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Lateral Lumbar Interbody Fusion

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Overview

Conditions such as spinal deformity, degenerative disk disease, adjacent segment disease, low-grade spondylolisthesis, spinal oncology, and traumatic deformity or instability are examples of conditions that may require instrumented spinal fusion. There are a variety of approaches to the spine, and these include anterior, posterior, and combined approaches. The choice of approach is largely dependent on the nature and location of the spinal pathology, surgeon preference and experience, and patient medical comorbidities. The lateral approach to the spine uses a retroperitoneal dissection to access the lateral aspect of the vertebral body or intervertebral disk. The minimally invasive lateral transpsoas approach for spinal fusion, also known as *direct lateral interbody fusion* (DLIF) or *extreme lateral interbody fusion* (XLIF), is designed to provide lateral access to the intervertebral disk and lateral vertebral body. This technique involves a retroperitoneal transpsoas dissection by splitting the fibers of the psoas muscle body to minimize the approach-related morbidity of an open lateral approach.

Pimenta[1] first introduced the idea of a lateral approach to the anterior spine in 2001, and Ozgur[2] later popularized the lateral transpsoas approach in what he called the "extreme lateral interbody fusion." Although this technique has been expanded to include performing a corpectomy through a minimally invasive transpsoas approach,[3] the focus of this chapter will be on lateral interbody fusion. The biomechanical advantages of using an interbody fusion to augment the anterior and middle column have been demonstrated and take advantage of the increased load sharing of the vertebral body compared with the posterior column.[4-6] Furthermore, the use of the DLIF approach allows for indirect neural decompression without exposing the thecal sac or the nerve roots. Likewise, the transpsoas approach does not require mobilization of the great vessels, nor does it carry the risk of retrograde ejaculation associated with a transabdominal retroperitoneal approach for anterior lumbar interbody fusion (ALIF).

The goal of the lateral transpsoas approach is to deliver a large interbody graft, while minimizing blood loss, and to reduce approach-related morbidity associated with larger lateral approaches. One of the greatest risks of the lateral transpsoas approach is injury to the lumbar plexus and genitofemoral nerve during the approach and dissection through the psoas muscle.[7-10] The risk of neural injury can be minimized with the use of multimodal neuromonitoring and appropriate radiographic guidance.

Indications

The lateral transpsoas approach can be used for any condition that requires access to the interbody space from T12–L1 through L4–L5 (Fig. 47-1). This approach cannot be used at L5–S1 because of the location of the iliac crest, which obstructs direct lateral access. Likewise, the lumbar plexus courses more anteriorly at the more caudal levels of the lumbar spine, and the iliac vasculature courses more laterally at the more caudal levels; thus both are at great risk. Oftentimes, and particularly in men, the L4–L5 disk space is also not accessible because of the size of the iliac crest. In the setting of a lumbar scoliosis, the more caudal levels may be accessible only on the convexity of the curvature, because the approach angle is more rostral (Fig. 47-2). Acosta and colleagues[11] showed that a large interbody graft delivered through a lateral transpsoas approach can provide some degree of coronal correction and focal restoration of sagittal alignment. Although the lateral transpsoas approach can have many applications, the ideal candidate is typically a patient with focal coronal imbalance or disk degeneration who does not require direct neural decompression. For example, a patient with adjacent segment degeneration above a prior posterolateral fusion may benefit from a lateral transpsoas interbody fusion (LTIF), because the interbody can restore some disk height and can supplement extension of the posterior instrumented fusion (Figs. 47-3 and 47-4). The posterior elements do not need to be disrupted, and the challenges of posterior revision surgery can be avoided; however, the patient must have favorable anatomy in terms of access to the intervertebral space and the working channel between the twelfth rib, and the iliac crest must be such that the procedure can be done safely and effectively.

Contraindications

There are a few technical/anatomic aspects that preclude the use of a lateral transpsoas approach in certain circumstances. For example, the lumbar plexus courses progressively more anteriorly at the more caudal levels. Thus despite the use of neuromonitoring, the risk of nerve damage at the level of L5–S1 is significant, and the lateral transpsoas approach should be avoided. Likewise, the iliac crest can often block direct lateral access to L5–S1.

Contraindications to the use of LTIF without posterior column support center on the biomechanical factors at a given level. Stand-alone LTIF should not be used at a level

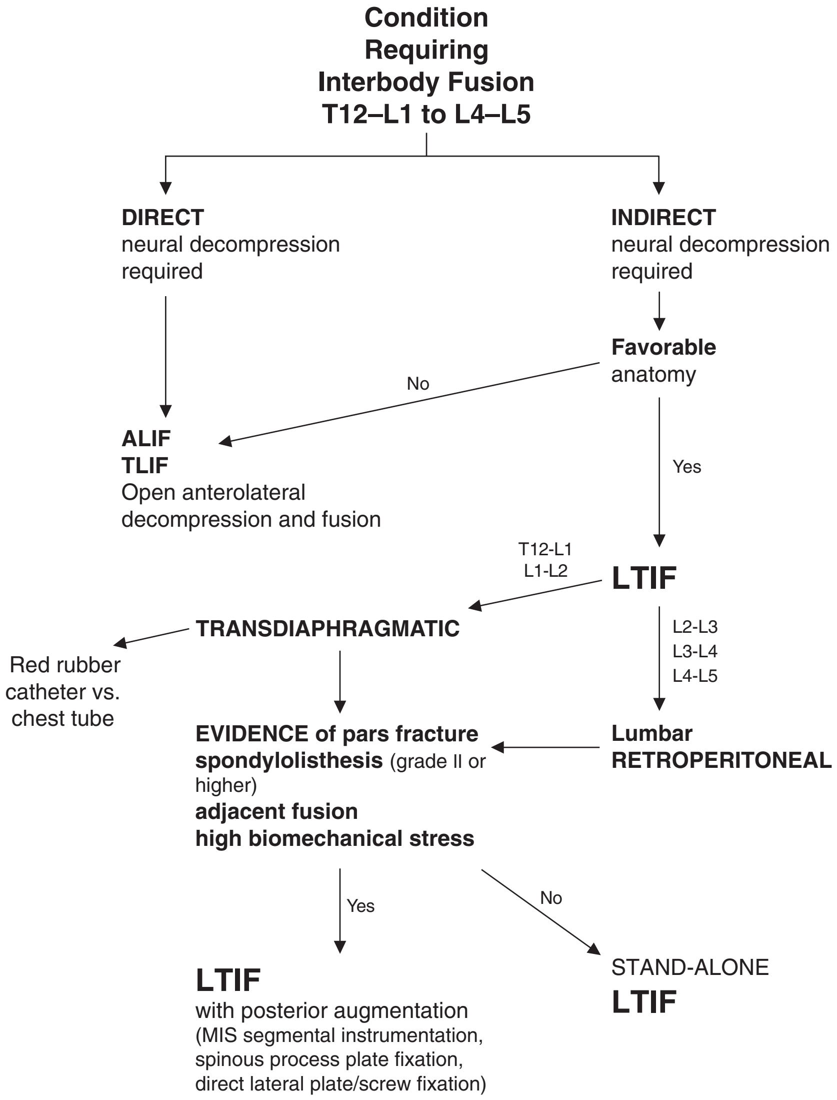

Figure 47-1 Algorithm for the use of lateral transpsoas interbody fusion. *ALIF,* anterior lumbar interbody fusion; *LTIF,* lateral transpsoas interbody fusion; *MIS,* minimally invasive surgery; *TLIF,* transforaminal lumbar interbody fusion.

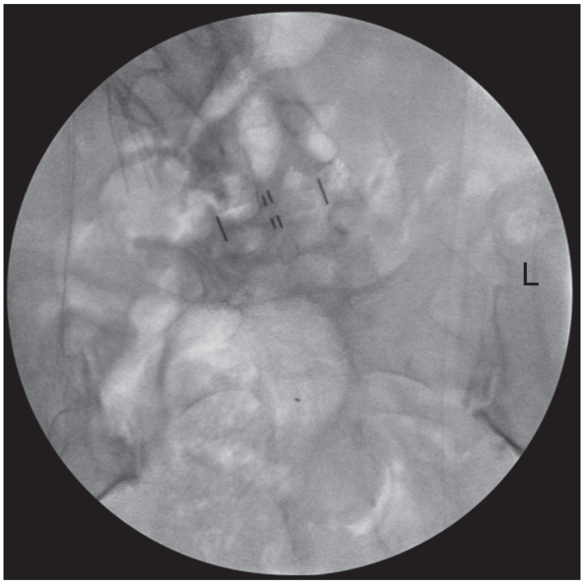

Figure 47-2 Intraoperative anteroposterior fluoroscopy image demonstrates placement of direct lateral interbody fusion graft from the convexity of the lumbar scoliosis. *L,* the patient's left side.

of high biomechanical stress, such as adjacent to a previous fusion or with a high-grade spondylolisthesis. In the setting of increased segmental stress, such as a pars fracture or at the apex of a kyphosis or scoliosis, posterior column support should be strongly considered. Posterior stabilization is often necessary to increase the stability of the construct, because lateral fixation has been not been shown to add construct stiffness compared with lateral interbody fusion alone.[12] The lateral transpsoas interbody approach is also contraindicated in patients who have undergone prior retroperitoneal surgery or those with a retroperitoneal abscess. Preoperative imaging may reveal abnormal vascular anatomy or an abnormally large psoas muscle that prevents safe access to the lateral spine. Any patient who requires direct neural decompression is also a poor candidate for a lateral transpsoas approach, because the lateral interbody fusion provides only indirect decompression with restoration of disk height and ligamentotaxis. Although LTIF has been shown to improve focal coronal alignment, it has not been shown to provide meaningful global sagittal correction.

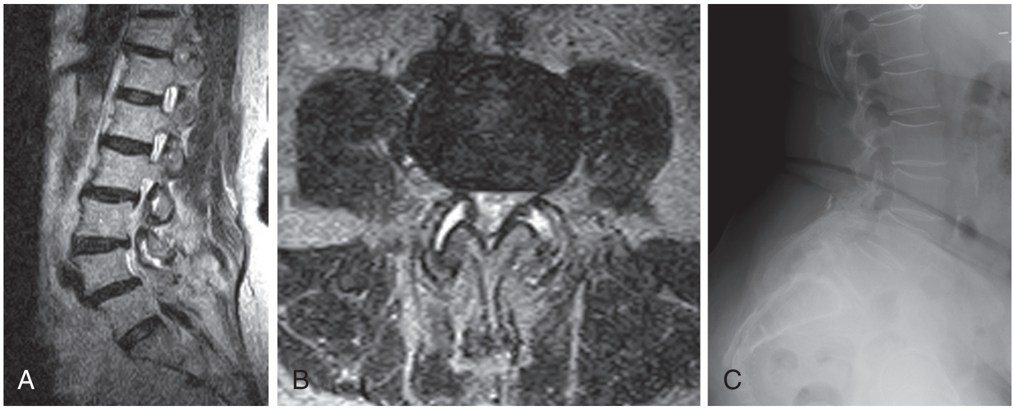

Figure 47-3 65-year-old woman with prior L4–L5 laminectomy and posterolateral fusion who developed adjacent segment degeneration. **A,** T2-weighted sagittal magnetic resonance imaging (MRI) demonstrates grade 1 spondylolisthesis and degenerative disk disease. **B,** T2-weighted axial MRI demonstrates significant facet degeneration and hypertrophy. **C,** Lateral standing radiograph demonstrates grade 1 L3–L4 spondylolisthesis and end plate changes.

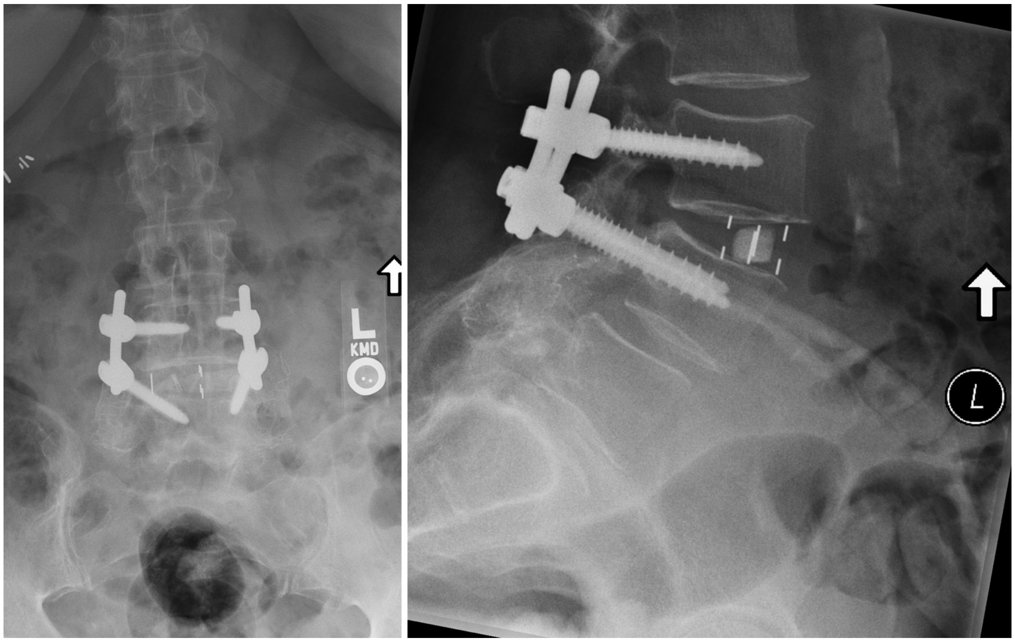

Figure 47-4 Postoperative anteroposterior (*left*) and lateral (*right*) radiographs following L3–L4 direct lateral interbody fusion and placement of segmental instrumentation through a minimally invasive approach.

Preoperative Planning

Careful study of preoperative imaging is essential when planning LTIF. The patient's anatomy must be closely evaluated to ensure that the disk space can be accessed safely and effectively. For example, a large psoas muscle, seen best on magnetic resonance imaging (MRI; Fig. 47-5) may prevent a transpsoas dissection. Likewise, the anatomic location of the aorta, inferior vena cava, and iliac vessels must be completely visualized to minimize the risk of vascular injury. When planning an approach to the upper lumbar spine, the eleventh or twelfth ribs may block direct access, thus necessitating an intercostal approach or a rib resection. The height of the iliac crest must also be taken into consideration, because it can block not only L5–S1 but sometimes L4–L5 also.

When performing an LTIF in the setting of lumbar scoliosis, the disk space can be accessed from either the concavity or the convexity of the curve. The advantages of approaching from the convexity include the fact that the lateral access of the spine is closer to the abdominal surface, thus minimizing the working depth through the tube. Likewise, the disk space is often widened on the convex side, making entering the disk space easier. Conversely, although the concavity is deeper, it allows the surgeon to reach multiple levels through a single incision. However, the lateral aspect of the disk space is often more collapsed on the concavity, making access to the disk space more difficult. The lumbar plexus also runs more anteriorly on the concavity, increasing the risk of nerve injury during the approach.

The approach to the T12–L1 and L1–L2 disk spaces is transdiaphragmatic. Thus it is important to plan for an intrathoracic exposure. Most often taking down the diaphragm does not necessitate the placement of a chest tube postoperatively, unless the pleura or lung parenchyma has been violated. It is important to close the diaphragm in layers completely, which can be done over a red rubber catheter, draining the intrathoracic space. After the final suture is placed, a Valsalva maneuver is performed, the red rubber catheter is removed, and the suture is tied down securely. Having support from colleagues in thoracic surgery is essential in the event of a complication.

Intraoperative use of fluoroscopy is essential when performing LTIF, and it is important to ensure that the appropriate radiology staff are available during the case. Intraoperative stereotactic navigation is an alternative to fluoroscopic guidance. The use of fluoroscopy provides significant radiation exposure; to minimize that exposure, stereotactic navigation can be used. However, the advantage of fluoroscopy is that it provides real-time anatomic assessment. Stereotactic navigation only provides a static image of the anatomy. As the diskectomy is performed, or in the setting of placing multiple interbodies, the navigation registration can become inaccurate. Likewise, the reference frame for stereotactic navigation must remain undisturbed throughout the case, or the navigation will become inaccurate.

Figure 47-5 T2-weighted MRI in the axial plane demonstrates a large psoas muscle that prevents safe access to the lateral spine.

Addressing the risks and benefits of LTIF with the patient before surgery is essential. The greatest risk is injury to the lumbar plexus. As many as 36% of patients will have ipsilateral iliopsoas weakness postoperatively, and the most commonly affected levels are L3–L4 and L4–L5.[13] Moller and colleagues[13] have also reported that 84% of those with subjective ipsilateral iliopsoas weakness improved completely by 6 months postoperatively. The etiology of such weakness is multifactorial in nature and includes dissection through the psoas muscle, edema, nerve stretch, and placement of the tubular retractors through the muscle down to the level of the lateral annulus. This risk can be minimized by docking the tubular retractor superficial to the psoas muscle and performing careful intramuscular dissection guided by neuromonitoring and direct visualization of the genitofemoral nerve.

Operative Technique

Positioning is a key component to performing a safe and successful LTIF. The patient is placed in the lateral decubitus position with the hip, not the waist, over the break in the operating table (Fig. 47-6). A beanbag can be used to help maintain position. The lateral aspect of the bottom knee must be thoroughly padded to reduce the risk of peroneal nerve compression. Likewise, the top leg should be bent as much as possible to relax the psoas muscle to aid in dissection. A pillow should be placed between the patient's legs, an axillary roll should be placed along the downside lateral chest wall, and all bony prominences should be fully padded to reduce the risk of additional injury. The bed should then be flexed to help open the lateral disk space on the side of approach. This also increases the working space between the twelfth rib and the iliac crest. Finally, the patient must be well secured to the bed. During the case, the fluoroscopy C-arm will remain in the neutral position in both the anterior-posterior (AP) and lateral planes, and thus the patient and bed can be manipulated to obtain true AP and lateral images. The patient must also be placed in a position on the bed such that the C-arm can freely pass beneath the table.

Before draping the patient, the C-arm gantry is placed at zero degrees (Fig. 47-7) and will remain there for the duration of the case. The patient will be moved with the bed to

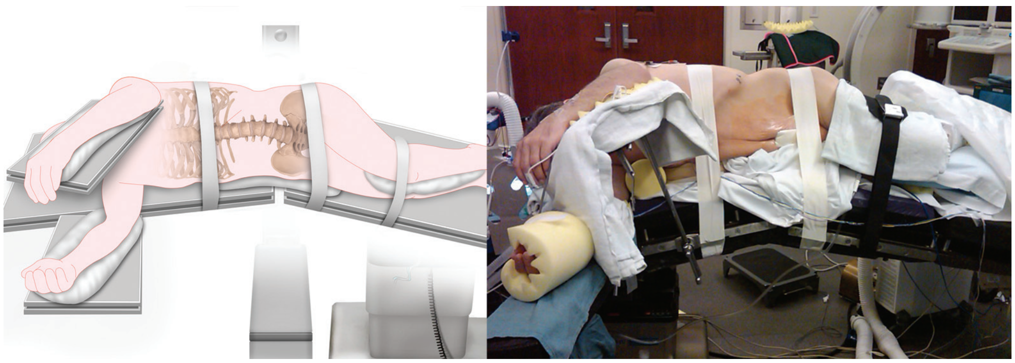

Figure 47-6 The patient is placed in the lateral decubitus position with the top leg flexed in order to relax the ipsilateral psoas muscle. The patient must be secured in place thoroughly using tape, padding, beanbags, or other methods.

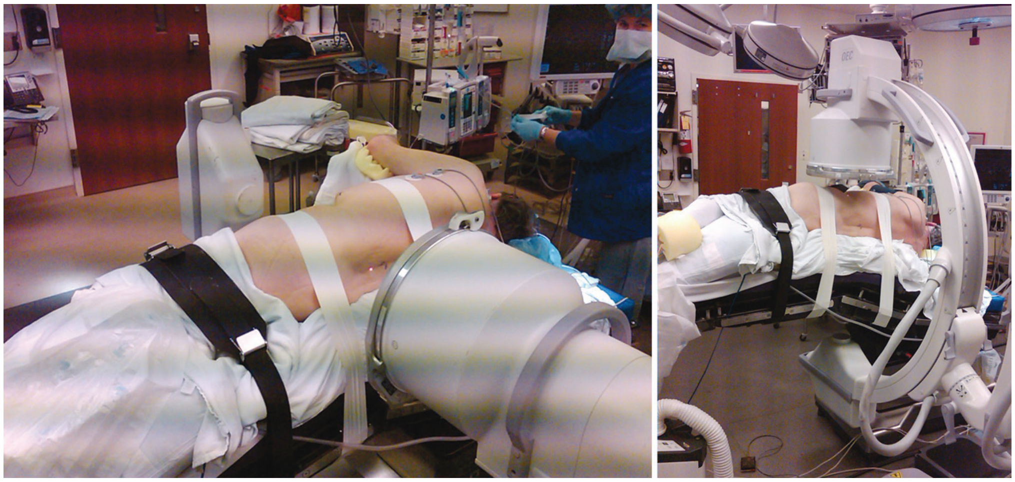

Figure 47-7 The zero-degree gantry of the C-arm.

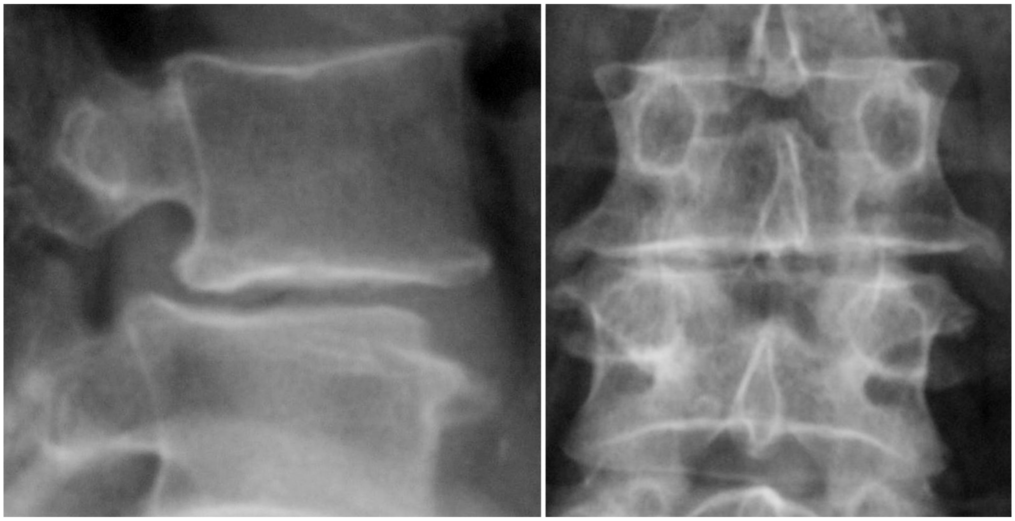

Figure 47-8 Radiographs demonstrate true lateral (*left*) and anteroposterior (AP) (*right*) images. Note that in the lateral view the end plates can be visualized easily, and the pedicles are superimposed. The AP view demonstrates the spinous processes at each level seen in the midline and the transverse section of each pedicle.

obtain true AP and lateral images. By maintaining a zero-degree gantry, the surgeon can confidently work perpendicular to the floor at all times at a comfortable angle and can access the disk space safely. Such orientation minimizes the risk of taking a trajectory that is too anterior, risking the aorta, inferior vena cava, or iliac vessels or placing the interbody graft off target into the foramen.

True AP and lateral images must be visualized at each operated level (Fig. 47-8). If multiple levels are being accessed, the patient and bed must be moved after each level to ensure true AP and lateral views for that level. In the lateral view, the end plates must be visualized cleanly, and the pedicles should be superimposed, so that only one pedicle is visualized. Likewise, in the AP view, the spinous processes at each level should be visualized in the midline, and the transverse section of the pedicles should be visualized equally bilaterally.

Once the true AP and lateral views have been obtained, the incision can be marked. Typically, the incision is 2.5 to 3.0 cm in length and can be localized marking an "X" over the targeted disk space using fluoroscopy (Fig. 47-9). A single incision can be used to access multiple levels, thus such an incision would be placed at the midpoint between the targeted levels. The ideal target is the anterior half of the disk space. The trajectory to the target must be perpendicular to the floor to ensure safe dissection. Once the incision and trajectory have been planned, and the patient is in the appropriate position with true AP and lateral images, the surgical site can be prepped and draped.

Dissection through the posterior abdominal wall is performed through the following layers, in order, from superficial to deep: skin, subcutaneous fat, external oblique muscle, internal oblique muscle, and transversus abdominis muscle. These layers can be dissected using a blunt instrument and with the assistance of handheld retractors. The muscle should be split in the direction of the muscle fibers, not by using a muscle-cutting technique. This dissection should be with performed with little resistance. If resistance is encountered, the surgeon is likely in the incorrect plane. Once the retroperitoneal fat is visualized, a finger sweep is performed

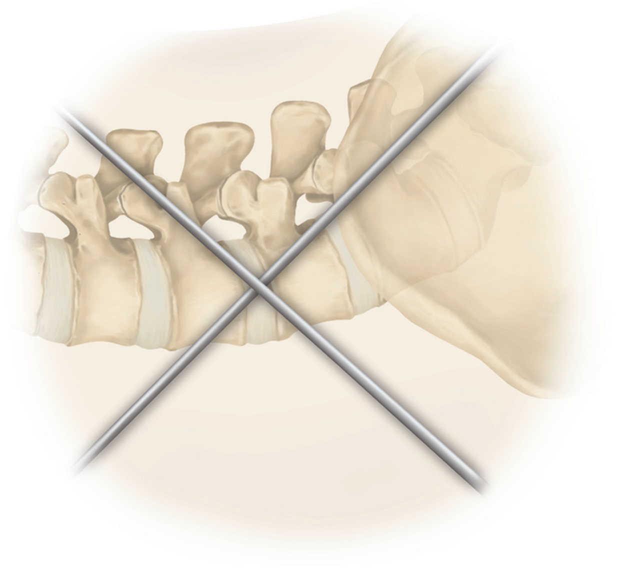

Figure 47-9 Schematic drawing of an "X" marks the incision over the targeted disk space.

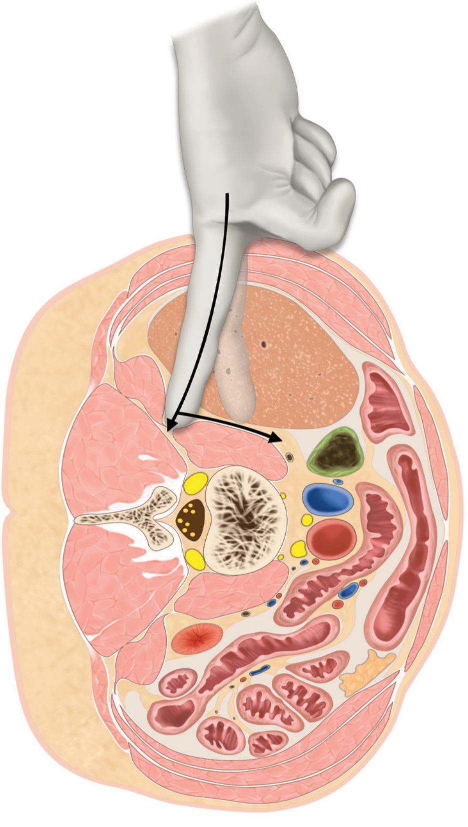

Figure 47-10 A posterior-to-anterior finger sweep is done, feeling along the transverse process and mobilizing the peritoneal contents anteriorly.

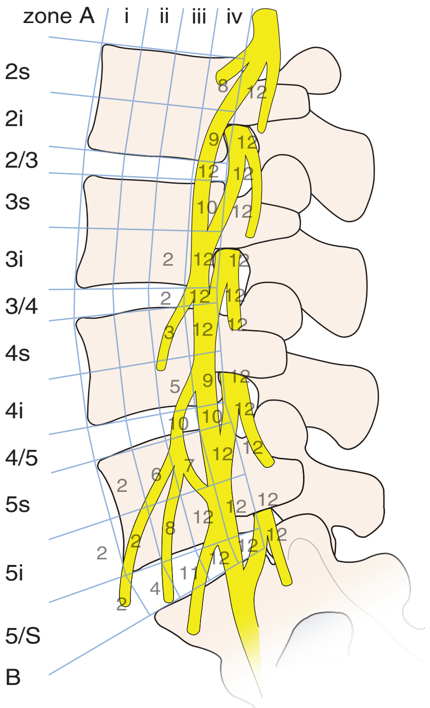

Figure 47-11 Schematic rendering of the lumbar plexus as it passes through the psoas muscle. (From Moro T, Kikuchi S, Konno S, Yaginuma H: An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery. *Spine (Phila Pa 1976)* 2003;28(5):423-428.)

in the posterior to anterior direction (Fig. 47-10). The transverse process of the spine can be palpated, and it can be used to guide the surgeon's finger down to the psoas muscle. The finger sweep then mobilizes the peritoneal contents anteriorly. At the level of T12–L1 and L1–L2, the diaphragm must be transected. It is sometimes helpful to tag the edges of the diaphragm with suture to aid in closing the appropriate layer at the conclusion of the case.

During the transpsoas dissection, the lumbar plexus and genitofemoral nerves are at risk of injury. Multiple studies have eloquently described the anatomic relationships and courses of the lumbar plexus nerves (Fig. 47-11).[9,10,14,15] The anterior one half to one third of the disk space is the safest target, because the lumbar plexus courses progressively more anteriorly and splays out at the more caudal levels. Furthermore, Davis and colleagues[16] have shown in cadaveric studies that the femoral nerve in particular courses through the midpoint of the disk space at L4–L5. Placement of the tubular retractor system through the psoas muscle thus puts these nerves at particular risk, not only for direct injury but also for traction injury. The genitofemoral nerve originates at the level of L1 and L2; it traverses the psoas muscle, from posterior to anterior, between the superior aspect of the L3 vertebral body and the inferior aspect of the L4 vertebral body. It travels along the anterior aspect of the lower psoas to provide genital, perineal, and medial thigh sensation. Other nerves at risk include the subcostal, iliohypogastric, ilioinguinal, and lateral femoral cutaneous nerves.[7,13]

The importance of neuromonitoring in the lateral transpsoas approach cannot be overemphasized. Although direct visualization of the genitofemoral nerve is the best way to prevent injury, neuromonitoring with both free-run and triggered electromyelograph (EMG) is required with the transpsoas approach to prevent injury to the branches of the lumbar plexus. The free-run EMG is used throughout the entire procedure. During the transpsoas dissection, the triggered EMG probe is passed through the muscle into the anterior one half to one third of the disk space. If EMG activity is detected, the probe is moved more anteriorly in a new trajectory. Fluoroscopy is used to ensure that the probe is passing into the disk space at the appropriate trajectory. A normal healthy nerve will typically stimulate at 2 mA, but a chronically compressed or injured nerve will typically require a higher level of stimulation to conduct a response, therefore the triggered EMG probe is typically set at 6 mA during dissection. Once the triggered EMG probe has safely passed through the psoas muscle and has been verified in the appropriate disk space using fluoroscopy, a guidewire is passed through the center of the probe into the disk space (Fig. 47-12).

Once the guidewire is in place, the triggered EMG probe can be removed. The tubular retractor system is then sequentially placed to dilate the working space through the psoas muscle to the lateral aspect of the annulus. Free-running EMG can help detect any nerve irritation while the sequential dilators are inserted. Typically, a 22-mm tube is used. The tubular retractor is then fixed in place to the multiaxial arm attached to the side of the operating table (Fig. 47-13). Additional stabilization of the retractor can be achieved using a stabilization screw placed through the retractor blade into the adjacent vertebral body. Before placing the screw, the triggered EMG probe can be used to ensure that the trajectory of the screw does not put any

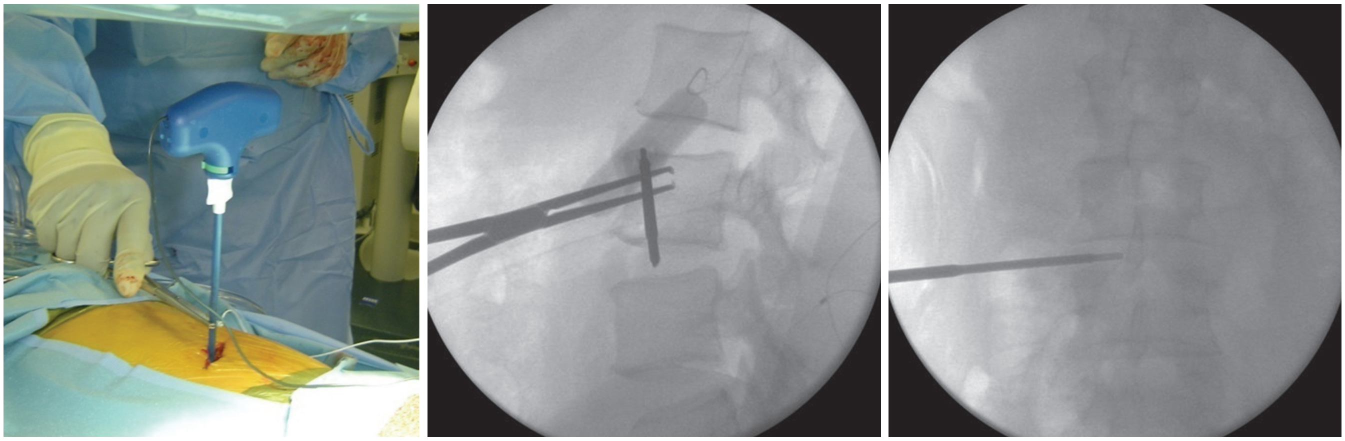

Figure 47-12 Placement of neuromonitoring probe through planned path of dissection through the psoas muscle all the way down to the lateral disk space.

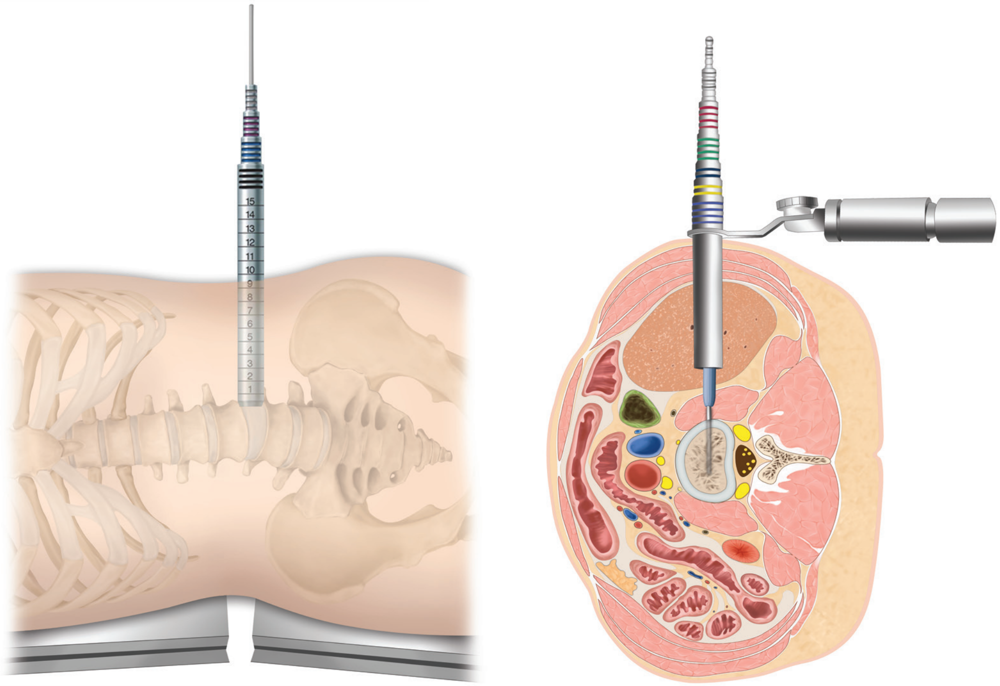

Figure 47-13 Sequential dilation of the tubular retractor system, docking on the lateral disk space.

neural structures at risk (Fig. 47-14). Typically, only one stabilization screw or shim, depending on the system used, is required. The stabilization screw should be placed close to the end plate to minimize risk to the segmental artery on the lateral vertebral body wall.

Because of the risk of either direct or traction injury to the nerves coursing through the psoas muscle, an alternative technique for docking the tubular retractor has been devised. By docking the tubular retractor superficial or lateral to the psoas muscle, the amount of tissue trauma to the muscle itself, as well as trauma to the nerves, can be greatly reduced. The advantages of shallow docking include the reduced risk for nerve and muscle tissue damage in an effort to help reduce injury to the lumbar plexus, iatrogenic ipsilateral psoas weakness, and postoperative iliopsoas pain. However, by docking shallow, the muscle around the tubular retractor can creep into the working channel and make visualization difficult. Likewise, it is essential to maintain the same dissection trajectory through the muscle with each pass of a new instrument.

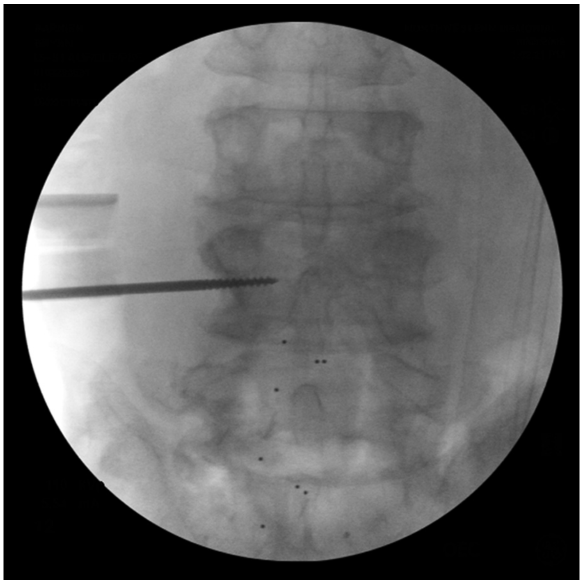

Figure 47-14 Radiographs demonstrate placement of the stabilization screw in the vertebral body.

Before starting the diskectomy, it is important to radiographically verify the appropriate level. Any remaining muscle tissue on the lateral vertebral body wall should first be probed with the triggered EMG probe in all four quadrants (Fig. 47-15), and it should be retracted out of the field using a blunt instrument and bipolar electrocautery if needed. Visualization can be enhanced by a variety of methods that include the use of loupe magnification, an operative microscope, or a light source that attaches to the tubular retractor.

The diskectomy is initiated with the annulotomy knife with the goal of fully detaching the intervertebral disk from the end plate and completely releasing the ipsilateral side. Eventually, the contralateral annulus must be completely released; this will enable the interbody graft to span the width of the vertebral body along the cortical rim and expand the disk height fully and symmetrically to provide maximal neural indirect decompression and to potentially provide some coronal correction. A Cobb periosteal elevator or disk shaver can be used to release the contralateral annulus (Fig. 47-16). The diskectomy can be completed using a combination of pituitary rongeurs, shavers, and curettes. It is imperative to maintain orientation and trajectory perpendicular to the floor to avoid grabbing any disk or soft tissue adherent to the annulus or vascular or neural structures.

Once the diskectomy is complete, various sequential trials of interbody graft sizes can begin. Ideally, the graft should span the width of the vertebral body and rest on the cortical rim to maximize its biomechanical strength and stability.[17] In the AP plane, the interbody should extend from pedicle to pedicle (Fig. 47-17). Once the appropriately sized trial is selected, the end plates should be prepared in order to optimize conditions for fusion. There are many different types of interbody grafts that can be used, depending on surgeon preference and clinical judgment. The tapered front of some interbody grafts helps to reduce the risk of violating the end plate when delivering the graft to the disk space. Likewise, when placing an interbody graft in the lumbar spine, a lordotic shape can be helpful to maintain appropriate lordotic

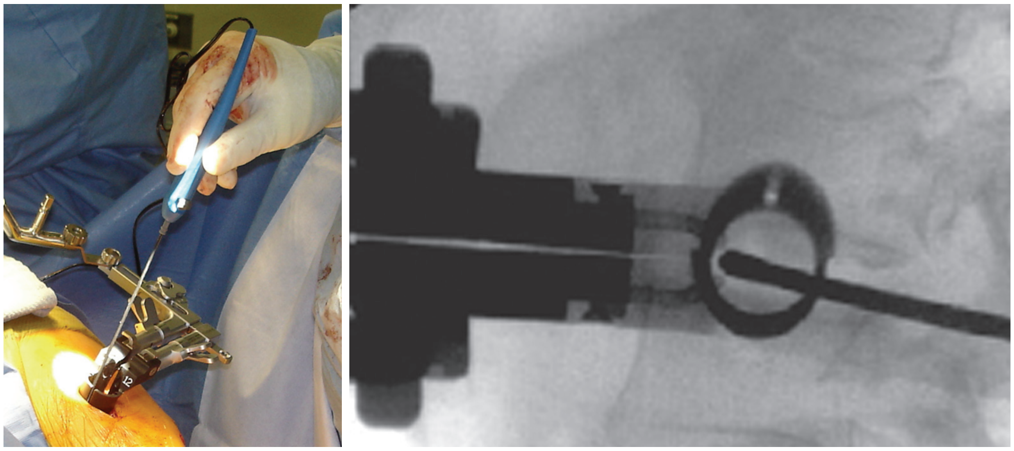

Figure 47-15 Final use of triggered electromyelograph probe before beginning diskectomy.

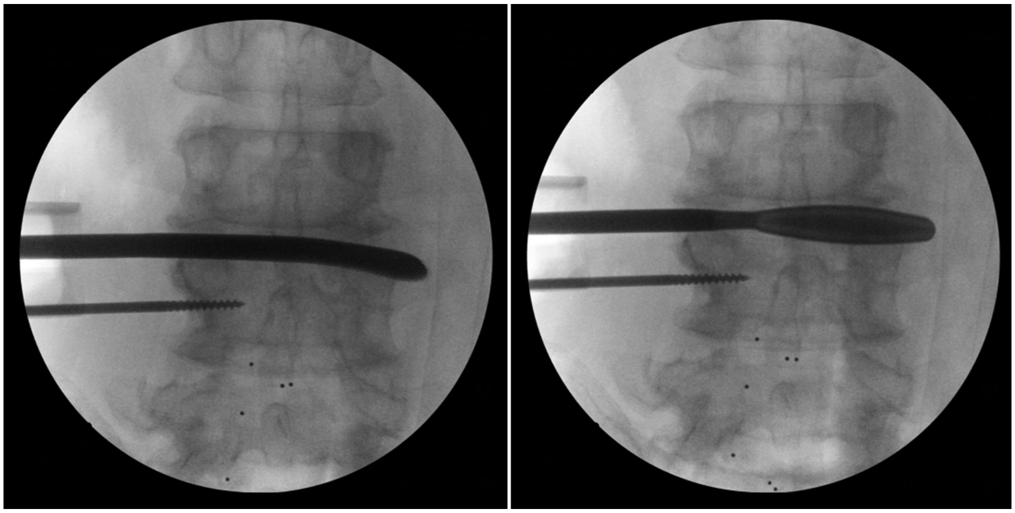

Figure 47-16 Radiograph demonstrates contralateral annulotomy.

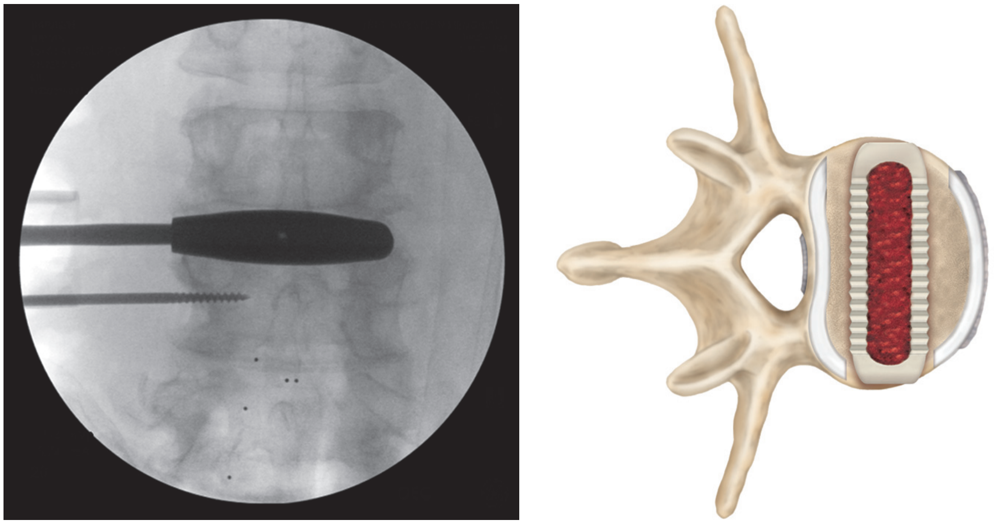

Figure 47-17 Radiograph (*left*) demonstrates proper placement of interbody graft. Schematic drawing (*right*) demonstrates placement of graft on the cortical rim of the vertebral body on its anterior half.

alignment. The use of osteobiologics is beyond the scope of this chapter and is largely based on the surgeon's clinical judgment. Final AP and lateral radiographs will verify appropriate interbody graft placement (Fig. 47-18).

Closure is performed in multiple layers: transversalis fascia, external oblique fascia, subcutaneous tissue, and skin. Special attention should be paid to closure of the transversalis fascia and external oblique to help prevent postoperative development of an incisional hernia. A GU-6 needle is helpful when closing the deep fascial layers, and the skin is ultimately closed with adhesive (Fig. 47-19).

Postoperative Care

A complete blood count should be obtained immediately postoperatively and the following morning to determine whether an occult retroperitoneal hemorrhage is present. Typically, patients undergoing LTIF do not require an orthosis postoperatively and typically spend only a few days in the hospital.

Complications and Bailout Strategies

One of the most common complications in the LTIF is injury to the lumbar plexus and associated nerves as they course through the psoas muscle. Moller and colleagues[13] reported that 36% of patients experience subjective ipsilateral iliopsoas weakness, 25% experience anterior thigh numbness, and 23% experience anterior thigh pain postoperatively. Eighty-four percent of patients with iliopsoas weakness improve completely by 6 months postoperatively, and most report being back to baseline strength by 8 weeks. By 6 months, 69% of patients with anterior thigh numbness improved, and 75% of patients with anterior thigh pain also completely improved. Docking the tubular retractor

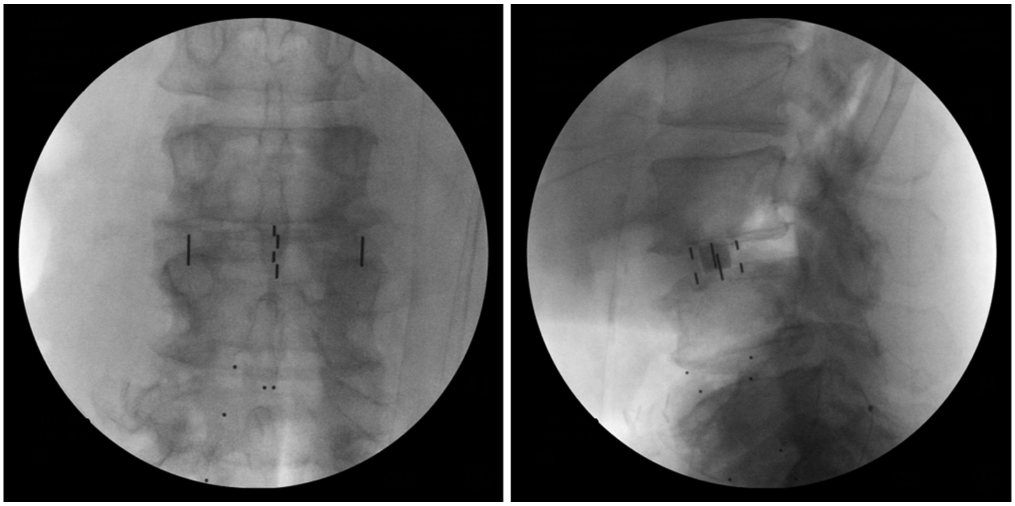

Figure 47-18 Fluoroscopy images demonstrate appropriate placement of graft.

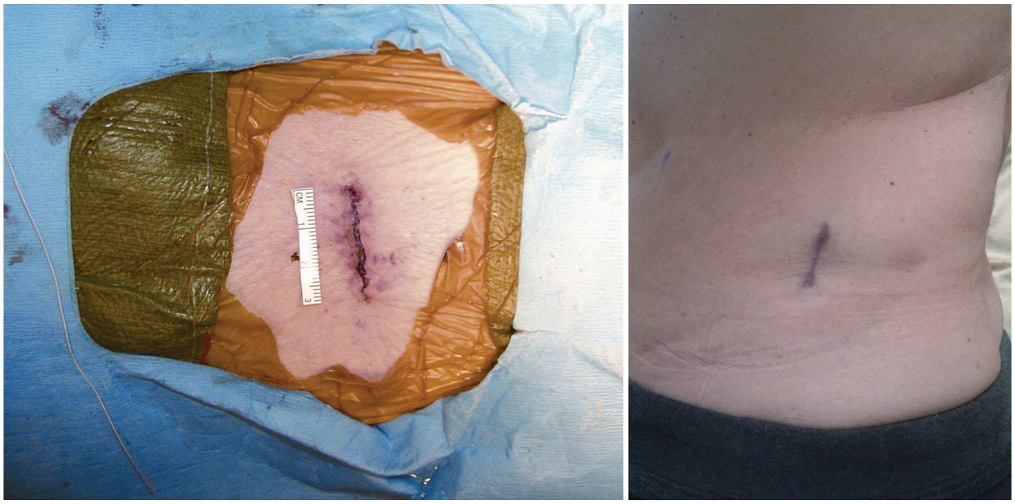

Figure 47-19 Photographs of incision following multilayer closure.

superficial to the psoas muscle aims to reduce the risk of direct or traction nerve injury.

In the event that the lumbar plexus cannot be identified upon transpsoas dissection, the validity of the neuromonitoring system must be verified. First, a technical problem with the monitoring itself must be ruled out. If the equipment is functioning properly, and the lumbar plexus cannot be identified, the potential risk to the lumbar plexus without neuromonitoring guidance is significant, such that aborting the case should be considered. Conversely, if multiple areas of the psoas muscle show response to stimulus, a more anterior position should be used. If a safe trajectory cannot be determined, the case may also need to be aborted. Patients should be made aware of this possibility preoperatively.

Segmental artery injury during LTIF is rare but must be dealt with quickly to avoid rapid blood loss. With the expeditious use of hemostatic agents and bipolar electrocautery, the bleeding can be definitively controlled through a tubular retractor. The rapid bleeding associated with a segmental artery injury can quickly compromise visualization through the tubular retractor. Likewise, given the potential for rapid loss of blood, the anesthesia team should be alerted as soon as possible in the event that hemodynamic issues arise.

Conclusion

The lateral transpsoas approach can be used for a variety of etiologies that require interbody fusion in the lumbar spine. Successful use of this technique begins with careful patient selection and thorough preoperative evaluation of the patient's anatomy. It is essential to use both radiographic and neurophysiologic guidance to safely and effectively perform the lateral interbody fusion.

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