14 Thoracolumbar Metastatic Spinal Disease

Charles A. Hogan and Robert F. McLain

Introduction

The thoracolumbar spine presents unique anatomical and biomechanical challenges for the treatment of spinal metastases. Physiologically, certain tumor types have predisposition for this region of the spine given Batson venous plexus drainage patterns. Anatomically, considerations include the transition into the stiffer thoracic cage from the more mobile lumbar spine, a relatively flat segment from T10 to L2 between regions of kyphosis and lordosis, transition from cord level to cauda level with the presence of the conus medullaris, costovertebral joints with rib heads blocking direct access to anterior structures, location of the great vessels and solid organs including the liver and kidneys, vascular perfusion as it pertains to the artery of Adamkiewicz [1], and, perhaps of most technical consideration, the presence of the diaphragm. Mechanically, the transition from coronally oriented thoracic facets (coupled with the stiffness of the rib cage) to sagittally oriented lumbar facets (with flexion/extension arcs transitioning to lateral bending and twisting arcs) increases mechanical load and potentially predisposes to increased mechanical construct failure.

When addressing the thoracolumbar junction, the anterolateral or lateral corridors provide access to anteriorly based tumor and epidural compression, allowing resection and spinal stabilization through anterior column support. Advances in surgical technology have allowed us to develop more minimally invasive strategies based on the established, well-validated principles of traditional open procedures.

Anterolateral Corridor Techniques

Various approaches through the anterolateral corridor include:

1. The traditional open transthoracic or retropleural thoracotomy (if working above the diaphragm) or open retroperitoneal approach (if working strictly below the diaphragm) approached via a lateral decubitus positioning.
2. The combined, open thoracoabdominal approach allowing access to the lateral thoracolumbar junction above and below the diaphragm (retroperitoneal below and intrathoracic above the diaphragm).

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3. The extracoelomic approach connecting the retroperitoneal and retropleural cavities by taking down the diaphragm by mobilizing the parietal pleura off the chest wall along with the diaphragmatic origin, as opposed to splitting the diaphragm at its base, staying truly retropleural.
4. A minimal access open combination of the above using a short segment of the traditional incision and exposure.
5. A true minimally invasive access strategy using specialized retractors and innovative light sources or endoscopy to access and treat only the segments requiring anterior resection or stabilization.

Anterolateral Corridor Obstacles

The lateral approach to the thoracolumbar junction is situated well above the level of the lumbar roots at risk of injury during direct lateral (DLIF) or extreme lateral (XLIF) approaches to the lower lumbar segments [2]. Sacrifice of a T11 or T12 root, if tumor involvement makes it necessary, is a minor consideration compared to loss of roots at L2 and lower, but entry into the canal at this level threatens the spinal cord and conus medullaris as opposed to spinal nerve roots [3].

When working from T10 to L2, the diaphragm is the most complicated structure [4, 5]. Its attachments consist of three major muscle groups (sternal, costal, and lumbar) and a central tendon consisting of three leaflets (right, left, middle). Major structures pass through three major openings: the vena caval opening (on the right, at T8), the esophageal hiatus (centrally, T10), and the aortic hiatus (paracentral to the left, T12). The thoracic duct and the azygous vein also pass through the aortic hiatus. The most relevant diaphragmatic attachments to the spine are the medial and lateral arcuate ligaments and left and right crura. Laterally the diaphragm is anchored to the parietal pleura over the ribs: anteriorly at ribs 7 and 8, laterally at ribs 9 and 10, and posteriorly at ribs 11 and 12. The more lateral of the posterior diaphragmatic structures are confluent with the fascia that trails distally to envelop the origin of the quadratus lumborum (lateral arcuate ligament) and the psoas (medial arcuate ligament). These arcuate ligaments are important landmarks for the surgeon approaching L1, as they both invest the transverse process of L1 [3, 6]. Sharp release of the arcuate ligaments off the tip of the L1 transverse process releases a key tether of the diaphragm and provides access to the lateral L1 vertebral body during the anterolateral approach. This permits the diaphragm release via the extracavitary or extracoelomic approach (i.e., staying entirely in the retroperitoneal and retropleural corridor, yet anterior to the quadratus lumborum and psoas).

The most medial structures are the crura, which anchor the central diaphragm to the spine itself. The right crus is wider and attaches to the transverse processes between L1 and L3. It runs cranial alongside the aortic hiatus (T12), loops up over the esophageal hiatus (T10), and then runs caudal to blend back into itself between the esophageal hiatus and the aortic hiatus (between T10 and T12). The left crus attaches in the vicinity of L1–L2, runs cranial alongside the aorta as it comes through its hiatus (T12), and then loops over the esophageal hiatus (T10) where it blends into the central tendon. In reality these structures are seen surgically as thickenings of connective tissue, becoming confluent with annulus and ALL.

Kawahara and Tomita et al., in their work with en bloc spondylectomy, found that the great vessels mobilize fairly easily from T1 to T12 but proved particularly challenging to mobilize at the L1 and L2 levels, primarily because of the crural attachments adherent and confluent with the vertebral periosteum and the anterior longitudinal ligament. They also demonstrated that the first two lumbar arteries and veins consistently run in the mesh of tissues between the medial crus and the vertebral column here [4].

Finally, vascular control—difficult in any case—can be dramatically more challenging when neovasculature and epidural hypertrophy are associated with a thoracolumbar tumor. Not only can the native vessels be hard to localize and control, duplicate vasculature and intramuscular neovasculature can be quite extensive in tumors such as renal cell, melanoma, or thyroid carcinoma. Angiography and preoperative embolization, sometimes twice, can determine whether tumor excision can be accomplished at all.

Patient Selection

While open approaches allow en bloc excision, when indicated, they also allow more certain vascular control. Intralesional approaches are more amenable to MIS techniques, which are most useful when local control can be reliably augmented by radiation or medical management, and vascular control is assured. The best candidates for consideration of lateral corpectomy approach would be those with predominantly anterior column disease and possibly unilateral pedicular involvement and a life expectancy/medical fitness to warrant surgery. Patients with true spinal instability and epidural cord compression, presenting with progressive neurologic deficit, would be clear candidates for surgical decompression to maintain or restore neurological function. Structural restoration may be possible through the primary anterior approach itself or may be carried out through a separate posterior approach with posterior segmental fixation [7].

Separation surgery, carried out through an MIS approach to debride tumor tissue immediately adjacent to radiosensitive neurological structures (roots and cord), allows more aggressive and effective use of stereotactic spinal radiosurgery and is an increasingly popular treatment algorithm. However, when dealing with traditionally radioresistant tumors and true spinal instability, surgical intervention in the form of corpectomy, anterior column support, and instrumented stabilization is still the soundest consideration.

Surgical Approaches: Localization

For tumors at the thoracolumbar junction, compare a preoperative X-ray to MRI or CT to establish the operative level in relation to a structure you will be able to identify on fluoroscopy—the most distal rib or a compressed, fractured vertebra. Alternatively, use live fluoro on a lateral, counting vertebra cranially from the sacrum. Regardless of the strategy, localization of the proper operative level is important to initiating the exposure at the best level and critical to MIS approaches. Some advocate a preoperative marker in the level of the operative pedicle placed by interventional radiology; if the patient is going for angiography or preoperative embolization, this may be reasonable.

Much MIS lateral work relies on satisfactory fluoroscopic imaging. It is exceedingly important to have the lateral fluoro view you see on the monitor correlate to a truly perpendicular trajectory to the floor. Passing instruments perfectly perpendicular to the horizontal helps avoid misadventures anteriorly into the vessels and posteriorly into the canal or exiting nerve roots. With the patient carefully positioned on the operating table, mark the outline of the superior and inferior endplates, anterior and posterior vertebral borders of the target vertebra using a metallic wand under fluoroscopy, and sketch the positions on the skin surface. Palpate the overlying rib and mark this as well. The intended incision is now drawn out in accordance with technique and goals of the case at hand. For an open approach, extend a line in line with your planned incision projecting anteriorly across the abdomen and posteriorly down the back (Fig. 14.1).

When planning the incision, considerations include number of levels for the corpectomy, need to place a laterally based plate and screws vs. corpectomy and anterior column support alone, and plan to stay extrapleural proximally vs. commit to being intrathoracic. For a mini-open one-level corpectomy, an oblique to transverse incision, crossing the midportion of the body (cranio-caudal), should suffice. For multilevel work, a longer oblique incision following the angle of the rib resection (running from cranial posteriorly to caudal anteriorly) is preferred.

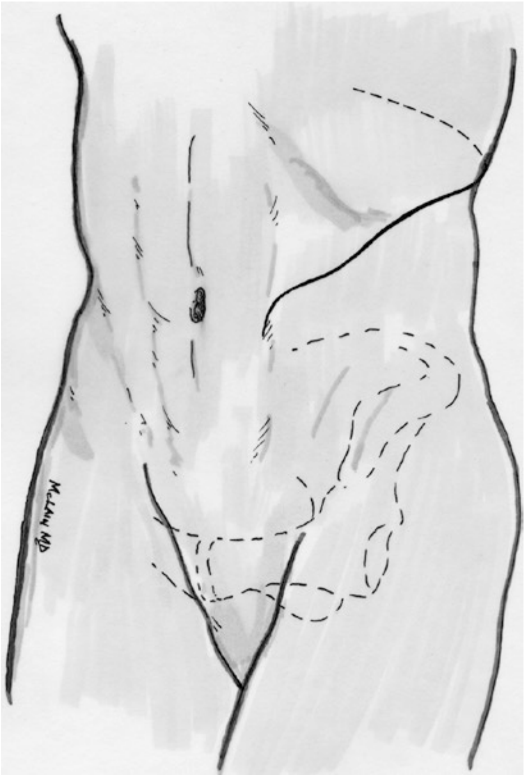

Fig. 14.1 Surgical incision for thoracolumbar exposure. Incision begins posteriorly over the costovertebral angle and is carried forward to the rectus sheath, turning distally there. For mini-open exposure, the midportion of this same incision is usually sufficient

Planning the Surgical Incision

Traditional mantra of taking the rib two levels above the surgical lesion provides wide exposure through the traditional open approach and thoracolumbar combined approaches but is less relevant for a minimal access open approach; take whichever rib is in the path to the spine with the patient in a perfectly lateral position [8, 9]. For MIS and minimally open procedures, specialized retractors provide focal retraction down a directly lateral corridor and in line with the targeted disc(s) and vertebra. If simply performing a vertebrectomy and placing a cage, exposure from disc to disc may be adequate. When applying a lateral plate and screws after a corpectomy, it is always easier to access the vertebral body below the defect than it is to place screws transversely across the endplate of the vertebral body above, which lies at or above the diaphragm.

Classic thoracoabdominal anterolateral approach to the thoracolumbar junction (transthoracic, retroperitoneal) involves taking the ninth or tenth rib [9]. This gives consistently good exposure but requires entrance into the chest cavity and chest tube placement. Extracoelomic approaches stay retropleural and may reduce morbidity by obviating need for chest tube placement, limiting duropleural fistula in setting of CSF leak, and decreasing potential for pleural adhesions, effusions, atelectasis, pneumonia, and pneumothorax [10, 11]. However, pleural adhesions or parietal pleura deficiency may make chest tube placement necessary in any case. Generally, taking a single well-planned rib allows access for the corpectomy and laterally based instrumentation. Techniques to extend access to an adjacent level would include an osteotomy of the rib above, hinging on the intact cortex to allow more exposure, segmental resection of another rib, or an extension of the primary incision and taking more rib posteriorly. If additional disc spaces must be accessed, either the subjacent rib may be osteotomized and retracted distally or a second rib may be incised distally or proximally to give access to additional disc spaces. A second rib incision will also facilitate the application of anterior spinal instrumentation such as rod and screw constructs. This second rib incision is performed through the same skin incision by simply retracting the skin distally over the bed of the selected rib two or three levels above or below the initial resection. The second periosteal incision is made through the bed of the rib but the rib is not resected.

Open Thoracoabdominal Approach (Retroperitoneal, Intrathoracic)

Traditionally, most spine surgeons accessing the thoracolumbar junction have used the open thoracoabdominal approach. Plan the incision directly overlying the rib that will allow access to the involved vertebra. Thoracoabdominal exposure is generally performed by taking the 9th, 10th, or 11th rib and consistently gives access from T11 to L2. The curvilinear incision starts posteriorly, in line with the rib; runs anterior along the rib itself, crossing the costochondral junction; and heads obliquely either toward the rectus sheath or more vertically and distally toward the ASIS. If instrumenting anteriorly down to L3, the incision should curve more distally. If performing a one-level corpectomy at L1 without plating, you won't need to complete the full distal extent of the incision. Come through the latissimus and posterior serratus in the center or top half of the rib so as to stay clear of the neurovascular bundle that runs inferiorly along the rib. Dissect the rib subperiosteally back toward the costovertebral joints and anteriorly all the way to the costochondral junction (AO or Cobb elevator). We prefer large straight and curved curettes to gain access around the rib and then a Doyen periosteal elevator to develop the plane along the deep surface of the rib. Disarticulate the rib tip from the costochondral junction; this small cartilaginous landmark will be the reapproximation start point for the multiple layers to be closed later. Generally take the rib as far back as the incision will allow the rib cutter to pass, to the posterior rib angle.

Intrathoracic Portion

Proximally, the endothoracic fascia lies just deep to the rib periosteum, and this is closely adherent to the parietal pleura. Vertical incision in line with the spine through both these layers takes you onto the lateral spine. The lung is clearly seen cranially and can be retracted with a deep broad retractor and moist lap sponge. The dome of the diaphragm is clearly seen caudally.

Retroperitoneal Portion

Initiate abdominal exposure via the bleb of retroperitoneal fat that directly underlies the cartilaginous anterior 10th rib tip. Abdominal muscular layers are taken sequentially with Kelly clamp and Bovie, in line with the wound. The junction of the transversalis abdominis and the cartilaginous rib tip is the key: this signifies the convergence of the abdominal musculature, the retroperitoneal space, and the diaphragm. Once the extraperitoneal fat is seen, bluntly develop the plane between peritoneum and posterior abdominal wall with a sponge stick or finger and sponge. The diaphragm is incised with a 1–2 cm cuff laterally around the rib attachment (to repair upon closure). Paired tag sutures should be placed in the anterior abdominal musculature and the free edge of the diaphragm, alternating black and green suture color, to facilitate anatomic closure. Reflect around the back of the peritoneal cavity, hugging peritoneum, onto the origin of the psoas and quadratus lumborum. Roll the dissecting finger anteriorly over the psoas onto the ventrolateral surface of the spine. The ureter is usually engulfed in retroperitoneal fat and falls away with the peritoneum, but in revision retroperitoneal surgery where scarring may be present, take care to identify this structure. Some consider urological consult to place ureteral stents to help ease identification. Avoid falling into the interval behind the psoas—"no man's land"—which leads to the transverse processes and neuroforamina and not the vertebral body. Protect the genitofemoral nerve running along the top of the psoas (Fig. 14.2).

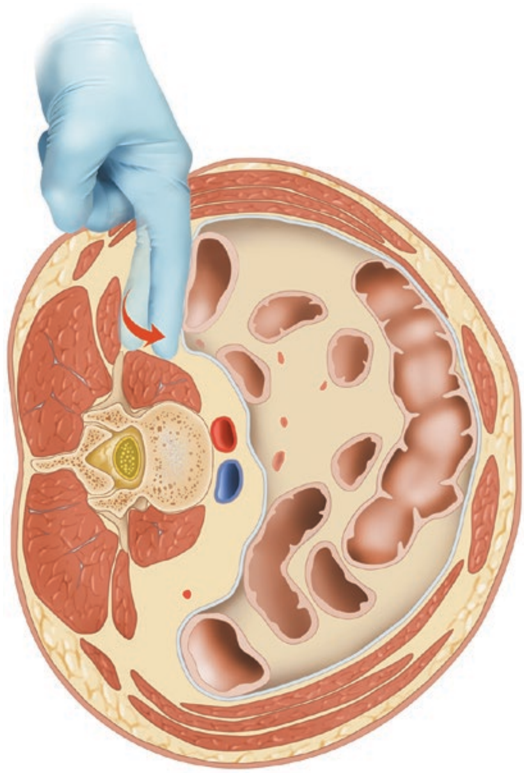

Fig. 14.2 Anterior surgical approach. The digital dissection is carried down to the surface of the psoas and then bluntly develops the plane over the surface of the psoas onto the lateral surface of the vertebral body. The plane between the anterior longitudinal ligament and the great vessels can be developed bluntly, but the vessels cannot be mobilized until the segmental vessels are isolated, ligated, and divided

Table-based retractors such as a Bookwalter or Omni are helpful, but a “C”-shaped malleable retractor inserted against the psoas to hold the viscera away and frame the surgical site helps keep hands free in the depth of the wound. Powerful retractors placed high in the flank can easily injure the spleen against the ribs. Moist lap sponges behind the broad blades protect skin edges and neurovascular bundles from hours of pressure and retraction.

Extracoelomic Approach Technique

The extracoelomic, or extracavitary, approach is extensile, provides a true anterior exposure, and simplifies the management of the diaphragm in thoracolumbar approaches. It may reduce the incidence of some complications commonly seen in transthoracic procedures, including intrapleural migration of bone graft and formation of pleural adhesions.

The principles for success with this approach remain the same as for any other: careful assessment of the patient, fundamental knowledge of the three-dimensional spinal anatomy, recognition of complicating factors and hazards, and skillful and meticulous surgical technique [10, 12].

This modification of the classic thoracoabdominal approach involves working purely in the extrathoracic (retropleural) and extraabdominal (retroperitoneal) cavities and connecting these two spaces by detaching the diaphragm from the chest wall. The diaphragm attaches in a straight line radiating laterally from the lower sternum to the arcuate ligaments that anchor off the L1 transverse process. It essentially becomes confluent with the intercostal muscles and the internal oblique muscles laterally, fanning out at the perimeter at each point. Since the ribs slant anteroinferior as they come around the chest, it makes sense that the posterior diaphragmatic attachment points correlate with the lowest vertebrae, and the lateral (costal) attachment points correspond to progressively higher ribs as you move anteriorly. The diaphragm doesn’t lie under any one rib. For different patients the same direct lateral approach at T12 may put you into the chest in one patient and the retroperitoneum in another [3]. The goal of the extracoelomic approach is to find the plane between the retropleural space above and the retroperitoneal space below and never enter the chest. This is easier done by finding the retropleural space posteriorly and then working caudally and anteriorly, taking the diaphragm down off the lateral chest wall as it blends into the superior portion of the ribs as you work anteriorly [13]. The fibrous inflammatory rind and possible pleural invasion may limit technical feasibility in some tumors; carefully scrutinize the MRI for extraspinal tumor involvement before planning this approach.

The thoracic cavity is opened through the bed of the 10th rib, carrying the incision across the costochondral junction before turning obliquely across the abdominal wall toward the lateral border of the rectus sheath. The parietal pleura is dissected away from the inner thoracic wall as described above. The rib is disarticulated from the costochondral junction, and the costal cartilage is split longitudinally to enter the abdominal cavity. Split the external oblique muscle along the line of its fibers, and then divide the internal oblique muscle with electrocautery. The transversus abdominis fascia is entered near the rectus sheath where it is thinnest. After developing the interval between the fascia and the peritoneum, dissect bluntly along the abdominal wall while splitting the fascia with electrocautery. If there is scarring in the retroperitoneum, the surgeon must identify the ureter before introducing electrocautery. Identify and stay anterior to the psoas muscle.

By dissecting proximally and distally through the retroperitoneal and the extrapleural space, the attachment of the diaphragm is identified along the insertion into the chest wall. The diaphragm can now be bluntly detached from the chest wall and dissection carried posteriorly to the crus. Wet sponges are applied over the exposed pleural and peritoneal surfaces, which can then be retracted with a fan retractor to hold the lung, diaphragm, and peritoneal contents anteriorly away from the spine. This allows exposure from the mid-lumbar to the mid-thoracic spine through a single incision (Fig. 14.3).

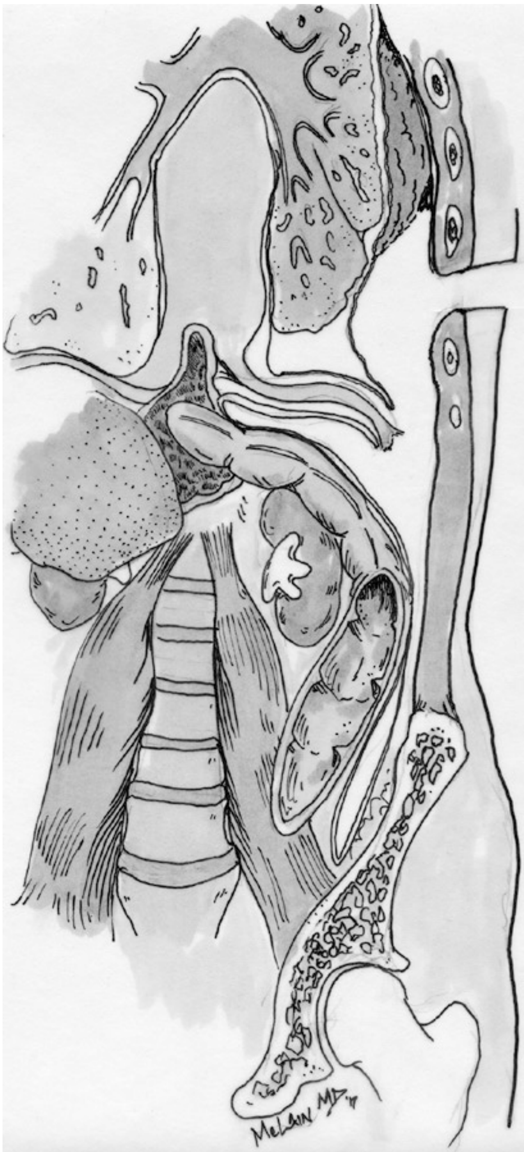

Fig. 14.3 The extracavitary or extracoelomic exposure elevates the parietal pleura from the chest wall, along with the diaphragmatic insertion, and then develops the plane from the diaphragm into the retroperitoneal cavity in the abdomen

On completion of the spinal procedure, the pleural and peritoneal tissues are allowed to fall back into their normal position. The diaphragm is not directly reattached to the chest wall but is allowed to re-approximate to the wall through the adhesion of peritoneal and pleural tissues.

Chest Tube Placement

When required, place a chest tube between the anterior and midaxillary line, via a stab incision one or two interspaces above the incision. Palpate the acromion or the ASIS under the drapes as a proxy to estimate your anterior to posterior position on the chest wall. Make the stab wound through the skin and fascia, off the superior aspect of the inferior rib (spare the neurovascular bundle). Spread muscle and puncture through the pleura with a Kelly clamp. Kelly clamp is used on sharp-angled end of the chest tube to guide this deeper into the chest to the desired location. We aim this cranially and posterior to the lung. Commonly use a 24F to 32F chest tube. Drain stitch anchoring the chest tube to the skin is helpful, as is petroleum gauze to act as a sealant about the borders of the stab wound. If known pleural violation, place to 20 cm wall suction. If placing prophylactically as a drain, place to water seal. Obtain CXR in PACU and the following morning. If concerned for a pleural violation, fill the thoracic cavity with saline and Valsalva: bubbles indicate pleural violation and should warrant consideration of chest tube placement especially if the pleural rent cannot be identified and repaired.

Red Rubber Catheter Technique for Evacuation of Retropleural Air

We recommend placement of a chest tube when knowingly performing a transthoracic approach (lateral transthoracic thoracotomy, thoracoabdominal approach) or when parietal pleural violation has inadvertently occurred (lateral retropleural thoracotomy, extracoelomic approach). If pleural violation is repairable and confirming no bubbles upon filling the chest with saline and intraoperative Valsalva, consider leaving only a drain. Intraoperative decision balances morbidity of chest tube placement with potential need for chest tube placement in the ensuing hours to days on the floor. In cases with low suspicion of having entered the parietal pleura, consider placement of a retropleural suction drain. Alternatively, retropleural air can be evacuated prior to final closure without a drain. A red rubber catheter is placed deep in the wound, between the layers of the endothoracic fascia and parietal pleura. These layers are closed with running stitch starting on either end and working toward the middle where the catheter lies. The external tip is placed under a water bath, anesthesia provides a Valsalva, and the air in this layer is evacuated while simultaneously removing the catheter and tying the last stitch.

Minimal Access Lateral Corpectomy Approach

A minimal access open approach (or mini-open) to the thoracolumbar junction affords access precisely to the target area, minimizing dissection through adjacent tissues and abdominal wall. The minimal access open approach uses a segment of the classic open incision, placing a 4- to 6-in. oblique incision over the 10th or 11th rib, extending from the proximal angle of the rib to the distal tip of the rib. As with the open approach, the rib is dissected subperiosteally and divided at the proximal angle and dislocated from the chondral cartilage. For a traditional intracavitary approach, the pleural cavity is entered just above the diaphragm and the retroperitoneal space, just below [14]. After separating the diaphragm from its lateral rim, self-retaining rib retractors can be placed to allow exposure of T11–T12 disc, down to the L1 vertebral body (Fig. 14.4).

Mini-open, left side up lateral, T12 corpectomy with anterior epidural decompression and placement of expandable interbody prosthesis from T11 to L1.

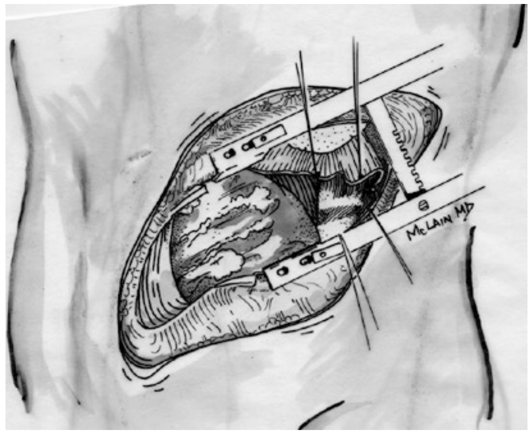

Fig. 14.4 The minimally open approach uses the mid-portion of the T10 rib resection to access the cavity above and below the diaphragm, taking down just enough diaphragm to allow corpectomy and plate fixation

Approach

For mini-open lateral T12 corpectomy, position perfectly lateral in the right decubitus, mark the T11, T12, and L1 vertebral bodies (T11–T12 and T12–L1 discs) using preoperative fluoroscopy, and plan a surgical incision running obliquely following the trajectory of the rib that directly overlies the level to be approached, usually the 10th rib for T12. Dissect onto the rib and expose subperiosteally, undermining soft tissues anterior and posterior to the incision. Protect the neurovascular bundle, and resect the rib cleanly to prevent sharp and jagged edges that would make blunt finger dissection challenging. Ensure the rib is taken sufficiently posterior to allow a working exposure and remove bony spikes. Wax bleeding rib bone. Though ultimately the retractor will be expanded only a few inches and wanded at depth depending on working location, adequate rib resection and mobilization of the planes will allow easier retractor placement with less tension.

An extracavitary approach is useful here. Incise the periosteum in the bed of the rib carefully, and bluntly dissect between the periosteum and the loosely adherent parietal pleura [12]. Define the plane between the endothoracic fascia and the parietal pleura, and mobilize this carefully and bluntly, cranially and caudally, using a digit and then a sponge stick. Use care to develop this plane widely as this will keep you retropleural and decrease the chances of making this a transthoracic transperitoneal approach. A wide fan retractor and moist lap sponge are placed to retract the parietal pleura, the visceral pleura, and the lung anteriorly in one envelope. Dissection continues along the posterior rib cage onto the lateral spine (cranial to the level of the psoas and crura) at the T12 level. With the parietal pleura reflected, the segmental vessels are more easily identified and isolated. Particularly in the mini-open approach, segmentals must be carefully ligated before they

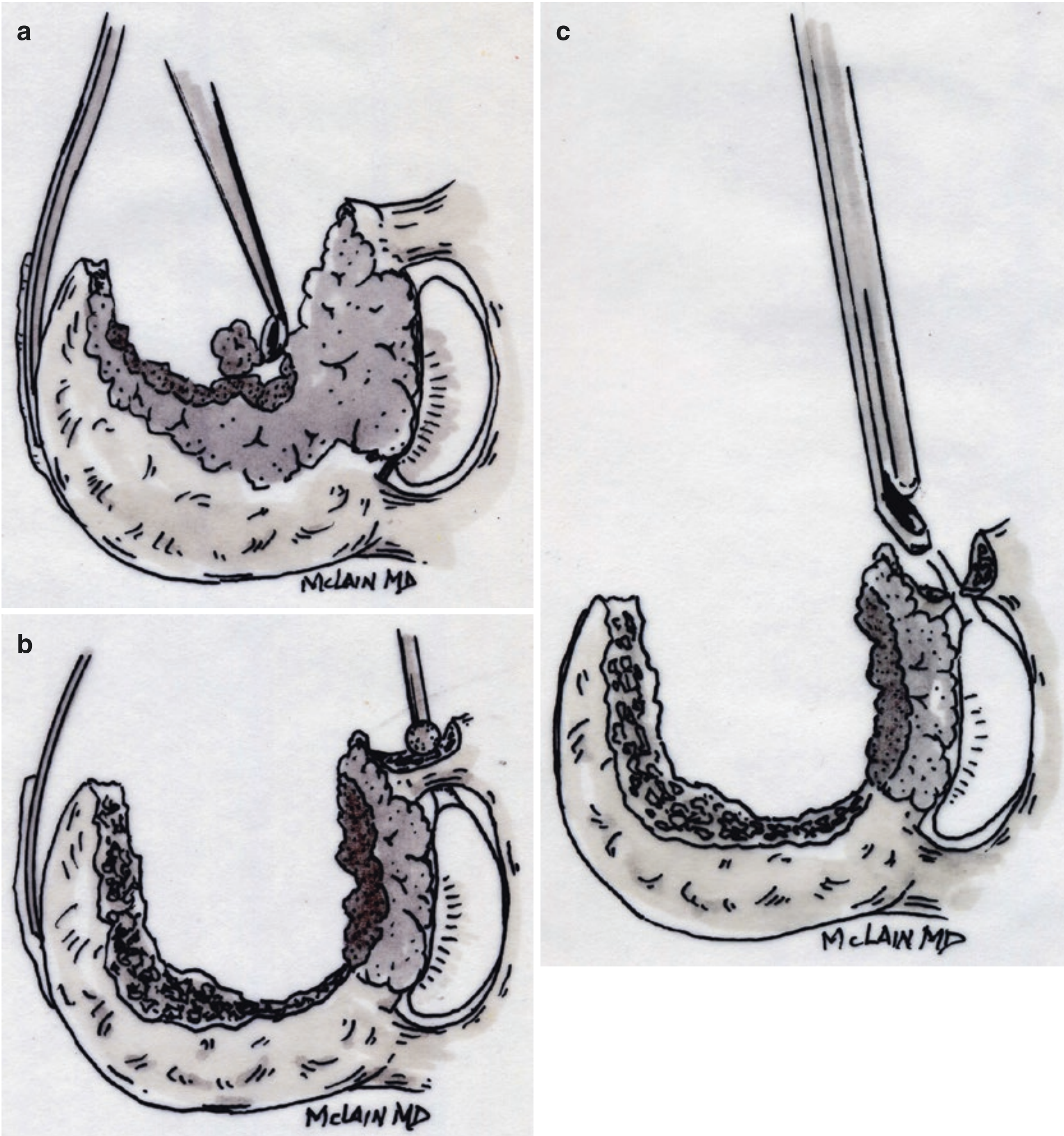

Fig. 14.5 (**a**) Corpectomy through the minimally open or fully open exposure begins by elevating the ALL and placing a malleable retractor to shield the great vessels and expose the lateral surface of the vertebra invested with tumor. Rongeurs and curettes can then quickly debulk the tumor and central vertebral cancellous bone to create a cavity ventral to the spinal canal. (**b**) If tumor is difficult to free from the spinal canal, and cord compression is significant to start with, a diamond burr can be used to take down the left-sided pedicle to allow entry into the canal from the side, avoiding blind curettage over the surface of the compressed cord and dura. (**c**) After thinning the pedicle to its medial cortex, a fine Kerrison can be inserted between the cortex and dura to complete the exposure, revealing the nerve root and the uninvolved dura and providing lateral access to the compressing tumor

are divided. Usually a silk tie ligature is placed on either side of the division and is supplemented with a hemoclip. The anterior longitudinal ligament can be raised off the surface of the vertebral bodies and discs using a sharp elevator and cautery. Once this interval is developed, a deep retractor, such as a malleable with a small reverse curve, can be inserted between the body and the ALL and toed back away from the involved vertebra, providing a shield for the great vessels during corpectomy (Fig. 14.5a–c). Corpectomy and stabilization can proceed as planned from here.

Minimally Invasive Surgical Approaches

With advent of improved retractors and imaging, improving visability, the ability to access the lumbar and thoracolumbar segments through true minimally invasive approaches has been developed to the point that some tumor surgery can be accomplished safely and effectively through an incision only a few centimeters long. In these cases, patient positioning can dictate success or failure, and particular attention is warranted.

Positioning

Turn the patient directly lateral on a reversed radiolucent slider bed with ability for lateral tilt, Trendelenburg and reverse Trendelenburg. Slide the patient as far cranial on the bed as is possible so the fluoroscopy unit will not be blocked by the table base when imaging the thoracolumbar junction. An axillary roll limits the brachial plexus and prevents shoulder issues. Place up the arm on a biplane arm holder or on pillows, with elbows and shoulders neutral and well padded but cranial to the path of fluoroscopic imaging. The neck is neutrally aligned and carefully handled by anesthesia throughout the positioning process (Fig. 14.6).

Flex the down leg only slightly at the hip and knee to balance the patient. Flex the up leg more acutely, as in Fig. 14.6, at the hip and the knee with pillows between the legs for support and to prevent pressure between bony prominences. While DLIF technique for mid-lumbar degenerative disease calls for breaking the bed in the so-called jackknife position to allow better access to the lateral spine, this is not recommended for pathological fractures and structurally unsound vertebrae affected by metastatic disease. Additionally, lateral bending has little effect on the thoracolumbar junction and lower thoracic segments targeted here. Maintaining the patient in side-bending for prolonged periods (particularly as required for corpectomy as opposed to discectomy and fusion) may also contribute to postoperative hip flexion weakness and anterior/anterolateral thigh neuropraxia [15].

Optimizing Fluoroscopic Imaging

After positioning the patient, but before securing the patient and prepping the flank, check fluoroscopic imaging to confirm orthogonal orientation of the spinal segments. On cross-Table AP at the operative level, observe pedicles in upper 1/3 of vertebral body, symmetrical in appearance, with the spinous processes bisecting pedicles directly in midline. On lateral fluoro, observe overlapping

Fig. 14.6 Positioning the patient on the operating table for any of the exposures discussed; allowing access to the flank, room for an emergent extensile exposure if complications arise; and facilitating precise and reliable fluoroscopic imaging

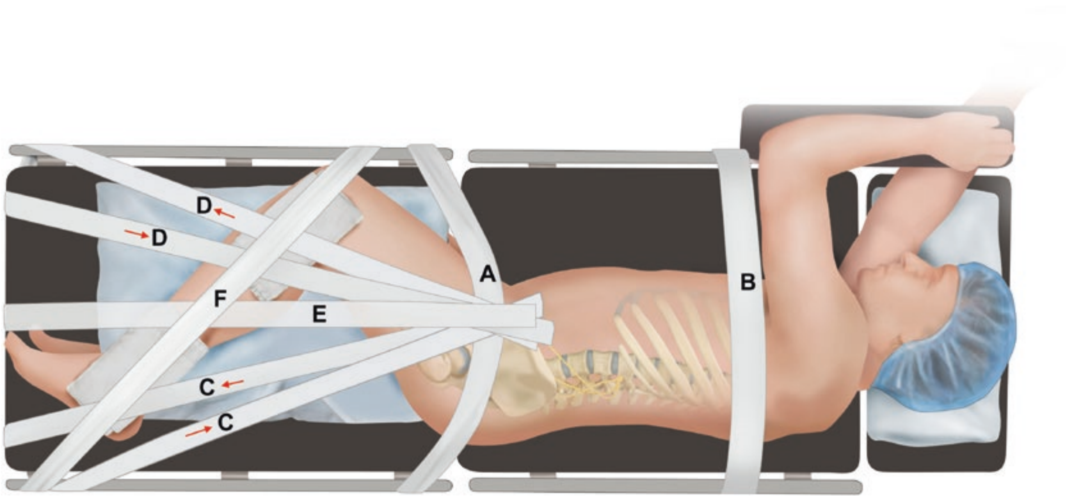

Fig. 14.7 Once the patient is in optimal position, 3″ silk tape is used, as shown, to immobilize the lower extremities and pelvis and the upper extremities and trunk to prevent shifting and malalignment during surgery

pedicles, crisp superior and inferior endplates, and crisp posterior vertebral lines. Once satisfied, secure the patient in final position and recheck orientation (Fig. 14.7). The surgeon can now tilt or elevate the table slightly to obtain the perfect cross-Table AP and lateral image with the C-arm in fixed positions.

The importance of having the patient anchored securely to the operating table without rotation of the torso relative to the pelvis cannot be overstated.

Use wide silk tape to circumferentially secure the chest to the OR table. Stay as cranial from planned surgical incision as is possible. Ensure chest excursion and lung tidal volumes are unchanged. Pad the knee and lateral malleolus on the upper leg, and secure the lower one half of the patient with wide silk tape running across the OR table in line with the lower leg and the femur, respectively. After taping across the iliac crest, the patient should not shift even if the table is tilted slightly side to side.

Fig. 14.8 Top-down lateral view through the upper lumbar spinal column showing image quality through a radiolucent retractor

Retractor Placement

Place the table-mounted base for the expandable retractor of choice. Different options exist, but the effective retractor has 3–4 blades that expand, toe out, and translate slightly based off the initial chosen position, anchored off the table through a flexible arm (Fig. 14.8). They also often have an intradiscal shim or vertebral body pin that can be placed to anchor the system deep to the spine while working. This may permit the surgeon to translate the retractor anterior or posterior, cranial and caudal from the initial starting position. Placement of an expandable cage through an expandable retractor with fiber-optic lighting becomes less of a struggle as the surgeon gains

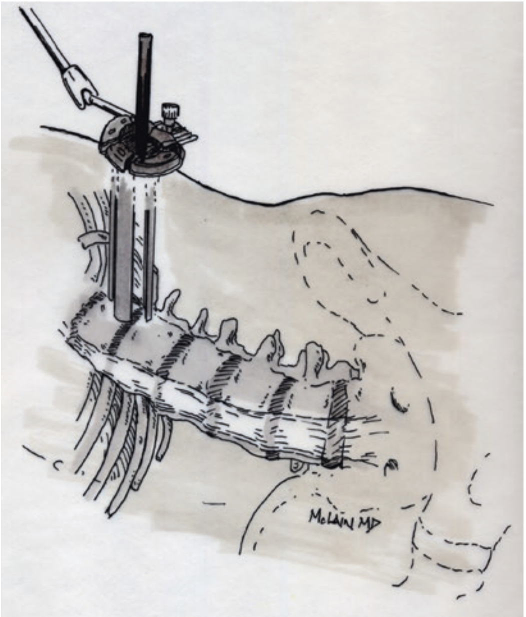

Fig. 14.9 Positioning the typical MIS retractor system over the thoracolumbar junction requires rib resection and elevation or takedown of the diaphragm. Breaking the table is not helpful in this exposure and could interfere with alignment when cage placement is performed

familiarity [16]. Placement of even the smallest MIS retractor at the thoracolumbar junction requires osteotomy or removal of the T12 and T11 ribs overlying the target vertebra below (Fig. 14.9).

Surgeons with extensive experience with DLIF and XLIF approaches for degenerative disease will have an advantage when taking on this kind of approach, and surgeons who have not used these systems may be better served through a traditional open approach. Managing bleeding, from bone, tumor, or a vessel, can be daunting through a small portal, and any surgeon should be prepared to immediately convert their minimally invasive approach to an open procedure if complications arise.

Corpectomy and Tumor Resection

Exposure of T12

Once the operative level is confirmed and retractor is placed, ensure adequate exposure cranial to caudal, anterior to posterior. Ideally one can see both discs and the intervening T12 body with retractor deployed and toed out. Our preference is to expose from T11–T12 disc to T12–L1 disc first. Loosen and reposition the retractor arm as needed. The lateral vertebral body may be soft if infiltrated with tumor, but care is first taken to isolate the segmental vessels via Bovie electrocautery vertical incision at the mid-body starting at the peak (disc) and working toward the valley (mid-vertebral body). Right-angle clamp isolates the vessels in the valley, and then tie these off with silk suture; hemoclips or ligature/bipolar may be less reliable or may come loose. Palpation with a Penfield can help to delineate the posterior vertebral body border: palpate along lateral body until you fall into the neuroforamen underneath the pedicle. Thrombin-gelatin matrix, thrombin-soaked Gelfoam, and cottonoids can tamp off radiculomedullary artery bleeding stirred up with the Penfield.

Exposure of L1

Recall the diaphragmatic attachments in this region: the left-sided lateral crus becomes confluent with ALL from L1 to L3, the medial arcuate ligament (investing fascia over the psoas) attaches to the lateral L1 vertebral body and the L1 transverse process, and the lateral arcuate ligament (investing fascia over the quadratus lumborum) attaches to the L1 TP and then along the posterior-most aspect of the 12th rib. Once the arcuate ligament attachments onto L1 TP are released, the confluence of ALL, crus, and arcuate ligament is released off the lateral L1 body with electrocautery. Particular care is taken to identify the segmental artery and vein as they run under the crus [7]. A Steinman pin can be placed transversely through the adjacent vertebra, just caudal to the L1 pedicle, to retract the psoas. Angle the pin anteriorly away from the canal as it advances, check the length on fluoroscopy, and dress the exposed, sharp end with a red rubber catheter tip to avoid surgeon or visceral injury. As one moves caudally, be aware of the confluence of lumbar nerve roots within the psoas and ensure that the psoas is swept posteriorly in its entirety before placing the retracting Steinman pin.

Discectomies

Discectomies are performed as per typical lateral interbody fusion discectomy at the T11–T12 and T12–L1 levels. Ensure thorough preparation of the endplates that will accommodate the anterior column support (fibular strut, expandable or structural cage, etc.) [17]. Complete the discectomies before starting corpectomy to minimize intraoperative bleeding; as long as the vertebra is intact, little blood is lost during discectomy, and once the discs are out, the corpectomy can be accomplished with much greater speed and safety, further minimizing bleeding.

T12 Corpectomy

Some surgeons prefer to start the corpectomy with an osteotome to mark the area of the corpectomy anteriorly, leaving a thin, protective shell of bone anteriorly and along the contralateral side. The cranial, caudal, and anterior borders of the corpectomy are now defined. The body remains attached by the contralateral pedicle. Rongeur away the remaining soft, tumor-ridden vertebral bone [18, 19]. The bone will often bleed briskly until the bulk of the tumor and pathological bone is removed. Pack the field intermittently as needed with hemostatic thrombin foam and dress bleeding bone with wax. Communicate with anesthesia prior to beginning the corpectomy. They should be caught up (if not ahead) before beginning the highest blood loss portion of the procedure. The final, posterior rim or rind of bone and tumor volar to the cord is carefully mobilized away from the canal, using fine curettes and pituitary rongeurs, working from the left to the right across the canal until the dura is free and clear.

Direct decompression of the canal may be very necessary in radioresistant tumors and compressive lesions already causing neurological symptoms. Soft or viscous tumors may be debrided away with a Penfield and suction, but fibrous and bony tumor needs to be carefully separated from the dura and pulled out of the canal and into the corpectomy defect without damaging the threatened neural tissues. Dense bony tissue can be thinned with a burr before mobilizing, and a long thin curette can be inserted behind the residual flap of tumor to reflect it piecemeal into the corpectomy defect. Curettes and pituitaries work across the surface of the dura to complete the dissection from pedicle to pedicle, endplate to endplate.

If the margin between the tumor and the vertebral cortex and PLL is difficult to reach, a diamond burr can be used to take down the lateral cortex of the pedicle at its junction with the vertebral body. As the cancellous bone of the pedicle is removed, the thin inner cortex can be separated from the underlying dura with a small curved curette, then resected with a Kerrison, exposing the exiting nerve root and the lateral surface of the dura from the lamina dorsally to the floor of the vertebral canal. From here decompression of the volar dura can proceed gently but under direct vision.

Place Anterior Column Support With or Without Side Plate and Screw Instrumentation

Once the corpectomy is complete, irrigate thoroughly with antibiotic-laden irrigation. Ensure adequate decompression of the anterior epidural space. Measure between neighboring T11 and L1 endplates, and select the cage or fabricate the strut graft that will be used for anterior column support. Select, pack, and place the cage with care to ensure the selected implant will fit through the retractor. As life expectancy warrants, pay attention to fusion techniques (pack contralateral allograft bone, pack the prosthesis with bone, etc.). Although radiation and disease may impair successful fusion, any of these TL approaches used for corpectomy will provide access to autograft rib. While not sufficient to bear loads on its own, rib struts stacked with a structural cage can dramatically improve the likelihood of anterior fusion and long-term construct survival.

If placing a locking side plate and screws, start the transverse screws in the posterior lateral corner of the vertebral body above or below and angle 10–20° away from the canal and parallel to the endplate itself. If the table has been broken at any time during the resection, return to neutral before placing the plate or locking the fixation in place. Place a small suction drain deep in the wound.

Posterior Pedicle Screw Fixation

If placing an interbody cage without a locking side plate, it is usually wise to augment spinal stability through bilateral posterior pedicle screw fixation. In highly unstable situations, these can be placed with the patient in the lateral decubitus position, but more commonly the patient can be rolled directly onto a radiolucent prone frame to complete the procedure. For a T12 corpectomy, percutaneously placed pedicle screws from T11 to L1 (with unilateral screw fixation in T12 on the contralateral side) are mechanically sufficient, but the surgeon may extend this cranially or caudally if there is any question about integrity of the anterior column support or bone quality. Anterior column support combined with bilateral posterior pedicle screw fixation has been shown sufficient in three-column reconstructions [17].

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