Symptomatic thoracic disc herniations account for less than 1% of all vertebral disc operations. The incidence of thoracic disc–related spinal cord compression is estimated at approximately one case per million individuals per year. The use of computerized tomography and MR imaging has resulted in a significant increase in the detection and diagnosis of this lesion, perhaps providing more symptomatic patients expeditious treatment; however, likewise increased is potential for "treating the image" by surgically treating patients with asymptomatic lesions. In as many as 15 to 37% of cases "incidental" thoracic disc herniations are visible on MR imaging, and yet there are no attendant complaints. It is hoped that the greater diagnostic accuracy afforded by MR imaging and the ability to perform serial imaging in conjunction with clinical assessments will create a clearer picture of the natural history of asymptomatic thoracic disc herniations.

Because patients with herniated thoracic discs present with a variety of symptoms, diagnosis is often unexpected or delayed. Pain localized to the back is the most common initial symptom, and the pain is frequently midline but may be uni- or bilateral. Some patients present with more characteristic radicular complaints. The pain may be constant or intermittent, and it may be exacerbated by activity or coughing, sneezing, or a Valsalva-type maneuver. Occasionally the pain mimics visceral pain. Patients with thoracic disc herniation have been diagnosed with cholecystitis, pancreatitis, and cardiac/intrathoracic disorders. Pain that radiates to the groin or testicle has been described by patients with T11–12 herniations. Sensory disturbances are also frequent, occurring in 24 to 61% of patients. Motor disturbances or myelopathy can be detected in roughly 60% of these patients, and symptoms of bladder dysfunction occur in approximately 24%.

Most (75%) of symptomatic thoracic disc herniations involve the lower four disc levels (T8–9 to T11–12); the most frequently affected level is T11–12. Only 4% of herniations affect the upper two disc levels. Most herniations are central or paracentral, and calcification is a common finding. Thoracic disc herniation also appears to be a disorder affecting middle-age individuals. Arce and Dohrmann have noted that 80% of thoracic disc herniations occurred between the third and fifth decade of life.

**SURGICAL APPROACHES FOR THORACIC DISC HERNIATION**

**Surgical Indications**

The indications for thoracic discectomy have yet to be firmly established, largely due to uncertainty about the natural history of the disorder but also because of concerns regarding the surgical approach–related morbidity and the inherent neurological risks of manipulation of this region of the neuraxis. Myelopathy, especially if severe or progressive, is viewed by most surgeons as a straightfor-
ward indication for thoracic discectomy. The presence of radicular pain is a less straightforward indication but is generally thought to respond well to one of the microsurgical decompressive operations. However, the role of surgery for nonradiating or atypical forms of thoracic or visceral pain continues to incite debate. Clearly, asymptomatic or incidental lesions do not warrant surgical intervention. The frequency with which MR imaging demonstrates thoracic disc herniations has only compounded the surgery-related dilemma. Awwad and colleagues have demonstrated that the radiological appearance of thoracic disc herniations did not correlate well with the presence or absence of symptoms. Several surgical approaches, with variations, have been described in the literature (Table 1). Since the observation reported by Logue that patients who underwent laminectomy suffered unacceptable morbidity, surgeons have emphasized the development of procedures in which the compressed lesion is approached as directly as possible and in which the manipulation of the thecal sac and spinal cord is minimized. Ransohoff and colleagues and Perot and Munro were early advocates of thoracotomy, and this approach produced good results. Surgical procedures in which the costotransversectomy approach or a transpedicular exposure is used have gained popularity over the years, largely because the anatomical region is more familiar to spine surgeons and because of the perception that thoracotomy produces a high rate of morbidity. The choice of surgical approach is predicated on several factors: the training and experience of the surgeon; the types of symptoms; the anatomical relationships among the herniation, the spinal cord, the nerve root, and the bone anatomy; and the consistency of the herniation (soft or calcified). Patient-related factors such as body habitus and comorbidities may also influence the choice of approach. Currently, the transthoracic approach is favored by many surgeons for the management of central or paracentral herniations in patients in whom myelopathy is present. Calcification of the protrusion is another factor that favors a transthoracic approach because a hard lesion will clearly require greater manipulation to achieve a decompression. Finally, the uncommon case of multilevel disc prolapse requiring operation may be amenable to a single anterior approach. Additional advantages of the transthoracic approach include excellent exposure of the ventral aspect of the spinal canal without the need for manipulation of the dura, the ability to preserve spinal stability in most cases without the necessity of fusion, and the ability to perform interbody fusion when indicated.

One disadvantage of the anterior approach may be that the surgeon is less familiar with the approach and the anatomy compared with posterior approaches. This can be avoided if the spine surgeon enlists the aid of a thoracic surgeon to assist in obtaining access. The patient may suffer greater postoperative pain compared with that related to some of the posterior microsurgical procedures and with thoracoscopy. Cerebrospinal fluid leakage, which can be problematic with calcified and intradural herniations, is also potentially more difficult to manage when using an anterior approach. Patients who have undergone prior thoracotomy and suffer thoracic and may also be poor candidates for the approach. The indications for fusion after transthoracic discectomy are also not standardized. Although interbody fusion in which autologous rib is harvested during the approach is frequently performed, the necessity of doing so has not been evaluated. The amount of bone removed in a standard discectomy for centrally located herniation is not likely to produce frank spinal instability. The potential for segmental back pain is not known. We generally consider undertaking fusion in patients in whom there was significant perioperative axial thoracic pain or in whom the extent of bone removal is thought to produce significant risk of delayed segmental motion or pain. Placement of instrumentation following simple thoracic discectomy is uncommon. We have performed interbody fusion in these patients by using autologous rib, allograft segments (humerus or fibula), and occasionally, titanium mesh cages with autograft.

### Surgical Anatomical Considerations

The relevant anatomical considerations include the relationship of the lesion to the ribs, the regional vascular anatomy, and the neural structures. The diaphragm and the mediastinum delineate the limits of the transthoracic exposure. The former is present at the level of T12–L1 and therefore presents the surgeon with a somewhat difficult operative corridor when working in the lower (T11–L1) thoracic region. In these cases, release of the diaphragm and a retroperitoneal dissection may prove beneficial. The mediastinum generally precludes a safe left-sided operative approach at T4–5 or higher. Rodts, et al., have described a right-sided approach at the level of the third rib for the extreme upper thoracic spine. Alternately, a splitting of the manubrium or a sternotomy may be required. The remainder of the thoracic spine can be generalized with the following features. The ribs possess two articular facets at their tip that articulate with the VB of the same level and the VB above. The head of the rib therefore covers the disc posterolaterally (except at the first, 11th, and 12th ribs, which articulate only with the lower vertebra [that is, the same level]). The head of the rib additionally overlies a portion of the neural foramen of the same level VB. For example, the fifth rib articulates with the trans-
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verse process and body of T-5, as well as the inferior VB of T-4, therefore overlying the T4–5 disc space. The neurovascular bundle traveling with the fifth rib contains the fifth intercostal nerve, which then passes under the pedicle of T-5, just below its articulation with the rib.

The ligamentous attachments in this region are noteworthy and include the radiate, costotransverse, intertransverse, and capsular ligaments. The radiate ligaments span out from the proximal rib head in a stellate fashion, attaching to the adjacent VBs and intervertebral disc along the ventral aspect of the rib. The costotransverse ligaments are primarily involved in attaching the neck of the rib to the articulating transverse process. The intertransverse ligaments interconnect the transverse processes, and the capsular ligaments span the short distance from the ventral transverse process to the dorsal portion of the articulating rib.

The sympathetic chain is comprised of a series of ganglia interconnected with interganglionic nerves. Within the upper thorax, the chain lies against the neck of the ribs, whereas at the lower portions of the thorax the chain moves ventrally along the lateral border of the VBs. Smaller splanchnic nerves may be found running anteriorly from the chain to visceral ganglia/plexi.

The diaphragm is a musculotendinous sheet extending between the thoracic and abdominal cavities. Its superior surface is covered with parietal pleura and pericardium, and its inferior surface is covered by the peritoneal peritoneum. The peritoneum separates from the posterior aspect of the diaphragm because of the intervening fat and the superior aspects of the kidneys and related structures.

The costal attachments of the diaphragm arise from the medial aspects of the seventh and eighth ribs anteriorly, the ninth laterally, and the 10th and 11th ribs posterolaterally. An attachment of the diaphragm at the tip of the 12th rib is present, forming the point of insertion of the lateral arcuate ligament. Posteriorly, the diaphragm attaches to the transverse processes of the VBs. The lateral arcuate ligament spans around the quadratus lumborum whereas the medial arcuate ligament spans across the psoas muscles. The intervening point of attachment is on the transverse process of L-1. The crura of the diaphragm, which are musculotendinous bands, extend along the anterolateral lumbar spine on their respective sides. The left crus typically extends to L-2, whereas the right-sided crus extends to the level of L-3. The aortic hiatus is medial to the crura.

The apex of the aortic arch is usually found at approximately T-4, with the descending aorta traveling along the anterior aspect of the thoracic VBs, just to the left of midline. Lying posterior and medial to the aorta is the thoracic duct, which can be injured during surgical approaches from the right or left side. In cases of right-sided approaches, the surgeon must note the presence of the azygous system, which runs to the right of midline along the anterior aspect of the VBs. At each level, a segmental vein and artery course along the midbody of the vertebra. These vessels divide into dorsal branches and more ventral intercostal arteries, which join with the corresponding intercostal nerves along the underside of the ribs. The dorsal branch gives off a small radiculomedullary branch into the intervertebral foramen, which may supply the exiting nerve root, the associated dura, or may constitute vascular supply to the spinal cord. The artery of Adamkiewicz is the most noteworthy of these radiculomedullary arteries. This significant arterial supply to the spinal cord usually arises from the left side of the aorta at T-8 to T-10 (although it may occur from the middle thoracic to upper lumbar regions). Although this artery may not always be present, it is important for the surgeon to realize that the segmental vessels lying along the VBs may supply blood flow for the spinal cord and that reasonable attempts to preserve these vessels are indicated.

The thoracic VB deserves special mention for several of its unique features relevant to surgery. Its axial shape demonstrates a concavity relative to the spinal canal, which must be considered when drilling along the lateral border of the body. The pedicles emanate from the superior portion of the body, much higher than those seen in the cervical or lumbar regions. The disc space itself is typically much narrower than that seen in the lumbar spine, thus necessitating partial removal of the adjoining VBs to secure a sufficient operative window.

Operative Procedure

Positioning. It is advisable to use double-lumen intubation during these procedures to allow for controlled lung collapse and to improve exposure of the spine. Once an adequate anesthetic state has been induced, the patient is placed in a lateral position on a bean bag. We believe a true lateral alignment will aid the surgeon in maintaining orientation to the spinal canal. The patient may also be placed in such a way that the break of the operating table is directly beneath the intended operative level so that flexing the table will cause the affected disc space to "open" during the operation. The side of approach is chosen based on several considerations. When the spinal cord is asymmetrically compressed, the approach should be made on the side with the largest herniation. In cases of true midline lesions, left-sided approaches are generally recommended for all but the upper (T-4 or higher) thoracic spine, because this exposure avoids the dome of the liver, vena cava/azygous system, and thoracic duct. Cases in which the spine is scoliotic also deserve mention as the concavity of the curve generally restricts the operative field. The relationship of the aorta to the posterolateral aspect of the vertebra must also be considered. Such factors as the presence of pulmonary disease and pleural adhesions may also influence the decision of operative approaches. The upper leg is flexed at the hip and the knee, allowing for relaxation of the psoas muscle. The lower leg can be maintained in a straight position. Padding is placed beneath the lower leg and between the legs to prevent the development of pressure sores and peroneal nerve injury. An axillary roll is placed to prevent neural injury.

Transthoracic Procedure. The curvilinear incision extends from the posterior angle of the rib anteroinferiorly to approximately the nipple line or several centimeters beyond. The incision should be placed approximately two ribs above the level of the rib corresponding to the affected level. Verification of this localization may be made on the preoperative anteroposterior chest x-ray film, on which a line drawn perpendicular to the axis of the spine at the level of the intended operative sight will cross the
ribcage at the best incision site. The musculature is sequentially divided using the Bovie electrocautery. Once the latissimus dorsi muscle has been divided, the surgeon can slide his hand within the subscapular space and count the ribs, verifying the rib to be resected. Using Cobb and Doyen elevators, a subperiosteal rib dissection is then performed and the rib is then divided and may be used as bone graft if fusion is performed. Care is taken to preserve the neurovascular bundle, as the nerve will guide the surgeon to the neural foramen. The bed of the rib is carefully opened, and the pleural cavity is entered. A rib spreader greatly facilitates the following operative procedure within the thoracic cavity.

The lung can be deflated at this point and/or retracted using blades covered using moist lap sponges. The ribs can again be counted, now from within the thorax, beginning with the second rib superiorly. The appropriate disc level is thus identified. This should be confirmed by obtaining intraoperative cross-table anteroposterior radiographs. As in the cervical region, the discs in the thoracic spine project into the thoracic cavity, whereas the VBs are actually concave. The parietal pleura is opened longitudinally, extending over both adjacent VBs, and a subperiosteal dissection performed until the disc space and VBs can be well visualized. The nerve can then be dissected from the pleura and used to verify the location of the neural foramen and pedicle. A careful dissection allows for visualization of the segmental vessels lying on the midportion of the body and a posterior mobilization of the sympathetic chain. As a rule the segmental vessels crossing at midbody are preserved, as is the sympathetic chain. The sympathetic chain is best mobilized dorsally, away from the VBs. If a segmental vessel requires ligation, then it is best performed away from the aorta (to allow for reasonable distance for manipulation and ligation) and at no more than three levels, so as to lessen the likelihood of spinal cord ischemia/infarction.

The rib head can then be removed using a variety of techniques that give access to the posterolateral aspect of the disc and the intervertebral foramen. After the radiate ligaments are incised, the rib head may be rongeured or drilled away. The margins of the disc, the ventral margin of the foramen, and the pedicles above and below are all identified. Using a high-speed diamond-tipped drill, the pedicle is thinned and removed to allow visualization of the spinal canal and the dura. This quickly orients the surgeon to the location of the lateral and ventral aspects of the spinal cord. The posterolateral aspects of the vertebrae adjacent to the disc are then removed with the drill. In patients with large central herniations, the bone removal should extend to a point at least halfway across the ventral spinal canal. Once the disc is exposed in this manner, the segmental vessels lying along the posterior aspect of the VBs. These tendinous structures blend with the annuli. Thus creating a trough by which the dorsal annulus may be pulled (away from the thecal sac) using currettes. The drilling and actual disc removal can be performed under the operating microscope for additional visualization.

Once the thecal sac and nerve root are decompressed, meticulous hemostasis is obtained with gentle tamponade (Gelfoam or the equivalent) and bipolar electrocautery. If the removal of the bone is limited to the posterolateral portions of the VBs, no bone graft or instrumentation is required.

**Transthoracic/Retroperitoneal Approach.** Lesions located within the lower portion of the thoracic spine, as discussed previously, present the surgeon with the difficulty of working next to the diaphragm. In most cases, it is prudent to plan on releasing the diaphragm during the surgical exposure. The incision is generally placed over the 10th rib, extending from the posterior axillary line to the lateral aspect of the rectus sheath. The rib is dissected subperiosteally, elevated from its bed, and divided as proximally as feasible, as previously described.

The costal cartilage is separated off and is then divided lengthwise. Beneath the incised cartilage, there is a small pad of adipose tissue, which indicates the entrance to the preperitoneal space. A finger can be inserted between the costal angle of the diaphragm and pleural cavity and the peritoneal cavity. After this blunt dissection is performed, the incision through the oblique muscles, the transversus abdominus, and transversalis fascia, is extended, and then the peristomeum of the rib bed is also divided. The peritoneal sac can then be dissected in all directions and retracted forward. The peritoneal sac is protected with moist laparotomy sponges. Because of the extensive fatty tissue, the kidney is palpable but not readily visible. Likewise, the ureter, which in a more caudal exposure can be routinely visualized lying along the posterior aspect of the peritoneal sac, is often not seen. The quadratus lumborum can usually be identified and then the psoas. One must avoid entering the retroperitoneal space, which is a blind pouch. Palpation medial to the quadratus will identify the transverse processes, which must not be confused with the VBs.

Opening the rib bed allows entry into the thoracic cavity and visualization of the peripheral phrenic attachment. The lung is protected as the diaphragm is divided within an inch of the periphery. This avoids causing significant denervation of the muscle that receives its innervation centrally, while still allowing for enough tissue to facilitate an efficient closure. Placement of marker sutures during this stage simplifies the proper realigning. The lateral attachment of the lateral arcuate ligament at the 12th rib is divided, as is the attachment medially at the transverse process of L-1. Gentle retraction of the lung and diaphragm can now be achieved. The crura of the diaphragm must be divided to expose the disc space. The surgeon should remember that the segmental vessels lie deep to the crura at the midpoint of the vertebrae.

Once the psoas is exposed, its medial points of attachment with the spine must be divided to gain access to the spine. These tendinous structures blend with the annuli. The segmental vessels are also identified and ligated prior to division. These maneuvers allow the psoas mass to be mobilized laterally, exposing the anterolateral aspect of the spine.

**Closure Procedure.** Once the discectomy is complete and hemostasis obtained, closure may be initiated. The thoracic cavity is repeatedly irrigated with warm saline. Once the cavity is filled, the lung can be reinfated to check for any air leaks. The lung is again deflated to facilitate closure of the diaphragm and ribs. If the retroperitoneal approach was used, the first step of closure involves the repair of the
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diaphragm. Using the marker sutures placed earlier, the diaphragm can be reaproximated with interval running sutures. One or two chest tubes should be placed along the posterior thoracic wall and passed through separate incisions above or below the surgical incision. The ribs are then reapproximated using heavy suture (No. 5 Ticron or similar suture) and tied in an interrupted fashion. The overlying muscular layers are closed with a running suture, maintaining separate muscular planes and a watertight suture line, both in the thoracic and abdominal regions. The subcutaneous tissues and skin may be closed in standard fashion. The chest tube(s) should be placed to water-suction and monitored for air leak and postoperative drainage.

If cerebrospinal fluid leak is observed during the course of the operation, it is rarely amenable to direct suture repair. It is therefore managed aggressively with the use of Gelfoam and recombinant fibrin glue and placement of a lumbar drain before the patient awakens from anesthesia. Small muscle stamps have also been used in this situation. The chest tube is removed as early as possible, before discontinuation of the lumbar drain.

Complications or consequences of the transthoracic approach include: pneumothorax, hemotorax, chylothorax, postthoracotomy pain, dureouleural fistula with cerebrospinal fluid effusion, pneumonia, flail musculature, great vessel injury, and sympathectomy.8 In addition hernias and visceral injury are associated with the retroperitoneal approach. Overall, however, this procedure offers relatively low mortality and morbidity rates (7–11%) in the properly chosen patients.8,15 The outcomes suggest that the transthoracic surgery provides effective treatment to alleviated pain (87%), hyperreflexia/spasticity (95%), and bladder symptoms (76%).15,28

DISCUSSION

The poor outcomes in laminectomy-treated patients with thoracic disc herniations were recognized by Logue12 in 1960. These unacceptable outcomes were instrumental in the development of alternative surgical strategies for managing this entity. Current surgical options include several posterolateral variations such as Larson’s lateral extracavitary approach13 and the retropelvic approach described by McCormick and associates.14 In addition a transpedicular or transfacet approach has been advocated.16 These procedures are generally cited for their relative technical difficulty and morbidity associated with the soft-tissue dissection. In our experience, the transpedicular approaches are quite useful when the herniation is located laterally and is soft in consistency, but their hinderance is that the ventral aspect of the spinal canal cannot be visualized. Using specially designed curettes, LeRoux and colleagues15 have reported an ability to decompress even midline discs via the transpedicular approach. As another refinement, Jho10 has advocated endoscopic guidance for the transpedicular procedure. Nonetheless, we have found that the visualization and control afforded by the anterior transthoracic route more than justifies its use in selected cases. Adequate visualization of the adjacent dura mater is critical when there are dense adhesions between the fragment and the dura. This situation is relatively common when the disc is calcified.

It is a truism in spine surgery that one generally chooses the most direct route to a lesion while seeking to minimize manipulation of the neural elements. For this reason, the transthoracic approach is optimal for the treatment of central and paracentral disc herniations, the most common locations for thoracic herniations. The presence of calcification and marginal osteophytes are also important considerations that favor the transthoracic approach over posterior and posterolateral procedures.

Although the thoracoscopic approach has been gaining popularity in recent years because of the associated reduced morbidity rates compared with those in open thoracotomy, the transthoracic approach should, in our opinion, remain a viable alternative therapeutic method for herniated thoracic discs. The relatively steep learning curve for the endoscopic approach combined with the small number of these reported cases suggests that, for all but a few centers, open thoracotomy will be the more familiar and therefore safer procedure. Familiarity with the transthoracic approach provides the surgeon with a means to treat not only herniated discs but a variety of other conditions affecting the spine, including tumors, infections, fractures, and deformity.

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