Minimally invasive transforaminal lumbar interbody fusion—indications and clinical experience

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ABSTRACT
Background: Transforaminal lumbar interbody fusion (TLIF) has emerged as one of the common procedures performed by spine surgeons. Back pain and radiculopathy due to degenerative disc disease, spondylolisthesis, or deformity are the usual indications. Minimally invasive surgery (MIS) techniques have proven to be effective in TLIF as they are associated with less blood loss, fewer wound complications and infections, faster recovery, and decreased hospital costs. The novel technique described in this study helps to achieve a circumferential lumbar fusion using a unilateral posterior approach, via a muscle-dilating exposure, thereby minimizing the approach-related morbidity.

Objectives: An overview of the minimally invasive TLIF (MIS-TLIF) procedures including indications, techniques, and clinical experience along with a review of the medical literature is hereby presented.

Methods: All patients who underwent MIS-TLIF for various indications at our institution from 2009 to 2014 were retrospectively reviewed. All patients in this series had low back pain as their predominant symptom, with varying degrees of radicular pain and neurologic symptoms. The data collected retrospectively for analysis were age, gender, previous diagnoses, revision diagnosis, duration of symptoms, levels of fusion, operating time, intraoperative blood loss, clinical and radiographic results after surgery, and complications. Back and leg pain quantified by visual analog scale scores preoperatively, postoperatively, and at the last follow-up were assessed for clinical outcomes.

Conclusions: Our clinical experience along with a review of the medical literature indicates that TLIF can be effectively and safely performed in a minimally invasive fashion for a wide variety of indications.

Key words: Back pain; degenerative disc disease; minimally invasive; radiculopathy; spondylolisthesis; transforaminal lumbar interbody fusion

Introduction
The spinal fusion procedure was introduced as a treatment option for chronic low back pain in degenerative disc disease more than 70 years ago.[1]

Hibbs and Albee were the surgeons to whom the procedure of performing spinal stabilization for the first time in 1911 has been attributed.[2,3] In 1933, Burnig[4] described anterior lumbar interbody fusion (ALIF), following which in 1940, posterior lumbar interbody fusion (PLIF) was performed by Cloward[5] using a spinous process autograft. He reported satisfactory results in more than 85% of 331 patients using this technique in 1951. Due to the high rate of pseudarthrosis with stand-alone grafts, the PLIF technique was augmented with instrumentation—initially utilizing the Harrington rods[6]
in the 1950s, later, the Hartshill rectangle,[7] and finally the pedicle screws.

Transforaminal lumbar interbody fusion (TLIF) was popularized by Harms and Jeszenszky as an alternative to PLIF.[8] TLIF offers several advantages including a decreased retraction of the dural sac that lessens the risk of postoperative radiculopathy. The major difference in the TLIF approach from the regular approaches is that the operation is performed unilaterally, and the bone graft is inserted into the disc space through one side.[9]

A major inconvenience, however, with both the conventional PLIF and TLIF procedures is the surgical approach in which a large midline skin incision has to be made with extensive muscle and aponeurosis detachment, resulting in significant iatrogenic soft tissue damage. They are typically lengthy procedures and require a long exposure, which may result in ischemic necrosis and atrophy of the paraspinal musculature and prolonged back pain.[9]

Foley et al.,[10] described an alternative procedure, the minimally invasive TLIF, which decreased the incidence of soft tissue injury but helped to achieve the same desired surgical objective.

Minimally invasive surgery refers to any procedure that is less invasive than open surgery while being used for the same purpose. The term was first coined by Wickham[11] in 1987 for procedures that would cause minimal damage to biological tissues at the point of instrument entrance. When compared to the open cases, the minimally invasive procedure offer improved peri-operative outcomes, improved or equivalent long-term effectiveness, and reduced rate of infection.[12]

MIS-TLIF, that involves a posterolateral extracanalicular discectomy and fusion, has been been reported as a safe technique. It may be performed without the risk of developing the potential complications of the combined ALIF and PLIF procedure.[8,13] We have been performing the MIS-TLIF for a variety of indications in our patients. This study represents an overview of our clinical experience, indications, and technique along with a review of the relevant medical literature.

Methods

This is a retrospective study of all patients who underwent minimally invasive TLIF at Fortis Hospital, Bengaluru, from 2009 to 2014, operated by the senior author.

Patient selection

Indications

The inclusion criteria included patients with disabling back pain with or without radiculopathy for more than 3 months not relieved by the conservative line of management (muscle relaxants, steroid injections, and pain medications) due to one of these causes: Primary degenerative disc disease at one or more lumbar levels; spondylolisthesis; failed back syndrome; degenerative spondylolisthesis; segmental instability; multiple recurrent disc herniations; and, foraminal stenosis associated with deformity. Patients of all age groups and of both genders were included in the study.

Several preoperative variables were recorded. These included age, sex, medical history, clinical findings, and type and grade of spondylolisthesis. Visual analog scale (VAS) pain scores provided a clinical assessment of low back pain. Spondylolisthesis or slip was measured using antero-posterior (AP) and lateral radiographs. The grade or percentage of slip was measured according to the Meyerding classification.

Surgical methods

The patient was given general anesthesia and placed prone on the operating table in a neutral position. Using fluoroscopic guidance, the correct level was identified and a skin incision 2–3 cm in length was made 3.5–4 cm lateral to the midline spinous process. The side of skin incision and facetectomy was chosen according to the subject’s symptoms of worse leg/back pain [Figure 1].

Deeper layer of the fascia was incised with a stab incision, and the smallest dilator was introduced between the multifidus muscle and the longissimus muscle up to the facet joint. Serial dilatation was done using dilators (MetrRx tube, Medtronic Sofamer Danek, USA). The quadrant retractor system of appropriate length was introduced medially and fixed using a flexible arm attached to the operating table. The AP and medio-lateral portion of the retractor were adequately expanded to expose the operative site including the facet joint and the surrounding area [Figure 2].

Figure 1: (a) Patient position and skin incision, (b) the operative set-up and C-arm fluoroscopy usage
The anatomical location was identified and confirmed using C-arm fluoroscopy [Figure 2]. Under microscopic visualization, the ipsilateral facet joint, pars inter-articularis, and the lamina were identified after removal of soft tissue [Figure 3 and 4]. Cuts were made using bone chisel, through the lamina, just medial to the facet joint and superiorly at the level of the pars, following which the inferior articular process became freely floating and was removed [Figure 3a]. These bone fragments were saved as autografts and were later used during the interbody fusion. The remaining part of the superior articular process of the facet was also resected using high speed drill [Figure 3a-c].

The ligamentum flavum was removed, and the nerve root and dura were identified. If decompression of the contralateral side was required, then the retractor was moved at an angle similar to the angle of the lamina, undercutting was done using drill from the base of the spinous process to the inferior portion of the lamina at the contralateral side, and was continued until the lateral recess of the contralateral side. The contralateral ligamentum flavum was carefully removed using a Kerrison punch, and the nerve root of the contralateral side was visualized.

The intervertebral disc was exposed in the location called the 'Kambin’s triangle’—bounded medially by the junction of the traversing nerve root and dura, inferiorly by the pedicle and supero-laterally by the exiting nerve root.

The posterolateral annulus was incised and complete discectomy was done using specialized instruments [Figure 4d]. The endplate was sufficiently removed using interbody preparation instruments [Figure 3b] until the anterior annulus was identified [Figure 4d and e]. In most procedures, retraction of the dura and the nerve root was minimal.

For interbody fusion, the contralateral side and the anterior portion of the prepared disc space were adequately filled with autologous bone fragments obtained during the operation in all cases [Figure 4f]. Additionally, if required, these were augmented with bone substitutes (beta tricalcium phosphate and hydroxyapatite).

After confirming the correct spacer size using interbody trial spacers, a polyether ether ketone cage [Figure 4g] was also filled with bone fragments and inserted as anteriorly as possible under C-arm fluoroscopic guidance.

Through the same exposure, the ipsilateral pedicle screw fixation was performed [Figure 4h-l]. Posterior fixation on the contralateral side was done using percutaneous pedicle screws and rod insertion (using Sextant or Longitude system— CD Horizon, Medtronic Sofamor Danek, USA) [Figure 5]. This was done as follows: Under anteroposterior and lateral fluoroscopic guidance, each pedicle was traversed with a Pedicle Access Kit needle followed by placement of a guide wire and then the needle was withdrawn. Appropriately sized pedicle screws were then inserted through the guide wire followed by the placement of a percutaneous rod. Intraoperative placement and position of implants were confirmed using a C-arm image intensifier [Figure 5b]. The surgical wound was closed using subcutaneous absorbable sutures.

**Clinical assessment**

For clinical evaluation, the VAS score and Oswestry Disability Index (ODI) before and after surgery, at 3 months, 6 months, and 1 year of follow-up were analyzed. In addition, the operative time, the volume of intraoperative blood loss, the hospitalization period after the surgery, and the time until ambulation after the operation were analyzed.

**Radiological assessment**

For evaluation, X-ray films of anterior-posterior, lateral, and individual Ferguson views at each interbody fusion level were undertaken both in the pre- and postoperative stages. The Ferguson view is an anterior-posterior X-ray directed parallel...
to the end plates of the vertebral body designed to visualize the interbody fusion.

For the evaluation of interbody fusion, at the final follow-up observation, the fusion rate was analyzed by applying the anterior fusion grade described by Bridwell et al., which includes the following four categories: Grade I: Fusion with remodeling and trabeculae; Grade II: Graft intact, not fully remodeled, no radiolucencies; Grade III: Graft intact, but a definite lucency; and, Grade IV: Definitely not fused, collapsed.
Results

A total of 300 patients underwent minimally invasive TLIF at our institute during this study period. Of these patients on regular follow-up, 170 were male and 130 were female patients [Table 1].

All age groups were included in the study. Among these patients who underwent a minimally invasive TLIF, the minimum age was 22 years and the maximum was 81 years and the mean age was 49.2 years.

Most of these patients had single-level TLIF (72%). The mean operative time (skin incision to closure) was approximately 1 h 55 min for a single level fusion. Almost a fifth (21%) of patients underwent a two-level fusion with an operative time of 3.7 h. Among the remaining patients (7%) who had a severe degenerative disc disease at three or more levels, some with lumbar scoliosis or re-do surgeries took longer to complete, averaging around 5.25 h. The estimated total blood loss for a one-level fusion was <60 ml; maximum blood loss was approximately 600 ml for a multilevel fusion. However, no patient required any intraoperative blood transfusion [Table 2].

All patients were mobilized within 24 h from the time of surgery. Due to minimal or no dural retraction during surgery, there were very few complications. Apart from dural tear, which occurred in only four patients (all four patients had undergone previous surgery), no other complications such as radicular pain, nerve root injury or vascular complications were noted in any of the patients.

No pedicle screw-related complications such as revision surgery for malpositioned screws were noted. There were no postoperative infections or prolonged surgery-related morbidity.

Clinical outcome

The VAS score and modified ODI were recorded pre- and postoperatively at 3 months, 6 months, and 1 year of follow-up.

Only three patients underwent revision surgery for adjacent level degenerative disease, one after 8 months, one after 5 years, and another patient after 1 year and then again after 2 years.

The average length of hospitalization was found to be 8.4 days, ranging from 3 to 23 days. Younger patients were discharged earlier as compared to the older adults. The length of stay in some patients was longer due to certain social reasons or associated co-morbid conditions.

Table 1: Demographics

<table>
<thead>
<tr>
<th>Demographics of the patient study group (n=300)</th>
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<tbody>
<tr>
<td>Male (%)</td>
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<tr>
<td>Female (%)</td>
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Table 2: Number of levels fused and estimated blood loss

<table>
<thead>
<tr>
<th>Number of levels fused</th>
<th>Number of patients (%)</th>
<th>Operation time (min)</th>
<th>Estimated blood loss (ml)</th>
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<tbody>
<tr>
<td>One level</td>
<td>72</td>
<td>115</td>
<td>~60</td>
</tr>
<tr>
<td>Two level</td>
<td>21</td>
<td>220</td>
<td>~130</td>
</tr>
<tr>
<td>Multilevel</td>
<td>7</td>
<td>315</td>
<td>~600</td>
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Table 3: Pain scores

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean±SD</th>
<th>P Unpaired t-test</th>
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<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative (within 3 months)</td>
</tr>
<tr>
<td>ODI</td>
<td>58.23±12.25</td>
<td>35.39±16.98</td>
</tr>
<tr>
<td>VAS</td>
<td>6.74±1.34</td>
<td>3.74±2.18</td>
</tr>
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ODI - Oswestry disability index, VAS - Visual analog scale, SD - Standard deviation
The results were then analyzed. VAS was used to determine the pain scores, and modified-ODI to assess the functional outcome of the patients before surgery and after surgery. The mean VAS scores for lower back pain was 6.74 before surgery, and the postoperative scores were 3.74, 2.04, and 1.34 at <3 months, 6 months, and 1 year, respectively [Table 3].

Statistical analysis for lower back pain was done using QuickCalcs GraphPad Software Inc., USA; unpaired t-test was applied to calculate the level of significance. The obtained results showed that there was a significant improvement in pain following the procedure based on the VAS score [Graph 1]. Similarly, ODI scores were also evaluated which suggested a significantly improved functional outcome of the patient following surgery when compared with the preoperative state.

**Radiological outcome**
The pre- and postoperative lumbo-sacral lateral X-rays were used to measure the grade of listhesis and postoperative fusion. The anterior interbody fusion was graded according to Bridwell’s grading which assessed trabeculae formation, graft placement, and radiolucency [Table 4]—67% of the patients in our study showed Grade I fusion at 1 year follow-up [Figure 6].

**Illustrative examples**
Example 1: A 38-year-old male with severe back pain for almost a year, not relieved with analgesics, and presently debilitated due to pain radiating along right lower limb. No neurological deficits were noted. He had a single-level degenerated disc and underwent one-level MIS-TLIF, completely relieved post operation [Figure 7].

Example 2: A 64-year-old male patient had severe low back ache for more than 10 years with symptoms of neurogenic claudication in both lower limbs since 2 years. No neurological deficits or loss of bowel/bladder control were noted. He underwent a two-level MIS-TLIF for his two-level degenerated discs [Figure 8].

Example 3: A 45-year-old male patient with severe back pain was on multiple analgesics but was unable to carry out daily activities due to pain. No neurological deficits
were noted. He underwent a multilevel MIS-TLIF and went home walking on the 4th postoperative day [Figure 9].

Example 4: A 27-year-old female patient presented with chronic low backache since 4 years, with acute worsening over 2 weeks, as well as gradually progressive pain radiating to the left lower limb. She had a high-grade spondylolisthesis and using MIS-TLIF, complete anatomic reduction was achieved. She was pain-free following the procedure [Figure 10].
Example 5: A 68-year-old female patient with severe low back ache for more than 2 years and difficulty in ambulation. She was walking with a bent posture and needed support to walk. She had progressive worsening over a few months with pain radiating to the right lower limb. No other deficits or bowel/bladder involvement were noted. This case of adult degenerative lumbar scoliosis was corrected using the MIS technique [Figure 11].

Discussion

Spinal surgery for degenerative diseases has evolved in an attempt to achieve adequate pain relief with good functional outcomes. Over the years, various interbody fusion techniques have been introduced such as the posterolateral fusion, posterior lumbar interbody fusion (PLIF), direct lateral interbody fusion (DLIF), or anterior lumbar interbody fusion (ALIF) as well as the traditional open transforaminal lumbar interbody fusion (TLIF). Minimally invasive TLIF is rapidly emerging as an acceptable and popular technique. Interbody fusion by the conventional midline posterior approach has been reported to have a higher incidence of complications resulting from severe muscle damage and blood loss due to the dissection and retraction of muscles when compared to MIS-TLIF[8,13]. Long-term results of the later procedure, however, may be similar to that seen in open surgery.[14,15]

This study reveals our clinical experience in achieving a good outcome with the technique of MIS-TLIF utilized in a variety of indications [Table 5]. The incidence of complications has also been noted to be less with MIS, which is comparable to the evidence in literature. There are a few such reports from studies by Indian authors.[8-10] prospectively studied 23 patients with MIS TLIF for degenerative spine disorders and demonstrated a good clinicoradiological outcome. Kandwal et al.[16] analyzed the usefulness of MIS TLIF in 23 cases of tuberculous spondylitis and found a good fusion rate with the use of the procedure.

![Image](http://www.neurologyindia.com)
A review of the literature shows a large number of studies comparing open and minimally invasive TLIF [Table 6]. In this article, we discuss the utility of MIS-TLIF for a wide variety of indications.

**Decreased blood loss and operative time**
In this study, the blood loss was <60 ml during a single-level TLIF, about 130 ml during a two-level TLIF, and about 600 ml during a three-level TLIF. However, none of the patients needed any blood transfusion and also none of them had any surgical drains placed. Studies consistently report a significantly less blood loss with minimally invasive TLIF than with open TLIF. In one of the studies, Issacs et al. [13] showed that the mean intraoperative blood loss for patients treated with open TLIF (1147 ml) was almost 2.5 times greater than the mean blood loss for MIS-TLIF patients (226 ml). Even the operative time was shown to be lesser than if not equal to that of open surgeries, ranging from 2 h for a single-level fusion to 6 h for multilevel fusions, which were comparable with the available evidence in literature.[21‑23]

**Early ambulation**
Studies reveal that patients treated with minimally invasive TLIF show a significantly early ambulation postoperatively than patients treated with open TLIF.[22,23] An earlier mobilization may be the result of diminished postoperative pain. In some studies,[29] the average time to ambulation for patients treated with minimally invasive TLIF (1.2 days) was almost 2 days earlier than the average time to ambulation for patients treated with open TLIF (3.4 days). Our study also shows the same result—all patients were mobilized early and usually within 24 h.

**Shorter length of stay**
In most of the studies,[19‑24] the length of hospitalization was significantly shorter for patients treated with minimally invasive TLIF than for patients treated with open TLIF. In fact, in one study,[29] the mean length of stay for patients treated with minimally invasive TLIF was as short as 3.2 days—almost 3.5 days shorter than the length of stay for patients treated with the open TLIF (6.8 days) procedure. In the present study, the mean length of hospitalization was 8.4 days, ranging from 3 to 23 days. Younger patients were discharged earlier as compared to the older adults. The longer duration of hospitalization in some patients was due to social reasons or due to the co-morbid conditions associated with some elderly patients.

**Other complications**
In the present study, the complications related to surgery in the immediate post operative period were minimal, and no infection was reported in any of these patients. Only four patients had cerebrospinal fluid leak/dural tear; however, no other complications such as atelectasis, switching over from the percutaneous to open technique, neurological deficits, implant malposition, hematoma, anemia, cage migration, wound infection, deep venous thrombosis, ileus, or nonunion were seen. None of the cases required a revision surgery. These good results have also been reported in literature.[34]

The quantitative analysis of back muscle degeneration after posterior lumbar fusion has also been done in some studies and a comparison of minimally invasive and conventional open surgery has been carried out. A significant muscle atrophy is usually evident following open surgery.[35]

**Fusion rates**
The present study showed satisfactory fusion rates (96%) which correlated well with the rates reported in literature.[26,28,30,33] The limited exposure inherent in all minimally invasive fusion techniques has the potential to affect the placement of adequate bone grafts and to carry out adequate graft site preparation to allow for arthrodesis to occur. Despite this concern, numerous studies have shown that the minimally invasive TLIF procedure has the potential to achieve comparable fusion rates to the conventional open surgical techniques [the minimally invasive TLIF showing a 93.4% and the open TLIF procedure showing a 93.8% fusion rate].[36]

**Pain relief**
The VAS score has been used to assess the degree of pain in many studies including the presenting one. The level of pain has been shown to be significantly reduced postoperatively utilizing this procedure.[20,26,28] None of the patients in this study received analgesics for more than 48–72 h. following surgery.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Literature</th>
<th>Present series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients</td>
<td>778 (16 case series)</td>
<td>300</td>
</tr>
<tr>
<td>Mean blood loss (ml)</td>
<td>255</td>
<td>263</td>
</tr>
<tr>
<td>Mean operative time (mins)</td>
<td>228</td>
<td>216</td>
</tr>
<tr>
<td>Pain relief (change in VAS)</td>
<td>5.2</td>
<td>5.4</td>
</tr>
<tr>
<td>ODI (improvement in %)</td>
<td>29.5</td>
<td>43.6</td>
</tr>
<tr>
<td>Fusion rates (%)</td>
<td>93.5</td>
<td>96</td>
</tr>
<tr>
<td>Complications (%)</td>
<td>14.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Infection</td>
<td>6.9</td>
<td>0</td>
</tr>
<tr>
<td>UTI</td>
<td>3.4</td>
<td>0</td>
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<tr>
<td>Neurologic deficits</td>
<td>20.7</td>
<td>0</td>
</tr>
<tr>
<td>Screw/cage complications</td>
<td>44.8</td>
<td>0</td>
</tr>
<tr>
<td>CSF leak</td>
<td>10.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Blood transfusion/coagulation</td>
<td>3.4</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>10.5</td>
<td>1.3</td>
</tr>
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</table>

VAS - Visual analog scale, ODI - Oswestry Disability Index, UTI - Urinary tract infection, CSF - Cerebro spinal fluid
There is increasing evidence to support that MIS-TLIF is a safe technique that can be used for a wide variety of indications. It has significant advantages over the open surgical procedures. The results in our series are comparable to that in the literature [Table 7]. This appears to be a large series reported from India. It is also worthy of note that in this series, there were no implant related infections.

**Limitations**

This study, however, has a few limitations. Firstly, this was not a randomized controlled study with a control group. This study was designed to analyze the role of MIS-TLIF procedure over a wide variety of cases; hence in this study, it was not intended to compare the results of the minimally invasive procedures with the conventional posterior open fusion procedures. There are inherent drawbacks in this study of being a single center, retrospective study. Yet, all patients were consecutively selected and prospectively worked up. Secondly, although surgical cases were included from 2009, the follow-up period was not sufficient. To overcome these limitations and to obtain more objective results, further comparative studies with a longer follow-up, as well as large scale prospective studies, may be required.

Further, certain technical limitations to the MIS-TLIF procedure may also arise in some rare situations. This procedure may allow only a partial unilateral laminectomy, which may not suffice when severe canal stenosis may require a more extensive decompression. Contralateral nerve root decompression may pose challenges. Some cases of spondylolisthesis may also be difficult to address using this procedure. In this situation, an open approach may be more beneficial. Yet, these limitations remain few and may be surmounted by proper patient selection and the surgeon's experience.

**Conclusions**

MIS-TLIF is a procedure that is routinely used for spine surgeries at our center. It is a safe technique and may even be a procedure of choice for a wide variety of indications with favorable results. With sufficient experience and a modest learning curve, this technique is associated with far fewer risk of complications than the open procedure.

**Acknowledgment**

We would like to acknowledge Clare Claiton, M.Sc., for her help in the preparation of this manuscript.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

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