Effectiveness of Robust Optimization in Head and Neck IMPT Dose Distributions

In order to mitigate the influence of range and patient setup uncertainties in IMPT, a method that takes the uncertainties into account during plan optimization via worst-case robust optimization was used. We used the standard deviation-volume histograms (SVH) area-under-the-curve as a single quantitative measure of the robustness of the plan. Figure 1 illustrates the use of SVH’s to evaluate robustness. Smaller is the area under the SVH curve, greater is the robustness. The PTV-based conventional plans and robustly optimized plans were generated for 14 head and neck cancer cases. We compared the mean evaluation metrics of those 14 cases and then obtained the corresponding p value via pair t-test to minimize the influence of patient variation.

Compared to PTV-based conventional plans, robust optimization led to more robust dose distributions for both targets and organs to uncertainties (smaller areas for all structures) (figure 2) and the targets were better covered by the prescribed doses (higher target D95 doses) with more homogeneous dose distributions (lower target D5 doses as well) (figure 3). Meanwhile, our method provided better protection for organs-at-risk (lower D1cc doses for spinal cord and brainstem, lower mean doses Dmean for oral cavity and parotids, and lower D1% doses for other organs) (figure 4). Those conclusions were almost all statistically significant ($p < 0.05$).

Our findings filled gaps in our knowledge about appropriate ways to mitigate the influence of uncertainties in IMPT and thus would lead to significant benefit for cancer patients.