Predicting dose-volume histograms for organ at risks using machine learning in head and neck Tomotherapy

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Purpose: Dose prediction models for organ at risks (OARs) were developed and validated for head and neck (H&N) Tomotherapy.

Materials and Methods: 58 Tomotherapy plans for nasopharyngeal cancer (NPC) patients were employed in this study. For each patient, the anatomical structures between the target volume and the OARs were characterized by using overlap volume histogram (OVH). Dose volume histograms (DVHs) for brain stem, right and left parotid gland, right and left submandibular gland, right and left cochlea, esophagus, and spinal cord were included in training parameters. Principal component analysis (PCA) was applied to reduce dimension of DVHs and OVHs. DVH prediction models for 9 OARs were trained and generated using 41 training data sets with the Ridge regression, Lasso regression, ElasticNet regression, and artificial neural network. The predicted DVHs were reconstructed through the inverse transformation of the predicted principal components (PCs). The models were validated with 17 validation cases.

Results: OVHs and DVHs for 9 OARs were characterized in 2 to 4 and 4 to 5 PCs, respectively. As a result of 10-fold cross validation, artificial neural network showed best performance, the lowest mean square error between predicted and original data set compared with others. In the validation tests of neural network model, the mean square error of brain stem, right parotid gland, left parotid gland, right submandibular gland, left submandibular gland, right cochlea, left cochlea, esophagus, and spinal cord were 0.0671, 0.0430, 0.0520, 0.0671, 0.0634, 0.0596, 0.0916, 0.0612, and 0.0684, respectively. In most cases, predicted DVHs for OARs were in good agreement with the original data, no significant statistical differences in dosimetric characteristics ($p > 0.05$). However, a predicted DVH for parotid glands showed slightly lower than original one, that is, there was room for improvement. By re-optimization of Tomotherapy plan with new dose constraints based on predicted dose value, we were able to obtain a new DVH that matched the predicted DVH for parotid glands.

Conclusions: We developed a DVH prediction model for OARs and validation results matched well with the original data in NPC Tomotherapy. The patient specific DVH prediction from individual patient anatomic features could improve plan quality.

Keywords: Prediction model, Dose-volume histogram, Machine learning, Head and neck cancer, Tomotherapy