Few disorders have undergone more dramatic changes in neurosurgical management than thoracic disc herniation and its evolving diagnosis and treatment. A relatively unusual diagnosis for the neurosurgeon to make, this disorder accounts for approximately five of every 1000 disc herniations encountered in the clinical setting. The natural history can vary from a chronic pain disorder to sudden catastrophic neurological compromise.

In 1911, the first surgical procedure for a herniated thoracic disc was reported by Middleton and Teacher (as described in Benjamin); it involved a patient with paraplegia who subsequently died. This dismal outcome was unfortunately not uncommon for patients with this disorder as recognition of the disease evolved.

The diagnosis of thoracic disc herniations had always presented a challenge, especially when based solely on history and clinical findings. Imaging this region of the spine, which is contained within the surrounding chest cavity within a plethora of different tissue densities, is also difficult. Before the introduction of MR imaging, clinicians were limited to the use of plain x-ray film and CT scanning. Plain films were useful when a calcified protrusion was present; however, although thoracic discs do have a higher tendency to become calcified than herniated discs in other vertebral locations, fewer than one half of these calcifications are evident on plain film studies. The advent of myelography and CT myelography dramatically improved the clinician’s ability to recognize thoracic disc disease radiographically. Overall, however, MR imaging is still the first-line modality for imaging the thoracic spine (Fig. 1). In the modern era of diagnostic MR imaging, the CT myelogram remains an indispensable adjunct in both the diagnosis of herniated disc material and is equally important in determining exactly which vertebral segment is involved. The risk of performing surgery at the wrong spinal level is ever present and obliges the surgeon to be vigilant and definitive in identifying the appropriate surgical level.

As stated earlier, the treatment of herniated thoracic discs has undergone significant changes since the first surgeries were attempted. Early cases were treated solely via a dorsal approach and involved a significant risk of causing irreversible paraplegia, with operative mortalities approaching 10%. As surgeons began to explore alternative techniques that allowed the lateral and ventral surface of the thecal sac to be exposed, the risk of neurological injury was reduced dramatically. The last decade has seen the application of minimally invasive methods to the treatment of thoracic disc herniation; these procedures have brought about a significant change in the postoperative care of these patients: critical care requirements and discharge times have been reduced dramatically.

The purpose of this report is to review the evolution that has taken place in the treatment of thoracic disc herniation, with special attention to improvements in anatomical approaches and advances in technology. Special emphasis will be given to the technique of thoracoscopic surgery for disc herniation.
HISTORY OF SURGERY FOR THORACIC DISC HERNIATION

Dorsal Approaches

Early treatment options for spinal cord compression from disc herniation were limited to simple laminectomy. The first known case of a surgically treated disc herniation was reported in 1922 by Adson (as described by Zeidman, et al.,) who performed laminectomy and disc removal.

Mixter and Barr reported three cases of ruptured thoracic disc herniations in 1934. Two of these patients developed postoperative transverse myelopathy, and the other was only mildly improved after some time (see Zeidman, et al.,) for historical review). The results of many other early dorsal approach procedures for herniated discs were typical equally dismal. In a pivotal paper published in 1952, Logue reported the results of surgery in a series of 11 patients: three postoperative cases of paraplegia, two deaths, and two cases of mild improvement after a temporary increased motor weakness. In 1969, Perot and Munro reviewed 91 cases from the literature on herniated thoracic discs, all treated by dorsal approaches. Exceptionally, Horwitz, et al., reported good outcomes in five consecutive cases of herniated thoracic discs treated using a dorsal approach.

Many variations in surgical technique were applied in these early cases. Some surgeons advocated simply performing a decompression without disc removal to avoid the potentially harmful effects of spinal cord manipulation required to reach the ventrally located disc herniation. The opposite extreme was to attempt to reach the disc material via an intradural approach that involved sectioning the denticulate ligaments with adjunctive rhizotomy. It was believed that this approach permitted improved ventral visualization. The significant rate of postoperative neurological deficits after laminectomy for thoracic disc herniation was thought to be due to a combination of vascular insufficiency and microcontusions secondary to spinal cord manipulation.

Posterolateral Approaches

To avoid spinal cord manipulation, many surgeons began to look for approaches that would allow a more direct approach to the disc space.

As with many of the surgical techniques that have been applied to the thoracic spine, the costotransversectomy bears its roots in the treatment of Pott’s disease. In 1894, Ménard first described the use of this technique to reach the vertebral body via an expleural route. In 1958 Hulme used costotransversectomy to treat thoracic disc herniation. The use of rib resection and removal of the transverse process in this approach provides a significantly more ventral window than that of laminectomy or later transpedicular techniques.

In 1978, Patterson and Arbit (as mentioned in Zeidman, et al.,) described an approach involving removal of the entire pedicle and facet, which provided a more direct line of exposure to the ventrally located disc space. This transpedicular approach evolved from recognition of the high morbidity rates associated with treating thoracic discs by using laminectomy, along with pulmonary and various other complications found with the alternative lateral and ventral surgical approaches to the thoracic spine. It should be noted that the degree of anterolateral exposure afforded by the transpedicular approach, although much improved over that of simple laminectomy, is still limited compared with the more extensive lateral and ventral exposures. This exposure is particularly important when treating a disc that is calcified or located in the midline. In the original series of Patterson and Arbit, all patients presented with myelopathy and reportedly made uniformly good recoveries.

A potential advantage to the transpedicular approach over costotransversectomy, transthoracic, and LECAs is that it entails no damage to the radicular vessels. The possible adverse effect of sectioning these vessels has long been a concern for many surgeons. It is well established that the thoracic spinal cord is a watershed vascular zone. The artery of Adamkiewicz (arteria magna radicularis) usually arises on the left side at T8–L2. Based on this anatomical fact, some surgeons have suggested obtaining an angiogram if the possibility exists for any division of left-sided thoracic radicular vessels. Mansour, et al., reported an interesting case in which a patient suffered from a Brown–Séquard syndrome from a left-sided lateral disc herniation at T9–10, with only radicular compression. The site happened also to be the location of the artery of Adamkiewicz in this patient, and thus the disc herniation was presumed to be the cause of a vascular event.

Continuing efforts to improve the exposure of the ventral surface of the spinal cord led to use of the LECA for herniated thoracic discs. Capener first developed this technique for the treatment of tuberculosis spondylitis; it was later applied to thoracolumbar fractures. This approach provided the following advantages over other methods for accessing the thoracic and thoracolumbar spine. 1) It afforded excellent ventral exposure of the cord. 2) It was a completely extrapleural procedure. 3) It pro-
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provided surgeons with the ability to span both the thorax and abdomen without taking down the diaphragm. Maiman, et al. used the LECA for thoracic disc herniation in 23 cases, and none of their patients experienced new deficits postoperatively. On the other hand, this approach has significant shortcomings. It requires exceptionally extensive soft-tissue dissection and manipulation. More seriously, the paraspinal muscles are mobilized medially, thus denervating and devascularizing these structures. This may contribute to poor wound healing and an increased risk for postoperative kyphosis. With this approach it may still be very difficult to remove intradural disc fragments, although in their series, Maiman, et al., did not find this to be the case.

The LPEA, developed by Fessler and colleagues provides exposure of the upper thoracic spine comparable to that provided by the LECA. The major additional risk entailed by this procedure compared with the LECA is that of significant shoulder girdle problems, due to the fact the scapula is mobilized in a lateral direction.

Ventral Approaches

Use of a transpleural approach to the thoracic spine for disc herniation dates to 1958, when Crafoord, et al. reported the use of this technique in a patient with a herniated disc. In 1969, Perot and Munro reported the use of this technique for thoracic disc herniation in two patients. In that same year, Ransohoff and Spencer reported the use of this technique in a patient with a herniated disc. In 1969, Perot and Munro reported the use of this technique for thoracic disc herniations treated with a transthoraic approach. Since the appearance of these two pivotal reports, there have been several series supporting the efficacy of this approach. Anatomically, it provides unparalleled ventral exposure of the spinal cord, which not only creates a safe working channel adjacent to the spinal cord but also provides the optimal angle for removal of intradural discs and for dural repair. It also permits multiple levels to be addressed via the same approach if required. The obvious disadvantage to the transpleural approach is the risk of pulmonary morbidity. Risk of injury to major vascular and visceral structures is also present. The initial postoperative days are also marked by a considerable amount of pain secondary to the thoracotomy approach and presence of a chest tube. It should also be noted that this technique is limited to treatment of the T-5 disc space or below.

Thoracoscopic Approach

The advantages of a minimally invasive ventral approach to the treatment of thoracic disc herniations seemed obvious. Today, most spine surgeons would agree that a ventral approach is most appropriate for anything other than a far-lateral disc herniation. The main obstacle to using the ventral approach was the associated morbidity of a thoracotomy. Patients were obliged to spend several days in the intensive care unit, undergo thoracotomy drainage, and experience significant postoperative pain. Intercostal neuralgia, both temporary and permanent, is also a potential drawback associated with this technique.

The dramatically improved optics and lighting of rigid glass endoscopes, developed by physicist Harold Hopkins in 1970, nurtured the rapid growth of endoscopic surgical techniques (see biographical articles by Gow and Jennings). Thoracic surgeons recognized the potential advantages of a minimally invasive technique for biopsy and drainage procedures compared with the currently available open technique, which involved significant risk of morbidity to the patient. In 1991 Lewis reported the use of VATS, which quickly proved to be a viable approach. Soon various centers were attempting increasingly complex procedures, including lung-lesion resections. Landreneau, et al., reported on 106 such cases in 1993, in which he compared VATS with thoracotomy. The patients who underwent VATS suffered less pain and had improved pulmonary function and superior shoulder girdle function compared with thoracotomy patients. In the same year, Mack, et al., published a report demonstrating the potential of VATS to provide a reliable route to the ventral surface of the thoracic spine. In 1995 Caputy, et al., demonstrated the successful use of VATS in performing a thoracic discectomy in both a cadaver and porcine model. In that same paper a clinical case of a thoracoscopic discectomy was also reported. Although thoracoscopy was well established in the field of thoracic surgery, the practicality of its use in spine surgery remained in question. The rapid development and availability of special long instruments has facilitated the application of thoracoscopic spine techniques (Fig. 2).

Several large series have since been published demonstrating the efficacy of VATS and the reduced morbidity associated with its use when compared with traditional open approaches. Note that although the benefit of VATS is usually compared only with the alternative of thoracotomy, some data suggest that it is also a less morbid procedure than costotransversectomy. Rosenthal and Dickman reported on a series of 55 patients who underwent thoracoscopic discectomy; they compared the rate of complications between thoracotomy patients and costotransversectomy patients with thoracic disc herniation. There were no instances of postoperative neurological deterioration in either the thoracoscopic or thoracotomy groups, but of those patients undergoing costotransversectomy, 7% experienced neurological deficits after surgery. Intercostal neuralgia, both temporary and permanent, has long been a significant problem associated with thoracotomy. The use of VATS has significantly reduced the incidence of this painful disorder, which frequently prevents...
patients from resuming their normal levels of activity. In the series reported by Rosenthal and Dickman, there was a 16% rate of intercostal neuralgia in the VATS group compared with 50% in those patients who had a thoracotomy. In all patients in the thoracoscopic groups with intercostal neuralgia, the condition was temporary and resolved completely within 1 to 2 weeks. In those patients undergoing a costotransversectomy there was a 20% rate of intercostal neuralgia.

A major criticism of minimally invasive surgery is the increase in the total amount of time that usually is involved in such procedures. Although it is certainly true that VATS takes longer than the transpedicular approach, this is not necessarily the case when compared with the alternative ventral approach, that is, the thoracotomy. In our experience with the performance of VATS for thoracic disc herniations, the mean operation time has been 260 minutes (unpublished data). In their group of 55 patients, Rosenthal and Dickman reported a mean operation time of 205 minutes. In thoracotomy patients the mean surgical time was 268 minutes, and those undergoing costotransversectomy spent an average of 280 minutes in the operating room. An additional concern regarding the current trend toward minimally invasive procedures is that the overall effectiveness of the procedure is jeopardized. If the patient is spared a painful and potentially morbidity-inducing thoracotomy only to undergo an endoscopic technique that leaves the pathology unresolved, then treatment has certainly failed. Rosenthal and Dickman examined the rate of retained disc fragments in those patients undergoing VATS, thoracotomy, and costotransversectomy, and found that in the thoracotomy group there were no instances of retained fragments, whereas in the thoracoscopy group 4% of patients retained incompletely removed fragments. Costotransversectomy yielded a retained disc fragment rate of 13%. In 1999, Dickman, et al. reported on a group of 15 patients who had undergone surgery for herniated thoracic discs and were found to have retained fragments. Eleven of these patients had previously undergone a posterolateral approach, one had undergone a thoracotomy, and three had undergone VATS. The vast majority of these lesions were calcified. Thoracoscopic techniques were used for reoperation in all but one patient, who required a thoracotomy.

From the above information, it appears that VATS provides a very effective method of treating thoracic disc disease, including reoperative situations. Although the data suggest that thoracotomy may provide a slight decrease in the rate of retained disc fragments, the significant difference in postoperative morbidity between these two procedures seems to support the use of a thoracoscopic approach.

**Description of Endoscopic Technique**

**Patient Position and Operating Room Setup.** The lateral decubitus position is used with the operative side up, unless the pathology is distinctly to the right; in that case the left side of the thorax is preferred due to the location of the inferior vena cava on the right. The patient is secured to the operating table with three-in tape; security is tested by rolling the table from side to side before the patient is prepared and draped. The spine surgeon and cardiothoracic assistant work on the ventral side of the patient, while the second assistant is positioned at the dorsal side. Two video monitors are positioned, one on each side of the patient's head (Figs. 3 and 4).

**Localization of Operative Level.** An x-ray film may be obtained after patient positioning is completed to assist in optimal port placement. Alternatively, the ports may be positioned followed by placement of a long bovie tip in the estimated disc space by counting from the first rib, which lies adjacent to the subclavian artery and underneath a pad of fat (Fig. 5). Proper placement of the operative ports is particularly important to ensure that awkward angles are not created for the surgical instruments. It is also important to avoid placing ports too close together;
this creates a frustrating situation in which the surgeon’s instruments tend to make contact with the shaft of either the endoscope or the suctioning device. A small skin incision is made toward the superior border of the caudal rib at the desired level to avoid damaging the neurovascular bundle of the cephalad rib. A Kelly clamp is used to enter the pleural cavity, being careful not to injure the underlying lung. The first port is placed, and this helps the surgeon visualize additional port placement. For a standard discectomy, three ports are typically used. The use of soft rubber ports has recently become popular, in the belief that they have less tendency to traumatize the intercostal nerve. It is not yet known whether the incidence of postoperative intercostal neuralgia has actually been reduced by the use of these devices. At this point, the chest surgeon explores the thoracic cavity and takes down any pleural adhesions. The patient is then rolled ventrally to allow the lung to fall away from the vertebral column. If this maneuver is not adequate to expose the vertebral structures, the anesthesiologist may be asked to attempt further deflation of the ipsilateral lung. Lung retraction may need to augmented by the use of a special fan retractor, although we frequently find that the aforementioned techniques suffice (Fig. 6).

**Rib Resection.** Once the operative level has been confirmed with certainty, the pleura over the disc space and proximal rib is incised. The segmental vessels are typically dissected and ligated with hemoclips, then cut with special endoscopically-guided cautery scissors. The pleura is then mobilized from the rib head by an endoscopic Cobb elevator. During our early experience with the procedure, the rib was typically removed in a 2- to 3-cm en bloc segment and saved for potential grafting. The current technique involves drilling the proximal 2 cm of the rib head with a rough-cut diamond burr (Midas Rex, Fort Worth, TX) (Fig. 7 and Video Clip 1). The diamond bit serves to control bone bleeding significantly, thereby improving visualization.

**Pedicle Removal.** The next step is to view a normal segment of the thecal sac. This is accomplished by a combination of drilling and application of Kerrison rongeurs. Bleeding from the epidural plexus is frequently encountered at this point, but is easily controlled with bipolar cautery or Avitene (Davol, Kalamazoo, MI).

**Creating a Working Trough.** To prevent causing anatomical deformity or vascular compromise in the spinal cord, a pyramid-shaped space is created ventral to the spinal cord by removing a portion of both the cephalad and caudal vertebral body with the drill (Fig. 8). Once this space is created, the disc material is pulled away from the thecal sac into this cavity (Video Clip 2). Throughout the procedure the disc is pulled away from the spinal cord and thus no instruments are placed in the canal. The amount of bone removed is dictated by the extent of the disc herniation. One must always remove enough of the vertebral body to be able to visualize normal dura on both sides of the disc herniation. For large calcified discs, something akin to a partial corpectomy is performed. Generous vertebral body resection is also performed when an intradural fragment is found. Instability has not been a problem in this procedure, and a graft is usually not placed.
Click here to view Video Clip 2.

Video Clip 2. A partial corpectomy, or working trough, has been previously created with the use of the drill. A portion of the calcified disc material has been decompressed from the spinal canal by pulling the disc away from the cord into the trough. An endoscopically-guided pituitary rongeur is used to remove a remaining disc fragment. The decompressed thecal sac is seen.

Click here to view Video Clip 3.

Video Clip 3. A thoracoscopic curette is seen being used to pull remaining calcified disc material into the working trough. The exposed lateral portion of the dura is clearly seen. This exposure is obtained by previous removal of the rib head and pedicle.

Click here to view Video Clip 4.

Video Clip 4. A straight probe is used to palpate across to the contralateral pedicle along the ventral surface of the decompressed thecal sac. This is done to assure that no remaining portion of herniated disc material is left behind. Again the motion of the heart can be seen in the bottom portion of the screen.

Any remaining bleeding is then controlled by Gelfoam with thrombin and Avitene. The pleural cavity is then irrigated with a copious amount of antibiotic solution, which is then suctioned out. A single chest tube is implanted; in most cases this remains in place for 24 hours.

**The Learning Curve**

The procedure used to access and treat lesions of the thoracic spine with the aid of endoscopic guidance entails the use of techniques that may be foreign to most spine surgeons. Becoming familiar with the hand–eye coordination required to manipulate the endoscope takes many hours before real agility is achieved. Becoming comfortable with the use of extremely long instruments also requires practice.

The authors believe strongly that it is the duty of academic programs to take the initiative in teaching both residents in training and surgeons in the surrounding community the new and evolving techniques, as well as to provide an environment for continued development of competency. At the George Washington University, for example, the neurosurgical residency program has developed structured training sessions in the endoscopic laboratory using live porcine models to train residents in thoracoscopic techniques before they attempt them in the clinical environment (Fig. 10). This has provided an invaluable experience for the safe and effective teaching of a demanding surgical technique. The authors hope that others will emulate this model for the education of others in the field.

**CONCLUSIONS**

The surgical treatment of few disorders has undergone as dramatic an evolution as that of thoracic disc herniation. From an era in which surgery incurred significant mortality and dramatic morbidity rates, the field has progressed to the point where effective procedures are viewed as routine, with significant improvements in patient outcome.

Continued advances in technique, surgical instrumentation, and endoscopic technology have suggested that the future may hold continued improvements for the treatment of this potentially devastating disorder. There are now many published reports of minimally invasive endoscopic surgery for the treatment of other disorders of the thoracic spine and neuraxis, such as tumors, as well as for placement of instrumentation. While such advances...
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should be viewed as welcome, their safety and efficacy must also be subjected to critical review before they can be accepted into the spine surgeon’s armamentarium.

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