

Minimally invasive thoracoscopic approach for anterior decompression and stabilization of metastatic spine disease

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Object. The choices available in the management of metastatic spine disease are complex, and the role of surgical therapy is increasing. Recent studies have indicated that patients treated with direct surgical decompression and stabilization before radiation have better functional outcomes than those treated with radiation alone. The most common anterior surgical approach for direct spinal cord decompression and stabilization in the thoracic spine is open thoracotomy; however, thoracotomy for spinal access is associated with morbidity that can be avoided with minimally invasive techniques like thoracoscopy.

Methods. A minimally invasive thoracoscopic approach was used for the surgical treatment of thoracic and thoracolumbar metastatic spinal cord compression. This technique allows ventral decompression via corpectomy, interbody reconstruction with expandable cages, and stabilization with an anterolateral plating system designed specifically for minimally invasive implantation. This technique was performed in 5 patients with metastatic disease of the thoracic spine, including the thoracolumbar junction.

Results. All patients had improvement in preoperative symptoms and neurological deficits. No complications occurred in this small series.

Conclusions. The minimally invasive thoracoscopic approach can be applied to the treatment of thoracic and thoracolumbar metastatic spine disease in an effort to reduce access morbidity. Preliminary results have indicated that adequate decompression, reconstruction, and stabilization can be achieved with this technique.

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KEY WORDS • metastatic spine disease • minimally invasive surgery • spinal cord decompression • thoracoscopy

As many as 70% of cancer patients have evidence of metastatic disease at the time of death,⁶ and involvement of the spine occurs in up to 40% of those patients.^{22,35} The spine is the most common osseous site for metastatic deposits, which can result in severe back pain, spinal deformity, pathological fractures, and neurological compromise.^{22,23} Among patients with metastatic spine disease, 10–20% have symptomatic spinal cord compression, resulting in > 25,000 cases per year, making spinal cord injury from metastasis more common than traumatic spinal cord injury.^{22,23,35}

The spinal region most commonly affected is the thoracic spine (70%), followed by the lumbar (20%) and cervical (10%) spine.^{7,13,14} Within the thoracic segment, 85% of metastases are located ventrally in the vertebral body and epidural space, 15% in the posterior element only, and < 5% in the epidural or subarachnoid/intramedullary space.^{7,14}

The management of metastatic spine disease is complex,

and options for treatment include surgery, radiation, and chemotherapy.^{23,35} With surgery, the optimal type of procedure is controversial. Laminectomy was once the treatment of choice for the management of vertebral metastatic disease;² however, results with this procedure were disappointing,^{14,17,32,41} mainly because of its inadequacies in addressing ventrally located masses. As a result, anterior approaches that led to better outcomes were developed for direct spinal cord decompression.^{19,24,31,32,38,39} At present, the usual anterior surgical approach for direct decompression and stabilization of the thoracic spine and thoracolumbar junction involves an open thoracotomy, although the procedure is associated with substantial access morbidity. Recently, minimally invasive thoracoscopic approaches have been developed for the surgical treatment of thoracic disc herniations and traumatic fractures to overcome the problems associated with thoracotomy.^{1,3,4,10,18,29,30,37} We here describe the application of a minimally invasive procedure for the surgical treatment of metastatic spinal cord compression and pathological fractures in the thoracolumbar spine, with an emphasis on recently developed reconstruction and stabilization techniques.

Abbreviations used in this paper: EBL = estimated blood loss.

TABLE 1

*Operative and follow-up data in 5 patients with metastatic spine disease who underwent a minimally invasive video-assisted endoscopic approach for ventral decompression and stabilization**

Case No.	Age (yrs), Sex	Vertebral Level of Disease	Diagnosis	Op Time (min)	EBL (ml)	FU (mos)	VAS Score & Frankel Grade	
							Preop	At Last FU
1	61, M	T-10	prostate adeno	240	900	NA†	8/10, C	4/10, D
2	62, M	T-11	esophageal adeno	250	500	4	3/10, E	0/10, E
3	67, F	T-11	breast cancer	300	350	6	7/10, E	3/10, E
4	48, M	L-1	renal cell carcinoma	270	800	6	8/10, E	4/10, E
5	52, F	L-1	breast adeno	240	500	6	8/10, C	4/10, E

* adeno = adenocarcinoma; FU = follow-up; NA = not applicable; VAS = visual analog scale.

† Lost to follow-up.

Clinical Material and Methods

Patient Population

Between 2002 and 2007, 34 patients with various pathologies involving the thoracic and thoracolumbar spine underwent thoracoscopic vertebrectomy by the senior author (M.H.S.). Of these patients, 5 presented with metastatic disease of the thoracic spine. Age, sex, vertebral level, pathology, operative time, EBL, and duration of follow-up for these 5 patients are summarized in Table 1. All 5 patients presented with severe back pain; 1 patient had progressive neurological deficits with lower-extremity weakness, and 1 patient presented with bladder incontinence and lower extremity weakness. Imaging studies in these patients revealed osseous destruction, deformity of the diseased thoracic vertebrae, or anterior spinal cord compression. Surgical indications included intractable pain caused by spinal instability/deformity from a pathological fracture, severe spinal canal compromise, and progressive neurological deficits.

Operative Technique

Preoperative Evaluation. In addition to regular spine-related imaging, preoperative radiographic evaluation should routinely include posteroanterior and lateral chest views to evaluate potential pleural fluid, fibrinous membranes, or adhesions in the pleural space. Patients with symptomatic spinal cord compression should be started on steroid therapy.²² A vascular metastatic lesion should be considered for preoperative embolization.¹⁶

Contraindications to Thoracoscopic Surgery. Specific patient comorbidities that make thoracoscopic surgery technically more difficult are pleural adhesions (for example, from previous chest surgery, trauma, or infection), which make access difficult, or pulmonary conditions that make it unsafe to perform single-lung ventilation (for example, chronic obstructive pulmonary disease or asthma). Patients with these conditions may be better served with an open thoracotomy or a lateral extracavitary approach.^{12,36}

Anesthesia and Patient Positioning. Thoracoscopic spine surgery is performed under general anesthesia. Patients undergo intubation with a double-lumen endotracheal tube to achieve single-lung ventilation for maximal surgical exposure. Alternatively, a single-lumen tube and an endo-

tracheal blocker can be used if double-lumen endotracheal intubation cannot be achieved. The correct position of the endotracheal tube is confirmed with a bronchoscope before and after final positioning.

The patient is placed in the lateral decubitus position and secured to the radiolucent operating table with a 4-point support system to the sacrum, pubic bone, scapula, and sternum. The legs are flexed slightly, an inflatable roll is placed under the axilla, and the top arm is placed on a Krause armrest. At this point, the C-arm fluoroscope is brought into position and used to ensure that the patient's spine is parallel to the operating table. In general, a left-sided approach is preferred for access to the thoracolumbar junction (T-11 to L-2) and a right-sided approach for the middle to upper thoracic spine (T3–10).⁶ It is essential, however, to individualize the side of the approach on the basis of the anatomy (aorta and vena cava) visualized on preoperative CT scanning.

Thoracoscopic Access and Exposure. After the patient is positioned optimally, the C-arm fluoroscope is used to obtain the lateral spine image. The involved vertebral bodies, discs, anterior spinal line, and posterior spinal line are marked on the skin overlying the lateral chest wall. Four access sites (portals) are then outlined around the level of the lesion (Fig. 1). The positions of the portals are crucial for optimizing working distances, image quality, and retraction. The working portal is centered directly over the level of the lesion. The portal site for the endoscopic camera is placed ~2–3 intercostal spaces away from the working portal, in the cranial direction along the axis of the spinal column for a thoracolumbar junction lesion. Alternatively, in middle to upper thoracic spine cases, the



FIG. 1. Photograph showing placement of the 4 access ports.

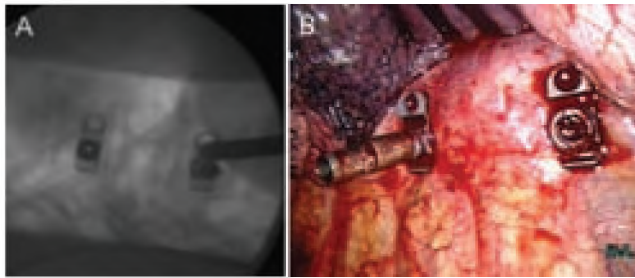


FIG. 2. Orientation after posterior vertebral body polyaxial screw placement. Fluoroscopic image (A) and intraoperative photograph (B) showing the placement of posterior polyaxial screws above and below the diseased vertebral body.

endoscope portal can be placed caudal to the working portal. The suction/irrigation portal is located ventral and slightly cranial to the working portal. The fourth portal for the retractor of the lung and the diaphragm is placed ventral and slightly caudal to the working portal. The working portal is ~ 3–4 cm in length (twice the length of the other portals) to accommodate insertion of an expandable cage.³³

After the lateral spine anatomy is outlined and the portal sites are marked, the entire lateral chest wall is prepped and draped for a potential conversion to open thoracotomy. It is important to consider and be prepared for the possibility of converting to an open thoracotomy if necessary. To minimize the risk of inadvertent injuries to underlying structures during placement of the access sites, the first portal is placed at the site furthest away from the diaphragm after single-lung ventilation has been initiated.

The first portal site is opened using a blunt dissection technique to minimize possible injury to the lung. The subcutaneous tissues and intercostal muscles are dissected bluntly without removing any rib, which minimizes local trauma. The pleural space is then exposed, and palpation is used to detect any pleural adhesions. The parietal pleura is opened. Once this pleura is opened and the collapsed lung is visualized directly, the first trocar is inserted and the 30° endoscope is introduced into the thoracic cavity. After the thoracic cavity has been inspected, the remaining 3 trocar sites are placed under direct endoscopic visualization. The key anatomical structures (spine, diaphragm, aorta, and azygos vein) are identified, and the endoscopic image is oriented so that the spine is parallel to the lower edge of the video monitor. The diaphragm usually inserts somewhere at the level from T-12 to L-1 and can be opened endoscopically if surgical exposure below the insertion is needed. The incision is usually placed 1–2 cm away from the diaphragmatic insertion site where the diaphragm naturally thins out. For the semicircular incision, we prefer using the harmonic scalpel, because it does not generate heat and smoke, which can impair endoscopic visualization. For exposure of L1–2, the diaphragm is opened further caudally for up to 5 cm. Although L-3 can be instrumented using a thoracoscopic approach, we prefer a mini-open, endoscope-assisted retroperitoneal exposure. After the diaphragm has been split, the retroperitoneal fat and peritoneal sac are bluntly dissected away from the fascia of the psoas muscle to expose the vertebral bodies.

For exposure of the thoracic vertebral bodies and intervertebral discs, a pleural flap must be elevated. The seg-

mental vessels of the operation field lie transversely across the mid-portion of the vertebral body deep to the parietal pleura. The harmonic scalpel with a hooklike tip is used to elevate and incise the parietal pleura. The pleura is then bluntly dissected, and the segmental vessels are identified, ligated, and divided. This process exposes the lateral vertebral body wall and discs.

Placement of Posterior Vertebral Body Screws and Spine Instrumentation. The MACS TL endoscopic anterolateral plate (Aesculap) consists of 2 clamps and 4 fixation screws with 1 clamp and 2 screws (1 anterior stabilization screw and 1 posterior polyaxial vertebral body screw) placed at each vertebral body adjacent to the diseased vertebra. The entry point of the posterior polyaxial screw is 10 mm anterior to the spinal canal in the upper or lower third of the vertebral body. The posterior screw above the diseased level is placed in the inferior third of the vertebral body, whereas the vertebral body screw below is placed in the upper third of the vertebral body (Fig. 2). These entry points avoid the segmental arteries located in the midportion of the vertebral bodies. Using the radiolucent impaction/targeting device, a short K-wire is placed under lateral fluoroscopy at the entry point. A cannulated awl is then passed over the K-wire to decorticate the entry point. The polyaxial screw-clamp assembly is inserted, and the K-wire is removed after the screw has been engaged. After the polyaxial posterior screws have been placed above and below the diseased body, the clamps are oriented perpendicular to the anterior aspect of the vertebral body, keeping in mind the relationship of the platforms with the aorta. By keeping surgical instruments within the boundaries of these clamps, mishaps with critical structures can be avoided.

Corpectomy and Spinal Canal Decompression. Endoscopic discectomy and corpectomy are performed in a manner similar to that in an open procedure. Discs adjacent to the diseased body are incised with an endoscopic scalpel and removed with rongeurs. The intervening diseased vertebral body is removed by performing a median corpectomy with straight and curved osteotomes (Fig. 3). The corpec-

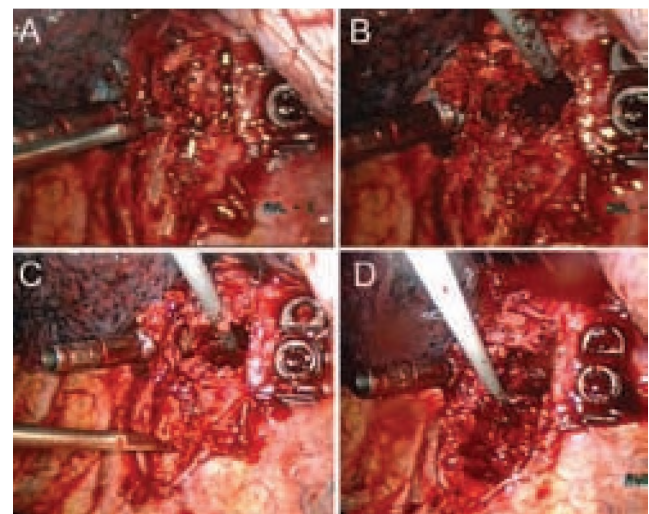


FIG. 3. Intraoperative photographs demonstrating sequential endoscopic corpectomy and canal decompression with endoscopic osteotomes.

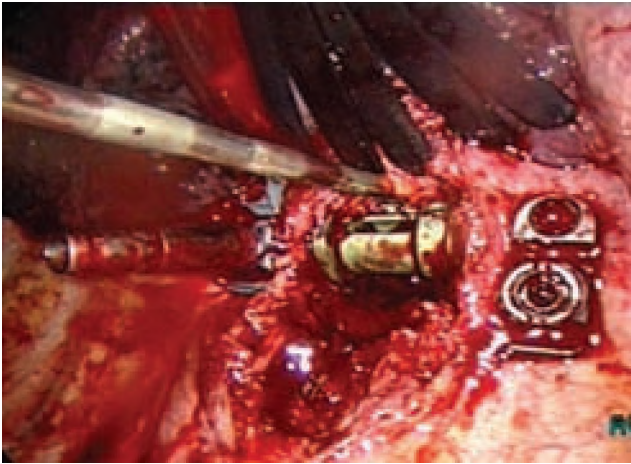


FIG. 4. Intraoperative photograph demonstrating interbody reconstruction with an expandable Synex cage.

tomy can be widened with osteotomes or a Midas Rex drill with a coarse diamond drill bit. The depth of the corpectomy across the midline is verified on fluoroscopy. The anterior spinal canal is decompressed by identifying and removing the ipsilateral pedicle. First, the ipsilateral rib head is followed to its attachment at the anterolateral spine and removed using the Midas Rex drill. This maneuver exposes the underlying pedicle and the neural foramen located at its base. The ipsilateral pedicle is then removed with the Midas Rex drill and endoscopic punches, which enables direct decompression and visualization of the anterior spinal cord. Free bone fragments and epidural tumor are gently pushed into the central corpectomy cavity and removed. Once decompression of the anterior spinal cord has been achieved, reconstruction of the vertebral body is undertaken.

Interbody Reconstruction and Endoscopic Stabilization. We prefer placement of an expandable cage (Fig. 4) for anterolateral thoracolumbar reconstruction after complete corpectomy.³³ A properly sized cage is placed under fluo-

roscopic visualization, while making note of the anteroposterior and lateral position. Cage expansion and distraction are then achieved, and allograft corpectomy bone can be packed around the cage. Next, the superior polyaxial screw-clamp system is placed into the superior vertebral body, if this has not already been accomplished. The anterolateral plate is dropped over the in-place posterior polyaxial screws, and the plate is secured by tightening the posterior screws and placing anterior stabilization screws at each level. The screw plate assembly is locked and torqued. All hardware is imaged for proper position with anteroposterior and lateral fluoroscopy.

Placement of Chest Tube, Closure, and Postoperative Care. The diaphragm is reapproximated with sutures, and the thoracic cavity is irrigated. A small 24 Fr chest tube is placed in the chest cavity apex through either the inferolateral retractor port or the lateral suction port under direct endoscopic visualization. Lung reinflation is visualized with the camera to ensure that all lobes inflate properly. Port sites are closed in multiple layers, and the chest tube is secured. A chest radiograph is obtained immediately to ensure proper lung inflation. The chest tube is initially connected to intermittent wall suction, then to water seal on postoperative Day 1 if the lung remains inflated on chest radiography. Daily chest tube outputs are recorded, and the chest tube is removed when output falls below 100 ml/day, which usually occurs on the 2nd postoperative day. A final chest radiograph is obtained before and after chest tube removal to verify proper lung inflation and the absence of pneumothorax.

Illustrative Case

History. This 61-year-old man (Case 1) had a 1-year history of untreated prostate adenocarcinoma. He presented to our emergency room with a 2-week history of severe back pain, lower-extremity weakness/paresthesia, and difficulty walking. He reported intact bowel and bladder continence.

Examination. The patient was nonambulatory and reported severe pain (8/10 on the visual analog scale) in the tho-



FIG. 5. Case 1. Preoperative sagittal (A) and axial (B) CT scans of the thoracic spine showing the T-10 burst fracture and the severe canal compromise as a result of the fracture fragment. Preoperative sagittal (C) and axial (D) T2-weighted MR images of the thoracic spine demonstrating spinal cord compression and signal changes within the cord substance.

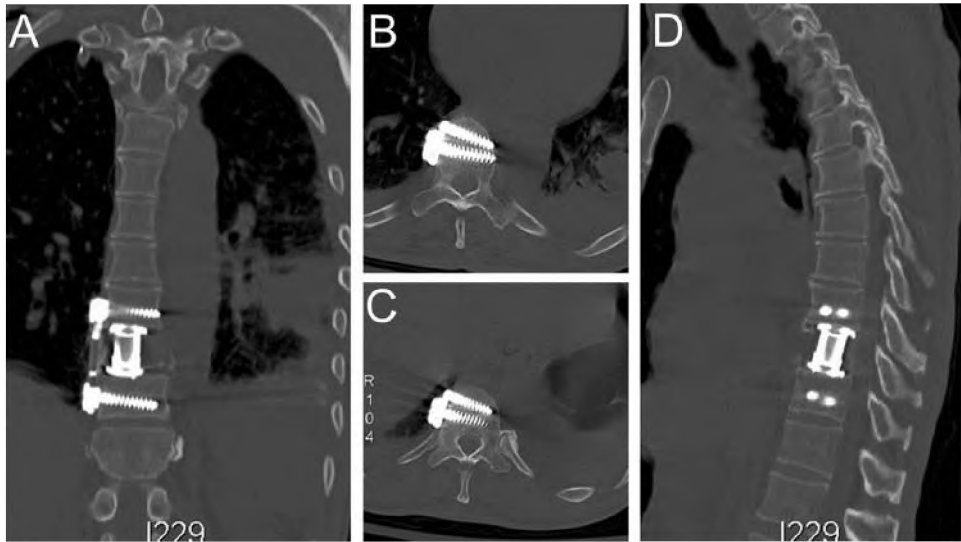


FIG. 6. Case 1. Postoperative coronal (A), axial (B and C), and sagittal (D) CT scans showing the final construct and adequate spinal canal decompression.

racolumbar area. His motor examination revealed 4/5 bilateral lower-extremity weakness. His neurological function was C on the Frankel Classification.¹¹

Computed tomography scans of the thoracic spine revealed a pathological burst fracture at T-10 with ~ 80% canal compromise (Fig. 5A and B). Magnetic resonance imaging demonstrated ventral spinal cord compression and signal changes within the cord substance (Fig. 5C and D). Imaging studies of the remaining spinal axes revealed metastatic disease at C-6, C-7, T-2, T-3, T-4, and T-6 with no spinal cord impingement.

Operation. The patient underwent a right-sided thoracoscopic T-10 corpectomy, interbody reconstruction using a Synex interbody cage, and anterolateral stabilization with the MACS TL plating system from T-9 to T-11, using the technique described above.

Postoperative Course. The patient fared well postoperatively and recovered full strength in his lower extremities. His pain improved significantly, and he was able to walk with a cane. The chest tube was removed on postoperative Day 2 with no complications. Postoperative CT scanning showed adequate spinal canal decompression and vertebral body reconstruction (Fig. 6). The patient was transferred to the oncology service on postoperative Day 4 to start spinal radiation therapy (Fig. 7). Final pathological findings were consistent with metastatic adenocarcinoma.

Results

Operative Data

In the 5 patients reviewed the mean EBL was 610 ml, and the mean duration of surgery was 4.3 hours. There were no intraoperative complications (for example, uncontrolled bleeding, cerebrospinal fluid leak, chyle leak, or visceral injuries) in this small series. Breathing tubes were removed immediately after surgery in the operating room, and no respiratory complications such as pneumonia, pleural effusion, or hemo/pneumothorax were encountered. Wound healing was uncomplicated in all patients. There

were no implant- or hardware-related complications at the last follow-up appointments.



FIG. 7. Case 1. Photograph showing incisions on postoperative Day 4.

Clinical Outcomes

All 5 patients reported significant pain reduction at their last follow-up visit. The 2 patients who had presented with motor weakness regained full strength. Three patients (Cases 2, 3, and 5) were discharged home on postoperative Days 6, 7, and 8, respectively, and 1 patient (Case 1) was discharged to radiotherapy on postoperative Day 4. The discharge of the remaining patient (on postoperative Day 10) was slightly delayed because of pain from a pelvic metastasis.

Discussion

With the advent of radiotherapy, standard treatment for metastatic spine disease with spinal cord compression consists of the administration of corticosteroids and radiation.^{7,26} Surgical treatment via simple laminectomy was largely abandoned because the results with laminectomy alone or in combination with radiation did not seem to differ from results with radiation alone.^{14,17,41} Subsequently, it was recognized that laminectomy failed because most spinal metastases are located in the vertebral body ventral to the spinal cord. Because laminectomy removes only the posterior element of the spinal column, the ventrally located tumor is often unresected and direct spinal cord decompression cannot be achieved. In addition, laminectomy can even cause instability with the removal of intact posterior elements when the anterior and middle columns are already compromised by tumor invasion. As a result, anterior surgical approaches were developed to achieve better outcomes. The rationale for anterior spinal surgery for metastatic spine disease seems intuitive and logical. First, it can provide direct spinal cord decompression with tumor resection via a vertebrectomy as most tumors are located ventrally. Second, it allows immediate interbody reconstruction and stabilization. Third, it carries a lower wound complication rate than posterior incisions. In uncontrolled surgical series with direct decompressive surgery combined with radiation, the reported posttreatment ambulatory rate was ~ 75% compared with 45% after radiation alone.^{7,14,17,26,31,38,39} A recent randomized study showed that significantly more patients treated with direct decompressive surgery followed by radiation are able to walk after treatment than those who were treated with radiotherapy alone (84% vs 57%). Patients who underwent surgery also retained the ability to walk longer, and more of them regained the ability to walk. Furthermore, surgical treatment results in a longer survival time, maintenance of continence, and a reduction in the need for corticosteroids and analgesics.³²

Traditionally, transthoracic vertebrectomy via an anterior approach requires an open thoracotomy, which can be associated with significant access morbidity.^{12,15} A traditional thoracotomy requires a large incision, muscle dissection, rib excision, and a long diaphragmatic incision for exposure of the thoracolumbar junction. These procedures can be associated with pain-control issues, prolonged chest tube drainage, and pulmonary complications. Walsh and colleagues⁴⁰ reported a morbidity rate of 29.5% and a mortality rate of 8.2% in a series of 61 patients who had undergone a transthoracic approach for resection of metastatic tumors in the thoracic spine. Complications included car-

diopulmonary (pneumonia, persistent pleural effusion, and respiratory failure), gastrointestinal, and renal symptoms, hardware failure, and cerebrospinal fluid leakage. Video-assisted thoracoscopic surgery has been used extensively by cardiothoracic surgeons. This minimal incisional approach, as compared with thoracotomy, has been associated with substantial clinical benefits, including reduced postoperative pain, shorter intensive care unit and hospital stays, shorter recovery time, faster return to activity, and reduced complication rates,^{8,10,20,21,25,27} all of which are critical to the quality of life of cancer patients with metastasis who have a mean survival of 8–12 months.^{9,39} The patients in the current study had an average blood loss of 610 ml, which compares favorably with open surgery cases. Walsh and colleagues⁴⁰ reported a median blood loss of 1 L in 61 patients who had undergone a transthoracic approach for resection of metastatic tumors in the thoracic spine. As a result, there is growing interest in applying this technique in the treatment of metastatic thoracic spine disease to achieve the same clinical benefits.⁵ The goal of this approach is to decrease access morbidity through a reduction in soft tissue trauma without compromising the safety and efficacy of the spinal procedures to be performed.

The surgical exposure to the ventral thoracic spine through the minimally invasive thoracoscopic technique is comparable to that of thoracotomy; the major differences are the extent of the superficial incisions, the muscle dissection, and the rib retraction. The 10-mm thoroscopes also provide excellent magnification and illumination. With this endoscopic technique, all levels from T-3 to L-3 can be accessed. In fact, some surgeons have found it easier to access the extreme ends of the thoracic cavity endoscopically rather than by using an open technique. For example, a thoracoscopic corpectomy at T-3 and T-4 does not require mobilizing the scapula or transecting the rhomboid muscles. Within these spinal segments, this approach can reach the entire vertebral body, the anterior spinal cord, and the ipsilateral pedicle and transverse process, thus allowing wide anterior decompression of the spinal cord, interbody reconstruction, and anterolateral stabilization, as shown by early results in our small series of patients.

On the other hand, there are some drawbacks to the use of minimally invasive thoracoscopic approaches. As with the thoracotomy, this anterior endoscopic approach cannot provide access to the posterior elements of the spine and affords only limited exposure of the contralateral pedicle. Thus, a posterior approach might be more suitable for patients with circumferential spinal cord compression. The minimally invasive thoracoscopic approach is not well suited for reduction and fixation of major spinal deformities (a posterior approach with instrumentation is needed for those circumstances). Furthermore, it can be more difficult to handle intraoperative complications such as hemorrhage and dural tears. The procedure may need to be converted to an open thoracotomy if complications occur. Finally, as with other new endoscopic techniques, the learning curve is steep because the technique requires a different set of cognitive, psychomotor, and technical skills. Nevertheless, it is the experience of the senior author that with experience the operations become easier and take less time.

The use of thoracoscopic vertebrectomy for metastatic tumors has been reported.^{10,28,34} The limiting factor in these

authors' experiences was the absence of an internal fixation system that can be applied endoscopically. Another disadvantage was the lack of an ideal interbody device. All of these authors used the Z-plate and polymethylmethacrylate for stabilization and reconstruction after endoscopic corpectomy. The Z-plate, however, is intended for use in an open implantation technique, and only time-consuming improvisation, such as screw fixation with strings to prevent loosening, enabled its use in minimally invasive procedures. In contrast, the MACS TL system was designed specifically for endoscopic procedures and has been shown to have excellent primary stability when compared with clinically well-established systems for thoracolumbar fractures.^{3,37} For interbody reconstruction, we prefer the use of expandable cages over polymethylmethacrylate because their ability to expand, collapse, and be repositioned allows a tighter fit. Furthermore, expandable cages can be used for interbody distraction if there is a kyphotic deformity associated with the pathological fracture.

Our preliminary results have demonstrated that the implantation of an interbody expandable cage and anterolateral plate can be safely performed via a thoracoscopic approach in patients with metastatic spine disease. Our initial clinical and operative results appear at least comparable with the results of open procedures and other thoracoscopic studies in patients with metastatic spine disease.^{15,34,37} A proper comparative evaluation with larger series of patients will be required to definitively compare the results of minimally invasive endoscopic spine surgery with open procedures in patients with tumors.

Conclusions

Minimally invasive thoracoscopic techniques can be applied to metastatic spine disease. The same spinal procedures (corpectomy, spinal canal decompression, interbody reconstruction, and stabilization) used during open surgery can be performed with minimally invasive techniques. Preliminary results have indicated that adequate decompression, reconstruction, and stabilization can be achieved with this technique. A larger series is required to demonstrate the potential benefit of the technique over open thoracotomy in the surgical treatment of metastatic spine disease.

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Disclaimer

The authors do not report any conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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