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Comparison of Outcomes of Lumbar Interbody Fusion and Full-endoscopic Laminectomy for L5 Radiculopathy Caused by Lumbar Foraminal Stenosis

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Abstract

This study compared the outcomes of microendoscopy-assisted lumbar interbody fusion (ME-LIF) and uniportal full-endoscopic laminectomy (FEL) for L5 radiculopathy caused by lumbar foraminal stenosis (LFS). ME-LIF was performed using an 18- to 20-mm tubular retractor and endoscope, and FEL via the translaminar approach (TLA) was performed at the dorsal part of the foramen using a 4.1-mm working channel endoscope. Patients with LFS treated using ME-LIF (n = 39) or FEL-TLA (n = 30) were retrospectively evaluated. Patients' background and operative data were collected. The 36-item Short Form Survey (SF-36), Oswestry Disability Index (ODI), and European Quality of Life-5 Dimension (EQ-5D) scores were recorded preoperatively and 2 years postoperatively. The background data of the two groups (ME-LIF and FEL-TLA) were similar. The mean operation times for ME-LIF and FEL-TLA were 110.7 and 65.2 min, respectively, and the mean length of hospital stay were 10.3 and 1.5 days, respectively. Reoperation was required for surgical site infection, and percutaneous pedicle screw malposition in three patients was treated using ME-LIF. During follow-up, second FEL-TLA and LIF were performed for recurrent L5 radiculopathy in one and three patients in the FEL-TLA group, respectively. Although the SF-36, ODI, and EQ-5D scores 2 years postoperatively improved in both groups, improvement in ODI scores was lower following FEL-TLA than following ME-LIF. FEL-TLA can be performed to treat patients with L5 radiculopathy caused by LFS. Although the ODI score improvement following FEL-TLA was unremarkable, FEL-TLA might be considered because of its better safety profile and minimal invasiveness than ME-LIF.

Keywords: lumbar foraminal stenosis, full-endoscopic spine surgery, minimally invasive, L5 radiculopathy, lumbar interbody fusion

Introduction

Symptomatic L5 radiculopathy caused by L5/S1 lumbar foraminal stenosis (LFS) is a common condition in the elderly.[1-3] Symptomatic LFS has been observed in patients with degenerative disc disease, scoliosis, spondylolysis, spondylolisthesis, and spondylolytic spondylolisthesis. A hypertrophic ligamentum flavum (LF) and osteophytes are occasionally observed in the foramen. Nevertheless, not all patients with the aforementioned pathological findings develop symptomatic LFS. Although L5 radiculopathy is more commonly observed than L1-L4 radiculopathies, the correct diagnosis is difficult to establish. It is sometimes difficult to distinguish LFS from L4/5 intraspinal canal stenosis

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or L5/S1 extraforaminal stenosis.[4] Therefore, L5/S1 LFS is one of the main causes of failed back surgery syndrome.[5]

If L4/5 intraspinal canal stenosis can be excluded, the surgical treatment of L5/S1 LFS is relatively simple. Microsurgical foraminotomy via the Wiltse paraspinal approach is a well-established strategy.[6] This strategy has been modified further,[7-9] and endoscope-assisted tubular surgeries have also been performed instead of microsurgery.[10] For decompression alone, it is important to perform bone removal to a sufficient extent; however, the occurrence of secondary instability is a factor that has to be considered seriously. In view of the instability, lumbar interbody fusion (LIF) has been selected primarily for the treatment of L5/S1 LFS by many spinal surgeons.[3,11] A better clinical outcome following LIF is expected regarding stabilization and gain of foraminal height; however, we could only find one study that compared decompression alone and LIF for LFS.[12] We could not find any study that compared full-endoscopic decompression and LIF for L5/S1 LFS.

Microendoscopy-assisted LIF (ME-LIF) is a combination of endoscope-assisted tubular surgery (decompression and cage insertion) and fixation using a percutaneous pedicle screw (PPS). We and other investigators previously reported that the operative outcomes were similar to those of conventional LIF.[13-18] In contrast, uniportal full-endoscopic spine surgery (FESS) was originally developed for the treatment of lumbar disc herniation and has recently been used for spinal canal stenosis.[19-21] Full-endoscopic laminectomy via the translaminar approach (FEL-TLA) has been developed for the treatment of LFS.[22,23] In the present study, we retrospectively compared the operative outcomes of two operative procedures (ME-LIF and FEL-TLA) and clarified the advantages and disadvantages of these approaches.

Materials and Methods

Patient selection

A total of 188 consecutive patients with L5/S1 LFS underwent posterior decompression using a 4.1-mm working channel endoscope (RIWOspine GmbH, Knittlingen, Germany) or ME-LIF using the METRx endoscopic system (Medtronic Sofamor Danek, Memphis, TN, USA) between January 2016 and March 2019. All patients had apparent L5 radiculopathy that was resistant to medical treatment, epidural steroids, and/or nerve block. All patients had LFS at the L5/S1 vertebral level and were treated using the unilateral paramedian approach. The exclusion criteria were (I) spondylolysis and spondylolytic spondylolisthesis; (II) degenerative spondylolisthesis (Meyerding classification: grade ≥II); (III) L5 radiculopathy that could be definitively diagnosed as extraforaminal stenosis; (IV) L5 radiculopathy that could not be distinguished as radiculopathy caused by combined L4/5 lumbar spinal canal stenosis (LSCS); and (V) LFS with lumbar spinal instability (vertebral motion on the flexion-extension lumbar lateral X-roentgenogram >3 mm). Eighty patients in the ME-LIF group and six in the FEL-TLA group were excluded from this study mainly due to exclusion criteria (I) and (II) and simultaneous surgical intervention for an adjacent vertebral lesion in the ME-LIF group. Sixteen patients in the ME-LIF group and 17 in the FEL-TLA group dropped out because of difficulty in accumulating follow-up data (Fig. 1).

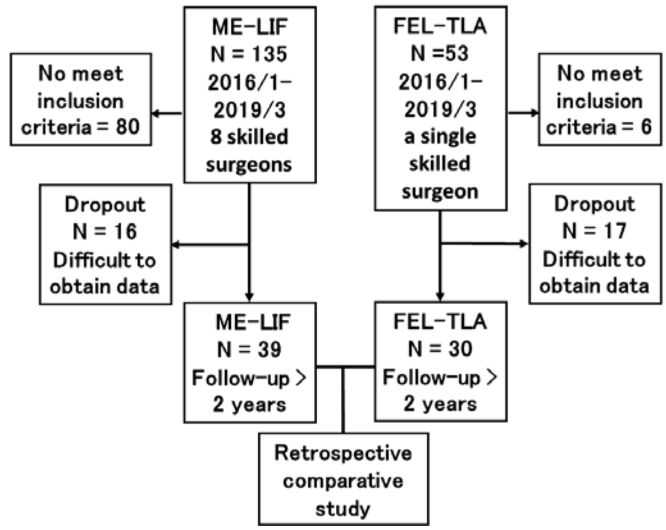

Fig. 1 Flow diagram of the study design.
ME-LIF, microendoscopy-assisted lumbar interbody fusion; FEL-TLA, full-endoscopic laminectomy via the translaminar approach.

All the procedures performed in studies involving human participants were in accordance with the ethical standards of the research committee of Iwai Medical Foundation (IRB approval no. 20200507) and with the 1964 Helsinki Declaration. Disclaimer documents for the surgical procedure were handed to the patients with explanations, and their informed consent was obtained.

Data collection

The patients' background data, including age, sex, body mass index (BMI), radiculopathy site, symptom duration, and presence or absence of preoperative L5 nerve root palsy (manual muscle testing [MMT] ≤3), were recorded (Table 1). Preoperative T2-weighted magnetic resonance imaging (MRI) and computed tomography (CT) were performed to determine the LFS grade according to Lee's classification (Supplementary Figure 1, Grade 0 [normal]; Grade 1 [mild degree of foraminal stenosis]; Grade 2 [moderate degree of foraminal stenosis]; and Grade 3 [severe degree of foraminal stenosis]).[24,25] The operation time, length of hospital stay, and surgery-related complications were obtained from the medical records (Table 2). The bodily pain domain of the 36-item Short Form Survey (SF-36) (scores ranging from 0% to 100%, with lower scores indi-

Table 1 Demographic data of 69 patients

Variables		ME-LIF (N = 39)	FEL-TLA (N = 30)	*p* value
Age, mean (SD)		66 (9.5)	65 (11)	0.92
Sex (male) [n (%)]		22 (56)	21 (70)	0.25
BMI, mean (SD)		23 (3.5)	24 (2.6)	0.17
Radiculopathy side*				0.38
	R [n (%)]	11 (28)	13 (43)	
	L [n (%)]	23 (59)	13 (43)	
	R and L [n (%)]	5 (13)	4 (13)	
Symptoms duration (months), mean (SD)		34 (56)	22 (21)	0.26
Lee's classification				0.017
	1 [n (%)]	3 (7.7)	2 (6.7)	
	2 [n (%)]	30 (77)	14 (47)	
	3 [n (%)]	6 (15)	14 (47)	
Paresis (MMT≤3), [n (%)]		2 (5.1)	3 (10)	0.44
Preoperative SF-36, mean (SD)		31 (7.8)	31 (8.0)	0.99
Preoperative ODI, mean (SD)		37 (14)	36 (13)	0.82
Preoperative EQ-5D, mean (SD)		0.62 (0.10)	0.62 (0.11)	0.93

*ME-LIF was performed on the side where the patient complained of more severe radiculopathy. FEL-TLA was performed on the side where the patient complained of more severe radiculopathy. In only one case, FEL-TLA was performed on both right and left sides with an 11-month interval.
BMI, body mass index; ME-LIF, microendoscope-assisted lumbar interbody fusion; FEL-TLA, full-endoscopic laminectomy via the translaminar approach; SF-36, 36-Item Short Form Survey; ODI, Oswestry Disability Index; EQ-5D, European Quality of Life-5 Dimensions.

Table 2 Univariate analysis of operative outcomes

		ME-LIF (N = 39)	FEL-TLA (N = 30)	*p* value
Operation time (min), mean (SD)		110 (33)	64 (15)	<0.001
Hospital stay (day), mean (SD)		10 (2.6)	1.5 (0.6)	<0.001
Intraoperative bleeding (mL), mean (SD)		34 (47)	2.0 (0)	<0.001
Complications	SSI [n (%)]	1 (2.6)	0 (0)	0.38
	malposition of PPS [n (%)]	2 (5.1)	0 (0)	0.21
SF-36 2 years, mean (SD)		45 (11)	41 (9.5)	0.21
ODI, mean (SD)		18 (17)	26 (17)	0.057
EQ-5D 2 years, mean (SD)		0.75 (0.22)	0.73 (0.18)	0.75

ME-LIF, microendoscope-assisted lumbar interbody fusion; FEL-TLA, full-endoscopic laminectomy via the translaminar approach; SSI, surgical site infection; PPS, percutaneous pedicle screw; SF-36, 36-Item Short Form Survey; ODI, Oswestry Disability Index; EQ-5D, European Quality of Life-5 Dimensions.

cating more bodily pain) was used for the evaluation of the patient's pain.[26] The overall outcome was evaluated using preoperative and postoperative Oswestry Disability Index (ODI) scores (scores ranging from 0 to 100, with higher scores indicating more disability related to back pain) and European Quality of Life-5 Dimension (EQ-5D) scores (scores ranging from 0 to 1, with higher scores indicating better quality of life).[27,28] The SF-36, ODI, and EQ-5D scores were obtained 2 years postoperatively (Tables 1 and 2).

Statistical analysis

The demographic data and outcome measures were compared between the two groups (ME-LIF and FEL-TLA) using the t-test for continuous variables and chi-squared test for categorical variables. The preoperative and postoperative outcome measures were compared using paired t-tests. Multiple linear regression was performed to determine the influence of the operative procedure on postoperative SF-36, ODI, and EQ-5D scores. Potential confounding factors, such as age, sex, and each preoperative measure, were adjusted for. All analyses were performed using STATA version 16.0 (Stata Corp. LLC, College Station, TX, USA). Statistical significance was defined as a two-sided *p*-value of <0.05.

Surgical technique

The patients were carefully logrolled in the prone position. Surgery was performed under general anesthesia combined with monitoring of motor-evoked potentials. During the surgery, a fluoroscope was placed across the center of the operating table to ensure appropriate timing.

ME-LIF was conducted by eight skilled surgeons. An 18- to 20-mm skin incision was made 20-30-mm lateral to the midline for decompression and cage insertion. The basic operative procedure has been described previously.[13-15] In brief, a tubular retractor (METRx: 18 mm, Medtronic Sofamor Danek, Dublin, Ireland) was initially placed at the vertebral lamina overlying the L5/S1 disc. All procedures leading to interbody fusion, including decompression, removal of an intervertebral disc, grafting of autologous bone, and cage insertion, were performed within the tubular retractor. Pedicle screws were inserted percutaneously under fluoroscopic guidance. The preoperative and postoperative CT images and intraoperative microendoscopic surgical field in patients who underwent ME-LIF are shown in Supplementary Figure 2. In addition to the basic endoscope-assisted decompression, we mainly used a 4-mm-wide chisel for bone removal instead of a high-speed drill to collect bone graft materials.

For FEL-TLA using a 4.1-mm working channel endoscope, surgery was performed by a single skilled surgeon (H. Koga). An 8-mm skin incision was made 15-20 mm lateral to the midline immediately above the corresponding L5 foramen under fluoroscopic guidance. The muscle attached to the vertebral laminae (VL) was carefully detached using a dilator. Next, an angled working sheath and endoscope were inserted onto the exposed VL, and the VL and the laterally collating inferior articular process (IAP) were removed using a 3.5-mm-diameter high-speed drill (NSK-Nakanishi Japan, Tokyo, Japan) until the cranial margin of the LF at the foramen could be accessed (Fig. 2A). The exposed superior articular process (SAP) was further removed across the caudal margin of the LF at the foramen (Fig. 2B). In principle, the adjacent vertebral pedicle was not removed to avoid unexpected bleeding. Finally, the underlying L5 nerve root and intervertebral discs were visualized (Fig. 2C). The LF should be removed as much as possible to confirm the underlying L5 nerve root and L5/S1 disc space (Supplementary video 1). If difficulty was encountered in complete removal of the LF, it was detached from the surrounding bone margin and separated from the underlying structures. After removal of the IAP and SAP, we confirmed decompression of the foramen outlet by inserting a curved dissector into the outlet and checking the position in the lateral view using the fluoroscope. After decompression, the endoscope and working sheath were carefully removed, and the skin was closed using a single suture. The extent of bone removal was further confirmed using CT (Fig. 2D-G).

For the reoperation, we carefully explained the advantages and disadvantages of LIF and FEL-TLA to the patient, and the choice was made by the patient. For the second FEL-TLA, partial pediculotomy was performed, but removal of the anterior osteophyte was not performed (Supplementary Figure 3).

Results

The demographic data of the patients are summarized in Table 1. This retrospective study included 39 patients in the ME-LIF group (22 men and 17 women) and 30 patients in the FEL-TLA group (21 men and 9 women). The mean age of the patients at surgery was 65.6 years in the ME-LIF group and 65.8 years in the FEL-TLA group. The mean BMI was 22.9 in the ME-LIF group and 24.0 in the FEL-TLA group. The symptom duration was 34.5 months in the ME-LIF group and 21.0 months in the FEL-TLA group. Both groups included cases of bilateral radiculopathy (ME-LIF, five cases; FEL-TLA, four cases) and moderate-to-severe L5 paresis (MMT ≤3) (ME-LIF, two cases; FEL-TLA, four cases). However, there were no significant differences in the patients' background characteristics between the groups, except in Lee's classification (Table 1).

There was a significant difference in the mean operation time between the ME-LIF group (110 ± 33 min) and FEL-TLA (64 ± 15 min) groups ($p < 0.001$), as well as in the mean length of postoperative hospital stay (10 ± 2.6 vs. 1.5 ± 0.6 days, respectively; $p < 0.001$). There was a significant difference in the mean intraoperative bleeding volume between the ME-LIF (34 ± 47 mL) and FEL-TLA (2.0 ± 0.0 mL) groups ($p < 0.001$; Table 2). Regarding complications, three patients in the ME-LIF group required subsequent operations for operative complications (surgical site infection, one case; malposition of PPS, two cases), but no complications were noted in the FEL-TLA group. During the 2-year follow-up period, LIF (three cases) and second FEL-TLA (one case) were performed for recurrent L5 radiculopathy in the FEL-TLA group.

The bodily pain domain of the SF-36 was used to evaluate the patients' pain. The preoperative SF-36 score (31 ± 7.8) in the ME-LIF group improved significantly postoperatively (45 ± 11; $p < 0.01$). The preoperative SF-36 score (31 ± 8.0) in the FEL-TLA group also improved significantly postoperatively (41 ± 9.5; $p < 0.01$). We further measured the improvement rate of SF-36 scores in the FEL-TLA group compared with that in the ME-LIF group using multiple linear regression analysis, which showed that the improvement in SF-36 scores 2 years after FEL-TLA was not significantly different between the two groups ($p = 0.098$; Table 3).

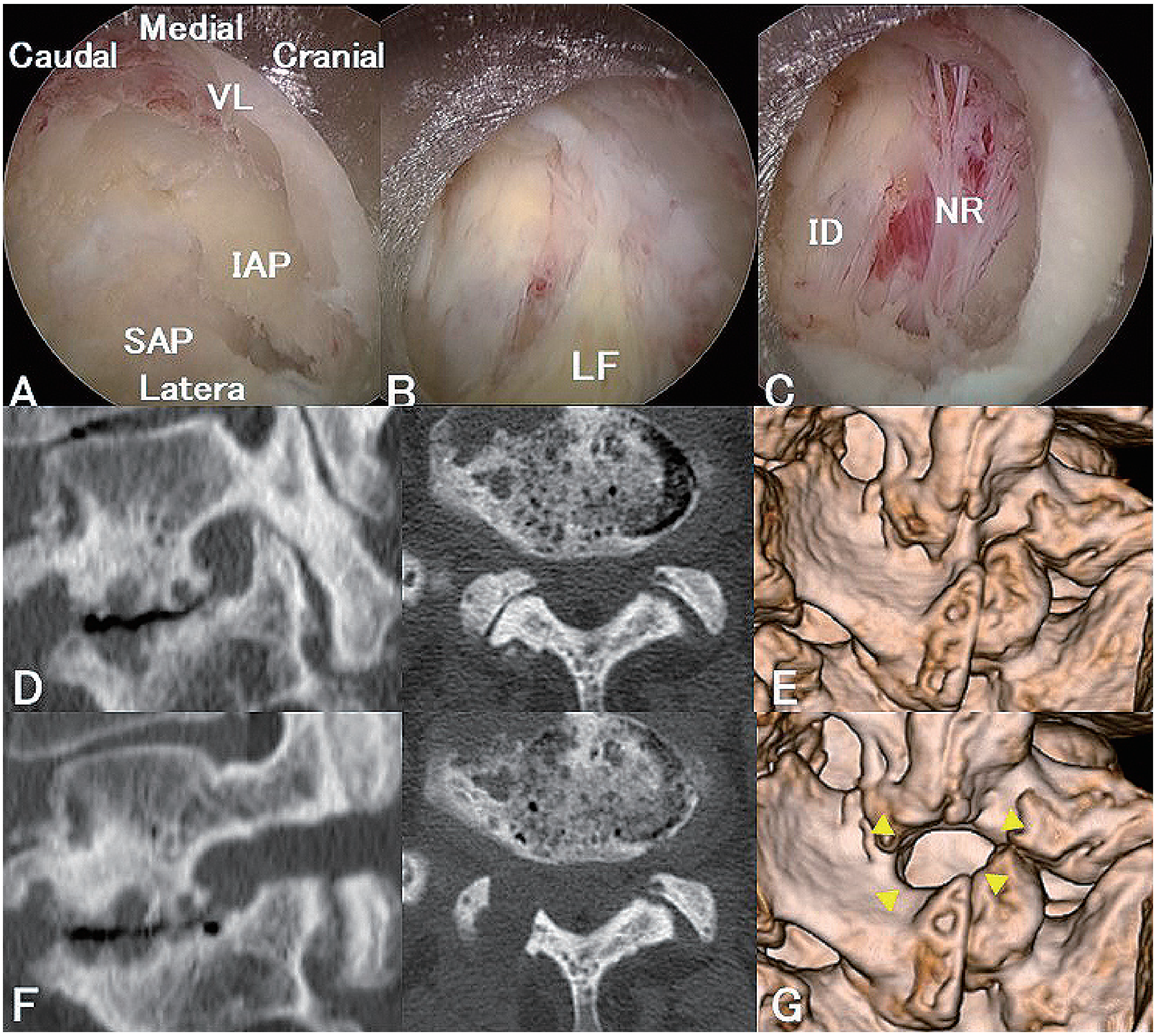

Fig. 2 Stepwise demonstration of full-endoscopic laminectomy via the translaminar approach (FEL-TLA) and preoperative and postoperative computed tomography (CT) images. (A) After removal of vertebral lamina (VL) and inferior articular process (IAP), the superior articular process (SAP) is exposed. (B) After removal of the SAP, the underlying hypertrophic ligamentum flavum (LF) is exposed. (C) After removal of the LF, the dorsal surface of the right L5 nerve root (NR) is exposed. The L5/S1 intervertebral disc (ID) is also visualized at the caudal site of the NR. (D) Preoperative sagittal (left) and axial (right) CT findings in a patient treated with FEL-TLA. (F) Postoperative sagittal (left) and axial (right) CT findings. Preoperative (E) and postoperative (G) three-dimensional CT findings. The arrow heads indicate removed bone areas.

The overall outcome was evaluated using ODI and EQ-5D scores. The preoperative ODI score (37 ± 14) in the ME-LIF group improved significantly postoperatively (18 ± 17; $p < 0.01$). The preoperative EQ-5D score (0.62 ± 0.10) in the ME-LIF group also improved significantly postoperatively (0.75 ± 0.22; $p < 0.01$). The preoperative ODI score (36 ± 13) in the FEL-TLA group improved significantly postoperatively (26 ± 17; $p < 0.01$). The preoperative EQ-5D score (0.62 ± 0.11) in the FEL-TLA group also improved significantly postoperatively (0.73 ± 0.18; $p < 0.01$).

We then measured the improvement rate of ODI scores in the FEL-TLA group compared with that in the ME-LIF group using multiple linear regression analysis, which showed that the improvement in ODI scores 2 years after FEL-TLA was lower than that after ME-LIF ($p = 0.027$; Table 3). Similarly, multiple linear regression analysis performed to determine the improvement rate of EQ-5D scores showed that the improvement in EQ-5D scores 2 years postoperatively was not significantly different between the two groups ($p = 0.73$; Table 3).

Discussion

Uniportal FESS was originally developed for the treatment of lumbar disc herniation and has recently been used for LSCS.[19-21] Technical refinements and the development of new instruments have expanded the scope of target diseases indicative for FESS. However, there are few

Table 3 Multivariate analysis of postoperative SF-36, ODI, and EQ-5D after 2 years

SF-36

Variables Operative procedure	ME-LIF	Coefficient base	95% Confidence intervals	*p* value
	FEL-TLA	−3.9	−8.6 to 0.75	0.098
Age		−0.16	−0.40 to 0.083	0.2
Sex (male)		0.11	−4.8 to 5.0	0.97
Preoperative SF-36		0.46	0.16 to 0.76	0.003

ODI

Variables Operative procedure	ME-LIF	Coefficient base	95% Confidence intervals	*p* value
	FEL-TLA	8.4	0.98 to 16	0.027
Age		0.47	0.11 to 0.83	0.012
Sex (male)		0.2	−7.5 to 7.9	0.96
Preoperative ODI		0.47	0.19 to 0.75	0.001

EQ-5D

Variables Operative procedure	ME-LIF	Coefficient base	95% Confidence intervals	*p* value
	FEL-TLA	−0.017	−0.11 to 0.079	0.73
Age		−0.0029	−0.0076 to 0.0018	0.22
Sex (male)		0.0077	−0.091 to 0.11	0.88
Preoperative EQ-5D		0.58	0.12 to 1.0	0.014

ME-LIF, microendoscope-assisted lumbar interbody fusion; FEL-TLA, full-endoscopic laminectomy via the translaminar approach; SF-36, 36-Item Short Form Survey; ODI, Oswestry Disability Index; EQ-5D, European Quality of Life–5 Dimensions.

studies on the use of uniportal FESS for the treatment of L5/S1 LFS.[5,22-24,29-31] Furthermore, we could not find a detailed study on the use of uniportal FESS being compared with LIF, which has been established as the standard treatment for L5/S1 LFS. Therefore, we retrospectively compared the outcomes of ME-LIF and FEL-TLA.

Based on our analysis, FEL-TLA was superior in terms of shorter operation time and length of postoperative hospital stay and lower intraoperative bleeding volume. In addition, FEL-TLA was associated with no surgery-related complications. The SF-36, ODI, and EQ-5D scores at the 2-year postoperative follow-up showed statistically significant improvements in both groups, but the ODI score in the FEL-TLA group was lower than that in the ME-LIF group upon multiple linear regression analysis. It is possible to include more severe cases of LFS in the FEL-TLA group based on the demographic data of Lee's classification (p = 0.017). One of the main reasons is that LIF and second FEL-TLA were performed for recurrent L5 radiculopathy in a total of four cases in the FEL-TLA group during the 2-year postoperative follow-up period. Furthermore, four patients complained of bilateral L5 radiculopathy, and three patients did not expect to undergo FEL-TLA on the contralateral side. As ME-LIF leads to an increase in foraminal height and stabilization of lumbar movement depending on cage insertion, bilateral L5 radiculopathy seems to be improved even via a unilateral paramedian approach. Although FEL-TLA has no such effects, it appears that it can be safely performed for bilateral L5 radiculopathy. It also appears that recurrent radiculopathy can be treated with a second FEL-TLA, similar to conventional foraminotomy.[32]

We further analyzed the FEL-TLA group, dividing it into ODI-improved and ODI-unimproved subgroups. In addition to Lee's classification, we calculated and compared the posterior disc height[33] between these subgroups. Unfortunately, we could not find any preoperative parameter that predicts the outcome of FEL-TLA (Supplementary Table 1). This subgroup analysis was conducted on a small number of cases; we are continuously accumulating data to identify such predictive parameters. Other radiographic parameters, such as disc wedging angle, which was already considered as a parameter,[8] should be analyzed in the future.

Another reason for the lower outcomes following FEL-TLA might be the difficulty in excluding the presence of extraforaminal stenosis. Some electrophysiological methods have been reported to distinguish L5/S1 extraforaminal stenosis from L4/5 intracanal LSCS.[34,35] However, distinguishing L5/S1 extraforaminal stenosis from L5/S1 LFS is more difficult than distinguishing L5/S1 LFS from L4/5 intracanal LSCS. Radiological studies have also reported this distinction. Takeuchi et al. reported the usefulness of oblique coronal T2-weighted imaging for the diagnosis of L5/S1 extraforaminal stenosis.[36] Eguchi et al. reported the usefulness of diffusion tensor imaging and diffusion-weighted magnetic resonance neurography for diagnosis.[37] Such radiological methods are not perfect and have limitations in terms of their diagnostic accuracy.

FEL-TLA is unsuitable for L5/S1 extraforaminal stenosis because the extraforaminal lesion cannot be directly approached. For FESS, the posterolateral approach (5-8 cm lateral from the midline) is suitable for L5/S1 extraforaminal stenosis.[38] We used a posterolateral approach for patients who were distinctly diagnosed with L5/S1 extraforaminal stenosis both electrophysiologically and radiologically. We realized the difficulty of making an accurate diagnosing, which is why L5/S1 extraforaminal stenosis is also referred to as "far-out syndrome" (FOS).[6] Nevertheless, the lumbar movement-stabilizing effects following LIF might also improve the symptoms of L5/S1 extraforaminal stenosis because the symptoms were improved in some patients with recurrence who underwent revision LIF.[39,40] Further development of diagnostic methods for FOS might improve the outcomes of FEL-TLA.

The safety and minimal invasiveness of this full-endoscopic surgical procedure are its principal benefits, and we also observed improvement in L5 nerve paresis in all three cases. Even 2 years postoperatively, the SF-36, ODI, and EQ-5D scores were statistically improved relative to the preoperative scores. Although adjacent segmental disease (ASD) was not noted in the ME-LIF group during the follow-up period, FEL-TLA might have an advantage in the absence of ASD.

Limitations

FEL-TLA was only performed by a single skilled surgeon in this study. Although other surgeons could not perform FEL-TLA during the study period (between January 2016 and March 2019), other surgeons can perform FEL-TLA at present. We are disseminating this surgical procedure to other surgeons outside of our hospital. The small number of cases is another limitation of this study; we are continuously accumulating such cases.

Conclusions

This retrospective study with a 2-year postoperative follow-up period showed that FEL-TLA performed using a 4.1-mm working channel has some advantages for the treatment of patients with L5/S1 LFS. We observed recurrent L5 radiculopathy in 4/30 patients (13.3%) treated using FEL-TLA; repeat FEL-TLA was possible as treatment. Although the ODI scores of patients treated using FEL-TLA were lower than those of patients treated using ME-LIF at 2 years postoperatively, it might improve after complete exclusion of patients with L5/S1 extraforaminal stenosis.

Supplementary Material

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Study Design

This was a retrospective comparative study.

Conflicts of Interest Disclosure

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