Extreme lateral interbody fusion (XLIF) (NuVasive Inc., San Diego, CA) and direct lateral interbody fusion (DLIF) (Medtronic Sofamor Danek, Memphis, TN) are novel minimally invasive transpsoas approaches to the lumbar spine for performing interbody fusions. Advantages of interbody fusions over posterolateral fusion have been detailed and include theoretically higher fusion rates, the possibility of achieving better sagittal alignment, and even possibly better outcomes.\textsuperscript{2,6,7,24} Anterior lumbar interbody fusion (ALIF) provides a theoretical advantage over posterior methods of interbody fusion by allowing a greater extent of disectomy, avoiding entry in to the spinal canal and subsequent scarring adjacent to the neural elements and sparing of the posterior elements of exposure-related damage.\textsuperscript{3,15,14} Despite its advantages, the ALIF approach is also associated with several serious complications including visceral and ureteral injury,\textsuperscript{8,19} vascular injury,\textsuperscript{15} and sexual dysfunction\textsuperscript{20} among others. Various minimally invasive techniques have been developed to perform ALIF including laparoscopic and endoscopic techniques\textsuperscript{10,22} and the miniopen approach.\textsuperscript{5,12} These, however, require a steep learning curve and the potential for serious complications remain.\textsuperscript{17} In addition, an endoscopic minimally invasive transpsoas approach has also been described.\textsuperscript{4} This, however, is of historic value and represents a technique that eventually evolved into both the XLIF and the DLIF.

For the purpose of this discussion, we will reference the XLIF approach. The discussion, however, does apply also to the DLIF. XLIF uses a minimally invasive, transpsoas approach to the spine (Fig. 19.1). The surgeon uses his or her finger to perform blunt dissection through a posterior paraspinal incision to escort dilators and a guide wire into position directly over the psoas muscle. Using his or her finger the surgeon is able to create a retroperitoneal space and protect the viscera and prevent possible injury. With the DLIF technique, some surgeons have chosen to perform this procedure through a single miniopen lateral approach without the use of the posterior incision to create the retroperitoneal space. With the single incision, the layers of the abdominal wall are directly visualized, and the retroperitoneal space is created under direct vision with passage of instruments through the psoas. In addition, the use of electrophysiological monitoring, including triggered and free-running electromyography (EMG), reduces the likelihood of injury to the lumbosacral plexus when accessing the disc space through the psoas muscle. Dilators, which contain insulated tips allow for EMG monitoring as they are introduced via the transpsoas approach to the disc space. If a dilator passes in proximity to the lumbosacral plexus, the surgeon is warned both visibly on a graphic display and also via auditory feedback. The surgeon can then adjust his or her trajectory to reduce the likelihood of neural injury. Given the location of the lumbosacral plexus described by Moro et al,\textsuperscript{16} a more anterior trajectory is safer especially at the L4-5 interspace. Nevertheless, genitofemoral nerve injuries can still occur. Simply using fluoroscopy and serial dilatation of the psoas muscle, the surgeon readily and safely can access the disc space. The major advantage of XLIF/DLIF is the fact that the procedure does not require a second access surgeon. Other advantages are reduced incidence of ileus, the anterior longitudinal and posterior longitudinal ligaments remain intact, the lack of need for bony resection as performed when posterior approaches for interbody fusion are being used, reduced operative time in comparison to other anterior approaches, and reduced postoperative hospital stay and analgesic requirements (Table 19.1). In deciding to use this approach over others, a flowchart is included to assist the reader in decision making versus other techniques (Fig. 19.2).

ANATOMIC CONSIDERATIONS

The minimally invasive transpsoas approach is limited by the 12th rib and the superior edge of the iliac crest. Since the approach is strictly retroperitoneal, scarring of the retroperitoneal space is a relative contraindication. Relevant anatomic structures in the transpsoas approach to the disc space include the lumbosacral plexus, the genitofemoral nerve, and the nerve roots relative to the psoas muscle. Lumbosacral plexus fibers originate from the ventral primary rami of T12-S4 and travel through the psoas muscle (Fig. 19.3). The rami enter postero-medially relative to the psoas and then pass anterolaterally. These fibers are in close proximity to the lateral border of the disc space. Anatomic variations of the lumbosacral plexus may be seen as often as 20% of the time.\textsuperscript{21} Moro et al investigated the configuration of the lumbosacral plexus, the genitofemoral nerve, and nerve roots in a cadaveric study to better understand neurologic risks associated with the transpsoas approach.\textsuperscript{16}
They defined four zones based on the distance between the anterior and posterior borders of the vertebral bodies; zone I was located anteriorly and zone IV was located adjacent to the posterior margin of the vertebral body. At L2-L3 and above, the lumbar plexus and nerve roots were found in zone IV or more posteriorly. They also found that if the genitofemoral nerve was excluded, at L4-L5 the nerves were seen in zone III. Thus, one considers a genitofemoral nerve injury as a minor complication, L4-L5 and above is considered a safe zone for transpsoas surgery. They advised that when dissecting the psoas muscle at L2-L3 and below, the dissection should proceed from the anterior vertebral body because the lumbar plexus and nerve roots (with the exception of the genitofemoral nerve) were not seen on this surface.

Typically the genitofemoral nerve branches from the L1 and L2 nerve roots, although variations exist with potential contributions from T12-L3. In the most common variation, the nerve traverses the psoas muscle and emerges on its surface in the range of L3 to L4. This is the basis for reported cases of genitofemoral nerve injury (with subsequent transient postoperative groin paresthesias) as a complication of the transpsoas approach.

Based on the more anterior locations of the lumbar plexus (with the exception of the genitofemoral nerve) and possible nerve roots at L3-L5 versus L2-L3 and above, a peripheral nerve injury is theoretically more likely to occur when performing a transpsoas approach at the L3-L4 and L4-L5 levels than at rostral levels.

The kidneys and ureter lie anteriorly to the psoas muscle. The aorta and vena cava lie in front of the vertebral bodies with

**TABLE 19.1**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLIF (posterior lumbar interbody fusion)</td>
<td>Direct access to the spinal canal, bilateral access for discectomy; allows posterior stabilization and onlay fusion via the same approach as interbody fusion; no access surgeon needed</td>
<td>Potential nerve root injury, dural injury, spinal canal scarring; limited feasibility above L4-5; potential paraspinal muscle damage with traditional approach</td>
</tr>
<tr>
<td>TLIF (transforaminal lumbar interbody fusion)</td>
<td>Reduced likelihood of neural injury compared to PLIF by removal of the inferior facet and accessing the disc space more laterally; access to the spinal canal can be achieved from the same approach; allows posterior stabilization and onlay fusion via the same approach as interbody fusion; no access surgeon needed</td>
<td>Potential nerve root injury, dural injury, spinal canal scarring; potential paraspinal muscle damage with traditional approach; limited discectomy performed from this approach</td>
</tr>
<tr>
<td>ALIF (anterior lumbar interbody fusion)</td>
<td>Greater extent of discectomy and release of the anterior longitudinal ligament, avoidance of entry into the spinal canal, sparing of the posterior elements of exposure-related damage</td>
<td>Serious potential complications including visceral and ureteral injury, vascular injury and sexual dysfunction. Ileus common</td>
</tr>
<tr>
<td>XLIF/DLIF ( Extreme lateral interbody fusion or direct lateral interbody fusion): Minimally invasive transpsoas approach for radical discectomy and fusion</td>
<td>Relatively easier access to multiple levels from T1-L5, especially useful for lumbar degenerative scoliosis, anterior and posterior longitudinal ligaments remain intact, theoretically reduced operative times compared with other anterior and lateral procedures, theoretically reduced analgesic requirements, reduced likelihood of vascular and viscus injury compared with ALIF (and sexual dysfunction), avoidance of spinal canal, avoidance of paraspinal muscle damage</td>
<td>Genitofemoral nerve distribution paresthesias very common, risk of lumbosacral plexus and femoral nerve injury; potential hip flexor and quadriceps weakness, at rostral levels possible diaphragmatic injury/pneumothorax</td>
</tr>
</tbody>
</table>

**Figure 19.1.** Minimally invasive approach to the spine using the transpsoas approach where a Percutaneous Access Kit (PAK) needle is used to access the disc space. (Image provided by Medtronic Sofamor Danek USA, Inc.)
Chapter 19 • Direct Lateral Approach to the Lumbar Spine

Are there any contraindications?
L5-S1 level
High-grade spondylolisthesis,
Retroperitoneal scarring or pathology
Medical comorbidities that would be a contraindication to fusion

Consider alternative techniques:
Nevertheless in cases in which an interbody fusion is needed at L5-S1 and at more proximal levels, XLIF/DLIF maybe useful for segments proximal to L5-S1, while an alternative interbody fusion technique is used at L5-S1 (e.g., degenerative scoliosis)

Is a direct decompression of the spinal canal needed at the interbody fusion level?

Consider TLIF/PLIF
Consider DLIF/XLIF

Are multiple levels being addressed?

Consider XLIF/DLIF
Consider single-level XLIF/DLIF vs. TLIF/PLIF

Figure 19.2. Flowchart.
Figure 19.3. Illustration showing the relationship of the lumbosacral plexus, femoral nerve, genitofemoral nerve, and other nerves to the psoas muscle. (Reprinted with permission from Moore KL, Agur AMR. Essential clinical anatomy, 2nd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2002.)
the aortic bifurcating at the L4-L5 disc space. Typically, the iliac veins join just below and to the left of this point. These are easily injured when performing ALIF, as these vessels must be meticulously dissected and managed. A transpsoas approach to the disc space is thus associated with a substantially reduced risk of vascular injury. Vascular injury, however, may still occur, especially if instruments are improperly placed or the anterior longitudinal ligament (ALL) is violated.

INDICATIONS

The transpsoas approach for lumbar interbody fusion is indicated as an alternative to ALIF. Although typically performed from L1-L2 down to L4-L5, it can be performed as high as the lower thoracic spine. It is particularly useful for lumbar degenerative scoliosis. In addition, it is an alternative to ALIF when prior anterior abdominal spinal access procedures have been performed. The procedure has also been described as a salvage method for failed arthroplasty. Anatomic limitations of the transpsoas technique at rostral levels are the rib cage and at caudal levels are the iliac crest. Nevertheless, the technique can be performed at higher levels by going in between the ribs. If the technique is used in such a manner, care should be taken to have the anesthesiologist hold inspiration while introducing the dilators to avoid damage to the lung.

Contraindications for the transpsoas approach include, high-grade spondylolisthesis, a very low-seated L4-5 disc, L5-S1 level and prior retroperitoneal surgery.

POSITIONING

The patient is intubated in the usual manner and EMG monitoring leads are placed. We then place the patient in the lateral decubitus position (Fig. 19.4). We tend to use the Skytron slider table (Skytron, Grand Rapids, MI) with the use of a kidney rest for most cases. An axillary roll is placed to minimize risk of an axillary neuropathy. In cases where it is used for lumbar degenerative scoliosis, the patient is positioned with the convexity of his or her curve facing upward in a lateral decubitus position (i.e., for a right-sided lumbar curve, the patient is placed into the left lateral decubitus position with the right side up). When L4-5 is included in the fusion, then access to the convexity of L4-5 may determine the lateral decubitus position. Otherwise for cases without scoliosis the right lateral decubitus position with left side up is our preferred approach. In addition, bolsters and generous padding are used to position the patient. The patient’s iliac crest is placed slightly below the kidney rest of the table. The kidney rest is then elevated to obtain maximum opening of the space between the ribs and the iliac crest to gain direct lateral access to the disc space. Alternatively, the AMSCO table (Amisco® OrthoVision® Table, STERIS Corporation Mentor, OH) can be used for large patients as it allows for breaking the table to increase the gap between the iliac crest and the 12th rib. We then use tape to secure the patient in position. The tape is placed over padding to minimize chances of abrasion to the skin. Fluoroscopy is then utilized, as it is critical to ensure that a true lateral image is obtained. This should be done with the C-arm perpendicular to the floor. We prefer to adjust the position to obtain a true lateral view by tilting the table, rather than rotating the C-arm, as this allows the surgeon to work directly perpendicular to the floor, thereby maintaining a safe trajectory for all instruments and allowing for a better sense of the intraoperative spinal anatomy.

PROCEDURE

After a true lateral image is obtained, the skin is marked. The center of the appropriate disc space is identified, and the skin overlying the space is marked. We prefer to make this incision obliquely in a lateral, superior to a medial, inferior position running in line with external abdominal oblique muscles. This helps ensure an excellent cosmetic result after wound closure. We usually attempt to access two disc spaces through one skin incision. A second incision is marked just lateral to the erector spinae. The surgeon’s finger should be able to reach from this lateral incision toward the primary incision.

Subsequently, the skin is prepped and draped in the usual manner. The posterior incision is made first. The surgeon then uses his or her finger to tease and divide the fascia and enter the retroperitoneal space. Initially, we used a blunt object, but with time and experience we found that one’s finger can perform the job more safely, although occasionally a dissecting scissor may be needed to pop through the fascia. Subsequently, the peritoneum is swept anteriorly, and the psoas muscle can be palpated inferiorly. The transverse processes are also identified. One’s finger should be able to feel the undersurface of the rib, inner surface of the iliac crest, psoas muscle inferiorly, and the transverse process posteriorly. This confirms entry into the retroperitoneal space and avoids the danger of creating a suprafascial space outside the abdominal cavity especially in patients with obesity. The surgeon then takes his or her finger up toward the marked incision above the disc space. The skin is incised, and the initial blunt dilator escorted down to the level of the psoas muscle on the surgeon’s fingertip. A lateral fluoroscopic image is taken to confirm the appropriate trajectory toward the disc space before entering the psoas muscle. The initial dilator should also be stimulated dynamically via the monitoring system at this stage as it is passes through the psoas muscle toward the disc space. The dilator position is then confirmed fluoroscopically and should be positioned at approximately the border of the anterior and middle thirds of the disc space. On lateral fluoroscopy, once the

Figure 19.4. Patient positioned in the lateral decubitus position with the kidney rest up in preparation for the transpsoas approach.
location is confirmed, a guide wire is gently introduced through the initial dilator into the disc space (Fig. 19.5). If an osteophyte is present, a mallet can be used to gently advance it. Subsequently, AP images are obtained to confirm the location of the guide wire. Dilators are then introduced sequentially through the psoas muscle. It should be stressed that as each dilator is introduced, EMG monitoring is used to confirm that no nerves are irritated/injured. The final dilator has markings on it, which can be used to assess the optimal length of the retractor blades. As the retractor blades are placed, they are also connected to the monitoring system. In general, tEMG responses with a threshold greater than 10 mA are considered safe. If the system registers a response, then the surgeon has the ability to change his or her trajectory through the psoas muscle.

The retractors are then adjusted and locked into place with a retractor articulating arm, which is attached to the bed. The surgeon holds the retractor in precise position while the assistant connects the arm. The dilated retractor blades are confirmed in location first on AP fluoroscopy and then on lateral fluoroscopy prior to discectomy being performed. In the DLIF technique, a threaded pin can be placed into the vertebral body to fix the retractor in place following proper positioning. In the XLIF technique, a disc shim can be inserted into the disc to similarly position the retractor.

The field is inspected after opening the retractor blades to ensure that there are no neural structures visualized in the field (Fig. 19.6). At times we have experienced this despite normal readings of the EMG monitoring system. If this does occur, the nerve can be swept posteriorly with a Penfield dissector and placed behind the retractor. Shims are supplied with the retractor, which can be useful for maintaining the nerve out of the field. Subsequently, the Penfield 4 dissector is used to clear tissue over the disc space. It is critical to also identify the anterior border of the disc space and the ALL (Fig. 19.7). By avoiding violation of the ALL, one can minimize the chance of vascular injury and also the chance of the graft either being placed too anterior or migrating into the abdomen.

A No. 15 blade is then used to incise the disc. Again the discectomy is centered over the anterior two thirds of the disc space without violation of the ALL. Pituitary rongeurs are used to remove disc material. A Cobb elevator is used to separate the cartilaginous end plate from adjacent vertebral body. Under fluoroscopic control using AP imaging, the Cobb elevator is used to release the annulus on the contralateral side and cross just beyond the disc space (Fig. 19.8). This is done with the aid of a mallet to ensure control. Once across the opposite side, the Cobb elevator is rotated 90° to stretch and release the annulus on the contralateral side. This is especially useful when correcting coronal deformity in scoliosis.

The disc spaces are then prepared using a series of curettes, rasps, box cutting curettes, and shavers as needed. The end plates are then meticulously prepared with rasps and curettes.

Figure 19.5. Lateral fluoroscopic image showing guidewire in the disc space. The wire is gently malleted into position using lateral fluoroscopy after an initial dilator is passed through the psoas position.

Figure 19.6. MaxAccess retractor in place. Note that the retractor is secured in place by an articulating arm and that the retractor is lighted. Figure 19.6B shows lateral fluoroscopic image of this.
Afterwards, serial trial spacers are used prior to placement of the implant. We prefer to use a slap hammer to remove spacers once they are in the disc space. The spacer size and length directly correspond to the final implant size. Subsequently, a correspondingly sized cage filled with bone graft/bone graft substitute extender and/or biologic material is placed. The implant is then impacted ideally between the anterior and middle third of the vertebral body. It should be noted that before removing the implant inserter, a lateral fluoroscopic image is obtained to ensure appropriate positioning of the graft (Fig. 19.9). When placing the graft, we tend to start its insertion tilted slightly posteriorly, and then redirect the implant as it is being malleted into position. This ensures that the ALL is not violated, and that the graft is not placed too far anteriorly.

**CLOSURE**

After both incisions are copiously irrigated with saline solution, buried Vicryl sutures are used to close the fascia, and then buried subdermal stitches with Steri-Strips are used for the skin. It should be noted that if multiple levels are being performed, the technique can be used via a single incision located at the center of the planned levels.

**COMPLICATIONS**

Transient postoperative anterior thigh/groin paresthesias are a frequently seen complication following the transpsoas approach. This may be due to injury to the genitofemoral nerve. In addition, based on the anterior locations of the lumbar plexus and possibly nerve roots at the levels L3-L4 and L4-L5, the lumbar plexus and femoral nerve are more likely to be injured when performing the lateral approach at caudal segments. An additional possible cause of these symptoms is psoas muscle

**Figure 19.7.** Extreme lateral interbody fusion (XLIF) patient post-discectomy note the anterior longitudinal ligament intact (arrow).

**Figure 19.8.** AP radiographic image shows Cobb elevator to the contralateral side. The Cobb is rotated to provide annular release.

**Figure 19.9.** Lateral X-ray confirming PEEK spacer in appropriate location in terms of anteroposterior placement.
manipulation and psoas hematoma. In our experience of greater than 100 cases, there were at least 5 cases of hip flexor weakness besides groin pain and anterior thigh paresthesias. These, however, all resolved within 6 weeks. Three cases of transient quadriceps weakness have also been noted localized to the vastus medialis, all in cases where the L4-5 was accessed. All three patients had a complete recovery of their quadriceps function within 6 weeks to 3 months. The vast majority of patients after XLIF/DLIF were noted to be ambulating by postoperative day 2 or 3. There have been no major or visceral injuries to date.

When performing XLIF/DLIF at L1-L2 or above, one could enter the pleural cavity and develop a pneumothorax. These are easily treated either by aspirating over a red rubber catheter in the operating room and closing the wound or by placing a chest tube. Asking the anesthesiologist to hold the breath in expiration at the time of introducing the dilators will also prevent any inadvertent injury to the lung especially at T11-12 and above.

In addition, careful attention must be paid to graft placement. A graft can certainly be placed too posteriorly with resultant canal or foraminal compromise. If the graft is placed too far anteriorly, the graft may dislocate into the abdomen. Considering all the above, the overall incidence of complications appears to be significantly less compared with those encountered when ALIF is performed.

We prefer to perform a posterior stabilization procedure in conjunction with a lateral transpsoas interbody fusion in our institution, nevertheless, in select cases there may be a role for standalone ALIF.

OUTCOMES

Few outcomes studies exist regarding XLIF, with long-term outcomes yet to be reported. Wright23 reported on the outcomes of 145 initial cases performed in the United States, only 5 patients were noted to have hip flexor weakness, which was transient. Importantly, there were no abdominal or vascular complications noted. Mean blood loss was 88 cc, and operative time was 74 minutes. Other smaller series have noted no complications.17,19

We have used the lateral transpsoas approach predominantly to treat adult degenerative scoliosis. The direct lateral fusion is complimented with the transarcual AxiaLIF fusion for L5-S115 following which posterior percutaneous multilevel pedicle spin instrumentation is performed. This combination of three novel minimally invasive techniques has enabled us to correct, stabilize, and fuse patients with adult scoliosis with considerably less morbidity than do open fusion for adult scoliosis. We have performed 35 cases to date using these novel minimally invasive techniques for correction of adult spinal deformity. We reported on the feasibility and technique on our first 12 patients treated in this manner with excellent early results.1 Mean blood loss for anterior procedures (transpsoas discectomy/fusion and in some cases L5-S1 interbody fusion) was 163.89 mL (SD 105.41) and for posterior percutaneous pedicle screw fixation (and in some cases L5-S1 interbody fusion) was 93.33 mL (SD 101.43). Mean surgical time for anterior procedures was 4.01 hours (SD 1.88) and for posterior procedures was 3.99 hours (SD 1.19). Mean Cobb angle preoperatively was 18.9° (SD 10.48) and postoperatively was 6.19° (SD 7.20). Mean preoperative visual analog score was 7.1; mean preoperative Treatment Intensity Score2 was 56.0. At a mean follow-up of 75.5 days, mean visual analog score (VAS) was 4.8 and mean treatment intensity score (TIS) was 28.0. We thus demonstrated that circumferential deformity correction was indeed achievable using the transpsoas approach for multilevel discectomy and interbody fusion, with operative times comparable to traditional approaches and blood loss considerably lower.

CONCLUSIONS

XLIF and DLIF are safe, novel, minimally invasive methods for performing interbody fusion primarily in the lumbar spine. As the technique is considerably different than ALIF, the complications experienced also are unique. Although there appears to be significantly less likelihood of visceral and vascular injury, complications still can occur. Through proper patient selection, appropriate patient positioning, and precise meticulous technique; it is possible to minimize complications and achieve good results.

REFERENCES