Zone-DR: Discovery Radiomics via Zone-level Deep Radiomic Sequencer Discovery for Zone-based Prostate Cancer Grading using Diffusion Weighted Imaging

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Abstract

Prostate cancer is the most commonly diagnosed cancer in men, however prognosis is relatively good given sufficiently early diagnosis. This motivates the need for fast and reliable prostate cancer grading. In this study, we investigate the efficacy of a discovery radiomics strategy for prostate zone-based cancer grading using a deep radiomic sequencer discovered from diffusion weighted imaging (DWI) data. More specifically, we propose Zone-DR, a discovery radiomics approach based on zone-level deep radiomic sequencer discovery that discover radiomic feature directly from DWI data. Experimental results using $12,466$ pathology-verified zones obtained from DWI data of 101 patients showed that the proposed Zone-DR approach achieved higher accuracy than a threshold-based approach for both ADC and CHB-DWI. Furthermore, the results also showed that the trade-off between sensitivity and specificity can be optimized based on the particular clinical scenario we wish to employ Zone-DR for, such as clinical screening versus surgical planning.

1 Introduction

Prostate cancer is the most commonly diagnosed cancer in North American men. Prognosis is relatively good given early diagnosis [1], thus motivating the need for early screening. Diffusion weighted imaging (DWI) has gained traction in recent years for prostate cancer screening. The most commonly used DWI modality currently is apparent diffusion coefficient maps (ADC), with the recently introduced computed high-b value diffusion weighted imaging (CHB-DWI) showing considerable promise [2].

The current approach to prostate cancer screening using DWI is a binary threshold-based strategy [3], which does not account for variations of the imaging equipment and protocol, and variations in signal characteristics of healthy and cancerous tissue in different areas of the prostate amongst different individuals when captured using DWI. In this study, we investigate the efficacy of ADC and CHB-DWI when applied to 12,466 pathology-verified prostate zone gradings from DWI data of 101 patients using a radiomics strategy. More specifically, we propose Zone-DR, a discovery radiomics approach based on zone-level deep radiomic sequencer discovery that discover radiomic features directly from DWI data.

2 Method

Since this is the first study on prostate zone-based grading via discovery radiomics, it is important to investigate and identify the appropriate zone-level radiomic sequencer design for the DWI-derived modalities being explored. To achieve this goal, we employ a machine-driven radiomic sequencer discovery strategy, where we perform Bayesian optimization (leveraging SigOpt's conditional experiment [4]) over a deep convolutional-based radiomic sequencer design space to discover the best deep radiomic sequencer for zone-based grading based on area under the curve (AUC) as the objective function for each modality. The optimal radiomic sequencer designs that were discovered are shown in Table 1.

The zone-level deep radiomic sequencer, with the design shown in Table 1, undergoes a radiomic sequencer discovery process to learn all the parameters of the sequencer. The loss function used to learn the parameters is binary cross-entropy. To account for grade imbalance, grade weights of 1 and 95 are used for negative-grade and positive-grade zones, respectively.

3 Results

Based on Table 2, Zone-DR achieves higher accuracy than the threshold-based approach for both ADC and CHB-DWI. This suggests that learning radiomic features directly from DWI data via deep radiomic sequencer discovery is important for distinguishing between positive and negative zones. In addition, the use of CHB-DWI with Zone-DR led to a higher AUC than ADC with Zone-DR. The sensitivity, specificity and accuracy values reported for Zone-DR were selected by choosing a point on the ROC curve that maximizes the sum of sensitivity and specificity. Using the chosen point, the use of CHB-DWI led to highest specificity while the use of ADC led to highest sensitivity, making the choice of modality and weighting between sensitivity and specificity useful for different clinical scenarios. For example, maximizing specificity is important for surgery for removal of prostate where you want to minimize false positive rates to avoid unnecessary surgeries. On the other hand, for cancer screening, maximizing sensitivity may be useful to avoid missing cancerous patients.

Based on the experimental results, it can be observed that the proposed Zone-DR approach can provide significantly improved cancer grading performance. Future research will look at a combination of modalities to achieve better results, as well as different deep radiomic sequencer designs.

Table 1: Optimal zone-level radiomic sequencer designs discovered for ADC and CHB-DWI

ADC	CHB-DWI
input	
conv3-15	conv3-10
	conv3-29
conv3-15	conv3-23
	conv3-46
conv3-18	conv3-106
flatten-288	flatten-1696
FC-341	FC-295

Table 2: AUC, specificity, sensitivity and accuracy for threshold-based approach and Zone-DR

Modality	Technique	AUC	Sensitivity	Specificity	Accuracy
ADC	Threshold		0.895	0.601	0.604
	Zone-DR	0.858	0.874	0.737	0.738
CHB-DWI	Threshold		0.733	0.824	0.823
	Zone-DR	0.882	0.828	0.873	0.873

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