eXtreme Lateral Interbody Fusion (XLIF®)

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XLIF® Thoracic Spine Surgery: The Minimal Answer to a Maximal Challenge

William R. Taylor

Historically, the technologic advancement of surgical methods of treatment for the thoracic spine has moved much more slowly than advancements for the cervical and lumbar spine. This discrepancy is probably the result of two major factors: the small numbers of non-trauma patients who become symptomatic from a disc in the thoracic region and the complexities surrounding the thoracic anatomy. Most significant traumatic spine injuries are treated in major metropolitan hospitals; thus many practicing spine surgeons have little experience with structures surrounding the thoracic spine, including the vasculature. Approach surgeons and assistant surgeons have even less familiarity with this region and may choose to undertake only the most common stabilization procedures. Additionally, because of the complexity of invasive, open thoracic procedures and the associated risks, symptomatic patients are often managed conservatively for longer periods and given significantly less encouragement to undergo surgery.

Because of recent innovations in thoracic minimally invasive spine surgery, surgeons can quickly and easily perform thoracic surgery or very complex minimal procedures without a thoracotomy. The instrumentation and technique have progressed in tandem, making the surgery less complicated and resulting in a procedure that is effective and less time consuming. Most importantly, however, XLIF (NuVasive®, Inc., San Diego, CA) makes surgery safer for the patient in even the most challenging cases.

The impetus to create truly minimally invasive spine surgery for the thoracic region began in the early 1990s with the development of the thoracoscopic sympathectomies, which were developed for patients with hyperhydrosis.[1-3] This building-block procedure eventually advanced to thoracic discectomies,[4,5] and complex corpectomies were undertaken to treat patients with thoracolumbar spinal trauma.[6,7] Although effective, these early procedures had an extremely steep learning curve, were exceptionally time consuming, and were very technologically demanding. If even the most minor portion of the necessary instrumentation was unavailable, it became nearly impossible to proceed with surgery.

Eventually, thoracoscopic and posterolateral approaches became more prevalent. Surgeons could choose to approach a lesion or fracture through an extrapleural,[8] retropleural,[9,10] or costotransversectomy incision.[11,12] Even a straight pediculotomy could be performed.[13,14] Although each of these access methods can be used to great effect, they do have limitations—longer access, dissection, and operative times, each of which exponentially increases the potential for blood loss and the risk of complications. None of these issues is minor, and all have a negative impact on the end result.

With the demand for a better procedure and the advent of truly minimally invasive instrumentation and methods, MAS® (NuVasive, Inc.) thoracotomy—using the extreme lateral interbody fusion (XLIF) thoracic technique—is rapidly gaining in scope and popularity. The MaXcess® Retractor (NuVasive, Inc.) can easily be deployed laterally between any level rib space or spaces T5-6 and below. Using the Retractor effectively creates a mild distraction, and a viable surgical corridor can be opened. This small but efficient dissection allows sufficient access to perform any surgical procedure in the thoracic spine in a minimally invasive fashion.

The thoracic XLIF procedure was adapted from the lumbar XLIF approach. Using similar instrumentation, the lumbar XLIF has been translated into the thoracic XLIF approach with a minimal need for changes in the technique and positioning. This approach can be used for any indication in the thoracic spine. Its advantages include that it provides open and direct visualization of the anatomy without the need to perform a complete thoracotomy. Lung deflation is unnecessary because the Retractors protect the lung. The access system includes an excellent lighting source, and a custom instrumentation package is incorporated, making it unnecessary to obtain specialized extra-long thoracic or extended anterior instruments from an outside provider before operative procedures can be performed.

Surgical Considerations

The XLIF thoracic procedure allows access to the thoracic spine through a direct lateral approach. The major anatomic landmarks to consider when preparing for this technique are the ribs, lung, diaphragm, aorta, and spinal anatomy.

The surgeon may choose to use double-lumen intubation to deflate the ipsilateral lung or may follow the described technique without deflating the lung. In the thoracic region, at least one direct lateral incision is necessary, depending on the number of spinal levels requiring treatment. Surgical access is either between the ribs, or, if necessary, a small section of rib is removed to expand access. Care should be taken to preserve the neurovascular bundle that lies under the inferior aspect of each rib.

Access is established by inserting an initial Dilator directed posteriorly along the interior chest wall and docking it, stopping at the junction of the rib head and vertebral body. After the Dilator and Retractor are placed, the Retractor is opened so the surgeon can visualize the pertinent anatomy; the Retractor is repositioned as needed. Preoperative magnetic resonance imaging (MRI) should be examined to identify the position of the aorta. In the midthoracic spine, especially in patients with scoliosis, the aorta tends to lie at the left lateral aspect of the vertebral body. In such cases, some surgeons approach from the opposite side to ensure that the instruments used to prepare the disc do not pass more than 2 mm through the contralateral anulus.

To successfully complete this technique, the following instruments are required:

- Radiolucent bendable surgical table
- C-arm
- Light source
- MaXcess III Access System
- MaXcess Articulating Arm
- MaXcess Disposable Kit
- XLIF thoracic instruments
- Anterior/lateral general instruments
- Interbody or vertebral body replacement (VBR) implants
- XLP™ Lateral Plating System (NuVasive, Inc.)
- NeuroVision® JJB System (NuVasive, Inc.)
- NeuroVision JJB Disposables

Step 1: Planning, Patient Positioning, and Operating Room Setup

The patient is placed on a bendable surgical table in a direct lateral decubitus position (at a 90-degree angle), with the appropriate side elevated. Depending on the patient's anatomy, the approach may be from the left or right side. Particular care is needed in prescreening imaging to determine the approach side and to avoid major vascular structures. I recommend a preoperative MRI or computed tomography (CT), not so much to assess the pathologic condition, which is confirmed before surgery is scheduled, but to evaluate the internal anatomy surrounding the operative lesion. The surgeon should identify the descending aorta, vena cava, diaphragm, lung fields, bony anatomy, vascular structures, and/or other anatomic variances before beginning the procedure. It is most common to approach from the left side, because in most patients the diaphragm is lower in that location, allowing easier access to the thoracolumbar junction. However, if a lateral vessel is found, especially one that descends into the surgical field when the spine is rotated, it is best to approach from the opposite side.

If the surgery involves lumbar levels (for example, L4-5) as well as thoracic levels, the patient is positioned so that the table break is directly under the greater trochanter. If the surgery includes only thoracic levels, the patient is positioned with the table break under the midsurgical level. The patient is secured with tape at the following locations (Fig. 19-1):

1. Just below the iliac crest
2. Over the thoracic region, ensuring that the tape does not interfere with the surgical exposure of the level of interest
3. From the iliac crest to the knee, then secured to the table
4. From one side of the table to the knee, past the ankle, then secured to the other side of the table

Fluoroscopy is used to verify the location. The surgical table should be flexed to open the space between the ribs (Fig. 19-2, *A*). Once the patient is secured with tape, the table is adjusted so that true anteroposterior images are obtained when the C-arm is horizontal and true lateral images are obtained when the C-arm is vertical (Fig. 19-2, *B* and *C*). These real-time films should provide a three-dimensional picture, allowing the pedicles, endplates, and vertebral bodies to be aligned perfectly with the true orthogonal images (as with lumbar procedures). The table should be adjusted when accessing each level to maintain this relationship. The NeuroVision control unit should be placed opposite the surgeon to provide an unobstructed view (Fig. 19-2, *D*).

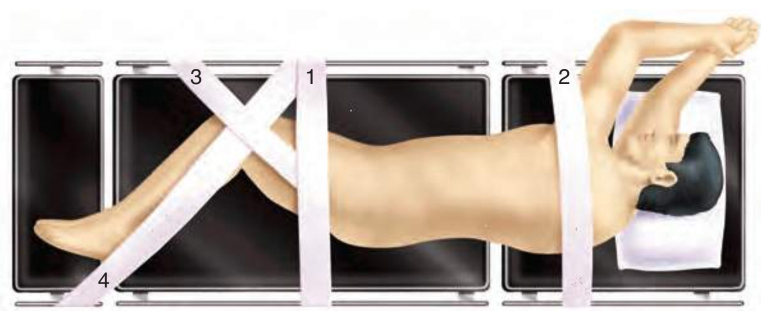

FIG. 19-1 The patient is positioned with the table break under the midsurgical level and secured with tape just below the iliac crest *(1);* over the thoracic region, ensuring that the tape does not interfere with the surgical exposure of the level of interest *(2);* from the iliac crest to the knee, then to the table *(3);* and from one side of the table to the knee, past the ankle, and to the other side of the table *(4).*

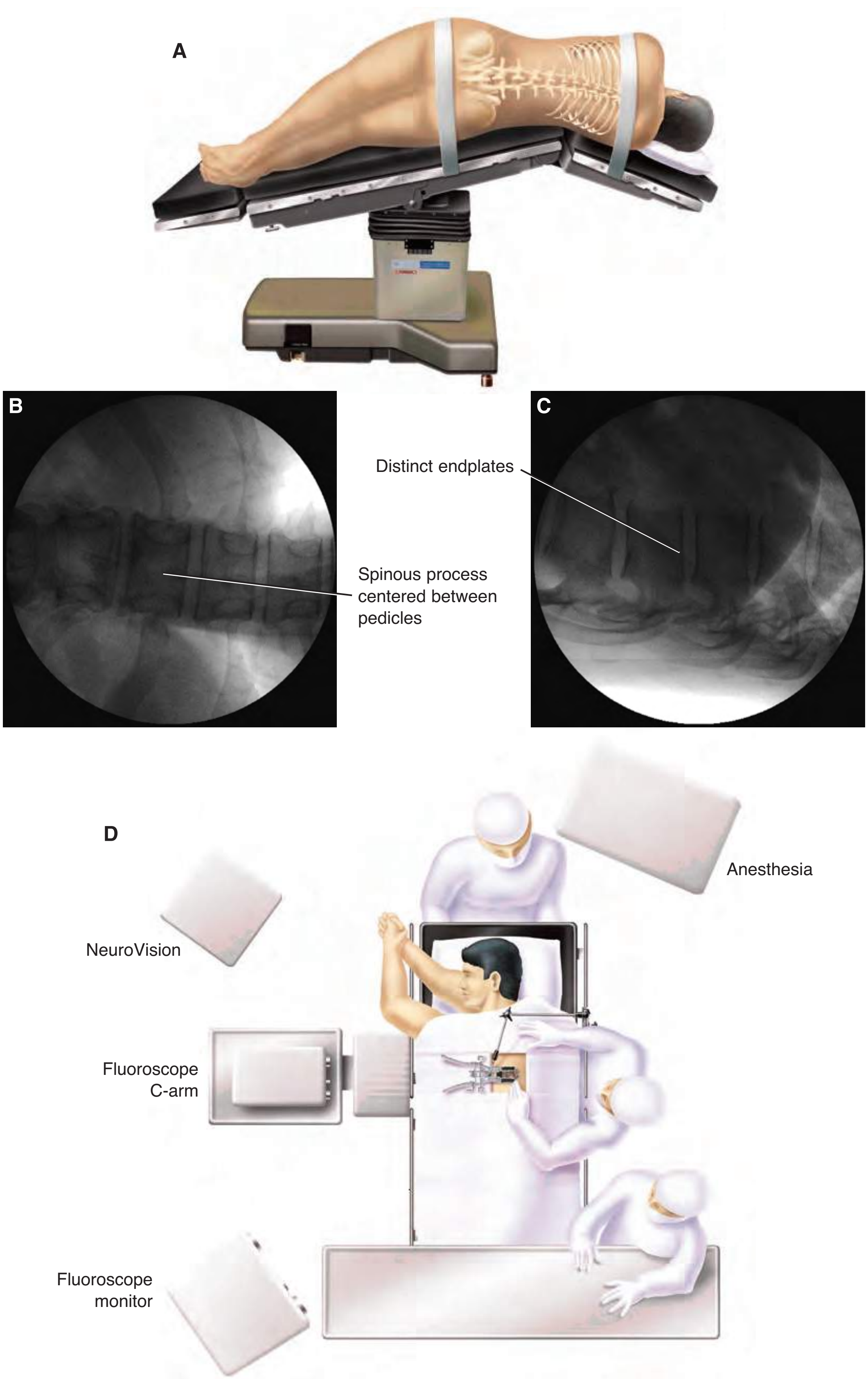

FIG. 19-2 **A,** The surgical table is flexed to open space between the ribs. **B** and **C,** True anteroposterior and lateral images show alignment of the pedicles, endplates, and vertebral bodies. **D,** The operating room setup allows an unobstructed view of the fluoroscopy monitor and NeuroVision screen.

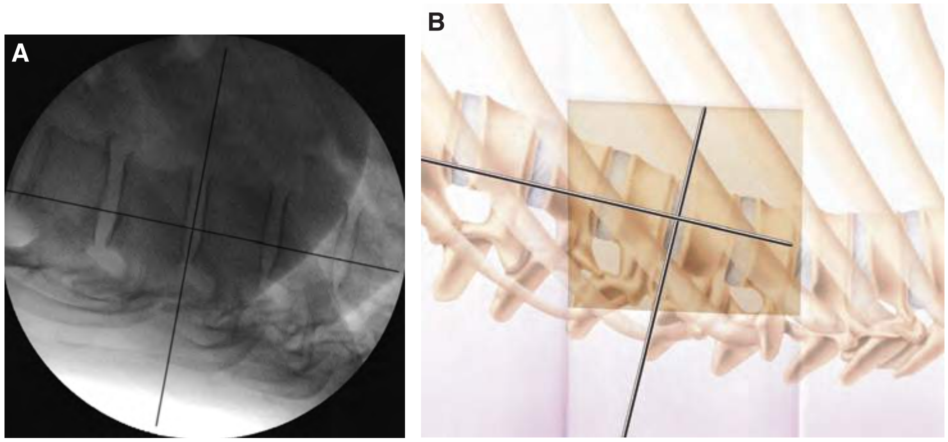

FIG. 19-3 **A,** The disc space is localized using lateral fluoroscopy. **B,** The predetermined access point at the intersection of the posterior and middle thirds of the disc space or vertebra is identified.

Step 2: Anatomic Landmark Identification and Initial Incisions

The surgical site is prepared aseptically, and the disc space is localized using lateral fluoroscopy. It may be necessary to count vertebral levels multiple times from above and below the surgical level to ensure that the correct level is targeted. When the correct level is aligned and identified, a single mark is made over the predetermined access point to the site of pathology at the intersection of the posterior and middle thirds of the disc space or vertebra (Fig. 19-3).

Step 3: Thoracic Access

An incision is made parallel to the ribs at the skin marking (Fig. 19-4, *A*). Dissection is performed through the subcutaneous tissue down to the ribs or intercostal space (Fig. 19-4, *B*). Two techniques are possible, depending on the desired size of exposure:

1. For a single-level discectomy, the rib-spreading technique is most commonly used. The standard technique involves dissection between the ribs, through the intercostal muscles, and down to the pleura. Pleural access is achieved by blunt hemostat dissection (Fig. 19-5).
2. As an alternative approach—with either a multilevel discectomy or corpectomy or when better visualization is necessary—a small portion of the rib (approximately 3 to 4 cm) can easily be resected at the beginning of the procedure. An incision is angled toward the rib with the midsection in the position of the access site incision. Thus the rib is exposed, identified, and stripped of the neurovascular bundle from su-

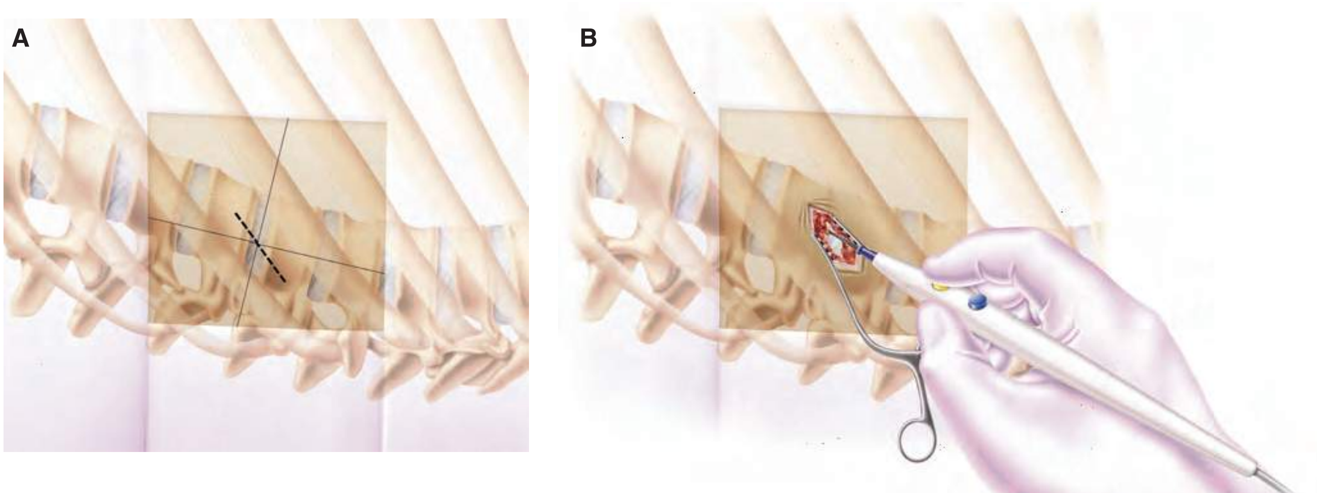

FIG. 19-4 **A,** An incision is made parallel to the ribs at the skin marking. **B,** Dissection is performed through the subcutaneous tissue down to the ribs or intercostal space.

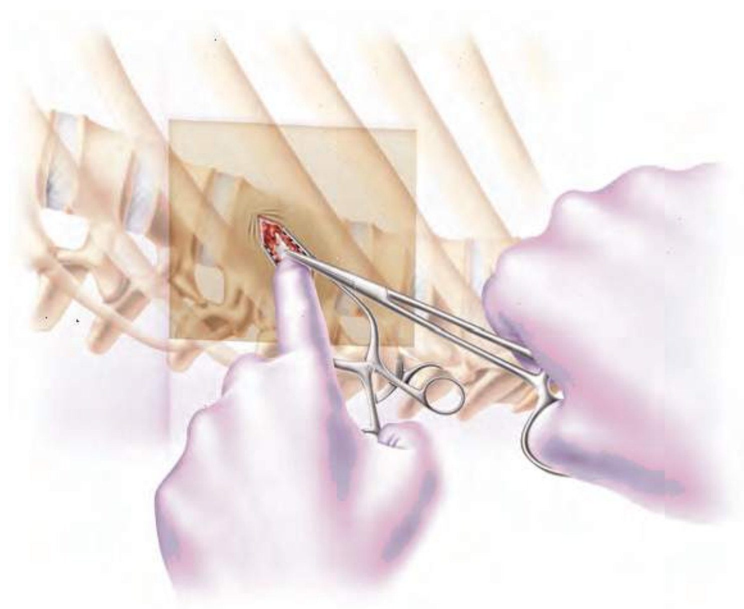

FIG. 19-5 In a single-level discectomy, the standard technique involves dissection between the ribs, through the intercostal muscles down to the pleura, which is then accessed by blunt hemostat dissection.

perior to inferior along its undersurface. A Rib Cutter, Kerrison, and/or Drill can be used to remove a portion of the chosen rib, which may be discarded or saved for bone graft material. With the rib dissection complete, a self-retaining Retractor is positioned, and after blunt or sharp dissection, the parietal pleura is identified and incised, and steps identical to those in the single-level procedure are completed. From this point, the remaining steps are the same for single-level and multilevel techniques.

Once the parietal pleura is incised, the surgeon uses an index finger to enter the pleural space and palpate the lung or diaphragm, displacing the structures anteriorly (Fig. 19-6, *A*). At this point, the lung can be seen in the field. When the chest wall is opened, a small diminution of lung volume caused by the loss of the internal vacuum occurs; this is just enough to allow safe placement of the Retractors without totally deflating the lung.

The initial (black) Dilator is introduced into the thoracic cavity and passed posteriorly along the ribs, down to the intersection of the rib head and the spine (Fig. 19-6, *B* and *C*).

The Retractor is placed in the cavity and the area is carefully examined for adhesions and other obstructions. This procedure is not typically recommended for or attempted in patients undergoing a revision procedure, who may have significant scarring in the access area. Once the absence of adhesions and obstructions is confirmed, a Dilator is placed laterally down the approach corridor.

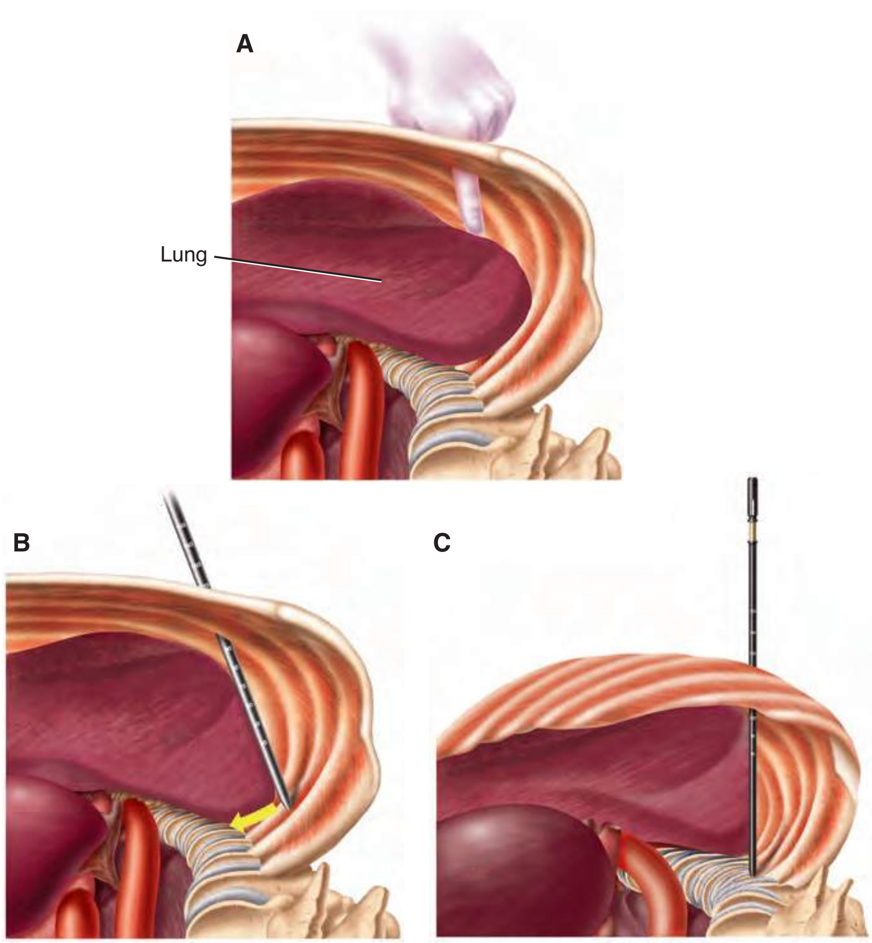

FIG. 19-6 **A,** Once the parietal pleura is incised, the index finger is used to enter the pleural space and palpate the lung or diaphragm and to displace the structures anteriorly. **B** and **C,** The initial (black) Dilator is introduced into the thoracic cavity and passed posteriorly along the ribs down to the intersection of the rib head and the spine.

Once the initial Dilator is on the spine, its position is verified with fluoroscopy. A lateral image is used to confirm that the Dilator is positioned in the posterior third of the disc space and parallel to the disc (Fig. 19-7, *A*). A cross-table anteroposterior image should confirm that the Dilator is positioned on, and in the plane of, the disc space (Fig. 19-7, *B*). Depth markings on the Dilator indicate the size of the appropriate length of the Blades to be attached to the MaXcess Access Driver (Fig. 19-8, *A*). The next two Dilators (magenta and blue) are then passed over the initial Dilator and down to the spine (Fig. 19-8, *B*).

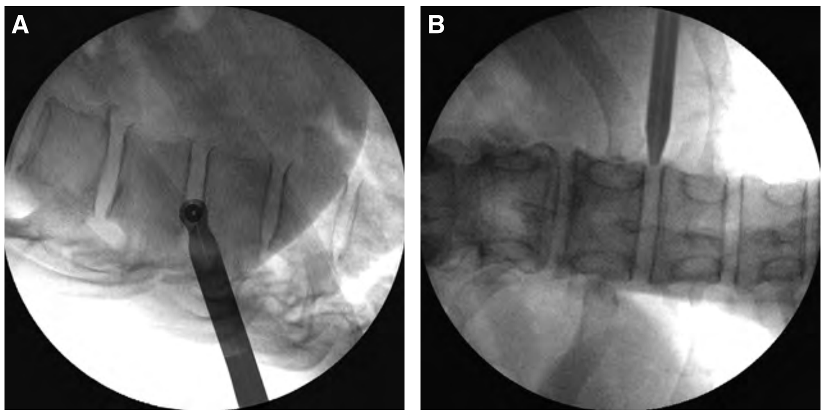

FIG. 19-7 **A,** A lateral image confirms that the Dilator is positioned in the posterior third of the disc space, parallel to the disc. **B,** A cross-table anteroposterior image confirms that the Dilator is placed on and in the plane of the disc space.

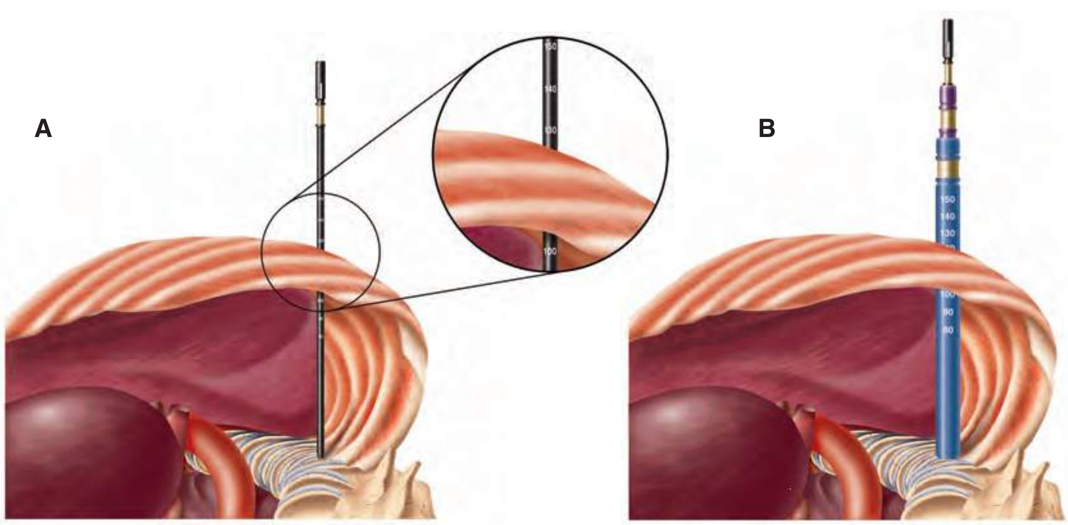

FIG. 19-8 **A,** Depth markings on the Dilator indicate the appropriate length of Blades to be attached to the MaXcess Access Driver. **B,** The next two Dilators, magenta and blue, are passed over the initial Dilator down to the spine.

TRANSITIONAL LEVEL (T12-L1) CONSIDERATIONS

Pleural access to the T12-L1 disc space and above may be established through the transthoracic approach, as previously described (Fig. 19-9, *A*). However, the T12-L1 level may also be accessed by passing between the ribs, through the diaphragmatic attachment at the ribs, and into the retroperitoneal space (Fig. 19-9, *B* and *C*). This method is most commonly employed when lumbar levels are also addressed. In such a scenario, the index finger is passed through the posterolateral incision made in the lumbar XLIF technique and into the retroperitoneal space to guide the initial Dilator down to the spine.

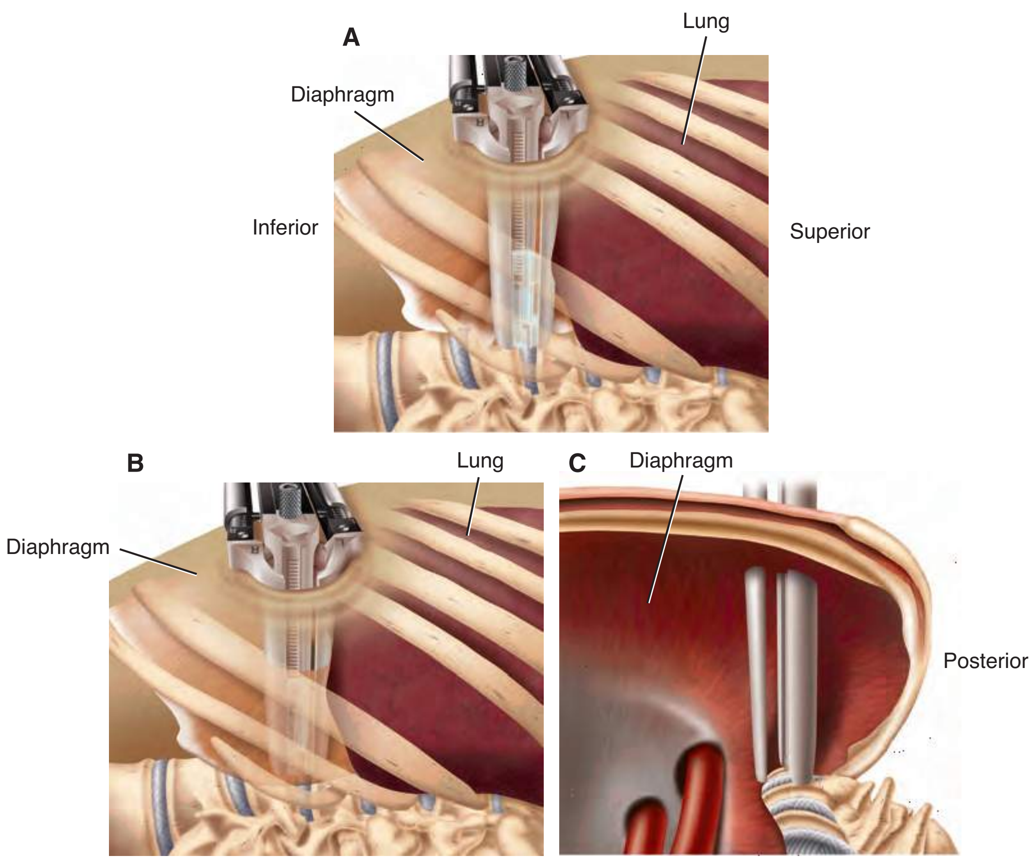

FIG. 19-9 **A,** Pleural access to the T12-L1 disc space and above may be established through the transthoracic approach. **B** and **C,** The T12-L1 level may also be accessed by passing between the ribs, through the diaphragmatic attachment at the ribs, and into the retroperitoneal space.

NEUROVISION MEP MONITORING

NeuroVision offers transcranial motor evoked potential (TcMEP) monitoring with clinically based alarm criteria and an easy-to-interpret user interface (Fig. 19-10, *A*). The NeuroVision MEP system provides unsurpassed efficiency in monitoring the safety and function of the descending motor pathways of the spinal cord, and it delivers critical patient information with more clarity than previous instruments.

MEP Manual Mode

MEP Manual mode provides a rapid and reliable method of confirming motor functionality throughout the procedure and includes the following features (Fig. 19-10, *B*):

- The system allows manual adjustment of the stimulation level for greater flexibility and speed.
- The interface correlates the amount of electrical stimulation with highly visible threshold response indicators of green or red, corresponding to muscle activity.

Working with the NeuroVision MEP Manual mode begins by setting the stimulation output dial to the desired level (in milliamperes). As the patient responds to this stimulation, the system communicates the presence or absence of a muscle response to the operating room staff: a green indicator lights when muscle activity is detected and with a red indicator when no muscle activity is found.

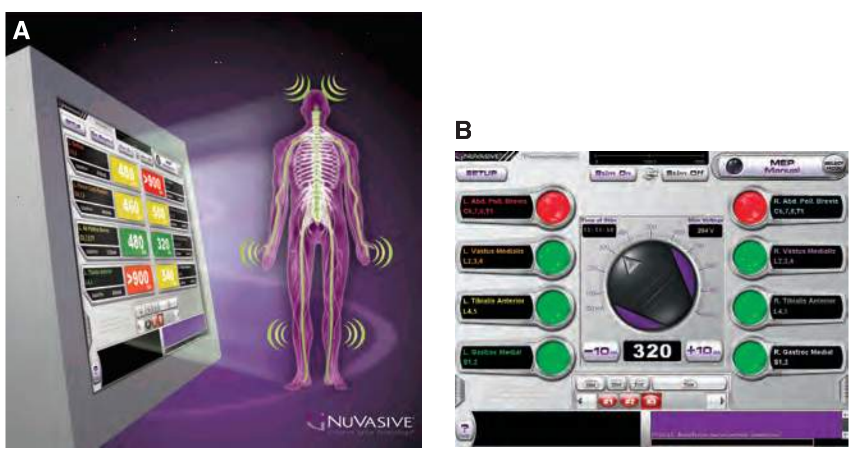

FIG. 19-10 **A,** NeuroVision provides transcranial motor evoked potential (TcMEP) monitoring with clinically based alarm criteria and an easy-to-interpret user interface. **B,** MEP Manual mode provides a rapid and reliable method of confirming motor functionality throughout the case.

Continued

C

FIG. 19-10, cont'd **C,** MEP Automatic mode provides clinically determined alarm criteria, rapid response thresholds, and easy-to-interpret results.

MEP Automatic Mode

NeuroVision MEP Automatic mode provides clinically determined alarm criteria and a simple, explicit interface (Fig. 19-10, *C*). The following features make this technology a valuable tool:

- Automation delivers threshold criteria that allow precise, repeatable coupling of the stimulation and response.
- Threshold responses can be quickly identified for multiple responding myotomes.
- Data are communicated at a higher speed than can be obtained manually.
- Changes in thresholds can be more closely tracked over time.
- All monitoring results are automatically recorded to a patient report.
- The threshold determination algorithm delivers the lowest stimulation required to elicit a response, maximizing patient safety.

Step 4: Exposure

The Access Driver is introduced over the third Dilator, with the handles pointing anteriorly (Fig. 19-11, *A*). Cross-table anteroposterior fluoroscopy is used to confirm the correct position of the Access Driver Blades on the spine and to ensure that the Blades are parallel to the disc space (Fig. 19-11, *B* and *C*).

With the Retractor Blades in position, an Articulating Arm is connected to the posterior arm attachment point (Fig. 19-11, *D*), which affixes the body of the Access Driver to the table. When the Retractor is opened, the center Blade moves anteriorly to retract the lung and/or diaphragm and expose the spine (Fig. 19-11, *E*). The Retractor can be turned slightly so that the spreading is done not against the ribs, but in the superior and inferior planes for a single level. With the Retractor in place, the surrounding structures are identified.

Gentle intercostal distraction is performed, and clear plastic Shims are placed in the single center Blade and in the cephalocaudal Blades (Fig. 19-11, *F*). These can be doubled toward

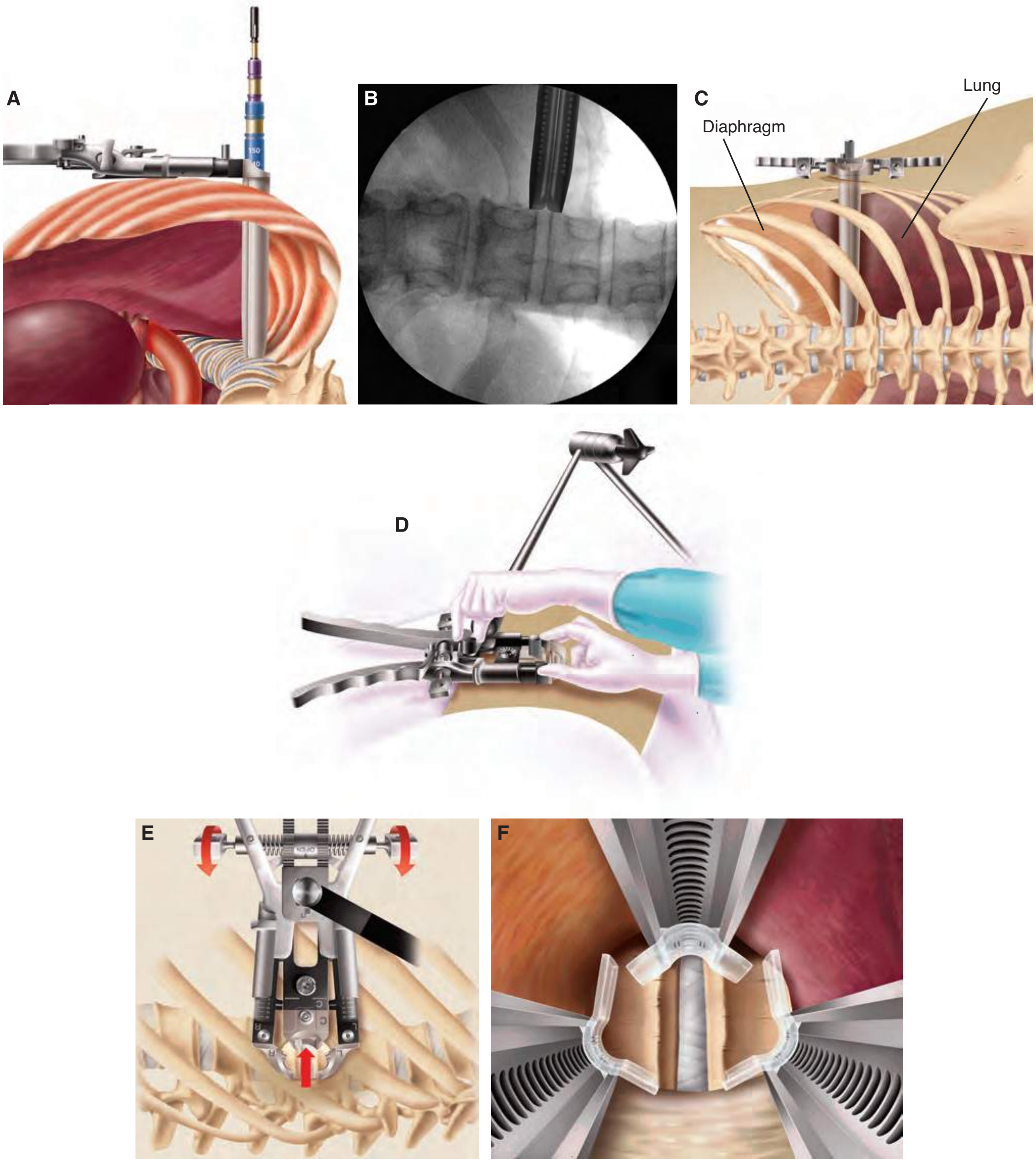

FIG. 19-11 **A,** The Access Driver is introduced over the third Dilator, with the handles pointing anteriorly. **B** and **C,** Cross-table anteroposterior fluoroscopy is used to confirm the correct position of the Access Driver Blades on the spine and to ensure that the Blades are parallel to the disc space. **D,** With the Retractor Blades in position, an Articulating Arm is attached to the posterior arm attachment site. **E,** When the Retractor is opened, the center Blade moves anteriorly to retract the lung and/or diaphragm and expose the spine. **F,** The Retractor is placed, gentle intercostal distraction is performed, and clear plastic Shims are placed in the single center Blade and in the cephalocaudal Blades.

the Retractor opening if the lung and/or diaphragm extend into the operative field. A lap sponge can be placed to further retract the lung if necessary.

In this way, access can be obtained from L1-2 to approximately the T5-6 level. Inferiorly, the diaphragm extends over that area, allowing access to the inferior levels from the retroperitoneal space. Superiorly, the intercostal spaces become smaller, which, along with the location of the scapula and the angle of the chest, makes access above the T5-6 location difficult.

If necessary, one or both of the cephalocaudal Blades can be rotated to expand the exposure in either direction to permit optimal access to the site of pathology. Care should be taken when expanding the Blades near the midvertebral body to minimize the risk of injury to segmental vessels.

Step 5: Anulotomy and Disc Space Preparation

The parietal pleura covers the surface of the spine and is incised to gain access to the disc space. An anulotomy approximately 16 mm in length (anterior to posterior) is created with an Anulotomy Knife. A Cobb Elevator may be passed along both endplates to release the disc and cartilage from the subchondral bone. The surgeon must be careful to avoid damaging structures deep to the contralateral anulus, as indicated on the preoperative MRI. Pituitaries, Curettes, Disc Cutters, Endplate Scrapers, and other disc preparation instruments can be used to thoroughly evacuate the disc and prepare the endplates for fusion (Fig. 19-12).

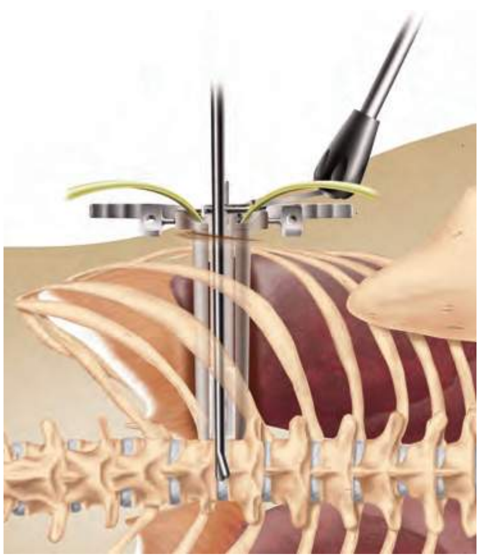

FIG. 19-12 Pituitaries, Curettes, Disc Cutters, Endplate Scrapers, and other disc preparation instruments are used to thoroughly evacuate the disc and prepare the endplates for fusion.

Step 6: Implant Sizing and Placement

Paddle Sizers may be used to distract the space, and the appropriately sized Trial is gauged. Under anteroposterior fluoroscopy, the Trial is gently impacted into the space until the distal end reaches the contralateral margin of the disc space. The proper anteroposterior position is verified using lateral fluoroscopy. Sequentially larger Trials are used until the desired fit and placement are achieved.

The corresponding implant is selected, filled with graft material, and gently impacted into the space while anteroposterior fluoroscopic monitoring is used to check placement. The ideally placed implant is centered across the space from a mediolateral perspective and in the center of the space from an anteroposterior perspective (Fig. 19-13, *A*). A segmental lateral Plate (XLP) can be placed to add stability to the construct as needed (Fig. 19-13, *B*).

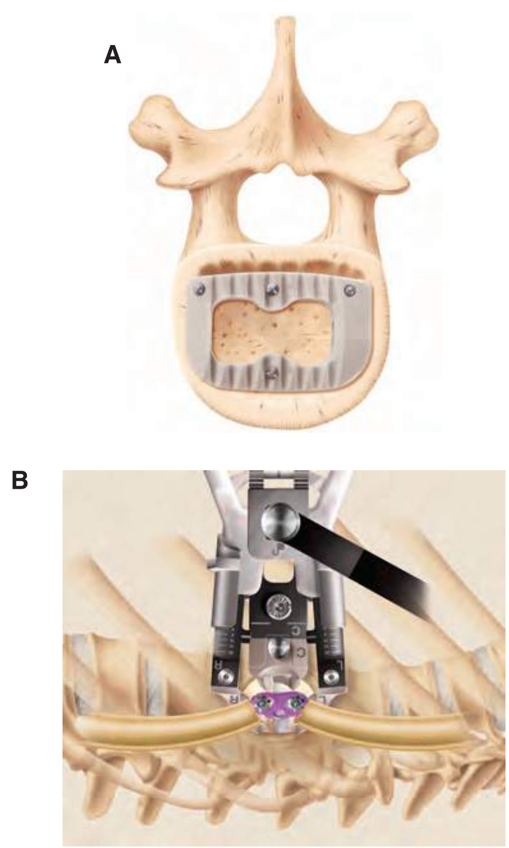

FIG. 19-13 **A,** The ideally placed implant is centered across the disc space from a medial/lateral perspective and in the center of the space from an anterior/posterior perspective. **B,** A segmental lateral Plate (XLP) can be used to add stability to the construct as needed.

Step 7: Closure

When the procedure is completed, the Retractor is removed under direct visualization to verify that there is no significant bleeding. A chest tube may be placed and the wound closed by layer. Alternatively, a red rubber catheter can be inserted and the pleural space aspirated with suction to remove air from the pleural cavity as the lung is inflated by the anesthesiologist. A chest radiograph should be obtained postoperatively. The skin is closed using standard subcuticular suture.

Indication-Specific Techniques

CORPECTOMY

Corpectomy is the most common procedure in the thoracic spine. In the inferiormost aspect of the dissection cavity, an L1 or a T12 corpectomy can easily be performed to treat a thoracolumbar fracture. In this location, when the Retractor is open, the superior leaflets of the diaphragm often extend over the vertebral body, obscuring its posterior and anterior aspects. With fluoroscopic guidance, the vertebral body is mapped out on the skin and over the course of the diaphragm in that location. The surgeon carefully continues the dissection down to the disc space at the first level within the midportion of the disc. Straying between the disc spaces will bring the dissection down on top of the segmental vessels, which often cannot be seen through the muscle of the diaphragm.

With the vertebral body mapped out over the diaphragm muscles, the muscle can be incised with a Bovie electrosurgical unit over the disc space. Quite often, an ultrasonic scalpel and/or a Bovie can be used to extend this incision superiorly over the entire body of L1 and/or T12. In these locations the vessels and neurovascular bundle are clipped and/or ligated using bipolar coagulation, as needed. The intervening vessels are controlled with a careful dissection. The corpectomy is completed and the superior half of the body of L2 can be easily identified for placement of inferior lateral instrumentation; alternatively, percutaneous pedicle screws can be placed posteriorly.

DISCECTOMY/FUSION

The second most common procedure in the midthoracic spine is discectomy. Herniation can occur anywhere from T5-6 to T11-12, but it occurs most commonly in the midthoracic curve at approximately T8-9 to T9-10. The diaphragm does not overlie this area, and the extent of the vertebral body is easily seen. Starting at approximately T10 and moving superiorly, the rib head covers the posterior half of the disc space and must be removed to adequately expose the posterior half and to decompress the dural sleeve. The rib head is removed quite simply by cutting the costotransverse ligaments and the remaining attachments with a sharp Cobb Curette. The rib is removed superiorly and taken out as a single piece. Alternatively, a high-speed Drill is used to remove the portion of rib. With the rib head removed, both pedicles and the foramen are easily identified, and a complete discectomy can be performed. Commonly, the disc is decompressed from the midportion to the anterior portion of the body, and then the space created allows the disc to be delivered anteriorly by using an angled Curette. In the midportion of the body in a large, barrel-chested person, the Retractors need to be as long as possible to perform this dissection. With the rib head removed, the discectomy is performed at the primary site, and, if necessary, the procedure is repeated at each additional location. Intervertebral fusion cages, bone grafts, and lateral Plates may be used as fixation requirements demand.

Conclusion

The minimally invasive XLIF thoracic procedure offers an excellent alternative to an open thoracotomy or a video-assisted thoracoscopic discectomy. The lung is easily controlled without deflation, and access all the way to lower portions of the spine is possible, using the diaphragm as a boundary. If necessary, a rib section can be removed for greater access at a single level or for multiple-level procedures. Alternatively, the intervals between the ribs can be accessed without removing a rib section. In addition, the Retractor is easily adapted to multiple thoracic pathologies, and the complications and difficulties of an open procedure are avoided. Closure is performed in the standard, layered manner and a chest tube can be placed to allow air, blood, and other debris to be removed from the pleural cavity.

Through a minimal corridor, complex corpectomies can be performed at most levels, allowing an approach for elective decompressive procedures and traumatic repair. We have successfully used this method to treat patients with traumatic spine injuries, metastatic tumor disease, thoracic disc disease, and to correct deformities. We have encountered no significant postoperative pulmonary problems, because we avoid dropping the lung during the procedure. We have also seen no evidence of pulmonary contusions. The skin can be closed and the remainder of the procedure conducted in the normal fashion, and a chest tube can be placed to release air from the cavity or to drain blood and other debris, if necessary. The Retractor is easily adaptable to the treatments of various thoracic pathologic conditions and avoids the complications and difficulties associated with an open procedure.

Thoracic XLIF surgery encompasses all of the positive aspects of a standard open procedure, with fewer significant risks. As this technology continues to develop, it is expected to become the preferred technique.

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