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Dosimetric Impact of Translations and Rotations in the Single-Isocenter Multi-Lesion Stereotactic Radiosurgery (SRS) Treatments

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Published 04/02/2023

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Categories: Medical Physics, Radiation Oncology
Keywords: radiotherapy treatment planning, multi-target srs, single isocenter radiosurgery

How to cite this abstract
Chen Y, Vinogradskiy Y, Shi W, et al. (April 02, 2023) Dosimetric Impact of Translations and Rotations in the Single-Isocenter Multi-Lesion Stereotactic Radiosurgery (SRS) Treatments. Cureus 15(4): a933

Abstract

Objectives:

In single-isocenter multi-target SRS treatment, off-axis targets are subjects to greater dose coverage loss due to set up uncertainties. There is a lack of studies evaluating the dosimetric impact of uncertainties in situations where >5 lesions are treated per isocenter. This work aims to evaluate the dosimetric impact of translations and rotations on dose coverage for multi-lesion SRS treatments.

Methods:

Ten patients (122 metastases, 7-22 metastases per patient) were included in this study. All patients were treated with Linac-based singe-isocenter dynamic conformal arcs. GTV to PTV margins ranged from 0 to 2mm. The dose distribution was virtually shifted/rotated around the isocenter and then used to re-calculate dose-volume histograms (DVH) for each target. Translations of ±1 mm in three directions and rotations of ±1° around three axis (total of 12 scenarios) were simulated separately for the dosimetric impact evaluation. To evaluate the impact on target coverage, the volume covered by the prescribed dose (V100) was used. The minimum of V100 was reported to present the worst-case scenario for the simulations with translations (V100-trans)/ rotations (V100-rot). The dosimetric change was analyzed as a function of target-to-isocenter distances and volume of the targets.

Results:

V100-rot of PTVs decreased 6.0% and 13.4% on average for the targets with isocenter distance < 4cm (29 metastases) and >6cm (40 metastases) while V100-trans of PTVs decreased 10.6% and 9.5% on average for these two groups, respectively. The coverage loss due to rotational uncertainties is associated with target-to-isocenter distances ($p< 0.01$) while the effect of translations is not significantly related to the target-to-isocenter distance ($p=0.15$). Dosimetric changes of PTVs are significantly associated with the target volume for both V100-trans (Spearman's correlation coefficient $rs =0.82$, $p< 0.01$) and V100-rot ($rs =0.57$, $p< 0.01$). No coverage loss was observed for 42 of 44 GTVs with margins ⩾1.5mm. With margins ⩽ 1mm, GTV coverage loss was more sensitive to rotations than translations for the distant targets. In contrast, for targets close to isocenter, translational errors would have a higher impact on the dosimetric change.

Conclusion(s):

Due to small targets, high doses per fraction, and the possibility of many metastases per treatment, multi-lesion SRS treatments require a high degree of dosimetric precision. Our results characterized the dosimetric impact of translations vs. rotations for the single-isocenter SRS treatments (7-22 metastases per treatment) and indicated that uncertainties in translations and rotations (machine limits) can result in significant underdosing of the target. The presented work provides seminal data underscoring the need for robustness analysis for multi-lesion SRS treatments.