SURGICAL APPROACHES TO THE THORACOLUMBAR SPINE

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Surgical treatment of diseases involving the thoracolumbar spine offers a unique challenge to the spine surgeon. Although more familiar posterior techniques are useful for a variety of thoracolumbar problems, the management of disease in this region is often optimized by an anterior approach. Thoracolumbar surgery requires an understanding of the relevant surgical anatomy, the pathologic processes affecting this region of the spine, and the relative indications and contraindications for particular operative strategies. It is also essential to be familiar with the management of potential morbidity, methods for avoiding complications, and selection of particular fusion techniques and instrumentation devices associated with specific operative strategies. Experienced anesthesia procedures, electrophysiological monitoring, physical and occupational therapy, and orthotics are essential to the complete care of these patients.

SURGICAL CONSIDERATIONS

Consideration of the relevant medical, surgical, and pathologic issues may suggest that surgery is appropriate for the patient with a thoracolumbar problem; the optimal approach to address this problem should be dictated by the goal of the operative procedure and the location of the involved pathologic process. Three general routes are available for exposure of the thoracolumbar area.

Posterior Approaches

These approaches include laminectomy and transpedicular and transfacet exposures of the thecal sac, nerve roots, and posterolateral disc space. Their advantages include familiarity to most surgeons and ease of multilevel decompression when compressive pathology is primarily posterior. Long segment fusions with screw, hook, and rod configurations are routinely performed through posterior exposures. More extensive vertebral resections may be performed bilaterally through the pedicles, although a greater risk of neurologic and vascular injury exists with this exposure, because visualization of the anterior and anterolateral vertebral canal is poor. Disadvantages include poor access to the ventral spinal canal making decompression difficult. Also, interbody instrumentation is not yet possible using posterior approaches in the thoracolumbar area.

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Posterolateral Approaches

Lateral extracavitary approaches and costotransversectomy afford access to the posterior and lateral quadrants of the thoracolumbar spine. Although anterior exposure of the spine is inferior to that achieved with anterolateral approaches, these surgical routes offer the option of performing simultaneous posterior instrumentation and fusion. Exposure of the intervertebral foramina is excellent. The lateral extracavitary approach offers lateral exposure across the midline. Disadvantages include extensive muscle dissection and longer operative times. Because dissection takes place superficial to the endothoracic fascia and intercostal muscles, nerve roots and intersegmental vessels may hinder exposure of the lateral vertebral bodies and may need to be sacrificed. Also, the placement of interbody instrumentation can be difficult, because anterior exposure of the thoracolumbar spine is not extensive.

Anterolateral Approaches

Retropleural thoracotomy and the anterolateral transpleural approach offer direct and wide visualization of the anterolateral spine across the midline which is not possible with posterior approaches. Transpleural thoracotomy yields unparalleled exposure of the anterior vertebral column over several segments. The deep operative field requires extensive incision and soft tissue dissection as well as retraction of the unprotected lung, however. Identification and decompression of the ventral spine canal can be problematic, because the rib head partially obscures the view and the epidural veins are difficult to control from this trajectory. Retropleural thoracotomy avoids some of these disadvantages. Although this approach is more lateral, it offers a shorter distance to the spine, more secure lung retraction, and better visualization of the anterolateral spinal canal via rib head and pedicle resection. Because dissection proceeds deep to the endothoracic fascia, mobilization and sacrifice of the foraminal neurovascular structures are avoided.

ANATOMY

Posterior Muscles

A thorough understanding of the anatomy of the thoracolumbar junction and paraspinous tissues in this region is essential. The posterior muscles are divided into several layers. The superficial layer includes the trapezius, which inserts caudally on the spinous process of T12, and the latissimus dorsi. The intermediate layer contains the serratus posterior inferior which passes between the lower ribs and spine; its aponeurosis blends with that of the latissimus dorsi to become the thoracolumbar fascia. The erector spinae (spinalis, longissimus, and iliocostalis) comprise the deep muscle layer and lie superficial and lateral to the paraspinal transversospinalis (rotatores, multifidus, and semispinalis) group. The fascia, which encloses the erector spinae, is contiguous laterally with the transversus aponeurosis of the abdominal wall. Over the thorax, the ribs lie ventral to the erector muscles. Caudally, the anterior layer of erector spinae fascia separates these muscles from the quadratus lumborum and intertransversarius muscles. The psoas muscle lies ventral to these and is apposed to the lateral vertebral bodies up to L1. The sympathetic trunk lies ventral to the psoas at its line of vertebral attachment and is dorsal to the retroperitoneal space. In the thorax, the sympathetic chain lies over the rib heads dorsal to the endothoracic fascia.

Thoracic and Abdominal Walls

Rib articulations with the spine are strengthened primarily by the radiate (costovertebral) and costotransverse ligaments (Fig. 1). The ribs at higher thoracic levels articulate

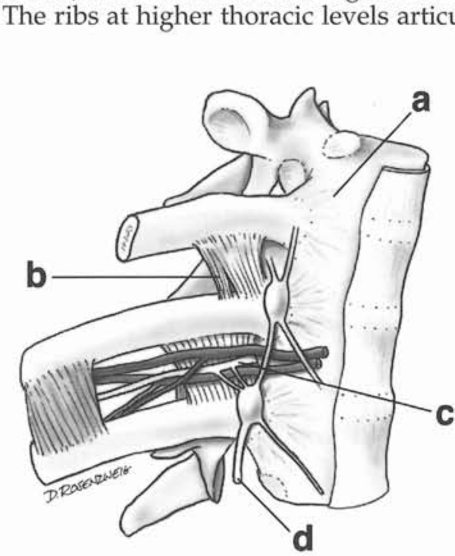

Figure 1. Ligamentous attachments of the ribs to the vertebral column. a = radiate ligament; b = costotransverse ligament; c = intercostal bundle; d = sympathetic chain.

at the level of the disc space above, that is, the sixth rib articulates at the level of the T5–6 disc space. Caudally, the ribs are apposed to the upper portion of the corresponding vertebral body. The 11th and 12th ribs lack costotransverse articulations. The intercostal space includes external, internal, and innermost intercostal muscles. The intercostal vessels and nerve run inferior to the rib in the costal groove between the internal and innermost intercostals. Deep to the intercostal muscle layer lies the endothoracic fascia, a loose fascial layer overlying the parietal pleura. It is known as Sibson's fascia in the upper thoracic region. The pleura extends down to the 10th rib in the midaxillary line and to the T12 to L1 vertebral body level medially. The lung does not occupy the inferior 5 cm of the costodiaphragmatic sinus and thus leaves a pleural sac known as Fontan's space.

The intercostal muscles continue as the muscles of the abdominal wall. The external intercostals correspond to the external oblique, the internal intercostals to the internal oblique, and the innermost intercostals to the transversus abdominis muscle. The aponeurosis of the transverse abdominal muscle runs from the tip of the 12th rib posteromedially to blend with the thoracolumbar fascia. Division of the transversus aponeurosis lateral to the quadratus lumborum gives access to the paranephric fat and renal fascia. Deep to the transversus aponeurosis lies the transversalis fascia, the abdominal equivalent of the endothoracic fascia. It is loosely applied to the parietal peritoneum anteriorly but more tightly attached to the diaphragmatic cupola in the region of its central tendon. The retroperitoneal space includes the kidneys, ureters, adrenals and their vascular pedicles, and the pararenal fat. On the right, the thoracolumbar spine is obscured by the right hemidiaphragm posterior to this retroperitoneal space and the intraperitoneal viscera: the right lobe of the liver, duodenopancreatic block, and hepatic flexure of the colon. On the left, the situation is similar with the view obscured by the spleen, fundus of the stomach, splenic flexure of the colon, and the tail of the pancreas.

Diaphragm

Anterior approaches to the thoracolumbar junction require an understanding of diaphragm anatomy (Fig. 2). The diaphragm is a dome-shaped musculotendinous structure with anterolateral attachments to the tips of the lower six costal cartilages, lower four ribs, xiphoid process, and thoracolumbar vertebral bodies. The aorta runs between the crura of the diaphragm at the T12 level. The crura insert on the lumbar spine medially between L1 and L3. The medial arcuate ligament bridges the psoas muscle from the vertebral body to trans-

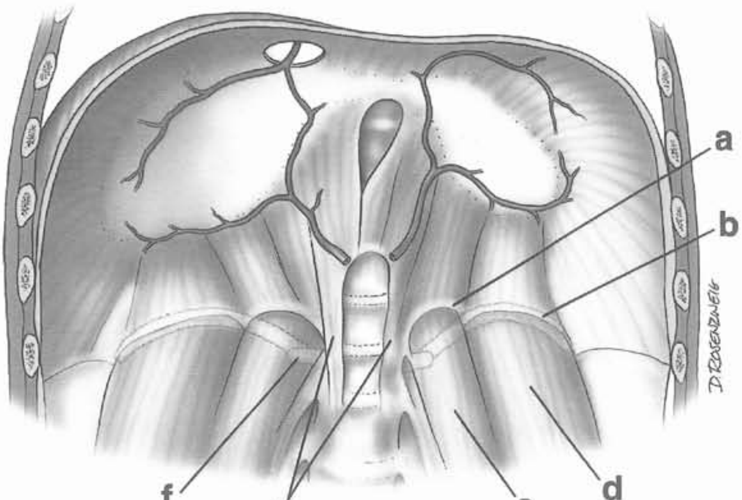

Figure 2. Anatomy of the diaphragm. a = medial arcuate ligament; b = lateral arcuate ligament; c = psoas; d = quadratus lumborum; e = crura of the diaphragm, f = L1 transverse process.

verse process of L1 or L2. The lateral arcuate ligament arcs over the quadratus lumborum muscle from the transverse process of L1 to the 12th rib.

The medial vascular and visceral structures encountered in this area are important when considering the appropriate surgical approach. From the left, the aorta is encountered; it is thick-walled and easily mobilized after division of segmental vessels (Fig. 3). The diaphragmatic arteries, celiac trunk, superior mesenteric artery, and left renal artery course within the pararenal fat. The iliohypogastric and ilioinguinal nerves descend laterally over the quadratus. The splanchnic nerves travel through the diaphragmatic hiatus over the aorta. Medial to the splanchnic nerves lies the junction of the lumbar and hemiazygos veins and the thoracic duct from T12 rostrally. From the right, the liver is suspended by the coronary ligament which may be divided for mobilization. The inferior vena cava is the predominant structure on the right anterior aspect of the spine. The azygos vein sends a tributary over the right crus of the diaphragm to the inferior vena cava. The intercostal veins enter the azygos and hemiazygos vessels on the right and left, respectively. The artery of Adamkiewicz usually arises on the left in the lower thoracic or upper lumbar region. The segmental vessels run toward their respective foramina, where they give off spinal and dorsolateral muscular branches. These vessels create an extensive collateral network around the spine and spinal canal (Fig. 4). Sacrifice of segmental vessels unilaterally over several levels is therefore safe when performed proximal to the neural foramen.[15, 31, 37, 56]

INDICATIONS

Trauma

Traumatic involvement of the thoracolumbar junction is common. Between 50% and 80% of fracture dislocations occur between T10 and L2.[21, 22, 33, 52] The inflection from a kyphotic to a lordotic curvature, transition from coronally to sagittally oriented facet joints, decrement in rigidity of the thoracic cage due to free lower ribs, and increase in size of the disc spaces are some of the specific anatomic factors that are responsible for the propensity for traumatic injury in this area. Although many thoracolumbar injuries are stable, others may involve significant neurologic deficit, spinal canal compromise, and acute or progressive deformity. Operative decisions for the treatment of traumatic thoracolumbar injuries should rely on the assessment of canal compromise, spinal stability, and the presence of sig-

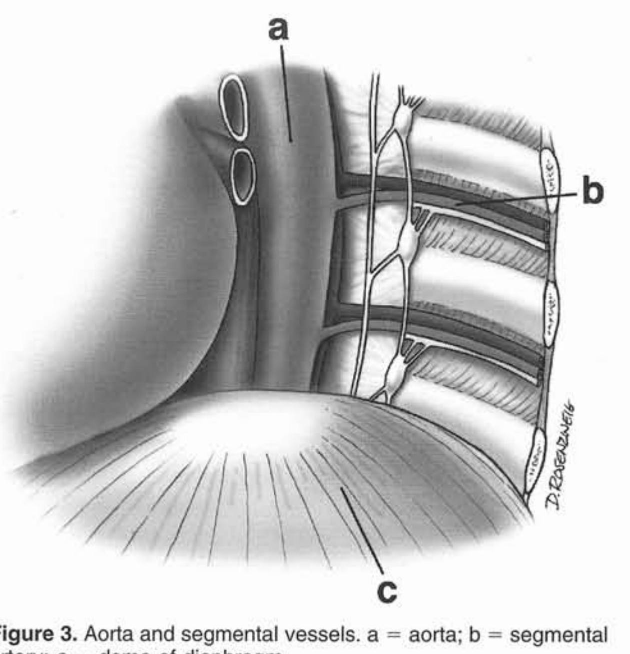

Figure 3. Aorta and segmental vessels. a = aorta; b = segmental artery; c = dome of diaphragm.

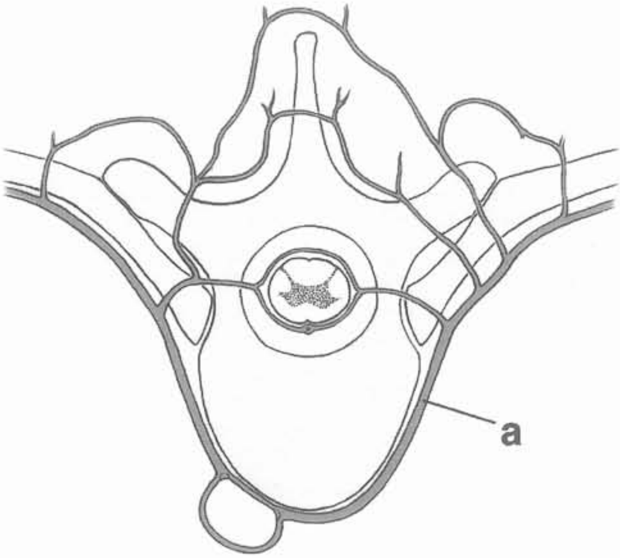

Figure 4. Anastomotic network of spinal cord blood supply. a = proximal division of segmental vessels preserves anastomotic supply to the spinal cord.

nificant deformity. Decompression of the canal, stabilization of the spinal column, and correction of deformity are the surgical goals.

The optimal approach is dictated by the type of injury and medical condition of the patient. The use of a posterior approach with instrumentation has been well documented. Reduction and immediate stabilization are possible. Decompression of the canal may be accomplished by ligamentotaxis or transpedicular corpectomy. Anterior interbody grafting is not possible from a direct posterior approach but may be performed using the lateral extracavitary route. Posterior canal decompression alone, however, is of little value for ventral neural compression and is destabilizing. Extensive experience has been reported on the treatment of thoracolumbar fractures via posterior stabilization with Harrington rods, variable spine plate systems, Cotrel-Dubousset instrumentation (SOFAMOR DANEK, Memphis, TN), and other universal spinal instrumentation systems.[14, 16, 18, 25, 41, 43, 69] There is little evidence that neurologic outcome is improved using these modalities versus less aggressive management in these series, but immediate stabilization may optimize rehabilitation and reduce length of hospital stay. The results of posterolateral decompression are equivocal, although delayed decompression may allow continued neurologic recovery in those patients whose course has plateaued.[23, 41, 47, 50] With posterior fixation, there may be significant loss of reduction over time and complications in up to one third of patients.[49, 50] Gertzbein et al[25] found that half of the thoracolumbar burst fractures treated with Harrington rods lost reduction. They suggested that this occurred due to the construct's inability to resist bending and torsional forces and that these procedures would be optimized with anterior bone grafts or use of more rigid posterior instrumentation. Better mechanical results have been achieved with the Cotrel-Dubousset and other systems.[12, 25, 50] Ebelke et al,[16] using Steffee plates with and without anterior grafting, also found better mechanical results in the anteriorly grafted patients. These grafts were placed via both the transpedicular route and staged anterior procedures.

A number of different traumatic lesions have been treated using anterior approaches, the most common of which are burst fractures. Management of these lesions has been controversial. Conservative management may yield excellent results when there is minimal canal compromise, intact posterior elements, and the patient has no neurologic deficit.[3, 10, 13, 21, 52, 65] Mumford[52] reported on a series of neurologically intact patients with an average of 37% decrement in canal diameter who were all managed with a combination of bed rest, bracing, and physiotherapy. The long-term results were good and excellent in two thirds of the cases, and satisfactory work status was achieved in 90%. Only one patient deteriorated and required surgery. Cantor et al[10] found that 95% of conservatively managed, intact patients returned to work and had an average length of hospital stay of 10 days. Despite these results, most fractures with greater than 40% loss of vertebral body height, greater than 50% canal compromise, major kyphotic deformity, or significant neurologic deficit are considered operative lesions, although an effective, randomized study is lacking.[5, 66] The indications for an anterior approach to thoracolumbar fractures are not absolute. Decisions may depend on the familiarity of the surgeon with various approaches and the presence of chest or abdominal trauma which may preclude anterior surgery. If the posterior elements are intact and there is significant canal compromise, anterior decompression may be optimal. Bohlman and his colleagues[5, 6] found better results in patients undergoing anterior decompression for thoracic and lumbar fractures. Esses et al,[18] in a series of patients with burst fractures randomized to either posterior distraction and pedicle instrumentation or anterior decompression and instrumentation, found a significant difference in canal clearance on early postoperative computed tomography scans with anterior surgery. There was no difference in neurologic outcome, and the complication rates were comparable between approaches. Kostuik[36] has reported on 80 patients with good results treated via an anterior approach using Kostuik-Harrington instrumentation and recommends this approach for acute injuries with major deficit and canal compromise, injuries older than 3 days with similar findings, and injuries older than 7 days with significant kyphotic deformity. From a biomechanical standpoint, anterior surgery is appealing, because restoration of height, axial load stability, and prevention of delayed deformity can be optimized. Improved stiffness and torsional rigidity may also be obtained with anterior grafting and instrumentation.[27] Overall, anterior procedures have been successful in the hands of experienced operators. Validation of their use awaits a randomized trial.[18]

Deformity and Degenerative Conditions

Posttraumatic kyphosis of the thoracolumbar spine has been treated by anterior, posterior, and combined approaches. Indications for surgical management have included progressive deformity, kyphosis greater than 30°, intractable pain, or persistent or progressive neurologic deficit.[11, 37, 48, 56] Prior laminectomy is a risk factor for the development of delayed kyphosis because it reduces the ability of the spine to withstand posterior element failure in flexion. Disruption of sagittal balance may result in a compensatory lumbar hyperlordosis.[37, 48] Fifty percent of the patients treated anteriorly by Malcolm et al[48] failed reduction with use of iliac crest grafts. These patients were mobilized early without supplemental anterior instrumentation. Iliac crest grafts alone may not provide adequate axial load stability, making instrumentation or prolonged recumbency necessary to improve these results.[37, 56] Neurologic improvement has been noted in 30% to 71% of patients after anterior decompression, and pain relief has been achieved in 68% to 98%.[37, 48, 56] Solid fusion and correction of deformity can be expected in over one third of patients.[37, 56] In Chang's series of 17 patients with posttraumatic kyphosis,[11] solid fusion was obtained in all patients using combined anterior release and posterior fusion and instrumentation with pedicle screws. The high failure rate of posterior surgery alone for this disease process makes the anterior approach alone, or in combination with posterior surgery, an excellent management option.

Adult thoracolumbar scoliosis has also been treated by a variety of approaches. Indications for operative intervention include severe axial and radicular pain, progressive deformity, and neurologic deficit.[38] Anterolateral approaches alone may be successful, often in combination with Zielke (Osteotech, Shrewsbury, NJ) instrumentation.[32, 46, 51, 63] The Dwyer system has also been used but with less favorable results.[34] Anterior approaches have been recommended for a variety of reasons, including the avoidance of iatrogenic flat back syndrome, which occurs more frequently with posterior procedures.[39] Severe deformities may optimally be treated with combined approaches.

Degenerative processes of the thoracolumbar junction are not uncommon. Thoracic disc herniation is prominent and is most frequently found at the lower thoracic and thoracolumbar segments of the spine. The peak incidence is at T11 to T12, where about one fourth of thoracic discs are located.[1, 9, 42, 54] A variety of surgical approaches have been used, and posterolateral techniques may suffice for posterolateral herniations.[42] Excellent results have also been obtained with a transthoracic approach with anterior bone grafting. Otani et al[54] have described the use of this technique in 23 patients presenting with myelopathy of varying degrees with excellent recoveries in all cases.

Infection

Infections of the spine may often result in spinal deformity and neurologic compromise that require correction. Early experience with spinal tuberculosis treated by an anterior transthoracic approach is noteworthy. Three fourths of patients achieved complete recovery from paraplegia, fusion rates were greater than 90%, and mortality was only 3%.[30, 31, 54] Anterior resection and fusion have a lower associated incidence of delayed deformity when compared with posterior procedures.[45, 64] For nontuberculous ventral cord compression, anterior decompression has been associated with better outcome than posterior surgery.[6, 17] Kostuik[35] reported on 15 patients with thoracic pathology treated in this fashion. Seven of 7 patients with neurologic dysfunction recovered completely. The addition of anterior instrumentation in these cases did not appear to affect the risk of surgical infection.[35, 53] For primarily dorsal compression with otherwise uncompromised spinal stability, posterior decompression is usually adequate.

Neoplasia

Both primary and metastatic spine tumors may involve the thoracolumbar junction and can be managed with anterior, posterior, or combined techniques. Metastatic lesions are the far more common of the two and occur in between 20% and 70% of patients with the most common cancers.[61] With longer survival accruing from advances in adjuvant therapy, intensive rehabilitation programs, and improved surgical techniques, a greater number of patients will be operative candidates. In most cases, lesions are located ventrally.[2, 26] It has been well demonstrated that laminectomy alone for the treatment of neoplastic disease of the spine with neurologic deficit from ventral compression is usually contraindicated.[4, 20, 26, 29, 40, 58, 67] Posterolateral approaches for decompression have been used more successfully and are particularly relevant for disease that includes three-column dysfunction or translocation, more than three segments of involvement, two or more separate areas of involvement, or a medically precarious patient.[8] Conversely, anterior surgery for compressive lesions will often result in return of function and is usually the most direct route for addressing the area of pathology[29, 35, 40, 57, 58, 61, 62] The indications for anterior decompression and stabilization of metastatic disease that have been used by various investigators include ventral cord compression with neurologic deficit, lack of tissue diagnosis, destruction of the spine by a paraspinal tumor, instability after radiation therapy, solitary relapse in a patient with known cancer, radioresistant tumors such as hypernephroma or melanoma, neurologic deterioration while a patient is receiving radiation therapy, and spinal instability as demonstrated by subluxation or an area of kyphotic deformity. Preoperative angiography and embolization may also be considered for patients with hypervascular tumors such as renal or thyroid metastases. Excellent results have been obtained with anterior decompression in cervical cases; these results may be extrapolated to the thoracolumbar region. Harrington[29] treated 10 patients with thoracolumbar neoplastic disease by anterior decompression and stabilization and reported excellent outcomes even in those patients with significant neurologic deficits. Anterior stabilization was performed with either Knodt or Harrington rods and methylmethacrylate. When compared with posterior decompression, anterior surgery yielded superior neurologic recovery in patients with major deficits (50% versus 33% significant recovery).[40] The majority of patients are ambulatory and report significant pain relief following anterior surgery.[62] Additionally, up to 80% of nonambulatory patients may regain the ability to walk, which is far better than after radiation or posterior surgery.[57, 62] Overall, pain relief may be obtained in about 80% of cases and motor improvement in 85%; median survival ranges from 12 to 16 months.[61] Neurologic deterioration is rare, and perioperative mortality varies from 6% to 8%. The overall complication rate ranges from 8% to 11%. These figures include patients who were not treated initially with anterior surgery; anterior approaches alone may decrease combined morbidity and mortality to less than 5%.[61]

SURGICAL TECHNIQUE

Posterior Approaches

Posterior approaches to the spine are generally familiar to the neurosurgeon. The technique for bilateral decompressive laminectomy is well known. Some technical points deserve emphasis. Strict hemostasis is optimal during the paraspinal muscle takedown. This can be achieved with monopolar cautery and strict adherence to the subperiosteal plane. Awareness of the location of the dorsal rami of the segmental arteries in the intertransverse spaces and control of these with bipolar cautery is important during a more lateral exposure for posterolateral fusion. Removal of the lamina should proceed carefully, as the underlying conus medullaris is less forgiving than the cauda equina in the lower lumbar region. Thinning of the lamina with Lexel rongeurs or a drill often facilitates removal. Kerrison bone biting instruments should be used only with careful attention to the amount of dural compression created by the footplate. The lateral extent of decompression is important. For dorsal decompression, the lateral margins of the dural sac should be visualized, but the facet joints should be left intact. This ensures adequate decompression of the cord, conus, and cauda equina, at the same time, minimizing the risk for postoperative instability.

The transpedicular approach affords posterior access to the disc space via removal of the pedicle and associated joint.[55] The technique has been frequently used for thoracic disc removal with good resolution of radicular pain but sometimes disappointing results for axial pain relief.[42] A transfacet pedicle-sparing approach has been described that preserves a portion of the joint and claims a better outcome with regard to axial pain.[60] Both approaches utilize a standard midline incision with subperiosteal dissection of the paraspinal muscles out lateral to the facet joint. A high-speed drill with a small burr is used to remove the joint and pedicle in the transpedicular approach or the midportion of the joint in the transfacet approach. After intradiscal decompression, long down-going curettes are used to deliver ventrolateral disc material into the disc space.

Posterolateral Approaches

The costotransversectomy and lateral extracavitary approaches to the thoracolumbar junction provide more lateral exposure of the spine than do the posterior approaches and still preserve the option to perform posterior instrumentation and fusion through the same exposure. Both approaches use the prone position. For costotransversectomy, an incision from the midline directed laterally over the appropriate rib is carried down to the rib laterally. Medially, the paraspinal muscles are divided to expose the facet joint and lamina. The rib and rib head are removed by dividing the costotransverse and costovertebral ligaments. The transverse process and pedicle can be removed with rongeurs and a high-speed drill. Removal of the medial cortex of the pedicle gives access to the lateral and ventral dural sac.[24, 28, 59]

The lateral extracavitary approach is more extensive. A longer midline incision is made, usually extending three segments above and below the pathology. Hockey-stick and semilunar incisions are also convenient. The thoracodorsal fascia is incised, and the trapezius aponeurosis is mobilized laterally. The paraspinal muscles are dissected medially from the spinous processes and laminae and laterally from the facets. These muscles are retracted contralaterally over the spinous processes. The necessary ribs can be removed as described above. Intercostal nerves may be retracted or ligated above L1. A subperiosteal dissection mobilizes the sympathetic chain, endothoracic fascia, and pleura anteriorly. Exposure of the lateral dural sac is obtained by removal of the pedicles. Corpectomy and interbody grafting can then be performed. Careful reapproximation of the tissue layers is important during closure.[19]

Anterolateral Approaches

Retropleural Thoracotomy

Two anterior approaches to the thoracolumbar area have been described. Exposure above and below the diaphragm is a requirement of nearly all these approaches. The major difference between approaches is the choice of the transpleural or retropleural route. We use a retropleural thoracotomy for pathology limited to two spinal segments or less. A left-sided approach is preferable, as the aorta is easier to mobilize than the vena cava and the liver does not obstruct the view. An epidural catheter for morphine administration may be placed to reduce postoperative pain and atelectasis from splinting. Evoked potentials may be useful when deformity correction is performed or when significant manipulation of the dural sac is anticipated. A cell saver is useful for extensive procedures or those with vascular pathology. A double lumen endotracheal tube is used for higher thoracic procedures but is not necessary below T6. The patient is placed on a beanbag in the lateral position with the lower leg flexed and the region of interest over the table break (Fig. 5). An axillary roll and adequate padding are important to prevent pressure neuropathies. Radiographs are obtained to confirm the correct level. Because of the caudal angulation of the ribs, it is optimal to make the incision over the rib two levels above the pathology; an incision over the 10th rib would be used for T12 pathology.

The incision begins approximately 4 cm lateral to the midline and extends over the rib to the midaxillary line (see Fig. 5). The subcutaneous tissues and back muscles are divided with cautery to the rib periosteum. This is dissected free with preservation of the intercostal bundle using curved dissectors. A Doyen dissector is used to strip the periosteum along the length of the rib as proximally as possible, usually to within 1 to 2 cm of the costotransverse joint. Rib cutters are used to remove the rib, which is saved for grafting (Fig. 6). The remaining intercostal muscle fibers and endothoracic fascia over the pleura are identified. The endothoracic fascia is a shiny tissue layer which lies deep to the rib periosteum; it is opened with scissors in line with the incision (Fig. 7). Using a Kittner clamp, the parietal pleura is freed from the endothoracic facia in ventral, rostral, and caudal directions to expose the rib heads and anterior spine (Fig. 8). The costodiaphragmatic sinus is freed of its pleura. Rather than incise the diaphragm circumferentially from the anterior chest wall, we use sharp subperiosteal dissection of the 11th and 12th rib diaphragmatic attachments to communicate the retropleural and retroperitoneal spaces. This requires a smaller and more caudal transdiaphragmatic opening. The peritoneum is gently swept with blunt dissection away from the posterior abdominal wall. Again, care must be taken to avoid dissection near the central tendon, where the peritoneum is thinner and more tightly applied. Tears result in herniation of abdominal contents and may be difficult to repair. The diaphragmatic dissection continues medially to elevate the medial and lateral arcuate ligaments off their underlying muscles. A cuff of the insertion onto the L1 transverse process is preserved for later reattachment. The subcostal nerve may be seen coursing over the quadratus at this point. Finally, the left crus is divided to complete communication of the thoracic and abdominal compartments. This is done inferior to the greater splanchnic nerve. The hemiazygos vein may require cautery or hemostatic clips. A table-mounted retractor is positioned to move the lung medially. The proximal rib head is then sharply dissected from its spinal attachments and removed (Fig. 9). The periosteum overlying the vertebral body is incised and dissected away from the spine. The psoas muscle is elevated laterally to the pedicles.

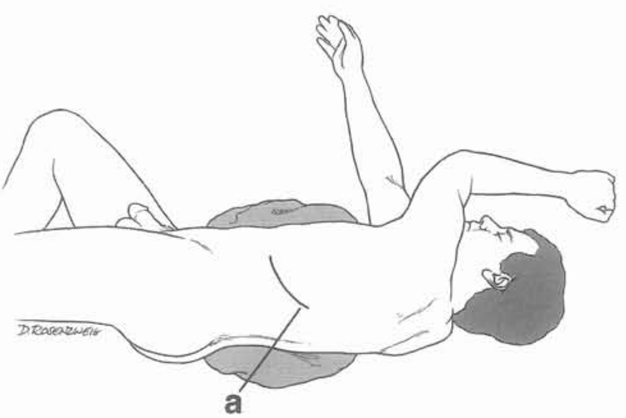

Figure 5. Positioning for operation. a = skin incision.

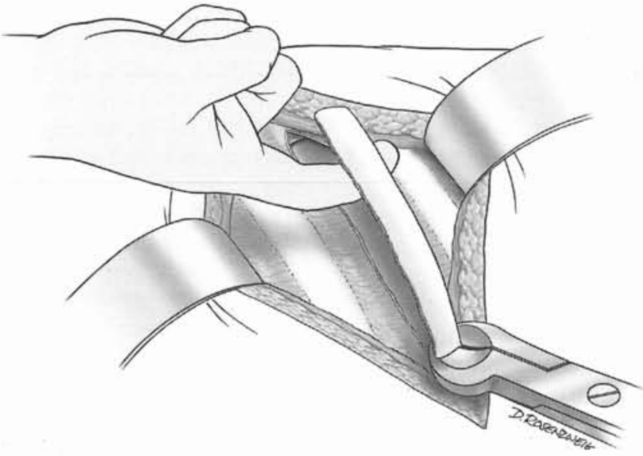

Figure 6. Rib resection. The resected segment may later be used for grafting.

Exposure of the ventral spinal canal begins at the disc space. The anterior longitudinal ligament and annulus are incised (Fig. 10). For entry into a single disc space, the segmental vessels need not be divided. Corpectomy requires ligation of these vessels midway between their origin from the great vessels and the neural foramina (Fig. 11). The disc space is evacuated with curettes and rongeurs (Fig. 12). The pedicle is identified and may be dissected with small, angled curettes or nerve hooks. Cautery should be avoided in proximity to the neural foramen. A high-speed drill is then used to perform a partial corpectomy,

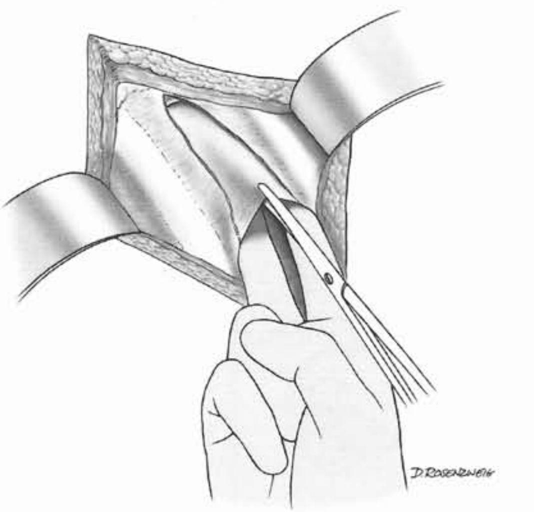

Figure 7. Incision of endothoracic fascia in the resected rib bed.

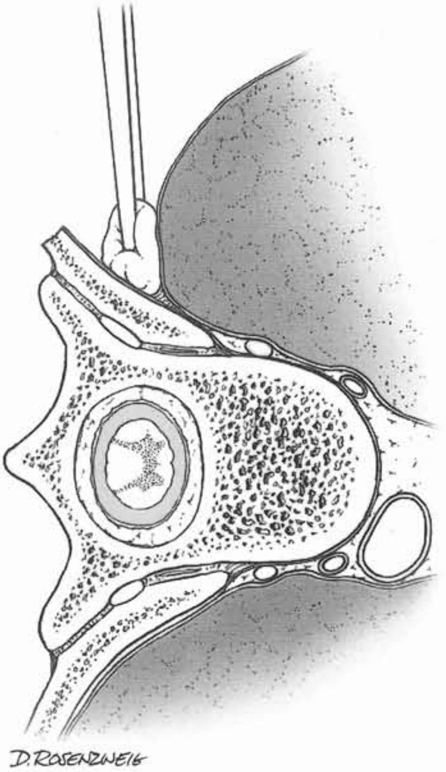

Figure 8. Dissection of the pleura. Separating the pleura extensively in the rostrocaudal direction helps to avoid tears.

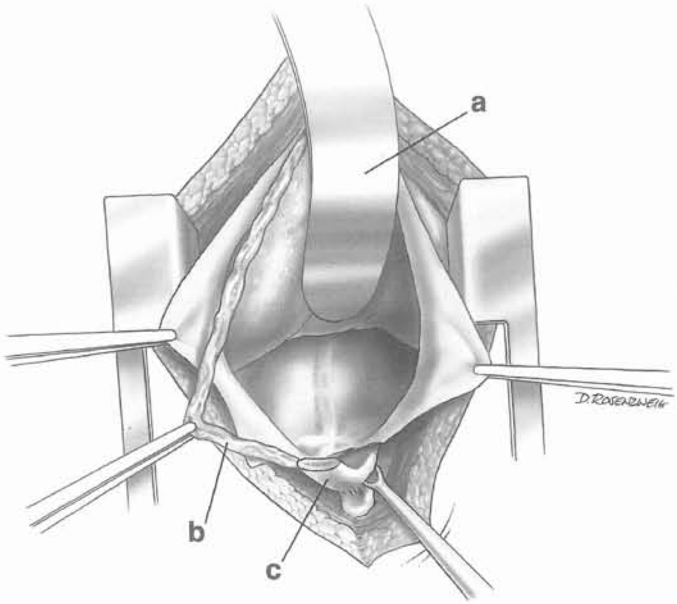

Figure 9. Removal of the head of the rib. a = retractor on lung; b = intercostal neurovascular bundle; c = proximal rib is disarticulated with curettes.

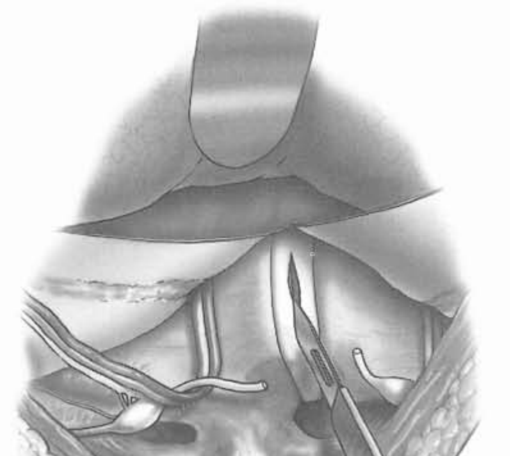

Figure 10. Incision of the disc space. Note that the sympathetic chain has been divided and the segmental vessels are at midbody level.

beginning at the disc space. The pedicle is drilled away to a thin layer of medial cortex, which can be removed with a Kerrison punch (Fig. 13). The posterior longitudinal ligament is usually visible at this point. Further bone removal is continued with the drill until there remains only a thin shell of posterior vertebral body cortex ventral to the posterior longitudinal ligament. This shell of bone and ligament is removed by pushing it ventrally into the corpectomy defect with a down-going curette. Bipolar cautery is used to stop epidural venous bleeding. The decompressed dura should be visible. Mortises are drilled into the superior and inferior vertebral bodies. Bone graft is placed into the interbody defect while distraction is applied with a spreader (Fig. 14). If instrumentation is used, it may be applied prior to grafting to assist in distraction for graft placement and compression for load sharing. Bone graft combinations of alloimplant femur or tibia and autologous rib are usually sufficient to provide an adequate load-bearing surface. Instrumentation with a lateral plate or other device may provide immediate stability and enhance the fusion rate.

In cases with a poor long-term prognosis and chance of fusion secondary to metastatic disease, Steinmann pins and methylmethacry-

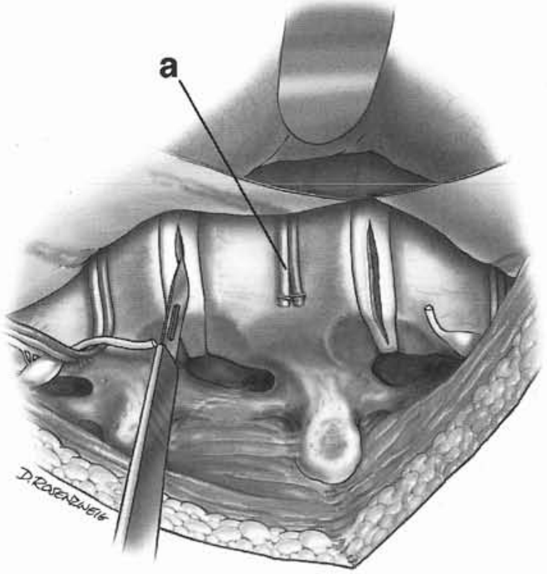

Figure 11. Preparation for corpectomy. a = segmental vessels have been divided proximal to the foramen.

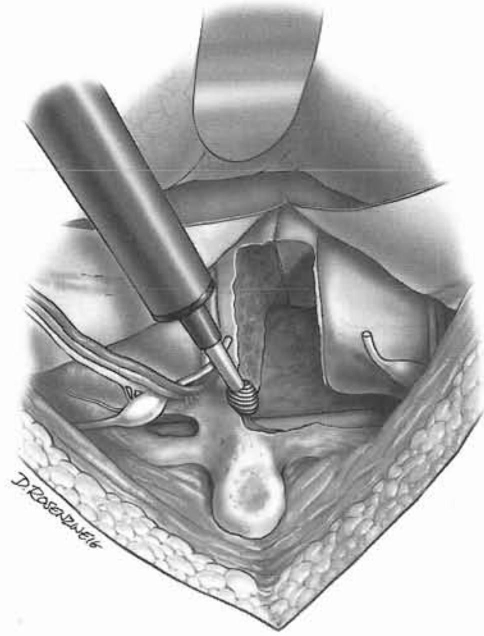

Figure 13. Drilling of the end plates and pedicle.

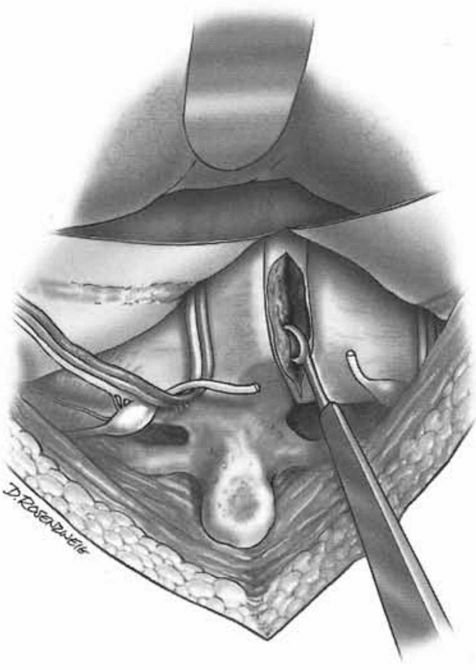

Figure 12. Evacuation of the disc space.

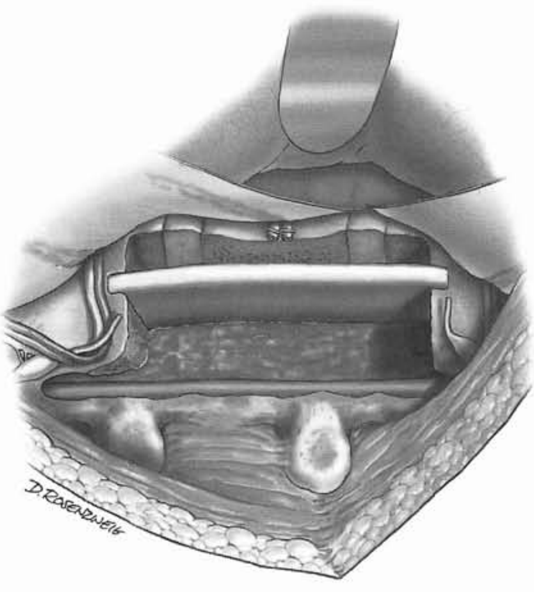

Figure 14. Bone graft placement.

late may be used. Instrumentation is applied with care to orient vertebral body screws laterally into the spine without threatening the canal posteriorly or soft tissues anteriorly. Low-profile devices may be preferable to further minimize the chance of soft tissue injury. The wound is irrigated. The diaphragm is reattached with sutures to the psoas, L1 transverse process insertion, quadratus, and costal cuff. Pleural tearing may require chest tube placement; the tube usually can be removed on the second postoperative day. The incision is closed in layers, taking care not to ligate the intercostal nerves which may cause significant postoperative pain and lateral thoracoabdominal wall hernias. Most patients may ambulate the day following surgery. A thoracolumbosacral orthosis is employed if instrumentation was not used.

Transpleural Thoracotomy

The transpleural approach is similar to that described above. It is based upon the operation initially used by Hodgson for the treatment of Pott's disease.[22] The lateral position is used. The incision is over a rib two levels above the pathology. The patient may be tilted on the table by 60° or 70° unless posterior instrumentation is to be used. After subperiosteal removal of the rib, the parietal pleura is incised. The diaphragmatic incision leaves a cuff of 1 cm for reattachment. Other details of the approach to the vertebrae are similar to that described above. A chest tube is inserted at closure.

Thoracophrenolumbotomy as described by Louis[44] for thoracolumbar junction exposure utilizes the supine position with extension of the back over the table break to maintain lordosis before any fixation. The incision is more anterior, over the ninth rib from the midaxillary line, and inclines interior to the border of the rectus, above or below the umbilicus, depending on the inferior extent of the spinal pathology. Exposure begins at the abdominal end of the incision with dissection through the transversalis to expose the peritoneum. The ninth rib is then dissected with opening of the pleura. The common costal cartilage is incised, and gentle retraction is applied. The abdominal surface of the diaphragm is bluntly dissected from the peritoneum, the lung is protected, and the diaphragm is incised leaving a cuff for reattachment. The diaphragmatic incision continues medially through the crus inferior to the greater splanchnic nerve as described above, and the subsequent exposure of the spine follows.

Stabilization

Appropriately chosen surgical approaches to the thoracolumbar area can provide excellent decompression of the neural element and resection of pathologic tissue. The postoperative stability of the involved segments is an important issue. Mechanical and neurologic stability is the goal in all cases. Bony fusion is often optimal, although in cases of neoplasia, it is not always possible. Posterior approaches may require no attempt at fusion or stabilization if the anterior and middle columns are intact and the facet joints are preserved. Significant posterior resections are destabilizing, and in the presence of anterior element compromise, they usually require fusion with intrumentation. Hook, rod, and pedicle screw constructs are frequently used and provide significant stability until bony union occurs. Anterior approaches may destroy the weight-bearing capability of the spine and consequently require interbody grafting. Interbody grafting alone provides stability in compression, but stability in extension, flexion, and rotation is limited. Placement of anterior devices may provide immediate stabilization and allow the application of distractive or compressive forces across the instrumented segments. A variety of systems are available. Plate-based systems include AO plates,[7] the Syracuse I-plate,[68] the Synthes I-plate (Synthes, Paoli, PA), and the Zdeblick Z-plate (SOFAMOR DANEK, Memphis, TN). Rod systems have been extensively reported. They include the Slot-Zielke (Osteotech, Shrewsbury, NJ), Kaneda (ACROMED, Cleveland, OH), and Kostuik-Harrington systems.[32, 36–40]

Complications with these devices may be encountered intraoperatively or in a delayed fashion. These include vascular or visceral injury, difficulty with screw placement or subsequent pullout, device failure, graft migration, infection, and pseudarthrosis. Management of these patients is optimized by physiotherapy, rehabilitation, and use of orthotics.

CONCLUSIONS

In summary, a number of disease processes affecting the thoracolumbar junction are treatable surgically. In appropriately chosen patients, the optimal surgical approach is dictated by the goal of the operative procedure, that is, decompression, stabilization, or correction of deformity, as well as the location of the pathology. Instrumentation systems may improve fusion rates and allow earlier mobilization. The importance of comprehensive medical and neurologic evaluation of these patients cannot be overemphasized.

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