Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

Clinical Outcomes and Safety of a Triple-Modality Approach Combining Decompression, Vertebral Augmentation, and Radiotherapy for Thoracolumbar Metastatic Tumors With Neurological Involvement

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Objective: To evaluate the clinical efficacy and safety of a triple-modality therapy—decompression, vertebral augmentation, and radiotherapy—in patients with thoracolumbar metastatic tumors accompanied by neurological injury.

Methods: A retrospective analysis was performed involving 86 patients who underwent treatment for thoracolumbar metastatic tumors with neurological involvement between January 2017 and December 2022. Participants were categorized into two groups: a control group (n = 45) that received conventional separation surgery combined with pedicle screw fixation, and an intervention group (n = 41) that received the triple-modality therapy. This therapeutic approach comprised (1) decompression through separation surgery, which involved excision of tumor tissue adjacent to the dura mater to establish a protective margin; (2) vertebral augmentation via bone cement injection into the affected vertebrae, along with bone cement-augmented pedicle screw fixation; and (3) stereotactic radiosurgery. Postoperative outcomes, including pain intensity, neurological function, and quality of life, were assessed and compared between groups.

Results: The intervention group experienced significantly longer surgical durations but demonstrated reduced intraoperative blood loss compared with the control group ($p < 0.05$). Both groups demonstrated improvements in pain levels, neurological function, and quality of life following surgery. However, the intervention group exhibited significantly lower visual analogue scale scores at the final follow-up ($p < 0.05$). Additionally, significant improvements were observed in the Frankel grade and Karnofsky Performance Status scores within the intervention group compared with the control group at the final follow-up (both $p < 0.05$). The Cobb angle in the control group demonstrated a significant increase from 1 week postoperatively to the final follow-up ($p < 0.05$).

Conclusion: The decompression-vertebral augmentation-radiotherapy triple-modality therapy demonstrated efficacy in alleviating pain, promoting neurological recovery, and improving quality of life while maintaining spinal stability and a low rate of complications.

Keywords: neurological injury, separation surgery, stereotactic radiosurgery, thoracolumbar metastatic tumors, vertebral augmentation

Background

The spine is a common site for bone metastases originating from malignant tumors, and the thoracolumbar region is the most frequently affected.[1,2] Metastatic involvement of the vertebral column often leads to structural compromise,

Received: 10 June 2025
Accepted: 20 September 2025
Published: 17 October 2025

pathological fractures, and metastatic epidural spinal cord compression. These pathological changes manifest clinically as sensory and motor deficits below the lesion level and, in severe cases, may progress to complete paralysis, substantially impairing quality of life among affected individuals.[3,4] Although total en bloc spondylectomy facilitates comprehensive resection of metastatic lesions, its application is limited due to the extensive surgical trauma and high complication rates associated with the procedure. These factors are particularly prohibitive in individuals with multiple metastatic sites or reduced physiological reserves. Consequently, the development of minimally invasive strategies capable of achieving effective spinal cord decompression, mechanical stabilization, and tumor control remains a prominent challenge in current oncologic spine care.[5–7]

Separation surgery, first introduced by Bilsky, involves resecting tumor tissue adjacent to the dura mater to decompress the spinal cord while preserving a circumferential margin of approximately 5 to 8 mm.[8] This margin facilitates the delivery of high-dose stereotactic radiosurgery (SRS) to the residual tumor mass, thereby minimizing direct surgical manipulation of neural structures. Unlike traditional total spondylectomy, separation surgery emphasizes functional preservation rather than complete tumor excision and has been associated with reduced surgical trauma and a lower incidence of perioperative complications.[9]

Individuals with thoracolumbar metastatic tumors are typically middle-aged or older and often present with osteoporosis, a condition that reduces pedicle screw anchorage strength and increases the likelihood of hardware-related complications, such as loosening, displacement, or dislocation. Bone cement-assisted vertebral augmentation has demonstrated efficacy in enhancing pedicle screw fixation strength and has gained increasing application in spinal stabilization procedures.[10,11] Moreover, bone cement contributes to vertebral reinforcement and pain mitigation in the context of metastatic involvement.

Based on these considerations, a triple-modality therapeutic strategy—decompression, vertebral augmentation, and radiotherapy—was developed. In this approach, separation surgery provides neural decompression and a protective margin for subsequent interventions; bone cement augmentation restores structural integrity and supports local tumor control; and postoperative SRS targets residual tumor tissue to reduce the likelihood of recurrence. The aim of this study was to assess the clinical efficacy and safety of this triple-modality therapy in comparison with conventional separation surgery combined with pedicle screw fixation. A retrospective analysis was conducted involving 86 individuals diagnosed with thoracolumbar metastatic tumors and neurological injury who received treatment between January 2017 and December 2022. Outcomes related to pain relief, neurological function, and quality of life were evaluated to inform clinical decision-making and provide an evidence-based foundation for treatment of this population.

Materials and Methods

Study Participants

Inclusion criteria were as follows: (1) confirmed diagnosis of thoracolumbar metastatic tumors based on computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography-computed tomography (PET-CT), or histopathological examination, with the primary malignancy under control; (2) presence of neurological deficits, refractory pain, and/or pathological vertebral fractures; (3) epidural spinal cord compression (ESCC) grade greater than 2; (4) estimated life expectancy of at least three months based on the Tomita and modified Tokuhashi scoring systems; (5) adequate physical status to tolerate surgical intervention; and (6) provision of informed consent by the individuals or their legal guardians.

Exclusion criteria were: (1) extensive metastatic disease involving multiple organ systems; (2) metastases affecting more than two thoracic or lumbar vertebral levels; (3) history of prior surgical procedures involving the thoracolumbar spine; and (4) incomplete imaging data or inadequate documentation during follow-up.

General Information

A retrospective analysis was performed involving 86 individuals diagnosed with thoracolumbar metastatic tumors and associated neurological deficits who underwent surgical treatment at the Department of Spine Surgery, Yantai Yantaishan Hospital, between January 2017 and December 2022. Participants were allocated to one of two groups based on the

treatment strategy employed: (1) control group, which underwent traditional separation surgery combined with pedicle screw fixation and SRS; and (2) intervention group, which received triple-modality therapy comprising decompression, vertebral augmentation, and radiotherapy.

This study complied with the Declaration of Helsinki and was approved from the Medical Ethics Committee of Yantai Yantaishan Hospital (YS Ethics No. 2024143). Written informed consent for the case details to be published was obtained from all individuals. For the elderly participants lacking decision-making capacity, informed consent was obtained from their legal representatives.

Surgical Techniques

Triple-Modality Therapy: Decompression, Vertebral Augmentation, and Radiotherapy

After administration of general anesthesia, individuals were positioned prone with thoracoabdominal suspension. Following routine aseptic preparation, a posterior midline incision was made, and the paraspinal musculature was dissected to expose the spinous processes, laminae, and facet joints of the affected vertebra and the two adjacent segments. Pedicle screw insertion points were identified, and a working channel was established using a probe. A positioning needle was inserted and verified using C-arm fluoroscopy. Hollow, side-hole pedicle screws were placed following tapping, and polymethylmethacrylate bone cement (1.5–2.0 mL per screw) was injected through the side openings. Bilateral pedicle punctures were performed at the affected vertebra, and bone cement was injected incrementally in small volumes to reduce the risk of cement leakage into the spinal canal. C-arm fluoroscopy was used for real-time monitoring to ensure accurate cement distribution and to avoid extravasation into the spinal canal or paravertebral venous plexus. Decompression was achieved using ultrasonic bone knives and related instruments to resect the spinous process, lamina, lower two-thirds of the lamina of the vertebra above, bilateral inferior articular processes, and the superior and inferior articular processes along with pedicles of the target vertebra. In some cases, intact pedicles were partially preserved. The ligamentum flavum was removed, allowing full exposure and decompression of the dural sac and nerve roots. The ventral posterior longitudinal ligament and the posterior aspect of the affected vertebral body were excised to establish a 5 to 8 mm safety margin around the spinal cord. Adherence to tumor-free principles was maintained throughout to limit intraoperative dissemination. The surgical field was irrigated with cisplatin solution, 5-fluorouracil, or sterile distilled water for five minutes to target residual tumor cells. Prophylactic antibiotics were administered postoperatively.

SRS was initiated two to three weeks after surgery upon adequate wound healing, and the treatment plan was stratified based on tumor lesion characteristics (location, volume, and shortest distance to the spinal cord):[12] (1) Single-fraction high-dose regimen: For patients with lesion edges ≥5mm from the spinal cord and a volume ≤10cm³, a single 24 Gy irradiation was administered; (2) Fractionated radiotherapy regimen: For patients with lesions adjacent to the spinal cord (edges < 5mm from the spinal cord) or a volume > 10cm³, an irradiation regimen with a total dose of 18–36 Gy, administered in 3–6 fractions, was adopted. The dose constraints for normal tissues strictly follow the guidelines of the International Commission on Radiation Protection and Metrology (ICRU): (1) Spinal cord: The maximum point dose (Dmax) during single-fraction irradiation was ≤14 Gy, and the total dose during fractionated irradiation was ≤25 Gy. (2) Nerve roots: The maximum dose (Dmax) was ≤16 Gy (single fraction) or ≤24 Gy (fractionated). Additional therapies, including chemotherapy or targeted treatments, were administered as indicated by the primary tumor pathology.

Traditional Separation Surgery

The operative procedure for the control group mirrored that of the intervention group, excluding vertebral augmentation and bone cement-assisted pedicle screw fixation. Postoperative SRS was administered following the same protocols.

Outcome Measures

Data collected included demographic and clinical variables such as age, sex, affected spinal segment, primary tumor type, surgical duration, intraoperative blood loss, Frankel grade, visual analogue scale (VAS) score, Karnofsky Performance Status (KPS) score, Cobb angle, incidence of bone cement leakage, and perioperative complications. For statistical analysis, Frankel grades were numerically coded (grade A = 1, B = 2, C = 3, D = 4, E = 5). Follow-up evaluations were

conducted at 1 week, 3 months, 6 months, and 12 months postoperatively, and subsequently at 6-month intervals. Imaging studies, including X-ray and other relevant modalities, were reviewed at each time point to assess internal fixation status and identify signs of hardware failure, including screw loosening, displacement, dislocation, or fracture.

Statistical Analysis

Statistical analyses were performed using SPSS version 26.0. Continuous variables such as age, scores, surgical duration, and intraoperative blood loss were expressed as mean ± standard deviation ($\bar{x} \pm s$). Between-group comparisons were conducted using independent-samples *t*-tests or one-way analysis of variance, as appropriate. Categorical variables were analyzed using chi-square tests. A *p*-value of less than 0.05 was considered statistically significant. Statistical values and *p*-values were reported to three decimal places, and all other numerical values were rounded to two decimal places.

Results

Clinical Data

A total of 86 patients with thoracolumbar metastatic tumors and neurological impairment were included in this retrospective study. The control group comprised 45 patients (20 males, 25 females) with a mean age of 63.64 ± 8.94 years (range = 46–81 years). The intervention group included 41 patients (22 males, 19 females), with a mean age of 64.10 ± 9.57 years (range = 49–86 years). Primary malignancies included 24 cases of lung cancer, 19 of breast cancer, 21 of thyroid cancer, 14 of renal cancer, 4 of prostate cancer, and 4 of other origins. Metastatic segments included 58 thoracic, 20 lumbar, and 8 combined thoracolumbar cases. Pathological fractures occurred in 8 of 41 patients (19.51%) in the intervention group, compared to 11 of 45 patients (24.44%) in the control group. No statistically significant differences in sex, age, primary tumor origin, pathological fracture, or affected spinal segments were observed between groups ($p > 0.05$), indicating comparability (see Table 1).

The mean operative duration was significantly longer in the intervention group (265.61 ± 48.70 minutes) compared to the control group (240.64 ± 36.82 minutes; $p = 0.008$). Mean intraoperative blood loss was significantly lower in the

Table 1 Baseline Demographic and Clinical Characteristics of the Patients

Indicator	Control Group	Intervention Group	*P*
Age (years, $\bar{x} \pm s$)	63.64±8.94	64.10±9.57	0.821
Sex (n)			0.393
Male	20	22	
Female	25	19	
Primary tumor (n)			0.600
Lung cancer	13	11	
Breast cancer	11	8	
Thyroid cancer	8	13	
Kidney cancer	7	7	
Prostate cancer	3	1	
Other types	3	1	
Segment involved (n)			0.825
Thoracic vertebrae	30	28	
Lumbar vertebrae	10	10	
Thoracic + lumbar vertebrae	5	3	
Pathological fracture (n)			0.582
Yes	11	8	
No	34	33	
VAS score	8.36 ± 1.07	8.29 ± 1.17	0.795
Surgical duration (min, $\bar{x} \pm s$)	240.64±36.82	265.61±48.70	0.008
Blood loss (mL, $\bar{x} \pm s$)	506.44±55.32	476.59±51.80	0.012

Abbreviation: VAS, visual analogue scale.

intervention group (476.59 ± 51.80 mL) than in the control group (506.44 ± 55.32 mL; p =0.012). The follow-up period ranged from 3 to 91 months, with a median duration of 21 months.

In the control group, five patients experienced postoperative complications: one developed a superficial wound infection, which resolved following debridement and resuturing; two sustained dural tears with cerebrospinal fluid leakage, which were managed through intraoperative repair, bed rest, intermittent tube clamping, and fluid infusion; and two exhibited screw loosening postoperatively, which was treated symptomatically. Both patients with screw loosening died during the follow-up period.

In the intervention group, two patients experienced complications: one had postoperative intraspinal bone cement leakage, which resolved after halting infusion without subsequent adverse effects; another developed a postoperative hematoma with progressive neurological decline three hours after surgery. Magnetic resonance imaging revealed a hematoma at the surgical site, which was surgically evacuated. Neurological function fully recovered within two days, post-intervention.

Pain Assessment

Pain levels were assessed using the VAS. The control group had a mean preoperative VAS score of 8.36 ± 1.07, while the intervention group had a mean score of 8.29 ± 1.17. No statistically significant difference was observed between the two groups at baseline (p = 0.795). At the final follow-up, both groups demonstrated significant pain reduction compared to preoperative values ($p < 0.001$). The control group's mean VAS score decreased to 3.67 ± 2.06, whereas the intervention group reported a lower mean score of 2.18 ± 0.98. The difference between the two groups at the final follow-up was statistically significant (p = 0.037), indicating that while both interventions were effective in pain alleviation, the intervention group experienced superior relief (see Figure 1).

Neurological Recovery

Neurological function was evaluated using the Frankel grading system, which assesses the severity of spinal cord injury (see Figure 2). Preoperatively, the control group included 4 patients graded A, 21 graded B, 13 graded C, and 7 graded D, with no patients in grade E. This distribution yielded a mean Frankel score of 2.51 ± 0.87. In the intervention group, 8 patients were classified as grade A, 15 as grade B, 10 as grade C, and 8 as grade D, also with no patients in grade E, resulting in a mean score of 2.44 ± 1.03. No statistically significant difference in Frankel grading was observed between the groups before surgery ($p > 0.05$). At the final follow-up, both groups demonstrated significant neurological improvement. The control group achieved a mean Frankel score of 3.80 ± 1.15, while the intervention group demonstrated a higher mean score of 4.82 ± 0.41, with the intergroup difference reaching statistical significance ($p < 0.05$).

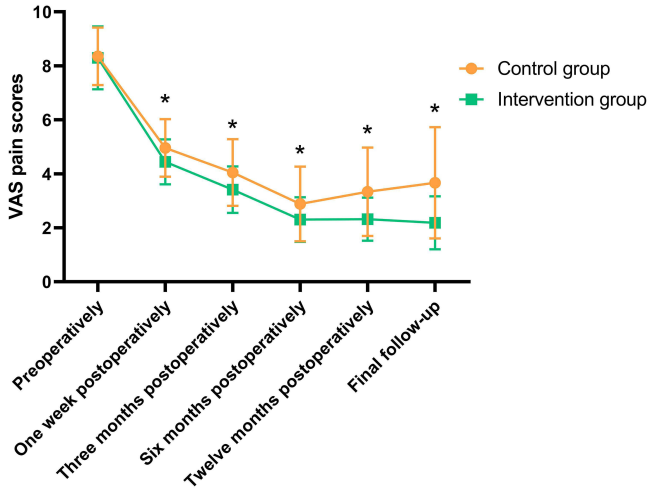

Figure 1 Comparison of VAS pain scores pre- and post-treatment. *Significant difference between the control and intervention groups at the indicated time point ($p < 0.05$).

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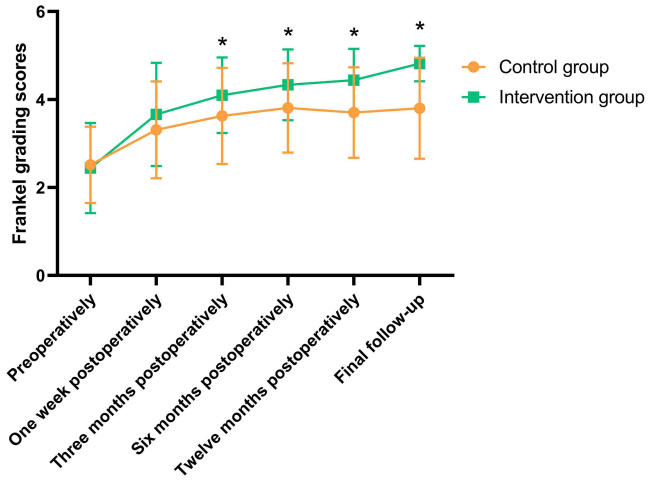

Figure 2 Comparison of Frankel grading scores pre- and post-treatment. *Significant difference between the control and intervention groups at the indicated time point ($p < 0.05$).

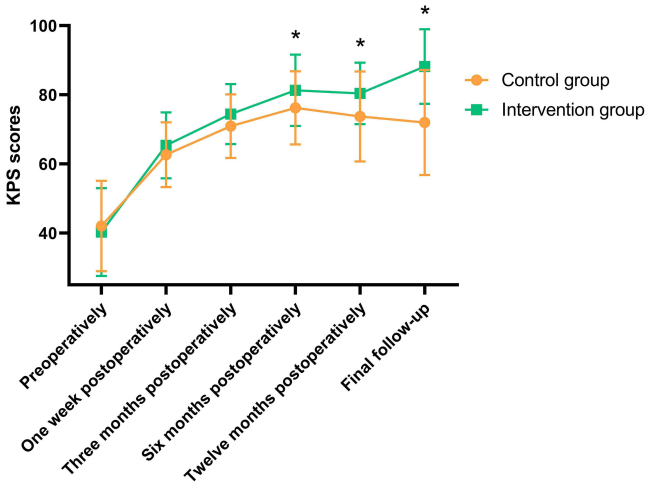

Figure 3 Comparison of KPS scores pre- and post-treatment. *Significant difference between the control and intervention groups at the indicated time point ($p < 0.05$).

Quality of Life Improvement

The KPS score was used to assess patients' quality of life (see Figure 3). Preoperative mean KPS scores were 42.00 ± 13.07 in the control group and 40.24 ± 12.75 in the intervention group, with no significant difference observed ($p = 0.531$). At the final follow-up, both groups exhibited notable improvement in functional status. The control group achieved a mean KPS score of 72.00 ± 15.21, while the intervention group reached a significantly higher score of 88.18 ± 10.79 ($p = 0.006$).

Comparison of Cobb Angle Before and After Treatment

Cobb angle measurements improved significantly in both groups at all postoperative time points compared to preoperative values ($p < 0.05$), with no significant intergroup differences observed at baseline or at any follow-up interval ($p > 0.05$; see Figure 4). In the control group, the Cobb angle increased significantly from 19.80 ± 4.24 one week after surgery to 22.47 ± 3.64 at the final follow-up ($p < 0.05$), indicating a degree of postoperative correction loss. In contrast, the intervention group exhibited minimal change in Cobb angle, increasing slightly from 20.34 ± 4.10 at one week postoperatively to 20.55 ± 3.73 at the final follow-up, a difference that was not statistically significant ($p > 0.05$), reflecting superior maintenance of spinal alignment.

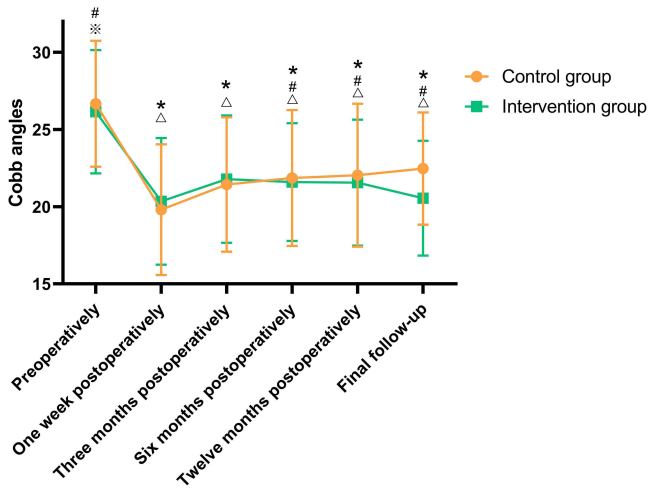

Figure 4 Comparison of Cobb angles pre- and post-treatment. *Significant change from preoperative values at the indicated time point in the control group ($p < 0.05$). #Significant change from one-week postoperative values at the indicated time point in the control group ($p < 0.05$). ΔSignificant change from preoperative values at the indicated time point in the intervention group ($p < 0.05$). ※Significant change from one-week postoperative values at the indicated time point in the intervention group ($p < 0.05$).

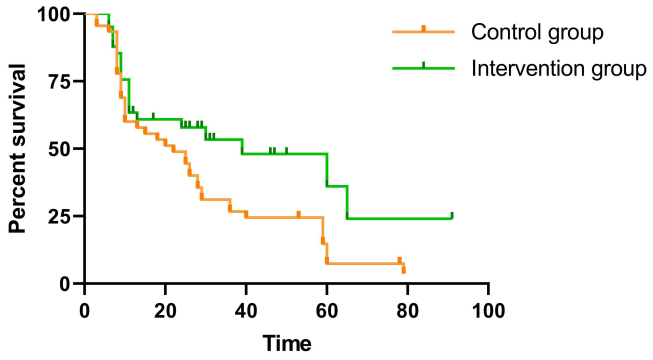

Figure 5 Kaplan-Meier survival curves for the control and intervention groups.

Survival Analysis

The median survival time for patients in the control group was 22 months, while the median survival time for those in the intervention group was 39 months (Figure 5). The 1-year postoperative survival rate was 60.00% (27/45) in the control group and 63.41% (26/41) in the intervention group. At the last follow-up, 43 patients (95.56%) in the control group and 31 patients (75.61%) in the intervention group had died due to primary tumor progression, respectively. A comparison of the survival distributions between the two groups revealed a significant difference (p = 0.035). MRI assessments at 6 months postoperatively showed that 88.89% (40/45) of patients in the control group and 90.24% (37/41) of patients in the intervention group had no tumor recurrence or progression in the surgical area. By the last follow-up, the local recurrence rate was 22.2% (10/45) in the control group and 9.8% (4/41) in the intervention group. The above data indicate that the triple therapy did not compromise the oncological control effect, but rather showed a superior trend in local control.

Representative Case

A 72-year-old male diagnosed with thoracic vertebral metastasis secondary to prostate cancer presented with a pathological fracture at the T9 vertebra, accompanied by spinal cord compression, complete loss of sensation and motor function in the lower extremities, and urinary and fecal incontinence. The patient's neurological function was classified as Frankel grade B, and the preoperative VAS score was 9. The patient underwent the triple-modality therapy comprising decompression, vertebral augmentation, and postoperative radiotherapy under general anesthesia. Following

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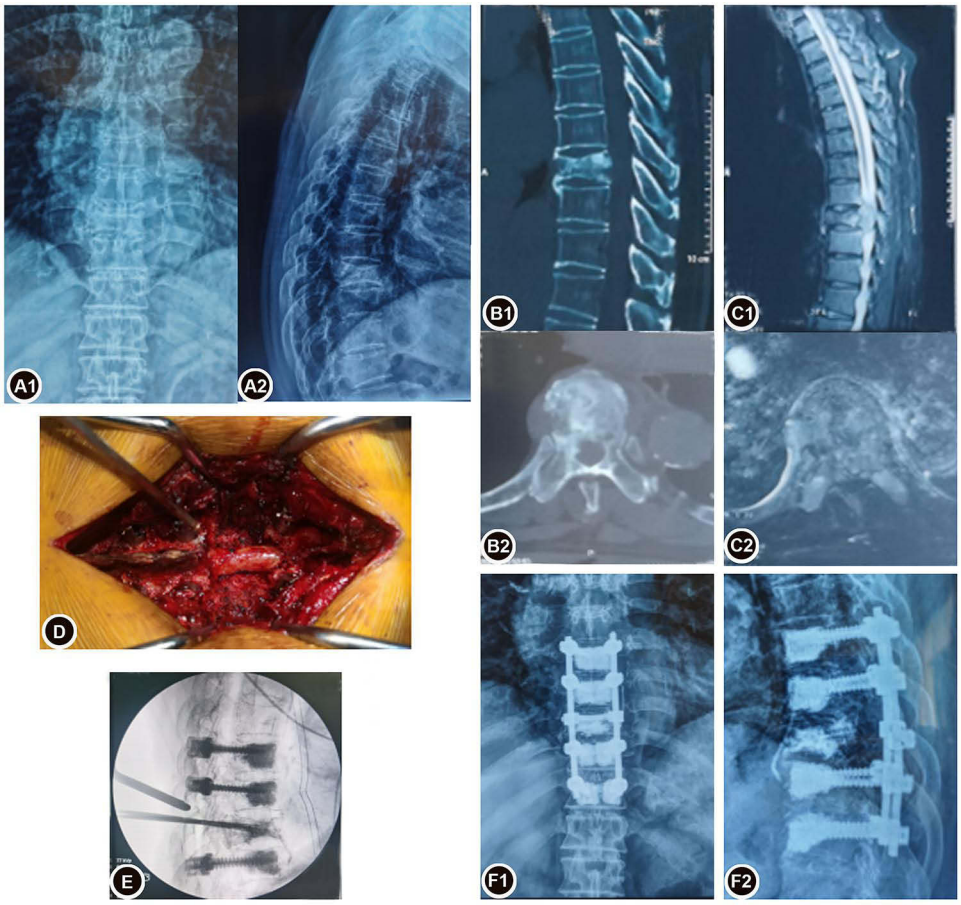

Figure 6 Representative clinical case of thoracic metastatic tumor involving the T9 vertebra: (**A1** and **A2**) X-rays demonstrated pathological fracture and destruction of the T9 vertebral body; (**B1** and **B2**) CT revealed T9 vertebral body pathological fracture, bone destruction of the T9 vertebral body and its appendages, and spinal canal stenosis; (**C1** and **C2**) MRI exhibited pathological fracture and destruction of the T9 vertebral body, tumor invasion into the spinal canal, and marked spinal cord compression; (**D**) intraoperative procedures involved separation surgery combined with circumspinal decompression; (**E**) bone cement augmentation of the affected vertebra and bone cement-augmented pedicle screw fixation were performed intraoperatively; (**F1** and **F2**) at 16-month follow-up, anteroposterior and lateral spinal X-rays demonstrated preserved thoracic vertebral alignment without evidence of implant-related complications such as loosening, displacement, or fracture.

surgery, the VAS score improved to 5 and the Frankel grade to C. After stabilization, the patient received SRS in the oncology department. At the one-year follow-up, further improvements were observed, with the patient achieving a Frankel grade of D and a VAS score of 2. During the survival period, no thoracic, lumbar, or back pain, nor lower limb numbness or symptom exacerbation, was reported (see Figure 6).

Discussion

The present study employed a triple-modality approach that integrated separation surgery, bone cement augmentation, and SRS to evaluate its clinical utility in managing thoracolumbar metastatic tumors with neurological impairment. Retrospective analysis indicated that the triple-modality approach resulted in superior outcomes in terms of pain alleviation, neurological function recovery, and enhancement of quality of life when compared to conventional separation surgery combined with pedicle screw fixation.

Separation surgery, an emerging technique, offers distinct advantages by decompressing neural elements through resection of tumor tissue adjacent to the dura mater while preserving a critical margin around neural structures. Residual tumor burden is subsequently addressed using SRS, thereby minimizing the extent of surgical trauma and reducing complication rates. However, conventional surgery often involves extensive resection of bilateral facet joints, pedicles, posterior longitudinal ligaments, ventral dural tumors, and portions of the vertebral body. This can significantly compromise spinal stability and increase the risk of postoperative hardware complications.

Instances of pedicle screw loosening, displacement, or dislocation may severely deteriorate quality of life and shorten survival duration. To address these concerns, improved spinal reconstruction strategies following separation surgery are required. Given the demographic characteristics of patients with spinal metastases—patients who are typically older and often have osteoporosis—the anchorage capacity of pedicle screws within the vertebral body is frequently suboptimal. Published literature has reported internal fixation failure rates following surgery for spinal metastases ranging from 1.9% to 16%, with symptomatic implant failure rates reaching 5.7%, asymptomatic failure up to 16.7%, and symptomatic failure following separation surgery reported at 2.8%.[13–15] Documented mechanisms of failure include screw loosening, displacement, and fractures of connecting rods or fusion cages. Consequently, the selection of a rational, safe, and mechanically stable internal fixation method that does not increase surgical trauma remains a critical factor for achieving optimal outcomes in the surgical management of spinal metastases.

The technique of bone cement-augmented pedicle screw fixation has been widely utilized in spinal procedures involving compromised bone quality, such as trauma, degenerative diseases, neoplasms, and related conditions, and has consistently demonstrated favorable clinical outcomes.[16–19] This method entails the injection of bone cement through the cannulated tail of the pedicle screw, allowing the cement to diffuse into the anterior and middle vertebral body via lateral apertures in the screw structure. This mechanism reinforces the vertebral body, reduces the likelihood of progressive vertebral collapse, and enhances spinal stability, thereby improving pedicle screw fixation strength.[20,21]

In the present study, no cases of internal fixation failure—including screw loosening, displacement, or dislocation—were observed among patients who received cement-augmented screws. Additionally, there was no significant change in the sagittal Cobb angle of the affected spinal segment between the 1-week postoperative evaluation and the final follow-up. The observed internal fixation failure rate was substantially lower than that associated with conventional separation surgery. These findings indicate that bone cement-augmented pedicle screw fixation offers superior mechanical stability in the context of separation surgery for spinal metastatic tumors and effectively mitigates the risk of delayed spinal cord injury due to postoperative kyphotic deformity.

The proposed triple-modality approach appears to optimize the management of spinal metastases by integrating decompressive surgery, immediate mechanical stabilization, and targeted radiotherapeutic control of residual tumor tissue. The 5 to 8 mm clearance achieved through separation surgery enables precise stereotactic radiotherapy dose delivery while avoiding excessive radiation exposure to the spinal cord, thus substantially reducing the risk of radiation-induced neurotoxicity. Bone cement augmentation not only contributes to vertebral stabilization but also exerts cytotoxic effects through polymerization-induced hyperthermia, thereby augmenting the DNA-damaging effects of SRS. Furthermore, the infiltration of bone cement into cancellous bone and its occlusion of vertebral venous sinuses serve to limit intraoperative vertebral bleeding during ventral tumor resection.

Compared to conventional separation surgery, this multimodal strategy significantly reduces intraoperative hemorrhage and addresses both mechanical and oncological challenges in a single-stage approach. It bridges the conventional divide between radical resection and palliative decompression by offering a minimally invasive, function-preserving therapeutic option, particularly suited to older adults with advanced disease and multiple comorbidities.

The present study introduces novel strategies for managing thoracolumbar metastatic tumors; however, there are several limitations which should be noted. (1) The relatively small sample size may limit the generalizability of the findings. (2) The short follow-up duration prevents a comprehensive evaluation of the long-term efficacy of the proposed approach. (3) Variability in primary tumor type and lesion segment distribution may influence the therapeutic outcomes of surgery and SRS. Due to the limited cohort size, stratified analyses based on these factors were not conducted. In addition, as a retrospective study, patient grouping was determined by clinical decision-making rather than randomization, which may introduce selection bias Future studies will focus on prospective, multicenter trials aimed at expanding the sample size, extending follow-up durations, and conducting subgroup analyses based on primary tumor type and lesion segment characteristics.

In conclusion, the triple-modality therapy—decompression, vertebral augmentation, and radiotherapy—demonstrates superior efficacy and safety in treating thoracolumbar metastatic tumors with neurological injury. This approach effectively alleviates pain, enhances neurological recovery, and significantly improves quality of life. However, due to the limitations of the present study, these findings should be interpreted with caution.

Abbreviations

ESCC, Epidural Spinal Cord Compression; SRS, Stereotactic Radiosurgery; VAS, Visual Analog Scale; KPS, Karnofsky Performance Status; PMMA, Polymethylmethacrylate.

Ethics Approval and Consent to Participate

This study complied with the Declaration of Helsinki and was approved from the Medical Ethics Committee of Yantai Yantaishan Hospital (YS Ethics No. 2024143). Written informed consent for the case details to be published was obtained from all individuals. For the elderly participants lacking decision-making capacity, informed consent was obtained from their legal representatives.

Funding

There is no funding to report.

Disclosure

The authors declare that they have no competing interests in this work.

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