

Loss of Target Coverage Due to Rotational Errors in Single Isocenter Multiple Target SRS: A Treatment Planning Study

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Abstract

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Abstract

Objectives: This study aimed to quantify the impact of rotational setup errors on target coverage in single isocenter multiple target (SIMT) stereotactic radiosurgery (SRS) for multiple brain metastases on a C-Arm Linac. Building upon prior theoretical work (Nakano 2020) that modeled geometric effects of setup uncertainty, this investigation directly evaluated how rotational errors influence delivered dose distributions using calculated phantom data. Specifically, we sought to compare the loss in target coverage derived from treatment planning studies with that predicted by geometric models.

Methods: In the treatment planning system, targets with diameters from 5 to 20 mm were placed 5 cm from isocenter within an SRS QA phantom (recommended PMMA material override density = 1.19). SRS plans were generated for each target using 4 noncoplanar VMAT arcs (couch angles 315, 0, 45, 90). Plans were normalized to D99.5%. Rotational setup errors about the treatment couch axis were simulated for range 0.5° to 2°, and dose distributions were recalculated for each rotation scenario using the original treatment plan MU and geometry. Target coverage metrics (V100% and Paddick CI) were extracted and compared with baseline (no induced couch rotation) conditions. Coverage loss was analyzed as a function of target size and magnitude of rotational error.

Results: Increasing rotational setup error resulted in progressive degradation of target coverage for off-isocenter targets: V100% decreased with increasing rotational error, with the greatest losses observed for smaller targets: up to 44.3% loss for 5 mm target at 2° rotation. Even for a 20mm target, a 2° rotation correlates with a coverage reduction of 11.9%. Compared with geometric estimates reported in prior studies, the phantom-based dose calculations demonstrated a more pronounced sensitivity to rotational error: for 10 mm target, we find 22.4% reduction vs Nakano reduction of 15.2%. Additionally, for this 10 mm target, the Paddick CI is reduced from 0.95 at no induced rotation to 0.76 at 1° and 0.55 at 2°.

Conclusion(s): Phantom-based dose recalculations indicate that the degradation of target coverage due to rotational setup errors in SIMT SRS is more substantial than previously predicted by geometric models. These results highlight the importance of minimizing rotational setup uncertainty—particularly for patients with small, off-isocenter metastases—and may inform future tolerance criteria and adaptive correction strategies in multi-target SRS workflows. This work provides clinically realistic and easily understood results that can be used to estimate target coverage loss in SIMT SRS when rotational errors are present in the patient setup.