Minimally invasive posterior thoracic fusion

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Thoracic spine fusion may be indicated in the surgical treatment of a wide range of pathologies, including trauma, deformity, tumor, and infection. Conventional open procedures for surgical treatment of thoracic spine disease can be associated with significant approach-related morbidity, which has motivated the development of minimally invasive approaches. Thoracoscopic and, later, video-assisted thoracoscopic surgery were developed to address diseases of the thoracic cavity and subsequently adapted for thoracic spine surgery. Although video-assisted thoracoscopic surgery has been used to treat a variety of thoracic spine diseases, its relatively steep learning curve and high rate of pulmonary complications have limited its widespread use. These limitations have motivated the development of minimally invasive posterior approaches to address thoracic spine pathology without the added risk of morbidity involved in surgically entering the chest. Many of these advances are ongoing and represent the forefront of minimally invasive spine surgery. As these techniques are developed and applied, it will be important to assess their equivalence or superiority in comparison with standard open techniques using prospective trials. In this paper the authors focus on minimally invasive posterior thoracic procedures that include fusion, and provide a review of the current literature, a discussion of future pathways for development, and case examples. The topic is divided by pathology into sections including trauma, deformity, spinal column tumors, and osteomyelitis. (DOI: 10.3171/FOC/2008/25/8/E9)

KEY WORDS • minimally invasive surgery • posterior thoracic fusion • spine surgery

CONVENTIONAL open procedures for surgical treatment of thoracic spine disease can be associated with significant approach-related morbidity. Anterior approaches, either transthoracic or transdiaphragmatic, have been associated with considerable postoperative pain, shoulder girdle dysfunction, and compromised ventilation.12,39,50 The standard posterior midline approach to the spine has been associated with significant muscle morbidity, including muscle denervation, increased intramuscular pressures, ischemia, and revascularization injury.29–32,71 Ultimately, these effects can lead to paraspinal muscle atrophy, scarring, and decreased extensor strength and endurance, and can contribute to increased postoperative and long-term pain.24,37,46,48,52,80,81,68,79

In an effort to mitigate the morbidities associated with conventional open spine procedures, recent advances in minimal access technologies have led to the application of minimally invasive approaches to all regions of the spine for decompression, arthrodesis, and instrumentation. Until recently, the vast majority of advancements in minimally invasive thoracic spine surgery have been based on the thoracoscope. Thoracoscopic and later VATS were developed to address diseases of the thoracic cavity and subsequently adapted for thoracic spine surgery in the early 1990s.20,25,26,45,65 Thoracoscopic spine procedures were initially used to perform thoracic sympathectomies, treat disc herniations, address vertebral body pathology, drain abscesses, and perform tumor biopsy procedures.17 Video-assisted thoracoscopic surgery has been subsequently used for scoliosis correction, anterior interbody fusions, osteotomies, corpectomies, and vertebral body instrumentation for tumors and fractures.17,19,40,55,62

Video-assisted thoracoscopic surgery is capable of providing the same exposure as the transthoracic approach and, compared with the open approach, has been shown to reduce the incidence of pulmonary morbidity, intercostal neuralgia, and shoulder girdle dysfunction.8,13 However, VATS for the treatment of thoracic spine disease has several limitations. First, the incidence rate of transient intercostal neuralgia and pulmonary complications such as postoperative atelectasis, pneumothorax, pleural effusion, and hemothorax has been reported to be 14.1–29.4%.8,23,49 Second, the learning curve for thoracoscopic procedures is steep and requires specialized training with laboratory teaching to master.9,62,65 Third, not all thoracic levels are equally accessible, with access to the most cephalad levels limited by the progressive narrowing of the thoracic diam-
suggests that retrospectively reviewed the reported on their extensive expen-

vasceral spine pathology. Many of these advances are ongoing and represent the forefront of minimally invasive spine surgery. As these techniques are developed and applied, it will be important to assess their equivalence or superiority in comparison with standard open techniques using prospective trials. In this paper we focus on minimally invasive posterior thoracic procedures that include fusion. We divide the topic by disease into sections including trauma, deformity, spinal column tumors, and osteomyelitis.

**Trauma**

The basic principles of surgical spinal trauma management include decompression, reduction, anterior column support, restoration of the posterior tension band when indicated, and fusion. Current surgical treatment of spine trauma typically involves conventional open exposures with placement of instrumentation and fusion. A recent systematic review of the surgical management of thoracolumbar trauma by Verlaan and colleagues suggests that patients with trauma may be particularly susceptible to increased operative blood loss and infection. In this review the median blood loss was in excess of 1 liter for posterior, anterior, or combined anterior–posterior procedures, and infection rates ranged from 0.7 to 10%. These increased vulnerabilities, coupled with the frequent presence of polytrauma in patients with spine fractures, have driven the application of minimally invasive approaches to address thoracic spine trauma to reduce the morbidity associated with standard open procedures. Although the use of VATS for thoracic spine trauma has been reported, the limitations of VATS, including a steep learning curve and its associated morbidities, have significantly limited its broad application. In addition, the use of VATS in trauma cases may be compromised by difficulty achieving hemostasis and by decreased lighting due to absorption of light by blood. Recently, substantial progress has been made toward developing posterior approaches for minimally invasive thoracic fusion to address surgical trauma.

Percutaneous posterior pedicle screw/rod fixation techniques have been developed and applied to the treatment of thoracic spine fractures. These techniques can be used to provide stand-alone fixation for stable burst or flexion distraction injuries, recognizing that instrumentation may need to be removed to prevent failure. Percutaneous instrumentation may also be used to supplement an anterior decompression/reconstruction either in conjunction with or as a separately staged procedure. In addition, temporary percutaneous posterior fixation may be used to facilitate mobilization or to prevent secondary injury in the setting of an unstable injury when definitive fixation is deemed unsafe.

Wild and colleagues retrospectively reviewed the records of 21 patients with thoracolumbar fractures who had been treated using posterior stabilization, without any anterior or posterior fusion, and using either minimally invasive percutaneous instrumentation (in 10 patients) or conventional open instrumentation (in 11 patients). Inclusion criteria included a type A thoracolumbar fracture (mainly type A3) based on the Magerl classification system and an associated angular kyphosis of more than 15° or narrowing of the vertebral canal of more than 20%. Exclusion criteria included rupture of the posterior longitudinal ligaments, fractures of the vertebral joint or vertebral arch, and any neurological deficits. Implants were removed after an average of 10 months after trauma to avoid implant failure. There were no significant differences in the degree of intraoperative reduction achieved between the patients treated using minimally invasive surgery versus those treated using conventional open surgical techniques. Although slightly greater for the minimally invasive approach, neither operative time (mean 87 vs 81 minutes) nor x-ray exposure time (mean 5.7 versus 3.1 minutes) differed significantly between the 2 groups. Blood loss was significantly less among patients treated using the minimally invasive approach, both intraoperatively (mean 194 vs 380 ml; \( p < 0.001 \)) and postoperatively (mean 156 vs 441 ml; \( p < 0.001 \)). The loss of correction showed no statistically significant difference between the minimally invasive and open surgery groups at 5 years following implant removal. In addition, functional outcome, as assessed using both the Hannover Spine Score and the 36-Item Short Form Health Survey, did not differ significantly between the 2 groups. The authors did note that the conventionally treated patients were significantly older (mean 34 versus 52 years; \( p = 0.01 \)) and had a significantly greater kyphotic deformity at the beginning (\(-18^\circ \) vs \(-14^\circ \); \( p = 0.005 \)). Whether these differences significantly affect the conclusions is unclear. Although there is considerable controversy regarding which vertebral body fractures should be treated using anterior column reconstruction, this study by Wild and colleagues does suggest that minimally invasive percutaneous posterior instrumentation offers significant advantages over the conventional open approach when posterior-only fixation is indicated for the treatment of thoracolumbar fractures.

Rampersaud and associates have also retrospectively reviewed 16 thoracolumbar trauma cases in which percutaneous posterior fixation was used as the primary means of fixation (in 11 patients) or as supplemental fixation to anterior corpectomy and reconstruction (in 5 patients). In 4 of the patients without fusion, the instrumentation was removed via a minimally invasive approach after the primary injury healed (at 6–18 months). No adverse events were noted as a direct result of the minimally invasive techniques. At follow-up, ranging from 12 to 24 months, there was no evidence of construct failure or loosening. Three patients with burst fractures were noted to have angular settling of < 5°, although each of these patients showed a net improvement in segmental kyphosis when supine injury radiographs were compared with follow-up radiographs of patients in the standing position. Ringel and colleagues reported on their extensive experience with minimally invasive transmuscular pedicle screw fixation of the thoracic and lumbar spine that includ-
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ed implantation of 115 internal fixators and 488 pedicle screws in a total of 104 patients. Screws were placed at all levels of the thoracic and lumbar spine, and fused segments ranged from 1 to 5. The median surgical duration was 93 minutes, and operative blood loss was always < 100 ml. Traumatic vertebral body fracture was the indication for 68 patients (65%). Although these authors did not specifically delineate complications and outcomes based on operative indication, they reported that overall 424 screws (87%) were judged to be good, 49 (10%) were judged to be acceptable, and 15 (3%) were judged to be unacceptable. No patients experienced new neurological deficits. Immediate surgical revision, which was always performed minimally invasively, was necessary in 9 patients for pedicle screw repositioning and in 2 patients for incomplete tightening of anchor bolts. In the entire series of patients, the only complications related to implantation of the internal fixator involved 2 patients with an unacceptable screw position who had new radicular pain that resolved completely after screw repositioning, and 2 patients with delayed wound healing. All but 2 of the patients with trauma underwent subsequent anterior minimally invasive thoracoscopic interbody fusions or vertebral body augmentations. Notably, Ringel and associates employed standard instrumentation that was not specifically designed for minimally invasive approaches and had 16 surgeons involved in screw placement, including staff, fellows, and senior residents. Although this study was primarily a feasibility study and did not include clinical outcomes, it does demonstrate prospectively that minimally invasive pedicle screw fixation, including at thoracic levels, is a safe alternative to open approaches.

Beyond the capacity to facilitate reduction and restoration of the posterior tension band in cases of thoracic trauma, the application of posterior minimally invasive approaches is being extended to anterior column reconstruction and fusion. In a recent report by our group (D. H. Kim, et al., unpublished data, 2008) provide a cadaveric feasibility study and a clinical case study of an approach for minimally invasive LEC. Using 6 cadavers, the authors performed six 1-level corpectomies and one 2-level corpectomy on various levels from T-4 to T-8 through an expandable 22-mm diameter tubular retractor (Quadrant, Medtronic) via paramedian incisions. The posterolateral aspects of the vertebral bodies were accessed extrapleurally, and intraoperative fluoroscopy and postoperative CT were used to assess the degree of decompression. An average of 93% of the ventral canal and 80% of the corresponding vertebral body were removed, and in no case was the pleura or the intrathoracic contents violated. In all cases, adequate exposure was achieved to allow interbody grafting. The authors also reported a clinical case of a T-6 burst fracture with retropulsed bone fragments in the canal following a motor vehicle accident (see Case 1 below). Thus the ability to address the anterior thoracic column with regard to decompression, reconstruction, and fusion—through a posterior minimally invasive approach for the management of trauma has been demonstrated.

Despite several advances toward successful minimally invasive surgery for the treatment of thoracic spine trauma, considerable work remains. First, and perhaps most important, there have been no randomized prospective studies to demonstrate the equivalence or superiority of the minimal-invasive approach compared with the open approach for the surgical treatment of thoracic spine trauma. Second, since the Sextant (Medtronic) minimally invasive posterior spinal fusion system is primarily designed for use in the lumbar spine (for example, lordotic curvature of the rod) and is limited in the number of vertebral levels that can undergo instrumentation, greater experience needs to be achieved and reported for instrumentation systems that may be more amenable to posterior thoracic fusion, such as the Viper System (Depuy) and the Longitude System (Medtronic). Third, the utility of the minimally invasive LEC approach for anterior column decompression and reconstruction needs to be assessed through additional clinical application. The LEC approach, in conjunction with using percutaneous pedicle screws, offers the potential to treat a substantial number of surgical patients with thoracic spine trauma from an entirely posterior, minimally invasive approach. Fourth, improved techniques are needed to facilitate minimally invasive reduction of complex dislocations (such as bilateral jumped facets) that fail to reduce with traction.

Case 1

This 44-year-old woman presented with severe midscapular pain after a motor vehicle accident. Imaging studies demonstrated a T-6 burst fracture with retropulsion of bone fragments into the spinal canal (Fig. 1A). She was neurologically intact, including normal motor strength, lack of bowel or bladder dysfunction, and lack of any signs of myelopathy. After an approximately 6-month trial of conservative therapy, she continued to have unrelenting midthoracic back pain, rated as 9 of 10 based on a numeric rating scale with 0 representing no pain and 10 representing unbearable pain. She underwent a T-6 corpectomy through a minimally invasive LEC approach, (D. H. Kim et al., unpublished data) followed by T5–7 arthrodesis with a rib autograft and T5–7 posterior instrumentation using percutaneous pedicle screws and the Sextant system. Postoperative AP and lateral radiographs (Fig. 1B and C) and a CT scan (Fig. 1, inset) demonstrated good spinal canal decompression and appropriate placement of interbody autograft and instrumentation. Her operative and postoperative courses were uncomplicated, and at the 16-month follow-up, she did not report any significant back pain, remained neurologically intact, and had returned to work as a heavy equipment operator.

Spinal Deformity

Pediatric Spinal Deformity

Pediatric spinal deformity includes a broad range of disorders with differing origins, natural histories, and treatments. Both the classification systems for pediatric deformity and the decision-making process for managing pediatric spinal deformity have been recently reviewed (J. S. Smith et al., unpublished data, 2008).

Adolescent idiopathic scoliosis is the most common pediatric spinal deformity and is defined as a coronal plane deviation of the spine of > 10º, measured using the Cobb method, without any evident clinical cause. Surgical indications for AIS most commonly include cosmesis and curves that are progressive in magnitude, especially if >
In addition, VATS has been utilized for anterior column resection, and these disabilities must be considered when designing thoracoscopic instrumentation systems. Sagittal plane deformities may be present in isolation or in combination with scoliosis (kyphoscoliosis). In distinct contrast to adolescents with idiopathic scoliosis, adults with scoliosis characteristically present with significant disability, including back and leg pain and neural deficits, and these disabilities must be considered when planning surgical treatment. The differing presentations of patients with adolescent and adult scoliosis reflect the frequent degenerative changes identified in the spines of the latter group (adults), including spondylolisthesis, central and foraminal stenosis, and rigid curves resulting from autofusion. Thus, the surgical management of adults with scoliosis is substantially different from that of adolescents.

The surgical goals for treating adult scoliosis include restoration or maintenance of spinal balance in both coronal and sagittal planes, foraminal and/or central bone decompression of neural elements as indicated, and maintenance of deformity correction, typically through instrumentation and ultimately arthrodesis. Currently, these goals are most commonly achieved via open approaches using posterior instrumentation, including hooks, wires, and/or screws that are typically connected using a 2-rod system to achieve stable correction of deformity through corrective forces. Anterior approaches for discectomies and release of the anterior longitudinal ligament may be used in conjunction with posterior fusion to improve deformity correction, especially in cases of large curves (>75°) that do not correct to 50° or less on radiographs of patients during bending.

In an effort to improve cosmesis and to reduce morbidity and recovery time, minimally invasive approaches utilizing VATS have been used to treat AIS. Anterior release and discectomy using VATS has been shown to produce similar spinal mobility as when performed through a standard thoracotomy approach. In addition, VATS has been used to place anterior instrumentation for correction of thoracic and thoracolumbar AIS. Retropective reviews have suggested that thoracoscopic spine instrumentation compares favorably with anterior instrumentation through thoracotomy and with posterior fusion. Although a limited number of groups demonstrate acceptable results using VATS for the surgical treatment of AIS, this approach is not widely used, probably due in part to the relatively steep learning curve, limitations in curve correction, and the high incidence of pulmonary complications.

Development of a minimally invasive approach for the treatment of AIS that applies more conventional skills and avoids entering the chest would be a significant advancement in the surgical treatment of this deformity. Lateral interbody discectomy and fusion systems have been developed for the lumbar spine, including DLIF (Medtronic) and XLIF (NuVasive). Development of a lateral approach for thoracic discectomy and interbody fusion would enable anterior release and fusion. Subsequent percutaneous or suprafascial pedicle screw placement, in combination with minimally invasive posterior instrumentation systems such as Longitude (Medtronic) and Viper (Depuy), would permit fixation and curve correction. Once developed and applied, such a minimally invasive approach could readily address the surgical goals of AIS with potentially powerful curve correction, a limited learning curve, and without the morbidity associated with surgically entering the chest.

**Adult Spinal Deformity**

Adult spinal deformity includes patients with persistent AIS, adult de novo scoliosis, and sagittal plane deformities. Sagittal plane deformities may be present in isolation or in combination with scoliosis. In distinct contrast to adolescents with idiopathic scoliosis, adults with scoliosis characteristically present with significant disability, including back and leg pain and neural deficits, and these disabilities must be considered when planning surgical treatment. The differing presentations of patients with adolescent and adult scoliosis reflect the frequent degenerative changes identified in the spines of the latter group (adults), including spondylolisthesis, central and foraminal stenosis, and rigid curves resulting from autofusion. Thus, the surgical management of adults with scoliosis is substantially different from that of adolescents.

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The predominant use of VATS for anterior column release in deformity has been for AIS. Although VATS may also be used for this purpose in adults with scoliosis, the pulmonary complications associated with entering the chest may be less tolerated in an older population with greater comorbidities. Lateral interbody discectomy and fusion systems have been developed for the lumbar spine, including DLIF and XLIF. Development of a lateral approach for thoracic discectomy and interbody fusion would enable anterior release and fusion. Minimally inva-

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Fig. 1. Case 1. A: Sagittal T2-weighted MR image demonstrates a T-6 burst fracture with retropulsion of bone fragments into the spinal canal. B and C: Anteroposterior (B) and lateral (C) radiographs obtained after a T-6 corpectomy performed through a minimally invasive LEC approach, with T5–T7 posterior instrumentation using percutaneous pedicle screws. *Inset:* Postoperative axial CT scan at the T-6 level showing removal of the left pedicle as part of the access window for a corpectomy.

45°, because even after skeletal maturation curves of this magnitude frequently progress. A less common surgical indication is back or rib pain unresponsive to conservative therapy. Neurological symptoms (such as radiculopathy) or deficits (such as motor weakness) are rare among patients with AIS. Thus, the surgical goals for treating AIS are primarily based on curve correction and restoration or maintenance of coronal and sagittal balance. Currently, these goals are most commonly achieved through open approaches using posterior instrumentation, including hooks, wires, and/or screws that are typically connected using a 2-rod system to achieve stable correction of deformity through corrective forces. Anterior approaches for discectomies and release of the anterior longitudinal ligament may be used in conjunction with posterior fusion to improve deformity correction, especially in cases of large curves (>75°) that do not correct to 50° or less on radiographs of patients during bending.

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We based our decision on the recent report by D. H. Kim and colleagues (unpublished data, 2008). Subsequent percutaneous or suprafascial pedicle screw placement in combination with minimally invasive posterior instrumentation systems such as Longitude and Viper can then be used to achieve fixation and correction of the thoracolumbar spine. Given that a frequent goal for surgical treatment of adult scoliosis is decompression of the neural elements, it may also be feasible to perform short-segment minimally invasive decompressions in combination with short-segment minimally invasive posterior fixation.

Case 2

This 76-year-old woman presented with an approximately 2-year history of severe low-back pain and bilateral lower extremity radiculopathy, more severe on the right and extending from the buttocks to the anterolateral thighs and calves. Her symptoms failed to significantly improve after using conservative therapies, including pharmacological management, physical therapy, and epidural steroid injections. She was neurologically intact, with normal motor strength, normal bowel and bladder function, and no signs of myelopathy. Preoperative radiographs demonstrated a thoracolumbar major curve and a compensatory thoracic curve. The thoracolumbar major curve measured 57° and corrected to 23° on radiographs of the patient during bending, and the compensatory thoracic curve measured 23° and corrected to 19° on radiographs of the patient during bending. The coronal and sagittal balances measured −9.3 cm and +11 cm, respectively. Preoperative MR imaging (E) demonstrates reasonable preservation of the L5–S1 disc, whereas axial T2-weighted MR images at the level of L4–5 (F and G) demonstrate moderate to severe bilateral foraminal stenosis. H and I: Anteroposterior (H) and lateral (I) full-length radiographs of the patient following T12–L4 DLIFs, L4–5 TLIF, L4 Smith-Petersen osteotomies, T12–L3 inferior articular process releases, and T10–L5 minimally invasive pedicle screw and rod fixation. These postoperative radiographs demonstrate correction of the thoracolumbar major curve to 4° and correction of the compensatory thoracic curve to 4°. The postoperative coronal and sagittal balances were improved to −1.7 cm and +5 cm, respectively.

The patient underwent a 2-stage operation. The first stage consisted of T12–L1, L1–2, L2–3, and L3–4 DLIFs through a single left-sided incision of approximately 4 cm. The second stage included an L4–5 minimally invasive TLIF using METRx X-Tube (Medtronic), Cornerstone interbody graft (Medtronic), bone morphogenetic protein (BMP, Medtronic), and local bone autograft. Suprafascial minimally invasive Smith-Petersen osteotomies were performed at L-4 and bilateral inferior articulating process releases were performed at T12–L1, L1–2, and L2–3. Minimally invasive pedicle screw and rod fixation from T10–L5 were performed using the Longitude system. Posterior arthrodesis at T10–11 and T11–12 was performed using bone morphogenetic protein. Postoperative radiographs demonstrated correction of the thoracolumbar major curve to 4° and correction of the compensatory thoracic curve to 4° (Fig. 2H–L). The postoperative coronal and sagittal balances improved to −1.7 cm and +5 cm, respectively. Although the patient had been receiving high doses of narcotics for pain relief preoperatively, at 6 weeks postoperatively she was nearly pain free and required only acetaminophen for mild back discomfort.

The decision whether to discontinue a long fusion at L-5 or the sacrum remains controversial. Prior studies have suggested a higher incidence of subsequent L5–S1 disc degeneration in constructs ending at L-5 than in those that include the sacrum; however, studies have also suggested that constructs extending to the sacrum are at greater risk of requiring revision surgery and are associated with a greater frequency of major complications, including nonunion and medical morbidity. We based our decision...
to stop at L-5 on the lack of significant L5–S1 disc degeneration, lack of L-5 spondylolysis, lack of significant pelvic obliquity, and lack of previous or current need for L5–S1 decompression.

Tumors of the Thoracic Spinal Column

The specific goals of surgical management of tumors of the spinal column depend on multiple factors, including the tumor type, extent of involvement of the spine, spinal stability, overall staging, life expectancy of the patient, and extent of compromise of the neural elements. Current surgical treatment of thoracic spinal column tumors involving the vertebral body typically includes tumor resection through either an open thoracotomy or through an open LEC with subsequent anterior column reconstruction, often supplemented with posterior column fixation. Given the often greater comorbidities of patients with cancer, efforts have been made to reduce the morbidity of surgical treatment for these patients.

A limited number of surgeons have reported experience using VATS to access tumors of the thoracic spinal column.\textsuperscript{22,27,57,63,70,74} Often, this also requires posterior instrumentation, and reports have documented the use of minimally invasive percutaneous pedicle screw fixation to supplement thoracoscopic anterior reconstructions.\textsuperscript{53} The limitations of VATS, including the potential morbidities associated with entering the chest cavity and the steep learning curve, leave room for improvement in the development of minimally invasive approaches to treat these patients.

As discussed above, D. H. Kim and associates (unpublished data, 2008) recently described a minimally invasive approach for LEC. Although primarily a feasibility study, they do provide a description of a successful clinical case involving a trauma patient. Application of this technique to patients with thoracic spine tumors offers the potential to reduce surgical morbidity in these often medically compromised patients. One of the greatest advantages of this approach is the ability to directly visualize the spinal cord throughout the decompression. In addition, the prone positioning of the patient in this approach enables percutaneous posterior instrumentation in a single stage. The clinical effectiveness of the minimally invasive LEC in the treatment of thoracic column tumors awaits application and comparison with the open or thoracoscopic approaches.

Case 3

This 55-year-old man presented approximately 6 months after radiation treatment for plasmacytoma of the T–4 and T–5 vertebrae with epidural extension (Fig. 3A–E). No additional lesions were identified on extensive systemic evaluation. He complained of stable bilateral lower extremity decreased sensation and dysesthesia, and circumferential chest tightness. Neurological examination results were within normal limits, including pinprick assessment of sensation in the lower extremities. The patient underwent minimally invasive posterior T4–5 vertebrectomy using the METRx Quadrant retractor system (Medtronic) with expandable cage reconstruction, followed by percutaneous pedicle screw placement from T–3 to T–6 using the Sextant

Fig. 3. Case 3. A–C: Anteroposterior (A) and lateral (B) thoracic spine radiographs and sagittal CT reconstruction imaging (C) demonstrate a plasmacytoma involving T-4 and T-5 in a 55-year-old man. D and E: Sagittal (D) and axial (E) T1-weighted MR imaging with gadolinium enhancement shows a tumor in the T-4 and T-5 vertebrae as well as significant epidural extension. F and G: Anteroposterior (F) and lateral (G) thoracic spine radiographs obtained after a minimally invasive posterior T4–5 vertebrectomy with expandable cage reconstruction, followed by percutaneous pedicle screw placement from T-3 to T-6. H and I: Postoperative axial CT images at the T-3 level demonstrate screw placement.
Minimally invasive posterior thoracic fusion system (Fig. 3F–I). There were no surgical complications, and the patient was discharged home.

Osteomyelitis

The goals of surgical management of osteomyelitis include ensuring adequate decompression of the neural elements, debridement if active infection persists, restoration of spinal alignment, and restoration and/or maintenance of spinal stability. Osteomyelitis of the thoracic spine may result in collapse of the vertebral body with potential spinal cord compromise and/or kyphotic deformity. Current surgical treatment may include a corpectomy and reconstruction for spinal cord decompression and/or restoration of normal spinal alignment. Treatment of osteomyelitis using VATS has been described.

Ringel et al.°° reported on a large series of patients undergoing minimally invasive transmuscular pedicle screw fixation of the thoracic and lumbar spine, including 26 patients with osteomyelitis. The intent of the procedure was to first provide posterior fixation and to subsequently perform anterior minimally invasive interbody fusions or vertebral body augmentations using VATS. Interestingly, 15 of the 26 patients were considered unfit for the usual staged anterior thoracoscopic approach due to multiple comorbidities. Thus, these patients were ultimately treated solely with percutaneous fixation and prolonged antibiotics. Although the authors did not provide follow-up data, such a construct is at significant risk of failure. Development of a minimally invasive surgical approach without the attendant risks of VATS could broaden the ability to treat thoracic osteomyelitis patients in need of surgery.

The minimally invasive LEC described by D. H. Kim and colleagues (unpublished data, 2008) has the potential to address the anterior column without surgically entering the chest and would enable combining percutaneous pedicle screw fixation into a single-stage procedure. The effectiveness of the minimally invasive LEC in the treatment of surgical thoracic osteomyelitis awaits application and comparison with alternative approaches.

Conclusions

Conventional open surgical procedures for treatment of thoracic spine disease can be associated with significant approach-related morbidity. Although the use of VATS for anterior approaches has been shown to offer several advantages compared with open thoracotomy, it has failed to gain widespread use. Recent advances in minimal access technologies have led to the development of posterior minimally invasive approaches for thoracic fusion. These techniques have been applied to a broad range of conditions, including trauma, deformity, tumor, and infection. As these novel techniques are developed and applied, it will be important to assess for their equivalence or superiority in comparison with standard open surgical techniques using prospective trials.

Disclosure

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