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Design and Development of a Comprehensive Dose Volume Histogram (DVH) Prediction Platform for Radiation Therapy (RT) Treatment Planning

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Objectives: The goal of this study was to create a comprehensive, clinical-site-independent DVH prediction platform for photon beam intensity-modulated RT. In contrast to prior work, the platform uses a single model per OAR to predict DVHs for plans with any protocol, number of targets, and target geometry (ex. prostate-only vs. prostate-plus-nodes, nasopharynx vs. neck). The predicted DVHs can be used for plan evaluation or as objectives to initialize treatment plan optimization.

Platform Design and Development: A custom random-forest-based ensemble model architecture was designed to account for factors known to influence OAR doses across disease sites, including a novel optimized target-OAR geometry categorization that accounts for the coincidence of OARs with multiple targets in the axial plane. Input features included overlap volume histogram, shape features, and prescription. Models were trained to predict normalized DVHs for single-target, sequential boost, and simultaneous integrated boost (SIB) plans with 1-4 dose levels. Performance was assessed with the average distance between predicted and true DVH curves, normalized to prescription dose (distance error).

To demonstrate the utility of the platform applied to different disease sites, 1336 prostate and 796 head and neck (H&N) cases were curated and randomly split into development and internal test sets (80%/20%). Models were developed with 5-fold cross-validation and Bayesian hyperparameter optimization for 76 H&N and 9 Prostate OARs. Final models were tested on a separate dataset of 13 prostate cases (9 prescriptions and 5 target geometries) and 19 H&N cases (13 prescriptions and 14 target geometries).

Results: For prostate, the average distance error over all OARs was 0.049 [95% CI: 0.035, 0.063] for internal testing and 0.042 [0.034, 0.050] for external testing. For H&N, it was 0.038 [0.030, 0.047] for internal testing and 0.067 [0.057, 0.077] for external testing. This indicates an average difference of 4-7% between predicted and actual DVH points.

Conclusions: We have developed and validated a flexible platform that uses a single model per OAR to predict DVHs for single-target, sequential boost, and SIB plans with varying prescriptions and target geometries. The platform has received FDA 510(k) clearance and has been in use in clinical practice since August 2022.

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