Minimally Invasive Anterolateral Corpectomy for Spinal Tumors

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INTRODUCTION

Surgical approaches for disorders of the thoracolumbar spine have traditionally included an anterior or posterior approach, or some combination of the two. The technique used generally depends on surgeon preference, lesion location, pathologic process, and affected level. Spine tumors are classified as extradural, intradural-extramedullary, or intramedullary. Most of these include benign intradural-extramedullary tumors that may grow to compress neural elements to cause symptoms. In the era of modern medicine, treatment options for primary or metastatic spine tumors include radiation, radiation plus chemotherapy, stereotactic radiosurgery, hormonal therapy, or surgical decompensation followed by radiation. However, vertebral tumors often require surgical treatment to obtain tissue for diagnosis, decompress neural elements, control pain, improve quality of life, alleviate symptoms, and address spinal instability pursuant to encroachment of the osseous anatomy. Radiation and chemotherapy alone are options for patients either with palliation in mind, or with newly diagnosed disease that shows no evidence of neurologic compromise or spinal instability. When surgery is indicated, the surgeon must consider histologic type of the tumor, prior treatments, tumor location (in the global spinal picture but also within the vertebral body or spinal column), and the patient’s life expectancy.

More than 90% of spinal column tumors in the United States are metastatic, most commonly from breast, lung, and prostate, while 30% to 70% of patients with cancer have vertebral involvement. The thoracic spine is most commonly involved with neoplasm (70%), followed by lumbar (20%) and cervical (10%), while multiple levels are affected in up to one-third of cases. Approximately half of all spinal tumors are extradural, 35% to 40% are intradural-extramedullary, and the remaining 5% to 10% are intramedullary.
In comparison with metastatic disease, primary osseous neoplasms are uncommon and are classified as benign or malignant. Such tumors can include osteoid osteoma, osteoblastoma, osteochondroma, aneurysmal bone cyst, eosinophilic granuloma, and cavernous hemangioma among the benign lesions; malignant pathology can include giant cell tumor, plasma cell tumor, lymphoma, osteosarcoma, chondrosarcoma, chondroma, and Ewing sarcoma. Patients most commonly present to their physician with complaints of progressive back or neck pain, although weakness may be a presenting symptom in cases where neural elements are compressed. Treatment options vary based on complete or incomplete deficits. One of the greatest stimuli for the advent of minimally invasive surgical (MIS) approaches is the reduction of morbidity through traditional surgery. This aspect is especially evident in the thoracic spine, where traditional anterior and posterior approaches are associated with significant morbidity. This article describes MIS anterolateral corpectomy in the treatment of spinal tumors, and reviews the current literature.

ANTERIOR-BASED APPROACHES

Traditional surgical approaches for the treatment of spinal tumors include anterior-based and posterior-based approaches, or a combination of both. Anterior transthoracic approaches have long been established in the management of many pathologic conditions of the anterior thoracic spine. The anterior approach offers easier access to the ventral aspect of the spine and allows decompression without the associated risks of spinal cord or nerve root manipulation but often requires a thoracotomy. There is significant morbidity associated with a thoracotomy, including pain from a large incision and increased muscle dissection, prolonged chest drainage, pulmonary complications such as contusions, atelectasis, effusions, hemothorax and chylothorax, and an extended hospital stay. Major complications with use of the thoracotomy approach have been shown in as many as 79% of patients. A lateral retropleural approach aims to be less destructive to the surrounding tissues by not compromising the pleura and using serial dilation as a course to the abnormality. In a more anterior approach the abnormality is encountered first, and the neural elements cannot be visualized until ventral decompression is completed. However, in the lateral retropleural approach the surgeon is able to visualize the thecal sac during the approach to the lesion, affording access to both the thecal sac and the abnormality at the same time. Occasionally the anterior longitudinal ligament may need to be resected, potentially leading to destabilization.

To mitigate some of the morbidity of the anterior approaches, MIS thoracoscopic techniques were developed and have proved to be effective, but challenging, in terms of learning curve and application. These approaches have been adopted as a means of gaining anterior access to the thoracic spine without requiring large incisions or rib resection. Complications, including transient intercostal neuralgia, postoperative atelectasis, pneumothorax and hemothorax, and pleural effusion, are considered to occur with a lower incidence than for open thoracotomies, with a reported range of 14.1% to 29.4%. The lateral retropleural MIS approach to the thoracolumbar spine is considered a variant of the thoracotomy, but combines many of the positive attributes of both anterolateral transthoracic approaches and the lateral extracavitary approach. It affords the surgeon the ability to remain outside the pleura while achieving a ventral decompression of the dural sac, which is especially important with centrally located abnormalities.

POSTERIOR-BASED APPROACHES

Indications for posterior approaches in spine oncologic surgery, which were first introduced by Capener and later modified by Larson and colleagues, include tumors involving the posterior elements or extending into the anterior column. Resection of the posterior elements, epidural tumor, and involved vertebral bodies can be performed through the transpedicular, costotransversectomy, or lateral extracavitary approach, depending on the location of the tumor and how far lateral and anterior the surgeon wishes to be. In general, posterior approaches to perform a corpectomy for tumor resection require the surgeon to visualize and occasionally manipulate the neural elements before encountering the abnormality. These approaches have the advantage of being familiar to most neurosurgeons, allowing for vertebral reconstruction and simultaneous posterior spinal instrumentation and fixation, and are especially suitable for upper thoracic lesions and multi-level disease, or in the setting of multiple medical comorbidities. However, visualization of the dural elements is limited to an oblique view. Extensive muscle dissection is required, and may be associated with copious blood loss. Sectioning of nerve roots may be required for placement of an interbody device, and its size or footprint is limited secondary to constraints imposed by a posterior approach, potentially leading to an increased rate of subsidence or pseudarthrosis.
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.11,28

The lateral retropleural extracavitary approach10,11,29 is a posterior-based option that provides access to the ventral vertebral column, but is associated with dissection of the lateral paravertebral musculature. It permits a direct view of the dura, neural elements, and any anterior abnormality simultaneously, and allows exposure of the lateral canal without potentially sacrificing the intercostal nerve or intraforaminal radiculomedullary artery.22,24 The dissection remains extrapleural, in contrast to the transthoracic approach, with a decreased risk of injury to the aorta, vena cava, and sympathetic plexus, as well as development of a duropleural cerebrospinal fluid (CSF) fistula.11,30,31 This approach is less destabilizing, with preservation of the anterior and posterior longitudinal ligaments and the posterior ligamentous structures. Just as for the other open techniques, a relatively large incision and extensive rib resection are again required.

In either case, proceeding through a traditional open approach leads to longer incisions than those required through a MIS approach. Larger wounds may prove more difficult to heal, particularly in this patient population who are often subjected to immunosuppressive chemotherapy and radiation for treatment of their underlying neoplasms.32,33 Patient pain and discomfort are also minimized through a less invasive approach from decreased surgical trauma. The advancement of several technologies, including tubular and expandable retractors, specialized instruments, and fiber-optic light sources, have allowed for the development of MIS techniques. In the following sections, the authors present their technique for MIS anterolateral approaches for the treatment of spinal tumors.

LATERAL-BASED APPROACHES

In an effort to avoid the morbidity related to a thoracotomy/thoracoscopic approach and the limited access/ extensive tissue dissection associated with posterior approaches, McCormick11 developed the lateral retropleural thoracotomy. This technique permits a direct view of the neural elements without the need to dissect or potentially sacrifice the intercostal nerve or intraforaminal radiculomedullary artery.1,22,24 Because of the extrapleural nature of the approach, there is less risk of injury to the aorta, vena cava, and sympathetic plexus, and a reduced risk of developing a duropleural CSF fistula.11,30 The anterior and posterior longitudinal ligaments are preserved, in addition to the posterior ligamentous structures, which provides for a less destabilizing surgery. However, this approach requires a significant incision and extensive rib resection (Fig. 1).

The MIS lateral approach uses the already outlined fundamental principles that provide a benefit from using the lateral retropleural approach. However, because of technological advances in retraction and instrumentation as well as fiber-optic light sources, the MIS version allows for a much smaller incision and a smaller amount of rib resection (Fig. 2). Blood loss, postoperative pain, time to mobilization, and hospital stay are all reduced with MIS approaches.34–37 However, they demand a significant amount of experience and entail a steep learning curve. The next section outlines the steps used in this procedure.

Surgical Technique and Anatomic Considerations

Preoperative planning

Initial evaluation begins with the history and physical examination. Pain, usually progressive in nature and either localized to the back or in a radicular distribution, is the most common presenting symptom. Neurologic deficit manifesting as motor weakness and/or sensory derangement can occur from compression or involvement of the spinal cord or nerve root, particularly for intradural tumors. Progressive spinal deformity may also occur.1,3

Radiographic evaluation nearly always includes magnetic resonance imaging (MRI) with and without contrast or, if MRI is precluded, a computed tomography (CT) myelogram, to delineate the lesion and assess the degree of neural compression. CT is recommended to determine the extent of vertebral involvement and for surgical planning. Standing scoliosis radiographs can be

Fig. 1. Lateral extrapleural thoracotomy approach. (From Schmidt MH, Larson SJ, Maiman DJ. The lateral extracavitary approach to the thoracic and lumbar spine. Neurosurg Clin N Am 2004;15:438; with permission.)
obtained to assess for any deformity, and flexion-extension films are appropriate if there are questions regarding instability. Radioisotope bone scans are sensitive for spinal column tumors demonstrating osteolytic or osteoblastic activity, and are frequently used for small lesions such as osteoid osteoma or for detecting metastases in the setting of known malignancy.\textsuperscript{38} Angiography is useful for hypervascular tumors, such as aneurysmal bone cyst, hemangioma, renal cell carcinoma, melanoma, or chordoma, to determine their blood supply and for preoperative embolization to reduce intraoperative blood loss.\textsuperscript{39–41}

\section*{Preparation and patient positioning}

The surgical techniques for the MIS lateral approach for access to the thoracic spine have been described previously.\textsuperscript{1,42,43} The patient is positioned under fluoroscopic guidance and is secured in a true and direct lateral decubitus position on a flexible radiolucent surgical table. For procedures involving only thoracic levels, the patient is positioned with the table break under the midsurgical level. The side of the approach is chosen depending on the location of the abnormality, surrounding viscera, and the vertebral level. Under fluoroscopic guidance, the index vertebral body level and abnormality are located and marked on the skin (see Fig. 2). A 3- to 6-cm oblique incision is marked parallel to the rib traversing the pathologic vertebral body at the midaxillary line.

\section*{Surgical approach}

The incision is made obliquely over the rib across the region delineated by the skin markings made previously. Dissection is carried down through the subcutaneous tissue to the ribs or intercostal space. Five centimeters of the immediately underlying rib, directly over the lesion, is dissected in a subperisteal fashion. Using a rib dissector or Cobb elevator, the rib is removed from the underlying pleura and neurovascular bundle, removed, and saved for autograft. The intercostal muscles and parietal pleura are incised to enter the thoracic cavity for a transthoracic approach, while the parietal pleura is swept anteriorly with blunt finger dissection for a retropleural approach. Further rib resection may be required if a larger exposure is needed. The rib resected for access to the thoracolumbar junction usually corresponds to 2 levels above the desired vertebral level (ie, 10th rib for access to T12, 11th rib for L1, and 12th rib for L2).\textsuperscript{43}

An index finger is used to enter the pleural space (for a transpleural approach) or the plane between the endothoracic fascia and pleura (for a retropleural approach). The appropriate plane is developed, and diaphragm and/or lung are mobilized anteriorly using a finger and/or sponge stick until the lateral face of the vertebral body, pedicle, and adjacent intervertebral discs are exposed. For access to the thoracolumbar junction, it should be noted that removal of the diaphragmatic-costal attachment may be required. Because of the lateral (costal) diaphragmatic insertion, and for access to L1, the lumbar or posterior attachments of the diaphragm must be sharply transected off the transverse process of L1. The intervening attachment between the medial and lateral arcuate ligaments must also be cut to fully expose the lateral vertebral body. If more anterior exposure of the vertebral body is needed, the ipsilateral crus, which extends along the anterolateral spine to L2 on the left and L3 on the right, may also be transected.\textsuperscript{42} Complications arising from this technique have yet to be reported, but further analysis may be mandated. For a left-sided approach, the aorta and hemiazygos vein are also retracted anteriorly. Segmental vessels are ligated as proximally as possible. Sequential tubular dilators are then inserted, and an expandable retractor system (MaXcess; NuVasive, Inc, San Diego, CA) is inserted over the largest dilator and secured with a flexible table-mounted arm assembly (Fig. 3).

\section*{Surgical procedure}

With the retractor placed and adequate exposure obtained, the operation is continued using standard surgical techniques. Resection of tumor, decompression of neural elements, and, when necessary, stabilization of the spine can be performed using this approach. For a guide to the

\textbf{Fig. 2.} Minimally invasive surgical approach with smaller incision and rib resection.
location and proximity of the spinal canal, dural exposure is performed before the corpectomy by removing the pedicle with rongeurs and a high-speed drill. The intervertebral discs above and below the vertebral body of interest are then removed, and osteotomes are used to delineate the area of the corpectomy. At this point, bony removal can be achieved using a combination of rongeurs, curettes, high-speed drills, and osteotomes. A thin layer of bone on the ventral and contralateral sides of the body and the anterior longitudinal ligament are preserved to protect mediastinal and thoracic structures.

For corpectomies, ventral reconstruction is performed using expandable titanium cages, biological allograft, and the rib autograft harvested during the approach. Spinal instrumentation is completed using ventrolateral plate/screw fixation through the expandable retractor and/or percutaneous posterior pedicle screw/rod fixation. Dural repair, when necessary after resection of intradural tumor, is performed with a running 5-0 suture. The dural repair is reinforced with fibrin glue, and CSF is drained through a lumbar catheter.

Following a transthoracic approach or in the event of a pleural violation air must be removed from the pleural cavity, which is traditionally accomplished by placement of a chest tube. Alternatively, a red rubber catheter can be situated in the pleural space through the wound, and placed under a water trap (ie, with the distal end submerged under water). The surgical wound is closed in standard fashion, including the muscular and fascial layers. The red rubber catheter is secured with a purse-string stitch, and a Valsalva maneuver with end-inspiratory hold is performed until no more air bubbles are observed to emanate from the submerged distal end of the catheter, representing evacuation of all air from the thoracic cavity. The red rubber catheter is removed as the purse string is tied. This technique obviates the use of a chest tube.

Postoperative care
A chest radiograph is obtained in the recovery room and on the morning of postoperative day 1, to verify the absence of pneumothorax if the aforementioned red rubber technique was used, or to verify placement and position of a chest tube if one was placed intraoperatively. In this case, it is initially placed on suction and weaned to water seal; serial chest radiographs are obtained to confirm reexpansion of the lung before removal of the chest tube. Declining oxygen saturation or recurrence of a pneumothorax warrants further evaluation and, if necessary, surgical reexploration. It is the authors’ practice to mobilize patients postoperatively with thoracolumbosacral orthoses, and obtain upright radiographs to verify hardware placement and stability.

Outcomes Using a Minimally Invasive Anterolateral Approach
Uribe and colleagues presented a series of 21 consecutive patients treated for thoracic spine tumors via an MIS lateral approach, 13 of who required corpectomy. Overall, the mean operating time was 117 minutes, estimated blood loss was 291 mL, and length of hospital stay was 2.9 days; for the group undergoing corpectomy,
the mean operating time was 124 minutes, estimated blood loss was 374 mL, and length of hospital stay was 3.5 days. There was 1 perioperative pneumonia, representing the lone complication in the series, and during a mean follow-up period of 21 months, 2 patients had residual tumor and 2 patients died of extraspinal metastasis. All 5 of these patients had undergone corpectomy. All patients either remained neurologically stable or improved with regard to their preoperative deficit, and pain and outcome measures demonstrated improvement from preoperatively to last follow-up. All patients required rib resection. No patient required single-lung ventilation during the procedure. However, subtotal resection of metastatic tumors (5 of 21) was not considered a failure of the technique.

Comparable data in the literature are scarce. A MEDLINE search performed on July 21, 2013 including the terms “corpectomy,” “spinal fractures,” “spinal fusion,” “thoracic vertebrae,” “postoperative complications,” “lumbar vertebrae,” “spinal cord compression,” “minimally invasive,” “MIS,” and “tumor” revealed 367 articles, more than 95% of which pertained to intracranial, cervical, or peritoneal visceral disease, were not available in English, or were limited to percutaneous vertebroplasty or kyphoplasty. There are several series of MIS approaches for spinal tumor, but in each case the approach was posterior or posterolateral for epidural or intradural-extradural tumors.44–46 There was one series of 8 transpedicular partial vertebrectomies without vertebrectomy reconstruction,47 and one case report of a transpedicular vertebrectomy with expandable titanium cage placement and percutaneous posterior instrumentation and fusion from T1 to T8.48 The latter case reported a blood loss of 1400 mL with a total operative time of 7 hours; the patient had a good neurologic outcome and was discharged on postoperative day 5.

Outcomes with the MIS anterolateral approach compare favorably with those of thoracoscopic techniques; Ragel and colleagues49 reported on a series of 21 anterior vertebral body reconstructions, 6 for tumor. Operative time, estimated blood loss, and length of hospital stay in this subset of patients were 4.9 hours, 758 mL, and 8.2 days, respectively. There was no difference with regard to these variables in a comparison with another group of 10 patients from the same institution who also underwent anterior vertebral body reconstruction via a traditional, open approach.49

Perhaps the best comparison can be found in a series of 39 patients undergoing corpectomy, 11 for tumor, by mini-open approaches using the SynFrame (Stratec Medical, Oberdorf, Switzerland) retractor, which is table-mounted like the MaXcess but fixes retractors around a ring, whereas the MaXcess is an expandable tubular retractor system. Five of the patients underwent a transthoracic approach for abnormality between T5 and T11; 3 patients underwent a transthoracic transdiaphragmatic approach for abnormality between T12 and L2; and the remaining 3 patients with lumbar abnormality underwent a retroperitoneal approach. Aside from use of a double-lumen endotracheal tube for ipsilateral lung deflation on entering the pleural cavity, slightly longer incisions and rib resections (6–10 cm in this series vs 6 cm), and chest-tube placement, the technique was largely similar. Including all patients in the series the mean total operative time and estimated blood loss was 181 minutes and 632 mL, and 188 minutes and 711 mL for the tumor patients. For the thoracic patients, inclusive of both tumor and trauma patients, the mean total operative time and estimated blood loss were 178 minutes and 535 mL; for those undergoing the transthoracic transdiaphragmatic approach, 178 minutes and 644 mL. Complications included a durotomy repaired with fibrin glue and muscle patch, a superficial wound infection, a postoperative ileus, and 2 cases of ilioinguinal hyposthesia.50

An earlier study also using the SynFrame reviewed the outcomes of 65 consecutive cases of anterior vertebral reconstruction via mini-open transthoracic approach (for thoracic or thoracolumbar abnormality) or retroperitoneal approach (for lumbar abnormality), 6 of which were for metastatic disease. The overall mean operating time was 170 minutes and blood loss was 912 mL; in the tumor cases the mean operative time was 112 minutes, which extended to 153 minutes in cases when removal of intracanal tumor or debris was necessary. In 4 of the metastatic cases, the reconstruction was performed using expandable Synex cages (Stratec Medical, Switzerland); the other 2 reconstructions were performed with steel plates filled with acrylic cement. In none of the 65 cases was single-lung ventilation necessary, nor were there any cases of intercostal neuralgia or post-thoracotomy complications.51

Mühlbauer and colleagues52 presented a small series of 5 lumbar anterior reconstructions, 1 for metastatic prostate tumor. The mean operative time in their series was 6 hours (5.1 hours for the anterior decompression and 7.25 hours for the 360° fusion) and the mean estimated blood loss was 1120 mL. To facilitate exposure, the MIASpas self-retaining retractor system was used. This system does not require table mounting, but is instead secured in place with 2 anchoring screws at the adjacent vertebral levels, analogous to a Caspar
pin retraction system for anterior cervical discectomy. The surgical approach used was similar to the description given herein of the lateral access to the lumbar spine, except that the investigators transected the medial insertions of the psoas and retracted the muscle dorsally. The tumor patient was fully ambulatory at 1 year.

**Advantages of the Minimally Invasive Lateral Approach**

The MIS lateral approach offers the advantages of using smaller incisions, leading to fewer wound-related complications and somatic pain, earlier mobilization, and shorter recovery times, which have been shown for other spine indications to increase pulmonary and metabolic function and decrease the risk of medical complications related to inactivity. Decreased blood loss, reduced incidence of unintended CSF leak, greater preservation of biomechanically important spinal anatomy, and decreased incidence of postoperative spinal instability and deformity are additional advantages of MIS approaches to spinal tumors. In comparison with more traditional approaches, adequate exposure to achieve the goals of surgery can be obtained with direct visualization of the abnormality while avoiding the extensive muscle dissection associated with posterior approaches or single-lung ventilation, large incision, and extensive rib resection required by anterior approaches. Furthermore, for a retropleural approach, tumor cell dissemination into the chest cavity is limited or prevented in comparison with open thoracotomy.

**Limitations of the Minimally Invasive Lateral Approach**

One major drawback of the MIS lateral approach is that the working distance is long in a relatively narrow working space. Familiarity with MIS techniques and experience working through these retractor systems is recommended. Dissection through the retropleural space may be rendered difficult if adhesions from previous ipsilateral thoracotomy are present. Similarly, spinal osteomyelitis and/or metastases can manifest with adhesive thickening of the parietal pleura and/or infiltration of the pleura by tumor or inflammatory fibrous tissue. In addition, if posterior instrumentation is required, a second incision must be made. It must be kept in mind that the MIS lateral approach is not a silver bullet intended to uniformly treat all neoplastic spinal abnormalities; depending on the location of the abnormality, more traditional approaches may be favorable. The posterior approach would be chosen for primarily posterior element involvement or tumor with or without bilateral pedicle invasion, as well as for lesions of the upper thoracic levels (T1–T4), given the anatomic constraints imposed by the mediastinum anteriorly and the axilla laterally at these levels.

**SUMMARY**

The MIS anterolateral approach offers direct visualization of the ventral and lateral spine, with surgical access to vertebral body and neural elements without the morbidity concomitant with either anterior or posterior approaches. Its safety and efficacy have been demonstrated in the treatment of spinal tumors, including corpectomy and vertebral reconstruction, with results comparable with or superior to more traditional approaches. It is an excellent option as choice of surgical approach and should be in the armamentarium of all spine surgeons.

**REFERENCES**


