In vivo Detection and Localization of Prostate Carcinoma using DTI

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Introduction

Despite its widespread use in prostate cancer management, conventional MRI has not proven specific enough to guide localized treatment. Recently, significantly improved prostate-to-cancer contrast was achieved using diffusion tensor imaging (DTI) in radical prostatectomy specimens [1]. To examine the potential value of similar methods *in vivo*, four patients scheduled for radical prostatectomy surgery were examined by DTI. After surgery, prostate specimens were examined via *ex vivo* DTI and histology. *Ex vivo* DTI of prostate specimens provides a link between *in vivo* DTI findings and histology.

Material and methods

MRI

In vivo DTI was performed using EPI with TRSE (twice-refocused spin-echo) diffusion weighting with a voxel resolution of 2.5 × 2.5 × 2.5 mm^3. Diffusion sensitizing gradients were applied along six directions: [Gx, Gy, Gz] = [1,1,0], [1,0,1], [0,1,1], [-1,1,0], [0,-1,1], and [1,0,-1]. Two diffusion sensitizing factors or *b* values = 0 and 0.500 ms/μm^2 were used to calculate diffusivities. T2W images were acquired using fast spin-echo with resolution 1.2 × 1.2 × 2.5 mm^3.

After surgery, prostatectomy specimens were fixed in formalin for more than 24 hrs and step-sectioned at 4 mm intervals before *ex vivo* DTI scans. *Ex vivo* DTI was performed on the pre-sectioned slices after regrouping with a spacer placed between adjacent slices. The *ex vivo* DTI was performed employing parameters reported previously [1].

Histology

Individual 4 mm sections were carefully labeled to permit localization of each section within the prostate. After paraffin embedding, all slides were stained with hematoxylin and eosin. Slides were examined and color-coded for the carcinoma and BPH in blue and red, respectively.

Results and Discussion

Prostates from two patients are described in Fig. 1. Panels A-C show matched slices from a prostate that had a significant presence of multi-foci carcinoma. Panels D-F show matched slices from a prostate that had a much smaller tumor extent (4%). Hypointensity at the peripheral zone (PZ) of both T2W images (Fig. 1A and D) is identified as carcinoma by an experienced radiologist. The corresponding slices of both *in vivo* ADC maps (Fig. 1B and E) are in good agreement with the T2W images. BPH regions show decreased ADC as well (Fig. 1 E), mimicking carcinoma. Both carcinoma and BPH regions are confirmed by the histology slides (Fig. 1C and F). The other two patients in this study had prostates showing only ~ 1% carcinoma extent by histology. *Ex vivo* DTI identification of tumor using both ADC and RA maps [1] found the amount of tumor to be less than or ~ 1%.

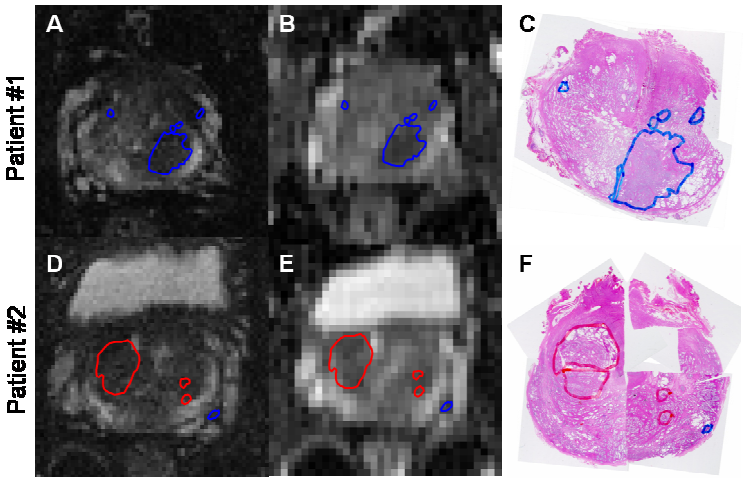

Fig. 1, *in vivo* T2W images (A and D), ADC maps (B and E), and Histology slides (C and F) of two patients

Carcinoma ROI identification *in vivo* was guided by *ex vivo* DTI images and histology. The measured *in vivo* prostate carcinoma ADC was 0.84 ± 0.10 (n = 2) μm^2/ms, similar to 0.91 ± 0.2 μm^2/ms reported by Gibbs, *et al.* [2] but likely different from 1.38 ± 0.52 μm^2/ms reported by Issa [3]. Other non-cancerous ROIs were defined in reference to the T2W images. The measured non-cancerous PZ and central gland (CG, including BPH) ADCs were 1.79 ± 0.15 μm^2/ms (n = 4) and 1.36 ± 0.15 μm^2/ms (n = 4), respectively. These ADCs for non-cancerous PZ and CG are comparable to those of Issa [3] and Sinha, *et al.*, [4] but are considerably greater than those reported by Gibbs, *et al.* [2]. Gibbs, *et al.* and Issa employed thicker slices (7mm) and lower in-plane resolution than the data reported herein. Partial volume effects are possibly the reason for the discrepancy in comparative ADCs. The partial volume effect is of great concern in prostate cancer DTI examinations. To be beneficial to patient care, the detection of small to medium sized tumors and identifying those tumors residing at the edge of the prostate are of particular interest and have implications for treatment stratification.

Patient motion and low SNR compromise the diffusion anisotropy calculation in the current *in vivo* DTI studies. Further improvements can be achieved by the use of gated data acquisition [4] and higher magnetic field strength.

Conclusions

In four prostate cancer patients, carcinoma exhibits a significantly decreased ADC compared to the non-cancerous PZ tissues. Both the size and the location of the histologically identified lesions correlate well with those identified by ADC maps. These preliminary findings represent the initial steps toward developing diffusion MRI for noninvasive identification and localization of prostate cancer. We are optimistic that further optimization of the method will provide useful information regarding patient care.

Reference

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