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 surfaces 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.

Key Words • thoracic spine • herniated disc • thoracoscopic surgery • endoscopy • minimally invasive surgery

Abbreviations used in this paper: CT = computerized tomography; LECA = lateral extracavitary approach; LPEA = lateral para-scapular extrapleural approach; MR = magnetic resonance; VATS = video-assisted thoracoscopic surgery; 3D = three-dimensional.
reported three cases of ruptured tho-
first developed this
It was
reviewed 91 cases from the literature on herniated
good outcomes in five
2
In a pivotal paper published in
first described the use of this technique to reach
reported the results of surgery in a series of
all patients pre-
Based on this
Neurosurg. Focus / Volume 9 / October, 2000
visualization. The significant rate of postoperative neuro-
early dorsal approach procedures for herniated discs were
opposite extreme was to attempt to reach the disc materi-
forming a decompression without disc removal to avoid
these early cases. Some surgeons advocated simply per-
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.,3) who performed laminectomy and disc removal.
Mixter and Barr25 reported three cases of ruptured tho-nic disc herniations in 1934. Two of these patients devel-
oped postoperative transverse myelopathy, and the other
was only mildly improved after some time (see Zeidman,
et al.,3 for historical review). The results of many other
early dorsal approach procedures for herniated discs were
typical equally dismal.12,13 In a pivotal paper published in
1952, Logue19 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 tempo-
rary increased motor weakness. In 1969, Perot and Mun-
ro20 reviewed 91 cases from the literature on herniated
thoracic discs, all treated by dorsal approaches. Excepti-
onally, Horwitz, et al.,14 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 per-
forming 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 materi-
al via an intradural approach that involved sectioning the
dentate ligaments with adjunctive rhizotomy.13,14 It was
believed that this approach permitted improved ventral
visualization. The significant rate of postoperative neuro-
logical deficits after laminectomy for thoracic disc her-
ination was thought to be due to a combination of vascu-
lar insufficiency and microcontusions secondary to spinal
cord manipulation.37

Posterolateral Approaches
To avoid spinal cord manipulation, many surgeons be-
 gan 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,
Ménard34 first described the use of this technique to reach
the vertebral body via an expulsive route. In 1958 Hulme15
used costotransversectomy to treat thoracic disc hernia-
tion. 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 trans-
pedicular techniques.

In 1978, Patterson and Arbit (as mentioned in Zeidman,
et al.,37) 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 trans-
pedicular 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 afford-
ed by the transpedicular approach, although much im-
proved over that of simple laminectomy, is still limited
compared with the more extensive lateral and ventral ex-
posures. 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,28 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 pos-
sible 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. Anatomical fact, some surgeons have suggested obtaining
an angiogram if the possibility exists for any division of
left-sided thoracic radicular vessels.5,14,21 Mansour, et al.,22
reported an interesting case in which a patient suffered
from a Brown–Séquard syndrome from a left-sided later-
al disc herniation at T9–10, with only radicular compres-
sion. The site happened also to be the location of the artery
of Adamkiewicz in this patient, and thus the disc hernia-
tion 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. Capener4 first developed this
 technique for the treatment of tuberculous spondylitis;
it was later applied to thoracolumbar fractures. This ap-
proach 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-

Fig. 1. Sagittal T1-weighted MR image of a herniated thoracic
disc with spinal cord compression at T-7. Note that the identity of
the spinal level cannot be absolutely confirmed from this study; it
is inferred by the marking. A myelogram is usually obtained to
confirm the level precisely.

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.,3) who performed laminectomy and disc removal.
Mixter and Barr25 reported three cases of ruptured tho-nic disc herniations in 1934. Two of these patients devel-
oped postoperative transverse myelopathy, and the other
was only mildly improved after some time (see Zeidman,
et al.,3 for historical review). The results of many other
early dorsal approach procedures for herniated discs were
typical equally dismal.12,13 In a pivotal paper published in
1952, Logue19 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 tempo-
rary increased motor weakness. In 1969, Perot and Mun-
ro20 reviewed 91 cases from the literature on herniated
thoracic discs, all treated by dorsal approaches. Excepti-
onally, Horwitz, et al.,14 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 per-
forming 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 materi-
al via an intradural approach that involved sectioning the
dentate ligaments with adjunctive rhizotomy.13,14 It was
believed that this approach permitted improved ventral
visualization. The significant rate of postoperative neuro-
logical deficits after laminectomy for thoracic disc her-
Surgical treatment of thoracic disc herniation

vided 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 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 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

Thoracoscopy provides a convenient, minimally invasive technique that permits a fairly large incision, thus is suited for thoracic disc herniation surgery. The added ability to visualize the spine and the surrounding structures has been particularly beneficial. The LECA was the first reported technique using a transpleural approach (Fig. 3). It was described by Valsalva in 1726 as a means of draining pleural effusions. The procedure employs a thoracoscopic approach to the thoracic spine for diagnostic or therapeutic purposes (Fig. 4). The procedure is performed under general anesthesia with the patient in the lateral decubitus position. A small incision is made in the sixth intercostal space posteriorly at the midaxillary line. A retractor is inserted into the pleural cavity to provide an unimpeded working channel. The pleura is incised and reflected to expose the thoracic spine. The use of VATS has significantly reduced the incidence of this painful disorder, which frequently prevents

Fig. 2. Photograph of three types of endoscopic drills. Cutting and rough-diamond burrs (bottom) are displayed. Long protective outer shafts minimize the risk of injury to other tissues.
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 thoracoscopic 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.

**Port Placement and Exploratory Thoracoscopy.** 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.

Click here to view Video Clip 1.

Video Clip 1. Thoracoscopic view of removal of the T-9 pedicle for a heavily calcified T8–9 herniated disc. The rib head has already been removed with the use of a drill. The use of the rough-cutting diamond bit can be seen to minimize the amount of bone bleeding encountered. A medium-sized hemoclip can be seen at the bottom of the screen on a previously divided segmental vessel. The pulsations of the heart can also be seen.

**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.
After the vertebral body is fully resected, the disc material may be safely pulled away from the spinal cord into the working trough (Video Clip 3). The decompressed canal must be palpated along the contralateral pedicle with a long probe (Fig. 9 and Video Clip 4) to check for any residual intradural fragment; if found, this should be carefully removed while dissecting the disc from the pia and arachnoid with a microdissector. The dura is then sealed with a tissue patch and fibrin glue. A lumbar drain is placed postoperatively. It is also recommended that the chest tube be placed on water seal, rather than suctioned.

**Discectomy.** After the vertebral body is fully resected, the disc material may be safely pulled away from the spinal cord into the working trough (Video Clip 3). The decompressed canal must be palpated along the contralateral pedicle with a long probe (Fig. 9 and Video Clip 4) to check for any residual intradural fragment; if found, this should be carefully removed while dissecting the disc from the pia and arachnoid with a microdissector. The dura is then sealed with a tissue patch and fibrin glue. A lumbar drain is placed postoperatively. It is also recommended that the chest tube be placed on water seal, rather than suctioned.

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
Surgical treatment of thoracic disc herniation

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.

References


Manuscript received August 17, 2000. Accepted in final form September 11, 2000.

Address reprint requests to: Timothy G. Burke, M.D., Department of Neurosurgery, The George Washington University, 2150 Pennsylvania Avenue, NW, Suite 7–450, Washington, DC 20037. email: timburke@gwu.edu.

Neurosurg. Focus / Volume 9 / October, 2000

7