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An Artificial Intelligence Agent for Rapid IMRT Planning of Prostate SBRT: A Feasibility Study

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Objectives: To develop an artificial intelligence (AI) agent for rapid IMRT planning of prostate SBRT. This AI agent predicts the radiation fluence intensity maps at pre-defined static beam angles in an IMRT plan. With this AI agent, a deliverable IMRT plan can be generated in less than 20 seconds as in a real-time execution without inverse optimization.

Methods: The developed AI agent centralizes a custom-designed deep-learning convolutional neural network, Dense-Res Hybrid Network (DRHN). DRHN connects 4 DenseNet blocks, 5 ResNet blocks, and 1 convolutional layer in a cascade architecture. The input of DRHN was 2D projections that characterize a patient's anatomy features at pre-defined beam angles, and the output of DRHN were 2D radiation fluence intensity maps. DRHN output was sent to a commercial treatment planning system (EclipseTM, Varian Medical System, Palo Alto, CA) for dose calculation and plan integrity check using a scripting interface for automated execution. 135 patients prescribed with 37Gy in 5 fractions were included in this work. 106 patients were used for the AI agent's training/validation, and the remaining 29 were used as independent tests. To minimize the plan quality dispersion, the plans for AI agent training were generated by an in-house prostate SBRT plan generator with a 7-beam arrangement and 10x flattening filter-free (FFF) energy mode. This in-house plan generator utilizes the scripting interface and automatically generate an IMRT plan based on institutional dosimetric guidelines. During the AI agent training, 2D projections with volumetric attenuation information were generated for PTV, bladder, and rectum. All projections at each beam angle were stacked as independent channels of AI agent input. The loss function was modeled as the wavelet transform errors with regions-of-interest (ROIs) weightings between the AI agent output and the ground-truth fluence maps of the training plans. 10-fold cross-validation regime was employed. The developed AI agent was evaluated in terms of plan dosimetric quality and execution efficiency. In independent test cases, key dosimetric parameters of the AI-generated plans, including 3D maximum dose and organs-at-risk (OARs) dose-volume parameters, were evaluated against institutional protocol guidelines. The investigated parameters were also compared with the corresponding values in the training plans with Wilcoxon signed-rank tests. Statistical significance level was determined at 0.05.

Results: After plan normalization (PTV D95% = 37Gy), 28 out of 29 AI plans met all institutional dosimetric guidelines. Compared to the training plans, slightly higher max dose

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(~1Gy difference) to bladder and BODY were observed in AI plans. Rectum max dose (D1cc) in AI plans were comparable with the training plans, and other rectum dosimetric results (D75%, D60%, D50%) were slightly improved from the training plans without significance. Each AI plan was generated in less than 20 seconds in a fully automated execution.

Conclusions: The developed AI agent can generate a prostate SBRT plan with clinically comparable dosimetric quality. Its high efficiency enables real-time execution. Further pre-clinical investigations will prepare the application of the developed AI agent for clinic use.