DOI:10.31557/APJCC.2026.11.1.53

RESEARCH ARTICLE

Stereotactic Radiosurgery and Stereotactic Radiotherapy for Brain Metastasis: Experience from a Tertiary Cancer Centre

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Abstract

Introduction: Brain metastases are a common and serious complication in cancer patients, significantly impacting neurological function and quality of life. Stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy (FSRT) offer focal, precise treatment options with potentially lower toxicity compared to whole brain radiotherapy. This study aims to evaluate the clinical outcomes and dosimetric parameters of SRS and FSRT in patients with brain metastases treated at a tertiary cancer center. **Materials and Methods:** A retrospective observational study was conducted on 13 patients with solitary brain metastases treated with SRS or FSRT from 2014 to 2022. Patient data, treatment details, and dosimetric parameters were collected. Overall survival (OS) and local progression-free survival (LPFS) were estimated using the Kaplan–Meier method. **Results:** The median age of patients was 56 years, with lung (62%) and breast (38%) as the most common primary tumors. The median OS was 12 months, with 1- and 2-year OS rates of 48% and 29%, respectively. LPFS at 1 and 2 years was 47% and 19%. Dosimetric parameters, including target volumes and plan quality indices, adhered to established stereotactic radiotherapy standards. No symptomatic radionecrosis was reported. Systemic therapy use was limited due to resource constraints. **Conclusion:** SRS and FSRT can be delivered with high dosimetric precision and acceptable toxicity in patients with brain metastases, even in settings with limited access to advanced systemic therapies. These findings support the continued use of focal radiotherapy modalities and underscore the need for larger prospective studies incorporating modern systemic treatments to optimize management and outcomes.

Keywords: Brain metastasis- SRS- SRT

Asian Pac J Cancer Care, **11 (1)**, 53-58

Submission Date: 09/27/2025 Acceptance Date: 12/07/2025

Introduction

Brain metastases are the most common intracranial tumours in adults, occurring in approximately 20–40% of all cancer patients during the course of their illness [1] . With advancements in systemic therapy and imaging, the incidence of brain metastases has increased, often presenting earlier in the disease course. These lesions are a major cause of morbidity and mortality, significantly affecting neurologic function and quality of life [2] .

Management depends on several factors, including age, performance status (PS), number, volume and location of brain metastases, presence of extracranial disease, and the primary tumour type [3, 4]. Treatment options include surgical resection, whole brain radiotherapy (WBRT), stereotactic radiosurgery (SRS), stereotactic radiotherapy (SRT), and best supportive care. Although WBRT is widely used, particularly in patients with multiple lesions, it is associated with cognitive decline and limited survival benefit in many cases [5].

In recent years, SRS and SRT have emerged as highly precise, focal radiotherapy techniques offering excellent lesion-specific control while sparing surrounding normal brain tissue. SRS delivers a single high dose to a defined target, whereas SRT uses fractionated dosing over 3–5 sessions, making it suitable for larger lesions or those near critical structures [6, 7]. These modalities provide shorter treatment durations, lower toxicity, and better

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neurocognitive outcomes compared to WBRT [8].

Randomised trials such as RTOG 9508 and JLGK0901 have established the efficacy of SRS in improving local control and survival in selected patient subsets [9, 10]. Contemporary guidelines now recommend SRS alone in patients with limited brain metastases and stable extracranial disease, underscoring the importance of individualised treatment approaches [11].

This retrospective study aims to analyse the clinical outcomes and dosimetric parameters associated with SRS and SRT in patients with brain metastases treated at our tertiary cancer centre.

Materials and Methods

This retrospective observational study was conducted in the Department of Radiation Oncology at Malabar Cancer Centre, Kerala, India. The study included all patients with brain metastases who underwent stereotactic radiation either SRS or SRT between January 1, 2014, and December 31, 2022. Data collection was carried out from May 1, 2023, to June 15, 2023. Patients of any age and sex who received SRS or SRT during the study period were eligible for inclusion.

Demographic details, clinical presentation, and treatment details were retrieved from medical records and radiotherapy charts. Dosimetric parameters, including gross tumour volume (GTV), planning target volume (PTV),Dose volume to normal brain tissue, Homogeneity index (HI), Radiation Therapy Oncology Group conformity index (RTOG CI), and Gradient index (GI), were extracted from the treatment planning system.

The primary outcomes assessed were overall survival (OS) and local progression-free survival (LPFS). OS was defined as the time interval from the date of diagnosis of brain metastasis to the date of death from any cause or the date of last follow-up. LPFS was defined as the time from diagnosis to either radiological progression of the treated lesion, death, or last follow-up, whichever occurred first. In the survival analysis, patients who were still alive at the last follow-up or lost to follow-up were treated as censored observations. This means their survival time was considered up to the date of last contact without an event (death or progression), and these censored times were incorporated into the Kaplan–Meier survival estimation accordingly.

Dosimetric parameters were expressed as mean ± standard deviation. Categorical variables were summarized using frequencies and percentages. Survival outcomes, including OS and LPFS, were estimated using the Kaplan–Meier method. All statistical analyses were performed using IBM SPSS software, version 20.0.

Results

A total of 13 patients were analysed. The median age was 56 years (range: 47–74 years). Of the 13 patients, 8 (61%) were female. Regarding performance status, 54% of patients had an ECOG PS of I, while 46% had PS II.

The lung was the most common primary site, observed in 8 patients (62%) and followed by breast in the remaining cases. Brain metastases were metachronous in the majority of patients (n = 9, 69%), occurring after the diagnosis of the primary malignancy. The remaining patients presented with synchronous brain metastases, identified at the time of initial cancer diagnosis. Only one patient (7.5%) had extracranial metastasis in addition to brain involvement. The most frequent site of brain metastasis was the left occipital lobe, identified in 5 patients (38%). All patients had solitary lesions. Patient and disease characteristics are summarised in Table 1.

Table1. Clinicodemographic Details of Patients

Age (Years)	Median 56 (%) Range 47-74
Gender	
Male	5 (38)
Female	8 (62)
Performance Status (ECOG)	
1	7 (54)
2	6 (46)
Primary	
Lung Cancer	8 (62)
Breast Cancer	5 (38)
Metastasis Timing	
Synchronous	4 (31)
Metachronous	9 (69)
Non Brain metastases	
Absent	12 (92)
Present	1 (8)

Four patients (31%) underwent surgical resection prior to SRS/SRT. None of them had residual disease postoperatively. One patient (7.5%) received a combination of WBRT and SRT for brain metastasis. Two patients (15%) received SRS, and the remaining patients underwent SRT. The majority of patients (n = 9, 69%) received systemic therapy following radiotherapy. Three lung cancer patients received combination chemotherapy with Pemetrexed and Carboplatin, and among these, one patient was additionally treated with Erlotinib and Osimertinib. Additionally, one patient with large cell neuroendocrine carcinoma was treated with an Etoposide and Carboplatin regimen. Among patients with breast cancer, three received Capecitabine, with one of these patients also receiving Lapatinib. In addition, two patients were managed with hormone therapy alone.

For patients treated with SRT, the most commonly prescribed dose was 30 Gy in 5 fractions (n = 5, 38%). For those who received SRS, the prescribed dose was 24 Gy in a single fraction (n = 2, 15%). Most patients (n = 12, 92%) completed the planned course of radiotherapy, while one patient (7.5%) discontinued treatment due to clinical deterioration. Radiation therapy doses are summarised in Table 2.

The mean GTV was 10.18 ±9.4 cc. Among patients who underwent resection, the mean CTV was 18.24 ±12

Table 2. Radiation Therapy (RT) Details of the Patients

RT Technique	(%)
SRS	10 (77)
SRT	2 (15)
SRT and WBRT	1 (8)
RT dose schedules	
30 Gy in 5 fractions	5 (38)
27 Gy in 3 fractions	4 (31)
24 Gy in 1 fractions	2 (15)
36 Gy in 3 fractions	1 (8)
20 Gy in 4 Fractions	1 (8)

Abbreviations: SRT- Stereotactic Radio Surgery, SRT- Stereotactic Radio Therapy, WBRT- Whole Brain Radiotherapy.

cc. The mean PTV was 23.29 ±22 cc. The mean RTOG conformity index (CI) was 1.3±0.5, the mean homogeneity index (HI) was 1.1±0.5, and the mean gradient index (GI) was 1.99±1.5. For SRS cases, the mean V10 and V12 of the brain minus GTV were 13.8 cc and 11.17 cc, respectively. For fractionated stereotactic radiotherapy (FSRT) cases, the mean V18 and V21 of the brain minus GTV were 58.78 cc and 53.65 cc, respectively. Regarding organs at risk, the mean Dmax was 6.4 Gy for the brainstem, 1.32 Gy for the optic nerves, and 0.78 Gy for the optic chiasm.

The local progression-free survival at 1 and 2 years was 47% and 19%, respectively. The overall survival at 1 and 2 years was 48% and 29%, respectively. The median overall survival was 12 months. The overall survival of patients with brain metastases originating from breast and lung cancer is depicted in Figure 1. The Kaplan-Meier survival curves demonstrate the estimated survival probabilities for both subgroups, revealing a median overall survival of 12 months for breast cancer patients and 8.5 months for those with lung cancer. Among patients who underwent surgery, the median survival was 4.5 months, while those treated with radiotherapy alone had a median survival of 12 months.

Discussion

Brain metastases are a common sequela of solid malignancies, particularly from lung and breast primaries. Advances in systemic therapy and imaging have increased their early detection. Treatment strategies have evolved to favour focal modalities such as SRS and SRT, especially in patients with limited intracranial disease. This study evaluated outcomes in patients with solitary brain metastases treated with SRS/SRT, focusing on clinical characteristics, treatment parameters, and survival.

Given the small sample size (n=13), this study is primarily descriptive and exploratory, lacking sufficient statistical power to establish definitive conclusions or detect meaningful between-group differences. All findings should be interpreted with caution, and no causal inferences can be made. The median age of our patients was 56 years, consistent with the typical presentation age of 50–70 years as described in Schouten et.al study [1, 12]. A slight female predominance (62%) may reflect the inclusion of breast cancer and non-smoking lung cancer cases, which are more prevalent in women. Most patients had good performance status (ECOG 1), a common inclusion criterion in studies of focal brain radiotherapy [12, 13].

The predominance of lung and breast primaries observed in our cohort aligns with established epidemiological data identifying these cancers as the most frequent sources of brain metastases. The higher proportion of metachronous brain metastases is consistent with prior reports that brain involvement typically manifests later in the disease trajectory. Furthermore, the low incidence of extracranial metastases in our patients reflects the typical selection of individuals with limited systemic disease for focal therapies such as SRS and SRT. These patterns underscore the representativeness of our patient population relative to previously published cohorts [12-14].

The most common site of brain involvement was the left occipital lobe (38 %), though anatomical distribution varies across studies depending on vascular patterns [1]. All patients had solitary lesions, a feature associated with favourable prognosis and suitability for focal therapies like SRS/SRT [13, 14]. This study is limited to patients with solitary brain metastases, which restricts the generalizability of the outcomes to patients with multiple lesions or more advanced intracranial disease.

Surgical resection was performed in 31 % of patients, all with complete resection. One patient received WBRT + SRT, while SRS and SRT were used in 15 % and 85 % of patients, respectively. This combined treatment strategy aligns with the findings of Mahajan et al., who demonstrated that surgery followed by SRS or SRT in patients with accessible brain lesions and good performance status leads to improved local control and neurological outcomes [15, 16].

Radiation dosing in our cohort aligns with established protocols. The most common SRT regimens were 30 Gy in 5 fractions (38 %) and 27 Gy in 3 fractions (31 %), while SRS was delivered as 24 Gy in a single fraction. These schedules mirror those reported in the literature [7, 10, 13], with dose selection tailored to lesion size,

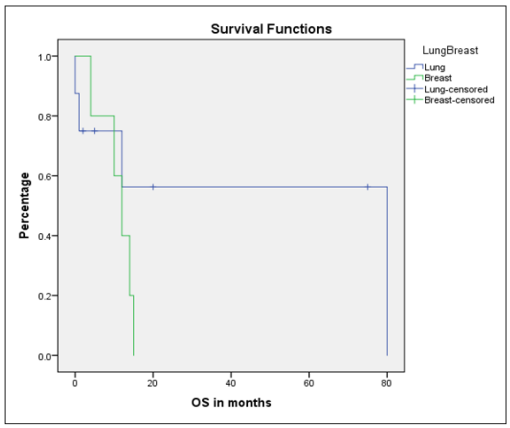

Figure1. Kaplan-Meier Curves for Overall Survival in Patients with Brain Metastases from Breast and Lung Cancer

location, and proximity to critical structures.

Treatment completion was high (92 %), with only one patient discontinuing due to clinical deterioration. This reflects the feasibility of SRS/SRT in appropriately selected patients, even those with advanced disease.

Our cohort's dosimetric parameters indicate strong adherence to established stereotactic radiotherapy planning standards. The average values for gross tumor volume, clinical target volume following resection, and planning target volume were all within acceptable ranges for brain metastasis treatments. Furthermore, our plan quality metrics including the RTOG conformity index, homogeneity index, and gradient index matched recommended benchmarks for stereotactic techniques reported in the literature [17, 18].

In SRS cases, the mean V10 and V12 of the brain minus GTV were 13.8 cc and 11.17 cc, respectively. These values are well within the safety thresholds associated with a low risk of radionecrosis [19, 20]. For FSRT, the mean V18 and V21 were 58.78 cc and 53.65 cc, respectively, consistent with contemporary FSRT dose-volume tolerances [19]. These findings are comparable to prior dosimetric studies that highlight the importance of individualised planning tailored to tumour size, location, and proximity to critical structures [17, 21, 22]. No cases of symptomatic radionecrosis were identified; detailed neurocognitive evaluation was not routinely available in this cohort.

With respect to organs at risk, the maximum doses delivered to the brainstem and optic apparatus in our cohort remained well within widely accepted safety constraints for stereotactic radiotherapy. Specifically, all values satisfied established guidelines of a brainstem Dmax below 12.5 Gy and optic nerve/chiasm Dmax below 8–10 Gy, thresholds recommended to minimize serious toxicity in both single- and multi-fraction SRS literature. This underscores the safety of our treatment approach and its adherence to published standards for critical structure protection in SRT and SRS [13, 19].

The 1-year and 2-year overall survival rates in our cohort were 48 % and 29 %, respectively, with a median OS of 12 months. These results are consistent with prior studies such as Chang et al., who reported a median overall survival of approximately 10 months in patients with 1–3 brain metastases treated with SRS. Similarly, Sahgal et al. observed a median overall survival ranging from 10 to 13 months among patients receiving FSRT or SRS. However, improved survival outcomes have been noted in select patient groups characterized by favorable prognostic factors, including good performance status, controlled extracranial disease, and the use of targeted systemic therapies in conjunction with local treatment [23]. However, other studies have shown improved survival, particularly in subsets of patients with favourable prognostic factors, such as good performance status, controlled extracranial disease, and use of targeted systemic therapies [16, 17]. Compared to published large series, the local control rates in this cohort were modest. Possible reasons include the retrospective methodology, heterogeneous dose regimens and limited access to modern systemic therapies.

In conclusion, this study highlights that SRS and FSRT can be delivered with high dosimetric precision and acceptable toxicity in brain metastasis patients. Our findings illustrate real-world clinical outcomes in a setting where advanced systemic therapy access is limited, underscoring treatment feasibility and safety. Larger prospective studies integrating modern systemic treatments are required to refine and validate optimal brain metastasis management strategies.

Clinical trial registration

Not applicable.

Conflicts of interest/Competing interests

Authors declare that they have no conflicts of interest.

Availability of data and material

The data sets used and/or analyzed during the current study are available from the corresponding authors per reasonable request.

Authors' contributions

Nabeel Yahiya, Anitta Francis, and Vinin N. V contributed to the conception, design, and final drafting of the manuscript. The remaining co-authors contributed to data collection. Chythra S contributed to the primary drafting of the manuscript. Geetha M supervised the study. All authors approved the final version for submission.

Ethics approval

This study was approved by the Institutional Ethics Committee of our institution.

Consent to participate

The requirement for informed consent was waived by the Institutional Ethics Committee due to the retrospective nature of the study.

Consent for publication

The requirement for consent for publication was waived by the Institutional Ethics Committee due to the retrospective nature of the study.

Acknowledgments

We express our sincere gratitude to our Director for the constant support and encouragement. We also extend our heartfelt thanks to Dr. Mohandos for his assistance with statistical analysis. We acknowledge the postgraduate residents and the dedicated staff of the Department of Radiation Oncology for their invaluable support throughout the course of this study.

Declaration on generative AI and AI-assisted technologies in the writing process

No generative artificial intelligence or AI-assisted tools were used in the writing, analysis, or preparation of this manuscript.

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