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Transpedicular approach for circumferential decompression and separation surgery as a safe and effective way to maximize surgical treatment for spinal metastases: a multicentric study

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OBJECTIVE Surgery for spinal metastases has undergone multiple transformations in operative technique, with the goal of enhancing local disease control and facilitating adjuvant therapies. The transpedicular approach offers a minimally invasive strategy for achieving circumferential spinal cord decompression, optimizing conditions for high-dose radiation therapies such as stereotactic body radiation therapy and safe cytoreduction. This study aimed to assess the safety and effectiveness of the transpedicular approach in achieving 360° spinal cord decompression.

METHODS In this multicentric retrospective observational study, the medical records of symptomatic patients who underwent circumferential decompression of the dural sac for spinal metastases between January 2018 and June 2023 were analyzed. Assessed data included perioperative complications and clinical outcomes in terms of neurological function and axial pain. Neurological status was evaluated using the American Spinal Injury Association Impairment Scale and modified Medical Research Council scale. Radiological assessments included epidural spinal cord compression grading and the Spine Instability Neoplastic Score. Statistical analyses were conducted to identify predictors of outcomes.

RESULTS Circumferential decompression was successfully achieved in all cases. Neurological improvement was observed in 76.3% of patients at discharge, with sustained functional benefits at a mean follow-up of 19.2 months. Postoperative pain improved in 84.2% of patients. A significant association was found between immediate postoperative neurological improvement and long-term outcomes ($p = 0.004$). Univariate logistic regression analysis indicated that immediate postoperative improvement significantly reduced the likelihood of deterioration at the last follow-up [Nagelkerke $R^2 = 0.135$, Exp(B) = 0.208; $p = 0.004$]. The total complication rate was 9.8%. Complications included CSF leaks (2.8%), wound infections (1.9%), and low rates of neurological deterioration (0.9%).

CONCLUSIONS The transpedicular approach provides a safe and effective route for circumferential spinal cord decompression in metastatic spinal disease. It minimizes perioperative risks, facilitates high-dose radiation therapy, and achieves favorable neurological and pain outcomes in thoracic and lumbar locations.

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KEYWORDS spinal metastasis; separation surgery; transpedicular approach; stereotactic body radiation therapy; stereotactic radiation surgery

ABBREVIATIONS AI-SCC = anterolateral spinal cord compression; ASCC = anterior spinal cord compression; CSCC = circumferential spinal cord compression; EBRT = external-beam radiation therapy; ESCC = epidural spinal cord compression; IONM = intraoperative neurophysiological monitoring; LOS = length of hospital stay; NSE = Neurology-Stability-Epidural compression; SBRT = stereotactic body radiation therapy; SINS = Spine Instability Neoplastic Score; SRS = stereotactic radiosurgery.

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Surgery for spinal metastases has undergone multiple transformations in terms of surgical technique. Given the advancements in stereotactic body radiation therapy (SBRT) and targeted therapies, the need for a more aggressive surgical strategy for local disease control has resulted in the incorporation of many different technological adjuncts.[1–10] Separation surgery has become one of the cornerstones in the treatment of spinal metastases.[11] For instance, a separation between the dural sac and the tumor of at least 2–3 mm is needed to avoid spinal cord damage before planning SBRT.[3,5,12,13] Furthermore, the advantage of a ventral decompression in selected cases has been demonstrated by previous studies: circumferential decompression of the dural sac has been shown to be associated with better neurological outcomes in terms of functional preservation or restoration both immediately after surgery and at follow-up, especially in classically radioresistant malignancies after external-beam radiation therapy (EBRT).[2,14,15] Spinal metastases most commonly originate from the vertebral body, and the dural sac typically has only a few millimeters of mobility. Therefore, a more aggressive decompressive approach targeting the ventral aspect of the sac is often justified, particularly in cases involving radioresistant tumors or unknown histologies. The transpedicular approach offers a safe and effective method to access the ventral dural sac and achieve circumferential decompression. Compared with costotransversectomy or anterior lumbar approaches, it carries a lower risk profile while providing reliable outcomes.[14–17]

This study is based on a large, multicenter institutional cohort in which the transpedicular approach was adopted for spinal malignancies and the clinical and radiological outcomes were evaluated. The primary aim was to assess the safety and effectiveness of this approach in achieving 360° spinal cord decompression.

Methods

In this multicentric retrospective observational study, the medical records of patients who underwent circumferential decompression of the dural sac for spinal metastases at the authors' institutions between January 2018 and June 2023 were analyzed. The study's primary objective was to evaluate the safety and effectiveness of circumferential decompression via a bilateral transpedicular approach, particularly in achieving adequate separation for subsequent SBRT or stereotactic radiosurgery (SRS) or aggressive cytoreduction. The study outcomes included complications (intra- and postoperative blood loss, CSF leaks, wound dehiscence, and wound infection) and clinical results (length of hospital stay [LOS] and postoperative pain control).

Data were prospectively collected and included demographic and clinical variables such as age, sex, primary tumor histology, the number and timing of spinal metastases, the affected vertebral levels, and pre- and postoperative neurological status based on the American Spinal Injury Association Impairment Scale. Mechanical instability was assessed using the Spine Instability Neoplastic Score (SINS), while the degree of epidural compression was evaluated using the epidural spinal cord compression (ESCC) scale. The Neurology-Stability-Epidural compression (NSE) score[18,19] and the NOMS (neurologic, oncologic, mechanical, systemic) framework[20] were applied to determine the need for surgery. The study also documented the type and extent of surgical decompression, the fixation techniques used, and neurological outcomes at the final follow-up. Neurological assessments were conducted by two neurosurgeons experienced in spinal oncology.

Inclusion and Exclusion Criteria

Inclusion criteria for the study were as follows: adult patients with spinal metastases from solid or hematological tumors causing ventral or circumferential compression of the dural sac, treated with the transpedicular approach for circumferential decompression; the presence of motor deficits in at least one limb (strength reduction with consequent significant standing or ambulating impairment was considered a motor deficit); and a minimum follow-up of 3 months, including complete clinical and radiological documentation.

Exclusion criteria included preexisting neurological conditions or other vertebral fractures that could independently affect neurological assessments; postsurgical, radiation, or systemic treatment complications that could impair the postoperative neurological evaluation; and the presence of additional skeletal metastases or vertebral bone metastases with epidural compression that could influence neurological outcomes.

Surgical Techniques and Radiological Evaluation

In this study, the extent of spinal cord compression was classified using the ESCC scale based on the anatomical location of the compression and the affected vertebral segments. The site of compression was further categorized into anterior spinal cord compression (ASCC), anterolateral spinal cord compression (Al-SCC), and circumferential spinal cord compression (CSCC). To achieve effective ventral decompression, circumferential decompression was consistently performed using a bilateral transpedicular approach. This technique, as described in previous studies, ensures adequate separation of the dural sac from the tumor, creating at least a 2- to 3-mm gap required for the safe application of SBRT or allowing a proper cytoreduction for proper neurological restoration.[21,22]

For ventral decompression in the thoracolumbar spine, the bilateral transpedicular approach was favored because it allows safe access to the ventral aspect of the dural sac while avoiding the increased risks associated with more invasive procedures like costotransversectomy or anterior lumbar approaches. Fixation was performed with titanium or carbon fiber screws, considering the extent of mechanical instability determined by the SINS. In cases requiring anterior reconstruction, PEEK or carbon fiber cages, titanium plates, and/or autologous bone were used.

After screw placement, bilateral laminectomy and facetectomy were performed, extending across the affected vertebrae and adjacent levels up to the pedicles above and below the lesion. The laminectomy aimed to "eggshell" the lamina using a high-speed drill, minimizing pressure from Kerrison rongeurs on the compressed spinal cord. A

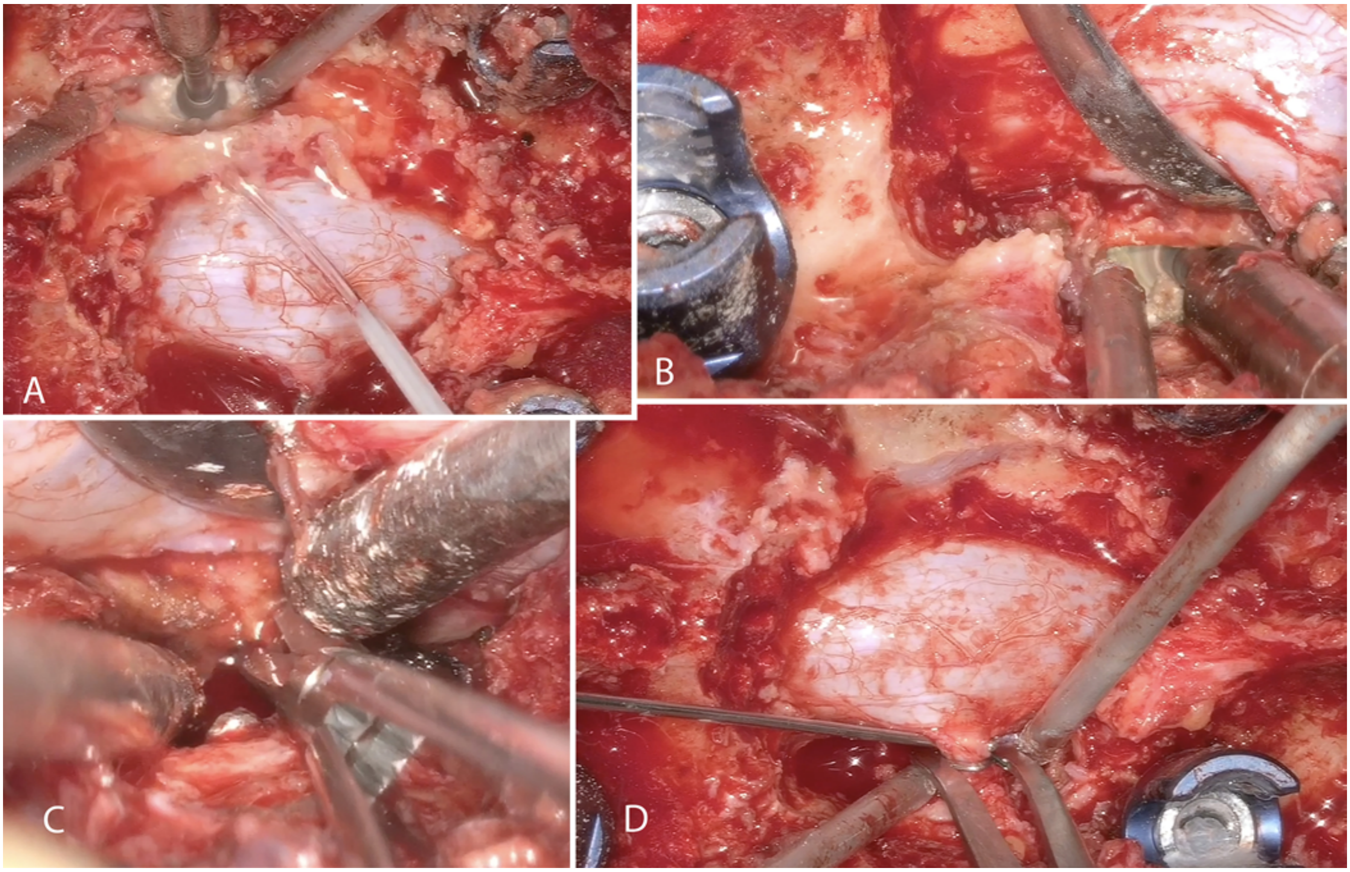

FIG. 1. Exoscopic view of the transpedicular approach for separation surgery. **A and B:** Pedicle drilling with initial preservation of the medial cortical wall. **C:** Ligation of the nerve root. **D:** Cutting of the posterior longitudinal ligament.

unilateral or bilateral pediculectomy was then completed by inner dry drilling of the pedicle until the vertebral body was reached (Fig. 1). The medial wall of the pedicle was preserved as a last protective barrier for the dura mater and then removed, while hemostasis was achieved through meticulous inner dry drilling to ensure safe pediculectomy. In thoracic locations, nerve roots were first ligated and then, in the absence of intraoperative neurophysiological monitoring (IONM) signal reduction after about 15 minutes, cut for better visualization of the corridor to the body. Once the posterior vertebral body was reached and the epidural neoplastic component was exposed, tumor removal was performed by debulking the lesion in the epidural space and the vertebral body (Fig. 2). The tumor was carefully detached from the dura, and the posterior longitudinal ligament was cut for a complete decompressive release. Once 360° decompression and sufficient separation of the tumor from the dura were achieved, further tumor removal was ceased (Fig. 3).

IONM was utilized in all surgeries to minimize neurological risks. Additionally, advanced imaging and navigational tools, including intraoperative ultrasound, CT-guided navigation, and either endoscopy or exoscopy, were used to enhance the precision and safety of decompression, ensuring proper tumor debulking and intraoperative assessment of decompression outcomes.

Postoperative Evaluation

Neurological outcomes were evaluated at discharge and during follow-up visits using the modified Medical Research Council scale for muscle strength. Neurological improvement was defined as an increase of at least 1 point in motor strength in one or more limbs, whereas neurological deterioration was recorded as a decrease of at least 1 point. Pain control and quality of life were assessed during each follow-up visit.

Statistical Analysis

Descriptive statistics, including mean, median, and standard deviation, are used to summarize continuous variables. Categorical data were analyzed using chi-square tests. For instances with low cell counts, associations were assessed using Cramer's phi and V. To examine relationships between key variables, such as surgical outcomes and complication rates, univariate and multivariate logistic regression analyses were performed. A p value ≤ 0.05 was considered statistically significant. All statistical analyses were conducted using IBM SPSS Statistics for Windows version 24.0 (IBM Corp.).

Results

A total of 215 patients (70.2% male, 29.8% female)

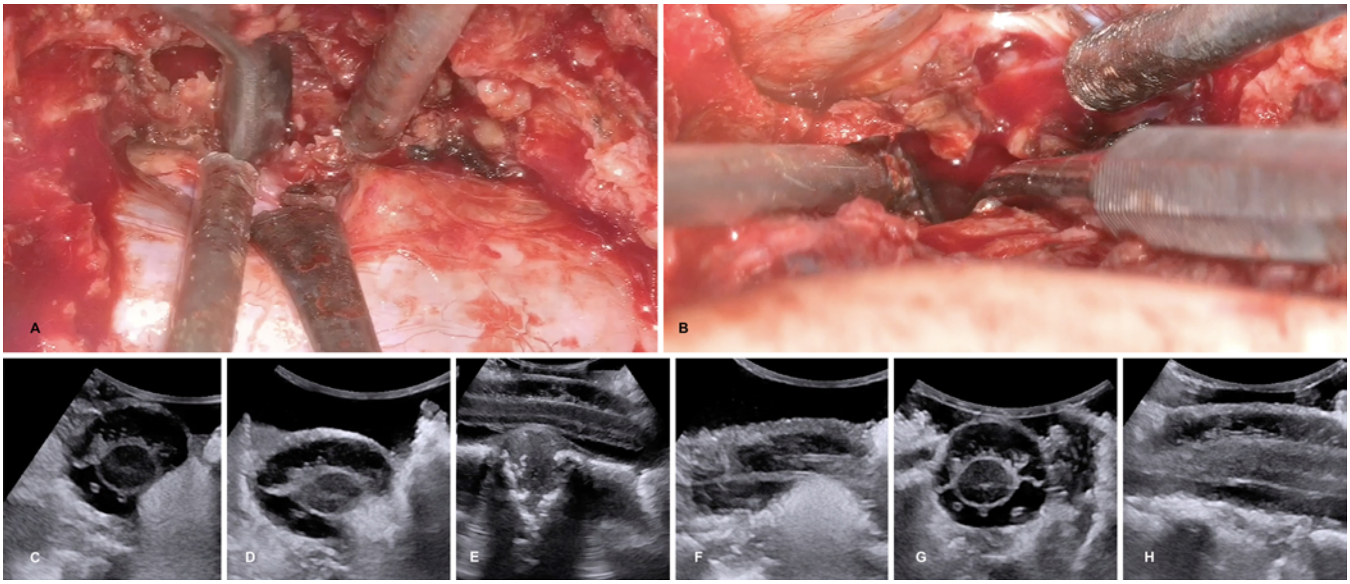

FIG. 2. Exoscopic view of ventral decompression and intraoperative ultrasound assessment. **A and B:** A Woodson dissector is used to separate the tumor from the dural sac and aid in safe cytoreduction. **C–F:** Intraoperative ultrasound images showing residual ventral compression during the procedure. **G and H:** Ultrasound images showing completion of the circumferential decompression.

were included in the study after applying inclusion and exclusion criteria to an initial cohort of 372 cases. The average patient age was 66.5 ± 10.8 years (median 69 years), with a mean follow-up of 19.2 months. The mean LOS was 4 days, and the median day of mobilization was the 2nd postoperative day. Detailed summary statistics are presented in Table 1.

CSCC was the most common presentation, occurring in 93 patients (43.3%), followed by ASCC in 71 patients (33.0%) and Al-SCC in 51 patients (23.7%). Circumferential decompressions were performed in all cases. Specifically, single-level decompression was carried out in 147 cases (68.4%), two contiguous levels were treated in 53 cases (24.7%), and decompression of two or more noncontiguous levels was performed in 15 cases (7.0%). Fixation was completed in all patients, while body replacement was necessary in 26 cases (12.1%). A bilateral approach was used for 122 patients (56.7%), while a unilateral approach was utilized in 97 patients (45.1%).

All 215 patients presented with preoperative neurological deficits. At discharge, neurological improvements were observed in 164 patients (76.3%), neurological stability in 49 patients (22.8%), and deterioration in 2 patients (0.9%) (Table 2). At an average follow-up of 19.2 months, 61 patients (28.4%) experienced worsening neurological status, with the majority of the deterioration occurring between 3 and 6 months postsurgery (20.5%) and between 6 and 12 months postsurgery (18.1%), mainly because of tumor progression (93.4%, 57 patients). In the other 4 cases, the deterioration was caused by hardware failure for mechanical or infectious reasons.

Preoperatively, all patients reported mechanical pain. At discharge, pain improvement was noted in 181 patients (84.2%), stability in 28 patients (13.0%), and worsening in 6 patients (2.8%) (Table 2). At the mean follow-up of 19.2 months, 75 patients (34.9%) reported worsening mechanical pain, most of which occurred between 6 and 12 months postsurgery (27.4%) and between 3 and 6 months postsurgery (12.6%), mainly because of other lesions, screw loosening, or body fracture with kyphosis after treatment.

A significant association was found between immediate postoperative neurological improvement and long-term outcomes (Table 3). Among patients with postoperative neurological improvement, 168 (78.1%) did not experience further deterioration, while 31 (14.4%) of those without initial improvement showed worsening at follow-up ($p = 0.004$). Univariate logistic regression analysis indicated that immediate postoperative improvement significantly reduced the likelihood of deterioration at the last follow-up [Nagelkerke $R^2 = 0.135$, Exp(B) = 0.208; $p = 0.004$].

Walking ability also showed notable improvement. Among patients with preoperative walking impairments, 27 (71.1%) regained the ability to walk after surgery ($p = 0.001$). Multivariate logistic regression analysis identified preoperative ambulation ability as the sole significant predictor of postoperative walking ability [Nagelkerke = 0.459, Exp(B) = 39.34; $p = 0.001$]. Similarly, postoperative ambulation status was the only significant factor predicting walking ability at follow-up [Nagelkerke = 0.573, Exp(B) = 74.29; $p = 0.001$].

Finally, complications were analyzed (Table 4). Intraoperative dural tears occurred in 7 cases (3.3%). However, postoperative CSF leaks developed in only 6 patients (2.8%), with the majority managed with bed rest, while 2 patients (0.9%) required revision surgery.

Wound dehiscence following radiation therapy was observed in 9 patients (4.2%) at a mean interval of 2.8 months. Postoperative wound infections occurred in 4 patients (1.9%); all were managed with advanced wound care performed by plastic surgeons, with only 3 patients (1.4%)

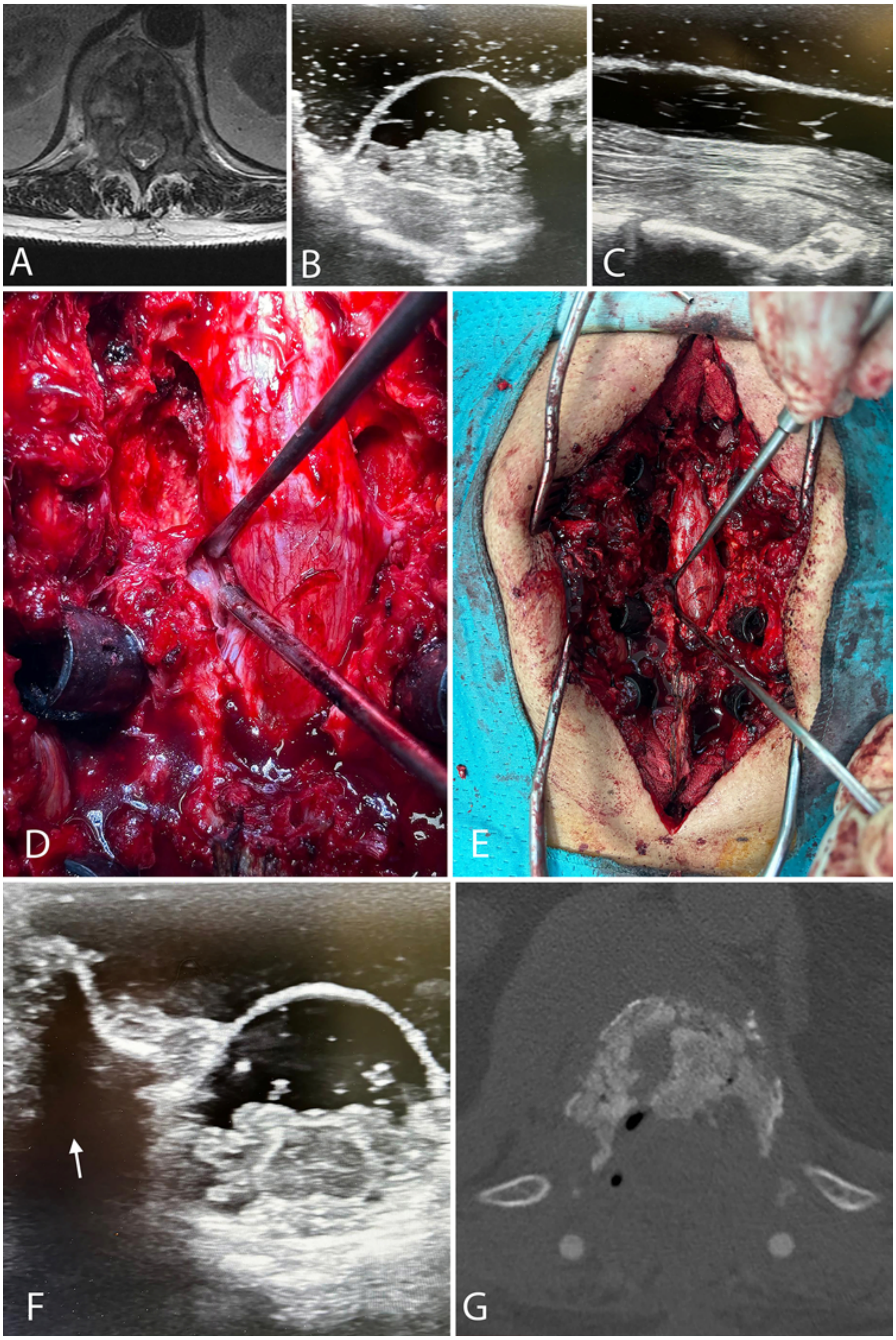

FIG. 3. Images and intraoperative photographs obtained in the case of a 56-year-old man with renal cell carcinoma complaining of mechanical axial pain and thigh numbness. **A:** MR image showing a T12 mixed lesion with vertebral body partial collapse and Bilsky grade 2 ESCC. Instability (SINS of 9, NSE score of 7) and the need for surgery were assessed. **B and C:** Intraoperative coronal (B) and sagittal (C) ultrasound images showing tumor compression on the ventral aspect of the cord. **D and E:** Intraoperative photographs showing the effective 360° decompression, achievable from a posterior approach through the transpedicular bilateral approach. **F:** Intraoperative ultrasound image showing tumoral decompression, safe CSF margins for further radiotherapy, and the transpedicular route (*arrow*). **G:** Postoperative CT scan revealing the entity of decompression on the ventral site.

TABLE 1. Patient demographics and clinical data

	Value
Patient characteristics	
Total patients	215 (100.0)
Sex	
Male	151 (70.2)
Female	64 (29.8)
Age, yrs	
Mean	66.5 ± 10.8
Median	69
Mean follow-up, mos	19.2
Mean LOS, days	4
Median day of mobilization	2
Presentation	
CSCC	93 (43.3)
ASCC	71 (33.0)
AI-SCC	51 (23.7)
ASA score	
1	2 (0.9)
2	115 (53.5)
3	98 (45.6)
ECOG PS	
0	28 (13.0)
1	81 (37.7)
2	106 (49.3)
Involved level	
Cervical	28 (13.0)
Cervicothoracic	11 (5.1)
Thoracic	107 (49.8)
Thoracolumbar	32 (14.9)
Lumbosacral	37 (17.2)
Histology	
Lung NSCLC	57 (26.5)
Thyroid	4 (1.9)
Breast	32 (14.9)
Melanoma	2 (0.9)
Prostate	38 (17.7)
HCC	6 (2.8)
Myeloma	23 (10.7)
Lymphoma	6 (2.8)
Colorectal	11 (5.1)
Lung SCLC	6 (2.8)
Renal cell	11 (5.1)
Pancreas	2 (0.9)
Other	17 (7.9)
SINS	
Stable	64 (29.8)
Potentially unstable	123 (57.2)
Unstable	28 (13.0)
ESCC grade	
Low grade	103 (47.9)
High grade	112 (52.1)
Surgical treatment	
Circumferential decompression	215 (100.0)
Single-level decompression	147 (68.4)
2 contiguous levels	53 (24.7)
≥2 noncontiguous levels	15 (7.0)
Fixation performed	215 (100.0)
Body replacement required	26 (12.1)
Bilat transpedicular approach	122 (56.7)
Unilat transpedicular approach	97 (45.1)

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ASA = American Society of Anesthesiologists; ECOG PS = Eastern Cooperative Oncology Group Performance Status; HCC = hepatocellular carcinoma; NSCLC = non-SCLC; SCLC = small cell lung cancer.
Values are given as number of patients (%) unless otherwise indicated.

requiring revision surgery. Neurological worsening after surgery was observed in 2 patients (0.9%). The total rate of complications was 9.8%. Finally, blood transfusions were necessary in 34 patients (15.8%), and the need for transfusion was significantly associated with high ESCC grades and multilevel surgeries ($p = 0.001$).

Discussion

The concept of separation surgery has significantly

TABLE 2. Neurological and mechanical pain outcomes

Outcome	No. of Patients (%)
Neurological status	
Preop neurological deficits	215 (100)
Neurological status at discharge	
Improvement	164 (76.3)
Stability	49 (22.8)
Deterioration	2 (0.9)
Neurological status at follow-up	
Worsened status	61 (28.4)
Deterioration btwn 3 & 6 mos	44 (20.5)
Deterioration btwn 6 & 12 mos	39 (18.1)
Mechanical pain	
Preop mechanical pain	215 (100)
Mechanical pain at discharge	
Improvement	181 (84.2)
Stability	28 (13.0)
Worsening	6 (2.8)
Mechanical pain at follow-up	
Worsened pain	75 (34.9)
Deterioration btwn 3 & 6 mos	27 (12.6)
Deterioration btwn 6 & 12 mos	59 (27.4)

TABLE 3. Associations and predictive factors for neurological and walking ability

	Value*	Nagelkerke R^2	Exp(B)	p Value
Immediate postop neurological improvement				
No long-term deterioration	168 (78.1)			0.004
Long-term deterioration (no improvement)	31 (14.4)			
Univariate logistic regression				
Likelihood of deterioration reduced		0.135	0.208	0.004
Preop walking impairment				
Walking ability at discharge				
Regained walking ability	27 (71.1)			0.001
No change	11 (28.9)			
Walking ability at follow-up				
Maintained walking ability	25 (92.6)			0.002
Deterioration	2 (7.4)			
Multivariate logistic regression				
Preop walking ability		0.459	39.34	0.001
Postop ambulation status		0.573	74.29	0.001

* Values are given as number of patients (%).

changed the management of vertebral metastases with ESCC.[11] This technique emphasizes decompression of the spinal cord by creating space between the tumor and neural structures, enabling the safe delivery of high-dose postoperative SBRT. Unlike traditional aggressive tumor resections, separation surgery focuses on preserving spinal stability and minimizing surgical morbidity while optimizing radiation therapy outcomes. Recent experiences indicate that this approach significantly reduces the risk of local progression, with 1-year local control rates exceeding 90% when combined with high-dose SBRT protocols.[23] Separation surgery is particularly beneficial for patients with high-grade metastatic ESCC of radioresistant tumors, where conventional EBRT often fails. Reconstituting the CSF space and decompressing the thecal sac ensures that radiation doses can be precisely delivered to residual tumor tissue without exceeding spinal cord dose tolerances. Outcomes from well-recognized institutions show that this hybrid therapy enhances both local control and quality of life, with fewer surgery-related complications and durable tumor control across diverse tumor histologies.[24] These advancements illustrate how separation surgery, in conjunction with modern radiation techniques, has redefined palliative care in spinal oncology.[3]

Furthermore, the transpedicular approach allows a feasible and safe way to reach the vertebral body and decompress the ventral aspect of the dural sac. Considering the still poor availability of SRS and the difficulty of EBRT to overcome tumor radioresistance, the transpedicular approach may represent a valuable option to obtain large ventral decompression and aggressive cytoreduction. Furthermore, it enhances the chances of functional preservation with low rates of complication, as demonstrated by previous experiences.[15] We reviewed the medical records of 215 patients from institutional databases to evaluate their neurological outcomes and complication rates and ultimately found improved long-term neurological function and tumor control rates and low complication rates.

Feasibility and Safety of the Transpedicular Approach

The transpedicular approach has proven to be a reliable and effective method for separation surgery in spinal metastasis.[21] The findings of this study confirm that this technique allows consistent tumor separation from the spinal cord, achieving a satisfactory circumferential decompression. Unlike traditional laminectomy, which targets only posterior decompression thus facilitating dural shifting, the transpedicular route ensures comprehensive ventral and circumferential access, for a more physiological dural reconstitution.[12]

Advancements in surgical technology have further enhanced the feasibility and precision of this approach.[25] Three-dimensional exoscopy, intraoperative ultrasound, or endoscopic visualization may improve anatomical clarity during ventral decompression, while IONM safeguards spinal cord function during tumor resection.[14,19,26–28]

TABLE 4. Postoperative complications

Complication	No. of Patients (%)
Total	21 (9.8)
Intraop dural tears	7 (3.3)
Postop CSF leaks	6 (2.8)
Managed w/ bed rest	4 (66.7)
Required revision surgery	2 (0.9)
Wound dehiscence after radiation therapy	9 (4.2)
Mean interval to dehiscence, mos	2.8
Postop wound infections	4 (1.9)
Managed w/ advanced wound care	4 (100)
Required revision surgery	3 (1.4)
Neurological worsening	2 (0.9)
Blood transfusions*	34 (15.8)

* Associated with high ESCC grades and multilevel surgeries (p = 0.001).

Among their benefits, these tools contribute to the low complication rates observed in our cohort. For instance, clearer intraoperative visualization sensibly reduces the risks of CSF leaks (3.2%), as previously shown.[13] The minimally invasive nature of the transpedicular approach also reduces operative time, blood loss, and LOSs compared with more invasive techniques like costotransversectomy or anterior lumbar approaches.[16] For instance, a quicker functional recovery represents a critical outcome in the setting of metastatic spinal disease treatment.

Improved Local Disease Control Through Ventral Decompression

Ventral decompression is a cornerstone of local disease management in metastatic spinal surgery, as most tumors originate in the vertebral body, causing ventral spinal cord compression.[29] Thus, circumferential decompression is essential to achieve a tumor-free margin around the spinal cord, a prerequisite for SBRT.[13] This approach aligns with the aforementioned goals of separation surgery, which prioritize creating a space of at least 2–3 mm between the tumor and the spinal cord. For this reason, dorsal decompression alone is often inadequate since it does not reconstitute the dural sac, and its decompressive power is limited to the few millimeters of shifting capability of the spinal cord, especially in thoracic locations. Therefore, posterior decompression hinders SBRT treatment when needed or achieves poor local control after ERBT in radioresistant tumors. The transpedicular approach provides direct access to the ventral tumor, enabling the needed 360° decompression in case of circumferential decompression and contributing to optimizing conditions for postoperative treatments, particularly for radioresistant tumors.[13,14,16]

Finally, advancements in spinal implants, with the routine use of carbon fiber instrumentation, ensure the mechanical durability of this strategy, showing a noninferior profile if compared with titanium[22] but reducing imaging artifacts, facilitating accurate monitoring of local disease control and radiosurgical planning.[22] By integrating such innovations, the transpedicular approach has evolved into a comprehensive strategy for managing complex spinal metastases.

It is currently unknown if the degree of separation could correlate with neurological outcomes. This is due to difficulties in estimating separation over the mandatory reconstitution of the thecal sac and CSF signal using intraoperative tools such as ultrasound or postoperative evaluation with MRI or CT myelography. One should consider artifacts of the tumor itself and surgery, the subjective evaluation of the hyperechoic signal of ultrasound, the sustainability of immediate postoperative MRI or CT myelography evaluation, different patterns of metastatic lesions, and oncological variables. Given that SBRT treatment has already proven to be volume independent, from this point of view, a few millimeters of separation proved to be enough for durable local control.[9] On the other hand, if one wants to correlate quality and extension of debulking with better neurological control, a more aggressive tumor removal could likely positively impact neurological outcomes of patients with radioresistant tumors that are not selected for SBRT and undergo EBRT after surgery. A few years ago, the main authors of this group published a study showing the importance of circumferential decompression, or rather of decompressing the sac by directly removing the source of compression, for improvement of postoperative neurological follow-up regardless of treatment after surgery.[14]

Complication Rates and Patient Outcomes

The safety of the transpedicular approach is further underscored by its low complication rates, making it an attractive option for managing metastatic spinal disease. In our study, 78.1% of patients demonstrated no neurological deterioration during the follow-up period. This rate compares favorably with more invasive techniques, which carry higher risks of complications, such as hardware failure, wound dehiscence, and prolonged recovery times.[15,30]

Infections are a significant concern in spinal surgery, particularly in immunocompromised cancer patients. The low incidence of postoperative infections observed in our cohort underscores the efficacy of the meticulous surgical technique and perioperative management, together with the acceptable surgical duration of the procedures. The transpedicular approach also minimizes risks associated with anterior or posterolateral approaches, such as vascular injury, retroperitoneal visceral damage, or pleural invasion with the necessity for thoracic drain placement. Its minimally invasive nature, combined with targeted ventral decompression, allows for shorter operative times and reduced intraoperative morbidity, which is essential for the multidisciplinary strategy.

Postoperative pain management is another critical factor influencing patient outcomes. The transpedicular approach, by avoiding extensive muscle dissection, results in lower rates of postoperative pain and faster mobilization. This aligns with the principles of Enhanced Recovery After Surgery, which emphasize early rehabilitation to improve overall patient outcomes.[31]

Interestingly, 15.8% of the cohort required a blood transfusion. This rate is slightly above the median blood transfusion rate described in the literature.[32] Given this, the majority of patients who needed transfusion were treated for more than one affected vertebra (73% with two or more decompressed vertebrae) and underwent surgery with low preoperative levels of hemoglobin due to their neoplastic conditions. However, despite this increased risk, use of the thrombin matrix, the dry-drilling technique, and the step-by-step bilateral transpedicular approach with accurate and gradual hemostasis allowed for intraoperative bleeding control.

Additionally, long-term studies are warranted to evaluate the durability of local disease control and the impact of circumferential decompression on overall survival. Investigating patient-reported outcomes, such as quality of life and functional independence, will provide a holistic understanding of the benefits of this approach.

Integration With SBRT and Multimodal Therapy

The synergy between surgical decompression and high-dose radiation therapy has revolutionized the treatment paradigm for spinal metastases, offering durable local control with minimal toxicity.[23,24,33] The transpedicular approach provides this separation and creates a favorable anatomical environment for delivering radiation. This is particularly beneficial for patients with radioresistant tumors, where precise targeting of high-dose radiation is essential to achieve local control.[23,24] Additionally, circumferential decompression reduces the risk of spinal cord edema and subsequent radiation-induced complications, further enhancing treatment safety.[33]

Achieving a stable and tumor-free separation zone is critical for the success of SBRT.[2,23,33,34] The transpedicular approach has demonstrated promising outcomes and can be regarded as a significant advancement within the expansive field of metastatic spinal disease. Furthermore, the role of systemic therapies, such as targeted agents and immunotherapy, is also expanding in the management of these pathologies while improving survival.[2] Thus, the chance of catching a proper and winning window of opportunity to treat spinal lesions is crucial. Future studies may explore the potential of combining transpedicular decompression with emerging therapies to optimize outcomes for patients with complex disease presentations.

Limitations

This study has several limitations. First, given the retrospective nature of the study, a selection bias might affect the obtained results. Moreover, the included patients were from only two spine centers, limiting the generalizability of the obtained results, especially concerning surgical outcomes. Finally, the strict inclusion criteria, such as the exclusion of patients with additional skeletal metastases or significant comorbidities, may reduce the applicability of the findings to the broader population of patients with spinal metastases. Further larger, prospective studies are surely warranted.

Conclusions

The transpedicular approach represents a safe, effective, and minimally invasive option for circumferential decompression in metastatic ESCC. The achievement of effective tumor separation facilitates high-dose SBRT and SRS, while more aggressive ventral decompression can provide better functional control regardless of subsequent treatment. Its low complication rates and favorable safety profile highlight its clinical value, making it a crucial tool in a spine surgeon's armamentarium. Prospective studies involving larger patient populations are needed to validate these findings and to establish standardized protocols for circumferential decompression according to histomolecular profiles.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Leone, Di Perna, Ajello, Colamaria, Tartara, Spetzger, Garbossa, Cofano. Acquisition of data: Di Perna. Analysis and interpretation of data: Leone, Garbossa. Drafting the article: Leone, Carbone, Cofano. Critically revising the article: Leone, Di Perna, Ajello, Colamaria, Carbone, Tartara, Spetzger, Garbossa, Cofano. Reviewed submitted version of manuscript: Leone, Carbone, Tartara, Cofano. Approved the final version of the manuscript on behalf of all authors: Leone. Statistical analysis: Di Perna. Administrative/technical/material support: Tartara. Study supervision: Di Perna, Ajello, Colamaria, Marengo, Garbossa, Cofano.

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