Methods and Complications of Anterior Exposure of the Thoracic and Lumbar Spine

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Objective: To review the methods and complications of exposing the anterior aspects of the thoracic and lumbosacral spine.

Data Sources: PubMed (journals database of the National Library of Medicine), text books, the University HealthSystem Consortium Clinical Process Improvement Benchmarking Project, a newspaper, and the US government Healthcare Cost and Utilization Project.

Study Selection: Descriptions of morbidity and mortality specifically related to anterior spine exposure depicted in both case reports and clinical series were used.

Data Extraction: Mortality data from clinical series with more than 30 cases were tabulated. Morbidity incidences were described.

Data Synthesis: The frequency of anterior exposure of the spine for structural operations is steadily increasing. Both thoracic and lumbosacral anterior spine operations are associated with exposure-related complication rates of 10% to 50%. Pulmonary complications are frequent after thoracic exposures. Chylothorax is the most common of several rarer chest-exposure complications. Vascular complications, particularly arterial thrombosis (<1% of cases) and venous bleeding (2%-15% of cases), are the most frequent complications at the lumbar level. Other lumbosacral exposure complications include ureteral and nerve (somatic and sympathetic) injury. The mortality rate in anterior spine exposures is less than 1%.

Conclusions: The exposure portions of anterior spine operations result in numerous complications. There are fewer reported complications with endoscopic exposures of the anterior spine than with open exposures, although endoscopic exposures have been used for less complicated cases. In comparable cases, neither exposure nor results of endoscopic operations have proven better than operations done through minilaparotomy incisions. Perioperative cooperation between exposing and spine surgeons is necessary to enhance results in anterior spine operations.

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ANTERIOR EXPOSURE OF THE spinal column provides surgical versatility and therapeutic success often unavailable via the posterior approach alone. Radiological techniques such as computed tomography, magnetic resonance imaging, and diskography have elucidated spinal structural abnormalities. As instrumentation has evolved, the incidence of anterior procedures alone or in combination with posterior ones has rapidly increased. According to the Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality,[1] an estimated 18 982 lumbar and lumbosacral fusions were performed in the United States in 1997. By 2002, the estimate was 29 583 cases—a 56% increase. Although there were fewer thoracic and thoracolumbar cases during that interval, the estimated increase of 304% was even more striking—2102 cases in 1997; 6404 in 2002.[1]

Neurosurgeons or orthopedists (spine surgeons) usually provide their own anterior exposures for operations on the cervical spine. Anterior exposures of the thoracic, thoracolumbar, lumbar, and lumbosacral levels are customarily provided by general, thoracic, or vascular cosurgeons (exposing surgeons). Whereas comprehensive technical descriptions of the most frequent procedures are included in spine surgery textbooks, they are not addressed in major general or thoracic surgery texts.[2-6]

Surgeons providing access to the anterior spine should know the anatomy, understand the structural operations being performed, and anticipate possible complications. Complications of the structural portions of the operations are well known, eg, infection, instability, instrument failure, arachnoiditis, and paralysis.[7] However, complications associated with the exposures for these procedures are less well recognized. This review ad-

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Table 1. Anterior Spine Exposure Incisions

Spine Anatomical Region	Incision
Cervicothoracic (C7-T2)	Oblique neck to median sternotomy
	High posterolateral thoracotomy
Thoracic (T3-T12)	Lateral thoracotomy
	Transpleural
	Retropleural
	Thoracoscopic
Thoracolumbar (T6-S1)	Thoracoabdominal
	Transpleural-retroperitoneal
	Retropleural-retroperitoneal
	Thoracoscopic
Lumbosacral (L2-S1)	Paramedian retroperitoneal
	Oblique anterolateral retroperitoneal
	Minilaparotomy retroperitoneal
	Open transabdominal (eg, Pfannenstiel)
	Endoscopic transabdominal
	Endoscopic retroperitoneal

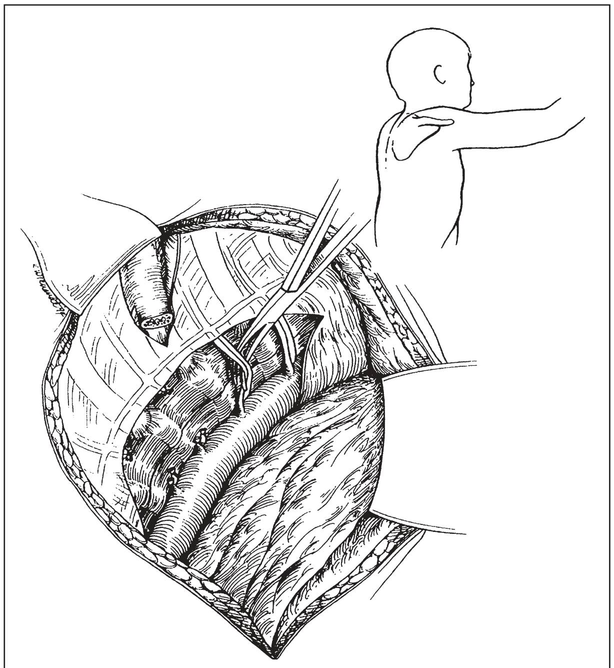

Figure 1. Transthoracic exposure of the right upper spine through lateral thoracotomy, with rib excised, posterior pleura longitudinally incised, and segmental vessels divided. Reprinted with permission from Lippincott Williams & Wilkins from Bridwell KH, DeWald RL, eds. *The Textbook of Spinal Surgery*. Vol 1. 2nd ed. Philadelphia, Pa: Lippincott-Raven; 1997:254.

dresses incisional techniques (**Table 1**) and nonstructural perioperative complications of anterior exposure of the thoracic and lumbar spine.

HISTORY

The main impetus for initially approaching the spine anteriorly was to treat Pott's disease. Neither drainage nor fusion was adequate from the back. Although the anterior approach to the lumbar spine was broached early in the 20th century, it was not until the 1930s that a reliable technique was introduced.[8] Ito et al[9] described a long, pararectus, muscle-cutting, retroperitoneal incision to treat the tuberculous spine. They used an oblique nephrectomy incision for the thoracolumbar junction and costotransversectomy for exposure of the thoracic spine. Others[10-12] used a transperitoneal approach to the anterior lumbar spine. Advocates[10-12] asserted that diseases other than infection, such as spondylolisthesis and disk abnormalities, were better managed anteriorly. Most of the described procedures were from L4 through S1.[10-12]

Two decades after anterior lumbar approaches had been described, Hodgson and Stock[8,13] described their extensive Hong Kong experience with anterior treatment of thoracic-spine Pott's disease. Variants of their transthoracic exposure were adopted worldwide.[14] Except in endemic pockets, Pott's disease is now a rare indication for spine surgery in the developed world.[15]

Instrumentation inventions have led to better operations for expanded indications. Posterior stabilization by Harrington rods[16] and anterior stabilization devices developed by Dwyer et al[17] were noteworthy innovations. Technical refinements have allowed surgeons to approach a patient's spine both anteriorly and posteriorly, with either staged or sequential operations under the same anesthetic, to treat destructive disorders, deformities, and fractures.[18,19]

ANTERIOR EXPOSURE OF THE THORACIC SPINE

Thoracic, Open

Rarely needed exposures of the anterior spine from C7 through T2 entail a complicated incision through important neck and mediastinal structures. A diagonal neck incision is extended to median sternotomy, dividing the sternocleidomastoid and strap muscles. The carotid sheath is retracted laterally and the innominate artery downward, providing access to the spine between the great vessels of the upper mediastinum.[14,18,20,21] Lateral exposure of T1-2 also can be done through a cephalad J extension between the scapula and spine of a high right posterolateral thoracotomy incision.[8,22,23]

Lateral thoracotomy has been the incision of choice for exposure of the anterior aspect of the thoracic spine since the article by Hodgson and Stock.[8] Some surgeons remove the rib at the top level of the spine's pathological abnormality.[24-26] Because of ribs' lateral, caudad curvatures, most surgeons remove ribs 1 to 2 interspaces above the affected spine.[8,15,20] The upper spine, T2 through T6, is approached more easily from the right side (**Figure 1**). Distal to that, the left side is preferred. In scoliosis, the chest on the side of spine convexity is entered.[24] In kyphosis, the aorta usually curves to the left, making the right chest the preferred access for that deformity.[13]

In retropleural thoracotomy, the pleura is dissected off of the undersurface of the endothoracic fascia. This provides the actual advantage of lateral access to the dural sac and the theoretical advantages of less pain and fewer pulmonary complications.[27] Although muscle-sparing incisions have been shown to decrease pain and pulmonary problems, their use in spine surgery has not been described. A rib for grafting would not be available with such incisions, and exposure might be too restrictive for

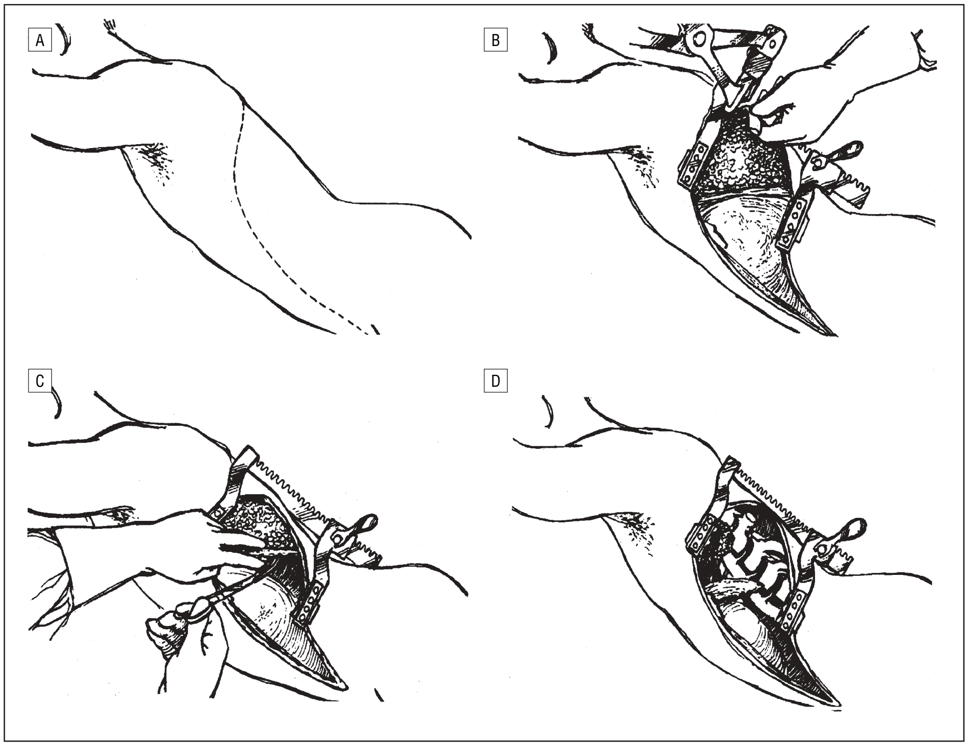

Figure 2. Exposure of the left thoracolumbar spine, showing the incision design (A), thoracic and retroperitoneal spaces (B), division of the diaphragm (C), and lateral aspects of cleared lower thoracic and upper lumbar spinous bodies (D). Reprinted with permission from American Medical Association from Burrington JD, Brown C, Wayne ER, Odom J. Anterior approach to the thoracolumbar spine: technical considerations. *Arch Surg*. 1976;111:458. Copyright 1976, American Medical Association. All rights reserved.

current hardware.[28] Excised ribs are frequently used as morcellized or strut grafts.[8,17] Vascularized rib grafts have the theoretical advantages of reliable viability and rapid fusion.[23,29,30]

Thoracolumbar, Open

Exposing the thoracolumbar junction requires a long, curvilinear incision from the lateral thorax to the medial abdomen.[31] The chest portion may be retropleural or transpleural.[27,32,33] In their initial report on anterior thoracic spinal surgery, Hodgson and Stock[8] described removing the 11th rib, entering the retroperitoneum, and retracting structures forward to expose the lower thoracic and upper lumbar spine. Most surgeons incise along one of the more cephalad, fixed ribs.[18,20,22] The extent of diaphragm division depends on the exposure needed. It may be incised longitudinally at the spine or at its periphery. If needed for greater exposure, the costochondral cartilage can be divided.

The lumbar portion of this exposure is always retroperitoneal. Abdominal wall musculature is divided without entering the abdomen. The peritoneal sac, aorta, kidney, ureter, and retroperitoneal fat are swept anteriorly, exposing the spine (**Figure 2**).[22,25,34]

Thoracic, Endoscopic

There has been increased interest in minimally invasive exposure of the anterior spine. Video-assisted thoracic surgery on the spine was described in the mid 1990s. Either side of the chest can be used for access, although procedures on the right avoid any retraction of the heart. Placement of operating and retraction trocars depends on the level of the pathological abnormality (**Figure 3**). Vertical orientation of the surgeon's view and instruments aids accuracy. Surgeons should be capable of performing thoracotomy if the operation cannot be completed endoscopically.[35,36]

Initial reports of video-assisted thoracic surgery on the anterior spine described relatively uncomplicated operations such as diskectomy, anterior release, and infection drainage.[37] Subsequent diskectomy experience resulted in decreased operative times and morbidity as well as a 2-year success rate of 70%.[38] Following technique refinements, endoscopic surgeons have addressed more challenging problems such as spinal metastases, fractures, spondylitis, and scoliosis, the latter operation requiring exposure of the upper lumbar spine through the diaphragm.[39-41]

In treating thoracic spine fractures, the cardinal goals of realignment, spinal decompression, vertebral body replacement, and fixation can be thoracoscopically accomplished.[42,43] There is less morbidity with thoracoscopic management of vertebral osteomyelitis than through standard thoracotomy incisions, an important consideration in treating the immunologically compromised patients in whom this disease often occurs.[43,44]

Many procedures require both anterior and posterior spine fusion. Verheyden et al[45] described an endoscopic operation with the patient in the prone position to provide both anterior and posterior exposure of the thoracolumbar spine. This operation has not received general acceptance.

Complications of Anterior Thoracic Spine Exposure

Exposure complications can be either those associated with most major operations or those related to the particular spine procedures being done (**Table 2**). The ar-

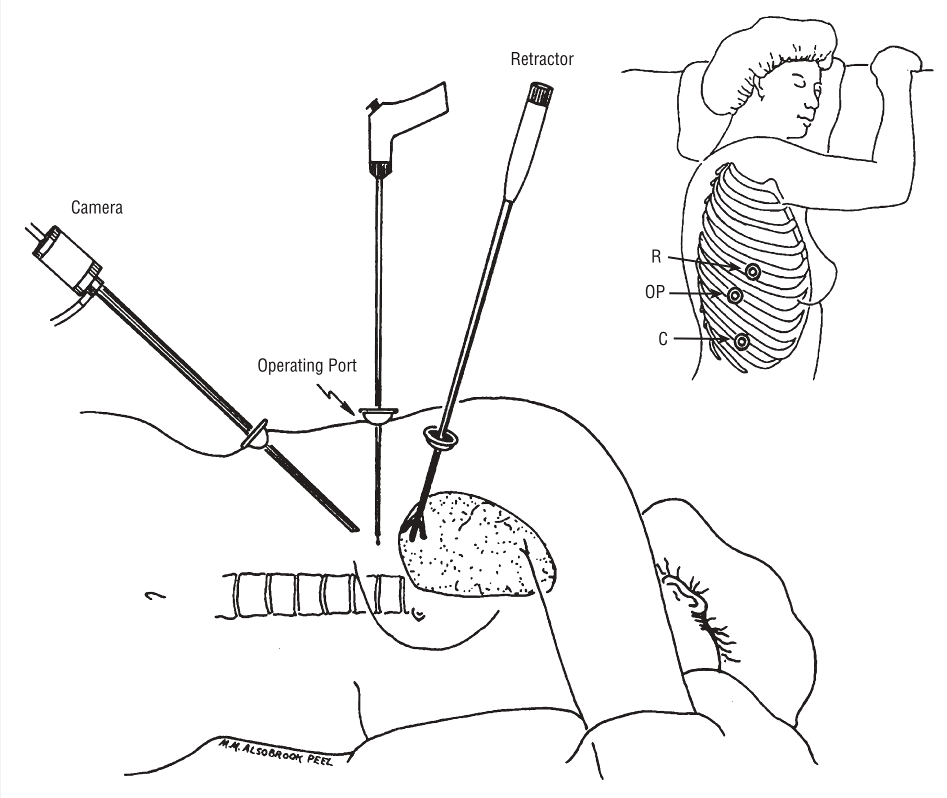

Figure 3. Endoscopic operation through the right chest on the midportion of the thoracic spine, showing the patient position and instrument placement. R indicates retractor; OP, operating port; and C, camera. Reprinted with permission from The Society of Thoracic Surgeons from Ikard RW, McCord DH. Thoracoscopic exposure of intervertebral disks. *Ann Thorac Surg.* 1996;61:1268. Copyright 1996.

Table 2. Complications of Anterior Spine Exposure

Spine Anatomical Region	Complications
Thoracic	Pulmonary (atelectasis, pneumonia, respiratory insufficiency)
	Technical (hemothorax, pneumothorax, pleural effusion, infection, wound disruption)
	Chylothorax
	Spinal cord ischemia
	Miscellaneous (cardiopulmonary, stroke, ileus, urinary tract infection, renal failure)
Lumbar	Vascular
	Arterial injury (thrombosis, hemorrhage)
	Venous injury (hemorrhage, thrombosis)
	Neurogenic (retrograde ejaculation, groin nerve injury, warm leg)
	Wound problems (infection, disruption, hernia, muscle denervation)
	Ureteral injury
	Miscellaneous (cardiopulmonary, stroke, ileus, urinary tract infection, renal failure)

ticles by Hodgson and Stock[8,13] on transthoracic exposure described several complications associated with all major operations in the chest—ileus, pneumonia, hemothorax, pneumothorax, cystitis, and wound infection. The 4 deaths in the first 100 cases were due to cardiac failure, tuberculosis, hepatic failure, and pneumonia.

Respiratory complications, including atelectasis, pneumothorax, pneumonia, and death, have continued to be the principal exposure-related postoperative problems. They have occurred in up to 50% of both adult and pediatric patients.[18,20,24,46-48] Impaired respiratory mechanics can cause significant immediate recovery problems and may remain abnormal for months.[49] The incidence of pulmonary complications has diminished in recent years, a result of better perioperative pulmonary therapy.[46] The reported incidence of pulmonary complications with thoracoscopic exposures is less than 10%.[35,38] These are usually minor, but death from pneumonia remains a possibility, especially in more complicated cases.[39]

Both spine and exposing surgeons should be concerned with protecting the spinal cord blood supply. The cord is nourished by anterior and posterior spinal arteries. To minimize the possibility of cord infarction, segmental arteries should be divided atop the spine bodies close to their origins to allow for collateral circulation through the internal mammary and intercostal arteries.[25,50,51] Collateral circulation from T4 through T9 is not as rich as that at the cervical and thoracolumbar levels.[18,52]

Cord ischemia with paraparesis or paraplegia occurs after thoracic aorta operations entailing bilateral disruption of segmental vascularity. The incidence of this complication with correction of thoracic spinal deformities that cause the same bilateral vascular injury is 1% to 5%.[51] Unilateral division of segmental arteries at their origins rarely results in cord injury.[26] The initial articles by Dwyer and colleagues[17,24] on scoliosis corrections described dividing from 3 to 16 arteries, resulting in no cord ischemia.

The anterior artery of Adamkiewicz delivers much of the blood supply to the lower one half of the cord. Located on the left side in 80% of patients, it may arise anywhere from T5 through L2, most often from T9 through

T12.[52] Although much cautionary admonition against injuring the artery of Adamkiewicz has been published, its sacrifice is usually tolerated without complication.[18,25,50,52,53] Should there be preoperative concern about cord ischemia and potential danger from sacrificing this vessel, magnetic resonance imaging is the standard for assessing its anatomy.[54]

Chylothorax is recognized as a complication of various cardiac and esophageal operations.[55] The anatomical course of the thoracic duct also exposes it to disruption during anterior exposure of the thoracic spine. The complication happens in fewer than 1% of such cases.[56,57] It can manifest after minimally invasive operations as well as open operations.[39] Although chylothorax can come from unexpected sites, awareness of the usual course of the thoracic duct should aid in preventing this complication.[57] Standard nonoperative and operative managements of established chylothorax include drainage, total parenteral alimentation, a low-fat diet, and ligation.[55,58,59]

Numerous unusual complications of anterior thoracic spine surgery should not be anticipated on a predictable basis. Whether due to optic neuropathy, retinal artery occlusion, or cerebral ischemia, postoperative vision loss can follow prolonged prone positioning of the patient as part of combined anterior and posterior operations.[60,61] Latissimus dorsi rupture is a rare postoperative wound complication.[62] Postthoracotomy incisional pain can follow anterior spine operations as well as other chest operations.[46] Intercostal neuralgia was an early noted problem with video-assisted thoracic surgery. This can be minimized by the use of soft trocars.[35,38]

In addition to frequent pulmonary complications, there is approximately a 10% to 30% incidence of other postoperative difficulties. These include cardiac (arrhythmia, myocardial infarction), vascular (stroke, deep vein thrombosis), technical (pneumothorax, wound and urinary tract infections, wound disruption, hemorrhage), and gastrointestinal (ileus) complications.*

ANTERIOR EXPOSURE OF THE LUMBAR SPINE

Lumbosacral, Open

Anterior exposure of L1 necessitates a thoracolumbar incision.[22] The L2 level can be reached with anterior approaches by appropriately lengthening incisions, dividing segmental arteries, and retracting the aorta medially. Such cephalad exposures are challenging, and initial approaches to the lumbosacrum addressed only the lower spine.

Stating that their method could expose as high as L3, Lane and Moore[12] described a transperitoneal approach to the most commonly addressed levels with disk disease, L4 through L5 and L5 through S1. They used a paramedian incision to perform diskectomy and bone grafting. The level of L5 through S1 is easily accessible through a small Pfannenstiel incision.[65]

In addition to risking injury to abdominal organs and a probability of ileus, transabdominal exposure of the higher lumbar segments is difficult. As the ability to perform anterior spine operations evolved, a retroperitoneal incision was adopted for access to L2 through S1. A left-sided approach is preferred because the aorta can be retracted more safely than the vena cava. Oblique, anterolateral incisions are made by dividing or splitting abdominal muscles.[22,66,67] The currently prevalent approach is via a left paramedian incision.[68] This incision is less traumatic than those requiring abdominal wall muscle division.[69] Lateral retraction of the rectus abdominis preserves segmental enervation (**Figure 4**).[70]

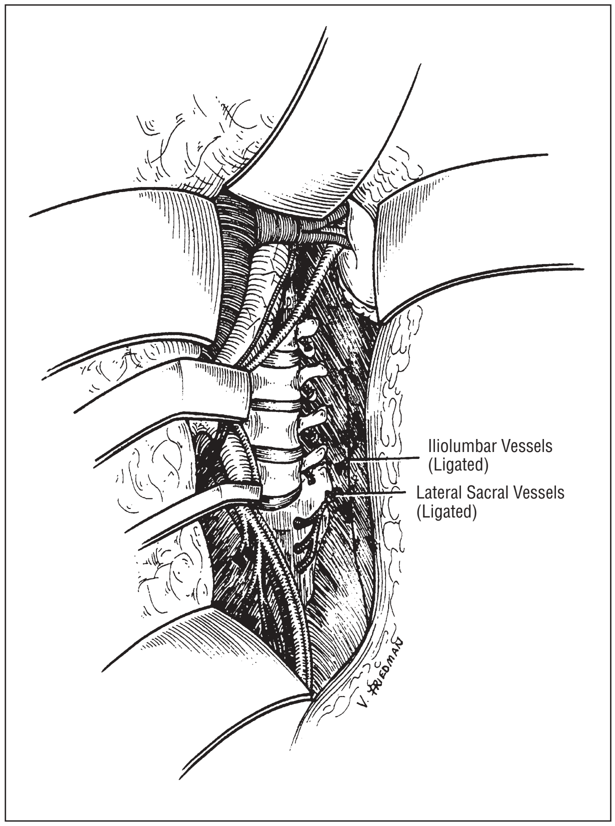

Figure 4. Retroperitoneal exposure of the lumbosacral spine through a left paramedian abdominal incision, with medial retraction of the great vessels after division of the branches. Reprinted with permission from Lippincott Williams & Wilkins from Bridwell KH, DeWald RL, eds. *The Textbook of Spinal Surgery.* Vol 1. 2nd ed. Philadelphia, Pa: Lippincott-Raven; 1997:270.

Various small anterior incisions have been used. Applying an 8-cm paramedian skin incision and rectus fascia Z-plasty, Dewald et al[71] have successfully exposed up to 3 levels of the lower lumbar spine. Brau[72] has similarly used transverse lower abdominal incisions to retroperitoneally expose up to 3 levels. Incision placement varies with the level undergoing the operation, with a longer, more diagonal incision needed for multiple levels.

The L5-S1 interspace lies caudad to the confluences of the common iliac arteries and veins, making its exposure usually uncomplicated. The middle sacral vessels must be controlled. The most difficult distal interspace to expose is L4-5.[72] It can be done by retracting the left common iliac vein and artery medially or by going between the vessels, reflecting the vein laterally. Harmon[68,73] identified iliocaval anatomical variations in more than 30% of his spine cases, including double left common iliac veins, a left inferior vena cava, and larger internal iliac veins in women. The most frequent anatomi-

References 13, 20, 23, 24, 30, 35, 38, 39, 46, 63, 64.

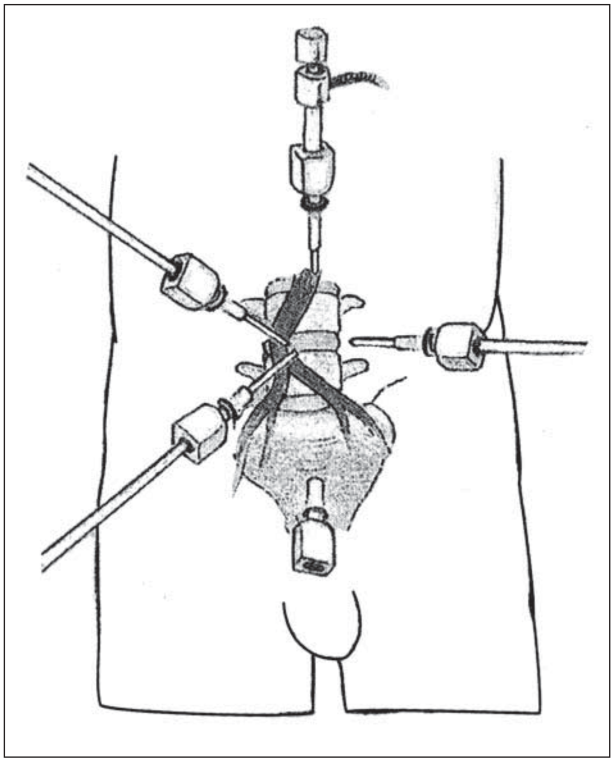

Figure 5. Laparoscopic exposure of the L4-5 interspace, with medial retraction of the great vessels. Reprinted with permission from Lippincott Williams & Wilkins from Lieberman IH, Willsher PC, Litwin DEM, Salo PT, Kraetschmer BG. Transperitoneal laparoscopic exposure for lumbar interbody fusion. *Spine*. 2000;25:511.

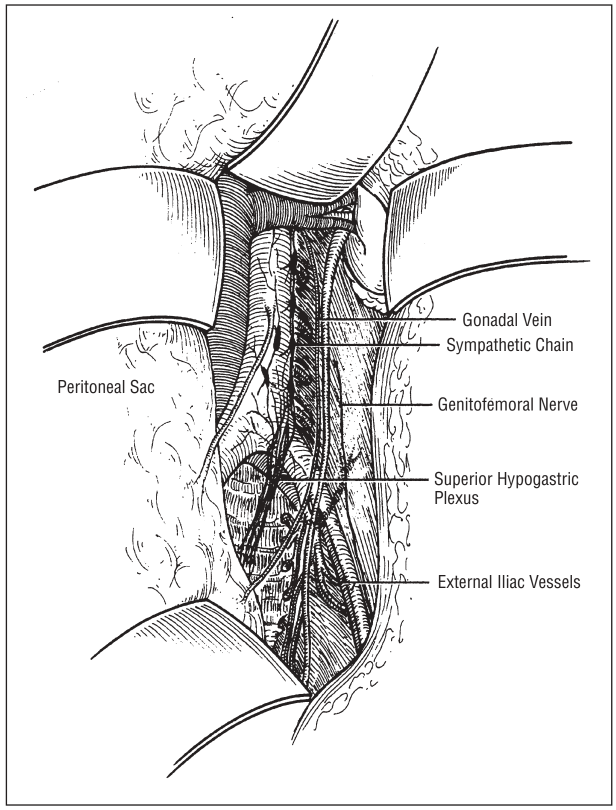

Figure 6. Retroperitoneal exposure showing various structures at risk for injury in anterior lumbosacral spine operations. Reprinted with permission from Lippincott Williams & Wilkins from Bridwell KH, DeWald RL, eds. *The Textbook of Spinal Surgery*. Vol 1. 2nd ed. Philadelphia, Pa: Lippincott-Raven; 1997:269.

cal inconsistencies are the degree of common iliac vein obliquity and the level of vena caval bifurcation. Confluence of the common iliac veins usually overlies the fifth lumbar vertebra but may vary with habitus.

It is easy to injure the common iliac vein, especially in freeing its posterior attachments. The iliolumbar vein is an especially fragile and inaccessible vein. This usually drains into the cephalad, posterolateral aspect of the left common iliac. The left common iliac also receives the easily seen middle sacral vein.

Lumbar, Endoscopic

The generally accepted endoscopic technique to expose the lumbar spine is transabdominal. Laparoscopic anterior access was initially used to expose the L5-S1 interspace. After 1-level diskectomies were reliably accomplished, surgeons began fusing the spine with bone dowels or titanium cages packed with bone. Multiple spine levels can be approached.[74-78] The less-used retroperitoneal endoscopic approach prevents complications of abdominal transgression, eg, adhesions and visceral injury.[79-81]

Laparoscopic celiotomies are done with the patient in a supine, Trendelenburg position to aid upward gravitation of the intestines in the insufflated abdomen. The sigmoid colon is retracted to the left. The posterior peritoneum is longitudinally incised in the midline. Because of its position beneath the left iliac vessels, the L4-5 interspace poses the most exposure problems (**Figure 5**).[75,78,82-84]

Complications of Anterior Lumbar Spine Exposure

The overall incidence of complications after anterior exposure of the lumbar spine is 30% to 40%.[46,85] Many of the minor complications such as wound infection and urinary retention are the same as those encountered with thoracic operations, but there are several major ones characteristic of anterior lumbar spine exposures (**Figure 6**).

Vascular injury is the most common of these complications.[66] Significant risks to both the arterial and venous sides of the circulation were noted in the early experience with these procedures. In 1936, Mercer[10] reported a death from superior mesenteric artery thrombosis after transabdominal treatment of spondylolisthesis. Contemporary case reports have described thrombotic complications in the aorta and iliac and popliteal arteries. Occurring in fewer than 1% of cases, these can be catastrophic, leading to permanent extremity deficits, renal failure, compartment syndrome, or death.[86-89]

Thrombotic complications usually occur in patients with risk factors that lead to vascular disease.[89,90] Long, difficult operations, especially those requiring both anterior and posterior incisions, also increase the likelihood of thromboses.[86,90] The retraction of great vessels by Steinmann pins in spine bodies or the blades of fixed abdominal retractors can lead to low flow and/or wall injury.[66,87,88,91,92]

Patients with thrombogenic risk factors or obvious peripheral vascular disease should be warned of potential thrombotic complications. Avoidance of traumatic or prolonged retraction of diseased vessels is important. Postoperative manifestations of ischemia may be subtle and confused with nerve injury. Early recognition of thrombosis and treatment by thromboendarterectomy or bypass will minimize sequelae.[89,90,92]

With careful dissection, intraoperative arterial bleeding is rarely a problem. However, immediate or late hemorrhage from open or laparoscopic exposures can occur.[82,93,94] Late hemorrhage may be more likely after thoracolumbar operations in which dissection is difficult and there is long contiguity between the aorta and spine-stabilizing hardware. Artery disruption leading to this complication may result from retraction, initial injury, or erosion from indwelling instruments.

Venous injury is more common than arterial injury in anterior lumbar spine exposures, reportedly occurring in 2% to 15% of cases.[66,85,86] Mobilization and retraction of fragile veins, particularly at the hazardous level of L4 to L5, can lead to intraoperative hemorrhage.[95,96] Vessel disruption may be caused by mobilization or retractor blades, with such injuries often being discovered at the end of operations when blades formerly placing tension on veins are released. Although tributaries as high as the renal vein can be injured, the left common iliac and iliolumbar veins and aberrant distal vena caval branches are especially vulnerable. The fragile, deeply located iliolumbar vein may be particularly difficult to control.[48,66,86,91]

Despite operations often lasting many hours and with prolonged retraction of major veins draining the lower extremities, a high incidence of iliocaval thromboses in anterior lumbar spine operations has not been reported.[66] Surgeons performing these procedures are well aware of this potential complication. Extensive use of preventive measures (anticoagulation, compressive hose, calf pumps) has not eliminated deep vein thromboses after anterior spine operations but may have limited them to fewer than 5% of cases.[46,95,97]

Genitourinary complications accrue from injury to nerve structures or retroperitoneal urinary tract organs, mainly the ureter. Injury to the hypogastric sympathetic plexus can lead to retrograde ejaculation and impotence. This risk is particularly high in older men with vascular disease, although there is even a small incidence in young boys undergoing scoliosis operations. In younger men, genital sympathetic nerve injury can cause priapism, as the parasympathetic stimulus to engorgement is then unopposed.[98,99]

The hypogastric plexus lies in the subserous fascia beneath the peritoneum. Extending distalward from the level of the fourth lumbar vertebra, it runs anterior to the aorta, crossing anterior to the left common iliac vein into the pelvis. In retroperitoneal approaches, the plexus is retracted forward and is thereby usually protected. Injury is more common with open or endoscopic transabdominal approaches requiring division of the posterior peritoneum. Longitudinal division of the peritoneum to the right of the midline with retraction of the underlying attached plexus to the left is recommended to abet its protection.[99-101] Minimization of cautery dissection and use of bipolar cautery when necessary are other measures to safeguard it.[76] Retrograde ejaculation has been reported in 0.44% to 25% of open and endoscopic cases.[46,78,83,85,99-103]

The ureter can be injured during anterior and posterior lumbar spine exposures.[104-106] It usually is adherent to the posterior peritoneum and is swept forward in retroperitoneal exposures.[73,107] Harmon[73] recommended dissecting out the ureter to avoid retracting it medially, but most surgeons feel that this threatens the organ's blood supply and unnecessarily exposes it to injury.[108,109]

There have been numerous descriptions of ureteral injury secondary to anterior lumbar spine exposure.[46,64,96,103,109,110] Although the exact incidence of the complication is uncertain, in larger reported series[46,64,103] of anterior exposures, it ranged from 0.3% to 8.0%. Like arterial thromboses, retraction as well as division may cause ureteral disruption. The injury is usually discovered postoperatively, often late.[103,109,110] Although some cases of partial transection can be treated by drainage of fluid collections and/or placement of ureteral stents, others may result in prolonged, complicated courses, perhaps including nephrectomy.[96,103,105,110-113] Routine prophylactic use of ureteral stents in spine operations has not been recommended.[114-117]

Various nerves are liable to injury in retroperitoneal operations. Running along the lateral aspect of the spine, the number of ganglia in the lumbar sympathetic chain varies considerably.[118] Division of the sympathetic trunk results in a transiently warm lower extremity. This complication should be avoidable with care.[25,83,102]

The iliohypogastric and ilioinguinal somatic nerves course along the lateral aspect of the psoas muscle toward the crest of the ilium. The genitofemoral nerve emerges onto the midportion of the ventral surface of the psoas and tracks distalward on its surface. These nerves provide sensation to the medial groin and external genitalia. Their damage in anterior spine operations has been noted.[85]

The incidence of anterior lumbar exposure wound integrity complications is uncertain.[25,67,102] They are more likely to occur in procedures requiring both anterior and posterior procedures.[119] In addition to the risk of postoperative incisional hernias, patients having diagonal flank incisions may develop peri-incisional abdominal bulges due to intercostal denervation of abdominal wall muscles.[120,121]

Other factors challenging wound integrity in patients undergoing anterior spine operations include comorbidities such as obesity, advanced age, tabagism, and cardiovascular disease. In a 2002 tabulation by the University HealthSystem Consortium,[97] 35% of patients undergoing spinal fusion had preoperative American Society of Anesthesiologists risk designations of 3 or higher. Blood loss and transfusions were significant. One quarter of patients in the University HealthSystem Consortium compilation required blood products. Although the mean recorded blood loss was half of a liter, many patients lost as much as 6 L. Unquantified risks to wounds are long operations in distorted positions. For instance, placing patients in the prone position to operate on their backs for hours challenges the security of just-closed anterior incisions.

There is a miscellaneous category of unsurprising complications that occur at the lumbar level. Ileus is less of a problem in retroperitoneal operations than in transperitoneal operations, occurring in 5% to 10% of cases.[71,85] This is not often enough to recommend the routine use

Table 3. Mortality Rates in Anterior Spine Operations

Source	Deaths, No./ Patients, No.	Mortality, %
Hodgson and Stock,[13] 1960	4/100	4.0
Dwyer and Schafer,[24] 1974	0/51	0.0
Burrington et al,[25] 1976	1/46	2.2
Malcolm et al,[63] 1981	0/32	0.0
Westfall et al,[30] 1987	3/85	3.5
Naunheim et al,[20] 1994	4/126	3.2
Faciszewski et al,[46] 1995	4/1223	0.3
Tiusanen et al,[102] 1996	0/83	0.0
Sundaresan et al,[119] 1996	2/110	1.8
McDonnell et al,[64] 1996	2/447	0.4
Grossfeld et al,[48] 1997	2/599	0.3
Oskouian and Johnson,[95] 2002	2/207	1.0
University HealthSystem Consortium,[97] 2003	6/966	0.6
Total	**30/4074**	**0.7**

of nasogastric suction. If a transperitoneal approach is used or if the abdomen is entered from the retroperitoneum, the bowel is exposed, thus introducing the possibilities of injury and postoperative obstruction.[48,83] Complications characteristic of all truncal cavity operations—urinary tract infection or retention, deep vein thrombosis, and adverse cardiopulmonary events—also occur after anterior lumbar spine operations (Table 2).[12,30,46,48,64,85]

COMMENT

Cosurgeons operating on the anterior aspects of spines have different goals. The spine surgeon develops a plan to remove, realign, or fix. Safely providing exposure to accomplish these goals is the aim of the participating exposing surgeon. These procedures are associated with complication rates higher than 40%, even in experienced hands.[46,102] Mortality rates are difficult to compare because of the heterogeneity of reported patient populations and operations. Deaths from endoscopic spine surgery are rare.[39] There were none in several large series in which operations were less extensive than those in which surgeons used open exposures.[37,43,83] In open cases, mortality rates ranged from 0% to 4%, with a mean of less than 1% (**Table 3**).†

The exposing surgeon must know generally what operation is to be done, and the spine surgeon must understand the limitations of exposures available to do it. Both surgeons should participate in perioperative care. Just as the spine surgeon teaches the patient about the operation, the exposing surgeon counsels the patient regarding the incision and the possible complications attendant to that. Exposing surgeons can abet protection of critical structures by assisting during the corrective portion of the operation.

Certain complications—deep vein thrombosis, wound infection, urinary tract infection—are common to both specialties. Spine surgeons must be relied on to detect technical complications such as slipped devices or neurological deficits. Exposing surgeons should pay attention to drainage systems, surface wounds, and systemic complications and should continue postoperative care until complications possibly deriving from their services are no longer considerations.

The burgeoning experience with anterior spine surgery has clarified exposure-related complications (Table 2). At the thoracic level, these include chylothorax, the slight threat of cord ischemia, and the very rare risk of vision impairment. Pulmonary complications remain the most prevalent postoperative problem in these patients.

There are more exposure-related complications at the lumbar level than at the thoracic level. Principal among these is vascular injury. The most likely arterial complication is thrombosis. Intraoperative bleeding is more likely from veins. Injuries to either side of the circulation can come from retraction or dissection. Other retroperitoneal structures subject to injury are the ureter and regional nerves.

Successful endoscopic operations, including robotics, on the anterior spine are characterized by the attributes of less pain and shorter hospitalization.[78] These features are also attainable through small open anterior incisions through which operations can be done more quickly and less expensively.[71,103] In comparable patients, fewer complications are associated with open, retroperitoneal spine exposure than with laparoscopic exposure.[112] Two obvious questions remain: (1) Can minimal surgery techniques be used for the most complicated spine operations? and (2) Since evaluation periods of the operations now being endoscopically performed have been brief, will the ultimate results be satisfactory?[122,123]

Indications for performing anterior spine operations on an aging population have expanded beyond neuropathy or functional debility to less precise diagnoses such as diskogenic pain. Structural abnormalities are being addressed by new devices such as artificial disks. The burgeoning insertion of such implements poses financial, medicolegal, and clinical questions.[124] Definition of operative indications is currently a greater challenge for spine surgeons than technical capability.[125,126]

Except in rare circumstances, spine surgery training programs do not teach their residents to expose, protect, or repair viscera or vessels. Therefore, participating general and thoracic surgeons must provide these skills and be prepared to manage complications that may accrue.

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