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Minimally Invasive Surgery Treatment for Thoracic Spine Tumor Removal

A Mini-Open, Lateral Approach

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Study Design. Prospective registry.

Objective. The objective of this study is to examine procedural and long-term outcomes of a mini-open, lateral approach for tumor removal in the thoracic spine.

Summary of Background Data. The majority of spinal tumors present as metastatic tumors in the thoracic spine. Conventional surgical treatments have been associated with high rates of approach-related morbidities as well as difficult working windows for complete tumor excision. Recent advances in minimally invasive techniques, particularly mini-open (minimally invasive, not endoscopic) approaches, help to reduce the morbidities of conventional procedures with comparable outcomes.

Methods. Twenty-one consecutively treated patients at 2 institutions were treated between 2007 and 2009. Treatment variables, including operating time, estimated blood loss, length of hospital stay, and complications were collected, as were outcome measures, including the visual analog scale for pain and the Oswestry disability index.

Results. Twenty-one patients with thoracic spinal tumors were successfully treated with a minimally invasive lateral approach. Operating time, estimated blood loss, and length of hospital stay were 117 minutes, 291 mL, and 2.9 days, respectively. One (4.8%) perioperative complication occurred (pneumonia). Mean follow-up was 21 months. Two patients had residual tumor at last follow-up. Two patients died during the study as the result of other metastases (spine tumor was secondary). Visual analog scale improved from 7.7 to 2.9 and Oswestry disability index improved from 52.7% to 24.9% from preoperative to the last follow-up.

Conclusion. The mini-open lateral approach described here can be performed safely and without many of the morbidities and difficulties associated with conventional and endoscopic procedures. Proper training in minimally invasive techniques and the use of direct-visualization minimally invasive retractors are required to safely and reproducibly treat these complex indications.

Key words: extreme lateral interbody fusion, lateral, tumor, minimally invasive, transthoracic, retropleural, metastatic, outcomes. **Spine 2010;35:S347–S354**

Traditional anterior and posterior approaches for the surgical treatment of the thoracic spine are associated with significant morbidity. To address these issues, minimally invasive approaches have been developed. One role has been for treatment of spinal tumors. Whether malignant or benign, one of the key factors is to improve the quality of life, and by decreasing the morbidity associated with the surgery itself, this goal may be more likely achieved.

Spinal tumors are classified as extradural, intradural-extramedullary, or intramedullary. Intradural-extramedullary tumors comprise approximately two-thirds of all primary spinal tumors. These are generally benign in nature, but can cause symptoms by compression of neural elements. On the other hand, intramedullary tumors are rare.[1] Tumors can also be categorized as primary or secondary (metastatic). Metastatic tumors most commonly affect the thoracic spine (70%), followed by lumbar (20%), then cervical (10%). Primary osseous tumors of the spine are uncommon in comparison to metastatic disease. They can be classified as benign or malignant.

The most common symptom is pain. Patients will often present with complaints of progressive back and/or radicular pain. Compression of the neural elements may lead to weakness, which, if left unaddressed, could lead to frank paralysis. Treatment options vary based on complete or incomplete deficits.

Treatment for primary or metastatic tumors to the spine includes radiation, radiation plus chemotherapy, stereotactic radiosurgery, hormonal therapy, or surgical decompression followed by radiation. Radiation alone and chemotherapy are options for patients with newly diagnosed disease without neurologic deficit, no evidence of instability, and are relatively asymptomatic; this is especially true for radiosensitive tumors. When surgery is indicated, the goals should include, but are not limited to, palliation, providing stabilization, preventing spinal cord compression, pain control, definitive diagnosis, improvement of the quality of life, and arthrodesis. Factors to consider when planning surgery include the histologic type of tumor and its location(s) within the spine, cord compression, portion of vertebrae involved, anticipated mode of spinal instability, type of prior or subsequent adjuvant treatment, and anticipated life expectancy of the patient.[2–4]

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The surgical treatment of thoracic tumors ranges from percutaneous vertebroplasty to anterior- and posterior-based open procedures.[5,6] Anterior-based approaches, such as traditional open thoracotomies, are effective in the treatment of the thoracic spine; however, they are associated with significant access morbidity.[7–11] Pain, prolonged chest drainage, pulmonary complications, and extended hospital stays are issues to be further considered after surgery. A lateral retropleural approach aims to be less destructive to the surrounding tissues by not compromising the pleura. To mitigate some of the morbidity associated with open procedures, minimally invasive thoracoscopic methods were developed and have proven to be effective, but challenging in terms of learning curve and application.[7–10,12]

Open, posterior-based approaches are better suited for lesions that involve the posterior elements or an extension into the anterior column.[2] Either the transpedicular or costotransversectomy approach allows for resection of the posterior elements, epidural tumor, and the involved vertebral bodies.[13,14] These approaches may be preferential for patients with significant medical comorbidities, multilevel disease, or involvement of upper thoracic lesions.[15] The lateral extracavitary approach is similar, but the access portal is more lateral with respect to the paravertebral musculature.

It is evident that there have been many advances in the treatment of pathology located in the thoracic spine. Minimally invasive techniques offer an alternative to traditional, open approaches. In this study, we describe our experience with the mini-open lateral approach for the removal of thoracic tumors.

Materials and Methods

A retrospective review of a prospectively maintained spine tumor database was performed of all consecutive patients who underwent a minimally invasive lateral approach for treatment of a thoracic tumor at 2 institutions between 2007 and 2009. All surgeries were performed by the 2 senior authors (J.S.U. and W.D.S.). The operative side and approach, either transthoracic or retropleural, was dictated by the location of the pathology and the surgeon's preference. Demographic variables such as sex, age, comorbidities, tumor pathology, and presenting symptoms were documented. All patient data were recorded including preoperative evaluation, operative procedure, postoperative follow-up, operative time, blood loss, length of hospital stay, and complications. Clinical outcome scores were also administered, measuring pain and function, before and after the surgery, using the visual analog scale (VAS) and Oswestry disability index (ODI). All patients were scheduled for routine follow-up at 2 weeks, 6 weeks, 3 months, 6 months, 12 months, and 24 months after surgery.

Surgical Approach

All patients were placed and secured in a true lateral position on a radiolucent table. Under fluoroscopic guidance, the index level and pathology were located and marked on the skin. In all cases, the side of the approach was chosen according to the vertebral level and the location of the abnormality. If a transthoracic approach was selected, then a 3- to 4-cm oblique incision was made parallel to and between the ribs. The intercostal muscles and parietal pleura were then incised as well to enter the thoracic cavity. If a larger exposure was required, then a portion of the rib was resected. When a retropleural approach was selected, a 6-cm long oblique incision (following the trajectory of the rib at the index level) was made at the midaxillary line. Approximately 5 cm of the rib immediately overlying the target level was dissected subperiosteally from the underlying pleura and neurovascular bundle and removed. The portion of resected rib was set aside for use as autograft in the setting of arthrodesis. Once the parietal pleura was exposed, the plane between the endothoracic fascia and the pleura was developed. The pleura was then mobilized anteriorly until the lateral side of the vertebral body, pedicle, and adjacent discs were exposed. During a left-side approach, the aorta and hemiazygos vein were also retracted anteriorly. An expandable retractor system (MaXcess®, NuVasive®, San Diego, CA) was then inserted and secured with a flexible table-mounted arm assembly. Once the retractor was placed and adequate exposure was obtained, the goals of the operation were performed using standard surgical techniques. A combination of high-speed drills, curettes, rongeurs, and osteotomes were used for bony removal. Through this approach the tumors were resected, the neural elements were decompressed, and the spine was stabilized when necessary.

In the event of a corpectomy, ventral reconstruction was performed using expandable titanium cages and bone autograft (rib). Spinal instrumentation was completed by ventrolateral plate/screw fixation (Traverse®, NuVasive, Inc) through the expandable retractor, and/or percutaneous posterior pedicle screw/rod fixation (SpheRx® DBR®, NuVasive, Inc). In instances where the dura was opened for resection of the tumor, it was repaired in a primary fashion with a running 5–0 stitch. Fibrin glue was then applied to the dural incision for reinforcement and a lumbar drain was placed.

In the event of a pleural violation or transthoracic approach, a red rubber catheter may be used to remove all air from the thoracic cavity as long as the visceral pleura has not been violated. The red rubber catheter is placed in the pleural space, out through the wound and into a water filled container with the end submerged under water. The wound is closed in the standard fashion including all the layers of muscle and fascia. A purse string stitch is placed around the red rubber catheter. A valsalva is performed, end inspiratory hold, until no more air bubbles are seen coming from the red rubber end under water. This signifies that all the air has been removed from the thoracic cavity. The red rubber catheter is removed as the purse string stitch is tied. This obviated the need for a chest tube.

Results

Between 2007 and 2009, 21 consecutive patients (14 males, 7 females) were identified who underwent a minimally invasive lateral approach to the thoracic spine for tumor removal. Sixteen patients underwent a left-sided approach, while 5 were from the right. The mean age was 57 years with a range of 30 to 80 years. The indications for surgery included pain, instability, spinal cord compression, and neurologic deficit. All patients successfully underwent a minimally invasive lateral approach without conversion to an open procedure. The mean operative time was 117 minutes. The mean total blood loss was 291 mL and ranged from 25 to 1650 mL. The average length of stay in the hospital was 2.9 days. Mean follow-up was 21 months

Table 1. Demographic Characteristics

Characteristic	No. Patients	(%)
Mean age (yr)	57	
Range	(30–80)	
Sex		
Male	14	66.7%
Female	7	33.3%
Mean BMI (kg/m^2)	31.7	
Comorbidities		
Tobacco	8	38.1%
HTN	10	47.6%
CAD	7	33.3%
COPD	5	23.8%
Tumor type		
Primary		
Meningioma	6	28.6%
Neurofibroma	5	23.8%
Plasmacytoma	2	9.5%
Hemangioma	1	4.8%
Osteosarcoma	1	4.8%
Giant cell tumor	1	4.8%
Secondary (mets)		
Myeloma	2	9.5%
Lung	2	9.5%
GI	1	4.8%

Yr indicates years; BMI, body mass index; HTN, hypertension; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; mets, metastases; GI, gastrointestinal.

with a range of 6 to 24 months. Of the 21 patients, 5 presented with neurologic deficit which improved after surgery. All other patients remained neurologically stable. Resection of the thoracic tumors necessitated a range of bony removal from minimal to a complete corpectomy depending on the goals of surgery. Assessment of the degree of resection was based on tumor histology. Subtotal resection of metastatic tumors was not considered a failure of the approach. In this series, 13 patients required a corpectomy for tumor resection. The tumors resected included both primary and secondary types, histologically consisting of neurofibromas, meningiomas, osteosarcomas, and other metastases. Complete demographic and diagnosis information is included in Table 1. The number of transthoracic and retropleural approaches were 16 and 5, respectively. Resection of a portion of a rib was performed in all patients. No patient required single-lung ventilation during the procedure.

Data collected were then subjected to statistical analysis. Comparison of outcome data for each patient was performed with a paired *t* test. Outcome measures assessed include the VAS pain score and the ODI measure of disability. There was a mean improvement of 4.8 in VAS scores and 27.8% in ODI. VAS before surgery averaged 7.7 ± 1.68 and improved to 2.9 ± 1.42 at the last follow-up visit, a 62.3% improvement. ODI before surgery averaged 52.7% ± 15% and improved to 24.9% ± 14% at the last follow-up visit, representing a 52.8% improvement (Figure 1).

Perioperative complications occurred in 1 patient (4.8%) who developed pneumonia after surgery. There were no intraoperative complications noted. No postoperative pneumothoraces were identified. There were no postoperative pseudomeningoceles or cerebrospinal fluid leaks. There was no injury to the lung or vascular structures during the approach. No evidence of infections or hardware failure was identified. Two patients were noted to have residual tumor on follow-up imaging. The tumor types were multiple myeloma and meningiomas. These patients were asymptomatic and did not require any further surgical intervention. Two patients, in whom the spinal lesion was a secondary metastasis, died secondary to their primary cancer at 6 and 12 months postoperative. They both remained neurologically intact at the time of their death. Individual treatment and complication variables are included in Table 2. Two representative case examples are shown in Figures 2 to 5.

■ Discussion

Surgical approaches for disorders of the thoracic spine have traditionally included anterior- and posterior-based approaches, or a combination of them.[16–20] When indicated, the goals of surgery for the treatment of tumors are to provide pain relief, decompress the neural elements, realign, and provide stability. The affected spinal level, pathologic process, as well as surgeon's preference often determines the technique used.

Posterior-Based Approaches

The posterior approaches (lateral extracavitary, transpedicular, and costotransversectomy), first introduced by

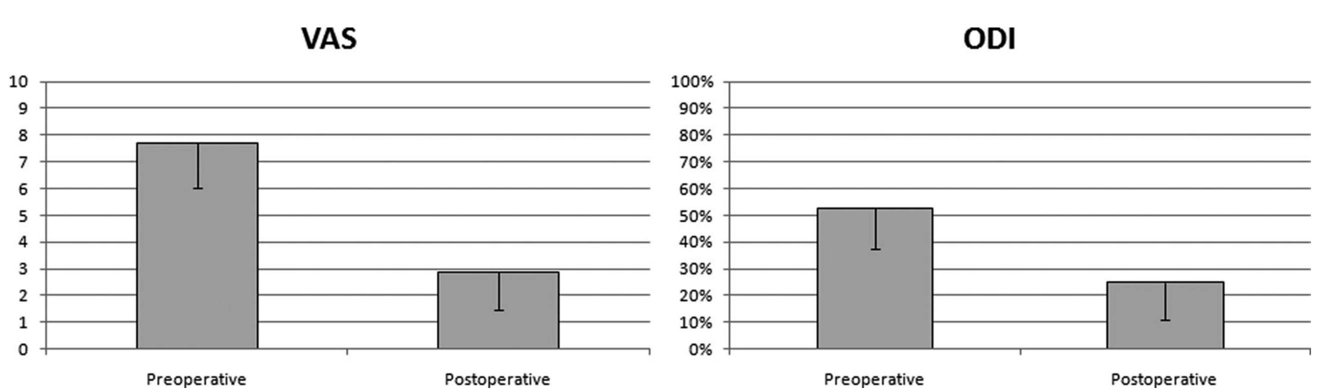

Figure 1. Outcome measures. VAS: Visual Analogue Scale, ODI: Oswestry Disability Index.

Table 2. Diagnosis and Treatment Information, per Patient

Patient Number	Age	Sex	Pathology	Procedure	Corpectomy Y/N	Instrumentation Levels	Instrumentation	Side of Approach	OR Time (min)	Blood Loss (cc)	LOS (days)	Complications
1	75	M	Multiple myeloma	T10 and T11 corpectomy	Yes	T9–T12	Bilateral pedicle screws	Left	135	350	3	None
2	80	F	Meningioma	T11–T12 XLIF	No	T11–T12	Anterolateral plating	Left	60	80	1	None
3	60	F	Adenocarcinoma GI tract	T12 corpectomy	Yes	T11–L1	Anterolateral plating	Left	45	300	1	Death—12 mo
4	40	M	Neurofibroma	T6–T8 lateral exposure	No	None	None	Right	210	350	2	None
5	70	F	Meningioma	T6–T7 XLIF	No	T6–T7	Anterolateral plating	Right	130	200	3	None
6	34	M	Hemangioma	T9 corpectomy	Yes	T8–T10	Anterolateral plating	Left	145	500	1	Pneumonia
7	30	F	Meningioma	T9 corpectomy	Yes	T8–T10	Anterolateral plating	Left	55	240	2	None
8	63	M	Plasmacytoma	T8 corpectomy	Yes	T7–T9	Anterolateral plating	Left	40	40	4	None
9	80	F	Neurofibroma	T7–T8 XLIF	No	T7–T8	Anterolateral plating	Left	60	120	1	None
10	60	M	Neurofibroma	T7–T8 XLIF	No	T7–T8	Anterolateral plating	Left	85	30	1	None
11	65	M	Neurofibroma	T7–T9 lateral exposure	No	None	None	Right	125	25	3	None
12	55	M	Multiple myeloma	T10 corpectomy	Yes	T9–T11	Anterolateral plating	Left	180	55	2	Residual tumor
13	53	F	Meningioma	T10 corpectomy	Yes	T9–T11	Anterolateral plating	Left	115	100	2	Residual tumor
14	38	M	Plasmacytoma	T9 corpectomy	Yes	T8–T10	Bilateral pedicle screws	Left	110	50	1	None
15	61	M	Osteosarcoma	T8 corpectomy	Yes	T7–T9	Bilateral pedicle screws	Left	55	250	1	None
16	40	F	Meningioma	T8–T9 XLIF	No	T8–T9	Anterolateral plating	Left	60	300	1	None
17	39	M	Giant cell tumor	T10 corpectomy	Yes	T9–T11	Anterolateral plating	Left	55	30	3	None
18	79	M	Adenocarcinoma of lung	T12 corpectomy	Yes	T11–L1	Bilateral pedicle screws	Right	284	100	16	Death—6 mo
19	48	M	Neurofibroma	T11–T12	No	None	None	Left	120	150	3	None
20	66	M	NSC Lung Ca	T9 corpectomy	Yes	T8–T10	Bilateral pedicle screws	Left	205	1650	6	None
21	64	M	Meningioma	T9 corpectomy	Yes	T8–T10	Anterolateral plating	Left	190	1200	4	None

M indicates male; F, female; Y/N, yes/no; OR, operating room; mins, minutes; cc, cubic centimeters; LOS, length of hospital stay; XLIF, Extreme lateral interbody fusion; GI, gastrointestinal; mo, months; NSC lung ca, non–small-cell lung cancer.

Capener and later modified by Larson, have become popular and are frequently used routes to access the spine in multiple different areas.[17,21] These approaches avoid the morbidities associated with entry into the chest and provide adequate exposure for neural decompression, corpectomy, vertebral reconstruction, and simultaneous posterior spinal fixation.[16,22] However, these approaches require extensive muscle dissection and typically result in copious amounts of blood loss. The disadvantages of the posterior approaches include an oblique view of the dural elements and possibly requiring sectioning of nerve roots for placement of interbody device. The posterior correction of a kyphotic defor-

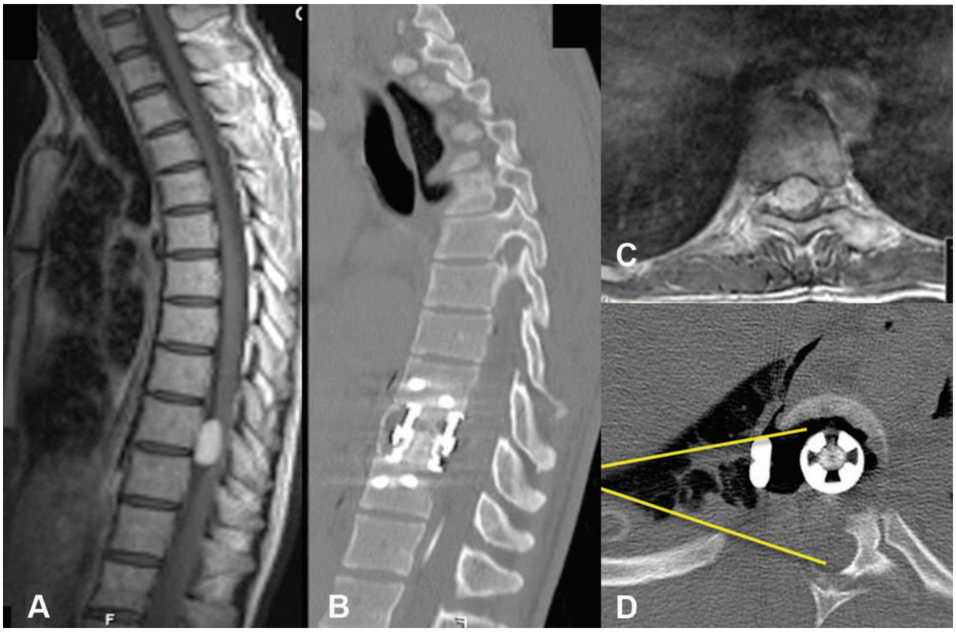

Figure 2. Preoperative sagittal and axial magnetic resonance imaging (**A**, **C**) and postoperative sagittal and axial computed tomography (**B**, **D**) showing a T9 corpectomy for resection of meningioma and placement of an expandable titanium cage with supplemental anterolateral plating. Approximate exposure area of the mini-open lateral approach is indicated by the yellow lines (**D**).

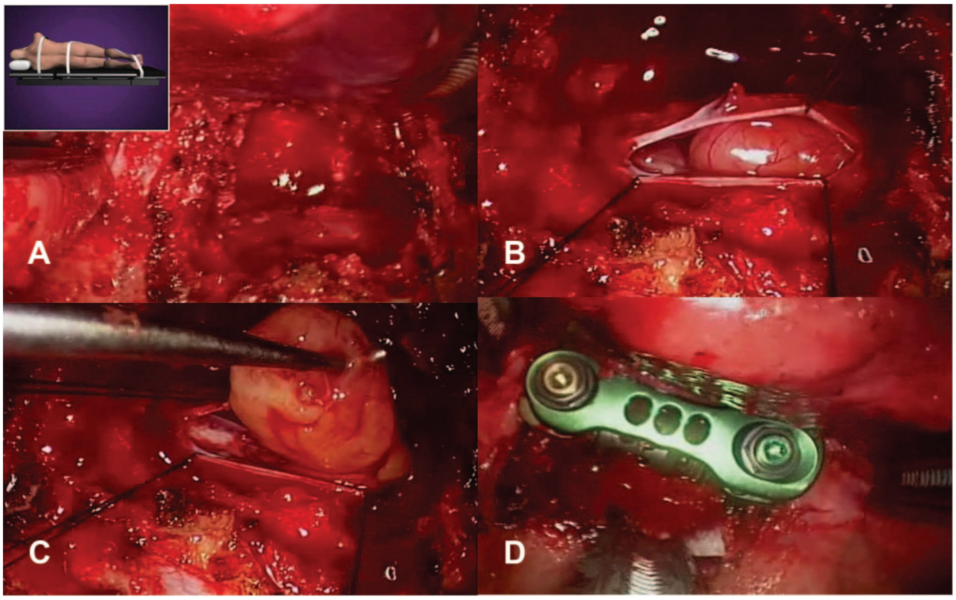

Figure 3. Intraoperative photographs of T9 corpectomy illustrating exposure of the dura (**A**), intradural tumor visualization (**B**), tumor resection (**C**), and placement of an expandable titanium cage and lateral plate (**D**).

mity also requires multiple fixation points both cranially and caudally. Surgical decompression of ventrally located cord-compressive lesions and the durability of kyphosis correction in patients with significant ventral column destruction from a solely posterior approach have been unsatisfactory.[18,23] The size (or footprint) of the interbody device that can be placed from posterior is limited secondary to constraints of the approach. This may lead to an increased rate of subsidence. Due to the unfavorable results obtained from posterior-only approaches, anterior-based approaches have been developed.[24–26]

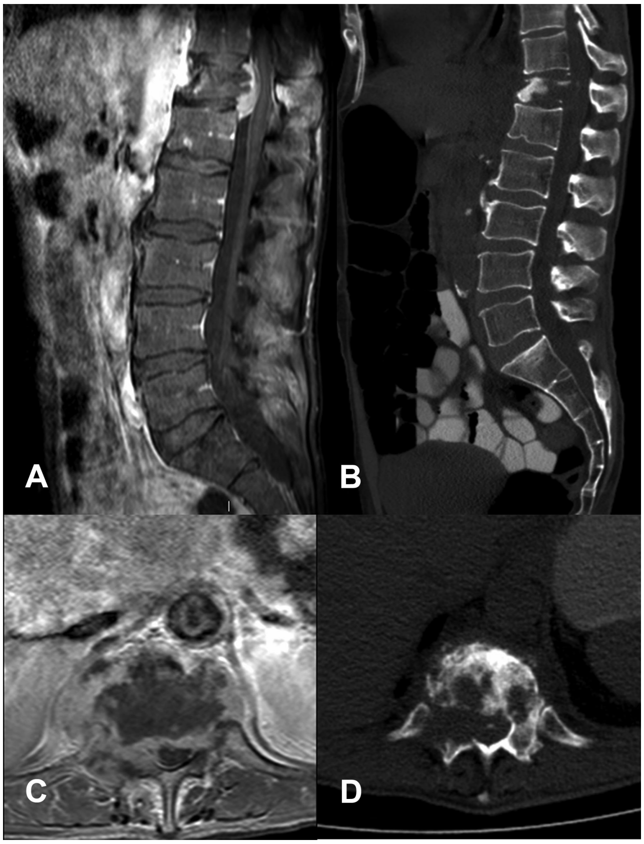

Figure 4. Preoperative sagittal and axial magnetic resonance imaging (**A**, **C**) and computed tomography (**B**, **D**) showing T12 metastasis with epidural compression.

Anterior-Based Approaches

Anterior transthoracic approaches have long been established in the management of many pathologic conditions of the anterior thoracic spine.[27] Anterior approaches provide adequate access to the ventral aspect of the spine and allow decompression without the associated risks of spinal cord or nerve root manipulation.[24–26] However, a thoracotomy requires a large skin incision, lung and rib retraction, and muscle dissection. These all can contribute to postoperative pulmonary dysfunction (such as pulmonary contusions, atelectasis, pleural effusions, hemothorax, and chylothorax), as well as significant peri- and postoperative pain from extensive rib resection. Major complications with use of the thoracotomy approach have been shown in as many as 79% of patients,[28,29] tend to extend hospitalizations, and increase medical resource utilization.[30]

To reduce the morbidity associated with thoracotomy, less invasive thoracoscopic techniques have been developed and refined for performing a thoracic corpectomy and reconstruction.[10,31,32] Thoracoscopy is capable of producing the same exposure as that with the transthoracic route without the need for a large incision or rib resection. Although the incidence of complications is considered to be lower than open in thoracotomies, rates have been reported to be as high as 14.1% to 29.4%.[31,33,34] Complications include transient intercostal neuralgia, postoperative atelectasis, pneumothorax, pleural effusion, and hemothorax.[31,33,34] Additionally, there is a steep learning curve for thoracoscopic procedures.[12,35,36]

One major disadvantage of anterior-based approaches is that in some instances the pathologic process is faced first and the neural elements are not visualized until the anterior decompression is completed. In select cases, the anterior

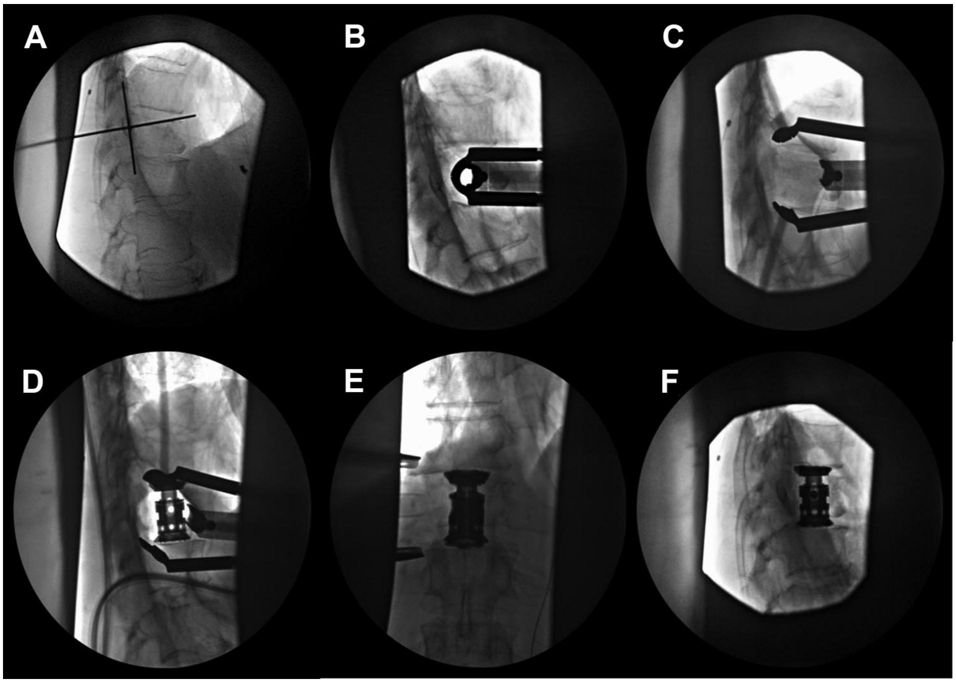

Figure 5. Serial intraoperative lateral fluoroscopy showing localization (**A**), retractor placement (**B**), retractor expansion (**C**), cage placement in lateral and anterior views (**D**, **E**), and immediate lateral postoperative fluoroscopy demonstrating tumor resection and cage placement using a minimally invasive lateral approach (**F**).

longitudinal ligament may need to be resected and this may lead to destabilization.

Lateral-Based Approach

In an effort to avoid the drawbacks and morbidity related to a thoracotomy/thoracoscopic approach or the extensive tissue dissection associated with posterior approaches, the retropleural thoracotomy was developed and popularized by McCormick.[18] Unlike posterior approaches, a retropleural thoracotomy permits a direct view of the dura/neural elements and allows the surgeon to expose the lateral canal without the need to dissect or potentially sacrifice the intercostal nerve or intraforaminal radiculomedullary artery.[10,32] In contrast to the transthoracic approach, the dissection remains extrapleural and potentially poses less risk of injury to the aorta, vena cava, and sympathetic plexus, while decreasing the chance of developing a duropleural cerebrospinal fluid fistula.[18,37,38] This approach allows the surgeon to have direct visualization of the dura and any anterior-based pathology simultaneously. There is preservation of the anterior longitudinal ligament, posterior ligamentous structures, and PLL, which is less destabilizing biomechanically. However, this approach requires a relatively large incision and extensive rib resection.[18]

MIS Lateral Approach

Traditional approaches to the thoracic spine have been associated with a significant amount of morbidity.[19,39–42] To address these issues, minimally invasive techniques have been developed. Minimally invasive surgery (MIS) aims to decrease muscle and tissue disruption, postoperative pain, blood loss, time to mobilization, and length of stay, without compromising the goals of surgery.[43] Many reports in the literature have already demonstrated the benefit of MIS techniques.[35,44–46]

With the advent of expandable and tubular retractors, specialized instruments, and fiber optic light sources, we are now able to perform a minimally invasive lateral approach (transthoracic or retropleural). As with all MIS, this approach is a technical variation that aims to achieve the same goals of surgery while decreasing the morbidity associated with the standard techniques.[18,20,47] This procedure combines all the advantages of the lateral approach with the benefits of MIS techniques. In the current series, the perioperative complication rate was 4.8% (1/21 patients) (pneumonia), which was considerably lower than reported rates in the literature, that is, 6.9% and 11.1% for posterior- and anterior-based approaches, respectively.[48] In our series of patients, we did not encounter any wound-related complications or infections. Street *et al* reported a 16.7% wound-related complication rate when using the posterolateral vertebrectomy approach.[49] The MIS lateral approach provided exposure to meet the goals of surgery (*i.e.*, tumor resection, decompressing the neural elements, and stabilization), while decreasing the approach-related morbidity. This approach avoids the extensive muscle dissection associated with the posterior approaches and provides a direct view of the pathology. It provides the same exposure as the anterior approaches but does not require single-lung ventilation, a large incision, or extensive rib resection. In the current series, patients of all ages (30–80 years) and both benign and malignant pathologies were able to be treated successfully.

Patients with metastatic cancer have multiple comorbidities, higher perioperative complication rates, are immunocompromised, and have a higher incidence of wound infection/dehiscence secondary to adjuvant therapy.[49,50] In this subset of patients, MIS offers the advantages of using smaller incisions leading to less wound-related complications and somatic pain. This may lead to an improvement in patient's health-related quality of life outcomes and hasten the initiation of adjuvant therapy. In fact, early mobilization has been shown in other spine indications to increase pulmonary and metabolic function, decrease the risk of medical complications related to inactivity, and decrease overall recovery time.[36] When a retropleural approach is used, there is an added benefit of preventing or limiting tumor cell dissemination into the chest cavity when compared with open thoracotomy.

One drawback of the minimally invasive retropleural approach to the thoracic spine is that if posterior instrumentation is required, then a second incision must be made. Also, when using the lateral approach, there is a long working distance in a relatively narrow working space. Surgeons attempting this approach should be familiar with MIS and working through an MIS retractor. Retropleural dissections may not be feasible after a previous ipsilateral thoracotomy secondary to adhesions. Patients with osteomyelitis of the spine and spinal metastases can have marked paraspinal pleural reactions with adhesive thickening of the parietal pleura and infiltration of the pleura by tumor or inflamed fibrous tissue.

In our series, no patient required conversion from a MIS approach to a standard open procedure. However, in certain instances, we would recommend and/or choose other approaches to the thoracic spine. For example, secondary to the constraints of the mediastinum anteriorly and the axilla laterally, in upper thoracic levels (T1–T4), we would recommend using a posterior approach. If there is primary involvement of the posterior elements with bilateral pedicle invasion, then we would also choose a posterior-based approach. In the event of any recurrences, either the same side or contralateral side may be used.

■ Conclusion

The surgical treatment of tumors located in the thoracic spine has been accomplished from the anterior, posterior, lateral, or a combination of these approaches. The MIS lateral approach to the thoracic spine achieves the same goals of surgery with the hope of decreasing the approach-related complications and morbidity of the traditional approaches. Whether benign or malignant, intradural or osseous, the MIS lateral approach was successful for the surgical treatment of various histologic types of tumors in all ages of patients. It is an excellent alternative and should be in the armamentarium of all spine surgeons.

■ Key Points

- The treatment of thoracic tumors can be performed by many different approaches, both anterior and posterior, which carry significant associated morbidities that increase frequency of complications, increase recovery time, and decrease the quality of recovery.
- Minimally invasive (endoscopic) approaches have been used for removal of thoracic tumors with varying efficacy, but without the morbidities commonly associated with open techniques.
- A mini-open, lateral technique may provide certain benefits, including direct visualization and the use of traditional techniques, without the difficulties of endoscopic and morbidities of open techniques.

References

1. Miller DJ, McCutcheon IE. Hemangioblastomas and other uncommon intramedullary tumors. *J Neurooncol* 2000;47:253–70.
2. Bell GR. Surgical treatment of spinal tumors. *Clin Orthop Relat Res* 1997;54–63.
3. Gokaslan ZL. Spine surgery for cancer. *Curr Opin Oncol* 1996;8:178–81.
4. Ryken TC, Eichholz KM, Gerszten PC, et al. Evidence-based review of the surgical management of vertebral column metastatic disease. *Neurosurg Focus* 2003;15:E11.
5. Deramond H, Depriester C, Galibert P, et al. Percutaneous vertebroplasty with polymethylmethacrylate. Technique, indications, and results. *Radiol Clin North Am* 1998;36:533–46.
6. Galibert P, Deramond H, Rosat P, et al. Preliminary note on the treatment of vertebral angioma by percutaneous acrylic vertebroplasty [in French]. *Neurochirurgie* 1987;33:166–8.
7. Huang TJ, Hsu RW, Liu HP, et al. Video-assisted thoracoscopic surgery to the upper thoracic spine. *Surg Endosc* 1999;13:123–6.
8. Huang TJ, Hsu RW, Li YY, et al. Minimal access spinal surgery (MASS) in treating thoracic spine metastasis. *Spine* 2006;31:1860–3.
9. Kan P, Schmidt MH. Minimally invasive thoracoscopic approach for anterior decompression and stabilization of metastatic spine disease. *Neurosurg Focus* 2008;25:E8.
10. Mack MJ, Regan JJ, Bobechko WP, et al. Application of thoracoscopy for diseases of the spine. *Ann Thorac Surg* 1993;56:736–8.
11. Gokaslan ZL, York JE, Walsh GL, et al. Transthoracic vertebrectomy for metastatic spinal tumors. *J Neurosurg* 1998;89:599–609.
12. Eck JC, Hodges S, Humphreys SC. Minimally invasive lumbar spinal fusion. *J Am Acad Orthop Surg* 2007;15:321–9.
13. Bilsky MH, Boland P, Lis E, et al. Single-stage posterolateral transpedicle approach for spondylectomy, epidural decompression, and circumferential fusion of spinal metastases. *Spine* 2000;25:2240–9; discussion 2250.
14. Menard V. Causes de la paraplegie dans le mal de Pott, son traitement chirurgical par l'ouverture directe du foyer tuberculeux des vertebres. *Rev Orthop* 1894;5:47–64.
15. Wiggins GC, Mirza S, Bellabarba C, et al. Perioperative complications with costotransversectomy and anterior approaches to thoracic and thoracolumbar tumors. *Neurosurg Focus* 2001;11:e4.
16. Graham AW III, Mac MM, Fessler RG. Lateral extracavitary approach to the thoracic and thoracolumbar spine. *Orthopedics* 1997;20:605–10.
17. Larson SJ, Holst RA, Hemmy DC, et al. Lateral extracavitary approach to traumatic lesions of the thoracic and lumbar spine. *J Neurosurg* 1976;45:628–37.
18. McCormick PC. Retropleural approach to the thoracic and thoracolumbar spine. *Neurosurgery* 1995;37:908–14.
19. Musacchio M, Patel N, Bagan B, et al. Minimally invasive thoracolumbar costotransversectomy and corpectomy via a dual-tube technique: evaluation in a cadaver model. *Surg Technol Int* 2007;16:221–5.
20. Scheufler KM. Technique and clinical results of minimally invasive reconstruction and stabilization of the thoracic and thoracolumbar spine with expandable cages and ventrolateral plate fixation. *Neurosurgery* 2007;61:798–808.
21. Capener N. The evolution of lateral rhachotomy. *J Bone Joint Surg Br* 1954;36-B:173–9.
22. Schmidt MH, Larson SJ, Maiman DJ. The lateral extracavitary approach to the thoracic and lumbar spine. *Neurosurg Clin N Am* 2004;15:437–41.
23. Fessler RG, Sturgill M. Review: complications of surgery for thoracic disc disease. *Surg Neurol* 1998;49:609–18.
24. Chen LH, Chen WJ, Niu CC, et al. Anterior reconstructive spinal surgery with Zielke instrumentation for metastatic malignancies of the spine. *Arch Orthop Trauma Surg* 2000;120:27–31.
25. Rosenthal D, Marquardt G, Lorenz R, et al. Anterior decompression and

stabilization using a microsurgical endoscopic technique for metastatic tumors of the thoracic spine. *J Neurosurg* 1996;84:565–72.
26. Sundaresan N, Shah J, Foley KM, et al. An anterior surgical approach to the upper thoracic vertebrae. *J Neurosurg* 1984;61:686–90.
27. Winn H. *Youmans Neurological Surgery*. 5th ed. Philadelphia, PA: Sanders; 2004.
28. Dimar JR, Wilde PH, Glassman SD, et al. Thoracolumbar burst fractures treated with combined anterior and posterior surgery. *Am J Orthop (Belle Mead NJ)* 1996;25:159–65.
29. Lu DC, Lau D, Lee JG, et al. The transpedicular approach compared with the anterior approach: an analysis of 80 thoracolumbar corpectomies. *J Neurosurg Spine* 2010;12:583–91.
30. Wood K, Buttermann G, Mehbod A, et al. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. *J Bone Joint Surg Am* 2003;85-A:773–81.
31. Dickman CA, Rosenthal D, Karahalios DG, et al. Thoracic vertebrectomy and reconstruction using a microsurgical thoracoscopic approach. *Neurosurgery* 1996;38:279–93.
32. Regan JJ, Mack MJ, Picetti GD III. A technical report on video-assisted thoracoscopy in thoracic spinal surgery. Preliminary description. *Spine* 1995;20:831–7.
33. McAfee PC. Complications of anterior approaches to the thoracolumbar spine. Emphasis on Kaneda instrumentation. *Clin Orthop Relat Res* 1994;110–9.
34. McAfee PC, Regan JR, Zdeblick T, et al. The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery. A prospective multicenter study comprising the first 100 consecutive cases. *Spine* 1995;20:1624–32.
35. Fessler RG, Khoo LT. Minimally invasive cervical microendoscopic foraminotomy: an initial clinical experience. *Neurosurgery* 2002;51:S37–45.
36. Rampersaud YR, Annand N, Dekutoski MB. Use of minimally invasive surgical techniques in the management of thoracolumbar trauma: current concepts. *Spine* 2006;31:S96–102.
37. Bohlman HH, Zdeblick TA. Anterior excision of herniated thoracic discs. *J Bone Joint Surg Am* 1988;70:1038–47.
38. Thiel W. *Photographic Atlas of Practical Anatomy*. 2nd ed. New York, NY: Springer; 2003.
39. Kim DH, O'Toole JE, Ogden AT, et al. Minimally invasive posterolateral thoracic corpectomy: cadaveric feasibility study and report of four clinical cases. *Neurosurgery* 2009;64:746–52.
40. Lu DC, Dhall SS, Mummaneni PV. Mini-open removal of extradural foraminal tumors of the lumbar spine. *J Neurosurg Spine* 2009;10:46–50.
41. Maciejczak A, Barnas P, Dudziak P, et al. Posterior keyhole corpectomy with percutaneous pedicle screw stabilization in the surgical management of lumbar burst fractures. *Neurosurgery* 2007;60:232–41.
42. Taghva A, Li KW, Liu JC, et al. Minimally invasive circumferential spinal decompression and stabilization for symptomatic metastatic spine tumor: technical case report. *Neurosurgery* 2010;66:E620–2.
43. Oppenheimer JH, DeCastro I, McDonnell DE. Minimally invasive spine technology and minimally invasive spine surgery: a historical review. *Neurosurg Focus* 2009;27:E9.
44. Guiot BH, Khoo LT, Fessler RG. A minimally invasive technique for decompression of the lumbar spine. *Spine* 2002;27:432–8.
45. Khoo LT, Palmer S, Laich DT, et al. Minimally invasive percutaneous posterior lumbar interbody fusion. *Neurosurgery* 2002;51:S166–1.
46. Mummaneni PV, Rodts GE Jr. The mini-open transforaminal lumbar interbody fusion. *Neurosurgery* 2005;57:256–61.
47. Jaikumar S, Kim DH, Kam AC. History of minimally invasive spine surgery. *Neurosurgery* 2002;51:S1–14.
48. Yonenobu K, Korkusuz F, Hosono N, et al. Lateral rhachotomy for thoracic spinal lesions. *Spine* 1990;15:1121–5.
49. Street J, Fisher C, Sparkes J, et al. Single-stage posterolateral vertebrectomy for the management of metastatic disease of the thoracic and lumbar spine: a prospective study of an evolving surgical technique. *J Spinal Disord Tech* 2007;20:509–20.
50. Ghogawala Z, Mansfield FL, Borges LF. Spinal radiation before surgical decompression adversely affects outcomes of surgery for symptomatic metastatic spinal cord compression. *Spine* 2001;26:818–24.