

Stereotactic radiotherapy treatment in brain oligometastatic patients

Fabiana Di Palma^{1 2 *}, Antonella Fontana²

1. Università degli Studi di Napoli Federico II, Naples, Italy ;

2. Santa Maria Goretti Hospital, Latina, Italy ;

* Correspondence: fbndipalma030203@gmail.com

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Radiosurgery; Neoplasm Metastasis; Radiotherapy Image-Guided (IGRT);

ABSTRACT

Oligometastatic disease is defined as a primary tumor with a limited number of distant metastatic sites, representing a low tumor burden. The aim of this study was to evaluate the efficacy of stereotactic radiotherapy (SRT), including radiosurgery, as a local treatment for brain oligometastases. Clinical records of patients with brain oligometastases treated at Santa Maria Goretti Hospital in Latina between November 2023 and August 2024 were retrospectively analyzed. Patients underwent SBRT with clinical and magnetic resonance imaging follow-up every three months. At a median follow-up of 6 months (range 2–11 months), the overall survival rate was 61%. Eight out of 13 patients were alive without treatment-related neurological complications. Response to SRT was assessed through clinical evaluation and post-treatment magnetic resonance imaging.

INTRODUCTION

Brain metastases predominantly affect the cerebral hemispheres, cerebellum, and basal ganglia and arise from primary tumors located in other anatomical sites. When the number of metastatic sites and lesions is limited, the condition is defined as oligometastatic disease, typically characterized by the presence of 1–5 lesions [1]. In this setting, stereotactic radiotherapy represents a key loco-regional treatment option. The main approaches include stereotactic radiosurgery (SRS), delivered in a single high-dose fraction, and fractionated stereotactic radiotherapy (SRT), administered in multiple high-dose fractions. SRT enables the delivery of ablative radiation doses with high precision while minimizing exposure to surrounding healthy tissues. Several clinical studies have reported a favorable toxicity profile and potential improvements in local control and survival in selected patients. Treatment selection requires a multidisciplinary evaluation integrating clinical and radiological data to ensure individualized planning. In this context, the use of advanced technologies and dedicated imaging strategies is essential. The combined use of contrast-enhanced CT and MRI during the planning phase allows accurate three-dimensional reconstruction of the target volume. Image registration software improves the delineation of target volumes and organs at risk, which is crucial for the radiotherapeutic management of oligometastatic brain disease.

MATERIALS AND METHODS

This is a preliminary, retrospective, descriptive study, including patients treated with stereotactic radiotherapy at the Radiation Oncology Unit of Santa Maria Goretti Hospital, Latina, between November 2023 and August 2024. Twenty patients (median age 64 years, range 51–81) with a diagnosis of oligometastatic disease were referred to the Radiation Oncology Unit. Thirteen patients had brain metastases, five had lymph node metastases, and two had lung metastases. For the present analysis, only patients with brain oligometastases (n = 13) treated with stereotactic radiotherapy were included. It should be noted that this is a very small sample, which limits the generalizability of the results.

All patients underwent clinical evaluation and radiological assessment to confirm limited metastatic disease and stability of the primary tumor. Patients were eligible if they met all of the following criteria: ECOG Performance Status 0–1 [2], documented oligometastatic disease with low tumor burden, stability of the primary tumor after previous treatments and absence of progressive systemic disease or presence of stable extracranial disease.

Patients underwent CT simulation in a stereotactic immobilization mask. Three radiopaque markers were positioned on the mask (central, right lateral, and left lateral) to identify the CT isocenter. CT scans were acquired with a 25 cm field of view, 1.25 mm slice thickness, and 1.25 mm interslice spacing, with coverage from the vertex to at least the second cervical vertebra (Figure 1). The complete dataset was transferred to the treatment planning system (TPS).



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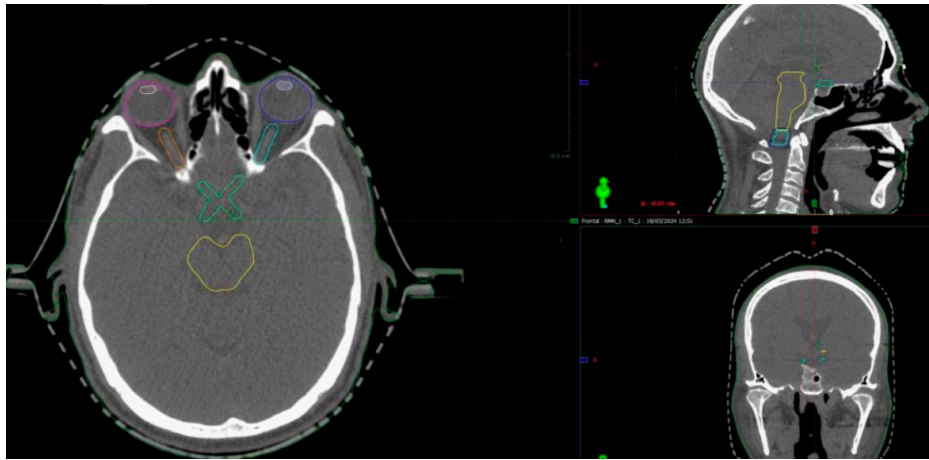


Figure 1

MRI simulation was performed using the same head support system, acquiring axial images with TIRM and T1-weighted sequences, with and without contrast. The MRI datasets were also imported into the TPS and rigidly registered with the CT images. The radiation oncologist delineated the gross tumor volume (GTV), clinical target volume (CTV), and planning target volume (PTV), as well as organs at risk (eyes, optic nerves, optic chiasm, lenses, brain, and brainstem).

Treatment plans were generated using volumetric modulated arc therapy (VMAT) with coplanar and non-coplanar arcs in a stereotactic approach (Figure 2).

Radiotherapy was administered as either single-fraction stereotactic radiosurgery or three fractions of 9 Gy (total dose 27 Gy). Dosimetric parameters were collected, including dose delivered to each organ at risk, minimum and maximum dose, and target coverage (percentage of the PTV receiving the prescribed dose)(Figure 3). Some detailed indices were not consistently available and are therefore not reported. Clinical and treatment data were collected anonymously. Due to the limited sample size, only descriptive statistics were used and no inferential statistical analysis was performed.

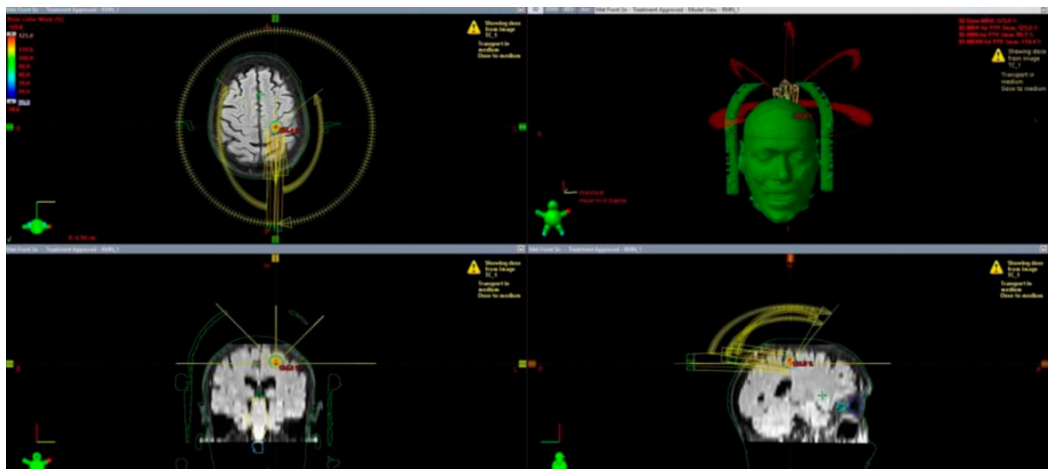


Figure 2

Plan optimization was performed by the medical physicist to ensure target coverage while respecting dose constraints for organs at risk. All plans were approved by a radiation oncologist. Patients were positioned on the treatment couch using the same immobilization system employed during simulation. Mask reference marks were aligned with room lasers and positional corrections were applied. Image-guided radiotherapy (IGRT) was performed using cone beam CT (CBCT) before each fraction. Treatment was delivered only after verification and approval of the setup.

RESULTS

Of 13 patients, 12 had metachronous oligometastatic disease, with brain metastases diagnosed after the primary tumor. One patient had synchronous disease, with brain metastases concurrent with the primary tumor.

Primary tumor histotype

Brain metastases originated from: 8 lung adenocarcinomas, 3 breast carcinomas, 1 rectal carcinoma, and 1 tumor of unknown origin compatible with intestinal histotype. Size of brain metastases:

10 patients: <20 mm

2 patients: 21–30 mm

1 patient: 31–40 mm

Radiotherapy treatment and tolerability

In 6 out of 13 cases, radiosurgery was performed, consisting of single-fraction stereotactic treatment with an ablative intent of 21 Gy in 1 fraction to the volume corresponding to contrast enhancement on MRI images, following evaluation of the dose–volume histogram (DVH)(Figure 3). In 7 out of 13 cases, fractionated stereotactic treatment with ablative intent was performed: 24 Gy in 3 fractions in 1 case and 27 Gy in 3 fractions in 6 cases.

All patients completed treatment according to the prescribed plan, with good tolerance (13/13). Stereotactic masks and CT-MRI registration ensured accurate positioning and precise target delineation, minimizing exposure to organs at risk. Verification was performed using image-guided radiotherapy (IGRT) with cone beam CT (CBCT).

Follow-up and outcomes

At median follow-up of 6 months (range 2–11), overall survival was 61%, with 8/13 patients alive without neurological complications with clinical and instrumental documentation of response to stereotactic radiosurgery (post-treatment MRI performed every 3 months) and 1/13 patient deceased due to cardiac complications related to systemic therapy post-treatment.

It should be noted that the available data did not include information on standardized response evaluation criteria, and the study is therefore limited to descriptive preliminary data. Additionally, the study is limited by the relatively short follow-up.

VMAT with coplanar and non-coplanar arcs provided optimal dose conformity, sparing critical brain structures and enabling treatment of patients receiving immunotherapy.

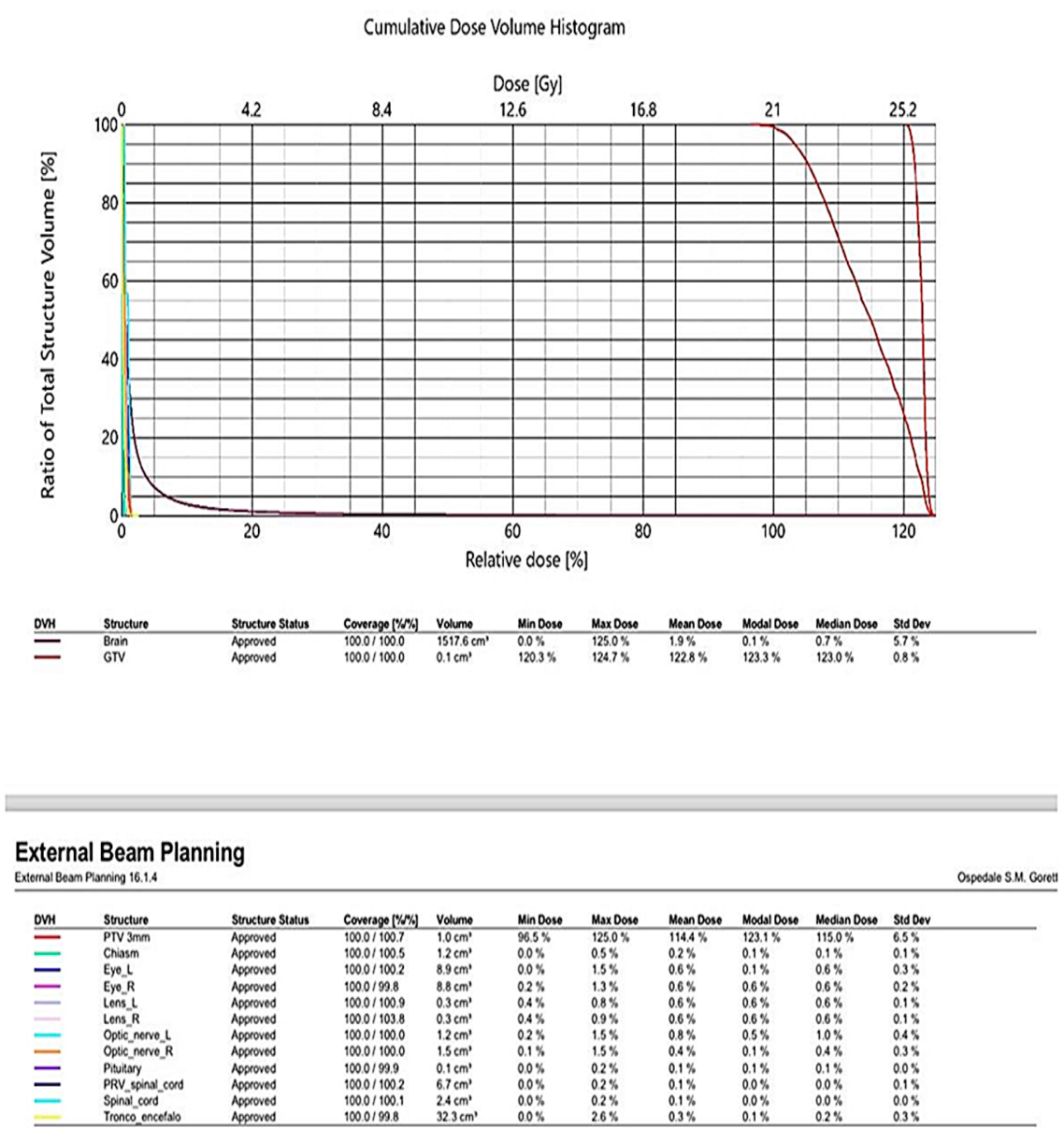


Figure 3

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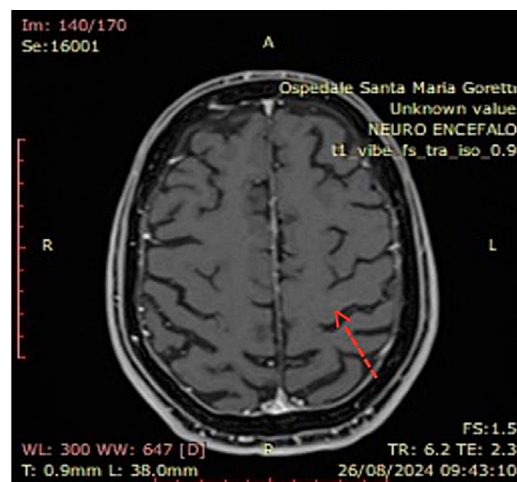
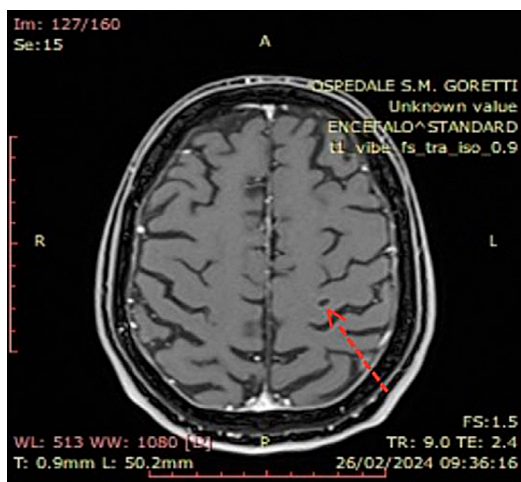


Figure 4: Comparison of brain MRI with contrast agent before and after radiosurgery in a patient with a single brain metastasis in the left fronto-parietal region.

DISCUSSION AND CONCLUSIONS

Technological advancements in the radiotherapeutic management of brain metastases in oligometastatic patients have enabled the delivery of ablative or curative-intent treatments in patients with good performance status, low tumor burden, and adequate treatment compliance. Accurate patient selection, supported by a multidisciplinary evaluation, remains essential to integrate stereotactic radiotherapy effectively into the therapeutic pathway, potentially combined with systemic therapies or focal surgical interventions.

CT-MRI image integration and advanced techniques such as VMAT and Cone Beam CT ensure treatment precision, allowing high-dose delivery in single or fractionated sessions while minimizing exposure to surrounding healthy tissues. These findings are consistent with previous studies highlighting the safety and efficacy of stereotactic radiotherapy for selected brain metastases [3] and are also in line with ASTRO guideline recommendations, which support the use of stereotactic radiosurgery (SRS) in patients with a limited number of brain metastases and an ECOG

performance status of 0 to 2 [4].

The role of the radiotherapy technologist (TSRM) in patient preparation, simulation, and verification, together with close collaboration with radiation oncologists and medical physicists, is fundamental to optimize treatment delivery and maintain high standards of care [5].

Given the small number of patients and the relatively short follow-up, the current results should be interpreted with caution and cannot be directly extrapolated to broader populations. Future studies with larger cohorts and extended follow-up will be necessary to strengthen the evidence, better define endpoints, and improve the clinical applicability of stereotactic radiotherapy (SRT) in patients with brain oligometastases.

In conclusion, these preliminary results, although based on a small sample size and limited follow-up, suggest that stereotactic radiotherapy (SRT), including radiosurgery, may represent an effective and safe local treatment option in this setting.

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