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Reducing the Number of Fractions for LINAC-Based Stereotactic Radiotherapy of Brain Metastases: Improved Target BED with Comparable Normal Brain Toxicity

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Abstract

Objectives:

To develop and clinically implement a stereotactic radiotherapy (SRT) auto-planning method for improving the biologically effective dose (BED) to tumor(s) for single-isocenter single- and multi-lesion (SISL/SIML) brain metastases by reducing the number of treatments while maintaining appropriate normal brain toxicity.

Methods:

A HyperArc-based RapidPlan model was generated using 49 previously treated, high-quality three-fraction (24-27 Gy) SRT plans with a focus on minimizing low dose spread to normal brain. The model was then used to replan 20 previously treated five-fraction (25-35 Gy) SRT plans to 27 Gy in three-fractions. All planning was done in Varian's Eclipse v16.1 for a TrueBeam LINAC (6 MV-FFF) with dose calculated using AcurosXB. Plan quality was evaluated on PTV conformity, target coverage, including BED of GTVs, and OAR doses in accordance with Alliance A071801, RSS Guidelines, AAPM TG-101, as well as in-house clinical criteria.

Results:

The SRT model was successfully trained on 39 of the three-fraction plans and validated on the remaining 10 plans. The training set had an average of 2.2 lesions ± 1.6 lesions (1 lesion – 8 lesions) with an average PTV volume of 4.89 cc ± 5.94 cc (0.07 cc – 31.82 cc). The testing set had an average of 1.7 lesions ± 0.8 lesions (1 lesion – 3 lesions) with an average PTV volume of 4.66 cc ± 5.89 cc (0.39 cc – 27.31 cc). When testing the model, the RapidPlan plans' PTV D95% were normalized to that of the original plans. The RapidPlan plans achieved a statistically significant ($p < 0.01$) increase in GTV D100% with the original plans receiving a mean value of 28.5 Gy ± 0.7 Gy (27.2 Gy – 29.9 Gy) and the RapidPlan plans receiving 29.4 Gy ± 0.6 Gy (28.4 Gy – 30.4 Gy). Furthermore, the RapidPlan plans demonstrated a statistically insignificant ($p = 0.12$), but a potentially clinically significant, decrease in the average normal brain V18Gy with the original plans receiving 8.81 cc ± 5.19 cc (4.03 cc – 19.36 cc) and the RapidPlan plans receiving 8.06 cc ± 4.49 cc (2.94 cc – 17.38 cc). The replanned five-fraction plans consisted of an average 2.1 lesions ± 2 lesions (1 lesion – 9 lesions) with an average PTV volume of 5.45 cc ± 6.89 cc (0.21 cc – 20.96 cc). The replanned five-fraction plans all achieved clinically acceptable plans. Plan normalization was set such that all PTVs' D95% received at least the prescription dose, resulting in a Paddick conformity index of 0.87 ± 0.05 (0.65 – 0.94) compared to the original five-fraction plans' Paddick conformity index of 0.88 ± 0.05 (0.74 – 0.94). The GTVs' average D100% was 29.1 Gy ± 1.1 Gy (25.7 Gy – 30.6 Gy). With a clinically used α/β ratio of 10 Gy, the minimum dose becomes an average BED10 of 57.3 Gy ± 3.1 Gy (47.8 Gy – 61.9 Gy) compared to the original five-fraction plans' BED10 of 52.9 Gy ± 4.5 Gy (46.8 Gy – 64.1 Gy), a statistically significant ($p < 0.01$) increase of 4.4 Gy BED10. All OAR doses were deemed clinically acceptable when considering the aforementioned criteria, including an average V18Gy of 9.9 cc ± 5.9 cc (1.3 cc – 25.8 cc) and an optic pathway D0.03cc of 2.8 Gy ± 3.7 Gy (0.4 Gy – 17.2 Gy). The replanned five-fraction plans had 2847 ± 534 (2229 – 4344) total monitor units. Plan generation using the SRT RapidPlan model took an average of 12.4 minutes ± 2.6 minutes, compared to 2-4 hours of manual planning by experienced planners.

Conclusion(s):

The SRT model developed in this research provides physicians the opportunity to reduce the number of fractions required to deliver an effective and safe dose of radiation for SRT of brain metastases, demonstrating the possibility of a shorter total treatment time achieving superior biological dose to tumors

and acceptable OAR doses, while adequately sparing normal brain tissue. Reducing the number of fractions leads to an improved patient experience with less time in the clinic, improving machine availability to treat more patients sooner. Furthermore, the use of machine learning and scripting allows for the generation of standardized SRT plans for brain metastases in less than 20 minutes, greatly improving the treatment planning workload and potentially enabling same-day SRT treatment in the future. Due to these advantages, the model is currently being used in our clinic to automatically generate three-fraction alternatives to manually generated five-fraction SRT plans. Patient reported clinical follow up outcomes for three-fraction SRT plans generated using this model will be presented in the future. We strongly encourage other clinics to begin implementing this, or similar, SRT techniques in their clinics.