Quantitative DTI Tractography of prostate gland in prostate cancer patients

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Purpose

To explore the Diffusion Tensor Magnetic Resonance Tractography for prostate gland in prostate cancer patients and investigate a feasibility for quantitative study of prostate cancer using 3D fiber tracts.

Introduction

Diffusion weighted MRI images acquired with at least six gradient directions can be used to obtain diffusion tensor, which is commonly used to visualize neuronal fiber map in a brain [1,2]. However, diffusion tensor imaging (DTI) seldom been used for other visceral organs. Prostate gland consists of various vascular, neural, and other anisotropic water paths that make DTI method applicable to prostate gland. Despite excellent MR contrast, accurate characterization of the extent and aggressiveness of prostate cancer remains an elusive goal [3]. To date there is no consensus of what type of MR imaging is best for specific prostate cancer screening. Recent works used DTI of the prostate gland to assess fractional anisotropy in the central gland and peripheral zone [4,5]. These works indicated potential anisotropy within the prostate gland. We suggest exploring such anisotropy using DTI Tractography and applying a quantitative approach to DTI study of prostate.

Theory and methods

DTI is the measure of tensor that is obtained from diffusion-weighted data and used to describe diffusion in anisotropic systems. If diffusion-weighted data is obtained using sensitizing gradients at least in six directions then it is possible to calculate a 3D diffusion tensor. The fiber tract direction will be indicated by the tensor's main eigenvector. The sensitivity of the method as a marker of prostate cancer is based on the model of the high cellularity of the tumor cells. The model implies restrictive isotropic diffusion in the tumor site. That makes it distinct from the surrounding healthy tissues as indicated by scalar ADC map and it also disrupts the paths of fiber tracts through the tumor region. The measure of that disruption is the number of tracts normalized to the size of the affected region.

We carried out HIPPA compliant retrospective study of N=25 men with biopsy proven prostate cancer. All patients undergone prostate MRI with endorectal coil on a 1.5 T MRI scanner. Diffusion weighted images were acquired as single shot echo-planar acquisition, with DWI protocol: b=0, 600 s/mm2, six gradient directions. DTI map was generated using Diffusion Toolkit and fiber tracts were visualized with TrackVis [6]. We identified multiple spherical regions of interest (ROI) over areas of pathologically proven tumor, the central gland, and normal peripheral zone of the gland. For quantitative analysis we introduced a tract density parameter, which is a tract number divided by the ROI volume (physical volume of a sphere), as a normalized measure of the number of tracts passing through the given ROI. The values were statistically analyzed using a paired t-test (SOFA statistics version 1.3.2.).

Results and discussion

The example of one of the case (58 yr. old man, Gleason score=8/10) is shown in Fig. 1, where a) is an ADC map of axial slice of prostate that shows tumor in the right peripheral zone; b) fiber tracts generated in the two identical spherical ROI (tumor and normal tissues in peripheral zone). The calculated tract density is tract number per physical volume of spherical ROI: 1.2 in tumor and 4.3 in normal parenchyma. This case shows quantitatively the difference between tumor and healthy tissues using DTI Tractography. The histogram of tract density for N=25 men is shown in Fig. 2. The results confirm our hypothesis on the tract density sensitivity to prostate cancer as shown on the histogram: mean tumor region tract density = 2.43, mean normal parenchymal tract density = 3.86, p value = 0.00010 that shows statistical significance ($p<0.05$). In addition, our observations indicate that DTI Tractography exposes a rich neurovascular fiber tract anatomy and complex architecture of the prostate gland. The Tractography map through whole gland also shows tract heterogeneity within the prostate capsule.

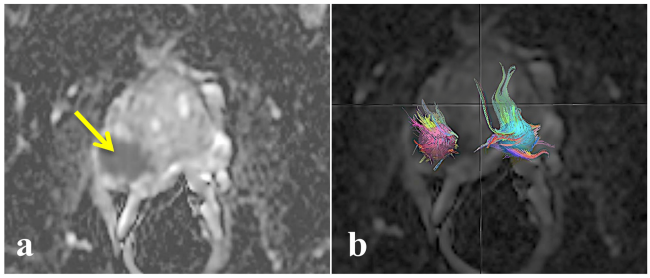

Figure 1: *a) ADC axial slice of prostate gland shows tumor in the right peripheral zone; b) corresponding fiber tracts generated through two spherical ROI (tumor and normal tissues), overlaid with ADC map.*

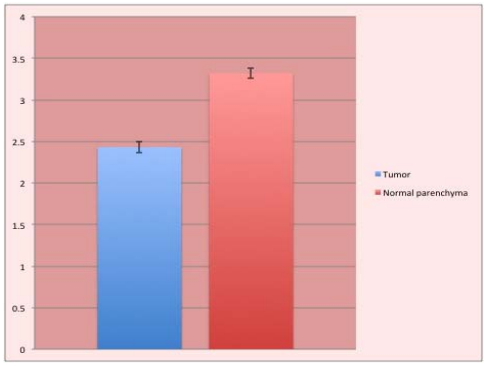

Figure 2: *The histogram shows that the mean tumor region tract density = 2.43, mean normal parenchymal tract density = 3.86 with p= 0.00010.*

Conclusions

DTI Tractography is a new imaging modality that has previously been introduced to brain MRI and also can be applied to other visceral organs. DTI Tractography of the prostate is feasible in-vivo in cancer cases [7] and well-depict congregate fibers within the prostate [8]. We applied this technique to prostate MRI and developed a quantitative approach that is able to discriminate tumor vs. normal tissue for diagnostic purposes. The quantitative analysis implies differences in tract number in tumor vs. normal gland, which is in good agreement with the structural observations of the fiber tracts in the gland. Since these differences are statistically significant we can design a novel imaging tool to determine size and/or aggressiveness of tumor during diagnostic or treatment phases of imaging. We will attempt to apply our method to analyze post radiation treatment cases where other modalities fail to yield contrast.

References: 1. Basser, P.J. et al., Magn Reson Med., 44(4), 625-632 (2000); 2. O'Donnell, L.J., Westin, C.-F., Neurosurgery Clinics Of North America, 22(2), 185-196 (2011); 3. Hricak H. et al., Radiology, 243, 28-53 (2007); 4. Bourne R.M., et al., Magn Reson Med., 68, 1943–1948 (2012); 5. Finley D.S, et al., Urology, 80(1), 219-23 (2012); 6. Wang R., Van J. Wedeen, TrackVis.org (ver. 0.5.1), Martinos Center for Biomedical Imaging, MGH, Boston; 7. Sinha S., and Sinha U., Magn Reson Med., 52, 530–537 (2004); 8. Manenti G. et al., Invest Radiol., 42(6), 412-9 (2007).