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Efficacy and Dosimetric Impact of Adaptive Gamma Knife Radiosurgery in the Management of Brain Metastases

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Abstract
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Abstract

Objectives:

This study investigates the clinical outcomes and dosimetric changes achieved with adaptive radiosurgery in patients with brain metastases, focusing on volumetric tumor response and protection of critical brain structures.

Methods:

A total of 31 patients with 47 metastatic brain lesions underwent adaptive stereotactic radiosurgery (SRS). The cohort had a mean age of 64.8 years, with an M:F ratio of 14:17. The primary malignancies included non-small cell lung cancer (NSCLC, 48.4%), small cell lung cancer (12.9%), genitourinary cancers (12.8%), and others. Lesions were predominantly supratentorial (61.7%), with volumes ranging from 0.041 cc to 49.6 cc. The median treatment duration was 16 days (range: 7–53 days), delivered in 2-5 fractions per lesion. The characteristics of the treatment plans, radiologic responses and clinical outcomes were analyzed for this cohort.

Results:

A significant volumetric reduction was observed following the first fraction, with a mean change of -22.8% (±32%) and a median reduction of 22%. Despite initial reductions, 6 lesions (12.8%) showed volume increases post-initial treatment. At final follow-up (median: 365 days, range: 27–2886 days), the median volumetric reduction was -95.9%, with 5 lesions demonstrating complete resolution. A polynomial function (3rd order) was used to model the relationship between initial volume and response.

Adaptive treatment allowed for significant dose reductions to critical structures, including the brainstem, thalamus, and motor cortex, with a median Dmax reduction of 6.5% and a mean Dmean reduction of 7.3%.

Conclusion(s):

Adaptive radiosurgery provides effective tumor control in brain metastases, with a notable volumetric reduction across treatments. Additionally, adaptive planning optimizes dosimetry, reducing radiation exposure to structures at risk, enhancing patient safety. These findings support the role of adaptive SRS as a critical tool in managing brain metastases while preserving neurological function.