

Minimally invasive transforaminal lumbar interbody fusion for dual-segment lower lumbar degenerative disease

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Abstract

Introduction: Transforaminal lumbar interbody fusion (TLIF) has been widely used to treat degenerative lumbar diseases. The PIPELINE Access minimally invasive system allows reduction of the trauma to the patient during TLIF.

Aim: To present our preliminary experience with the minimally invasive TLIF (mTLIF) technique performed on the first 7 patients with dual-segment lower lumbar degenerative disease (DS-LLDD).

Material and methods: A retrospective analysis was performed on the first 7 patients with spondylolisthesis and foraminal stenosis operated upon between January 2011 and June 2013. All 7 patients underwent fusion at the L4-S1 level.

Results: The pedicle screws entered the spinal canal in 2 patients. No other intraoperative or postoperative complications occurred with the mTLIF technique. Improvement of the leading symptom in the early postoperative period (sciatica: 7/7, low back pain: 7/7) was achieved in all patients. The mean improvements in the visual analog scale scores for low back and leg pain were 5.1 and 5.7 points, respectively. The mean Oswestry Disability Index scores were 52% (range: 20–74%) before surgery and 27% (range: 10–48%) at the 3-month follow-up (mean improvement: 25%). The average hospital stay was reduced to 6 days.

Conclusions: Our initial experience suggests that the mTLIF technique is a viable method for treating DS-LLDD. Nevertheless, longer observations on larger groups of patients are needed to reliably evaluate the safety of the method and sustainability of the results.

Key words: pedicle screw, minimally invasive spine surgery, transforaminal lumbar interbody fusion, lumbar degenerative disease.

Introduction

Since Harms and Rolinger first described transforaminal lumbar interbody fusion (TLIF) in 1982 [1], this approach has been widely used in treating degenerative lumbar diseases [2–5]. Unlike that in posterior lumbar interbody fusion (PLIF), the TLIF device enters the intervertebral space through the posterolateral intervertebral foramen, avoiding excessive traction or injury to the dura mater and nerve roots, subdural venous plexus bleeding, and formation of

postoperative epidural scars and protecting the anterior longitudinal ligament and most of the posterior longitudinal ligament from injury [6–8]. Transforaminal lumbar interbody fusion has also shown advantages in revision and upper lumbar surgery [9–11]. However, the operative field in traditional TLIF is close to small joints, and requires extensive dissection and traction of paraspinal muscles. Injury to paraspinal muscles can result in postoperative lumbar weakening and chronic low back pain (LBP), thus affecting the postoperative quality of life of patients [8].

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To minimize the incidence of adverse events associated with the surgical approach, a variety of minimally invasive techniques for lumbar spine surgery have been developed. Minimally invasive TLIF (mTLIF), first proposed by Foley *et al.* in 2003 [6], only dilates the muscles, thereby significantly reducing iatrogenic damage to soft tissues. Subsequently, another mTLIF surgical approach via the paraspinous intermuscular space (Wiltse approach) was widely promoted. With continuous improvements in surgical instrumentation and with technological maturity, mTLIF has been widely applied in treating lumbar degenerative diseases such as lumbar disc herniation, lumbar spinal stenosis, or lumbar spondylolisthesis [12–18]; however, the mTLIF procedure is complex and prolonged in multi-segment lumbar degenerative disease, and has a higher intraoperative incidence of adverse events, increasing the demands on the surgeon's skill and patience [12, 14]. In treating multi-segment lumbar degenerative disease, our hospital previously used open TLIF, which led to more bleeding, prolonged postoperative bed confinement, longer average hospital stay, relatively prolonged persistence of various degrees of back pain, and longer recovery time before return to work. Therefore, we began to apply mTLIF to treat multi-segment lumbar degenerative disease, to evaluate its safety and adverse events. In this study, we retrospectively analyzed and reported the clinical data of 7 patients with dual-segment lower lumbar degenerative disease (DS-LLDD) treated using the PIPELINE Access system at our hospital between January 2011 and June 2013.

Aim

We aimed to present our preliminary experience with the mTLIF technique conducted on the first 7 patients with DS-LLDD who were followed up for at least 6 months.

Material and methods

Patients and symptoms

The first 7 patients with at least 6 months' follow-up after a 2-level mTLIF procedure for lumbar degenerative disease were retrospectively analyzed. The group included 4 men and 3 women ranging in age from 35 to 59 years (mean age: 46 years). All procedures were performed between January 2011 and June 2013 by one orthopedist.

In 5 patients, the main indication for surgery was foraminal stenosis. These 5 patients presented with chronic sciatica, and 4 of them had radicular leg weakness. In the remaining 2 patients, the indication for surgery was spondylolisthesis and foraminal stenosis. These patients presented with LBP and minor sciatica. The details of the patients are shown in Table I. In all patients, the indication for interbody fusion was the need for at least unilateral facetectomy.

Anesthesia and positioning

All patients underwent general anesthesia induction and were placed in the prone position, with the chest and iliac crests padded with soft pillows and the abdomen suspended.

Preoperative radiography

The vertebral pedicles were positioned under C-arm radiography guidance preoperatively, with teardrop-shaped shadows appearing in the anteroposterior image (Photo 1). The pedicle shadows were then connected using a marker for labeling.

Surgical procedure

The skin and lumbodorsal fascia were incised in turn along the central connecting line of the pedicles (incision length: ~6 cm). Under C-arm guidance, the needling position of the pedicle screw was explored using a locator, which was then punctured to a depth of about 2 cm at an angle from the 10 o'clock (left) and 2 o'clock (right) positions, respectively. At this time, standard anteroposterior and lateral radiographs were taken simultaneously. If the C-arm-guided screw tip did not exceed the lateral edge of the teardrop shadow, and the lateral image showed that the screw tip had already passed the pedicle, the location of the screw was considered safe and correct (Photos 2 and 3). The screw was then further inserted for about 2–2.5 cm, followed by removal of the locator inner core, placement of an indwelling needle, and withdrawal of the locator.

The gap between the multifidus and longissimus muscles was found under direct vision, and then bluntly dissected with the index finger to the vertebral lamina. The level 1 expansion sleeve of the PIPELINE system was then placed at the outer edge of the upper lumbar vertebral lamina, and gradually expanded to expose the surgical field, including the

Table 1. Summary of 7 patients who underwent the mTLIF procedure

Patient number	Age	Symptom duration	Prior surgery (number)	Main complaint	Sciatica	Strait leg raising test	LBP	Leg paresis	Claudication	Surgery level	Interbody device
1	47	18	0	Sciatica	Yes	40°	Yes	Yes	No	L5-S1	TLIF
2	35	24	0	Sciatica	Yes	30°	Yes	Yes	No	L5-S1	TLIF
3	40	48	0	LBP	Yes	Absent	Yes	No	No	L5-S1	TLIF
4	59	8	0	Sciatica	Yes	50°	Yes	Yes	No	L5-S1	TLIF
5	53	12	0	Sciatica	Yes	60°	Yes	Yes	No	L5-S1	TLIF
6	41	20	0	LBP	Yes	Absent	Yes	No	No	L5-S1	TLIF
7	47	40	0	Sciatica	Yes	40°	Yes	Yes	No	L5-S1	TLIF
Patient number	Length of hospital stay [days]	Follow-up duration [months]	VAS leg before surgery	VAS leg 3 months follow-up	VAS leg diff.	VAS back before surgery	VAS back 3 months follow-up	VAS back diff.	ODI before surgery	ODI 3 months follow-up	ODI diff.
1	4	6	7	1	6	5	1	4	30	24	6
2	5	12	8	2	6	7	2	5	50	20	30
3	6	24	2	0	2	8	3	5	54	28	26
4	5	12	9	1	8	6	1	5	72	30	42
5	4	12	10	2	8	6	2	4	74	48	26
6	6	48	2	0	2	9	2	7	20	10	10
7	5	12	9	1	8	7	1	6	66	32	34

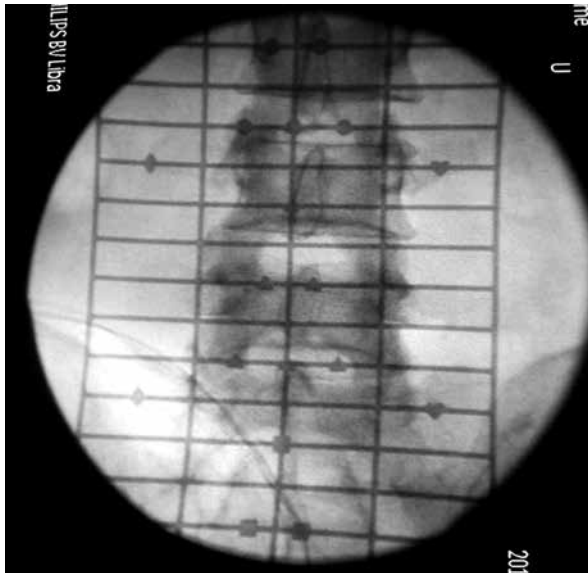


Photo 1. Normal image of vertebral pedicles preoperatively positioned under C-arm-guided X-ray

2 joint capsules of the upper and lower segments for fusion and the outer edge of the upper lamina. The lower lateral articular process at the upper lumbar vertebral lamina and the upper articular process of

the lower lumbar vertebrae were then chiseled away. The ligamentum flavum within the intervertebral foramina was also removed for access. At this time, the upper and lower nerve roots and herniated disc could be seen clearly. After retracting and protecting the upper and lower nerve roots and dural sacs, the intervertebral disc was removed, and the disc space was then carefully processed. The lateral recess of the lower lumbar vertebrae was then blindly expanded for nerve root decompression, followed by interbody bone grafting and placement of the fusion set. The upper disc was then processed using the same method. The pedicle screws were then placed in turn along the direction of the guide pin. After removing the guide pin, one connecting rod was placed on either side and moderately compressed to restore lumbar lordosis and prevent the displacement of interbody fusion. One drainage tube was placed in the decompression zone.

Efficacy determination

The operative time, intraoperative blood loss, adverse events, and length of hospital stay were analyzed. The visual analog scale (VAS) was used to assess pain intensity before surgery, and at 3 days

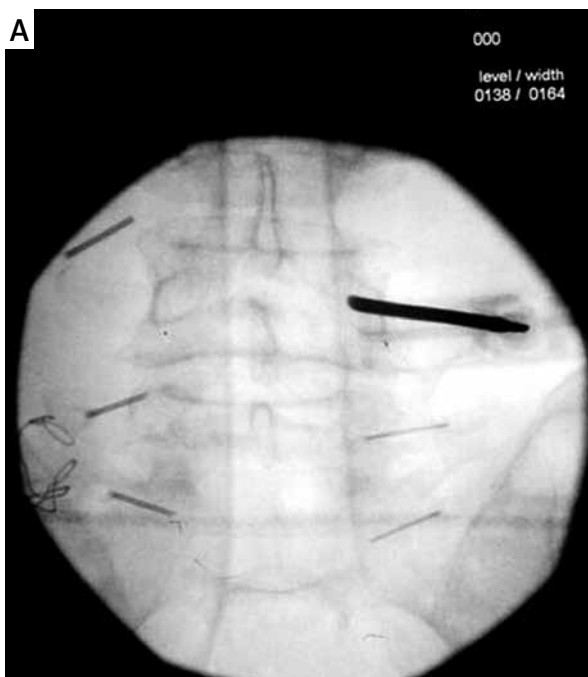


Photo 2. Intraoperative C-arm-guided normal image showed that the screw tip did not exceed the lateral edge of the “teardrop” shadow, and the lateral image showed that the screw tip had already passed the pedicle; the location of the screw thus could be confirmed as safe and correct



Photo 3. A, B – Preoperative images of lumbar over-flexion and over-extension indicated L4 slippage ($^{\circ}$) and L5 lumbar spondylolysis, **C** – preoperative MRI indicated L4-S1 disc degeneration and smaller sagittal diameter, **D-F** – normal, lateral, and sagittal CT images, respectively, 4 months after the surgery indicated that the lumbar spondylolysis was reduced without loss, the lumbar physiological curvature was restored well, the inner fixation had no shift, and the interbody bone grafts had begun fusion

and 3 months after surgery, as well as for subjective feelings 6 months after surgery, to comprehensively determine the efficacy of the method [19]. The assessments were as follows: excellent – LBP and leg pain had completely disappeared, and the patient had no physical activity limitation, had no need for

painkillers, and could squat; good – most of the back and leg pain had disappeared, and the patient could engage in previous work, had mild limitations in physical activity and occasional need for painkillers, and could squat; acceptable – LBP and leg pain had partly disappeared, and the patient could engage

in previous work or light physical work with slight limitations, had a common need for painkillers, and could squat with a slight limitation; and poor – back pain and leg pain were unchanged or worse, and the patient could not perform previous work, had significantly limited physical activity, had regular need for painkillers, and could not squat without support. The functional status was assessed using the Oswestry Disability Index (ODI). The radiographs and computed tomography scans were evaluated and compared for signs of hardware failure, screw loosening, spinal instability, and vertebral fusion. The outcome was evaluated at a minimum of 3 time points: 3 days, 3 months, and 6 months after surgery.

Results

Operative duration and intraoperative blood loss

The operative time ranged from 180 to 300 min (mean: 200 min). The mean intraoperative blood loss was 250 ml (range: 120–600 ml).

Intraoperative adverse events

The pedicle screws entered the spinal canal in 2 patients, requiring repair and correction. No injury to the dural sac or nerve roots occurred intraoperatively.

Postoperative bed confinement time and average hospital stay

The postoperative bed confinement time was 1–2 days, and the mean hospital stay was 5 days.

Postoperative follow-up and efficacy

The patients were followed up for 6 months to 2 years, with a return-to-work time of 1–2 months. Improvement of the leading symptom in the early postoperative period (sciatica: 7/7, LBP: 7/7) was achieved in all patients. All patients recovered well, and excellent or good results were achieved in 100%. According to the VAS, the mean LBP intensities were as follows: before surgery 6.8 (range: 5–9), before discharge 3.6 (range: 0–6), and at 3-month follow-up 1.7 (range: 1–3). For leg pain, the mean VAS scores were as follows: before surgery 6.7 (range: 2–10), before discharge 3.2 (range: 1–4), and at 3-month follow-up 1.0 (range: 0–2). The mean improvements in VAS for LBP and leg pain were 5.1 and 5.7 points,

respectively. The mean ODI scores were 52% (range: 20–74%) before surgery and 27% (range: 10–48%) at the 3-month follow-up. A mean improvement of 25% in the ODI compared to the preoperative baseline was achieved.

Discussion

Posterior lumbar interbody fusion and TLIF are the primary methods used for the treatment of lumbar degenerative diseases. However, both techniques involve an extended incision, major surgical trauma, and a large amount of intraoperative bleeding [20]. Furthermore, because of extensive dissection of the paraspinal muscles, postoperative back pain and weakness may persist, thus affecting lumbar function [8]. During mTLIF, 1 expandable sleeve is inserted intramuscularly, enabling procedure completion with the sleeve. The lesion can be exposed with small incisions, and iatrogenic soft tissue injuries can be minimized. mTLIF also reduces the occurrence of denervation and paraspinal edema caused by peeling of lumbodorsal muscles [21]. Intraoperative blood loss, operative time, and postoperative need for pain-killing medication were reduced [22–24], enabling earlier ambulation and reducing the incidence of deep vein thrombosis [25]. The hospital stay and return-to-work time were shortened, providing economic and social benefits for hospitals and society [26].

In this study, the desired effects of mTLIF were achieved in 7 patients with DS-LLDD, and the advantages were especially apparent in terms of reduced intraoperative blood loss, postoperative bed confinement time, postoperative pain intensity, and average hospital stay, with earlier rehabilitation than with TLIF. However, the disadvantages were the relatively longer operative time and higher rates of intraoperative adverse events, which were caused by the limitations of mTLIF itself (i.e., as the surgery is performed through a small tube, there are greater limitations in vision and positioning than in open surgery). Moreover, the longer operative time and more complex procedure of 2-segment mTLIF can challenge the surgeon's skill and patience [12, 14]. Surgeons must be familiar with both open and minimally invasive surgery, and must be knowledgeable about the 3-dimensional anatomy around the spine. The pedicle screws were inserted into the spinal canal in 2 patients, requiring postoperative repair and correction,

although no dural sac or nerve root injury occurred. The lessons and experience from these failures can be summarized as follows: intraoperative localization should be confirmed using both standard anteroposterior and lateral radiographs, with the anteroposterior radiograph emphasized to ensure that the spinous process is located midway between the bilateral teardrop shadows; the anatomical characteristics of the images should be combined, and the needling point should be located slightly outside of the teardrop; when the needling point is determined, and the screw has been inserted 2 cm, an anteroposterior radiograph should be taken again to confirm that the screw tip does not extend beyond the edge of the teardrop; the anteroposterior radiograph should be combined with the lateral image to confirm that the screw tip has passed through the pedicle and is in a safe and correct position; and an ambiguous screw position intraoperatively should be confirmed with intraoperative C-arm-guided 3-dimensional scanning for timely adjustment.

Conclusions

In this clinical study, we found that the 2 cases of screw insertion into the spinal canal occurred because of misjudgment of the standard position of the positioning needle. After the analysis, we established new assessment criteria, as follows: the positioning needle should be just through the pedicle on lateral radiographs and not exceeding the inner edge of the teardrop shadow on anteroposterior radiographs. This assessment method can improve the accuracy of screw positioning. In addition, it is crucial to ensure that the pedicle screw nail enters in a straight line; otherwise, placement of the pedicle screw connecting rod would be difficult in 2-segment fusion. The clinical data showed that the PIPELINE system is a viable tool for TLIF in DS-LLDD. However, as the sample size was not large, we plan to apply this method to more clinical cases to obtain more clinical data and confirm its clinical efficacy.

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Conflict of interest

The authors declare no conflict of interest.

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