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Surgical Metastasectomy in the Spine: A Review Article

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Key Words. Metastasectomy • Neoplasm metastasis • Patient selection • Spine • Surgical oncology

Abstract

Background. The use of surgical metastasectomy (SM) has increased across cancer types in recent decades despite the increasing efficacy of modern systemic treatment modalities. Symptomatic spinal metastases severely compromise patients' performance status. However, as spinal SM is a complex surgery with potentially significant complications, it is not considered the treatment of choice.

Methods. We reviewed the articles on SM in several primary cancers with different types of metastatic lesions and extracted the data from relevant articles to provide a comprehensive review including the surgical techniques, indications, reported outcomes, and future prospects of SM in spinal metastases.

Results. Total en bloc spondylectomy (TES) is a method of spinal SM associated with a lower risk of tumor recurrence and complications. Intralesional transpedicular osteotomy using a fine threadwire saw allows prevention of spinal cord and nerve root injuries. Spinal SM is considered suitable for patients with controlled primary disease having no evidence of disseminated extraspinal metastases, a completely resectable solitary lesion in the spine, and adequate cardiopulmonary reserve to tolerate the surgery. Metastatic lesions from kidney and thyroid cancers have been reported as the best candidates for spinal SM. Although data about spinal SM are limited, the reported outcomes are favorable with acceptable local recurrence rates in long-term follow-up.

Conclusion. In patients with isolated resectable spinal metastases, complete SM including TES is a useful option as it can improve function and survival. However, appropriate patient selection and surgical feasibility remain the most important aspects of management. ***The Oncologist*** 2021;26:e1833–e1843

Implications for Practice: Surgical metastasectomy for spinal metastases may be a potentially curative treatment option with a low risk of local recurrence and lead to prolonged long-term survival if appropriate patients are selected and if the surgery is carried out by experienced surgeons in high-volume centers.

Introduction

Surgical metastasectomy (SM) has been performed more frequently for a series of cancer types in the recent decades despite the increasing efficacy of other modern systemic treatment modalities [1–5]. SM improves the overall survival and has become a standard treatment for pulmonary metastases in sarcoma [6] and colorectal liver metastases [7]. In patients with solitary or oligometastatic disease, complete SM may eliminate all tumor cells with the potential to grow, metastasize, and ultimately lead to death [8]. In addition to the retrospective single-institution studies reporting the efficacy of SM, multicenter prospective trials have further substantiated that SM has the potential to improve survival [9, 10].

The lungs are the most common sites of metastatic disease [11–14]. Over recent decades, the potential survival benefits of pulmonary SM have been increasingly recognized in the literature [15]. Since resectable pulmonary lesions rarely deteriorate the general condition, activities of daily living, or quality of life (QOL), the symptoms cannot play a major part in the decision-making process [15]. The easy surgical accessibility and the lack of major complications make pulmonary SM a viable treatment choice [11, 13, 16, 17].

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The spine is the most common site affected by osseous metastases [18]. Metastatic lesions in the spine occur in 20% to 40% of patients with cancer, and up to 20% of them become symptomatic [19–21]. Spinal metastases often result in severe pain and neurological symptoms, reducing the performance status (PS) and QOL, and increasing patient mortality, even if conservative treatments are applied [22–24]. In general, systemic therapy including chemotherapy, molecular-targeted biological agents, and immunotherapy are more effective against visceral metastases from solid tumors than against osseous metastases [25]. In patients with spinal metastases, a lowered PS affects mortality directly as well as indirectly by hampering the application of systemic therapies. Because of these factors, spinal metastases, when resectable, are one of the most important indications for SM. However, because of the significant complications associated with surgery, the use of SM for bone metastases, especially those located in the spine, has been limited [26]. Therefore, the treatment of spinal metastases is generally palliative to maintain or improve PS and QOL, providing pain relief and maintenance or recovery of neurologic function [27].

Complete SM of spinal lesions is extraordinarily challenging and technically demanding because the spine contains the spinal cord and nerve roots and is in close proximity to major vessels. In the conventional excisional surgery for spinal metastases, piecemeal excision is commonly practiced. One of the biggest disadvantages of this method is the high risk of residual tumor tissue in the vertebra and surrounding structures at the site, leading to a higher rate of local tumor recurrence.

Spondylectomy, which is defined as the complete resection of the tumor-affected vertebra, for excisional surgery of spinal tumors, was first reported by Stener [28]. In the 1990s, Tomita et al. developed total en bloc spondylectomy (TES), aiming at complete surgical resection of spinal tumors with a lowered risk of tumor recurrence and complications [29] (Fig. 1). The TES procedure has been popular among spine surgeons treating spinal tumors. Improvements in surgical techniques and preoperative embolization achieve favorable outcomes with low morbidity [30–32], and TES has been performed for solitary and resectable spinal metastases [33–36]. Cogent evidence showing the efficacy of pulmonary SM has now been established [15]. However, there is no consensus about the efficacy of SM for spinal metastases because of its rarity and the lack of studies with high-quality evidence. Here, we review the surgical technique of complete SM for spinal metastatic lesions, the potential indications, and the published clinical outcomes, and we discuss the future prospects.

Materials and Methods

Studies were identified by searching the PubMed database using the keywords "spinal metastasis," "metastasectomy," "en bloc resection," and "spondylectomy." All studies relevant to our topic were included. To reflect the most contemporary practice, studies published before 2000 were excluded. Only papers published in English were reviewed. To examine the long-term clinical outcomes of spinal SM including postoperative survival and local recurrence rates, studies with 10 or more patients undergoing spinal SM for single primary malignancies were collected (Table 1). To examine perioperative complications of spinal SM including TES in high-volume centers, studies with 50 or more patients undergoing spinal SM in a single institute were collected (Table 2). If the literature search revealed more than one relevant article per institution, we selected only the latest study with the maximum number of patients for the analysis.

Results and Discussion

Surgical Techniques

The detailed description of the surgical techniques for TES has been presented in the literature [30, 31]. In TES, surgeons perform en bloc resection of the posterior element (posterior arch) followed by en bloc resection of the anterior portion (vertebral body) to salvage the spinal cord (Figs. 1 and 2). The surgical approach is decided according to the affected spinal level(s) and the degree of tumor development. For TES of the cervico-thoracic junction, and lower lumbar lesions, a posterior-anterior approach is usually required. The nerve roots at these levels must be preserved. In the lower lumbar spine, the large vessels are very close to the vertebral body, and the iliac wings and lumbar plexus block the delivery of the vertebral body posteriorly. Therefore, at these levels, vertebral body resection via an anterior approach is performed after posterior element resection via a posterior approach. For TES of T2–L1 vertebral lesions, a single posterior approach is employed. Transection of the nerve roots at the tumor-affected level is allowed to salvage the spinal cord during blunt dissection and resection of the vertebral body via a posterior approach. In some patients with enlarged tumors expanding to the anterior paravertebral area, a prior anterior dissection via an anterior approach helps surgeons safely perform the subsequent posterior TES procedure. For TES of L2–L3 vertebral lesions, an initial dissection via an anterior approach including detachment of the diaphragm crura from the tumor-affected vertebra is often employed. In the following resection of the L2–L3 vertebrae via a posterior approach, the L3 nerve roots should be preserved to prevent significant impairment of the lower limb functions. However, transection of the L2 nerve roots does not cause postoperative neurologic deterioration affecting activities of daily living [37].

Complete SM for spinal metastases should be well balanced between achieving local cure and preventing perioperative complications. Boriani et al. proposed a clock type (transverse) classification of vertebral involvement by the tumor by categorizing the concentric layers involved (Fig. 3) [38]. This classification method is excellent to help decide between marginal or wide en bloc resection for malignant primary tumors of the spine. However, in most patients with spinal metastases who are candidates for spinal SM, the tumor involves at least one pedicle with epidural spinal cord compression (Fig. 3). During spinal SM of such cases,

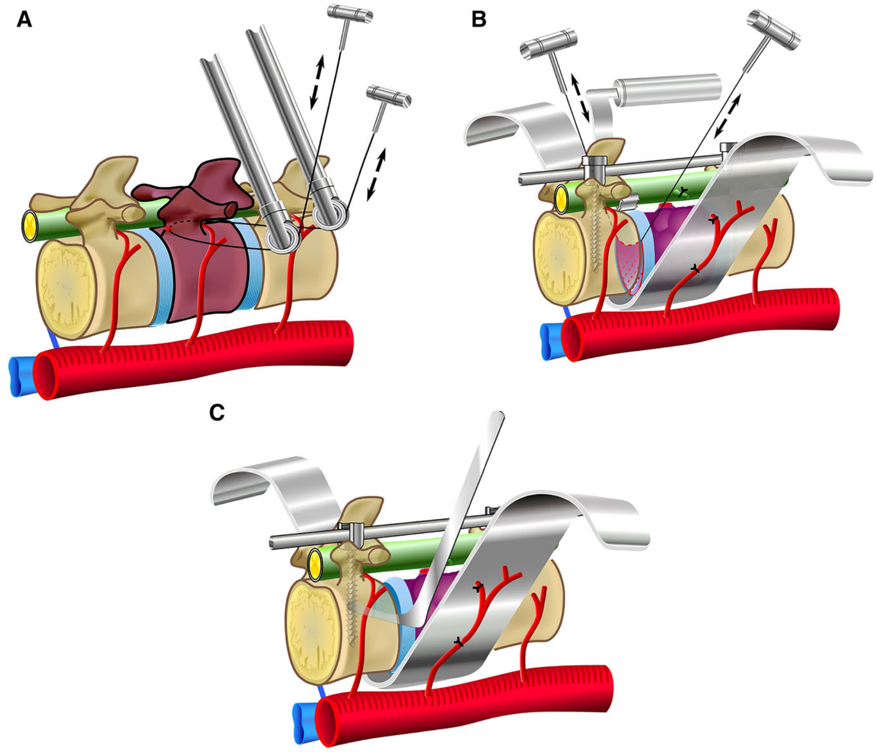

Figure 1. Operative schema of total en bloc spondylectomy. The purple-colored vertebra indicates tumor-affected one. **(A):** Transpedicular osteotomy using a fine threadwire saw. **(B):** Anterior column osteotomy using a fine threadwire saw. **(C):** An L-shaped chisel is also useful in anterior column osteotomy at the disc level.

an intralesional transpedicular osteotomy using a fine threadwire saw should be carried out to prevent spinal cord and nerve root injuries. Although the procedure is not marginal in this situation, it is very practical, and most spine surgeons employ this technique for achieving complete resection of the tumor-affected vertebra [30, 31, 39–42].

Hemivertebrectomy (partial resection of the tumor-affected vertebra) is sometimes employed in spinal SM. Sagittal resection, as proposed by Boriani et al. [38], is mostly indicated in cases involving the lumbar spine (Fig. 4). In the thoracic spine, TES is safer and more feasible than sagittal resection to prevent spinal cord injury and other complications in most cases. Resection of the posterior arch is indicated if the tumor is located only in the posterior spinal element. However, in patients with a large tumor extension to posterolateral sides into the extraosseous paraspinal tissues, intralesional extracapsular excision (piecemeal total excision) is employed to achieve complete SM without significant perioperative complications. This procedure including piecemeal total excision is also employed for complete SM in the cervical spine where the vertebral arteries are present in close proximity.

In our institute, postoperative radiation therapy is not routinely administered. However, it should be considered based on intraoperative findings including intralesional procedures.

Indications

In our opinion, the key issue in identifying patients with spinal metastases for SM is appropriate selection. As is the case with SM for metastases of other organs, spinal SM including TES is only considered suitable for patients with a well-controlled primary cancer when the following conditions are met: (a) absence of disseminated or uncontrolled extraspinal metastatic lesions, (b) complete resection of the solitary lesion in the spine is feasible, and (c) if the patient has adequate cardiopulmonary reserve to tolerate surgery. Future clinical research in the field may be directed toward methods of correctly identifying appropriate patients for spinal SM.

General Conditions

Perioperative morbidity and mortality are important factors to determine the appropriateness of surgical resection, particularly in patients with advanced malignancies [1]. The indication for complete SM depends on patient-specific factors (age, PS, comorbidities, patient preferences and expectations) as well as tumor-related factors. Careful assessment of the operability of the patient (Eastern Cooperative Oncology Group PS grade ≤3) and preexisting comorbidities are crucial.

Disease Conditions

Patients with fewer metastatic lesions have better survival than their counterparts. The median survival after SM is longer for patients with a single metastatic tumor than for patients with multiorgan metastases [43, 44]. Spinal SM should be performed to a limited extent compared with pulmonary SM because it is more invasive and demanding. Therefore, patients with solitary and relatively stable disease are good candidates for spinal SM, whereas those with rapidly progressive disease are not. Patients with oligometastatic

Table 1. Long-term clinical outcomes of complete surgical spinal metastasectomy for single primary malignancies

Author [ref.] (pub yr)	Primary cancer	No. of patients	Age, yr, mean (range)	Follow-up after surgery, mean (range), months	OT, mean (range), min	IBL, mean (range), mL	Estimated median survival time: Survival rate after surgery	Local recurrence in the operated spine, *n* (%)	Major complications (*n*)
Kato [35] (2021)	RCC	65	58.8 (N/A)	75.1[a] (3–251)	N/A	N/A	8.3 yr: 77%, 62%, and 48% (3-, 5-, and 10-yr)	4 (6.2%)	Spinal cord infarction during preoperative AT (1) Major vessel injury (1) Deep SSI (5) Transient paraparesis (2)
Demura [34] (2011)	DTC	10	57.2 (39–77)	60.2[b] (27–125)	548 (391–650)	1713 (630–4,000)	N/A: 90% (5-yr)	1 (10%)	Pleural effusion (2) Chylothorax (1)
Kato [68] (2016)	DTC	20	59.4 (N/A)	N/A[c]	N/A	N/A	N/A: 84% and 52% (5-and 10-yr)	1 (5%)	N/A
Jia [73] (2018)	PG	11	40.6 (23–64)	41.5[b] (8–118)	N/A	N/A	9.8 yr: N/A	5 (45%)[¶]	Pleural tear (1) Pulmonary edema (1) Constipation (1) SSI (1) CSF leakage (2)
Kato [36] (2020)	LMS	10	52.8 (24–69)	50.2[a] (10–204)	490 (356–750)	935 (100–2,900)	4.4 yr: 90%, 70%, and 47% (1-, 3-, and 5-yr)	2 (20%)	PTE (2) Pneumothorax (1)

[¶]No local recurrence was observed in the three patients undergoing en bloc resection, although it appeared in five of the eight patients undergoing piecemeal total resection.
[a]Clinical data of all patients were analyzed ≥3 years after surgery (the minimum 3-year follow-up data).
[b]Clinical data of all patients were analyzed ≥1 year after surgery (the minimum 1-year follow-up data).
[c]Clinical data of all patients were analyzed ≥4 years after surgery (the minimum 4-year follow-up data).
Abbreviations: AT, arterial embolization; CSF, cerebrospinal fluid; DTC, differentiated thyroid carcinoma; IBL, intraoperative blood loss; LMS, leiomyosarcoma; N/A, not available; OT, operating time; PG, paraganglioma; pub yr, year of publication; PTE, pulmonary thromboembolism; RCC, renal cell carcinoma; SSI, surgical site infection.

Table 2. Perioperative complications of spondylectomy (vertebrectomy) for spinal tumors in high-volume centers

Author [ref.] (year of pub.)	No. of patients (no. of patients with metastatic tumor)	Study period	Age, mean (range), years	OT, mean (range), min	IBL, mean (range), mL	Rate of patients with perioperative complication (those in major or minor complications)	Rate of patients with perioperative death	Local recurrence rate
Lee [77] (2014)	62 (62)	2005 to 2010	60 (21–87)	342 (N/A)	2,236 (N/A)	12.9% (N/A)	9.7%	N/A
Boriani [78] (2011)	220 (55)	1990 to 2015	44 (3–82)	548 (391–650)	1,713 (630–4,000)	46.3% (major 32.9%, minor 13.4%)	3.2%	15.3%
Liu [79] (2018)	78 (78)	2008 to 2016	59 (29–77)	375 (N/A)	2,088 (N/A)	33.3% (N/A)	N/A	5.1%
Roser [80] (2019)	137 (137)	2006 to 2016	61 (25–83)	240	1,490 (100–9,000)	27.0% (major 20.4%, minor 6.6%)	N/A	N/A
Zhou [81] (2019)	90 (90)	2005 to 2016	60 (20–82)	354	1,416	24.4% (N/A)	N/A	1.1%
Demura [60] (2021)	307 (225)	1990 to 2017	53 (20–82)	565 (251–1,381)	1,682 (100–21,250)	67.1% (major 39.7%, minor 27.4%)	1.3%	10.4%

Abbreviations: IBL, intraoperative blood loss; N/A, not available; OT, operating time; pub., publication; ref., reference.

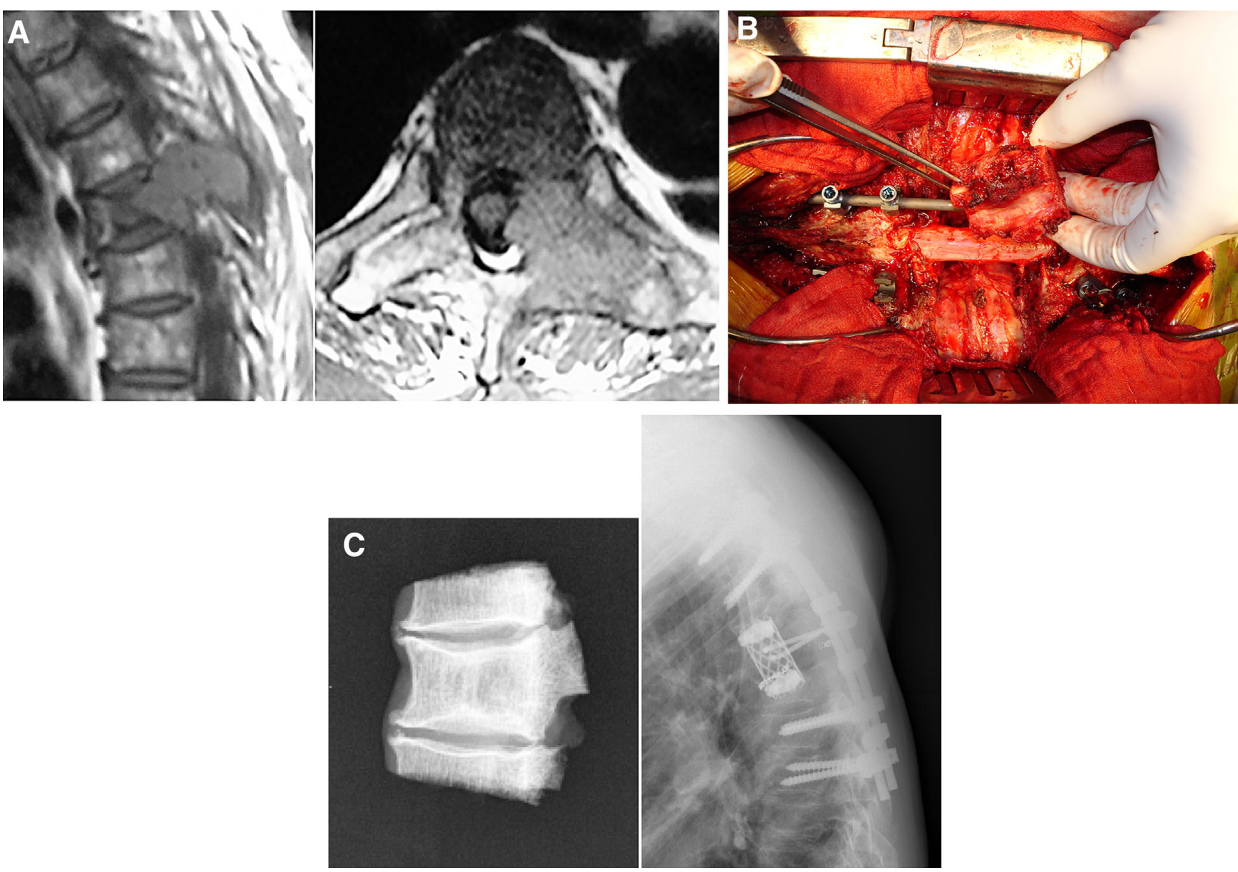

Figure 2. Isolated spinal metastasis from a renal cell carcinoma at T5 in a 62-year-old man. He is alive with a good performance status 14 years after surgery. **(A):** Axial (left) and sagittal (right) images of T1-weighed magnetic resonance imaging of the T5 vertebra showing tumor expansion to the epidural space and the adjacent vertebrae. **(B):** Intraoperative photograph of the resected specimen (total en bloc corpectomy). **(C):** Radiographs of the resected specimen (left) and the reconstructed spine in lateral view (right).

lesions that cannot be alternatively treated using a better local or systemic therapy can also be considered as candidates for this surgery.

Estimated Life Expectancy

Prognosis is one of the key factors in determining the appropriate treatment option for patients with spinal metastases. A majority of surgeons agree that palliative surgery for spinal metastases should be considered for patients with an estimated life expectancy of ≥3 months [1, 45–47]. In contrast, complete SM for spinal metastases is associated with a greater surgical stress and should only be considered for patients whose life expectancy is estimated to be ≥12 [48, 49] or ≥24 months [50, 51]. Several evaluation systems have been reported to estimate life expectancy of patients with spinal metastases and to help select the appropriate treatment option [48–50, 52–56]. Over recent decades, various modern systemic therapies have been developed, and, as a result, more patients with spinal metastases live longer. In our opinion, spinal SM should be offered to patients who are predicted to survive for 2 years or more. In a recently published systematic review for prognostic factors in patients with spinal metastases, the authors identified various cancer-specific prognostic factors in their meta-analysis and indicated that a tumor-based evaluation system might enhance the accuracy of survival prediction [57]. Kumar et al. suggested a concept of readmission-free survival as an assessment tool for patients' general condition, appropriateness of interventional procedures, and underlying disease burden in patients undergoing surgery for spinal metastases [58]. For proper patient selection for spinal SM, cancer-specific assessment systems for predicting survival periods, including the survival category of 2 years or more, are desired.

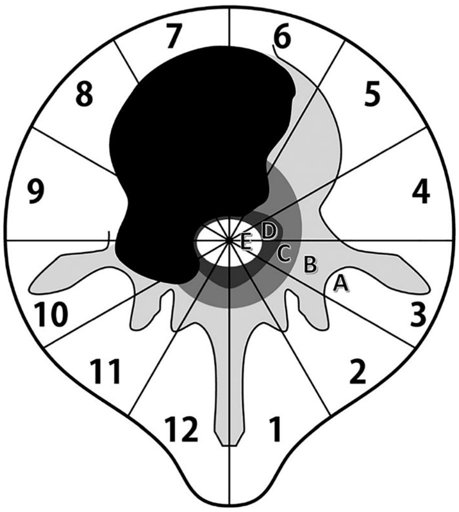

Figure 3. Typical example of isolated spinal metastasis indicated for spinal metastasectomy according to the Weinstein-Boriani-Biagini descriptive system [60]. The letters A–E are used to denote radial levels ("layers") of vertebral involvement. **(A):** Extraosseous paraspinal tissues. **(B):** Intraosseous (superficial). **(C):** Intraosseous (deep). **(D):** Extraosseous (extradural). **(E):** Extraosseous (intradural).

Feasibility of Complete SM (Size and Location)

Complete SM of the cervical spine is often difficult and challenging because of the nearby vital structures including vertebral arteries. Piecemeal total excision is applied for SM in this location. TES is usually indicated for lesions in the thoracic and lumbar spine where metastatic lesions often occur. An isolated lesion involving a single vertebra in the thoracic or the lumbar spine is an ideal indication for spinal SM. In our institute, the tumor involving three consecutive vertebrae or less is indicated for TES. Murakami et al.

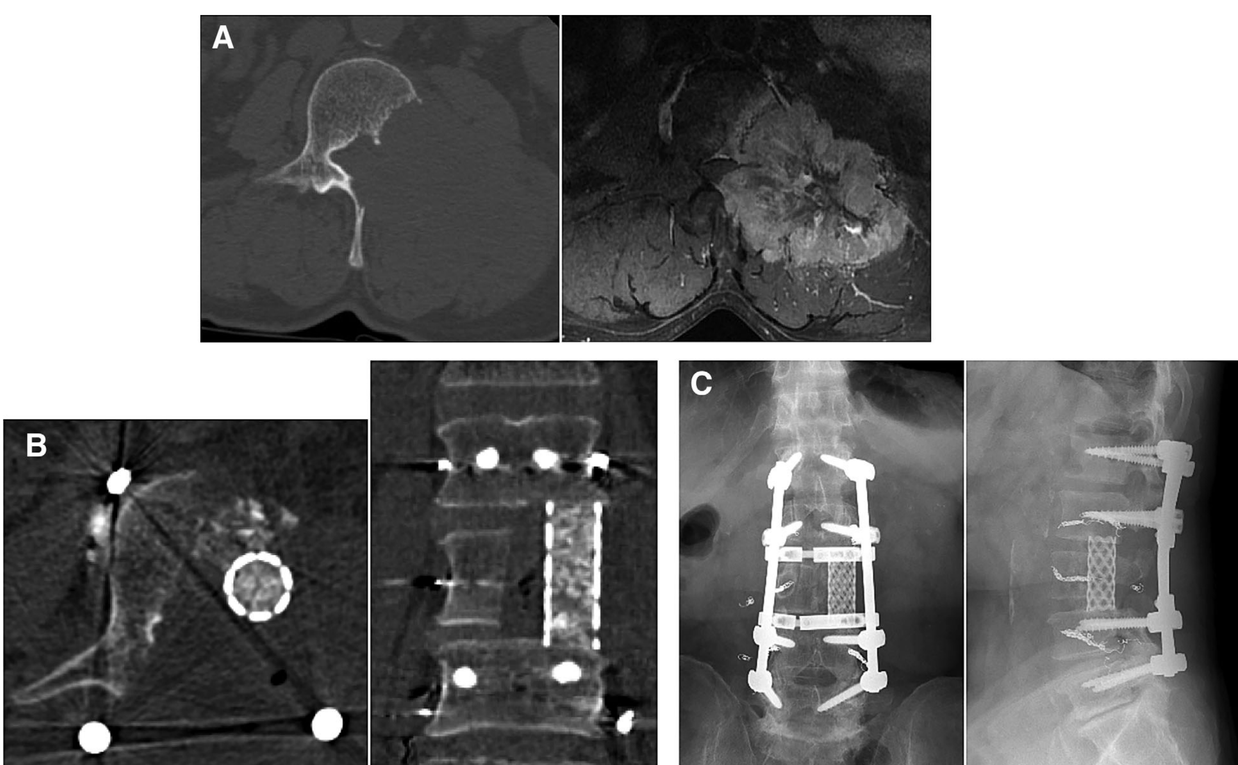

Figure 4. Isolated spinal metastasis from a renal cell carcinoma at L3 in a 65-year-old man. His performance status remained well from the surgery until 4 years later, when he died. There was no tumor recurrence at the operated site. **(A):** Axial images of computed tomography (left) and magnetic resonance imaging (right) showing the tumor involving the postero-lateral portion of the L3 vertebra, expanding up to the paraspinal muscles. **(B):** Axial (left) and coronal (right) images of postoperative computed tomography. **(C):** Anterolateral (left) and lateral (right) views of postoperative radiography.

reported that TES performed on up to three vertebrae did not adversely affect the neurologic functions even with the interruption of the artery of Adamkiewicz during the procedure [59]. However, the resection of multilevel vertebrae is more demanding and has an increased complication rate [60]. Bartlett et al. reported that high-volume centers (defined as the top 10% by volume) perform ≥60% of all SMs across cancer types [1]. As with other major surgeries [61, 62], high-volume centers report a lower incidence of perioperative mortality after SM. This may be attributed to experienced surgeons and co-medical staff taking a more appropriate approach to patient selection and treatment, which is a very important factor toward achieving successful surgical outcomes in patients with advanced malignancies [63]. A previous study from a well-experienced institution reported that surgical techniques in spine tumor surgeries that decreased intraoperative blood loss were related to diminished operating time and surgical stress [64]. The decreasing trend in inpatient mortality suggests that SMs are now safer than before [1]. It could help expand the potential applications of spinal SM.

Primary Tumor

Primary tumor type and histologic assessment are essential factors for determining the appropriate treatment in patients with metastatic diseases. For patients with spinal metastases, the choice of therapies, including SM, should be made according to the characteristics of the primary cancer. Of all the major malignancies, metastatic lesions from kidney and thyroid cancers are the best indications for spinal SM. Osseous metastases from these two tumors have the following common characteristics: (a) they most commonly affect the spine [23, 24, 65]; (b) they present as destructive osteolytic lesions [23, 24, 65]; (c) they are more intractable to systemic and radiation treatments than metastases from other primary cancers [23, 24, 65]; and (d) based on the current guidelines for isolated skeletal metastatic lesions, including in the spine, complete SM with removal of the entire tumor is recommended, if feasible [22, 66, 67]. Excellent clinical results were reported after complete SM for these metastases [34, 35, 68].

Previously, patients with advanced non-small cell lung cancer (NSCLC) were not considered candidates for curative-intent treatment because of their poor prognosis. However, since patients with oligometastases have more favorable prognosis than those with more advanced NSCLC, they may benefit from systemic therapy combined with curative-intent treatment for the metastatic lesions [69]. Several current guidelines recommend local treatment for selected patients with oligometastatic diseases with a curative intent [70, 71]. An earlier case series reported good results after spinal SM for metastatic lung adenocarcinomas [33].

Other studies have also shown the efficacy of SM for pulmonary metastases in bone and soft tissue sarcomas [12–14]. Krishnan et al. reported that SM significantly prolongs survival in patients with metastatic diseases from soft tissue sarcomas [72]. A recent study reported favorable results after spinal SM for metastatic leiomyosarcoma [36].

Metastatic lesions from other primary tumors are not usually indicated for spinal SM. Breast and prostate cancers are common malignancies that develop skeletal metastases. These metastases are usually effectively treated with systemic and radiation therapy; thus, they do not require spinal SM.

Outcomes

Although there are an increasing number of articles about spinal SM, there are few describing complete SM in the spine that provide detailed outcomes, including postoperative survival rates. Table 1 summarizes the clinical outcomes from five published articles about complete SM for spinal lesions from single primary malignancies. Although the data may suffer from selection bias inherent to the retrospective nature of the studies, the postoperative survival data are favorable with acceptable local recurrence rates on long-term follow-up [34–36, 68, 73]. The completeness of resection is a major factor associated with durable postoperative survival. Complete surgical resection resulted in superior outcomes over palliative or cytoreductive surgery [34, 68, 73].

Metastatic spine disease has long been considered an aggressive disease in patients with end-stage cancer, and it is thought, therefore, that SM plays no role. However, a significant proportion of patients with spinal metastases from kidney or thyroid malignancies have a solitary spinal lesion without extraspinal bone metastases or other organ metastases. These patients are eligible for aggressive surgical treatment, including SM [74, 75]. Complete SM is considered an important prognostic factor for these patients with bone metastases [74–76]. Several studies reported that the patients with coexistence of controlled lung metastases had a favorable outcome with spinal SM [35, 36, 68].

Several authors in high-volume centers have reported perioperative complications associated with complete SM in the spine (Table 2) [60, 77–81]. Although fair evaluation and comparison of the data were difficult because of the different definitions, a significant proportion of patients, between 13% and 67%, experienced perioperative complications. Some authors reported a significantly higher frequency of serious postoperative complications in elderly patients and patients undergoing resection of multilevel vertebrae [60, 79, 82]. In our retrospective study of 307 patients undergoing SM of spinal metastases between 1990 and 2017, we reported that 20% of the patients had intraoperative bleeding more than 2,000 mL, and four patients (1.3%) died within 2 months [60]. In the recent years, with experienced and refined surgical techniques, we had only 6 patients (3.5%) with intraoperative bleeding more than 2,000 mL and no deaths within 2 months among the 172 patients undergoing the procedure from 2010 to 2020. Less invasive surgical approaches are recommended for patients with metastatic spinal tumors to help reduce surgical stress and complications, if feasible [83]. Careful selection of appropriate candidates is associated with minimal perioperative morbidity or mortality and is paramount to securing the efficacy of spinal SM.

Future Prospects

For oligometastatic disease, spinal stereotactic body radiotherapy (SBRT) has recently become the mainstay of treatment for long-term control of spinal metastases [25, 27]. For patients with epidural diseases, separation surgery focused on spinal cord decompression is carried out to create a target for radiation prior to SBRT [84]. Studies with a large cohort report a 1-year local control rate of 72%–90% for various types of primary cancers including radiosensitive tumors [85–90]. Several studies report the clinical outcomes of SBRT for spinal diseases from radiation-resistant kidney cancer, indicating a local control rate of 83%–94% after 1 year and 57%–87% after 3 or 4 years [91–95]. The current study of SM for kidney cancer spinal metastases reports a local control rate of 94% after the mean postoperative follow-up of >6 years and no local recurrence >2 years after surgery [35]. SBRT has a lower rate of complications, including the vertebral fracture rate following the treatment of 4.2%–34.4% [85, 96, 97]. However, spinal SM has the potential to improve local control with acceptable rates of complications (Table 1) [34–36, 68, 73].

Recent advances in chemotherapy and immunotherapy have the potential to treat solitary or oligometastatic diseases without the need for surgical intervention. These advances in systemic therapies may lead to a subset of patients with metastatic cancer who present with incomplete response and develop residual drug-resistant diseases that may benefit from SM [15]. Recent studies have evaluated the role of SM following checkpoint and targeted therapies for advanced melanoma [2, 98]. He et al. [98] reported an improved overall survival and durable disease control in patients undergoing SM of oligometastatic melanoma after targeted therapy. The current trends suggest that the prolonged survival afforded by effective systemic therapies may allow further opportunities for effective surgical treatment [1].

The critical anatomy of the spine coupled with good results of SBRT for spinal metastases make it difficult to justify SM for spinal metastatic lesions even with the favorable results [35, 36, 68]. However, we would like to point out other factors that may affect the use of spinal SM. Spine surgeons mainly treat patients with non-neoplastic diseases such as spinal deformity, trauma, infection, and degenerative diseases. Therefore, they have not considered spinal SM as a realistic treatment option for spine metastases with the absence of sufficient knowledge of cancers and experience in tumor surgeries. In contrast, thoracic surgeons are more active in treating patients with metastatic cancer than spine surgeons because their main surgery is curative excision of primary lung cancers, and their surgical techniques and experience are directly applicable to pulmonary SM. Because of these circumstances, the indications and efficacy of spinal SM have been underestimated among spine surgeons and cancer specialists. Based on the excellent clinical results of spinal SM with a practiced surgical technique, spinal SM should be considered a good treatment option for appropriately selected patients, and it can maintain PS in the long term and potentially prolong survival. Surgical feasibility with a lowered risk of perioperative complications is an important factor for driving the decision of surgery. Therefore, spinal SM should only be performed in well-experienced and high-volume centers.

Contrary to the expectations of most clinicians, the development of effective and modern systemic treatment modalities has increased the number of spinal SM and the publication of related articles, especially in Asian countries [33–36, 68, 73, 77–82, 99–102]. Although the number of candidates with an indication for spinal SM is still limited among patients with spinal metastases, we expect these to increase, especially in countries where SBRT is not widely available. Future indications and optimal timing for spinal SM within the interdisciplinary management of metastatic disease remain dynamic subjects. The experience and skills of many medical professionals are required in determining the best therapeutic strategy, including spinal SM, for treatment of patients with spinal metastases. The oncological utility of SM in patients with a favorable tumor profile should be examined to strengthen the evidence and compared with probable outcomes of radiosurgical treatments.

Conclusion

The use of SM is increasing across various cancer types. As recent advances of radiation therapy help in the treatment of spinal metastases, expert surgical techniques for spinal SM improve clinical outcomes with a lower complication rate. We conclude that for certain patients with isolated and removable spine metastases, a complete SM with TES is a useful option as it can improve function and survival. However, appropriate patient selection and surgical feasibility remain the most important aspects of management. We strongly recommend a multidisciplinary team approach for combined decision-making in patients with spinal metastases.

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Disclosures

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