Minimally Invasive Transforaminal Lumbar Interbody Fusion (TLIF)

Technical Feasibility and Initial Results

James D. Schwender, MD,* Langston T. Holly, MD,† David P. Rouben, MD,‡ and Kevin T. Foley, MD§

Abstract: Forty-nine patients underwent minimally invasive transforaminal lumbar interbody fusion (TLIF) from October 2001 to August 2002 (minimum 18-month follow-up). The diagnosis was degenerative disc disease with herniated nucleus pulposus (HNP) in 26, spondylolisthesis in 22, and a Chance-type seatbelt fracture in 1. The majority of cases (n = 45) were at L4–L5 or L5–S1. A paramedian, muscle-sparing approach was performed through a tubular retractor docked unilaterally on the facet joint. A total facetectomy was then conducted, exposing the disc space. Discectomy and endplate preparation were completed through the tube using customized surgical instruments. Structural support was achieved with allograft bone or interbody cages. Bone grafting was done with local autologous or allograft bone, augmented with recombinant human bone morphogenetic protein-2 in some cases. Bilateral percutaneous pedicle screw–rod placement was accomplished with the Sextant system. There were no conversions to open surgery. Operative time averaged 240 minutes. Estimated blood loss averaged 140 mL. Mean length of hospital stay was 1.9 days. All patients presenting with preoperative radiculopathy (n = 45) had resolution of symptoms postoperatively. Complications included two instances of screw malposition requiring screw repositioning and two cases of new radiculopathy postoperatively (one from graft dislodgement, the other from contralateral neuroforaminal stenosis). Narcotic use was discontinued 2–4 weeks postoperatively. Improvements in average Visual Analogue Pain Scale and Oswestry Disability Index (preoperative to last follow-up) scores were 7.2–2.1 and 46–14, respectively. At last follow-up, all patients had solid fusions by radiographic criteria. Results of this study indicate that minimally invasive TLIF is feasible and offers several potential advantages over traditional open techniques.

Key Words: lumbar, fusion, minimally invasive, transforaminal lumbar interbody fusion

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Transformal lumbar interbody fusion (TLIF) has become an increasingly popular method for lumbar arthrodesis.1–5 Like standard posterior lumbar interbody fusion (PLIF), TLIF provides for a “360°” spinal fusion using a dorsal approach. Interbody lumbar fusion techniques have been reported to have higher arthrodesis rates than posterolateral onlay techniques.6,7 A typical PLIF procedure requires significant retraction of the neural elements to provide adequate exposure of the disc space. In contrast, the more lateral exposure of the interspace afforded by TLIF requires minimal, if any, neural retraction. In addition, whereas a typical PLIF necessitates bilateral neural retraction and bilateral epidural dissection for interspace preparation, the lateral-to-medial trajectory of a TLIF allows complete interspace preparation and fusion to be performed through a unilateral approach. Irrespective of the exact method of arthrodesis, conventional lumbar surgery performed via a posterior approach is associated with significant soft tissue morbidity that can adversely affect patient outcomes.8–13 Minimally invasive posterior lumbar fusion techniques are designed to reduce the iatrogenic soft tissue injury that occurs with muscle stripping and retraction during routine spinal exposure.14 In this article, a novel method of performing the TLIF procedure using a minimally invasive approach is detailed. The authors describe the indications, surgical technique, results, and complications for a series of 49 patients who underwent minimally invasive TLIF. Although the authors have previously reported the technique, this is the first report in the medical literature that presents the results of minimally invasive TLIF with a minimum of 18 months’ follow-up.15

MATERIALS AND METHODS

Patients
A total of 49 patients underwent the minimally invasive TLIF procedure at the authors’ institutions between October 2001 and August 2002 and were included in this series. There were 19 men and 30 women with ages ranging from 23 to 80. Mechanical low back pain and lower extremity radicular pain
were the chief complaints in 45 patients; 4 had mechanical back pain alone. Eleven patients had previously undergone surgery at the same level. The index diagnosis was degenerative disc disease with herniated nucleus pulposus (HNP) in 26 patients, spondylolisthesis in 22, and a Chance-type seat belt fracture in 1. The majority of the cases (n = 45) were performed at the L4–L5 and L5–S1 levels. The remainder of the cases were performed at L3–L4 (n = 3) and L2–L3 (n = 1). Mean preoperative Visual Analogue Pain Scale (VAS) ratings averaged 7.2 cm on a 10-cm scale. Mean preoperative Oswestry Disability Index averaged 46%.

Surgical Technique
Following induction of general endotracheal anesthesia, the patients were positioned prone on a radiolucent table. Before prepping the patient, lateral and anteroposterior (AP) C-arm fluoroscopic images were obtained to ensure that the pedicles could be adequately imaged prior to starting the case. With use of fluoroscopic guidance, a 2.5-cm incision was centered on the interspace of interest approximately 45–50 mm lateral to the midline. The approach was carried out on the side ipsilateral to the worst radiculopathy. A K-wire was used to penetrate the fascia, after which serial dilators were used to create a muscle-sparing surgical corridor as originally described for the microendoscopic discectomy (MED) procedure. An appropriate-length 22- or 26-mm-diameter METRx (Medtronic Sofamor Danek, Memphis, TN) tubular retractor was docked on the facet joint complex (Fig. 1). The remainder of the procedure was performed with the operative microscope or with loupe magnification, depending on surgeon preference. A total facetectomy was carried out using a high-speed drill and/or bayoneted osteotomes. The removed bone was denuded of all soft tissue, morselized, and then later used for interbody graft material. The lateral margin of the ligamentum flavum was resected to expose the ipsilateral exiting and traversing nerve roots. Typically, only the most lateral margin of the traversing root was exposed so that it could be identified, protected, and decompressed as necessary (Fig. 2). If needed, though, the tubular retractor could be “wanded” (angled) medially so that a more extensive decompression could be carried out (including decompression of central canal stenosis). At this point, distraction was performed, which allowed better access to the interspace, improved visualization of the annulus, and further protected the nerve roots. Intervertebral distraction was performed in one of two manners. A separate, 2.5-cm, “mirror image” incision was made on the contralateral side centered over the interspace, and a custom-designed, minimally invasive laminar-type spreader was placed between the spinous processes and used to provide interspinous distraction. Another option was to place the contralateral Sextant (Medtronic Sofamor Danek) screws and rod through this incision, distract the interspace, and then provisionally tighten the screw–rod connections in the distracted position. A discectomy was next performed through the ipsilateral tubular retractor. Epidural veins were controlled with bipolar cautery; thrombin-soaked Gelfoam was used for additional hemostasis, as necessary. Once this had been done, further distraction was achieved using interbody distractors inserted into the disc space through the ipsilateral METRx tube (Fig. 3). This distraction was maintained via provisional tightening of the contralateral Sextant construct (Fig. 4). Customized surgical instruments and the lateral-to-medial trajectory of the tubular retractor allowed

FIGURE 1. A 22-mm-diameter tubular retractor in position, 4.5 cm lateral to the midline. Note the oblique approach (arrow).

FIGURE 2. View through the tubular retractor. The lateral margin of the traversing root is visible (arrow). S = superior, M = medial, I = inferior.
the surgeon to access the contralateral side of the interspace to complete the discectomy and prepare the endplates for fusion. Typically, cartilaginous material was removed from the endplates, but their cortical portions were retained. Depending on surgeon preference, structural allograft bone, cages, bone morphogenetic protein (BMP), and/or local autologous bone graft were placed into the interspace. The local autograft (combined with a BMP-soaked collagen sponge, in some cases) was placed anteriorly and contralateral to the annulotomy within the interbody space. Additional autograft bone was placed into the interspace after insertion of the structural graft, if space allowed. Once the interbody fusion had been carried out, the tubular retractor was removed and an ipsilateral Sextant pedicle screw–rod construct was placed through the same incision. Compression was applied to the construct prior to final tightening, providing compression of the bone graft within the middle column and recreating lordosis. If it had not already been done, a contralateral Sextant construct was placed through the contralateral incision. A 16- or 18-mm-diameter tubular retractor of appropriate length was inserted through the contralateral incision for placement of autograft bone and/or BMP into the facet joint.

**RESULTS**

The mean follow-up was 22.6 months with a range of 18–28 months. There were no conversions from the minimally invasive approach to an open surgery. Bilateral pedicle screws were placed in all cases. The average operative time was 240 minutes (range 110–310 minutes). The mean estimated blood loss was 140 mL (range 50–450 mL). The average length of stay was 1.9 days (range 1–4 days). All 45 patients presenting with preoperative radiculopathy had resolution of their symptoms postoperatively. All patients with mechanical low back pain noted improvement of their pain. Typically, patients progressively increased their activity levels and resumed full activity at 3 months postoperatively. Outcomes were quantified using the VAS and the Oswestry Disability Index. From a preoperative average of 7.2 cm, the VAS score decreased to 2.2 cm at 1 year postoperatively and 2.1 cm at last follow-up. The average Oswestry score decreased from 46% preoperatively to 18% at 1 year and 14% at last follow-up. Narcotic use was discontinued, on average, between 2 and 4 weeks postoperatively. At a minimum of 18 months’ follow-up, all cases appeared to have solid radiographic fusions as judged by the presence of trabecular bony bridging, ≤3° motion on flexion–extension views, and intact hardware.

There were a total of four complications in the series. Two patients required repositioning of misplaced pedicle screws. There were no neurologic sequelae as a result of this. Two other patients developed radiculopathies postoperatively: one due to graft dislodgement and a second to contralateral neural foraminal stenosis. These new radiculopathies resolved with reoperation.

**Case Example**

This patient sustained a distractive flexion injury at L4–L5 in a motor vehicle accident (he was wearing a lap belt but no shoulder harness). He presented 1 week post trauma with mechanical low back pain and bilateral lower extremity pain. Figure 5A is a plain lateral radiograph of the injury. Figure 5B is a magnetic resonance image (MRI) of the same patient that reveals discoligamentous disruption at L4–L5 and retropulsion...
of disc material into the spinal canal. The patient underwent a minimally invasive TLIF via a 22-mm-diameter tubular retractor placed from a left-sided approach. The herniated disc material was removed, and the interbody fusion was supplemented with percutaneous pedicle screws and rods. The patient’s surgery was uneventful. He was discharged on postoperative day 2 and returned to school 1 week later. Figure 5C and D are AP and lateral radiographs taken 2 years postoperatively. They demonstrate a solid fusion, intact hardware, and re-establishment of lumbar lordosis with good maintenance of disc space height. The patient’s skin incisions are shown in Figure 5E. The 1-in incision on the left was the site of the METRx tubular retractor placement and subsequent placement of percutaneous pedicle screws (once the tubular retractor had been removed). The pedicle screws on the right were placed through two separate 0.5-in incisions, as the patient’s spinal deformity did not reduce with simple positioning and the divergent pedicles at L4–L5 required significantly different trajectories for screw insertion.

DISCUSSION

TLIF

The TLIF procedure was popularized by Harms as a method to achieve interbody lumbar fusion through a unilateral posterior approach. As with the PLIF procedure, TLIF offers a number of potential benefits over conventional posterolateral intertransverse arthrodesis, including increased fusion surface area, copious fusion blood supply via cancellous vertebral body bone, complete access for medial and lateral decompression, and restoration of intervertebral body height. However, PLIF has been associated with a significant rate of neurologic injury secondary to the retraction and manipulation of the neural elements that are required to access the disc space. Ray described a series of 236 patients who underwent posterior placement of an interbody cage and noted a 10% incidence of transient foot weakness postoperatively.

The transfemoral approach of TLIF provides access to the disc space without the need for significant retraction of the
nerve roots or thecal sac. Additionally, the lateral approach makes revision surgeries less challenging, as there is less need to mobilize the nerve roots away from scar tissue. The TLIF approach also preserves the posterior longitudinal ligament complex as well as other midline supporting bony and ligamentous structures, which are frequently disrupted during the PLIF procedure. Last, TLIF is a unilateral procedure and therefore avoids the need for bilateral dissection within the epidural space.

**Rationale for Minimally Invasive TLIF**

Open instrumented lumbar fusion procedures are associated with significant morbidity related, in large part, to the iatrogenic soft tissue and muscle injury that occurs during routine surgical exposure. The deleterious effects of the extensive muscle stripping and retraction have been well documented in the medical literature.8–13,22 These undesired side effects of lumbar surgery occur so commonly that the term “fusion disease” has been coined to describe their occurrence. Kawaguchi et al8,9 evaluated the effects of retractor blade pressure on the paraspinous muscles during surgery. They found that elevated serum level of creatine phosphokinase MM isoenzyme, a direct marker of muscle injury, is related to the retraction duration and pressure. This was corroborated by Styf et al,14 who determined that the retractor blades may, in fact, increase intramuscular pressure to ischemic levels. This iatrogenic muscle injury can cause long-term problems that can negate the beneficial effects of the surgery itself. Rantanen et al15 concluded that patients who had poor outcomes after lumbar surgery were more likely to have persistent pathologic changes in their paraspinous muscles. Mayer et al16 evaluated trunk muscle strength in patients with previous lumbar surgery and determined that patients who had undergone fusion procedures were significantly weaker than discectomy patients. The goal of minimally invasive spinal surgery is to achieve the same objectives as the comparable open procedure via a less traumatic approach. Although lessening the approach-related morbidity is a primary aim of minimally invasive spine surgery, this must be accomplished without compromising the efficacy of the procedure.

In the current study, the authors successfully performed the minimally invasive TLIF procedure in 49 patients using the METRx tubular retractor system. This system evolved from the MED procedure and was initially developed for microdiscectomy; customized instruments as well as larger tubular retractors have made the TLIF procedure feasible.15 Serial dilation of the paraspinous operative corridor allows the surgeon to dissect through the muscle and fascia with minimal tissue trauma. Percutaneous pedicle screws can be placed through the same incisions.17,18

The creation of a working channel between the muscle fibers permits access to the bony anatomy without the need for muscle stripping, unlike the open TLIF procedure. As a result, the estimated blood loss in our series averaged only 140 mL, including pedicle screw placement. Blood loss during conventional lumbar fusion surgery can be quite significant; in fact, patients commonly donate autologous blood preoperatively or a cell saver is used during the surgery. None of the 49 patients required a blood transfusion. They appeared to have less postoperative pain following the minimally invasive TLIF procedure as compared with similar open procedures. This likely underlies the relatively short average hospital stay in this series of <2 days. Moreover, narcotic use was completely discontinued, on average, between 2 and 4 weeks postoperatively. Although there are many potential benefits to the minimally invasive TLIF procedure, the technique does have its drawbacks and limitations. As with any new surgical technique, there is a learning curve that must be surmounted before technical proficiency can be achieved. This is particularly true for minimally invasive procedures, where anatomic disorientation can occur because standard landmarks that are visualized during open procedures may be unexposed. Minimally invasive TLIF is more technically demanding than open TLIF because of the smaller working area and the need for longer and bayoneted surgical instruments. Furthermore, placement of percutaneous pedicle screws requires the surgeon to be able to accurately interpret AP and lateral fluoroscopic images to safely insert these devices.

There were four complications in this series, which occurred fairly early in our experience. Two were secondary to screw misplacement, and the remaining two were because of graft dislodgement and contralateral neural foraminal stenosis. Screw misplacement can be minimized by attention to anatomic detail. Use of intraoperative electromyography might also prove helpful in avoiding this potential complication. Compression of the screw–rod construct at the end of the case, in conjunction with pre-existing (although asymptomatic) contralateral lateral recess stenosis, likely led to the occurrence of contralateral radiculopathy. This could be minimized by avoiding overcompression of the screw–rod construct. Also, when neural compression is present on the side contralateral to the TLIF approach, consideration should be given to direct decompression of the neural structures on that side. This can be accomplished by inserting a tubular retractor through the contralateral incision prior to contralateral percutaneous pedicle screw placement.

Although technically demanding, minimally invasive TLIF offers a number of potential advantages over traditional open, dorsal lumbar fusion techniques. The procedure is feasible and can be performed with a relatively low complication rate. Our preliminary results appear promising. Further analysis and follow-up will be required to determine rates of fusion at 2 years and long-term outcomes.

**REFERENCES**

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