SUBSPECIALTY PROCEDURES

MINI-OPEN ACCESS FOR LATERAL LUMBAR INTERBODY FUSION

Indications, Technique, and Outcomes

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Abstract

Background: Lateral lumbar interbody fusion (LLIF) is a relatively new procedure. It was established as a minimally invasive alternative to traditional open interbody fusion. LLIF allows the surgeon to access the disc space via a retroperitoneal transpsoas muscle approach. Theoretical advantages of the LLIF technique include preservation of the longitudinal ligaments, augmentation of disc height with indirect decompression of neural elements, and insertion of large footprint cages spanning the dense apophyseal ring bilaterally^{1,2}. The original 2-incision LLIF technique described by Ozgur et al., in 2006, had some inherent limitations³. First, it substantially limited direct visualization of the surgical field and may have endangered nerve and vascular structures. Additionally, it often required multiple separated incisions for multilevel pathologies. Finally, for surgeons with experience in traditional open retroperitoneal surgery, utilization of their previously acquired skills may have been difficult with this approach. To overcome these limitations, we adopted the mini-open lateral approach, which allows for visualization, palpation, and electrophysiologic neurologic confirmation during the procedure⁴.

Description: As detailed below, the patient is positioned in the lateral decubitus position and a single incision is carried out centered between the target discs. For single-level LLIF, the incision spans approximately 3 cm and can be lengthened in small increments for multilevel procedures. After blunt dissection, the retroperitoneal space is entered. The psoas muscle is split under direct visualization, carefully avoiding the traversing nerves with neurosurveillance⁵. A self-retaining retractor is used, and after thorough dissection, the disc space is sized with trial components. The implant is filled with bone graft materials and is introduced using intraoperative fluoroscopy.

Alternatives: The 2-incision LLIF technique or traditional anterior or posterior lumbar spine interbody fusion techniques might be used instead.

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Rationale: LLIF offers the reported advantages of minimally invasive surgery, such as reduced tissue trauma during the approach, low blood loss, shorter length of stay, decreased recovery time, and less postoperative pain. LLIF allows for the placement of a relatively larger interbody cage spanning the dense apophyseal ring bilaterally. The lateral approach preserves the anterior longitudinal ligament and posterior longitudinal ligament. These structures allow for powerful ligamentotaxis and provide extra stability for the construct. Compared with other approaches, LLIF has a reduced risk of visceral and vascular injuries, incidental dural tears, and perioperative infections. Although associated with approach-related complications such as motor and sensory deficits, LLIF can be a safe and versatile procedure^{1,2}.

Introduction

The mini-open access technique utilizes a single mini-open incision, which allows for visualization, palpation, and electrophysiologic neurologic confirmation during the lateral lumbar interbody fusion (LLIF) procedure.

Indications & Contraindications

Indications (Video 1)

- Any lumbar spine conditions requiring interbody fusion in L1-L5 (additionally including thoracolumbar and thoracic via transthoracic approaches)
- Degenerative scoliosis
- Degenerative spondylolisthesis (mild to moderate)
- Nonunion
- Adjacent breakdown and/or adjacent segment disease
- Degenerative disc disease
- Revision surgery and removal of implants (e.g., total disc replacement retrieval, posterior lumbar interbody fusion, and transforaminal lumbar interbody fusion)

Contraindications

- L5-S1 pathology
- Severe and/or unstable spondylolisthesis⁶
- Poor bone quality and/or osteoporosis (risk factor for cage subsidence)
- Rising psoas sign⁷ and high iliac crest for an L4-L5 procedure
- Infection
- History of retroperitoneal infection (e.g., diverticulitis)
- History of retroperitoneal injury or dissection¹

Video 1 Patient presentation.

Step-by-Step Description of the Procedure

Step 1: Patient Positioning and Setup

Position the patient in the lateral decubitus position and perform radiographic confirmation (Video 2).

- After placement of appropriate lines and the induction of general anesthesia, reposition the patient in the lateral decubitus position with appropriate pressure points padded. With regard to laterality, approach the side that allows best access to the L4-L5 disc. This usually corresponds with the concavity of any scoliotic curve in patients with a coronal plane deformity⁴.
- Place an axillary roll to protect the brachial plexus.
- Fix the axillary and pelvic areas with adhesive tape to properly secure the patient to the table. The lateral decubitus position is inherently more unstable than the supine or prone position. It is common that patients with obesity or spinal deformity fall forward or backward, if not properly secured to the table.
- Afterward, increase the distance between the iliac crest and the rib cage, if necessary, by gently flexing the operating table with the pelvis as the distal pivoting area.
- Perform further taping with all pressure points well padded.
- Perform radiographs after correct patient positioning is achieved. Confirm the surgical level with anteroposterior and lateral radiographs, and ensure that there is no rotation (Fig. 1).

Fig. 1

Fig. 1 Lateral positioning with a break in the table.

Video 2 Phase 1: Patient positioning, setup, skin marks, and preparation.

Step 2: Skin Marks and Preparation

Draw the skin marks and prepare and drape the flank.

- Draw the skin marks for the incision using lateral radiographs. Mark the anterior and posterior margins of the vertebral body as well as the target disc space. If a single level is involved, center the incision at the disc space. If (as in the depicted case) 2 levels are addressed, center the incision between the 2 target discs (Fig. 2).
- Prepare and drape the flank in the usual sterile fashion.

Fig. 2

Fig. 2 Skin marks.

Step 3: Skin Incision and Superficial Dissection

Perform a single mini-open incision and access the retroperitoneal space (Video 3).

- After a time-out, perform a skin incision with a surgical blade centered on the level previously marked on the skin. For a single-level procedure, the incision normally spans approximately 3 cm. Lengthen the incision in small increments, if additional levels are involved (Fig. 3).
- Dissect subcutaneous and fat layers using electrocautery. Use a self-retaining retractor to easily maintain exposure.
- Expose the fascia and bluntly divide it with 2 Kelly clamps in opposite directions.
- Utilize a muscle-splitting approach. Minimally split fibers of the external oblique, internal oblique, and transversus abdominis muscles along the direction of their respective fibers.
- Access the retroperitoneal space, which is developed under direct vision (Fig. 4).

Fig. 3

Fig. 4

Fig. 3 Mini-open technique.

Fig. 4 Access to the retroperitoneal space, which is developed under direct vision.

Video 3 Phase 2: Skin incision, dissection, end-plate preparation, and implant insertion.

Step 4: Deep Dissection

Use direct visualization, palpation, and electrophysiologic neurologic confirmation to access the target disc through the psoas muscle.

- Gently move the abdominal and retroperitoneal contents from posterior to anterior and identify the psoas muscle.
- Split the fibers of the psoas muscle along the direction of their long axis and expose the underlying target disc space through the use of 2 Wylie renal vein retractors (Medline) (Fig. 5).
- Use direct vision to maintain the dissection plane ventral to the neural elements throughout the course of the operation.
- Use a handheld electromyography (EMG) probe to confirm the dorsal position of the exiting nerve roots and lumbar plexus at each level (Fig. 6). This should be done in addition to conventional neuromonitoring (somatosensory evoked potentials and spontaneous EMG)].
- If a traversing nerve is encountered during the procedure, gently retract it dorsally (Fig. 7).
- After fluoroscopic confirmation of the target level, use a self-retaining retractor system (e.g., MaXcess; NuVasive) instead of the handheld retraction to maintain exposure (Fig. 8).

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 5 Handheld retraction.

Fig. 6 Handheld EMG probe. The surgeon receives immediate audible and visual feedback regarding the proximity of the nerves of the lumbar plexus.

Fig. 7 Gentle retraction of traversing nerves.

Fig. 8 Self-retaining retractor system (MaXcess; NuVasive).

Step 5: Discectomy and End-Plate Preparation

Perform a discectomy and prepare the end plates.

- Perform an anulotomy with a scalpel and remove disc material using a pituitary rongeur (Fig. 9). Minimize the use of curets to avoid violation of the end plates.
- Use Cobb elevators to detach cartilage from the end plates and to carefully release the contralateral annulus. This aids a balanced and parallel distraction.
- Use subsequently placed bullets (insert and rotate distraction dilators) and trial components of different sizes. Insert the bullets slightly over the contralateral edge of the end plates.
- Confirm the position of the trials using biplanar fluoroscopy. The end plates should be symmetrically distracted in the anteroposterior image. When the disc space is more severely collapsed, more frequent radiographic control is needed to confirm that the trial is located in an adequate position without any violation of the end plates.

Fig. 9

Fig. 9 Discectomy.

Step 6: Implant Insertion

Size the implant, fill it with graft material, and insert it.

- Select an adequately sized implant, avoiding overstuffing of the disc space to minimize implant subsidence and to prevent end-plate fractures. In the depicted case, a 12 by 55-mm implant is selected for the L3-L4 disc space.
- After irrigation, fill the implant with your choice of graft material (Fig. 10). In the depicted case, the implant is packed with recombinant human bone morphogenetic protein-2 (rhBMP-2) on its carrier sponge. This is our preferred material. If BMP is used (off-label), special care should be taken not to allow BMP to pass through the end plates, which might lead to an osteoclastic reaction in the bone. In cases in which BMP may be contraindicated, use demineralized bone matrix, bone marrow aspirate, or iliac crest bone graft instead of BMP.
- Introduce the implant under anteroposterior and lateral fluoroscopic viewing. The implant should be positioned to span the vertebral body and rest on the dense apophyseal ring bilaterally.

Fig. 10

Fig. 10 The LLIF cage. Note particularly the width of the cage, which generally is the same width as the vertebral body.

Step 7: Additional Adjacent Levels

If necessary, address additional adjacent levels through the same incision (Video 4).

- If additional adjacent levels are surgically treated, carry out a similar maneuver (Steps 4, 5, and 6). It is possible to address several (3 or 4) levels through the same incision, especially if the spine is approached from the concavity of the scoliotic curve in patients with a coronal plane deformity⁸. In the depicted case, a 10 by 50-mm implant was selected for the L2-L3 disc space.
- The final implant can either be left as a stand-alone LLIF or supplemented by a lateral screw or plate, depending on the surgeon's preference.

Video 4 Phase 3: Additional adjacent levels, imaging, and wound closure.

Step 8: Imaging and Wound Closure

Obtain final radiographs and perform a layered wound closure.

- After addressing all target levels, confirm satisfactory realignment and placement of instrumentation with radiographs (Fig. 11).
- After irrigation, close the wound in a layered fashion (Fig. 12).
- At the end of the procedure, either turn the patient supine and extubate or turn the patient prone for additional fixation. The interbody fusion of the anterior spinal column can be supplemented by posterior pedicle screw fixation resulting in a circumferential fusion construct⁸. This can be performed either during the same surgical setting or in a staged fashion to allow additional patient recovery time. Consider additional posterior fixation in settings of high biomechanical stress, including instability, sagittal imbalance, and spondylolisthesis and/or spondylolysis⁹.

Fig. 11

Fig. 12

Fig. 11 Postoperative (left) and preoperative (right) radiographs. In the images on the left, note the ideal position of the cage. In the top left image, anteroposterior metal markers show the cage extending the entire width of the disc and vertebral body with support from the lateral aspect of the vertebral body bilaterally. In the bottom left image, the lateral radiograph shows the central to anterior position of the cage to maximize lordosis.

Fig. 12 Surgical wound after closure.

Results

Our institution's experience with the mini-open access for LLIF has been previously reported. The revision rate for our patients who underwent stand-alone LLIF was 10.3%¹⁰. In a minimum 2-year follow-up study of patients undergoing LLIF for lumbar spine pathology, we found significant improvements in the visual analog scale score for pain (53% improvement), Oswestry Disability Index (43% improvement), and physical component summary of the Short Form-12 (41% improvement)¹¹. In another study, we assessed the complication profile of the mini-open LLIF procedure¹². The rate of persistent surgery-related sensory and motor deficits after a minimum follow-up of 1.5 years was 9.6% and 2.3%, respectively. A review of the cases of 900 patients treated with the mini-open LLIF approach from 2006 to 2013 at our institution revealed an overall incidence of vascular injury of 0.056% per case⁴.

Pitfalls & Challenges

- For surgeons who are unfamiliar with the regional anatomy, the LLIF technique is technically demanding. Adequate training and experience are necessary¹.
- Approach-related neurologic complications such as motor and sensory deficits remain a concern. However, neurologic complications have been shown to decrease with increasing surgeon experience with the LLIF procedure¹³. The risk of these neurologic complications should be well discussed with the patient before the surgery.

- Electrophysiologic neuromonitoring is useful to prevent postoperative motor deficit, but sensory nerves cannot be monitored during the procedure. Our data showed that procedures at L2-L3 were associated with more postoperative sensory symptoms than at other levels¹⁴.
- The use of electrocautery should be minimized or avoided during the approach in order to reduce possible denervation of the abdominal wall musculature. Blunt dissection should be performed instead¹⁵.
- The contralateral anulus needs to be released to aid a balanced and parallel distraction. However, overpenetration into the contralateral psoas muscle should be avoided since contralateral psoas injuries and motor deficits have been reported¹⁶⁻¹⁸.
- Overstuffing of the disc space by using oversized implants should be avoided to minimize cage subsidence and end-plate fractures.
- Although the rate of vascular and visceral complications during LLIF has been reported to be low, potentially lethal and even fatal intraoperative injuries to the great vessels have been reported^{4,19,20}. For this reason, immediate access to a general or vascular surgeon at the site where the surgery is being performed is highly recommended^{15,20}.
- Higher immediate procedure costs should be weighed against possible long-term benefits compared with traditional open approaches.

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