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DBSI-Net: Artificial Intelligence Detection of Clinically Significant Prostate Cancer Using Diffusion Basis Spectrum Imaging and Biparametric MRI

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Introduction/Background

Clinically significant prostate cancer (csPCa) remains challenging to distinguish from benign and indolent lesions on biparametric MRI (bpMRI), resulting in false positives for radiologists and artificial intelligence (AI) models. Diffusion basis spectrum imaging (DBSI) has been applied to prostate MRI to characterize tissue microstructure through decomposition of diffusion-weighted MRI signals, with prior correlations demonstrated between DBSI metrics and prostate histopathology. We propose the development of DBSI-Net, an AI model integrating DBSI, bpMRI, and clinical data for detection of csPCa. We compare its performance with Diffusion Histology Imaging (DHI), a prior DBSI-based AI approach, and bpMRI-based AI models.

Methods/Intervention

This retrospective study included 313 patients with elevated PSA who underwent bpMRI with a custom DBSI sequence. Reference standard lesions were established through radiologist segmentation and prostate biopsy. The dataset was divided into training and test cohorts (2:1), with all models trained using 5-fold cross-validation. The DBSI-Net pipeline (Figure 1) combined a highly sensitive nnUNet lesion detector trained on bpMRI (nnUNet_g), principal component analysis of DBSI metrics, and a support vector machine to ensemble nnUNet_g, DBSI, and clinical metrics into a lesion detection map. Comparator models included UNet and nnUNet trained on bpMRI alone and DHI trained on DBSI alone. Model performance was evaluated using case-based ROC analysis and lesion-based free-response ROC (FROC) analysis, summarized by partial area under the FROC curve (pAUFROC).

Results/Outcome

At the case level, DBSI-Net achieved an AUROC of 0.84, significantly outperforming nnUNet_g, DHI, UNet, and nnUNet (AUROCs 0.70–0.73; p=0.01). At a PI-RADS ≥3 operating point, DBSI-Net achieved sensitivity and specificity similar to an expert radiologist (0.84/0.68 vs. 0.84/0.63). At the lesion level, DBSI-Net achieved a pAUFROC of 0.74, outperforming other models (pAUFROC 0.22-0.68). DBSI-Net output accurate lesion segmentations unlike DHI (Figure 1), predicted aggressive tumors with high probability (Figure 2), and reduced false positives relative to bpMRI-only models (Figure 3).

Conclusion

DBSI-Net has a high performance in case-level classification and lesion-level detection of csPCa, outperforming AI models trained on bpMRI or DBSI data alone.

Statement of Impact

DBSI-Net has the potential to aid radiologists in detecting aggressive prostate cancers and limiting

unnecessary morbid prostate biopsies.

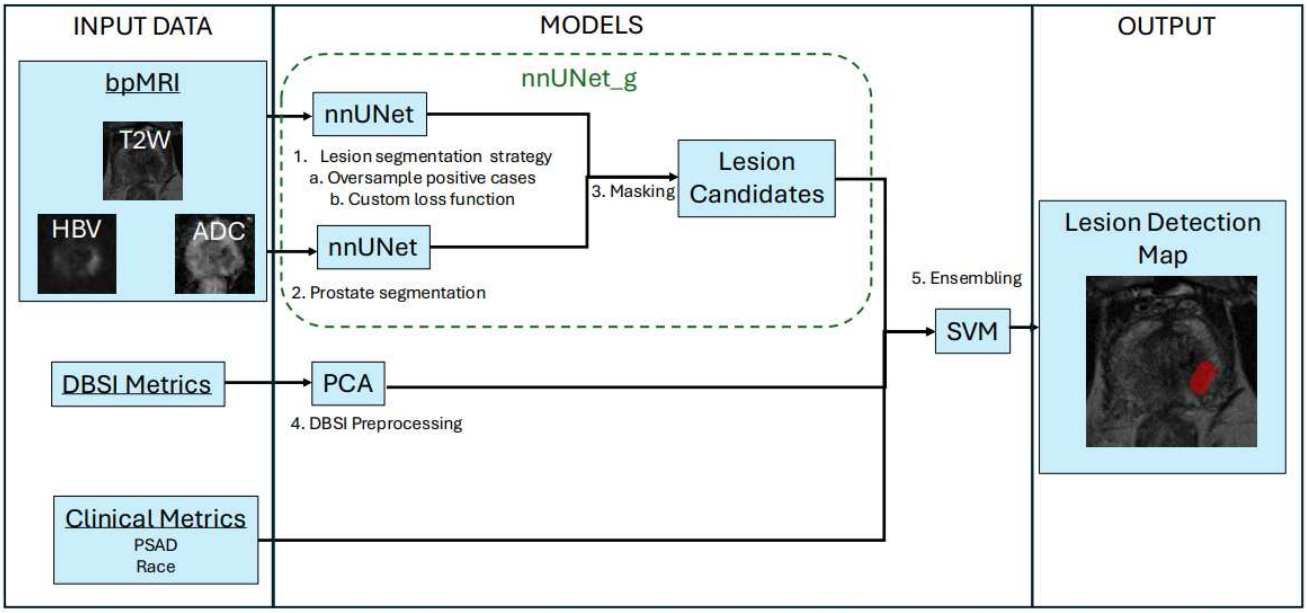

Figure 1. DBSI-Net Pipeline. Input data include biparametric prostate MRI (bpMRI) images: T2-weighted (T2W), high-b value diffusion (HBV) and apparent diffusion coefficient maps (ADC), diffusion basis spectrum imaging (DBSI) metrics, prostate-specific antigen density (PSAD), and race. A nnunet_g model consists of several nnUNet submodels trained to 1. segment lesions at high sensitivity, 2. segment the prostate, and 3. mask the lesions by the prostate segmentation. DBSI metrics were condensed using principal component analysis (PCA). A support vector machine (SVM) ensembled nnUNet_g predictions, DBSI metrics, and clinical metrics into a lesion detection map.

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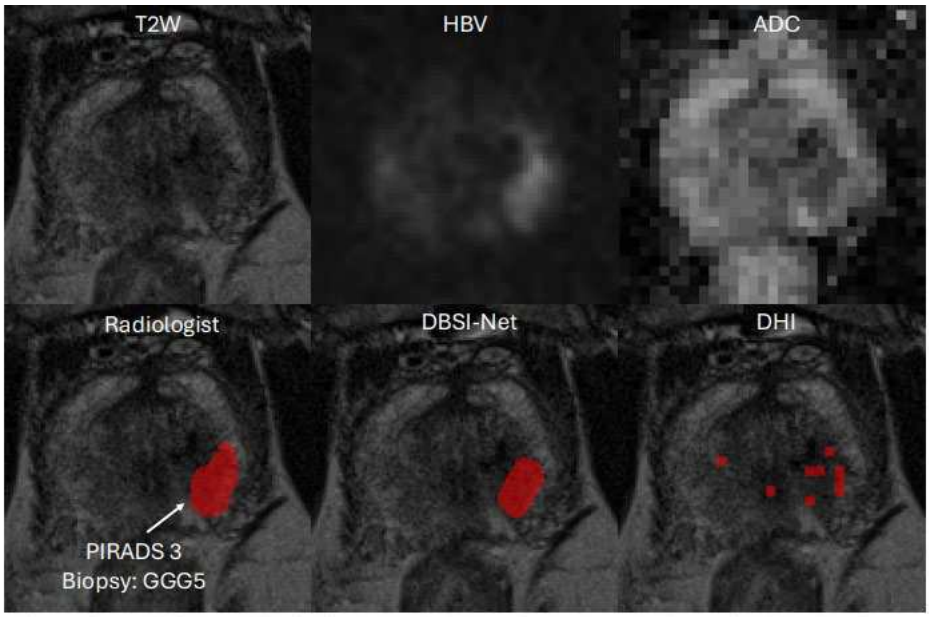

Figure 2. Output of DBSI-Net and Diffusion Histology Imaging (DHI) as a visual overlay to the biparametric MRI T2-weighted image (T2W) with corresponding high-b value (B2000) (HBV) and apparent diffusion coefficient (ADC) map. The radiologist interpreted this as a PI-RADS 3 lesion and their ground truth segmentation is shown for reference. Images are from a 65-year-old patient with PSA 6.3. Biopsy demonstrated Gleason grade group 5 (GGG5) prostate cancer.

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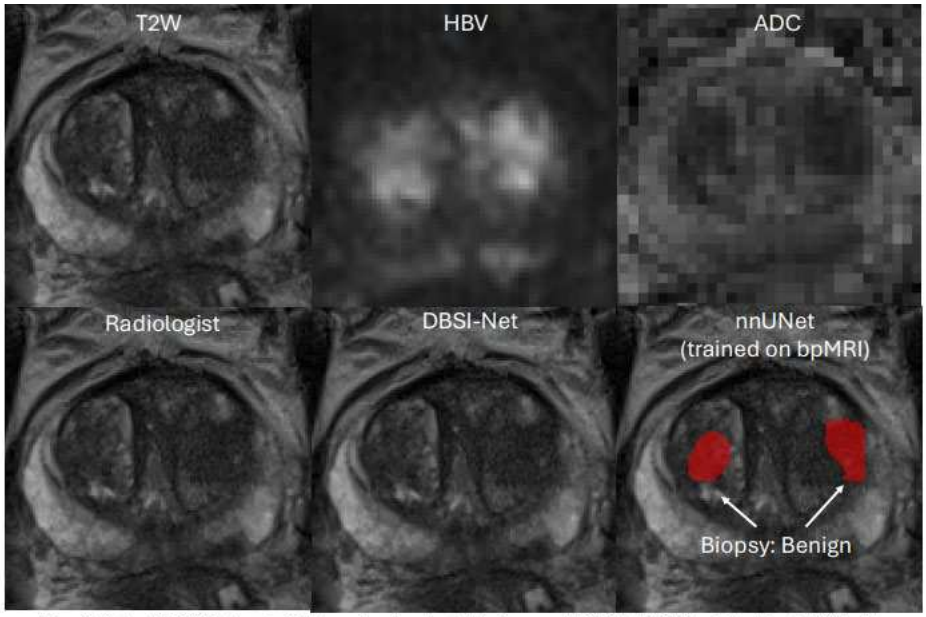

Figure 3. Output of DBSI-Net and nnUNet as a visual overlay to the biparametric MRI (bpMRI) T2-weighted image (T2W) with corresponding high-b value (B2000) (HBV) and apparent diffusion coefficient (ADC) map. nnUNet, trained on bpMRI alone, detected two false positive lesions in areas of benign prostatic hyperplasia that were correctly omitted by DBSI-Net and the radiologist. Images are from a 61-year-old patient with PSA 5.8. Biopsy was benign.

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Keywords

Prostatic Neoplasms; Computer-Aided Diagnosis; Diffusion Magnetic Resonance Imaging; Artificial Intelligence; Deep Learning