Dose-Volume Histograms Guided Deep Dose Predictions

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Purpose/Objective

Radiotherapy treatment planning involves creating a plan to deliver the radiation dose while minimizing damage to healthy organs. Traditionally, this planning is done semi-manually by dosimetrists who define constraints for the dose delivered to different structures. Recently, deep learning techniques have shown promise in automating parts of this process by predicting the 3D dose distribution based on patient scans. Dose mimicking1 is then used to find the treatment plan. However, these techniques lack interaction between the dosimetrist and the treatment planning system (TPS). We propose including target Dose-Volume Histograms (DVHs) in the dose prediction model. Modifications of the target DVH make the process interactive.

Material and Methods

We used a cohort of 168 patients from the ICM radiotherapy department (Institut régional du Cancer de Montpellier). We have developed a deep-learning model to predict the 3D dose distribution for radiotherapy treatment planning. We used a standard U-net with the CT scan, the Principal Target Volume (PTV) contour, the Rectum contour, and the Bladder contour as inputs.
To incorporate DVH information, the model uses a technique called Direct Affine Feature Transforms (DAFT)2. Three models were compared: one without DVH data (model C, classical U-net), one with DVH data incorporated at the bottleneck layer (model B), and one with DVH data incorporated throughout all encoder-decoder connections (model A).

Results

Quantitatively, the networks incorporating the DVH data performed better, with Mean Absolute Error (MAE) on a test set of 2.42 Gy (model A), 2.58 Gy (model B), and 3.18 Gy (model C). The dataset comprises patients prescribed 62 Gy on the PTV and others 78 Gy on the PTV. We observe that model C could not adapt to the different prescriptions and consistently predicted a dose that looks like a 65 Gy prescription. Conversely, models A and B adjusted their deep dose predictions to the prescription. These modifications in the predicted 3D dose indicate that the models adapted their predictions to fit the DVHs.

Conclusion

Our study demonstrates the possibility of incorporating DVH data into deep dose generation models. Dose prediction is more accurate with DVHs, and our model adapts better to varying prescriptions. This technique allows a new dose optimization workflow where dosimetrists only need to design the DVHs that suit them. The TPS will compute the deliverable plan that best matches the DVHs asked. Moreover, while one cannot transfer a 3D dose from one patient to another, DVHs are comparable across patients. Hence, after finding one DVH set that suits a center's practices, calculating the optimal plan for new patients will only need minor modifications.