CLINICAL ARTICLE

Early Clinical Evaluation of Percutaneous Full-endoscopic Transforaminal Lumbar Interbody Fusion with Pedicle Screw Insertion for Treating Degenerative Lumbar Spinal Stenosis

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Objective: To compare the clinical efficacy of percutaneous full-endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) with percutaneous pedicle screws (PPSs) performed by using a visualization system with that of minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) for the treatment of degenerative lumbar spinal stenosis (LSS).

Methods: From June 2017 to May 2018, the data of a total of 78 patients who met the selection criteria were retrospectively reviewed and were divided into the Endo-TLIF group (40 cases) and the MIS-TLIF group (38 cases) according to the surgical method used. The visual analog scale (VAS) and the Japanese Orthopaedic Association (JOA) scale were administered preoperatively and at the 1-week, 3-month, and 1–2-year follow-ups. The fusion rate and major complications, including revision, were also recorded.

Results: All the patients were followed up for 24 to 34 months, with an average follow-up of 30.7 months. The intraoperative blood loss and length of hospital stay for the Endo-TLIF group (60.56 ± 0.36 mL, 8.12 ± 0.92 days, respectively) were statistically significantly lower than those for the MIS-TLIF group (65.47 ± 0.91 mL, 9.66 ± 1.34 days, respectively) ($P < 0.05$). The VAS and JOA scores of the patients in the two groups at postoperative 1 week, 3 months, 1 year, 2 years (Endo-TLIF VAS: 4.16 ± 0.92, 3.72 ± 1.54, 1.32 ± 0.45, 1.29 ± 0.34; JOA:16.71 ± 0.99, 19.86 ± 0.24, 24.91 ± 0.97, 25.88 ± 0.52; MIS-TLIF VAS: 4.17 ± 1.41, 2.98 ± 0.91, 1.54 ± 0.32, 1.33 ± 0.18; JOA: 16.67 ± 0.67, 19.58 ± 0.65, 25.33 ± 0.73, 25.69 ± 0.33) were statistically significantly improved from the preoperative scores (Endo-TLIF: 8.45 ± 1.44, 14.36 ± 0.56; MIS-TLIF: 8.11 ± 0.93, 14.45 ± 0.34, respectively) ($P < 0.01$). The VAS and JOA scores of the Endo-TLIF group were statistically significantly better than those of the MIS-TLIF group at 3 months and 1 year after surgery ($P < 0.05$). There were no statistically significant differences in the scores between the two groups at any of the other time points ($P > 0.05$). There was no significant difference in the intervertebral altitude between the two groups at the 3-month (11.36 ± 0.23, 11.21 ± 0.42, respectively) or final follow-up (10.88 ± 0.64, 10.81 ± 0.39, respectively) ($P > 0.05$). Dural tears, cerebrospinal fluid leakage, infection, and neurologic injury did not occur. Both groups showed good intervertebral fusion at the last follow-up. The intervertebral fusion rate was 97.5% (39/40) in the Endo-TLIF group and 94.7% (36/38) in the MIS-TLIF group, with no statistically significant difference between the two groups ($\chi^2 = 0.118$, $P = 0.731$). At the final follow-up, the modified MacNab's criteria were 92.5% and 89.5% between the two groups.

Conclusion: Endo-TLIF with percutaneous pedicle screws (PPS) performed by using a visualization system for lumbar degenerative disease may be regarded as an efficient alternative surgery for degenerative lumbar spinal stenosis. It is a safe and minimally invasive way to perform this surgery and has shown satisfactory clinical outcomes.

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Introduction

Lumbar spinal stenosis is a common disease, which is mainly characterized by a series of symptoms of intermittent claudication with or without nerve root pain caused by compression of nerve root and cauda equina. The effect of conservative treatment in most patients is not good, which seriously affects quality of life and often needs surgical treatment.

In 1952, posterior lumbar interbody fusion (PLIF) was first proposed by Cloward[1]. After many technical improvements, new internal fixation devices were released and these operative methods provided a safe and reliable approach for the surgical treatment of degenerative lumbar spine diseases[2–8]. However, intervertebral bone grafts are considered to be the ideal fusion method. There are also several problems, such as the need for partial laminectomy, facetectomy, ligamentum flavum dissection, and open incisions in the musculature. First, the absence of a tension band in the posterior spine not only causes iatrogenic spinal instability, it also increases the load of the internal fixation system. Second, intraoperative extreme pulling of the cauda equina and bilateral nerve roots can increase the risk of nerve injury. Third, these surgical methods have been reported to result in dural sac and nerve root sleeve tears, intraspinal hematoma, intervertebral space infection, severe epidural adhesion, and other complications. Therefore, more minimally invasive surgical methods for decompression and fusion, as well as fixation to increase the stability of the spine, should be explored.

In recent years, with the development of endoscopic decompression technology[9–11], increasingly more types of minimally invasive surgery for spinal diseases have been used[3, 6–8]. However, lumbar degenerative diseases with vertebral instability and narrowing of intervertebral spaces cannot be resolved by endoscopic decompression alone.

However, despite the development of endoscopic fusion technology and vertebral fusion[12], the technology is not as effective as expected. A number of complications have been reported, such as those requiring the need for the fusion device to be removed[12]. Frederic Jacquot reported that seven patients had postoperative radicular pain, 13 (13/57) patients underwent conventional second revisions due to cage migration after a mean period of 8 months, one patient exhibited screw migration, two patients developed infections, and one patient developed a local *Staphylococcus aureus* posterior infection. Therefore, the authors do not recommend the technology until technical improvements are made. Therefore, on the basis of the advantages and disadvantages of various minimally invasive methods, we combined endoscopic transforaminal lumbar interbody fusion (Endo-TLIF) with percutaneous pedicle screws (PPSs). In addition, we further improved the endoscopic decompression technique by using visual technology, which not only reduces the number of fluoroscopies needed, but also improves the safety of surgery. We located the facet joint rather than the tip of the superior articular process. Along the needle, we used a dilating tube to gradually expand the muscle toward the facet joint.

Under the protection of the dilated tube, the soft tissue was cleared, and foraminoplasty was performed under direct vision, which can prevent damage to blood vessels and nerves. It can not only reduce the need for intraoperative fluoroscopy and the amount of radiation that patients and surgeons are exposed to, but can also stop bleeding in advance and provide a clearer surgical field of vision. Continuous saline irrigation was generally used, and the process of foraminoplasty was visualized; thus, total or partial occlusion during facetectomy was avoided, regardless of the surgeon's experience and shorten the learning curve. In previous studies, through the posterolateral Kambin's triangle approach[13] *via* the extendable channel, intravertebral decompression was achieved, a fusion device was implanted, and posterior percutaneous pedicle screws[2] were inserted, which eliminated the dissection of paravertebral muscle to avoid postoperative paravertebral muscle neurodegeneration. In the operation, posterior structures of the spine, such as the spinous process, bilateral facet joints, and lamina were able to be preserved, significantly reducing surgical trauma which can prevent iatrogenic instability and increase the load on the internal fixation system. In addition, the cauda equina and bilateral nerve roots were less detracted, and the recovery time after the operation decreased.

In this retrospective research, our objectives were to: i) introduce a new modified concept and surgical procedures of Endo-TLIF using the full visualization system; ii) demonstratethe efficacy and safety of Endo-TLIF in the treatment of degenerative lumbar spinal stenosis; and iii) explore the advantages of Endo-TLIF by comparing with traditional transforaminal lumbar interbody fusion.

Here, we analyzed 78 cases of degenerative lumbar spinal stenosis treated by Endo-TLIF and minimal invasive-transforaminal lumbar interbody fusion (MIS-TLIF) from June 2017 to May 2018 and compared the clinical efficacy of these two surgical methods, as reported below.

This research was approved by the ethics committee of Third Hospital of Henan Province and was performed according to the ethical standards outlined by the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. All patients signed informed consent forms.

Materials and Methods

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (i) patients diagnosed with lumbar spinal stenosis (LSS), with or without disc herniation; typical symptoms of intermittent claudication and symptoms that could not be alleviated or were aggravated after at least 3 months of nonsurgical treatment; X-ray, computed tomography (CT), or magnetic resonance imaging (MRI) findings (Fig. 1) of the lumbar spine that are consistent with the symptoms and signs; (ii) patients who underwent Endo-TILF or MIS-TLIF surgical methods; (iii) visual analog scale (VAS), the Japanese Orthopaedic Association (JOA) scale, the modified MacNab criteria, and complications were compared; (iv) patient-related outcomes were documented; and (v) a retrospective research.

Exclusion criteria were as follows: (i) patients with spondylolisthesis, instability, and obvious scoliosis or kyphosis; (ii) patients with severe heart, brain, kidney or other types of disease who cannot tolerate the operation; a history of lumbar surgery; severe osteoporosis; or lumbar tumor, tuberculosis or infection.

Patient Data

From June 2017 to May 2018, the data of a total of 78 patients who met the selection criteria were retrospectively

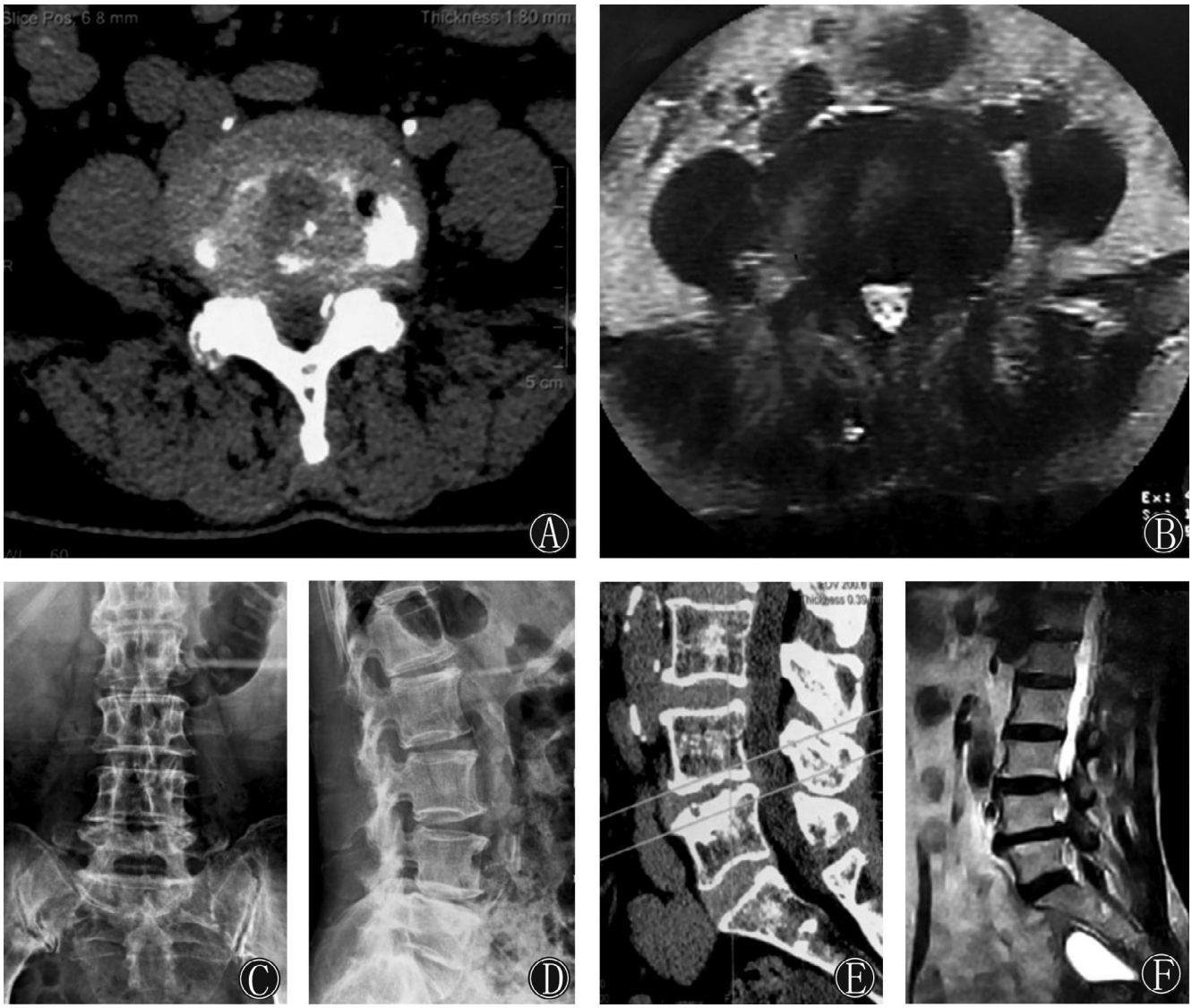

Fig. 1 The CT scans (A, E) of the $L_{4\text{-}5}$ segment revealed a mass disc protruding into the spinal canal and with spinal stenosis. Axial (B) and sagittal MRI (F) revealed $L_{4\text{-}5}$ disc degeneration, intervertebral space stenosis, spinal stenosis, and compression of the dural sac. The preoperative anteroposterior (C) and rightlateral (D) X-ray images of the patient revealed a narrow intervertebral space and hyperosteogenesis.

reviewed, and the patients were divided into the Endo-TILF group and the MIS-TLIF group according to the surgical method used.

There were 40 patients (23 males and 17 females), with an average age of 56.93 ± 1.66 years, in the Endo-TILF group. The levels of LSS were diagnosed to be $L_{3,4}$ in seven cases, $L_{4,5}$ in 24 cases and L_5S_1 in nine cases. Therewere 38 patients (20 males and 18 females), with an average age of 57.01 ± 0.95 years, in the MIS-TLIF group. The levels of LSS were diagnosed to be $L_{3,4}$ in eight cases, $L_{4,5}$ in 22 cases, and L_5S_1 in eight cases. The average disease courses of the Endo-TILF group and the MIS-TLIF group were 8.12 ± 1.32 months and 8.34 ± 0.88 months, respectively. The differences in age, sex, and disease course of the patients were not statistically significant ($P > 0.05$), suggesting comparability (Table 1).

Surgical Procedures

Endo-TILF Group

Anesthesia and Position. Preoperatively, with the patient in the prone position, all patients were under general anesthesia, and continuous routine monitoring was performed for the blood oxygen partial pressure, blood pressure, electrocardiography, neuroelectrophysiology, and blood gas analysis.

Approach and Exposure. We marked the operation puncture angle and projection points for screw insertion on the skin, as demonstrated in Fig. 2A. Intraoperatively, during endoscopic surgery, we used the visualization system. After determining the skin entry point, which is 8 cm away from the posterior midline with an angle of 25° from the horizontal line, the surgeon located the target site, called the facet joint, by inserting an 18-gauge needle under the guidance of the C-arm (Fig. 3A). Then, with guide rod replacement, the working channel was rotated slowly along the direction of the guide bar (Fig. 3B,C).

Decompression. After the ring saw and full-endoscopic device were inserted, radio frequency ablation was additionally used for soft tissue removal, prehemostasis, partial facetectomy and foraminoplasty under the endoscopic visualization system with 0.9% saline solution. After facetectomy and foraminoplasty, the nerve roots and dural sac were exposed (Figs 2B,C). The advantage of this new technology is that the surgical area could be visualized, and total or partial occlusion during facetectomy was avoided, regardless of the surgeon's experience. The ring saw was retreated. Then, complete discectomy and endplate preparation were performed by using pliers under the fluoroscopic and endoscopic visualization system (Figs 2D,E).

Fusion and Fixation. A fusion prosthetic device was implanted for measuring the height of the intervertebral space (Figs 3D,E). After the procedure, the bone fragments were decompressed and allografted (Fig. 2F). Alumbar interbody fusion cage (Fig. 2G) was then inserted into the intervertebral space under fluoroscopic and endoscopic visualization (Figs 3F,G). Pedicle screws and bilateral connecting rods were then inserted, and the instruments were tightened (Figs 3H,I). Finally, the surgical area was thoroughly rinsed, and the bleeding was stopped again. No drainage tubes were placed because they can cause minor surgical trauma. The surgical instruments were removed and the incision was closed. Schematic diagram of the key procedures of Endo-TLIF surgery (Fig. 4).

MIS-TLIF Group

Anesthesia and Position. The patients laid prone on the operating bed under general anesthesia.

Approach and Exposure. C-arm fluoroscopy was used to locate the intervertebral space with the lesion, make an incision at the marked points of the upper and lower pedicles on the decompression side, and gradually separate the subcutaneous tissue and muscle space through the Wiltse approach.

Decompression. After the articular process was defined, the quadrant channel system was placed to expose the operative field, remove part of the vertebral lamina and superior

TABLE 1 Comparison of the baseline data between the Endo-TLIF and MIS-TLIF groups

Item	Endo-TLIF group (n = 40)	MIS-TLIF group (n = 38)	P value
Gender (M/F)	23/17	20/18	>0.05
Age ($\bar{x} \pm s$, years)	56.93 ± 1.66	57.01 ± 0.95	>0.05
Period ($\bar{x} \pm s$, months)	8.12 ± 1.32	8.34 ± 0.88	>0.05
Segment (cases)			>0.05
L_{3-4}	7	8	
L_{4-5}	24	22	
L_5S_1	9	8	
Incision length ($\bar{x} \pm s$, cm)	1.46 ± 0.24	2.31 ± 0.32	<0.01
Operation time ($\bar{x} \pm s$, min)	100.92 ± 1.34	90.45 ± 1.87	<0.001
Estimated blood Loss ($\bar{x} \pm s$, mL)	60.56 ± 0.36	65.47 ± 0.91	<0.001
Hospitalization stay ($\bar{x} \pm s$, d)	8.12 ± 0.92	9.66 ± 1.34	<0.001

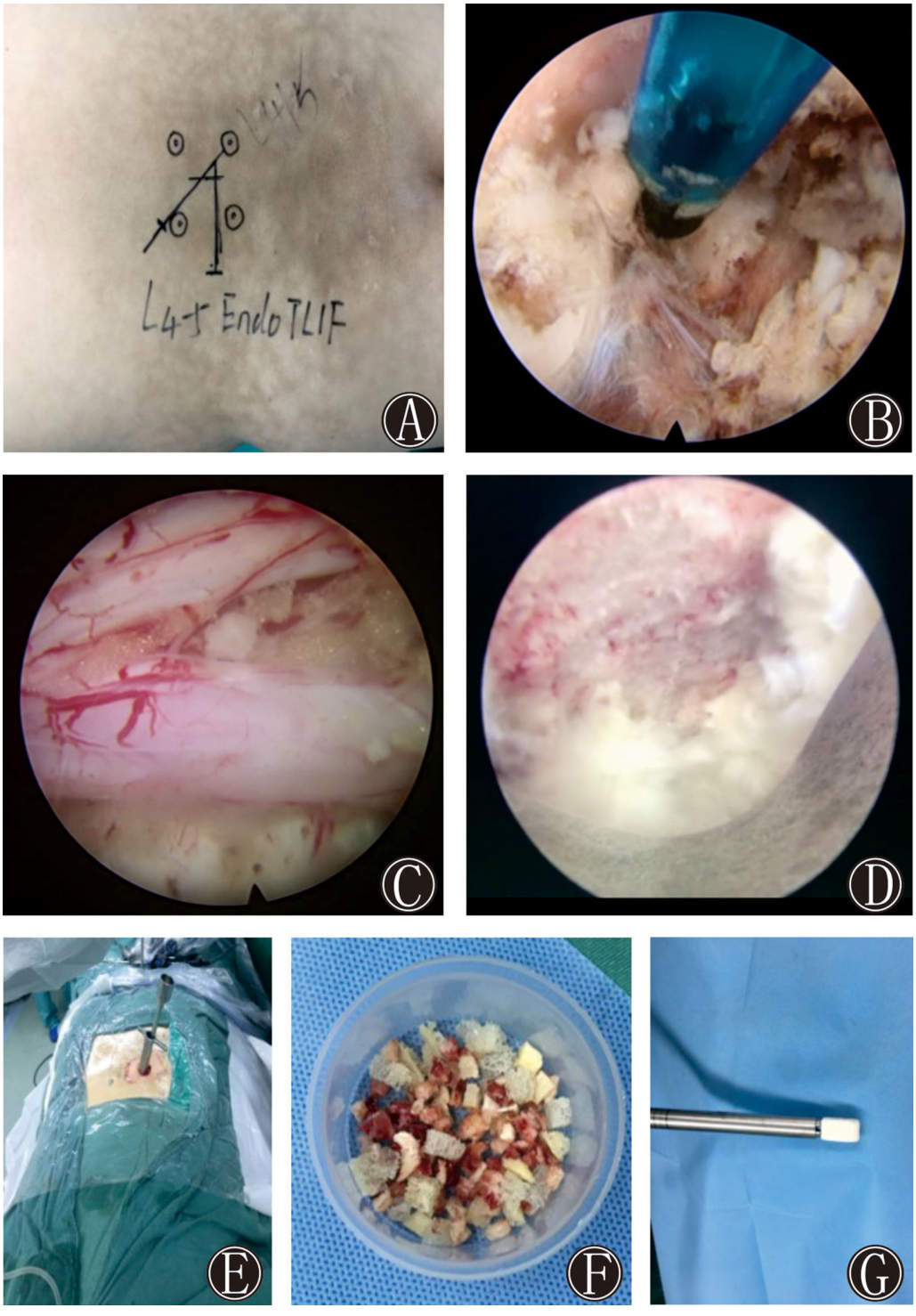

Fig. 2 Percutaneous endoscopic transforaminal lumbar interbody fusion with pedicle screw insertion. (A). The puncture angle marked on the skin. (B). Radio frequency ablation was used for soft tissue removal, prehemostasis, partial facetectomy and foraminoplasty under the endoscopic visualization system. (C). Ipsilateral facetectomy and unilateral hemilaminectomy were performed under endoscopic visualization of the nerve roots, and the dural sac was decompressed. (D). Complete discectomy was performed, and the endplate was prepared under the fluoroscopic and endoscopic visualization system. (E). The endoscopic visualization system was used for transforaminal approaches to the lumbar spine. (F). Bone fragments from decompression and the allograft. (G). A lumbar interbody fusion cage was then placed under fluoroscopic and endoscopic visualization.

and inferior articular processes on the symptomatic side, and fully decompress the central canal and lateral recess.

Fusion and Fixation. The cartilage endplate of the intervertebral space was prepared step by step, the bone that was removed during the operation was trimmed into broken bone particles and used to fill the fusion cage, the excess bone particles were used to fill the front of the intervertebral space for compaction, and then, the corresponding fusion cage was inserted into the intervertebral space. Pedicle screws were routinely placed on both sides, connecting rods were

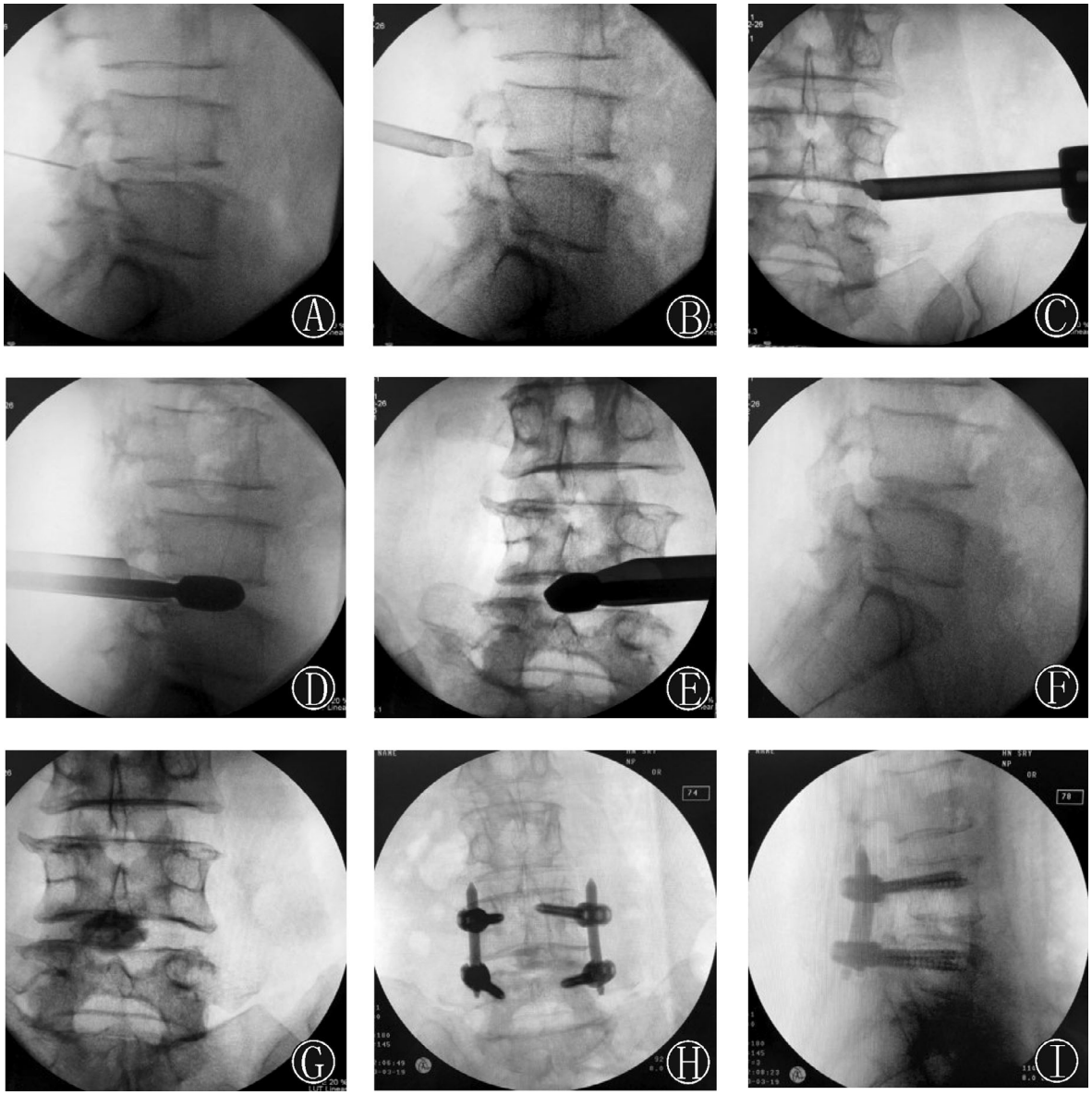

Fig. 3 (A). The target site, called the facet joint, was located by inserting an 18-gauge needle under the guidance of the C-arm to identify the L_{4-5} segment. (B and C). The working channel was rotated slowly along the direction of the guide bar in lateral (B) and anteroposterior (C) X-ray images. (D and E). An image showing a fusion prosthetic device in the disc space. (F and G). An interbody fusion cage was used for fluoroscopic and endoscopic visualization. (H and I). Percutaneous pedicle screw fixation was conducted under fluoroscopic guidance. [Correction added on 15 January 2021, after first online publication: Figure 3 has been amended.]

installed, the operating devices were removed, and the incisions were rinsed and sutured layer by layer.

It was suggested that the patient remained in bed for 2–3 days and took anti-inflammatory and analgesic drugs orally for 1–2 weeks. Lumbar X-ray, MRI, and CT images (Fig. 5) were taken 3 days after surgery. In addition, the patients needed to wear braces for out-of-bed activities for approximately 6–8 weeks.

Outcome Measures

Visual Analog Scale. The VAS was used to evaluate the degree of pain in the back and leg, and the rate of fusion was evaluated according to the Suk criteria. VAS ranges from 0 to 10. A score of 0 means no pain.A score <3 indicates that the patient has mild pain but can bear it. A score of 4–6 means that the patient has pain that affects sleep but is bearable. A score of 7–10 indicates that the patient has

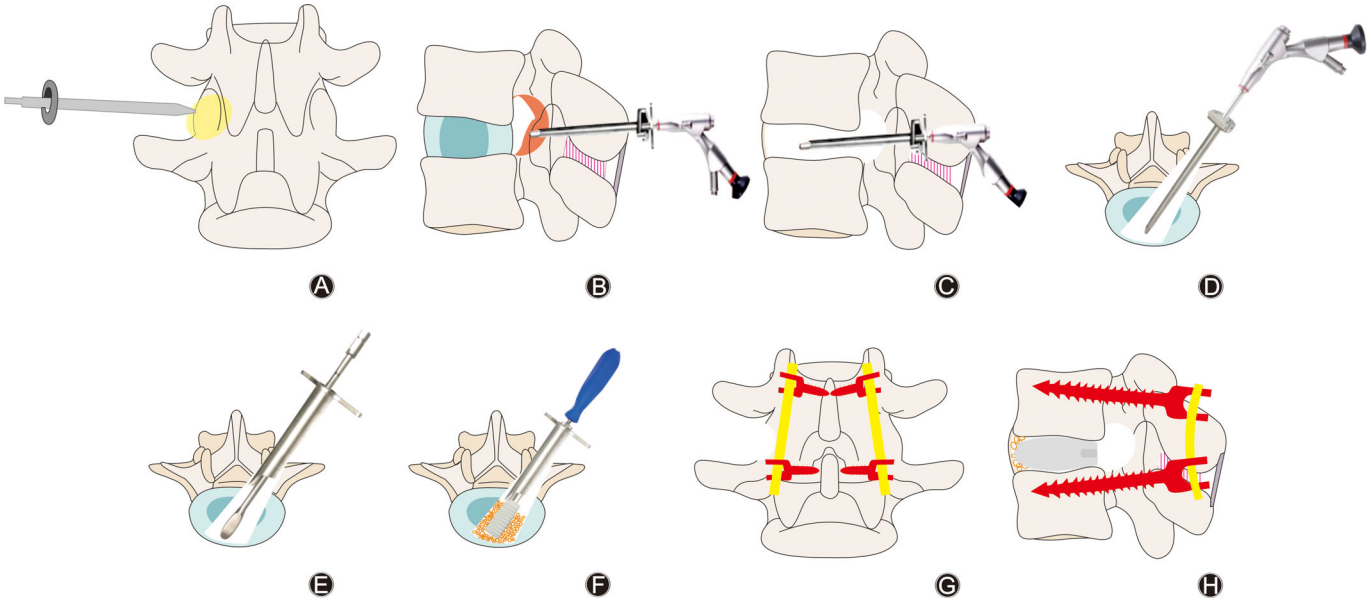

Fig. 4 Schematic diagram of the key procedures of Endo-TLIF surgery. (A). Insertion of the working channel. (B). Partial facetectomy and foraminoplasty under the endoscopic visualization system. (C, D). Discectomy and endplate preparation were performed under the fluoroscopic and endoscopic visualization system. (E). A fusion prosthetic device was implanted for measuring the height of the intervertebral space. (F). Insertion of lumbar interbody fusion cage and autologous bone fragments. (G, H). Fixation of percutaneous pedicle screws and rods.

increasingly intense pain, which is unbearable, affecting appetite and sleep.

Japanese Orthopaedic Association. The JOA score was used to evaluate neurological function, and includes subjective feeling, clinical signs, activities of daily living, and urinary bladder function. The total score of subjective feeling is 9, including low back pain, leg pain and/or numbness and walking ability, and each item is divided into four grades. A score of 3 means normal, and a score of 0 indicates the worst function. The total score of clinical signs is 6, including Lasegue test, sensory and motor disorders, and each item is divided into three grades. A score of 2 means normal, and a score of 0 indicates the worst function. The activities of daily living is 14, including supine turn over, standing, washing, flexion, sitting (about 1 h), weightlifting, walking, each item is divided into three grades. A score of 2 means normal, and a score of 0 indicates the worst function. Urinary bladder function is −6, 0 indicates normal, −3 indicates slight limitation, and 0 indicates obvious limitation. The score range is 0–29 points: the higher the score, the better the functional recovery.

Modified MacNab's Criteria. The modified MacNab's criteria were used to assess the treatment outcomes of the patients. The criteria are as follows with four grades. Excellent: symptoms disappear completely, return to the original work and life. Good: slight symptoms, slightly limited activities, no effect on work and life. Fair: symptoms are relieved, activities are limited, affecting normal work and life. Poor: there is no difference is perioperative period, even aggravated.

The VAS and JOA scale were administered preoperatively and at the 1-week, 3-month, and 1–2-year follow-ups. The fusion rate and major complications, including revision, were also recorded.

Statistical Analysis

All analyses were conducted using SPSS statistical software, version 22.0 (SPSS Inc., Chicago, IL). The summary statistics of the normally distributed quantitative variables were expressed as means and standard deviations. The differences in the means for the continuous variables were compared using Student's *t*-test.The categorical data were summarized as ratios and percentages, and the differences in the proportions were tested by the χ^2 test. A P value of <0.05 was considered statistically significant.

Results

Follow-Up

All patients were followed up for 24 to 34 months, with an average follow-up of 30.7 months.

General Results

The intraoperative blood loss and length of hospital stay for the Endo-TLIF group were significantly lower than those for

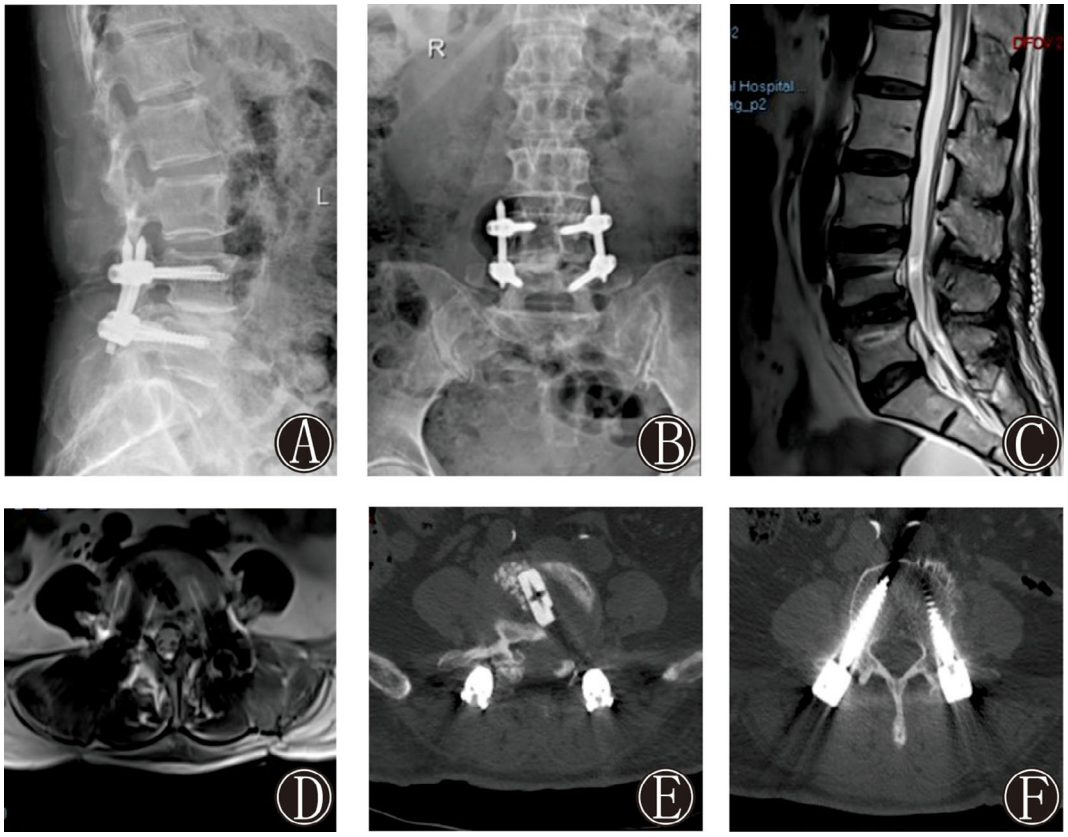

Fig. 5 The postoperative right lateral (A) and anteroposterior (B) X-ray images showed the final construct with the cage and percutaneous pedicle screws. No signs of spinal cord compression were found in the sagittal (C) or axial MRI scans (D) taken at 3 days postoperatively. The CT axial scans of the lumbar spine (E and F) taken on postoperative day 3 indicated that full decompression was performed. The pedicle screws and fusion device were well positioned.

the MIS-TLIF group, with statistically significant differences ($P < 0.05$) (Table 1).

VAS and JOA

The VAS and JOA scores of the patients in the two groups statistically significantly improved from before to after surgery ($P < 0.01$).

The VAS and JOA scores of the Endo-TLIF group were statistically significantly better than those of the MIS-TLIF group at 3 months and 1 year after surgery ($P < 0.05$). There were no statistically significant differences in the scores between the two groups at any of the other time points ($P > 0.05$) (Tables 2 and 3).There was no significant difference in the intervertebral altitude between the two groups at the 3-month or last follow-up ($P > 0.05$) (Table 4).

Modified MacNab's Criteria

At the final follow-up, the modified MacNab's criteria were 92.5% and 89.5% between the two groups.

TABLE 2 Changes in the VAS score from baseline to each time point postoperatively and the differences between the two groups

Groups	Preop	Postop 1w	Postop 3 m	Postop 1 y	Postop 2 y	Statistic value
Endo-TLIF	**8.45 ± 1.44**	4.16 ± 0.92	3.72 ± 1.54	1.32 ± 0.45	1.29 ± 0.34	$F = 3.206$ $P = 0.029$
MIS-TLIF	**8.11 ± 0.93**	4.17 ± 1.41	2.98 ± 0.91	1.54 ± 0.32	1.33 ± 0.18	$F = 2.979$ $P = 0.038$
Statistic value	**$t = 1.231$** **$P = 0.221$**	$t = 0.037$ $P = 0.970$	$t = 2.566$ $P = 0.012$	$t = 2.476$ $P = 0.015$	$t = 0.644$ $P = 0.521$	-

VAS, visual analogue scale.

TABLE 3 Changes in the JOA score from baseline to each time point postoperatively and the differences between the two groups

Groups	Preop	Postop 1w	Postop 3 m	Postop 1y	Postop 2y	Statistic value
Endo-TLIF	14.36 ± 0.56	16.71 ± 0.99	19.86 ± 0.24	24.91 ± 0.97	25.88 ± 0.52	$F = 8.120$ $P = 0.000$
MIS-TLIF	14.45 ± 0.34	16.67 ± 0.67	19.58 ± 0.65	25.33 ± 0.73	25.69 ± 0.33	$F = 8.110$ $P = 0.000$
Statistic value	$t = 0.852$ $P = 0.397$	$t = 0.208$ $P = 0.836$	$t = 2.548$ $P = 0.013$	$t = 2.152$ $P = 0.035$	$t = 1.915$ $P = 0.059$	-

JOA, Japanese Orthopedic Association.

TABLE 4 Changes in the intervertebral altitude from baseline to each time point postoperatively and the differences between the two groups

Time	Endo-TLIF group	MIS-TLIF group	Statistic value
Preop	8.27 ± 0.11	8.35 ± 0.43	$t = 1.139$ $P = 0.259$
Postop 3 m	11.36 ± 0.23	11.21 ± 0.42	$t = 1.970$ $P = 0.053$
Postop 2y	10.88 ± 0.64	10.81 ± 0.39	$t = 0.580$ $P = 0.564$

Complications

In the present series, major complications such as dural tears, CSF leakage, infection, and neurologic injury did not occur. According to the Suk criteria, both groups showed good intervertebral fusion at the last follow-up. The intervertebral fusion rate was 97.5% (39/40) in the Endo-TLIF group and 94.7% (36/38) in the MIS-TLIF group, with no statistically significant difference between the two groups ($\chi^2 = 0.118$, $P = 0.731$). The migration of the lumbar interbody fusion cage occurred in one patient due to a small amount of bone being in the cage. The patient underwent revision surgery and recovered well at 6 months postoperatively.

Discussion

Feasibility of Endo-TLIF in the Treatment of Degenerative Lumbar Spinal Stenosis

In this study, we performed Endo-TLIF with PPSs in patients with lumbar degeneration. According to our results, the effect was excellent or good in 37 cases and fair in two cases. Osman[14] first reported the endoscopic TLIF technique using a working-channel endoscope. In 2019, Nagahama *et al.*[15] reported that 25 patients underwent percutaneous endoscopic transforaminal lumbar interbody fusion (PE-TLIF). The mean follow-up period, surgery time, and blood loss were 22.7 months, 125.4 min, and 64.8 mL, respectively. The JOA score improved from 13.3 to 28.0. The Roland–Morris disability questionnaire score improved from 10.3 to 3.3. Bone fusion was observed 1 year postoperatively in 22 out of 25 patients (88%). The results reported in the literature are comparable to our results.

Efficacy and Safety of Endo-TLIF with Pedicle Screw Insertion

However, the following researchers reported good results. Kamson *et al.*[16] reported that there were two cases of postoperative sympathetically mediated pain and three of 85 patients underwent reoperations (97.6%, 96.4%) due to hardware migration (two incidents) and negative re-exploration (one incident). Nonunion and instability were evident on the dynamic X-rays at the final follow-up in one of 18 patients due to bone resorption in a study by Lee[17]. The patient refused revision because she had comorbidities and a high risk of a poor reaction to anesthesia. In our study, major complications, such as dural tears, CSF leakage, infection, and neurologic injury, did not occur. However, the migration of the lumbar interbody fusion cage occurred in one patient due to a small amount of bone being in the cage. The patient underwent revision surgery and recovered well at 6 months postoperatively. Thus, we consider that internal fixation and the retention of the posterior spinal tension band may lead to few complications, increase the rate of intervertebral fusion and stability, and reduce the occurrence of cage migration.

Compared with the MIS-TLIF group, the Endo-TLIF group had less blood loss, less normal tissue damage, shorter hospital stays and faster recovery. This method helps reduce access trauma by using muscle dilation rather than muscle retraction. Compared with traditional TLIF, this method can not only reduce the risk of surgical injury and the operation cost, but also yield the same benefits. The results of this study showed that this method had the advantages of less trauma, less bleeding, less severe postoperative pain, early onset, faster recovery, and a shorter hospital stay. Complications such as severe epidural adhesion are avoided.

Strategies and Advantages of Endo-TLIF in the Treatment of Degenerative Lumbar Spinal Stenosis

This method is unlike previous methods, such as the transforaminal endoscopic surgical system (TESSYS), which was reported by Hoogland, and the Yeung Endoscopic Spine System(YESS), which was first reported by Yeung[9, 18, 19]. Continuous saline irrigation is generally used. To further improve the safety of endoscopic surgery and shorten the learning curve for surgeons, during endoscopic surgery, we

used the full visualization system. Continuous saline irrigation was generally used, and the process of foraminoplasty was visualized; thus, total or partial occlusion during facetectomy was avoided, regardless of the surgeon's experience (Figs 2B, C). The surgeon located the target site, called the facet joint, by inserting an 18-gauge needle under the guidance of the C-arm rather than at the tip of the superior articular process (Fig. 3A). Along the needle, we used a dilating tube to gradually expand the muscle toward the facet joint. Under the protection of the dilated tube, the soft tissue was cleared, and foraminoplasty was performed underdirect vision with a mirror, which can prevent damage to blood vessels and nerves. It cannot only reduce the need for intraoperative fluoroscopy and the amount of radiation that patients and surgeons are exposed to but also enable radio frequency ablation to be performed under direct vision to stop bleeding in advance, provide a clearer surgical field of vision, and improve the surgical safety.

The development of improved visualization systems[20] and easily maneuverable instruments will make the procedure easier and more practical to perform[21]. Recently, robot-assisted endoscopic transforaminal lumbar interbody fusion was conducted in a patient with multilevel degenerative spondylosis, and this method increases the accuracy of instrumentation placement, decreases the occurrence of complications, and reduces the level of radiation exposure[22]. In general, we think that the use of a robot can not only improve the safety and effectiveness of surgery, it can also shorten the learning curve for surgeons[21]. At the last follow-up, this technique can achieve the same clinical effect as the MIS-TLIF surgery. Thus, Endo-TLIF with percutaneous pedicle screws and a visualization system for lumbar degenerative disease may be regarded as an efficient alternative surgery for lumbar spinal stenosis.

Limitations

In recent years, endoscopic lumbar surgery has evolved from simple decompression to simultaneous decompression and fusion. Although satisfactory short-term results have been achieved, the level of evidence-based medicine is insufficient for the retrospective summary of the experience of a single institution. Nevertheless, we need to conduct long-term follow-up and multicenter, randomized controlled clinical trials to promote evidence-based medicine.

Conclusion

Endo-TLIF with PPSs and a visualization system for lumbar degenerative disease may be regarded as an efficient alternative surgery for LSS. It is a safe and minimally invasive way to perform this surgery and has shown satisfactory clinical outcomes.

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