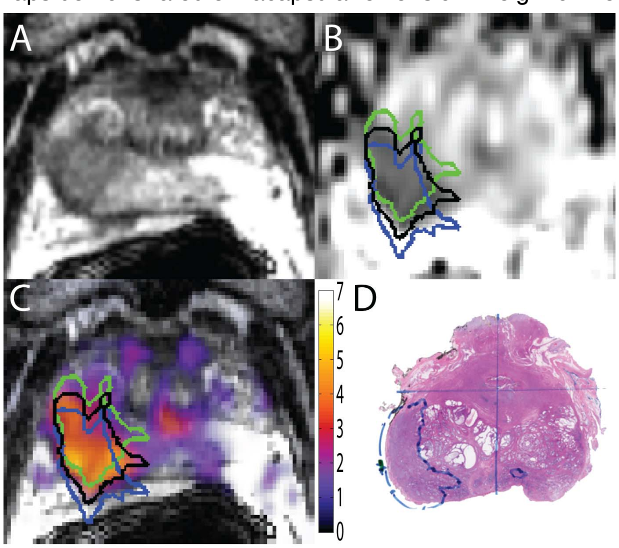

Table 1. Distortion distance of the whole prostate and tumor regions of interest due to B0 inhomogeneity

	Mean (standard deviation) (mm)	Maximum distortion (mm)
Whole prostate distortion	3.2 (2.2)	12
Tumor ROI distortion	3.2 (2.4)	13

Figure 1. Patient example of the effects of distortion on localizing tumor. (A) T2 image, used as the imaging anatomic gold standard. Note that the tumor is in the right posterior quadrant. (B) Distortion-corrected low b-value ADC map, with the region of low ADC outlined in black. The blue and green ROIs represent the regions of low ADC without distortion correction (blue: in-phase encode direction, green: reverse phase encode direction). (C) RSI-MRI image that incorporates the distortion correction and converts the cellularity map based on multiple b-values to a standardized z-score map, overlaid on the T2 anatomic image. The blue and green ROIs are the regions of RSI signal without distortion correction while the black ROI is distortion corrected. (D) Whole-mount histopathology confirming the location of extraprostatic extension in the right posterior quadrant.

Discussion: Diffusion imaging, because it uses an echo planar trajectory, is sensitive to B0 inhomogeneity. This manifests as distortion in the phase encode direction. By collecting data in both the forward and reverse phase encoding directions at b = 0, enough information is collected to correct for the distortion in the phase encode direction. This technique [4], along with others, is used to correct for distortion in brain diffusion imaging. Although diffusion imaging in the prostate is becoming the standard of care in prostate MRI protocols, distortion correction has not yet been widely implemented for prostate diffusion imaging. As demonstrated in this abstract, distortion correction improves tumor localization for diffusion imaging. Diffusion imaging best discriminates benign from suspicious lesions. With the advent of MRI-ultrasound fusion guided biopsies and high-intensity focused ultrasound treatment, accurate localization is necessary. Surgical planning also depends on differentiating between extraprostatic extension of tumor and the tumor remaining within the capsule, a decision that could be made with accurate imaging. Distortion distances of up to 13 mm due to standard diffusion imaging may grossly misdirect treatment decisions and therapies. Distortion correction for diffusion imaging has the potential to improve the standard of care for prostate MRI.

Conclusion: Improved localization of prostate cancer by MRI will allow better surgical planning, targeted biopsies and image-guided treatment therapies. Distortion distances of up to 12 mm due to standard diffusion imaging may grossly misdirect treatment decisions. RSI-MRI corrects for distortion and improves tumor localization.

References: [1] Lim HK, et al. Radiology; 2009. [2] Isaebert S, et al. JMRI; 2013. [3] White N, et al. Hum Brain Mapp; 2013. [4] Holland D, et al. Neuroimage; 2009.

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