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Supplementing of a HyperArc-Based RapidPlan Model with Multicriteria Optimization for the Management of Complex Recurrent Head and Neck Stereotactic Radiotherapy

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Abstract

Objectives:

A conventional daily dose of radiation therapy treatment for recurrent head and neck (RHN) tumors causes significant dosimetric and technical challenges due to treatment related radiation induced toxicity concerns and unfavorable treatment outcomes. Recent studies have shown stereotactic radiotherapy (SRT) as a feasible treatment option for the management of these complex patients who have already received a full course of radiation. Within our clinic we have begun using Varian's HyperArc module to deliver fast, safe, and effective treatments for RHN cancers that adequately protect adjacent organs-at-risk (OAR) while allowing potential dose escalation to the tumor center. To complement this technique, we seek to develop and validate a HyperArc-based RapidPlan model capable of generating high-quality RHN SRT treatment plans in a timely manner. Additionally, we test the capabilities of multicriteria optimization (MCO) to explore tradeoffs in complex RHN SRT plans.

Methods:

A RapidPlan model was developed using 29 high-quality, manually generated, previously treated HyperArc RHN SRT plans. The plans had prescriptions of 30-40 Gy in 5 fractions (25), 10 Gy in 3 fractions (3), and 10 Gy in 1 fraction (1). Model generation and plan testing was conducted in Eclipse v16.1 with plans being generated using the HyperArc module on a TrueBeam LINAC with a 6 MV-FFF beam. Dose was calculated using AcurosXB with optimization conducted by the Photon Optimizer algorithm, both with the GPU enabled. The plans were divided into training and testing sets based on their fractionation schemes, number of lesions, and PTV volume. The training set consisted of 25 plans with an average of 1.1 lesions ± 0.4 lesions (1 lesion – 3 lesions), an average PTV volume of 67.49 cc ± 54.03 cc (4.15 cc – 232.41 cc), one single-fraction plan, two three-fraction plans, and 21 five-fraction plans. The testing set consisted of 4 plans with an average of 1.3 lesions ± 0.4 lesions (1 lesions – 2 lesions), an average PTV volume of 69.35 cc ± 84.53 cc (8.77 cc – 235.98 cc), one three-fraction plan, and three five-fraction plans. After fine-tuning the model for dosimetric and geometric outliers within Varian's Model Configuration application, the testing plans were replanned using the model with the process being automated via the Eclipse Scripting API. The plans were normalized such that 95% of the PTV volume received the prescription dose, similar to the original clinical plans. The RapidPlan plans were evaluated against the original clinical plans for several maximum OAR doses including the larynx, mandible, brainstem, and carotid arteries. Additionally, the mean PTV and GTV doses were assessed. Due to the varying prescription doses, the difference between the original plan values and the RapidPlan values was used to gauge the performance of the model. If the resulting model plans did not achieve favorable dose distributions, they were then loaded into the MCO interface to explore available tradeoffs between target coverage and OAR sparing.

Results:

The testing RHN SRT plans were generated in 13.7 minutes ± 1.5 minutes (12.3 minutes - 16.3 minutes) measured from the end of the HyperArc plan generation module to the final dose being finished calculating. The mean PTV dose for the RapidPlan plans was increased by 1.2 Gy on average with the mean GTV dose being increased by 1.4 Gy on average. The larynx saw a 4.4 Gy decrease in dose on average from the original clinical plans to the RapidPlan plans. Similarly, the right mandible saw a 2.4 Gy decrease, with one plan receiving a 7.8 Gy reduction from 26.7 Gy to 18.9 Gy. The brainstem, however, saw an increase in dose from the original plans to RapidPlan plans of 2.7 Gy on average, this was particularly skewed by Test Plan #4 (PTV volume = 235.98 cc) where the adjacent brainstem had been extensively spared, receiving only 9.3 Gy in the

original plan to receiving 20.3 Gy in the RapidPlan plan, although a noticeably increase, this value was still within clinical protocol tolerances. All other plans received comparable dose distributions and were deemed clinically acceptable. MCO was used on Test Plan #4 to explore the possible tradeoffs available between the maximum dose to brainstem and the PTV mean dose. MCO took approximately 25 minutes to generate the initial tradeoff exploration for three selected objectives (brainstem maximum dose, PTV D100%, and PTV D95%). After generating the exploration options, the brainstem maximum dose was improved at the cost of the PTV dose, slightly reducing the PTV D95% while greatly improving the brainstem maximum dose. After calculating the final dose and renormalizing the plan such that the PTV D95% received the prescription dose, the brainstem maximum dose was 13.0 Gy, an improvement of 7.3 Gy from the initial RapidPlan plan. However, this tradeoff came at the cost of the PTV mean dose being reduced from 34.2 Gy to 33.7 Gy. The other most notable change was a reduced maximum dose to the GTV from 39.1 Gy to 37.3 Gy. Although reduced when compared to the initial RapidPlan plan, the MCO plan still escalates tumor dose slightly when compared to the original clinical plan.

Conclusion(s):

The technique introduced in this research demonstrates a promising SRT clinical workflow for the treatment of complex RHN tumors in a timely manner. Leveraging knowledge-based planning allows for lesser skilled treatment planners to generate high-quality, clinically acceptable plans in a shorter amount of time compared to experienced manual planners, not only standardizing plan quality but improving accessibility of high-quality radiation therapy treatments for RHN tumors. The addition of multicriteria optimization enables real-time feedback for exploring various tradeoffs encountered for RHN tumors, providing a useful tool for complex SRT plans. We are actively refining the HyperArc-based RapidPlan model for in clinic use and further exploring the utility of MCO.