Optimized Correlated Diffusion Imaging for Prostate Cancer Detection

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Introduction: Diffusion magnetic resonance imaging (dMRI) is increasingly becoming the standard of care for detection and diagnosis of prostate cancer. Correlated Diffusion Imaging (CDI) is a new dMRI technique that exploits joint correlation of diffusion attenuations across different gradient strengths, durations, and timings to enhance delineation of healthy and cancerous tissues [1,2,3]. In this study, we introduce an optimized CDI (oCDI) technique, in which the contribution of diffusion attenuation at different gradient strengths, durations, and timings are optimized to further enhance the delineation between healthy and cancerous tissues.

Methods: dMRI is a promising imaging modality in which the sensitivity of tissue to Brownian motion of water molecules is measured by applying pairs of magnetic field gradient pulses with opposite phases, where the signal loss due to spin dephase is controlled by b (Eqn. 1), which among other factors consists of gradient strength and duration, and the time between the two pulses [4]. The dMRI signal (S) is formulated as: Eqn. 1 $S = S_0 e^{-bD}$ where S_0 is the signal intensity without diffusion and D represents the diffusion strength or velocity. In the proposed oCDI technique, a sequence of dMRI signal acquisitions are performed at different b values (b_i), and the following weighted signal mixing is performed to obtain the final CDI image signal:

Eqn. 2 $oCDI(x) = \int \ldots \int_{b_i}^{b_j} S_i(x)^{\alpha_i} \ldots S_j(x)^{\alpha_j} P(S_i(x), \ldots, S_j(x) | \mathrm{V}(\mathrm{x})) \times \mathrm{d}S_i(x) \ldots \mathrm{d}S_j(x)$

where P is the conditional joint probability density function and V(x) is a local subvolume around x. To determine the optimal values for α_i to α_j in the weighted signal mixing function, a training dataset is used where the tumour regions have been contoured by a radiologist. A grid search is performed to determine a set of parameters that yield the maximum area under ROC curve (AUC) via a leave-one-patient-out cross-validation approach.

Results: The performance of the proposed oCDI was evaluated using clinical dMRI data of 17 patients with cancer acquired using a Philips Achieva 3.0T machine at Sunnybrook Health Sciences Centre, Toronto, ON, Canada. All data was obtained retrospectively under the local institutional research ethics board. The images obtained using oCDI were compared with apparent diffusion coefficient (ADC) maps as well as those obtained using the original CDI technique [1] for delineation of healthy and cancerous tissue for prostate, as shown in Figure 1. The AUC of the proposed oCDI technique was also compared against that of ADC map and the original CDI technique. The results are shown in Table 1.

Conclusion: Optimized CDI significantly improved the separability of cancerous and healthy tissues in prostate dMRI and hence, it is a promising technique for prostate cancer screening.

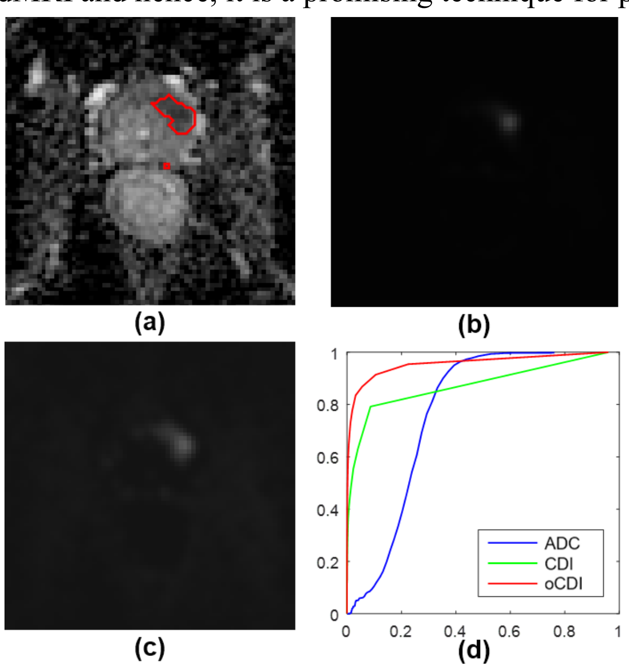

Table 1. AUC results of ADC map, original CDI and the proposed optimized CDI (oCDI)

	ADC	CDI	oCDI
AUC	0.5346	0.8462	0.9184

References:
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Figure 1. (a) ADC map (tumour contoured in red), (b) CDI, (c) oCDI, (d) ROC curves for all 17 cases for detection of prostate cancer. Tumour is shown as a brighter nodule in the proposed oCDI (c) compared to original CDI (b).