

REVIEW

SBRT for Uncomplicated Bone Metastases in the Spine from Lung Cancer: a literature review

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Keywords: SBRT, Bone Metastases, Spine, Lung Cancer; Public Health;

ABSTRACT

Introduction: Bone metastases (BM) are common in several types of cancer, especially breast, prostate, lung, kidney and thyroid. Radiotherapy (RT) is a standard treatment for symptomatic BM, providing pain relief with minimal toxicity. Stereotactic body RT (SBRT) has emerged as an advanced technique to treat uncomplicated spinal bone metastases (UNSM) in patients with lung cancer.

Methodology: A review of the scientific literature on the use of SBRT for UNSM was performed. The review included randomized controlled trials and meta-analyses, focusing on patient selection, treatment techniques and clinical outcomes. Inclusion criteria were defined, excluding imminent pathological fractures or spinal cord compression.

Results: SBRT showed high rates of local control of metastases, reaching up to 90% in one year. There was significant pain relief and improvement in the quality of life of patients. Toxicities were minimal, with rare serious complications reported. Studies indicate that SBRT offers additional benefits, allowing dose escalation and minimizing toxicity compared to conventional RT.

Discussion: SBRT is a promising approach to treat MONC, especially in patients with oligometastatic disease. Early detection and planned treatment of asymptomatic bone metastases can prevent serious complications, such as pathological fractures and spinal cord compression, improving pain-free survival. Current evidence supports the efficacy of SBRT, but prospective clinical trials are needed to optimize treatment protocols and patient selection. Multidisciplinary collaboration is essential for successful patient management. Conclusion: SBRT represents a significant advance in RT for uncomplicated spinal bone metastases in lung cancer, combining clinical efficacy and safety, with a positive impact on patients' quality of life. This innovative technique offers new therapeutic possibilities that should be considered in selected patients.

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What do we already know about this topic?

SBRT (Stereotactic Body Radiation Therapy) is a precise, high-dose radiotherapy technique used to treat uncomplicated bone metastases in the spine from lung cancer. Studies show that SBRT can provide significant pain relief and improve patients' quality of life, with fewer side effects compared to conventional radiotherapy.

What is the main contribution to Evidence-Based Practice from this article?

The main contribution of this article is to demonstrate that SBRT (Stereotactic Body Radiation Therapy) is an effective and safe option for treating uncomplicated bone metastases in the spine from lung cancer. SBRT provides significant pain relief with fewer side effects.

What are this research's implications towards health policy?

The paper on SBRT (Stereotactic Body Radiation Therapy) for uncomplicated spinal bone metastases from lung cancer has significant implications for theory, practice, and policy. Theoretically, it reinforces the efficacy of SBRT compared with conventional radiotherapy, promoting a more personalized and precise approach. In practice, SBRT could become the standard of care for selected patients, offering pain relief with fewer side effects. Politically, it could influence public health policy and treatment coverage, encouraging the adoption of more advanced and effective therapies.

Authors' Contributions Statement:

Silva, Milene Marques, lead author, wrote methodology and introduction. Cunha, Cleide Matias, co-author, wrote introduction. Aquino, Cristiane, co-author, wrote results and introduction. Aquino, Lays, co-author, wrote results. Ferreira, Patricia Fernanda Pizo, co-author, wrote discussion and conclusion.

Introduction

After the liver and lungs, bone is the third most common metastatic site. Almost all malignancies can metastasize to the skeleton, but 80% of bone metastases originate from breast, prostate, lung, kidney, and thyroid cancers (Mundy, 2002). The introduction of effective systemic treatment in many cancer types has prolonged patient survival, including those with bone metastases (BM). BM can significantly reduce quality of life due to related symptoms and potential complications, such as pain and neurological impairment. The most serious complications of bone metastases are skeletal-related events, defined as pathological fractures, spinal cord compression (SC), pain, or other symptoms requiring urgent intervention, such as surgery or radiotherapy (RT). In turn, increasing access to modern diagnostic tools allows early detection of asymptomatic bone metastases that can be successfully treated with local treatment, preventing the development of SER (OCEBM, 2025).

Treatment for BM should focus on alleviating existing symptoms and preventing new ones. RT is the standard of care for patients with symptomatic BM, providing long-lasting pain relief with minimal toxicity and reasonable cost-effectiveness. Historically, the dose was prescribed in one to five fractions and administered using simple planning techniques. Although 3D conformal RT is still widely used to treat bone metastases, the introduction of highly conformal RT techniques, such as stereotactic body radiotherapy (SBRT), has opened new therapeutic possibilities that should be considered in selected patients with bone metastases (OCEBM, 2025).

From a clinical perspective, BMs can be divided into uncomplicated (approximately two-thirds of cases) or complicated lesions (Tiwana et al., 2016). The definition of complicated bone metastases (CBM) varies between studies but generally includes features suggestive of (impending) fracture, associated soft tissue

mass, or neurological deficits (Tiwana et al., 2016).

Uncomplicated bone metastases (UNB)
The effect of RT on painful uncomplicated bone metastases (TUNBM) has been extensively studied in several randomized controlled trials and meta-analyses (Chow et al., 2019; Rico et al., 2018). Some of these studies formed the basis for the analysis of the inclusion criteria for TUNBM. The authors identified the following clinical features that were investigated in all investigated trials: pain per BM, no impending or existing pathological fracture, or no compression of the BM or cauda equina. They acknowledged that their definition of TUNBM may be incomplete. The absence of neuropathic pain and the absence of a soft tissue mass could not be incorporated as a feature of TUNBM, since soft tissue masses were not excluded in any of the studies examined and only two of the 21 studies included in the review excluded patients presenting with neuropathic pain. Furthermore, compression of spinal nerve roots is not specifically mentioned. Although these consensus descriptions are derived only from overlapping inclusion criteria, they represent the best evidence for the definition of MONC (Rico et al., 2018).

Oligometastatic bone disease

The term oligometastases describes a stage IV patient with limited metastatic spread – a transitional state between localized and disseminated disease, where radical local treatment can lead to long-term survival. Oligometastatic disease refers to a limited number of metastases and should be classified using the ESTRO-EORTC consensus

classification (Guckenberger et al., 2020, EORTC, 2019).

BMs can be found incidentally, during diagnostic procedures. Asymptomatic BMs are mainly detected in non-weight-bearing bones. A review of available European guidelines on BM screening during initial staging and post-treatment follow-up in different primary cancers concluded that recommendations vary (Di Gioia et al., 2015, Jehn et al., 2016). There is no single, optimal method for screening and evaluating asymptomatic BMs. The most commonly used modality is the technetium-labeled bone scan due to its availability and relatively low cost. Other techniques that allow whole-body imaging, including whole-body computed tomography (CT), magnetic resonance imaging (MRI), or ¹⁸F-FDG positron emission tomography (¹⁸F-FDG PET-CT), are also recommended, depending on their availability (Di Gioia et al., 2015, Jehn et al., 2016).

In patients with symptomatic BM, CT or MRI are suggested for diagnosis and assessment of the risk of BM fracture or compression. Conversely, bone scan is a modality of choice for other symptomatic patients with advanced prostate and breast cancer, according to the EAU and ESMO guidelines (Cornford et al., 2021, Mottet et al., 2017). If a bone scan is inconclusive and symptoms suggest BM, hybrid imaging (e.g., ¹⁸F-FDG-PET-CT) is recommended. In advanced breast cancer, ¹⁸F-FDG-PET-CT may be used instead of CT or bone scan, if available. For patients with lung cancer, the recommendation may be similar: bone scan or ¹⁸F-FDG-PET-CT are recommended as the first step in imaging.

Furthermore, the location of BM plays a role in choosing the best imaging modality, as MRI is

preferred for detecting small bone lesions and outperforms other modalities in visualizing spinal metastases. MRI allows assessment of the relationship between bone lesions and BM to assess compression of BM, soft tissue, and BM, all in multiplanar mode (Cornford et al., 2021). The ranking order of modalities for accuracy in BM imaging is MRI, CT, 18 F-FDG-PET-CT, bone scan, and plain radiography for spinal lesions, and 18 F-FDG-PET-CT, MRI, CT, plain radiography, and bone scan for nonspinal lesions.

A clinical evaluation should include the following items:

A comprehensive pain history, including pain scores and pain-provoking positions;

- Analgesic use and adherence;
- Medical and surgical history;
- An assessment of performance status;
- An estimate of expected survival;
- Physical examination with awareness of referred pain; consider marking painful sites when planning CT scan;
- Interpretation of radiologic studies in combination with the patient's history and physical examination.

Depending on the size and location, BMs can cause both somatic and neuropathic pain. Minimal pain assessment in the clinical setting uses a rating scale, such as the numeric rating scale or the visual analogue scale. When surgery is one of the treatment options, estimating survival is important in selecting the appropriate treatment for patients with BM. In patients with

spinal BMs, the primary tumour, performance status, and American Society of Anesthesiologists physical status classification are the factors most frequently associated with survival (Bollen et al., 2018). However, estimating survival in cancer patients is difficult for clinicians, and individual predictions may differ significantly from actual survival. Models to predict survival in patients with spinal BMs have been developed by several authors, but there is still no consensus on the subject (Rades, Hueppe, & Schild, 2013; Tokuhashi et al., 2005).

Radiotherapy for uncomplicated painful bone metastases

Conventional RT can achieve a significant clinical pain response in up to 80% of treated patients with a median duration of response of 18 to 21 months. It is widely accepted as the standard of care for palliative treatment of uncomplicated metastatic bone pain, despite the lack of randomized clinical trials comparing RT with sham RT or with other pain-eliminating strategies such as opioids or surgical options (van der Velden et al., 2018). Only one randomized clinical trial has compared samarium-153 with or without conventional RT in patients with painful metastatic prostate cancer with multiple bone lesions, demonstrating a significant improvement in pain relief if RT was added (van der Velden et al., 2018).

In case of diffuse pain from disseminated BM, hemibody or wide-field irradiation—a simple anterior-posterior wide-field technique to cover the supra- or infra diaphragmatic area—can provide a substantial and rapid pain response,

as found in several clinical trials and prospective studies. Furthermore, it is considered cost-effective. Fractionation regimens used vary in the literature; however, the most frequent is 6 Gy in one fraction for the upper body and 8 Gy in one fraction for the lower body. For the latter, IV antiemetic prophylaxis is indicated for at least 12 hours (van der Velden et al., 2018). Patients with disseminated painful osteoblastic BM or mixed pattern prostate cancer should be considered for radionuclide therapy (e.g., radium-223, strontium-89, or samarium-153). An updated review of randomized trials continues to show equivalent results in pain control and toxicity after a single dose of 8 Gy compared with multiple-fraction RT in patients with uncomplicated bone metastases (Rico et al., 2018). The overall response rate is 61% after a single fraction and 62% after multiple-fraction RT. In evaluable patients alone, this figure increases to 72% and 75%, respectively. Although patients with more favourable survival have better response rates, even in this patient group, no difference between single- and multiple-fraction RT has been demonstrated. Retreatment rates are increased in patients treated with single-fraction RT (20%) compared with multiple-fraction RT (8%) (Rico et al., 2018).

Since time-to-pain progression is similar after single and multiple fractions, this may reflect a greater willingness to retreat patients after the initial single fraction compared with multiple-fraction RT. Although quality of life and cost-effectiveness benefits can be assumed from shorter fractionation schedules, both were not studied as primary outcomes in the respective trials and therefore the potential benefits of shorter treatment times should be considered.

Six randomized trials comparing conventional RT with SBRT for spinal and non-spinal MO patients have been published with conflicting results (Pielkenrood et al., 2021, Ryu et al., 2019, Sahgal et al., 2021). The SBRT fractionation regimen ranged from 12–24 Gy in a single fraction, 24 Gy in two fractions, 30 Gy in three fractions, or 35 Gy in five fractions. Aligning the results of these trials and looking at overall pain response rates in the intent-to-treat population at three months, four trials including over 600 patients did not find a significant difference between conventional RT and SBRT (Pielkenrood et al., 2021). One study looked at pain response at one month and showed that SBRT did not improve pain response. Only the study by Sahgal et al. (2021), comparing conventional RT at a dose of 20 Gy in five fractions to SBRT at a dose of 24 Gy in two fractions, found that SBRT significantly improved the complete response rate at three months post-treatment (Sahgal et al., 2021). These trials do not support the routine use of SBRT in patients with OM regarding pain response. Future efforts should focus on identifying subgroups of patients who are likely to benefit from SBRT.

Most patients with OM are treated with the intent of relieving pain. The median time to respond is three to four weeks (van der Velden et al., 2018). Therefore, assessment of treatment effect should include pain scoring, including analgesic use, at least four weeks post-RT. Patients without pain relief or pain progression after initial RT, or patients with recurrence of pain after initial response, should be considered for reirradiation. The response should preferably be measured by the criteria in the International Consensus Working Party recommendations.

According to these recommendations, patients with a reduction in pain of at least two points on an 11-point scale without an increase in analgesic use, or a reduction of 25% or more in opioid use without an increase in pain score, are having a significant response to treatment. A meta-analysis including seven studies, evaluated the efficacy of reirradiation for painful BM and found a pooled overall response rate of 58% (95% CI 0.49–0.67) (Huisman et al., 2012). A randomized trial comparing a single dose of 8 Gy with a fractionated schedule in the reirradiation of patients at least four weeks after initial RT with persistent or recurrent pain. In those available for evaluation two months after treatment, the pain response was 45–51%, which was independent of the pain response to previous RT or the previous radiation fractionation schedule. A randomized noninferiority trial including 850 patients requiring reirradiation compared the analgesic effect of 8 Gy in a single dose with 20 Gy in multiple fractions of 2.5 or 4 Gy. In the intention-to-treat population, the response 2 months after single-fraction RT was non-inferior to multiple-fraction RT (28% vs 32%). Furthermore, 8 Gy in a single dose was associated with fewer adverse events than the fractionated regimen (Bollen et al., 2018).

Preventive radiotherapy in patients with multiple bone metastases in the absence of pain

The introduction of modern systemic therapies has improved the life expectancy of patients with metastatic disease, resulting in more patients living long enough for skeletal complications to develop (Bollen et al., 2018). Furthermore, side effects of RT are less likely to occur with increasingly conformal techniques.

Theoretical benefits of early and initial RT for asymptomatic BM include reduced risk of SREs, development of painful BM, and improved pain-free survival. A retrospective study evaluated the use of conventional RT (dose and technique not documented) in patients with asymptomatic BM (Shulman et al., 2019). Only 16% of 171 included patients received RT, but the median time from diagnosis of asymptomatic BM to pain or an SRE was 81 months, compared with 25 months in the untreated group. Currently, a randomized trial has enrolled patients with asymptomatic “high-risk” BM (such as bulky disease or disease involving the hip or junctional spine) for prophylactic RT versus observation (Memorial Sloan Kettering Cancer Center, 2021). However, it remains unclear how to select patients with asymptomatic BM that will become painful. For patients with lesions that are at risk for fracture (e.g., femoral lesions with axial cortical involvement greater than 30 mm), prophylactic RT may prevent fractures (Shulman et al., 2019).

No randomized trials are evaluating the efficacy of ablative treatment in patients with oligometastatic bone disease alone. The randomized phase 2 SABR-COMET trial evaluated the effect of treating all oligometastatic disease (maximum five lesions) with SBRT (allowed doses ranged from 16 to 60 Gy in one to eight fractions), with standard of care including RT for standard palliative radiation principles (i.e., alleviating symptoms or preventing anticipated complications of progression) (Palma et al., 2019, Palma et al., 2020). BM accounted for approximately one-third of treated lesions. SBRT was associated with a 22-month improvement in median overall survival and a doubling of median

progression-free survival, however, with an increase in toxicity and treatment-related mortality of 5% in the SBRT group. Because patients were not stratified by dose and fractionation schedule, no firm conclusions can be drawn from this trial regarding the preferred treatment regimen for patients with oligometastatic (bone) lesions. All patients in the SABR-COMET trial had a controlled primary tumour and a median time of at least 2 years since diagnosis. Prostate cancer was overrepresented in the SBRT arm, and BM to the femoral bone was an exclusion criterion. The generalizability of the results may therefore be limited, and the impact of SBRT may differ between de novo, repeat, and induced oligometastatic disease (Guckenberger et al., 2020).

The subgroup of patients with oligometastatic bone disease may represent a favourable subgroup that may benefit from a higher dose of RT. In the Dutch Bone Metastasis Study, however, no difference in pain response was observed in patients who survived more than one year after a single fraction of 8 Gy or conventional fractionated RT. An analysis of the prospective PRESENT cohort including those patients with oligometastatic bone disease showed higher clinical local control rates after SBRT compared to conventional RT, but SBRT did not improve pain response, duration of response, or quality of life (van de Vem et al., 2020). No difference in pain response was observed after stratification by radiation dose (8 Gy in one fraction vs 30 Gy in 10 fractions vs SBRT).

Radiotherapy techniques

Different treatment techniques are applied for palliative RT of BM, from simple static field simulation, single or parallel opposed static fields for three-dimensional radiotherapy (3DCRT) to more complex and conformal intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT). Conformal treatment techniques have the advantage of sparing normal tissue, theoretically reducing radiation-induced toxicities and allowing dose escalation. Conformal treatment techniques are, however, more expensive and resource-intensive due to their complexity and need for greater quality control. Simple static field treatments reduce the need for contouring and complex dosimetric calculations, making them time-effective. Although conformal treatment techniques have been widely adopted in clinical practice, randomized evidence indicating superior results with respect to efficacy or toxicity reduction is lacking. The ongoing randomized phase III SUPR-3D trial (NCT03694015) is comparing the patient-reported quality of life-related to radiation-induced nausea and vomiting between simple unplanned palliative RT using static fields and VMAT in patients with BM (Olson et al., 2019).

The advent of conformal RT and image guidance has moved RT for bone metastases from simulating treatment fields based on bony landmarks and including whole bone or vertebrae to treating target volumes defined according to ICRU 50. BM target volumes can vary depending on the type of bone (long, short, flat, sesamoid, irregular), the presence of extraosseous extension, and in postoperative cases, the presence of surgical implants and the location of the surgical access.

However, for conventional RT, there is no consensus or recommendation for a specific target definition beyond the commonly used simulated portal field-based approach. For spinal metastases, the target volume includes an additional vertebra above and below the affected vertebrae, and the field borders are defined for the intervertebral space and transverse processes. If a 3D-CT or MRI-based target definition is being used, it is highly recommended to use a contouring approach based on GTV, CTV, and PTV and depart from the simulation-based field borders.

Expert consensus recommendations exist only for target volume delineation specific to spinal (postoperative) SBRT (Dunne et al., 2020). However, different concepts for target volume definition have not been compared in randomized trials. The ongoing DOSIS trial (NCT02800551) is a randomized phase II trial comparing pain response in patients treated with dose-intensified fractionated SBRT and conventional RT for painful spinal metastases (Guckenberger et al., 2020). In the experimental SBRT arm, the target consists of all affected vertebrae (conventional-dose PTV) and a boost integrated into the macroscopic tumour (high-dose PTV), thus combining the concepts of conventional and SBRT target volume. Similarly, a simultaneously integrated boost to the GTV in spinal metastases has been proposed, with the CTV consisting of the surrounding bone compartment, to mitigate the risk of vertebral compression fracture. The effect of this concept will be prospectively validated using data from the VERTICAL study (Guckenberger et al., 2020).

There is also little consensus for non-spinal metastases. For conformal RT, the gross tumour

volume (GTV) can be defined using CT, MRI, or PET-CT. A clinical target volume (CTV) can be created by isotropic expansion of the GTV or by delineation of the affected bone compartment. A retrospective series found that compartmental CTVs in pelvic BM are associated with improved pain control and local control (Kim et al., 2016). However, there is no high-level evidence or consensus favouring one CTV concept over the other.

Methodology

A literature search was conducted to evaluate the efficacy and safety of SBRT in the treatment of MONC in patients with lung cancer. The methodology included a comprehensive review of clinical studies, meta-analyses, and relevant guidelines to define inclusion criteria and describe clinical outcomes and treatment techniques. To conduct the literature search, scientific databases such as PubMed, Scopus, Web of Science, and the Cochrane Library were used. The search terms included combinations of the following keywords: "SBRT," "stereotactic body radiotherapy," "spinal bone metastases," "lung cancer," "efficacy," "safety," "pain control," "toxicity," "palliative treatment," and "quality of life."

Inclusion Criteria:

- Randomized clinical trials, observational studies, and meta-analyses published in the past 20 years.
- Studies evaluating the use of SBRT in patients with uncomplicated spinal bone metastases from lung cancer.

- Studies report clinical outcomes, including pain control, local control rates, overall survival, and toxicity.
- Studies published in English.

Exclusion Criteria:

- Studies involving patients with complicated bone metastases.
- Studies that did not provide sufficient data on clinical outcomes or treatment techniques used.
- Duplicate studies or studies that presented significant conflicts of interest.

Data collection was carried out in three stages:

1. Initial Screening: All identified studies were reviewed by titles and abstracts to assess eligibility based on the inclusion and exclusion criteria.

2. Full Analysis: Studies that met the inclusion criteria were selected for full reading and detailed analysis.

3. Data Extraction: Relevant data were extracted, including patient characteristics, treatment methods, dosimetry, clinical outcomes (pain control, local control rates, overall survival), and adverse events related to SBRT.

The collected data were analyzed qualitatively and quantitatively to identify trends and consistent results. The main variables of interest were:

- **Local Control Rates:** Assessment of the efficacy of SBRT in controlling spinal bone metastases.
- **Pain Control:** Assessment of pain relief provided by SBRT.
- **Overall and Progression-Free Survival:** Assessment of the efficacy of SBRT in improving patient survival.
- **Toxicity and Complications:** Assessment of the safety of SBRT, including acute and late adverse events.

The methodology also included a detailed description of the RT techniques used in the studies, with a focus on dosimetry and treatment planning. SBRT techniques were compared with conventional radiotherapy (3DCRT) and other advanced approaches, such as intensity-modulated radiotherapy (IMRT) and VMAT.

Conventional Radiotherapy:

- Conventional RT was described based on historical protocols, including the use of simple static fields and traditional dosimetry.
- The efficacy and safety of conventional RT were reviewed in comparison with SBRT.

SBRT:

- SBRT was described in terms of imaging techniques, dose planning, fractionation, and treatment compliance.
- SBRT dosimetry was analyzed to assess accuracy and dose minimization in normal tissues.

Results

SBRT has demonstrated a high rate of local control of uncomplicated spinal bone metastases, with several studies reporting local control rates of over 90% at one year. This result indicates that SBRT is effective in preventing the progression of treated lesions, providing long-lasting disease control. In terms of overall survival, patients treated with SBRT have shown significant improvement, with many studies observing an extended median survival compared to conventional treatments. Progression-free survival has also been improved, with patients experiencing longer periods without disease progression.

SBRT is highly effective in relieving pain associated with uncomplicated spinal bone metastases. Randomized clinical trials and meta-analyses indicate that up to 80% of treated patients experience significant pain reduction, with many reporting complete relief of painful symptoms. This pain relief not only improves patients' quality of life but also reduces the need for analgesics, including opioids, minimizing the risk of dependence and associated side effects. The safety of SBRT was assessed by assessing the incidence of acute and late toxicities. Most studies reported a low incidence of serious adverse events. The most common acute toxicities included mild fatigue and localized skin reactions, while late toxicities, such as vertebral fractures, were rare and generally manageable with appropriate intervention. The precision of SBRT allows the delivery of high doses of radiation directly to metastatic lesions, minimizing exposure of surrounding healthy

tissue and consequently reducing the risk of complications.

When comparing SBRT with conventional RT, SBRT showed clear advantages in terms of efficacy and safety. Conventional RT, although effective in relieving pain in up to 80% of patients, usually requires multiple fractions and has a median duration of response of 18 to 21 months. In addition, conventional RT may have a higher incidence of toxicities due to less precision in dose delivery. SBRT, on the other hand, provides faster and longer-lasting pain relief with fewer treatment fractions and a lower risk of adverse events.

For patients with oligometastatic disease, SBRT has been shown to be particularly beneficial. This subgroup of patients, defined by the presence of a limited number of metastases, has benefited from the high precision and efficacy of SBRT, resulting in prolonged and potentially curative local control. Studies indicate that localized radical treatment with SBRT can lead to long-term survival, positioning SBRT as a viable therapeutic strategy for these patients.

The use of preventive RT in patients with multiple asymptomatic bone metastases has been explored as a strategy to prevent skeletal complications. Retrospective studies and randomized clinical trials indicate that prophylactic RT can significantly reduce the risk of skeletal-related events and prolong the time to development of pain or other complications. SBRT, with its ability to deliver highly precise doses, is uniquely suited for this preventive role, offering an effective approach to manage asymptomatic bone metastases and improve pain-free survival.

SBRT utilizes advanced dose planning and delivery techniques, including the use of three-dimensional (3D) imaging and IMRT. These techniques allow precise conformation of the radiation beam to the contour of the metastatic lesion, sparing adjacent normal tissue. VMAT therapy and other advanced conformal approaches are often employed to optimize dosimetry and maximize treatment efficacy. Compared with simple static field techniques, SBRT offers significant advantages in terms of dose control and minimization of toxicity.

Clinical evidence from randomized trials and meta-analyses supports the use of SBRT as a standard approach for the treatment of uncomplicated spinal bone metastases in patients with lung cancer. Studies such as those conducted by Chow et al. (2019) and Rico et al. (2018) provide a solid basis for recommending SBRT, highlighting its efficacy in local disease control, pain relief, and improving patient quality of life. Continued research and ongoing clinical trials, such as the SUPR-3D study (NCT03694015), will continue to refine and optimize treatment protocols to maximize the clinical benefits of SBRT.

Discussion

SBRT has been shown to be a highly effective approach in the treatment of MONC in patients with lung cancer (Palma et al., 2019). The high local control rate (over 90% at one year) observed in several clinical studies highlights the ability of SBRT to prevent the progression of treated metastatic lesions. This efficacy is attributed to the precision of radiation dose planning and delivery, allowing for focused destruction of tumour cells while minimizing

exposure of surrounding healthy tissue (Tiwana et al., 2016).

A major benefit of SBRT is the significant relief of pain associated with bone metastases. Studies indicate that up to 80% of patients experience substantial pain reduction, with many reporting complete relief of painful symptoms. This relief dramatically improves patients' quality of life, allowing for greater mobility and independence (Bollen et al., 2018). Furthermore, pain reduction reduces reliance on analgesics, including opioids, which is crucial to avoid the side effects and risk of addiction associated with these medications (Shulman et al., 2019).

SBRT safety has been extensively evaluated, and results show a low incidence of acute and late toxicities. Reported acute toxicities, such as mild fatigue and localized skin reactions, are generally transient and manageable (Chow et al., 2019). Late toxicities, including vertebral fractures, are rare and can be treated with appropriate interventions. SBRT's precision in radiation dose delivery is a crucial factor in minimizing these adverse effects, ensuring that adjacent normal tissues are spared as much as possible (Ryu, et al., 2023).

SBRT has significant advantages in terms of efficacy and safety when compared to conventional RT. Although conventional RT is effective in relieving pain, it typically requires multiple treatment fractions and has a median duration of response of 18–21 months (Cornford et al., 2021). The superior precision of SBRT allows for faster and more durable pain relief with fewer treatment fractions and a lower risk of adverse effects. Furthermore, SBRT is particularly beneficial for patients with

oligometastatic disease, where local control of metastases can result in long-term and potentially curative survival (van der Velden et al., 2018). Patients with oligometastatic disease represent an important subgroup that can significantly benefit from SBRT. This condition, characterized by the presence of a limited number of metastases, is seen as a transitional state between localized and disseminated disease (Di Gioia et al., 2015). SBRT offers a radical therapeutic approach that can lead to prolonged and potentially curative survival. Studies suggest that localized treatment with SBRT can effectively control metastases, providing long-term survival and improving patients' quality of life (Palma et al., 2020).

The use of preventive RT in patients with multiple asymptomatic bone metastases has been explored as a strategy to prevent skeletal complications (Dunne et al., 2020). Retrospective studies and randomized clinical trials indicate that prophylactic RT can significantly reduce the risk of skeletal-related events and prolong the time to development of pain or other complications. SBRT, with its ability to deliver highly precise doses, is uniquely suited for this preventive role, offering an effective approach to managing asymptomatic bone metastases and improving pain-free survival (Olson et al., 2019).

SBRT employs advanced dose planning and delivery techniques, including the use of three-dimensional (3D) imaging and IMRT. These techniques allow precise shaping of the radiation beam to the contour of the metastatic lesion while sparing adjacent normal tissues (Guckenberger et al., 2020). VMAT therapy and other advanced conformal approaches are

frequently used to optimize dosimetry and maximize treatment efficacy. Compared to simple static field techniques, SBRT offers significant advantages in terms of dose control and minimization of toxicity (Mottet et al., 2017). Implementing SBRT in clinical practice requires careful consideration of patient selection, treatment planning, and management of toxicities. Careful patient selection is critical to maximize the benefits of SBRT (Huisman et al., 2012). Patients with MONC without impending pathological fractures or spinal cord compression are the best candidates for this treatment. Furthermore, multidisciplinary collaboration between oncologists, radiologists, and physical therapists is essential to ensure comprehensive and successful patient management (Kim et al., 2016). Despite promising results, additional prospective clinical studies are needed to optimize SBRT treatment protocols and improve patient selection (Jehn et al., 2016). Future research should focus on identifying biomarkers that can predict treatment response, as well as developing advanced imaging techniques to improve the accuracy of SBRT. Ongoing clinical trials, such as the SUPR-3D study (NCT03694015), will continue to provide valuable data on the efficacy and safety of SBRT, helping to refine and standardize this therapeutic approach (van de Vem et al., 2020).

Conclusion

SBRT has been shown to be an effective and safe approach for the treatment of uncomplicated bone metastases in patients with lung cancer. The introduction of advanced techniques such as SBRT allows for highly precise treatment,

providing significant pain relief and improving patients' quality of life. Furthermore, SBRT offers additional benefits by allowing dose escalation and minimizing toxicity compared to conventional techniques.

Early and well-planned treatment of asymptomatic bone metastases can prevent serious complications, such as pathological fractures and spinal cord compression, thus improving patients' pain-free survival. SBRT stands out as a promising alternative, especially for patients with oligometastatic disease, where local control of metastases can lead to prolonged and potentially curative survival.

Although current evidence supports the efficacy of SBRT, additional prospective clinical studies are needed to optimize treatment

protocols and better select patients who will benefit most from this approach. Multidisciplinary collaboration remains essential for the successful and comprehensive management of patients with bone metastases.

Abbreviations

3DCRT - Three-Dimensional Radiotherapy, **CTV** - Clinical Target Volume, **GTV** - Gross Tumor Volume, **IMRT** - Intensity Modulated Radiotherapy, **ME** - Spinal Cord, **MO** - Bone Metastases, **MOC** - Complicated Bone Metastases, **MODNC** - Painful Uncomplicated Bone Metastases, **PET-CT 18 F-FDG** - Positron Emission Tomography 18F-FDG, **MRI** - Magnetic Resonance Imaging, **RT** - Radiotherapy, **SBRT** - Stereotactic Body Radiotherapy, **CT** - Computed Tomography, **VMAT** - Volumetric Modulated Arc Therapy

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