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abstract

Planning Target Volume Margin in Linac-Based Stereotactic Radiosurgery for Brain Metastases

Radwa Hamed Sabra, Hany Samy Attallah, Khaled EL-Shahat, Aliaa Mahmoud, Mahmoud Abdallah, Ibraheem Haggag, Emad Moustafa, Adel Yassin

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Planning Target Volume Margin in Linac-Based Stereotactic Radiosurgery for Brain Metastases

Author: Radwa Hamed Sabra[1], Hany Samy Attallah[1], Khaled EL-Shahat[2], Aliaa Mahmoud[3], Mahmoud Abdallah[3], Ibraheem Haggag[3], Emad Moustafa[3], Adel Yassin[2]

Affiliation: [1]Armed Forces College of Medicine, Clinical Oncology Department, Egypt
[2]Al Azhar University, Clinical Oncology Department, Egypt
[3]The International Medical Center, Radiation Oncology Department, Egypt

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Introduction: Stereotactic radiosurgery (SRS) has become a cornerstone in the radiotherapeutic management of brain metastases, enabling highly conformal dose delivery with steep dose gradients. Target definition typically includes the gross tumor volume (GTV), with optional expansion to a planning target volume (PTV) to account for setup uncertainty and intrafraction motion. However, the optimal GTV-to-PTV margin remains controversial: some protocols adopt no margin (GTV = PTV), whereas others apply 1–2 mm expansions. Because SRS dose gradients are sharp, even small geometric expansions may substantially increase irradiated normal brain volume, potentially impacting the volume of brain receiving 12 Gy (V12), which is commonly constrained (e.g., to ≤10 cm^3) to mitigate toxicity. Notably, a 2-mm uniform expansion around a 20-mm lesion can markedly increase target volume and may meaningfully elevate V12. Aim was to compare the dosimetric consequences of 0-mm, 1-mm, and 2-mm GTV-to-PTV expansions in Linac-based SRS for single brain metastases.

Methodology: This dosimetric study retrospectively re-evaluated treatment plans for 20 patients with single brain metastasis treated with linac-based SRS at our center. The GTV was delineated on fused planning CT and high-definition MRI datasets (both with 1-mm slice thickness). The institutional routine defines CTV = GTV (no margin) and PTV1 = GTV + 1 mm. For the purpose of this analysis, three planning scenarios were compared: PTV0 (GTV = PTV, 0-mm margin), PTV1 (GTV + 1 mm), and PTV2 (GTV + 2 mm). To characterize near-target dose spill, two "peel" volumes were constructed from the GTV: Peel1 = (PTV1 − GTV) and Peel2 = (PTV2 − GTV), and their dosimetric parameters were analyzed separately. The dose prescription followed the classic RTOG 90 – 50 study.

Results: AThe mean volume of PTV1 is 6.11(SD: ±4.68), and the PTV2 is 7.88 (SD: ±5.67) that the mean of PTV1 is smaller than the mean PTV2 by 23% (p=0.006) Using a 1 mm margin vs. 2 mm reduces the V12 mean volume by more than 14%, V12 PTV1: 5.45 (SD: ±2.18) vs. V12 PTV2: 6.35 (SD: ±2.77) (p=0.000). For the peel analysis, the mean isodose li-

ne of Peel1 significantly (p = 0.022) increased by 2% when the margin increased from 1 mm to 2 mm i.e. 102.99% (SD: ±2.09) vs. 104.96% (SD: ±2.30). In addition, the Peel2 mean dose was significantly (p = 0.013) increased by 3% i.e. 98.92 (SD: ±2.38) vs. 102.85 (SD: ±5.79).

Conclusion: In this cohort, expanding the GTV to a 1-mm PTV margin provided more favorable dosimetry than a 2-mm margin, with significantly smaller target volumes and meaningful reductions in V12 and peritumoral dose spill. These findings support the preferential use of a 1-mm GTV-to-PTV margin in linac-based SRS for single brain metastases when institutional setup accuracy and image guidance are robust.

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