CHAPTER 302

Anterior Lumbar Instrumentation

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Biomechanical insufficiency of the ventral lumbar spine is a common clinical problem encountered by spinal surgeons. Its effective management requires a comprehensive understanding of the indications for ventral surgical intervention, spinal biomechanics, anterior spinal anatomy, ventral surgical approaches, and techniques for spinal stabilization. Loss of the structural integrity of the anterior and middle columns of the spine may be caused by the pathologic destruction of the vertebral body secondary to neoplastic, traumatic, infectious, and degenerative processes, or it may occur as an iatrogenic consequence of surgical decompression. These may all be indications for anterior lumbar instrumentation. Additionally, correction of spinal deformity may require anterior stabilization of the lumbar spine.

A variety of anterior fixation techniques and devices provides the spinal surgeon with several options when planning anterior lumbar surgery. Anatomic factors place constraints on surgical approaches to the upper, mid, and lower lumbar regions and also, to some degree, on the type of instruments that may be used. Selection of the approach and type of construct depend, among other factors, on the specific indications for surgery, the levels involved, and whether any posterior procedure has been performed or is planned.

INDICATIONS

There are several broad indications for anterior lumbar stabilization, regardless of the specific pathology present. When the stability of the anterior column is in jeopardy or when ventral spinal arthrodesis is desired, an anterior approach may be necessary to ensure proper stabilization and bony fusion. Midline or bilateral ventral decompression of the spinal canal, when necessary, is best accomplished through an anterior approach. Finally, anterior stabilization is indicated in cases where ventral correction of a deformity is preferred or necessary to restore proper spinal alignment. A clear understanding of the surgical indications based on the specific pathology and cause of instability is essential to planning appropriate surgery and achieving optimal outcomes.

Neoplasm

The spinal column is the most frequent site of bony metastases[1]; up to two thirds of these arise from breast, prostate, lung, and hematopoietic cancers.[1-6] Primary tumors of the spine, on the other hand, are extremely rare. Less than 10% of reported bone tumors and soft tissue sarcomas involve the spine.[7,8] Clinical manifestations of spinal tumors result from expansion of the periosteum or cortex, pathologic compression fractures, spinal instability, spinal deformity, and direct compression of neural elements. By far the most common symptom produced by either primary or metastatic lesions is pain,[9-12] stereotypically a constant pain that is not relieved by rest and intensifies at night. Progression of the tumor beyond the confines of the vertebral body may produce myeloradiculopathy because of direct compression of neural elements or compromise of vascular supply. Acute partial loss of neurological function may be an indication for urgent surgical intervention because studies have shown improvement in neurological function following early surgical treatment in such circumstances.[13,14]

Numerous series have reported the successful treatment of spinal neoplastic disease with a ventral or ventrolateral approach.[6,14-22] Prognostic factors, including tumor type and location, preoperative neurological status, overall life expectancy and medical condition correlate with surgical outcome[23,24] and should be carefully considered in formulating a management strategy for each patient.

Trauma

Compared with fractures of the thoracolumbar junction, fractures of the lumbar spine distal to L2 are relatively uncommon, with less than 4% of all fractures involving L3-5.[25,26] Certain mechanisms of high-energy traumatic injury tend to be associated with both thoracolumbar and lumbar fractures. Falls from a significant height that produce a substantial axial load may result in unstable burst fractures. Passengers wearing lower abdominal seat belts during motor vehicle accidents may sustain flexion or flexion-distraction injuries to the lumbar or thoracolumbar spine, with the seat belt acting as a fulcrum.

The decision to treat a lumbar spine trauma patient operatively is based on multiple factors. In addition to the presence of a neurological deficit, the extent of spinal canal encroachment or compromise, loss of vertebral body height, degree of local kyphotic deformity, and fracture pattern may guide treatment decision making.[27-38] Various classification schemes have been proposed for spinal fractures, many of which are based on Denis' three-column model of spinal stability and on the mechanism of spinal injury.[39-43] Generally, a fracture that compromises the anterior and middle columns is likely to be unstable, but isolated anterior column involvement causing significant kyphosis may also warrant surgical intervention to prevent the development of a progressive deformity.[44] The surgeon must also decide whether a stand-alone anterior construct is appropriate or if a circumferential (anterior-posterior) construct and arthrodesis are necessary.

Surgical decompression is the first-line treatment for a patient with an acute partial neurological deficit due to neural compression following trauma. Emergent decompression is recommended for a progressive neurological deficit and a grossly unstable spine. The indications for operative treatment of patients with fixed neurological deficits are less clear. Advocates who favor delaying surgery believe that there is a reduced risk of neural injury and intraoperative blood loss with surgery after the acute period.[45,46] Proponents of early surgery, on the other hand, contend that it provides the best opportunity for neurological recovery and that delaying intervention may make it more difficult to achieve fracture reduction or spinal correction. Patients may also be mobilized early after surgery, thereby avoiding the complications of prolonged bed rest.[47]

Degenerative Disease

Degenerative disease is a common condition of the lumbar spine, which is often characterized by chronic, progressive instability.[48] Reconstruction of the anterior column can effectively improve sagittal balance, restore lumbar lordosis, and enlarge the neural foramina, reversing the pathologic consequences of degenerative processes.[49,50] Anterior interbody fusion may be indicated for a wide range of degenerative pathology including degenerative disk disease, lumbar instability, iatrogenic instability, pseudoarthrosis following posterior arthrodesis, or a grade I or II spondylolisthesis.[50-58] There are, however, several relative contraindications to anterior interbody fusion procedures including severe osteoporosis, grades III and IV spondylolisthesis, and extensive vertebral body destruction. In cases of severe degenerative destruction of vertebral bodies, or a significant local spinal deformity, multisegmental ventral instrumentation constructs may be necessary, either alone or in conjunction with posterior fixation.

Infection

Bacterial organisms, usually *Staphylococcus aureus*, are the most common causes of spinal infections, and most spinal infections are treated with intravenous antibiotics and immobilization before the onset of a neurological deficit or spinal deformity.[59-61] Operative indications include a progressive neurological deficit, a significant spinal deformity, intractable pain, or, more rarely, progression of the infection despite appropriate antibiotic therapy. Because infections of the vertebral body affect the anterior and middle columns, the surgical approach must provide access to the ventral spine to allow complete débridement of the active infection. This often involves discectomies and a corpectomy of the involved vertebral body followed by a fusion. Evidence suggests that the rate of postoperative infection is not increased in the presence of metallic implants provided débridement has been adequately performed.[59,62]

SURGICAL APPROACHES

The decision of which approach to use is influenced primarily by which lumbar levels are involved and by the goals of surgery. Over the years, several ventral approaches for access to the anterior lumbar spine have been developed and refined.[58,63,64] The approach selected should provide maximal visualization of the lesion and regional anatomy. For instance, exposure of the thoracolumbar junction for access to L1 requires a thoracoabdominal approach and release of the diaphragm. Lesions located between L2 and L5 can be addressed through a flank or paramedian incision and a retroperitoneal approach. If midline exposure of L2 to L5 is required, a transperitoneal approach is often most direct. The side of the approach is ultimately dictated by the location and nature of the pathology, but a left-sided approach is usually preferred because the liver is avoided and the aorta is easier to mobilize and less susceptible to injury than the vena cava. Our practice is to use a general or vascular surgeon for anterior approaches to the lumbar spine to ensure a safe and adequate exposure. We scrub in, however, as assistants, to gain experience with the approaches and to help tailor the exposure to the requirements of the individual case.

Thoracoabdominal Approach (T11-L2)

The thoracoabdominal approach provides for the best exposure of T12-L2. This approach requires a rib resection; generally, resection of the rib two levels above the level of primary pathology is performed.[65-67] Hence, resection of the ninth rib provides the best window of access to T11-12, and is accomplished through a transthoracic approach, whereas exposure of T12-L1 may be accomplished via a thoracoabdominal 10th rib approach. Generally, thoracoabdominal exposure can be extended distally to gain access to additional lumbar levels without significant difficulty.

The patient is placed in the lateral decubitus position. A left-sided approach is usually preferred to avoid the inferior vena cava and the liver. An incision is marked using fluoroscopy and is made from the lateral border of the paraspinal musculature along the 10th rib to the junction of the rib and the costal cartilage.[68] A circumferential subperiosteal rib dissection is performed using monopolar cautery and Doyen dissectors with care taken to avoid the neurovascular bundle that lies on the inferior aspect of the rib. The rib is divided posteriorly at the angle of the rib and at the junction of the rib and costal cartilage. The rib is removed, the remaining costal cartilage is divided lengthwise with a knife or scissors, and the flaps of cartilage are retracted. The retroperitoneal space is identified with blunt dissection deep to the costal cartilage and the peritoneum is dissected off the inferior surface of the diaphragm. The peritoneum is then retracted medially, and the abdominal musculature is divided in layers, revealing the diaphragm. The endothoracic fascia within the rib bed is divided along with the parietal pleura, which is deep to it. The soft tissue is swept off the thoracic and abdominal surfaces of the diaphragm, which is then incised circumferentially leaving a cuff of muscle of approximately attached to the chest wall. The crus of the diaphragm is cut and elevated off the spinal column. Alternatively, the diaphragm is bluntly stripped from the chest wall with a Cobb elevator or sponge stick. This technique obviates the necessity of reapproximating the diaphragm at closure. A large Deaver retractor is used to retract the peritoneal sac anteromedially, and a large rib retractor opens the 10th rib space to reveal the thoracolumbar junction. In the lumbar spine, the psoas must be elevated dorsolaterally off the vertebral bodies to allow full visualization as far distally as the lesion dictates, taking care not to injure the lumbar plexus that runs within the muscle or the genitofemoral nerve that runs on its surface. A table-mounted retractor with multiple adjustable arms is used to maintain exposure during the procedure.

Before closure a chest tube is inserted and tunneled out through a separate incision located distal to the main incision. The diaphragm is sutured to the peripheral cuff. The costal cartilage is carefully approximated, which reestablishes the separate retroperitoneal and thoracic spaces and helps to define the layers of the abdominal musculature. The rib bed is closed with interrupted permanent sutures, and the skin incision is closed in standard fashion. Postoperatively, the chest tube is typically connected to low wall suction, weaned to water seal, and removed within 48 to 72 hours postoperatively.

Retroperitoneal Flank Approach (L2-4)

The retroperitoneal flank approach offers anterolateral access to the midlumbar region (L2-4). L5 may be accessible in some patients depending on the height of the iliac crest. True midline anterior access and contralateral exposure are not possible with this approach; a midline transperitoneal approach is used if this is necessary.

The patient is placed in a lateral decubitus position with appropriate padding to prevent pressure ulcerations and neuropathies. If an electric operating table is used, the patient is positioned so that flexion of the operating table opens the space between the iliac crest and costal margin; otherwise a small rolled towel or pad may be used to achieve the same position. The incision begins in the midaxillary line between the inferior margin of the ribs and the iliac crest and follows an inferior oblique course to the lateral edge of the rectus sheath. The level of the incision is determined using fluoroscopy based on the desired level of exposure (Fig. 302-1). For lesions of the upper lumbar spine, the incision should be made above the umbilicus along the 11th or 12th rib. Occasionally a portion of the rib may be osteotomized or excised to improve exposure and can then be subsequently used as graft material. For lesions in the midlumbar spine, the incision starts at the level of the umbilicus. The lower lumbar spine is accessed through an incision superior to the

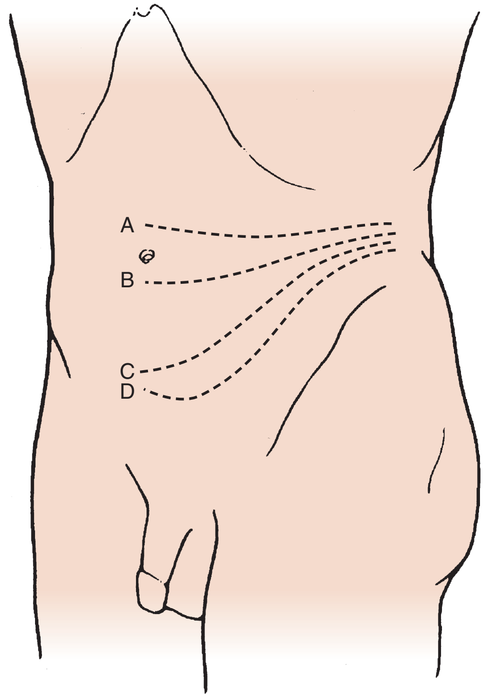

FIGURE 302-1 Transverse incisions for the retroperitoneal approach: L2-3 **(A)**, L3-4 **(B)**, L4-5 **(C)**, and L5-S1 **(D)**. *(From Benzel EC.* Spine Surgery: Techniques, Complication Avoidance, and Management. *Philadelphia: Churchill Livingstone; 1999.)*

midpoint between the umbilicus and the symphysis pubis. If exposure distal to L4 is required, the medial aspect of the incision can be extended caudally, essentially adding a paramedian approach type of incision to the traditional flank incision.

The underlying musculature, including the latissimus dorsi, serratus posterior inferior, external oblique, and internal oblique muscles, are transected in line with the skin incision. The transversalis fascia is identified and divided to enter the retroperitoneal space. The underlying peritoneum is identified as a semitranslucent layer and carefully separated from the abdominal wall using blunt dissection with a finger or a sponge stick. Adhesions, particularly toward the midline at the rectus sheath, may require sharp dissection. A plane between the quadratus lumborum muscle and retroperitoneal organs is developed, and the viscera, including the kidney, perirenal fat, and ureter, are retracted medially (Fig. 302-2). Dissection dorsal to the psoas muscle is avoided because this plane ends in a blind pouch. The dissection is continued caudally, mobilizing the peritoneum off the posterior abdominal wall to the level of the sacrum. The retroperitoneal organs and peritoneal contents are padded with moist sponges and retracted medially and positioned outside the operative field using a table-mounted retractor system. The dissection continues dorsomedially to identify the psoas muscle and genitofemoral nerve. This nerve lies along the ventral surface of the psoas muscle and should not be injured (Fig. 302-3). The psoas muscle may require dorsolateral mobilization with a Cobb elevator and monopolar coagulation to expose the spine. Overly aggressive retraction of the psoas should be avoided to prevent injury to the lumbosacral plexus located within the muscle. The sympathetic trunk, which lies just medial to the psoas along the ventrolateral surface of the vertebral bodies, should be preserved if possible (see Fig. 302-3). Division of the sympathetic trunk may result in unilateral decreased sympathetic tone in the lower extremity. Patients may complain of a cold contralateral leg because the retained sympathetic activity in the normal limb maintains

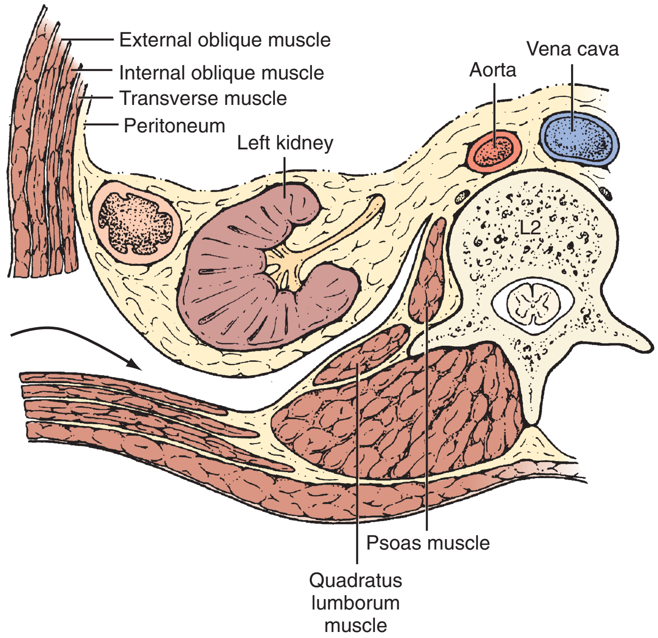

FIGURE 302-2 Axial view of ventrolateral retroperitoneal approach. *(From Benzel EC.* Spine Surgery: Techniques, Complication Avoidance, and Management. *Philadelphia: Churchill Livingstone; 1999.)*

vasoconstriction. At the lower lumbar regions, particularly L4-5, the common iliac vessels lie along the lateral aspect of the vertebral bodies and may require medial or lateral mobilization to increase exposure.

Intraoperative fluoroscopy or radiographs are used to confirm the vertebral levels. The lateral surface of the lumbar vertebrae is concave, and the surface of the intervertebral disk is convex. The lateral surface of the pedicle and the dorsal limit of the vertebral body are cleared of soft tissue with curets. This delineates the

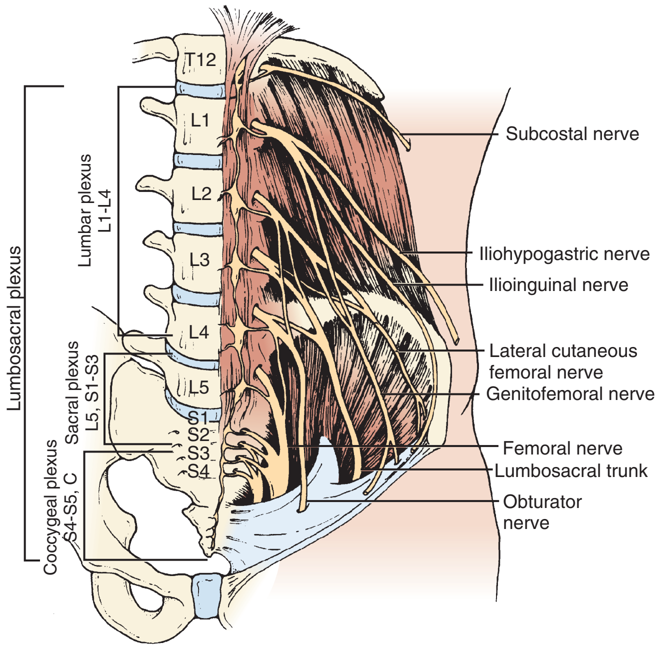

FIGURE 302-3 The lumbosacral plexus. *(From Benzel EC.* Spine Surgery: Techniques, Complication Avoidance, and Management. *Philadelphia: Churchill Livingstone; 1999.)*

intervertebral foramen and the location of the neurovascular bundle. The use of electrocautery in proximity to the neural foramen is avoided to minimize the likelihood of injury to a significant radicular artery. Unlike in the thoracic region, the nerve roots of the lumbar spine cannot be sacrificed. The segmental vessels are ligated at the level of the midvertebra and divided.

Once the vertebral elements are cleared of soft tissue, decompression, fusion, and internal fixation are performed. After the procedure, the retroperitoneal and peritoneal contents are returned to their normal anatomic positions. A drain is not routinely used. The muscle layers are reapproximated individually and sewn with a heavy absorbable suture. The skin is closed either with staples or a subcuticular stitch. Use of an external orthosis such as a thoracolumbar spinal orthosis postoperatively is determined based on the security of fixation and surgeon preference.

Transpsoas Approach (L1-5)

In recent years the field of minimally invasive surgery has expanded to involve surgical approaches to the spine as surgeons and patients seek novel methods to reduce tissue trauma during surgery, lessen postoperative discomfort, and shorten hospital stays. To this end, a novel approach through the psoas muscle offers a lateral approach that may be accomplished through one or two small (3- to 4-cm) incisions using tubular retractors and avoids the need for either a transperitoneal or retroperitoneal anterior approach.[69]

The patient is placed in a full right lateral decubitus position. The desired disk level is located in the midaxillary line under fluoroscopy using a radiopaque marker, and the incision is marked on the patient's side. A second mark is made posteriorly at the border between the erector spinae and abdominal oblique muscles. A small incision is made here and the surgeon's index finger is inserted anteriorly through the muscle layers. Blunt dissection is used to spread the muscle fibers until the retroperitoneal space is reached. The index finger is then used to sweep the peritoneum anteriorly while palpating down to the psoas muscle. An incision is then made at the first lateral skin mark, and a tubular dilator system is introduced and guided by the index finger safely to the psoas muscle, where it will overly the disk space to be operated. Alternatively, a single, slightly larger incision may be made in the flank through the muscle layers and blunt retroperitoneal dissection used to dissect medially to the psoas muscle.

After the expandable tubular retractor is docked on the surface of the psoas muscle, a blunt electromyography (EMG) probe is used to test for the proximity of the lumbar plexus. The dissection occurs between the middle and anterior third of the psoas muscle to avoid the lumbar plexus, which lies dorsally. Sequentially larger dilators are introduced through the psoas muscle to the annulus of the disk, followed by the retractor blades. EMG stimulation is again performed systematically throughout the extent of the exposed muscle. If no response is obtained with careful stimulation, the muscle may then be divided and, if necessary, removed within the confines of the retractor. When the surface of the disk is exposed, the position of the retractor is reconfirmed by fluoroscopy. Further retraction, if necessary, should be directed anteriorly to prevent additional pressure on the posterior portion of the psoas and the neural elements within it. The diskectomy and interbody fusion are performed. On closure the retractor blades are removed slowly while hemostasis is carefully confirmed, and the two small incisions closed in the standard fashion. Patients often may be discharged within 24 hours of the surgery.

The transpsoas approach has some limitations. The distal limit of the transpsoas approach is determined by the height of the iliac crest. Access to more than two adjacent intervertebral disks requires additional incisions. Because the trajectory of the approach is directly lateral, it is generally best suited for intervertebral grafting for arthrodesis rather than for decompressive procedures. Additionally, the placement of anterior instrumentation (vertebral body screws and rods) may be difficult.

Paramedian Retroperitoneal Approach (L3-S1)

Direct anterior exposure of the distal lumbar levels can be obtained through a paramedian retroperitoneal route. Compared to the flank approach, the paramedian approach provides a more direct anterior exposure and minimizes disruption of the muscles of the anterolateral abdominal wall. The paramedian approach is particularly useful for interbody grafting for arthrodesis and for decompression of the spinal canal when bilateral exposure of the vertebrae is necessary. It is also used for exposure of L5-S1 where a flank approach is usually prohibited by the ilium.

The patient is positioned supine with a bolster placed below the lower back to elevate the sacrum and facilitate the exposure. A vertical (midline or paramedian) or transverse (Pfannensteil) incision may be used, but a paramedian incision offers the benefits of preserving the rectus sheath and allowing rostral or caudal extension if necessary. The rectus sheath is opened along the lateral border of the rectus muscles. The muscles are retracted to expose the posterior rectus sheath and transversalis fascia. The transversalis fascia is incised to expose the underlying retroperitoneal fat and the peritoneum.

The plane between the transversalis fascia and peritoneum is developed with blunt dissection, and the parietal peritoneum is freed from the lateral abdominal wall. The abdominal contents and peritoneum, along with the kidney and ureter, are reflected medially to expose the ventral lumbar spine (Fig. 302-4). Dissecting the peritoneum off the ventral abdominal wall allows full mobilization of the peritoneal contents. The remainder of the dissection is similar to the ventrolateral retroperitoneal approach.

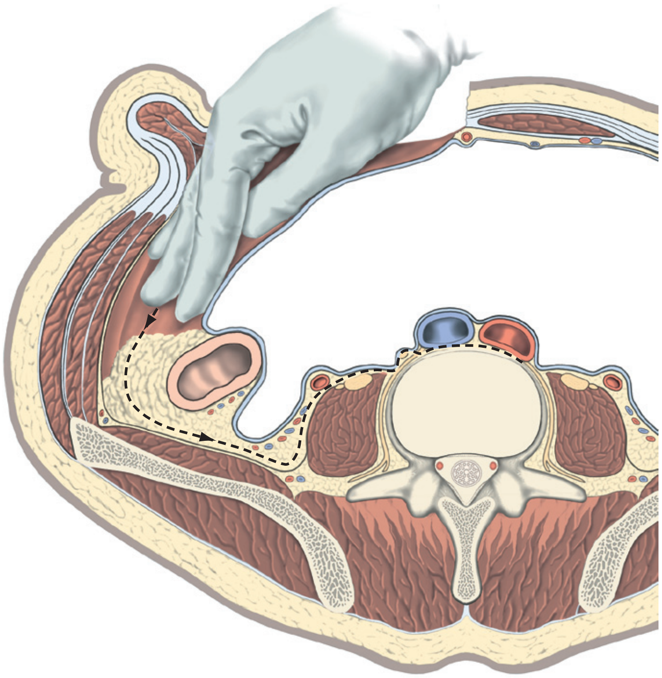

FIGURE 302-4 The plane between the transversalis fascia and the peritoneum is developed laterally. The abdominal contents are mobilized medially.

For exposure of L5-S1, the dissection proceeds medial to the left common iliac artery. The superior hypogastric plexus is the terminal extension of the preaortic sympathetic plexus. This fine, thin collection of nerves is most commonly found arching over the left iliac artery crossing the L5-S1 disk space. The superior hypogastric plexus provides innervation to the internal vesicle sphincter; injury to these nerves can result in retrograde ejaculation. Great care must therefore be taken in clearing prevertebral tissue from the ventral L5-S1 disk space. The use of electrocautery superficial to the anterior longitudinal ligament is avoided. All prevertebral tissues, including the hypogastric plexus, are bluntly swept to the right. The middle sacral artery and vein are identified inferior to the aortic bifurcation and are ligated and divided. The common iliac vessels are mobilized and retracted laterally.

L4-5 is best approached laterally to the vessels because the origin of the vena cava and the bifurcation of the aorta are typically ventral to L5. If the origins of the vena cava and aortic bifurcation are abnormally high, an interiliac approach may be attempted. The aorta and iliac artery are mobilized and retracted toward the right. Ligation and division of the segmental lumbar vessels facilitate exposure. The iliolumbar vein must also be identified, ligated, and divided during exposure of L4-5 to allow medial retraction of the iliac vein and access to the disk space.

Once the procedure is completed, the abdominal contents are returned to their normal anatomic position, and the fascial and muscular layers are closed separately. Postoperative care is identical to that for the ventrolateral approach.

Transperitoneal Approach (L4-S1)

The transperitoneal approach provides a direct route to the anterior lumbar spine and is ideal for visualizing L4-5 and the lumbosacral junction. Higher lumbar levels can be exposed but considerable vessel retraction may be required. Levels rostral to L4 are usually most safely and effectively exposed through one of the retroperitoneal approaches described above. As for most ventral approaches to the lumbar spine, our practice is to use a general or vascular surgeon for the transperitoneal approach.

Preoperatively, the patient must receive a bowel cathartic to cleanse the intestines. Broad-spectrum antibiotics are administered in case of bowel perforation. The patient is positioned in a similar fashion as for a paramedian retroperitoneal approach. The umbilicus serves as a reference for the level. An incision caudal to the umbilicus, several centimeters rostral to the pubis, is used for an approach to L5-S1. A midline vertical incision or a Pfannenstiel incision may be used. The underlying fascia, subcutaneous tissue, and peritoneum are incised in line with the incision to enter the abdominal cavity.

The abdominal contents are packed in a moist sponge and retracted into the upper abdomen to expose the posterior peritoneum. The peritoneum is incised in the midline over the aorta. The incision continues caudally over the right common iliac vessels to enter the retroperitoneal space. At the level of the iliac vessels, the incision proceeds medially to avoid the ureter. The peritoneal flaps are retracted laterally over the iliac vessels. The retroperitoneal portions of the large bowel are mobilized and retracted to the left to expose the aortic bifurcation and sacral promontory. Adjacent to the aorta, the ureters and hypogastric plexus are also visualized and treated with caution. Typically, the aortic bifurcation lies at L4 and the inferior vena cava origin starts at L5, but variations are common. The surgeon must be aware of these anatomic variants and adjust the operative plan as needed. Anterior branches of the aorta, including the inferior mesenteric artery, the middle sacral artery, and the segmental lumbar arteries, are also encountered with the transperitoneal approach. A higher incidence of hypogastric plexus injury and subsequent retrograde ejaculation have been reported with the transperitoneal approach versus the retroperitoneal approaches.[70] Judicious use of bipolar cautery and sharp and blunt dissection of the tissues ventral to the annulus may minimize this risk. Monopolar cautery should only be used extensively within the disk space.

When the spinal procedure is completed, the posterior peritoneum is closed with absorbable suture. Drainage of the retroperitoneal space is seldom required. The abdominal contents are then returned to their anatomic position to prevent intestinal torsion and obstruction. The individual fascial and muscular layers are reapproximated with absorbable sutures. After the procedure, bowel function should be assessed before the patient's diet is advanced.

BIOMECHANICS OF ANTERIOR LUMBAR INSTRUMENTATION

At a minimum, most anterior lumbar constructs include an interbody graft or device placed in line with the neutral load-bearing axis. This element resists the compressive forces created by axial loading of the lumbar spine. Functionally, then, the interbody device primarily acts in distraction. Interbody grafts provide little resistance to extension or axial rotation. Their effect on lateral flexion is variable and depends on the size and shape of their interfaces with the vertebral end plates. To achieve greater rigidity of the overall construct, fixation of the vertebral bodies is often performed. This may be either with anterior vertebral fixation with a screw rod or plate instrumentation, or posterior pedicle screw fixation. Pedicle fixation is discussed elsewhere; so the focus of this brief discussion is structural anterior interbody grafting and anterior vertebral fixation.

Most anterior lumbar fixation constructs are variations on the rigid cantilever beam design.[71] Screws are placed into the vertebral bodies above and below the pathology for single-level disease, or segmentally for more extensive procedures not requiring corpectomies, such as thoracolumbar scoliosis correction. The screws are attached rigidly to longitudinal members, typically either a rod or a plate. Similar to the interbody grafts, the cantilever beam construct functions in distraction most of the time by resisting compressive forces. Because of its rigid attachment to the vertebrae, however, it also resists extension, axial rotation, and lateral bending.

Ideally, the axial compressive forces (load) should be shared between the cantilever beam instrumentation and the interbody graft. If excessive force is borne by the instrumentation, the bone graft material may resorb and a pseudarthrosis may result. The interbody graft or device should therefore be placed under gentle compression. Care must be taken, however, if compression is directly applied to the instrumentation; significant ventrolateral compression can create a segmental kyphosis or scoliosis.

Anterior lumbar instrumentation, including the use of appropriately sized and placed grafts, can effectively correct some spinal deformities. Small grafts placed in the ventral disk space or larger lordotic grafts covering most of the vertebral end plates can increase segmental lordosis and correct a relative or frank kyphosis. Correction of a lumbar scoliosis can be achieved through the placement of small structural grafts in the concavity of the intervertebral disk spaces and compressing across lateral vertebral body screws. Proper graft selection and placement are essential in this situation to avoid simultaneously creating a relative lumbar kyphosis through ventral compression. A kyphoscoliosis or significant kyphotic deformity is a relative contraindication to an anterior-only correction procedure.

Expandable vertical cages of titanium and polyetheretherketone (PEEK) are currently available in sizes appropriate for use in the lumbar spine following a single or multilevel corpectomy. These offer the advantage of ease of placement because they can be placed in the intervertebral defect and then be expanded to engage the adjacent end plates. It may be possible, particularly in the setting of ligamentous laxity or dorsal column disruption, to overdistract the cage and create a segmental deformity. Also, although distraction of the device may initially create significant pullout resistance, ligamentous creep will occur and the device may loosen. Although vertebral fractures adjacent to expandable cages have been reported, a causal relationship has not been established.[72] The role of expandable cages in anterior lumbar reconstructive surgery and their merits and disadvantages relative to fixed devices remains to be elucidated.

A critical decision in the surgical planning process that must be made is whether sufficient dorsal stability exists to allow an anterior-only construct to be used or if an anterior-posterior construct is necessary. Although a large, properly placed interbody graft or device is an effective distraction device, an anterior construct is least able to provide resistance against flexion. If the dorsal tension band structures are incompetent, an anterior-only construct may not be sufficiently stable to provide an acceptable long-term outcome.

INSTRUMENTATION

General Principles

A number of general principles are followed when instrumentation is to be inserted into the ventrolateral lumbar spine, regardless of the type of construct chosen. The main surgical goal is to achieve stability with the lowest profile and maximal implant-to-bone contact. Maximal surface contact between the bone and implant is desirable to distribute the application of forces evenly.

Typically, vertebral body screws are inserted at fixed coordinates based on the concave configuration of the posterior cortical wall. In general, an awl should be used to start any screw hole before drilling to prevent slippage and catastrophic injury. The dorsal screws are placed 8 to 10 mm ventral to the posterior cortical surface and 8 to 10 mm from the end plate. These coordinates, along with a trajectory inclined 10 degrees ventrally, ensure that the screw does not enter the spinal canal. Ventral screws are inserted either parallel to the dorsal vertebral cortex or with a slight dorsal inclination to triangulate the screws and decrease the risk of pullout. All screws should be countersunk within the construct to obtain a low profile. Several systems require only unicortical screw purchase, but bicortical purchase increases the stability of any construct. Penetrating the contralateral cortex by more than 2 to 3 mm should be avoided.

A translational deformity can occur with two-rod constructs because of an intrinsic bending moment between the rods.[71] This can be avoided by cross-fixation of parallel rods and by triangulating the screws within the vertebral body. Some of the newer constructs avoid a parallelogram configuration by offsetting the screws in the sagittal and coronal planes within a single vertebral body. Distraction and compression are applied to the screws before and after the graft is inserted. Excessive distraction across the defect can cause neurological injury from stretch and vascular compromise. Particular care with distraction should be taken if the anterior or posterior longitudinal ligament is incompetent.

Instrumentation Constructs

Many constructs are available for ventral fixation and fusion of the lumbar spine, and these can be broadly categorized into screw-rod constructs, screw-plate constructs, and interbody devices. The screw-rod and screw-plate constructs can be fixed either in a direct anterior or anterolateral position. Although the major function of these constructs is to provide increased rigidity and arthrodesis, the anterior plate constructs also serve to prevent ventral dislodgment of an interbody graft or device.

Screw-rod constructs generally consist of vertebral body plates, cancellous screws, paired rods, and a method of fixing the rods to the screws, either directly or through vertebral body plates. The screws provide a means for distraction across the defect during insertion of an interbody strut graft. A transverse coupler or parallel connector can be used to increase the stability of the construct against both rotatory and flexion-extension forces. Most of these devices allow multisegmental fixation.[73]

The screw-plate constructs generally consist of a titanium locking plate, cancellous vertebral body screws, and compression screws. With earlier plating systems, distraction across the corpectomy site was obtained with a separate instrument because the plate provides no anchor for distraction. Once the graft is in place, compression is applied through a separate set of screws, which can provide a limited degree (typically up to 3 mm) of compression.[73] However, newer plating systems incorporate slotted plates, allowing greater compression across the corpectomy site after the plate is positioned for precise seating of the graft.

An interbody device may be used when intervertebral support is desired following a diskectomy or corpectomy, particularly if an appropriate structural bone graft, either autologous or allogeneic, is not available. Compared with more traditional posterior fusion constructs, anterior interbody fusion has some surgical and biomechanical advantages.[74-78] The goals of ventral placement of an interbody device or graft are to restore disk height and lumbar lordosis, to distract the intervertebral foramen, and to provide a favorable fusion environment, all without disturbing the posterior tension band.

Interbody Grafts and Devices

The initial interbody grafts were human allograft, typically obtained from the femur or humerus. These are osteoconductive, have biomechanical properties similar to the vertebral bodies, and are customizable in the operating room.

Vertically oriented titanium cages have the advantage of being able to be cut to a specific size to custom-fit an interbody space or corpectomy defect. Polymer-based materials such as PEEK are also used to create interbody fusion devices. The advantages of PEEK cages may include a lower incidence of subsidence and their radiolucency, which permits easier assessment of bone growth. Finally, expandable cages, both metallic and PEEK, have been developed to provide a fusion construct over larger vertebral defects, particularly following vertebral body resection or resection of large spinal metastases, where they provide an optimal fit and deformity correction through in vivo expansion of the device. There have been some reports of adjacent level vertebral body fractures using expandable cages, owing to the forces used to expand the cages. Biomechanical data indicate that most of these devices increase stability beyond that of the normal intact spine, but no conclusive studies have demonstrated the superiority of one device over another.

COMPLICATIONS

Potential complications related to anterior lumbar instrumentation can be divided into major and minor and classified as visceral, vascular, neurological, and construct-related. Complications related to the graft and instrumentation include pseudarthrosis, graft or construct dislodgment, and instrumentation failure. The cumulative incidence of complications for anterior spinal fusion has been reported to be as high as 40%.[79,80] Major catastrophic complications occur less often.

Vascular injuries have been reported to follow anterior lumbar fusion in up to 15% of cases.[81,82] Such injuries are more common with a rectus incision than with a flank incision.[81] The aorta, inferior vena cava, common iliac vessels, and their associated branches are all potentially at risk, depending on the specific approach used and the vertebral levels exposed. The left-sided approach is favored because arterial structures are easier to mobilize than venous structures and also because hemorrhage from an arterial vessel is usually easier to control. Inflammatory, neoplastic, or degenerative processes or adjuvant therapy for neoplastic disease, such as radiation or chemotherapy, may increase scarring around the vessels, making dissection more difficult. Bleeding from either type of vessel should be managed directly and expeditiously. Digital pressure is often the initial step in controlling a vessel laceration. Temporary hemostatic clamps can also be placed to control bleeding and to allow repair of the defect. Excessive lateral retraction of the iliac vessels can lead to spasm or thrombosis. If a thrombus occurs, the assistance of a vascular surgeon may be required to perform a thrombectomy.

Significant blood loss can also occur during corpectomy. Close communication with the anesthesiologist and ensuring the patient is hemodynamically optimized before performing a part of a procedure with an anticipated risk of significant blood loss will minimize the risks to the patient. Preoperative embolization may also be used to reduce the risk of hemorrhage associated with the resection of a vascular neoplasm.

Most visceral complications consist of bowel and ureteral injuries. Bowel perforations, most often encountered with a transperitoneal approach, should be repaired by a general surgeon. Inadequate closure can lead to peritonitis, sepsis, or abscess formation. A functional ileus is common after intra-abdominal surgery and typically resolves spontaneously within 2 to 3 days.[83] A mechanical ileus may result if the bowels are not returned to their normal anatomic location. Failure to recognize a mechanical obstruction can compromise blood flow and lead to the devastating consequences of bowel ischemia. The ureter is frequently manipulated during a retroperitoneal approach but is usually lateral to the transperitoneal exposure. Excessive mobilization or traction can lead to injury or fibrosis. If mobilization is required, particularly with a rostral lumbar exposure, a generous cuff of soft tissue should be left surrounding the ureter to preserve blood flow.

Various neurological injuries are associated with an anterior lumbar approach. The preaortic sympathetic plexus forms the superior hypogastric plexus distal to the aortic bifurcation ventral to the L5-S1 intervertebral disk space, which provides innervation to the sphincter urethrae muscle. Deinnervation of this muscle causes retrograde ejaculation in men, a significant complication that can result in functional sterility. The reported incidence of this complication ranges from 5% to 22%.[81,84,85] Within 1 to 2 years, function returns completely or partially in as many as one third of these patients. If a ventral approach to L5-S1 is planned in a male patient, this potential complication is discussed frankly and the advisability of sperm banking explained to him. Penile erection is mediated through the parasympathetic plexus and should not be injured when standard anterior approaches are used.[86] If erectile dysfunction is associated with an anterior lumbar procedure, it is usually nonorganic. Injury to the lumbosacral plexus and to the femoral and genitofemoral nerves is possible during dissection or retraction of the psoas muscle; ipsilateral leg weakness or paresthesias result. Decompression and graft insertion can injure the exiting nerve roots and cauda equina, producing lower extremity or bowel and bladder deficits. Careful technique and planning can help avoid such injuries.

CONCLUSION

Ventral instrumentation of the lumbar spine is an important tool for the effective treatment of anterior lumbar pathology. With advances in construct design, contemporary spinal surgeons have an array of instrumentation options from which to choose. The decision to use instrumentation and the choice of construct should be approached logically and judiciously. A thorough understanding of the appropriate indications, biomechanics, and surgical techniques is required before these implants are used. Practicing surgeons should always consider several questions when contemplating the use of instrumentation constructs: (1) What is the indication for a spinal implant? (2) How has the pathology affected the biomechanics of the spine? (3) What is the appropriate type of construct to restore the integrity of the spine? (4) What is the goal of placing an implant? With these considerations in mind and a treatment plan developed for each patient based on established treatment principles, optimal clinical outcomes can be achieved.

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