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Minimally Invasive Transforaminal Lumbar Interbody Fusion for the Treatment of Degenerative Lumbar Diseases

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Study Design. Prospective cohort study.

Objective. To determine whether minimally invasive transforaminal lumbar interbody fusion (TLIF) using the tubular retractor system reduces the approach-related morbidity inherent in conventional open surgery.

Summary of Background Data. Posterior lumbar fusion using the tubular retractor system has been reported and described well. Supporters have claimed that minimally invasive techniques reduce soft-tissue trauma, blood loss, postoperative pain, transfusion needs, and the length of hospital stay, as compared with reports describing the traditional open procedure. However, there are few studies of minimally invasive TLIF, especially studies that directly compared minimally invasive and open approaches in a single center.

Methods. Between May 2005 and December 2006, a total of 62 patients underwent 1-level TLIF by 1 surgeon in 1 hospital. Of 62 patients, 32 underwent minimally invasive TLIF using the tubular retractor system, and the other 30 underwent the traditional open procedure. The operative duration, blood loss, complications, and recovery time were recorded. The clinical outcomes were evaluated by the Oswestry Disability Index and the Visual Analog Scale. The soft-tissue injury was assessed by measuring serum creatine kinase. Radiographic images were obtained before surgery and during follow-up.

Results. The minimally invasive group was found to have reduced blood loss, fewer transfusions, less postoperative back pain, lower serum creatine kinase on the third postoperative day, a shorter time to ambulation, and a briefer hospital stay. The Oswestry Disability Index and Visual Analog Scale scores were significantly lower in the minimally invasive group during follow-up. However, the open group had a shorter operative duration. The complications in the 2 groups were similar, but 2 cases of screw malposition occurred in the minimally invasive group.

Conclusion. Minimally invasive TLIF as a management of 1-level degenerative lumbar diseases is superior to the traditional open procedure in terms of postoperative back pain, total blood loss, need for transfusion, time to ambulation, length of hospital stay, soft-tissue injury, and functional recovery. However, this procedure takes longer operative duration and requires close attention to the risk of technical complications. Longer-term studies involving a larger sample are needed to validate the long-term efficacy of minimally TLIF.

Key words: minimally invasive, traditional open, transforaminal lumbar interbody fusion, tubular retractor system. **Spine 2010;35:1615–1620**

Transforaminal lumbar interbody fusion (TLIF), a unilateral posterior approach for achieving an interbody arthrodesis, is an effective method for the management of a variety of degenerative lumbar diseases. The interspace is accessed by performing a unilateral facetectomy, which exposes the posterolateral disc space. If necessary, the exiting nerve root, traversing nerve root, and adjacent dural sac can be identified and decompressed.[1–8] Nevertheless, like other open posterior procedures, it involves stripping and retracting the paravertebral muscles to provide an adequate surgical field. The iatrogenic injury of muscle and soft tissue is an important cause of postoperative low back pain.[9–14] This pain might even counteract the effects of surgery. Some authors think of the pain as "fusion disease."[9] At the same time, the damage of anatomic structures in spine surgery may have negative effects on adjacent segments. Lai *et al*[15] considered this to be one of the reasons for adjacent segment degeneration after fusion.

The advantages of minimally invasive spinal instrumentation techniques have been reported, including less soft-tissue injury, reduced blood loss, less postoperative pain, briefer hospital stay, and shorter recovery, while achieving clinical outcomes comparable with the equivalent open procedure.[9–12,16–19]

There are few studies of the actual advantages of minimally invasive techniques compared with the traditional open surgery for instrumented TLIF. The purpose of this study was to evaluate the difference between minimally invasive and open TLIF by comparing the perioperative data, and clinical and radiographic outcomes of both procedures carried out by 1 surgeon in 1 center.

Materials and Methods

Patient Population

Between May 2005 and December 2006, a total of 62 patients underwent 1-level TLIF by 1 surgeon in our hospital. Patients admitted on odd-numbered days were assigned to the minimally invasive group, and those admitted on even-numbered

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The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

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Figure 1. Tubular retractor used in the minimally invasive TLIF approach.

Figure 2. Incision about 2.8 cm long.

days were assigned to the open group. Of the 62 patients, 32 underwent minimally invasive TLIF using the tubular retractor system (METRx X-tube, Medtronic Sofamor Danek, Memphis, TN) (Figure 1), and the remaining 30 underwent the traditional open approach. Demographics and procedure data for the 2 groups are listed in Table 1. The index diagnosis was discogenic low back pain, intervertebral space stenosis with unilateral huge lumbar disc herniation, foraminal stenosis, separation of the posterior ring apophysis at the level of spinal stenosis, low-grade spondylolisthesis, and single segmental instability (Table 1). All patients were confirmed by anteroposterior and lateral plain radiographs, computed tomography (CT) scans, and magnetic resonance images (MRI). Patients with previous spinal surgery were excluded. All patients complained of serious low back pain, with varying degrees of radiating pain and neurologic symptoms. Conservative management was no response or inadequate response to total patients for 6 months before surgery.

Table 1. Patient Information

	Minimally Invasive Group	Traditional Open Group	*P*
No. cases	32	30	
Gender (M/F)	18/14	14/16	0.450
Age (yr)	51.4 ± 7.2	52.0 ± 6.4	0.063
Mean height (cm)	167.2 ± 7.9	164.6 ± 8.1	0.201
Mean weight (kg)	65.8 ± 10.9	63.6 ± 11.3	0.436
Medical insurance (%)	71.9	66.7	0.657
Index diagnosis			0.145
Discogenic low back pain	6	4	
Unilateral lumbar disc herniation	13	4	
Foraminal stenosis	3	8	
Separation of posterior ring apophysis	3	4	
Low-grade spondylolisthesis	5	8	
One segmental instability	2	2	
Level of fusion			0.313
L3–L4	1	2	
L4–L5	20	16	
L5–S1	11	12	

Minimally Invasive Technique

In the minimally invasive TLIF group, after induction of general anesthesia, the patient was positioned prone on a radiolucent operating table. Lateral and anteroposterior C-arm fluoroscopic images were obtained to ensure the disease segment, and the pedicle positions were marked on the body surface. Two intended incisions were planned by connecting a line between the outer portions of the superior and inferior pedicles (approximately 3.0 cm off midline) (Figure 2). After skin and thoracolumbar fascial incision, a plane was developed on the lateral border of the paraspinal muscles by using progressively larger dilator tubes. Finally, the tube retractor was expanded to provide an operative field from a diameter of 2.5 to 4.0 cm and achieve pedicle-to-pedicle exposure. For patients with unilateral nerve root compression, TLIF was performed on the symptomatic side to ensure adequate foraminal decompression.

On the basis of anatomic landmarks and monitoring by C-arm fluoroscopy, the pedicles were probed and the pedicle screws were inserted. Furthermore, the pedicle screws and rod contralateral to the decompressed side were connected. Then, sequential distraction of the intervertebral space was achieved by gradually distracting the contralateral pedicle screw and rod system. On the decompressed side, adequate decompression was achieved by cutting the inferior portion of the lamina, hypertrophied superior and inferior articular processes, and ligamenta flava. The intervertebral space and endplate were prepared. Adequate spongy bone was obtained from the iliac crest. Before placing the titanium cages, the anterior disc space was packed with spongy bone. Then, the cages were grafted and the pedicle screws were mildly compressed and enclasped, to restore lumbar lordosis and maintain the restored disc height. Before closing the incision, two 100 mL drainage tubes were placed in the double incision.

In L5–S1 cases, subcutaneous segregation was always performed from the same incision to ilium, and an anular drill was used to obtain spongy bone. In L4–L5 cases, an incision of approximately 1 cm was made at the donor site.

Assessment of Results and Follow-up

The data collected from both groups prospectively were age, gender, preoperative diagnoses, clinical and radiographic results after surgery, surgical time, blood loss, total amount of transfusion, length of hospital stay, time to ambulation, and complications. Before surgery, and on the third and seventh postoperative days, serum creatine kinase (CK) was measured to evaluate soft-tissue injury. All results were evaluated by 2 independent physicians.

A total of 57 patients were followed up for at least 24 months and to a maximum of 42 months; 3 cases with minimally invasive TLIF and 2 with open TLIF were lost to follow-up. The Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) were used to assess the preoperative and postoperative pain and disability status. Anteroposterior and lateral radiographs were also taken on the third day, and on 3, 6, 12, 18, 24, and 36 months after surgery (Figure 3A–D). Six patients with the minimally invasive procedure were checked by multislice CT scans at 6 months after surgery for evaluating fusion status (Figures 3E and 4A–C).

Statistical Assessments

Student *t* test was used to compare continuous variables (age, blood loss, surgical time, time to ambulation, length of hospital stay, and CK levels). The Mann–Whitney test was used for the time to ambulation. The χ^2 contingency table was used to compare dichotomous values (gender, medical insurance, level of fusion, and preoperative diagnoses). Fisher's exact test was used to evaluate the differences in total amounts of transfusion and complications. Tests of between-subject effects were used to evaluate the differences in ODI and VAS scores for postoperative back pain between the groups. In all analyses, a $P < 0.05$ was considered to be significant.

■ Results

There were no statistical differences in the age, gender, height, weight, level of fusion, and preoperative diagnoses between patients undergoing the minimally invasive approach and the open procedure (Table 1). The duration of the open procedure was approximately 16 minutes shorter than the minimally invasive approach, and postoperative drainage did not differ between 2 groups (Table 2). The minimally invasive group had significantly less intraoperative blood loss, total blood loss, and transfusion than the open group (Table 2). The recovery time in the minimally invasive group, including the time to ambulation and length of hospital stay, was shorter than the open group (Table 2). Serum CK was significantly lower in the minimally invasive group than in the open group on the third postoperative day, and the values did not differ by day 7 (Table 3). The average postoperative ODI and VAS scores were significantly reduced in both groups. However, compared with the open group, the scores in the minimally invasive group improved more (Table 4).

Radiographs at the minimum 24-month follow-up revealed neither internal fixation failure (screw breaks and cage shifts), nor adjacent segment degeneration, including intervertebral space stenosis and instability.

Complications are shown in Table 5. In the open approach, 1 case had deep venous thrombosis verified by color Doppler ultrasound and 1 case developed deep wound infection. After closed continuous irrigation and suction drainage, infection was completely controlled. Screw malposition was found in 2 cases in the minimally invasive group, but did not cause neurologic complications. No case needed to be revised during follow-up.

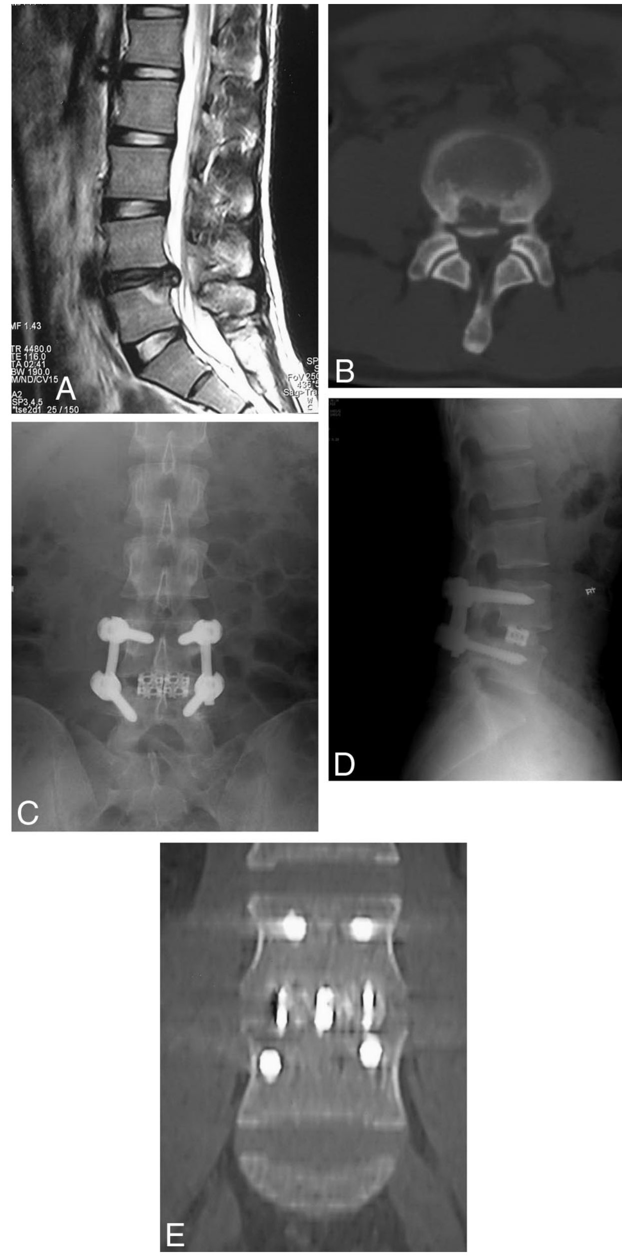

Figure 3. **A,** MRI showing clear compression of the dura at L4–L5. **B,** CT scan showing separation of the right posterior ring apophysis of L5 posterior, and the bone flap intruding toward the spinal canal. **C,** Anteroposterior radiographic image on the third postoperative day showing internal fixation and cages. **D,** Lateral radiographic image on the third postoperative day showing internal fixation and cages. **E,** Coronal CT image reconstruction at 6 months after surgery showing that bony trabeculation crossed the cages/endplate interfaces and a solid fusion was achieved.

■ Discussion

TLIF has gained popularity because of the use of innovative surgical concepts; decompression and cage grafting are performed through a unilateral approach. This approach provides exposure of the disc space while requiring less dural and nerve root retraction. The con-

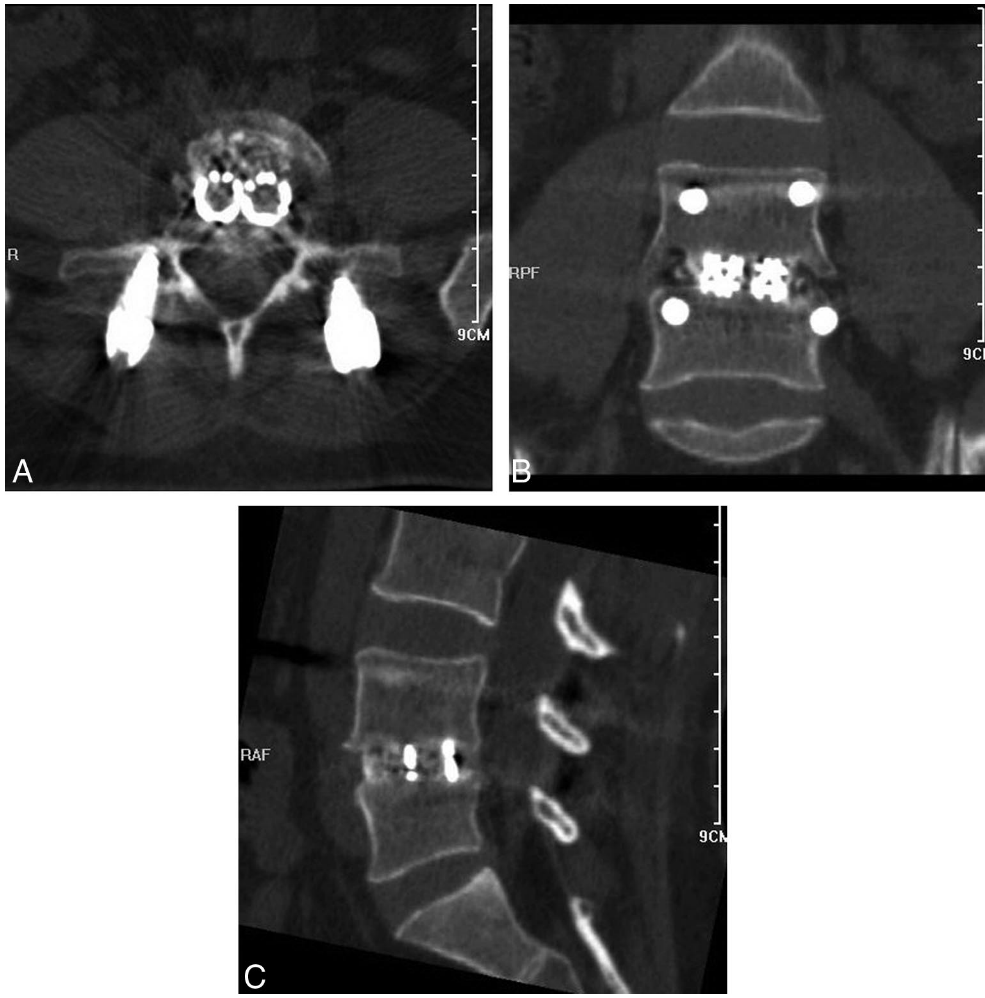

Figure 4. **A,** Horizontal CT image reconstruction at 6 months after surgery showing position of cages. **B,** Coronal CT image reconstruction at 6 mo after surgery showing that bony trabeculation crossed the cages/endplate interfaces and a solid fusion was achieved. **C,** Sagittal CT image reconstruction at 6 mo after surgery showing that bony trabeculation crossed the cages/endplate interfaces and a solid fusion was achieved.

tralateral zygapophysial joint is preserved, and the posterior longitudinal ligament complex as well as other midline supporting bony and ligamentous structures, which are frequently disrupted during the posterior lumbar interbody fusion, are also preserved. In addition, the lateral approach makes revision surgery less challenging, as there is less need to mobilize the nerve roots away from scar tissue.[1–8,20–22] Nevertheless, like other open posterior procedures, TLIF involves stripping and retracting the paravertebral muscles to provide an adequate surgical field. Excessive intraoperative dissection and retraction can lead to atrophy and denervation of the paraspinal muscles, and the normal physiologic function of these muscles may be lost, resulting in an increased risk of "fusion disease."[9–14] Also, damage to soft tissue around the vertebral plate has an adverse effect on adjacent segments and the blood supply for fusion. Complications such as pseudarthrosis and adjacent segment degeneration may occur.[15,23,24]

Unlike the traditional open TLIF procedure, minimally invasive TLIF uses a tubular retractor system to obtain a working channel within the muscle fibers, and

Table 2. Perioperative Data

	Minimally Invasive Group	Traditional Open Group	*P*
Operative duration (min)	159.2 ± 21.7	142.8 ± 22.5	0.005
Intraoperative blood loss (mL)	399.8 ± 125.8	517 ± 147.8	0.001
Postoperative drainage (mL)	178.2 ± 75.2	194.4 ± 79.3	0.412
Total blood loss (mL)	578 ± 138.8	711.4 ± 157.3	0.001
Amount of transfusion (mL)	0 ± 0	0.40 ± 0.97	0.017
Time to ambulation (d)	3.2 ± 1.9	5.40 ± 2.0	<0.001
Length of hospital stay (d)	9.3 ± 2.6	12.50 ± 1.8	<0.001

Table 3. Serum Creatine Kinase for Soft Tissue Injury After Surgery (IU/L)

	Minimally Invasive Group	Traditional Open Group	*P*
Preoperative	66.8 ± 23.7	64.3 ± 15.4	0.644
3 d	642.4 ± 244.5	966.9 ± 259.7	<0.001
7 d	91.9 ± 36.9	97.9 ± 42.5	0.567

Table 4. ODI and VAS for Postoperative Pain and Disability Status at 24-Month Minimum Follow-up

	Preoperative	6 mo	12 mo	18 mo	24 mo
ODI (minimal)*	49.7 ± 11.8	20.5 ± 8.7	22.5 ± 9.7	24.8 ± 11.2	24.7 ± 10.1
ODI (open)	52 ± 12	24.4 ± 10	26.2 ± 9.3	27.1 ± 9.1	27.2 ± 8.4
VAS (minimal)†	6.8 ± 1.2	2.2 ± 1.0	2.4 ± 1.2	2.4 ± 1.4	2.3 ± 1.5
VAS (open)	6.8 ± 1.4	2.6 ± 1.0	3.0 ± 1.1	3.1 ± 1.3	3.2 ± 1.2

*$P = 0.021$.
†$P = 0.008$.
ODI indicates Oswestry Disability Index; VAS, visual analog scale.

permits access to the bony anatomy without stripping muscle. During this process, muscle fibers are pushed aside gradually by the tube wall and a channel is established rapidly and effectively. The time for surgical exposure is shortened. Meanwhile, the muscle fiber organization is not severely disrupted because of being pushed aside in an orderly manner. This may leave fewer scars within the muscle after surgery. Thus, the physiologic function of paraspinal muscles is maximally protected. Furthermore, because the soft tissue is retracted uniformly by the tube wall, excessive local pressure can be avoided or prevented, which helps to alleviate muscle injury. Serum CK is a marker to assess muscle injury.[25–28] In the current study, the serum CK in cases receiving the minimally invasive procedure was significantly less on the third postoperative day, than in those with the open approach.

For the aforementioned reasons, the less traumatic minimally invasive approach may result in less postoperative pain than the open procedure. In the current study, the VAS scores for pain were significantly different between the 2 groups. Also, less intraoperative trauma and postoperative pain allowed patients to ambulate earlier. The average time to walk in the minimally invasive group was 3.2 days, whereas in the open group it was 5.4 days. Regarding the length of hospital stay, the average time in the minimally invasive group was 9.3 days, as compared with 12.5 days the open group, which is a statistically significant difference. This held good for the long-term outcomes. The ODI scores of the minimally invasive group were lower than the open group during follow-up.

Table 5. Complications at 24-Month Minimum Follow-up

	Minimally Invasive Group	Traditional Open Group	*P*
Screw malposition	2	0	0.492
Cage migration	0	0	—
CSF leak	0	0	—
Superficial wound infection	3	1	0.613
Deep wound infection	0	1	0.484
Neurologic deficit (>6 mo)	0	0	—
Deep venous thrombosis	0	1	0.484
Pulmonary embolus	0	0	—
Ileus (>3 d)	1	2	0.607
Nonunion	0	0	—
Revision surgery	0	0	—
Total	6	5	1

Furthermore, almost all the soft tissue in the surgical field was retracted by the tube wall, which not only provided good exposure, but also reduced the intraoperative blood loss. In the minimally invasive group, the average blood loss was 399.8 mL and none needed a transfusion, whereas in the open procedure, the average blood loss was 517 mL and 0.40 U of blood was transfused.

Adjacent segment degeneration from the spinal fusion received special attention. Morbidity can range from 0% to 100%,[29] and it is generally agreed that iatrogenic spine and soft-tissue injury is an important cause.[29–31] The minimally invasive procedure minimizes iatrogenic injury, and is favorable for preventing or reducing the risk of adjacent segment degeneration. From the radiographs, none of the minimally invasive cases showed adjacent segment degeneration, including intervertebral space stenosis and instability of the adjacent segment. No degeneration was identified in the open procedure either. The reasons may be as follows. First, the follow-up time was short. Second, and most important, the cases were only assessed by radiograph during follow-up, except for 6 minimally invasive cases that had CT. To confirm adjacent segment degeneration, MRI or CT scans may be necessary.

Operative Notes and Limitations

It is important to precisely orientate the disease segment before surgery. A guide pin must be placed on the surface of the zygapophysial joints. The pin cannot be moved during insertion of the tubular retractor system, otherwise there might be a risk of the pin penetrating the ligament flava, entering the vertebral canal, and possibly injuring the *cauda equina* or nerve roots. Close to the surface of zygapophysial joints, small-diameter tubes are pushed around to move away the soft tissue in the surgical field and achieve a good exposure. The thoracolumbar fascia is tenacious, and it was hard to expand it with the tubular retractor. So, like the skin, the thoracolumbar fascia is incised with a scalpel. The intervertebral space could be distracted and maintained by using a combination of intervertebral spacers and the contralateral pedicle screws and rod in the distracted position. It should be emphasized that minimally invasive surgery aims to not only to protect normal tissue as far as possible, but also to minimize the skin incision. In our minimally invasive group, the skin incision was slightly longer than the diameter of the retractor, but we did our best to protect the paraspinous muscles and spinal osseous structures.

The minimally invasive procedure depends significantly on the surgeon's skill and knowledge of surgical anatomy. In contrast to the traditional open approach, where the surrounding anatomy is visualized well, minimally invasive exposure is generally limited to the area of surgical interest and key anatomic landmarks within the limited field of view.[10] Thus, a clear understanding of three-dimensional spinal structure is crucial.[9,10] Depending simply on endoscope, it might be difficult to judge the orientation of screw entry and the decompression field. We gained a complete understanding by directly "watching" the operative field through the tubular retractor, in combination with the endoscope system.

The current study had some limitations. First, the follow-up was imperfect. The MRI and CT scans, which could have been used to assess postoperative soft-tissue injury and fusion status, were not performed in all cases. This also limited the assessment of adjacent segment degeneration. Second, the sample size was small and the follow-up periods were not long. Although our preliminary results are promising, the long-term efficacy of minimal TLIF needs to be validated by further studies.

Our preliminary results suggested that minimally invasive TLIF was superior to the traditional open procedure in the management of 1-level degenerative lumbar diseases. The minimally invasive procedure was superior in terms of postoperative back pain, total blood loss, transfusion, time to ambulation, length of hospital stay, soft-tissue injury, and functional recovery. However, it required a somewhat longer operation and closer attention to the risk of technical complications.

■ Key Points

- Minimally invasive TLIF as a management of 1-level degenerative lumbar diseases was superior to the traditional open procedure in terms of postoperative back pain, total blood loss, need for transfusion, time to ambulation, length of hospital stay, soft-tissue injury, and functional recovery.
- Operative duration was longer in the minimally invasive TLIF group.
- Minimally invasive procedure depends significantly on knowledge of surgical anatomy and technical skill.
- Further long-term, prospective, randomized controlled studies involving a larger study group are needed to confirm the long-term advantages of minimally invasive TLIF.

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