Prostate Cancer Detection and Gleason Score Prediction in mp-MRI via Deep Learning

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Introduction and Objective: Multi-parametric MRI (mp-MRI) is a powerful tool for the diagnosis of prostate cancer (PCa), but the current scoring system for mp-MRI has inter-observer variability to detect clinically significant PCa (csPCa) and to distinguish csPCa from indolent PCa [1]. Here, we propose novel multi-class deep learning models to detect csPCa automatically and predicts their Gleason score (GS) using mp-MRI.

Specific Aims: To develop and evaluate novel multi-class deep learning models that jointly detect clinically significant PCa and predicts Gleason score using mp-MRI.

Rationale and Background: Interpreting prostate mp-MRI requires a high level of expertise as radiologic findings rely on subjective scoring of qualitative characteristics on mp-MRI, resulting in substantial inter-observer variation and a lack of sensitivity and specificity[1]. Deep learning[2] is an active research area that aims to complement and overcome limitations of the current scoring systems, PI-RADS.

Methods and Materials: We retrospectively collected 417 patients who underwent pre-operative 3T mp-MRI prior to robotic-assisted laparoscopic prostatectomy. Genitourinary (GU) radiologists reviewed mp-MRI, referring to wholemount histopathology and annotated all MRI-visible lesions. A total of 728 lesions, consisting of 286 GS 3+3, 270 GS 3+4, 110 GS 4+3, 30 GS=8 and 32 GS>9, were annotated. We developed FocalNet, an end-to-end multi-class deep learning model, to jointly detect csPCa and predict their aggressiveness using GS. FocalNet predicted for the pixel-level label of six classes: non-lesion, GS 3+3, GS 3+4, GS 4+3, GS=8, and GS>8. We used GS>6 as our working definition of csPCa. FocalNet was trained by the joint loss of focal loss (FL)[3] and mutual finding loss (MFL) and evaluated with 5-fold cross-validation. Each fold contained 333 or 334 training cases and 84 or 83 cases for validation. The free-response receiver operating characteristic (FROC) analysis was used to measure the lesion detection sensitivity versus the number of false-positive detection per patient on average, and the performance of predicting GS was assessed by ROC analysis.

Results: Examples for the lesion detection via FocalNet in comparison with the histology-based MRI annotation are shown in Fig. 1. Fig. 2 (left) shows the FROC analysis for clinically significant PCa. FocalNet achieved 88% sensitivity for csPCa at the cost of 1 false-positive per patient, outperforming the best baseline deep learning model, U-Net-Sing, by 11.1%. The partial area under the curve between 0.01 and 1 false positives per patient for FocalNet was 0.685±0.056, in comparison with U-Net-Sing of 0.596±0.061. The radiologist's performance (10+ years of clinical prostate MRI reading), shown as the green markers with 95% confidence intervals, was only 1.5% higher than FocalNet at the same false positives per patient. Fig. 2 (right) shows the ROC analysis for GS>7 vs. GS<7. FocalNet achieved ROC area under the curve (AUC) of 0.81±0.01, in comparison with U-Net-Multi (0.72±0.01) and Deeplab (0.71±0.02).

Discussion and Conclusion: We showed a new multi-class deep learning model, FocalNet, to jointly detect prostate cancer and to predict different Gleason score groups. In 5-fold cross-validation, FocalNet achieved 88% sensitivity to detect csPCa at 1 false-positive per patient, 1.5% lower than experienced radiologists, and an AUC of 0.81 for the classification of csPCa.

References: 1. Ruprecht, Oliver, et al. *European journal of radiology* 81.3 (2012): 456-460. 2. Song, Yang, et al. *Journal of Magnetic Resonance Imaging* (2018). 3. Lin, Tsung-Yi, et al. *IEEE transactions on pattern analysis and machine intelligence* (2018).

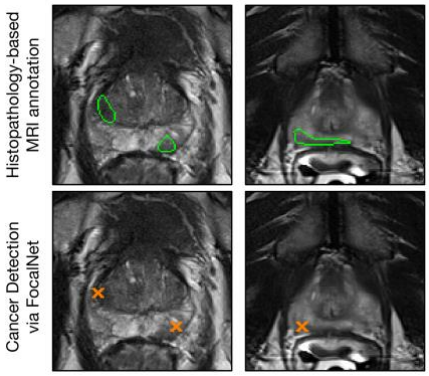

Fig. 1: *FocalNet Illustrations of detection csPCa.*

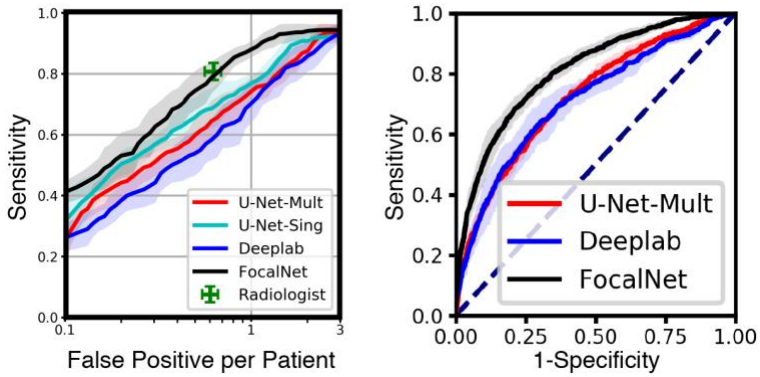

Fig. 2: *FROC analysis for detection of csPCa (left) and ROC analysis for classification of csPCa (right).*