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Mini-Open and Minimally Invasive Transforaminal Lumbar Interbody Fusion: Technique Review

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This article describes both the mini-open and the minimally invasive tranforaminal lumbar interbody fusion (TLIF) techniques. The mini-open TLIF technique uses an expandable tubular retractor through a Wiltse approach and provides an alternative to the standard open surgical technique for TLIF. Alternatively, a nonexpandable tubular retractor can be combined with percutaneous screw fixation for a more minimally invasive approach. Patient selection, as in open procedures, is important in achieving desirable outcomes. Minimally invasive approaches to TLIF provide an elegant approach to treating various lumbar spinal pathologies. Minimally invasive TLIF requires an excellent working knowledge of anatomy. Minimally invasive approaches for TLIF reduce blood loss and shorten hospital stay when compared with open approaches.

KEYWORDS tranforaminal lumbar interbody fusion (TLIF), minimally invasive, mini-open, Wiltse approach, spondylolisthesis

In 1968, Wiltse et al[1] first described the paraspinal sacrospinalis muscle-splitting approach to the lumbar spine. The Wiltse approach decreased bleeding and provided a more direct approach to the transverse processes and pedicles. Unlike the traditional midline incision, it was also thought to decrease postoperative pain and avoid disruption of the supraspinous and interspinous ligaments. The Wiltse approach has recently been adapted for tranforaminal lumbar interbody fusion (TLIF). The safety and efficacy of TLIF have been demonstrated previously by several authors.[2-6] Advances in technique have led to 3 predominant approaches for TLIF: open by using a standard midline approach, mini-open by using a bilateral Wiltse plane approach with expandable tubular retractors, and minimally invasive with 1 nonexpandable or expandable tubular retractor and bilateral percutaneous screw placement. This article describes the use of mini-open and minimally invasive approaches for TLIF.

Indications

Spinal instability or deformity resulting from scoliosis or spondylolisthesis as well as low back pain from degenerative disk disease can be treated by using TLIF.[7] The indications for surgery summarized in the lumbar fusion guidelines should be considered before offering patients minimally invasive, mini-open, or open spinal fusion surgery.[7] Typically, we use the mini-open technique with bilateral expandable retractors to perform bilateral decompression and fusion at 1 or 2 levels in patients with spondylolisthesis and bilateral foraminal stenosis. We use the minimally invasive TLIF (with unilateral tubular retractor and percutaneous screws) in cases in which only unilateral decompression is needed. Decreased blood loss and muscle trauma and shorter hospital stays have been associated with TLIF procedures by using minimally invasive approaches.[2,4,5,8,9]

Relative contraindications to the mini-open or minimally invasive approach include fusions of 3 or more segments (the retractors usually only expand to 2 levels), exposures deeper than 9 cm (the maximum retractor depth), high-grade spondylolisthesis, and deformity requiring osteotomies or multilevel reduction. In addition, patients with distorted anatomical landmarks for pedicle fixation (such as those with prior posterolateral fusions) are not ideal candidates for a minimally invasive surgery technique (Table 1).

Preoperative Evaluation

History and Physical Examination

The surgeon should obtain a detailed history and physical examination to assess for evidence of neurologic compromise resulting from neural compression. Motor strength, sensory

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Table 1 Relative Indications and Contraindications for Minimally Invasive TLIF

Relative indications
Spondylolisthesis (usually grade I or II)
Degenerative disk disease causing discogenic low back pain (1 or 2 levels)
Recurrent lumbar disk herniation with significant mechanical back pain
Postdiskectomy collapse with neural foraminal stenosis and radiculopathy
Third time (or more) of recurrent lumbar disk herniation with radiculopathy (with or without back pain)
Pseudarthrosis of prior lumbar fusion
Postlaminectomy kyphosis
For cases with bilateral symptomatic stenosis and degenerative disk disease or spondylolisthesis, we prefer to use a bilateral mini-open approach.
For cases with unilateral stenosis and degenerative disk disease or spondylolisthesis, we prefer to use a unilateral minimally invasive nonexpendable retractor tube or unilateral mini-open expandable retractor with percutaneous screws.
Relative contraindications
High-grade spondylolisthesis (grade III or IV)
Deformity cases requiring 3 column osteotomies or SPOs at 3 or more levels (mini-open TLIF might be performed with SPOs at 1 or 2 levels)
Three or more levels of spinal disease requiring treatment
One-level disk disease causing radiculopathy without symptoms of mechanical low back pain or instability
Severe osteoporosis
More than 9 cm of tissue depth
Altered posterolateral anatomical landmarks (prior posterolateral fusions)

Adapted from Lu DC, Mummaneni PV: Mini-open approaches, in Perez-Cruet MJ, Pimenta L, Beisse R, Kim DH (eds): Minimally Invasive Spine Fusion: Techniques and Operative Nuances. St. Louis, MO, Quality Medical Publishing, 2011.

deficits, reflexes, and range of motion should be carefully documented. To assess for back pain generators, we typically ask patients to flex and touch their toes to load their disk and reproduce discogenic pain. We also palpate the facets and load the facets in extension to see whether they are pain generators.

Radiographic Work-up

Neurogenic claudication, low back pain, and radicular symptoms should be investigated with magnetic resonance imaging (MRI). Lateral flexion and extension films (dynamic radiographs) help the examination of pathologic motion segments in the lumbar region (Fig. 1). Some surgeons might also investigate disk degeneration with diskography. Others might try facet blocks with steroid to assess for facet-mediated back pain. In patients with osteoporosis or an underlying malignancy, a computed tomography (CT) scan of the lumbar spine might assist in further assessment of bony anatomy. Of particular importance is the depth of tissue from the skin surface to the spine (measured with axial CT or MRI), which should be determined to ensure the accessibility of the mini-open approach. Soft tissue measurements of 9 cm or more might be a relative contraindication. Also, the surgeon should assess for kyphoscoliosis with 36-inch radiographs if applicable. It is important to note that rotational scoliosis will make a minimally invasive TLIF more challenging as a result of difficulty with intraoperative fluoroscopic visualization.

Operative Setup

Patients with lumbar flat backs are positioned prone on a Jackson table with supportive chest and pelvic pads. It is important to be careful when using an open-bottom operat-

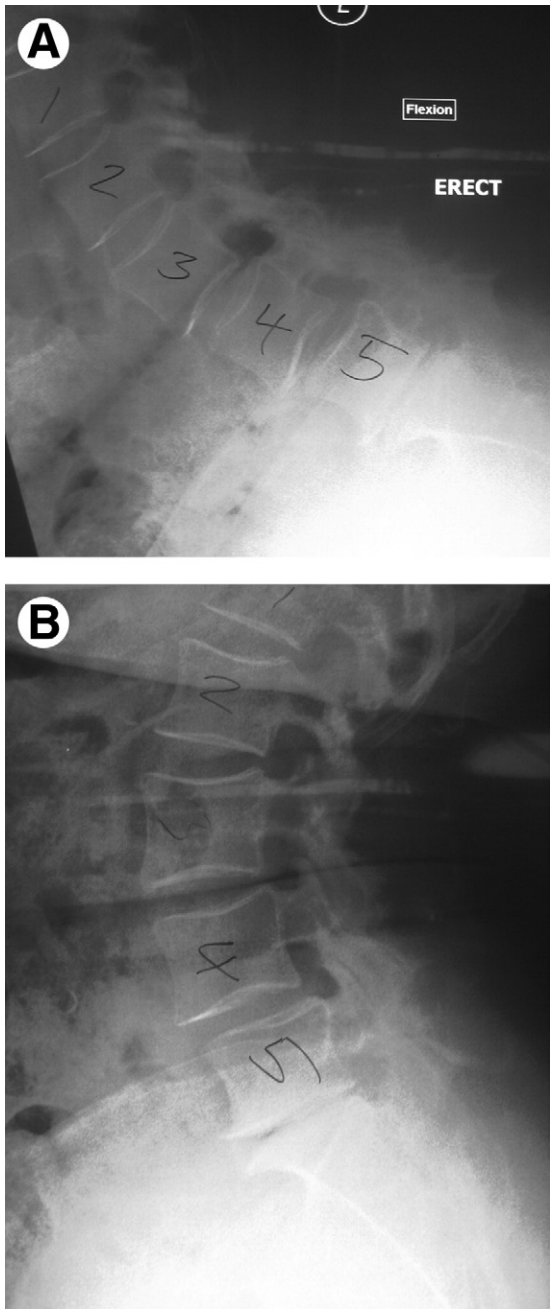

Figure 1 Dynamic lateral radiographs of lumbar spine (A, flexion; B, extension) demonstrating a mobile L4/5 grade 1 spondylolisthesis.

ing table with obese patients, because the weight of their pannus can result in hyperlordosis. In such patients we often use a Wilson frame on a Jackson table because it provides more support for the pannus. Also, in patients with severe lumbar stenosis in addition to spondylolisthesis, we prefer to use a Jackson table with a Wilson frame for positioning. During the interlaminar decompression, we "crank up" the Wilson frame to splay the lamina apart. This maneuver tenses the ligamentum flavum and makes decompression easier. After the decompression, we lower the Wilson frame into a lordotic position ("crank down" the Wilson frame). We then fixate the rods to the screw heads after the frame is in lordosis to avoid fixating the patient in a "flat-back" position. The arms are typically abducted at the shoulders to avoid interference with fluoroscopy. Perioperative antibiotics are given before the skin is incised. For most cases, we typically use intraoperative electromyography (EMG) during decompression and/or instrumentation, and we check the tap or screw stimulation thresholds with EMG to help avoid medial breaches of the pedicle screws.

Surgical Technique

Initial Incision and Placement of Dilators and Tubular Retractor

After sterile prep and drape, fluoroscopy is used to identify and mark the skin overlying the appropriate level for the incision location. Specifically, on the anteroposterior (AP) view, we mark the patient's skin with the superimposed position of the pedicles bordering the intended level or levels of fusion.

For the mini-open approach, the incision extends from the outside margins of the pedicle locations, approximately 4 cm lateral to midline, which allows the Wiltse paraspinal muscle-splitting approach to be performed (Fig. 2). After incising the skin and fascia, a plane is developed between the multifidus and longissimus muscles, and this pathway to the spine is progressively enlarged with sequential dilator tubes. An appropriate length, expandable tubular retractor can then be positioned on each side. The inner dilators are easily removed. A flexible arm attached from the side of the operating table to the expandable tubular retractors adds stability and allows angulation. The retractors should angle from lateral to medial to allow the correct angle for pedicle screw placement. A confirmatory lateral fluoroscopic image is performed.

Mini-Open Pedicle Cannulation

By using Bovie electrocautery and dissecting curettes, the lateral facet complex, transverse processes, and pars interarticularis are identified and exposed. Care should be taken not to injure the facet above the intended fusion site when exposing the superior transverse process and superior pedicle screw entry site. The pedicle screw entry point (the junction of the midpoint of the lumbar transverse process with the lateral aspect of the superior articulating facet) is decorticated with a high-speed drill. With a mini-open approach a gearshift is used to navigate down the pedicle into the vertebral body (similar to a standard open approach). Because of the limited visualization through a tubular retractor, the lamina can be mistaken for the transverse process, leading to attempted placement of the pedicle screw at the lamina/spinous process junction instead of at the transverse process/facet junction. It is important particularly early in a surgeon's experience that radiographic confirmation with fluoroscopy is made before placement of screws. After the pedicle is probed and tapped, a small amount of a flowable hemostatic agent is placed in the pedicle hole. If necessary, a foraminotomy for nerve root decompression can be performed, and a hemilaminectomy can be achieved with medial angulation of the tubular retractor. This technique is repeated for any additional levels of instrumentation.

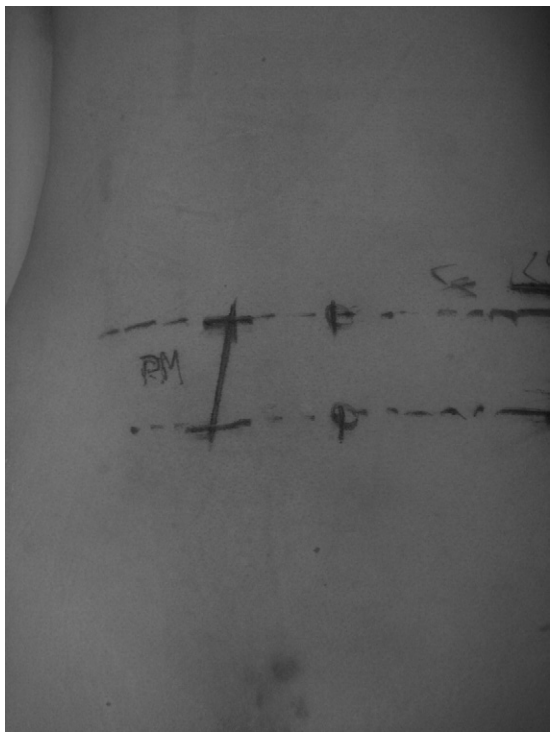

Figure 2 Skin incisions are marked under fluoroscopic localization of L4 and L5 pedicles; a linear incision on one side for the tubular retractor; 2 stab incisions on the other side for percutaneous screws.

Minimally Invasive Pedicle Cannulation

When a nonexpandable tubular dilator is used, percutaneous screws can be placed bilaterally. When we use a mini-open approach and there is no significant foraminal stenosis on the contralateral side, percutaneous screws might be used on that side. The incisions for the percutaneous screws are localized by using AP and lateral fluoroscopic imaging over the pedicles. A Jamshidi needle is placed in each pedicle, followed by placement of a K-wire. The needle is removed while the assistant stabilizes the K-wire to prevent unintended migration of the K-wire (Fig. 3). A sheathed tap is advanced over the K-wire until it traverses the pedicle on the lateral fluoroscopic view. The sheathed tap is then stimulated for EMG response, and stimulation with <5 mA is suggestive of a pedicle breach (Fig. 4). Cannulated screws are then advanced

Figure 3 A cannulated sheathed tap is inserted over the K-wire while the assistant stabilizes the K-wire.

over the K-wire under radiographic guidance, and the K-wires are removed.

Transforaminal Lumbar Interbody Fusion

If a TLIF is to be performed, first the pedicles adjacent to the intended TLIF disk space are cannulated. For minimally invasive TLIF, we do not place the pedicle screws until the interbody space is prepared and the TLIF cage is inserted; otherwise, the pedicle screw heads might impede access to the disk space. After the pedicle screw pathways have been created, small pedicle markers can be placed in the prepared bony holes. These markers serve to provide visual anatomical cues and help the surgeon avoid violating the pedicles with the drill.

A facetectomy and foraminotomy are then performed with a high-speed drill or small osteotome and mallet to expose the disk space, which is just above the lower pedicle screw cannulation hole. The disk is incised with a long-handled scalpel and removed with end plate shavers, pituitary rongeurs, and curettes. Care should be taken to remove the cartilage from the end plates without injuring the bony end plates both above and below the disk space. Interbody trials are used to serially dilate the disk space. An appropriately sized lordotic cage is then selected on the basis of the cage template trial that has a secure fit, and it is implanted into the disk space with the autograft packed in it. Additional autograft is also packed within the disk space around the cage. Subsequently, the pedicle markers are removed, and the pedicle screws are placed. If a bilateral decompression is required, 2 surgeons can work simultaneously through a bilateral mini-open technique (Fig. 5). If further lordosis is needed, bilateral facetectomies and laminotomies are performed (Smith-Peterson osteotomy [SPO]), and the pedicle screws are compressed to close the SPO. This maneuver increases segmental lordosis.

Figure 4 The sheathed tap is stimulated for EMG response, and stimulation with <5 mA is suggestive of a pedicle breach.

Figure 5 Simultaneous bilateral decompression can be achieved by using 2 sets of expandable tubular retractors in a mini-open fashion. This approach might also be used to perform SPO (bilateral laminectomies with complete facetectomies).

Bone Graft Material

There are several sources of graft material for fusion. The goal should be to optimize the chance for solid arthrodesis. General principles to consider are the underlying properties of the selected material. There are 3 components of bone healing and fusion: osteogenesis, osteoinduction, and osteoconduction. Osteogenesis forms bone at a cellular (osteoblastic) level through the activity of osteoprogenitor stem cells. Osteoinduction enhances bone formation by recruiting and inducing undifferentiated tissue to differentiate into bone. Osteoconduction creates scaffolding to guide the growth of closely apposed, growing, and healing bone.[10] Iliac crest autograft remains the gold standard, with the osteogenic, osteoinductive, and osteoconductive components required to achieve fusion, but it comes with associated donor site morbidity. In addition, some surgeons have used bioactive agents either alone or in combination with local autograft. The most commonly used bioactive agent is recombinant human bone morphogenetic protein (rhBMP-2). This protein works by osteoinduction, enhancing factors in the fusion pathway, and

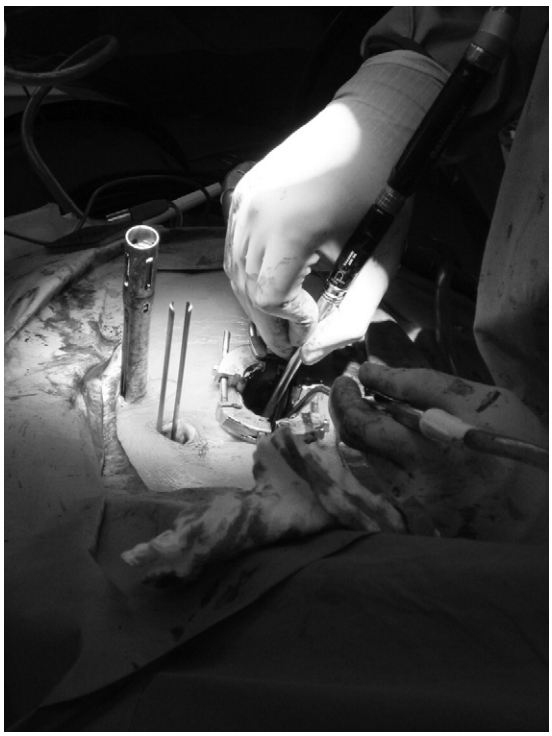

Figure 6 Spinal canal decompression is accomplished by angling the tubular retractor medially onto the hemilamina.

it is approved by the Food and Drug Administration for use in anterior lumbar fusion procedures only. There have been reports of heterotopic bone formation by using rhBMP-2 with TLIF, and it is therefore now our preference to use iliac crest autograft.[10] The iliac autograft might be harvested through the same posterolateral skin incision used for an L4/5 or L5/S1 TLIF. The posterior superior iliac spine is easily assessed from a Wiltse approach by elevating the skin laterally and dissecting above the fascia to reach the iliac crest.

Decompression of the Neural Elements

After the TLIF has been completed, if spinal canal decompression is needed, it can be performed by angling the expandable tube medially onto the hemilamina (Fig. 6). An ipsilateral hemilaminectomy can then be performed by using a high-speed drill and small bone Kerrisons and curettes. The ligamentum flavum might be removed with curettes after the bony work has been done. We remove the ligamentum flavum after all drill work is finished to reduce the risk of durotomy.

Placement of Pedicle Screws

Ipsilateral pedicle screws are inserted after the TLIF under radiographic guidance. Screw stimulation with EMG monitoring is performed to help verify that there are no medial screw breaches.

Placement of Bone Graft and Rods

For the mini-open approach, the bony facet surface is decorticated. Bone graft is placed over the transverse process and/or might be packed into the facet joint. Next, a measured rod is secured to the pedicle screw heads with locking caps either under direct visualization for a mini-open technique or through the use of a rod driver for percutaneous screws.

Closure

The wound is irrigated with antibiotic solution, and hemostasis is confirmed. The tubular retractor is removed, and the fascia and skin are closed in a layered fashion. If applicable, the same steps are followed for the contralateral side. A subfascial drain might be placed for 24 hours. We recommend using AP and lateral fluoroscopy to verify the screw position before removing the sterile drapes.

Complications

Potential complications that can occur during a mini-open procedure include instrument malposition, durotomy, and nerve root injury. Because of the limited exposure and reduced working space, appropriate pedicle screw placement can be difficult and requires excellent working knowledge of the anatomy seen through the tubular retractor. AP and lateral fluoroscopy can help locate the pedicle screw entry points and assist with anatomical reference points. Before the screw is placed, a small, ball-tipped feeler probe is used to palpate the inside walls of the pedicle to assess any wall violations. If a pedicle wall breach is identified, then an alternative trajectory can be found with fluoroscopy. To minimize the potential for durotomy, we prefer to prepare and tap the pedicle screw entry points before exposing the nerve roots or thecal sac. Cerebrospinal fluid leaks can be difficult to repair when using a minimally invasive approach. However, if encountered, we attempt to close the dural defect primarily by using a small needle driver and dural suture. A small piece of dural substitute and fibrin glue are applied to the region to create a seal. If necessary, a lumbar drain might be placed for additional cerebrospinal fluid diversion. One advantage of the smaller opening is decreased space for potential pseudomeningocele formation.

Conclusions

Minimally invasive approaches to TLIF provide an elegant approach to treating various lumbar spinal pathologies. Minimally invasive TLIF requires an excellent working knowledge of anatomy. Selection of a minimally invasive versus a mini-open approach is dependent on the need for unilateral versus bilateral decompression or SPO. For bilateral decompression and SPO we prefer the bilateral mini-open approach. For patients who need unilateral decompression we use the minimally invasive technique with percutaneous pedicle screws.

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