Track Density Imaging for High Resolution Diffusion Tractography in the Prostate With and Without Tumor

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Introduction Prostate cancer is the most common cancer in men and the second-most common cause of cancer-related death. Multiparametric MRI of the prostate, which combines multiple MRI contrast mechanisms, has evolved into a powerful tool for localizing tumor within the prostate gland and monitoring treatment. Detection of central gland tumors, extracapsular extension and neurovascular bundle involvement remain important challenges in prostate cancer imaging. Recently, nerves running within the prostate neurovascular bundles have been visualized using MR diffusion tractography[1]. Track density imaging (TDI)[2] further exploits fiber tractography to construct images with novel tissue contrast and spatial resolution exceeding the native resolution of the diffusion weighted acquisition. This technique has been evaluated in the brain[3] and applied to characterization of white matter infiltration in glioblastoma[4]. In this study, we investigate TDI as a complement to multiparametric 3T prostate MRI.

Methods Study was approved by the local institutional review board with informed consent. 19 patients who were referred for multiparamentric prostate MRI underwent diffusion imaging sequences in addition to a standard clinical MRI examination. The distribution of Gleason grading was: G3+3 (12) G3+4 (4), and G4+4 (1) (one patient had no tumor on recent biopsy). 14 patients were being managed by active surveillance, 4 had received radiation therapy, and 1 hormonal therapy. Patients were imaged using a 3T MRI scanner (GE Healthcare) and endorectal coil (MedRad). Standard clinical examination included high resolution T2 fast spin echo, large field of view T1 gradient echo, diffusion imaging with low (b=600 s/cm^2) and high (b=1350 s/cm^2) diffusion sensitization, and MR spectroscopy. Dynamic contrast enhancement images were performed in a portion of patients. For tractography, diffusion weighted EPI was acquired (TR/TE=5000s/min, BW 250 kHz, matrix 128x128, FOV 24 cm, slices 21 x 3 mm). One image with b = 0 was acquired followed by b = 600 images along 25 non-collinear directions. Scan time was approximately 2.5 minutes. Note that the scan time was nearly identical to our standard clinical diffusion weighted scan (which is performed with 6 directions x 4 averages versus 25 directions x 1 average). Two tractography algorithms were compared as a basis for track density imaging: tractography based on diffusion tensor imaging (DTI) versus high angular resolution diffusion imaging (HARDI) tractography based on spherical deconvolution. Images were reconstructed at a voxel size of 0.3 x 0.3 x 0.3 mm, as compared to the native diffusion data with a voxel size of 1.8 x 1.8 x 3 mm. Image overlays were created using OSIRIX[5]. Clinical MRI interpretation was obtained from the official radiology report.

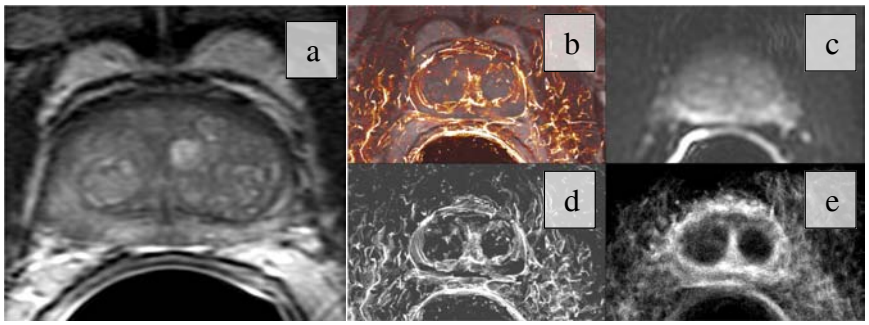

Figure 1: 62 yo with biopsy-proven G3+4 tumor managed by active surveillance. Sample slice without visible tumor. **a**: T2 axial **b**: T2 with TDI overlay, **d**: DWI, **e**: TDI with DTI tractography, **e**: TDI with HARDI tractography

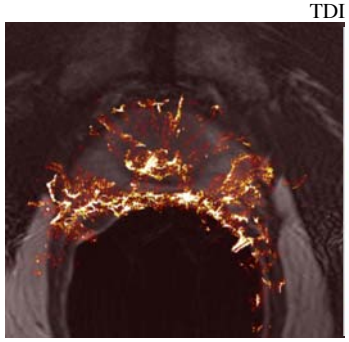

Figure 2: 52 yo with G3+4 tumor T2 + TDI overlay(non-tumor slice)

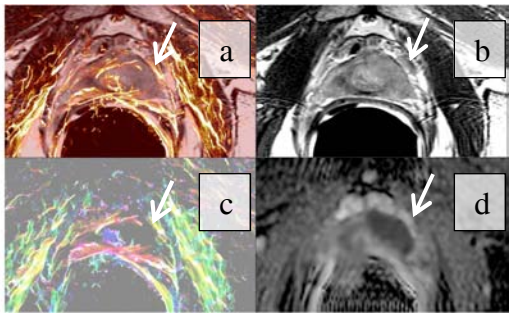

Figure 3: 78 yo with central gland tumor (arrow) **a**: T2+TDI **b**: T2, **c**: TDI (color coded direction), **d**: ADC

Results TDI was technically successful in all subjects except four subjects where diffusion weighted images were degraded by brachytherapy seeds. There was visually precise alignment with high-resolution T2 images.

Figure 1: Tumor-free axial slice from a patient with biopsy-proven G4+3 prostate cancer. TDI images computed using DTI (1d) and HARDI (1e) tractography are compared. TDI images demonstrate features with higher apparent spatial resolution than the diffusion-weighted images from which they were derived (1c). Tracks are seen surrounding the gland and surrounding nodules of BPH in the central gland. A paucity of tracks are seen in the peripheral gland. Images generated using DTI tractography (1d) are sharper with better-defined tracks than images obtained using HARDI tractography (harmonic order = 8) (1e).

Figure 2: Example of radially oriented tracks in the central gland, which was seen in some patients.

Figure 3: Biopsy proven tumor (arrows) in the central gland of a patient that appears to interrupt circularly oriented tracks. Overall, two subjects were seen with clear interruption of tracks by tumor in the central gland.

Discussion TDI was shown to be technically feasible in the prostate with scan time nearly identical to clinical standard diffusion weighted images. At least two patients show tracks within the central gland that are interrupted by tumor. Current efforts are focused on optimizing imaging and reconstruction parameters. Further work aims to validate the physical basis of the tracks that are observed and determine the utility of this technique for detecting central gland tumors, extracapsular extension, and neurovascular involvement.

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