

RESEARCH ARTICLE

Open Access



# Comparison of lumbar endoscopic unilateral laminotomy bilateral decompression and minimally invasive surgery transforaminal lumbar interbody fusion for one-level lumbar spinal stenosis

Wenbin Hua<sup>†</sup>, Bingjin Wang<sup>†</sup>, Wencan Ke, Xinghuo Wu, Yukun Zhang, Shuai Li, Shuhua Yang and Cao Yang<sup>\*</sup>

## Abstract

**Background:** The aim of the present study is to compare the clinical outcomes and postoperative complications of lumbar endoscopic unilateral laminotomy bilateral decompression (LE-ULBD) and minimally invasive surgery transforaminal lumbar interbody fusion (MIS-TLIF) to treat one-level lumbar spinal stenosis (LSS) without degenerative spondylolisthesis or deformity.

**Methods:** A retrospective analysis of 112 consecutive patients of one-level LSS undergoing either LE-ULBD or MIS-TLIF was performed. Patient demographics, operation time, estimated blood loss, time to ambulation, length of hospitalization, intraoperative and postoperative complications were recorded. The visual analog scale (VAS) score for leg and back pain, the Oswestry Disability Index (ODI) score, and the Macnab criteria were used to evaluate the clinical outcomes. The healthcare cost was also recorded.

**Results:** The operation time, estimated blood loss, time to ambulation and length of hospitalization of LE-ULBD group were shorter than MIS-TLIF group. The postoperative mean VAS and ODI scores decreased significantly in both groups. According to the modified Macnab criteria, the outcomes rated as excellent/good rate were 90.6 and 93.8% in the two groups. The mean VAS scores, ODI scores and outcomes of the modified Macnab criteria of both groups were of no significant difference. The healthcare cost of LE-ULBD group was lower than MIS-TLIF group. Two cases of intraoperative epineurium injury were observed in the LE-ULBD group. One case of cauda equina injury was observed in the LE-ULBD group. No nerve injury, dural injury or cauda equina syndrome was observed in MIS-TLIF group. However, one case with transient urinary retention, one case with pleural effusion, one case with incision infection and one case with implant dislodgement were observed in MIS-TLIF group.

(Continued on next page)

\* Correspondence: [yangcao1971@sina.com](mailto:yangcao1971@sina.com)

<sup>†</sup>Wenbin Hua and Bingjin Wang contributed equally to this work.

Department of Orthopaedics, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, China



© The Author(s). 2020 **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

(Continued from previous page)

**Conclusions:** Both LE-ULBD and MIS-TLIF are safe and effective to treat one-level LSS without degenerative spondylolisthesis or deformity. LE-ULBD is a more minimally invasive option and of less economic burden compared with MIS-TLIF. Decompression plus instrumented fusion may be not necessary for one-level LSS without degenerative spondylolisthesis or deformity.

**Keywords:** Endoscopic, Unilateral laminotomy bilateral decompression, Minimally invasive surgery, Transforaminal lumbar interbody fusion, Lumbar spinal stenosis

## Background

Lumbar spinal stenosis (LSS) can be caused by degenerative facet joints, hypertrophic ligamentum flavum, bulging or protrusion of the intervertebral discs, spondylolisthesis and or a combination of the above pathological lesions [1, 2]. These pathological lesions may cause radicular leg pain and neurogenic claudication [1, 3, 4]. Surgery may be necessary to relieve the symptoms and improve function after failed conservative treatment in patients with LSS [1, 3, 5].

Microsurgical procedures was firstly described by Yasargil and Caspar in 1977 [6]. Microscopic laminotomy and foraminotomy remains the gold standard for the decompression of LSS [7, 8]. Minimally invasive unilateral laminotomy bilateral decompression was performed to treat LSS with less injury to the paraspinal musculoligamentous structures [4, 9]. To further minimize injury to the paraspinal musculoligamentous structures, lumbar endoscopic unilateral laminotomy bilateral decompression (LE-ULBD) has been used to treat LSS in recent years [4, 8, 10, 11].

Laminotomy with medial facetectomy may result in segmental spinal instability, instrumented fusion may be necessary in some cases to prevent segmental spinal instability after decompression of LSS [12, 13]. Transforaminal lumbar interbody fusion (TLIF) has been performed to treat LSS since 1980s [14]. Minimally invasive surgery transforaminal lumbar interbody fusion (MIS-TLIF) was firstly described by Foley et al. and had been commonly performed to treat LSS with minimized injury to the paraspinal musculoligamentous structures [15–17].

Even though both decompression alone and decompression plus instrumented fusion has been performed to treat patients with LSS, it is controversial about the necessity of instrumented fusion after decompression [8, 12, 18, 19]. Besides, degenerative spondylolisthesis and scoliosis are two associated conditions which may determine the surgical management of LSS. The purpose of the present retrospective study is to compare the clinical effect, safety and complications of LE-ULBD and MIS-TLIF to treat one-level LSS without degenerative spondylolisthesis or deformity.

## Methods

### Patient population and grouping

This retrospective study included 112 patients (44 males, 68 females) with one-level LSS, who underwent LE-ULBD or MIS-TLIF in our department between January 2016 and December 2017. The present study was conducted in accordance with the guidelines of the Declaration of Helsinki and was approved by the ethics committee of our College. Written informed consents was obtained from each patient. In these patients, 32 surgeries were performed by LE-ULBD and the other 80 surgeries were performed by MIS-TLIF.

Inclusion criteria were as follows: patients with (1) main symptoms, including leg pain, numbness, motor weakness or neurogenic claudication; (2) computed tomography and/or magnetic resonance imaging indicating central stenosis and/or lateral recess stenosis, in agreement with clinical symptoms and signs; (3) a history of failed conservative treatment, including physical therapy and nonsteroidal anti-inflammatory drugs intervention for more than 3 months; and (4) follow-up for at least 24 months. Exclusion criteria were as follows: patients with (1) degenerative spondylolisthesis or deformity; (2) tumors, infections, or other lesions; and (3) a surgical history involving the corresponding segment [4, 20]. Each patient that met all the criteria underwent either LE-ULBD or MIS-TLIF under general anesthesia. The surgery procedures were chosen according to preoperative conversation, a variety of patient factors and surgeon preference.

### Surgical technique

All the surgeries were performed by the senior author, who has many years of experience in open and minimally invasive lumbar canal decompression, and lumbar endoscopic visualized discectomy. Both LE-ULBD and MIS-TLIF were performed under general anesthesia with the patient in the prone position.

### LE-ULBD

Posteroanterior and lateral fluoroscopy were used to locate the interlaminar space at the surgery segment. A 10 mm skin incision was made laterally to the outer border

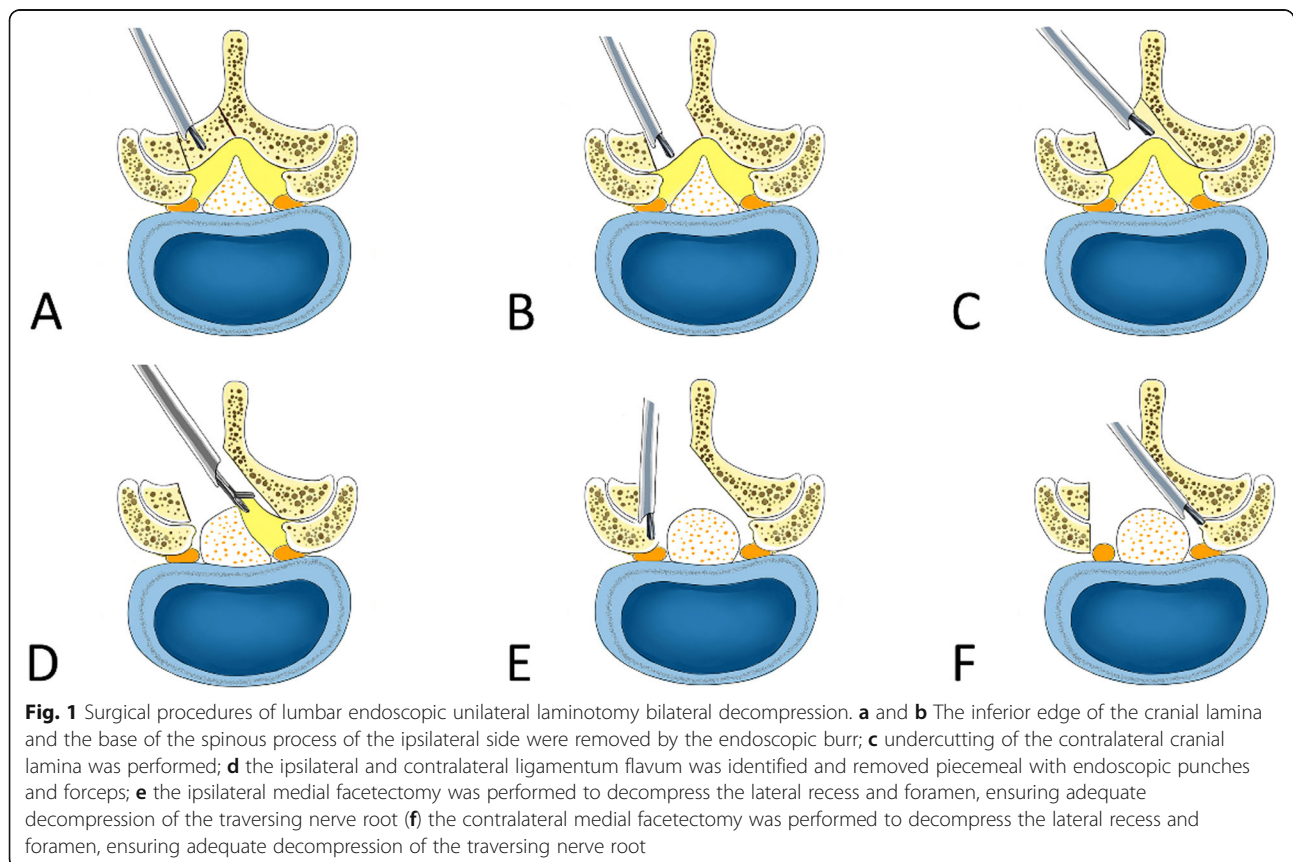
of the interlaminar window. Soft tissue expanders were applied via the incision in order to separate the muscles to allow the insertion of the working sheath and the endoscopic surgical system (working channel 4.3 mm, outside diameter 7.0 mm, working length 130.0 mm, lens angle 30 degrees). All the subsequent procedures were performed under constant irrigation with excellent endoscopic visualization.

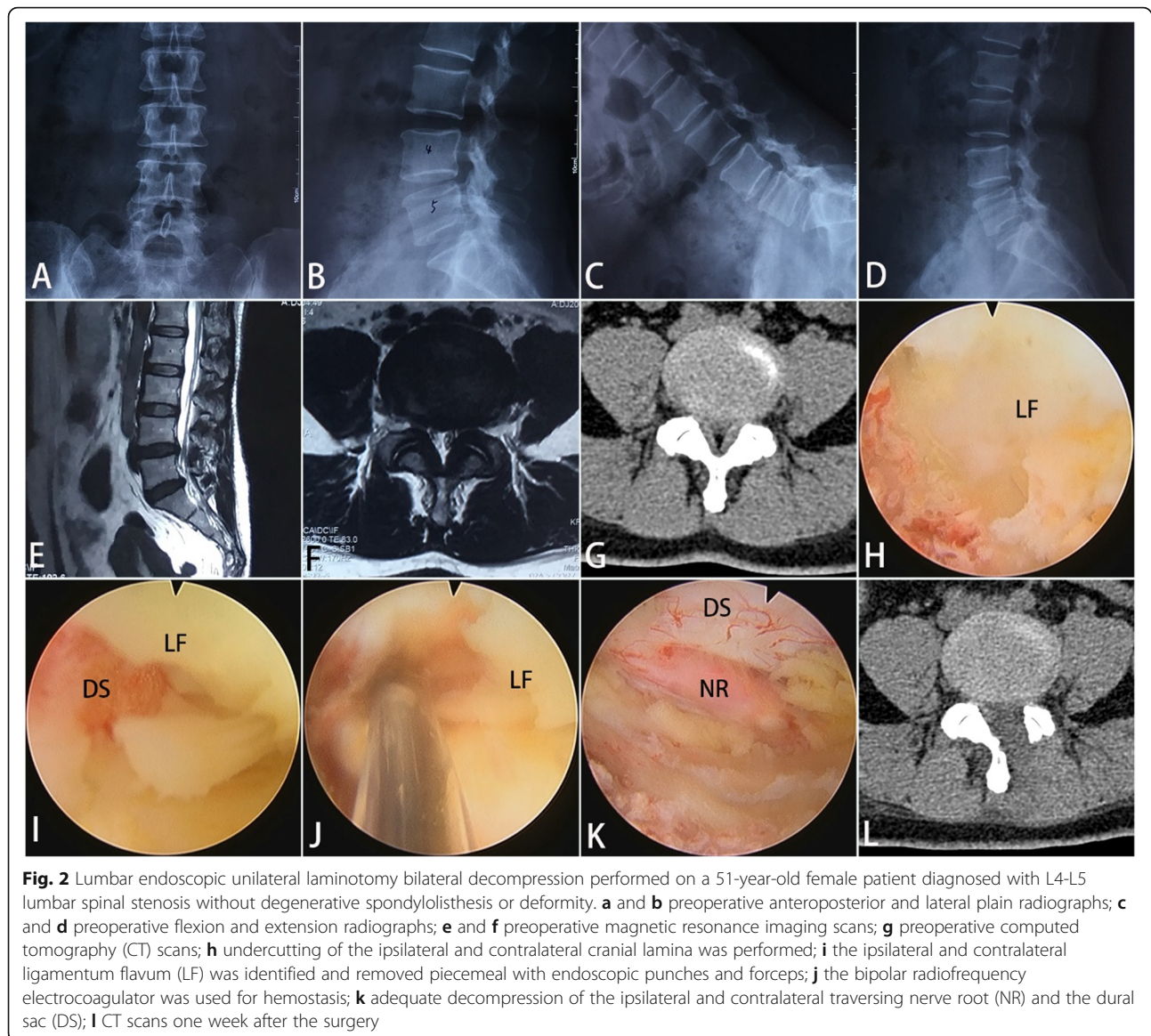
The inferior edge of the cranial lamina and the base of the spinous process of the ipsilateral side were removed by the endoscopic burr, enabling access into the spinal canal. Once the epidural space was entered, undercutting of the contralateral cranial lamina was performed. Then the ipsilateral and contralateral ligamentum flavum was identified and removed piecemeal with endoscopic punches and forceps. Subsequently, ipsilateral and contralateral medial facetectomy was performed to decompress the lateral recess and foramen, ensuring adequate decompression of the traversing nerve root. Once the traversing nerve root was decompressed, it was reflected medially using a blunt dissector. These procedures were presented in Fig. 1. The bipolar radio-frequency electrocoagulator was used for hemostasis, soft-tissue clearance and adhesion release. Prior to surgery completion, we ensured there was no significant

dural sac damage or active bleeding. No drainages were required. A representative case is shown in Fig. 2.

#### MIS-TLIF

Posteroanterior and lateral fluoroscopy were used to locate the pedicles of the surgery level. The Wiltse approach was undertaken through a paramedian skin incision. A Quadrant tubular dilator was used for unilateral facet exposure. Facetectomy was performed on the ipsilateral side in order to visualize the transforaminal disc space. Laminectomy and lateral recess decompression were performed to decompress the spinal canal. Besides, the tubular retractor could be angled medially to complete a more extensive decompression of central canal stenosis and the contralateral side [16]. Ligamentum flavum was adequately resected to expose the ipsilateral traversing and exiting nerve roots. A standard discectomy and endplates removal were performed to allow for an intervertebral cage insertion [16]. The autogenous and allogeneic bone graft was placed anteriorly and contralateral to the annulotomy, then an intervertebral cage filled with autogenous and allogeneic bone graft was placed. In addition, unilateral pedicle screws were placed ipsilateral to the approach, and contralateral pedicle screws were placed through a contralateral





incision. Rods were sized appropriately and subfascially tunneled through the paramedian incisions. The incisions were irrigated and closed in layers with drainages kept for no more than 48 h. A representative case is shown in Fig. 3.

#### Clinical evaluation

The operation time, estimated blood loss, time to ambulation, length of hospitalization, Intraoperative and postoperative complications were recorded. Follow-up examinations were conducted at 3, 6, 12 and 24 months postoperatively. Postoperative magnetic resonance imaging or computed tomography imaging was performed when necessary. The visual analog scale (VAS) score for leg pain and back pain (range, 0–10), Oswestry Disability

Index (ODI) score (range, 0–100) and modified Macnab criteria were recorded preoperatively and at follow-up postoperatively. The surgery cost, anesthesia cost, surgical equipment and medical materials cost was also recorded.

#### Statistical analyses

All data are presented as mean  $\pm$  standard deviation. SPSS 22.0 (IBM Corp., Armonk, NY, USA) was used to perform the statistical analyses. GraphPad Prism 6 (Graph Pad Software, Inc., San Diego, CA, USA) was used to generate plots. Nonparametric statistical analysis, including Mann-Whitney U test or Wilcoxon signed-rank test were used. A *p*-value of less than 0.05 was considered statistically significant.



**Fig. 3** Minimally invasive surgery transforaminal lumbar interbody fusion performed on a 70-year-old female patient diagnosed with L4-L5 lumbar spinal stenosis without degenerative spondylolisthesis or deformity. **a** and **b** preoperative anteroposterior and lateral plain radiographs; **c** and **d** preoperative flexion and extension radiographs; **e-g** preoperative magnetic resonance imaging scans; **h** preoperative computed tomography (CT) scans; **i** and **j** postoperative anteroposterior and lateral plain radiographs; **i** anteroposterior and lateral plain radiograph 6 months after the surgery

**Results**

**Demographic data**

The clinical characteristics of both groups were summarized in Table 1. The mean duration of the main symptoms was 5.1 ± 1.8 months, ranging from 3 to 60 months.

**Clinical outcomes**

The operation time, estimated blood loss, time to ambulation and length of hospitalization of LE-ULBD group were shorter than MIS-TLIF group (Table 2). The mean VAS scores and ODI scores improved significantly post-operatively in both LE-ULBD and MIS-TLIF groups (Table 3). According to the modified Macnab criteria, the outcomes rated as excellent/good rate were 90.6 and 93.8% in the two groups (Table 4). The mean VAS scores, ODI scores and outcomes of the modified Macnab criteria of both groups were of no significant difference (Fig. 4).

**Table 1** Baseline Characteristics of the Two Groups

	LE-ULBD	MIS-TLIF	P value
N	32	80	–
Male/ Female	12/20	32/48	0.808
Age (years)	56.7 ± 9.1 (28–77)	58.8 ± 10.5 (39–85)	0.515
Levels involved			
L2-L3	0 (0%)	2 (2.5%)	0.652
L3-L4	3 (9.4%)	2 (2.5%)	
L4-L5	20 (62.5%)	52 (65%)	
L5-S1	9 (28.1%)	24 (30%)	
Preoperative symptoms			
Back pain	29 (90.6%)	71 (88.8%)	0.777
Leg pain	28 (87.5%)	70 (87.5%)	1.000
Numbness	26 (81.2%)	67 (83.8%)	0.751
Motor weakness	21 (65.6%)	58 (72.5%)	0.473

*N* indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion

**Table 2** Clinical Outcomes and Complications of the Two Groups

	LE-ULBD	MIS-TLIF	P value
N	32	80	–
Operation time (min)	139.5 ± 31.2 (85–240)	161.1 ± 45.6 (60–300)	0.023
Estimated blood loss (ml)	51.9 ± 10.9 (40–80)	146.6 ± 80.3 (50–400)	< 0.001
Time to ambulation (h)	11.7 ± 3.6 (8–28)	22.1 ± 9.5 (12–48)	< 0.001
Length of hospitalization (d)	2.7 ± 0.9 (1–4)	11.2 ± 2.4 (7–17)	< 0.001

N indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion

**Complications**

Intraoperative and postoperative complications of LE-ULBD and MIS-TLIF group were also compared (Table 5). Two cases of intraoperative epineurium injury were observed in the LE-ULBD group. One case of cauda equina injury was observed in the LE-ULBD group. This case was presented with foot dorsiflexion and defecation dysfunction and recovered within 6 months. No nerve injury, dural injury or cauda equina syndrome was observed in MIS-TLIF group. However, one case with transient urinary retention, one case with pleural effusion, one case with incision fat liquefaction and one case with implant dislodgement were observed in MIS-TLIF group. No reoperation was observed within 90 days or during 24 months of follow-up.

**Healthcare cost**

The surgery cost, anesthesia cost, surgical equipment and medical materials cost of LE-ULBD group were less than MIS-TLIF group (Table 6).

**Table 3** Comparison of VAS and ODI Scores in the Two Groups

		LE-ULBD	MIS-TLIF	P value
N		32	80	–
VAS leg pain	Pre-op	7.2 ± 0.8	7.0 ± 0.9	0.655
	3 months Post-op	2.1 ± 0.6*	2.1 ± 0.5*	0.847
	12 months Post-op	1.6 ± 0.5*	1.5 ± 0.5*	0.061
	24 months Post-op	1.5 ± 0.5*	1.4 ± 0.5*	0.252
VAS back pain	Pre-op	5.6 ± 1.4	5.5 ± 1.5	0.672
	3 months Post-op	2.3 ± 0.5*	2.5 ± 0.7*	0.249
	12 months Post-op	2.1 ± 0.3*	2.2 ± 0.6*	0.335
	24 months Post-op	1.8 ± 0.4*	2.0 ± 0.5*	0.328
ODI (%)	Pre-op	53.2 ± 4.6	52.9 ± 6.2	0.767
	3 months Post-op	25.1 ± 3.7*	26.6 ± 4.2*	0.126
	12 months Post-op	21.4 ± 2.6*	21.3 ± 2.8*	0.780
	24 months Post-op	18.8 ± 2.1*	19.4 ± 2.1*	0.212

N indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion, Pre-op preoperative, Post-op postoperative, VAS Visual Analog Scale, ODI Oswestry Disability Index. \*P < 0.05 versus preoperative data

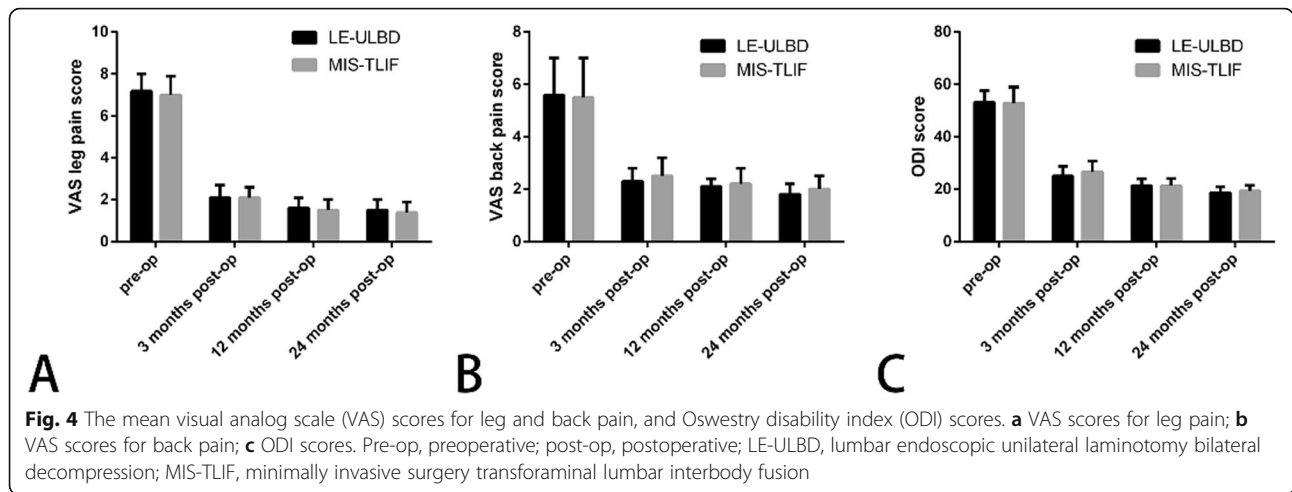
**Discussion**

LSS is traditionally treated with open or microscopic laminotomy and foraminotomy via a midline lumbar incision [21]. However, extensive detaching the paraspinal muscles from the spinous processes and lamina may cause increased intraoperative blood loss, postoperative pain and weakness secondary to muscle denervation [21]. Besides, supraspinous and interspinous ligaments injury and extensive facetectomy may cause iatrogenic spinal instability, requiring additional posterior fixation for stabilization [4, 21, 22]. Therefore, various minimally invasive techniques were developed to minimize the surgical trauma [7, 9, 23]. Patients with neurogenic claudication secondary to LSS without degenerative spondylolisthesis or deformity could be treated by both decompression alone and decompression with instrumented fusion [12, 18, 19]. LE-ULBD and MIS-TLIF are two common minimally invasive procedures to treat LSS, and typical representative of decompression alone technique and decompression plus instrumented fusion technique, respectively. The development of endoscopic spine surgery has been evolving rapidly, therefore it is feasible to perform interlaminar decompression via both LE-ULBD and MIS-TLIF [20]. The present retrospective study revealed that both LE-ULBD and MIS-TLIF are effective to treat one-level LSS without degenerative spondylolisthesis or deformity. While, LE-ULBD is a more minimally invasive option for patients with one-level LSS without degenerative spondylolisthesis or deformity. Moreover, LE-ULBD is of less economic burden than MIS-TLIF.

**Table 4** Comparison of Modified Macnab Evaluation in the Two Groups

Modified Macnab evaluation		LE-ULBD	MIS-TLIF	P value
Outcome	Excellence (N)	22	51	NS
	Good (N)	7	24	NS
	Fair (N)	3	5	NS
	Poor (N)	0	0	NS
Excellence/good rate (%)		90.6	93.8	NS

N indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion, NS not significant



During LE-ULBD, laminotomy and and foraminotomy could be safely performed under excellent endoscopic visualization to guarantee complete decompression, minimize surgical trauma, and prevent spinal instability [8, 10, 11]. However, sufficient decompression without violating the stability of the facet joints may be technically difficult in cases with narrow interlaminar spaces, posterior marginal osteoproliferation of the vertebrae, ossification of the posterior longitudinal ligaments, and recurrences [8, 10]. Excessive facetectomy may be inevitable for sufficient lateral recess decompression and foraminotomy, exacerbating postoperative instability. In the present study, undercutting of the cranial lamina was performed during LE-ULBD to overcome the difficulty during insertion of the working sheath [4]. Additionally, the excellent endoscopic visualization achieved during LE-ULBD ensured the undercutting of the cranial

lamina, minimized facetectomy, and sufficient decompression of the lateral recess and foramen.

The advantages of LE-ULBD were to perform bilateral decompression via a unilateral approach with minimize traumatization to the paraspinal musculoligamentous structures; to ensure the sufficient decompression the lateral recess and foramen under excellent endoscopic visualization to minimize neurological injury; and to preserve the stability of the spine with minimized foraminotomy [4, 8, 10, 11]. On the other hand, LE-ULBD has some disadvantages, such as the steep learning curve. Muscles, facet cysts, and ligaments may be difficult to identify under endoscopic visualization, increasing the risk for iatrogenic injury.

MIS-TLIF has been demonstrated to be a safe option for lumbar fusion with minimized iatrogenic traumatization to the paraspinal musculoligamentous structures [16, 17]. Compared with traditional open TLIF, MIS-TLIF was of similar good clinical outcomes, fusion rates, less postoperative back pain, shorter time to ambulation, and length of hospitalization [16, 17]. MIS-TLIF was performed to achieve the sufficient decompression of LSS, immediate improvement of spinal alignment, and prevention of spinal instability.

While it is controversial about the necessity of instrumented fusion after decompression of LSS [8, 12, 18, 19]. Nowadays, there are growing evidences suggest that decompression alone is better for LSS without degenerative spondylolisthesis or deformity [24]. Försth et al. [19, 25] found that decompression with instrumented fusion did not result in better clinical outcomes than decompression alone for LSS with or without degenerative spondylolisthesis. Compared with decompression alone surgery, the addition of instrumented fusion to decompression surgery significantly increased the hospital costs, including the costs of surgery and the length of hospitalization [19]. In the present study, both LE-ULBD

**Table 5** Complications of the Two Groups

	LE-ULBD	MIS-TLIF	P value
N	32	80	-
Intraoperative complications			
Dural tears	2 (6.2%)	0 (0%)	0.025
Cauda equina injury	1 (3.1%)	0 (0%)	0.114
Intraoperative complication rate	3 (9.4%)	0 (0%)	0.006
Postoperative complications			
Transient urinary retention	0 (0%)	1 (1.2%)	0.527
Pleural effusion	0 (0%)	1 (1.2%)	0.527
Incision fat liquefaction	0 (0%)	1 (1.2%)	0.527
Incision infection	0 (0%)	0 (0%)	1.000
Implant dislodgement	-	1 (1.2%)	-
Postoperative complication rate	0 (0%)	4 (5.0%)	0.200

N indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion

**Table 6** Healthcare Cost of the Two Groups

	LE-ULBD	MIS-TLIF	P value
N	32	80	–
Surgery cost	7125.4 ± 852.3 (6221–8256)	10,479.5 ± 1100.6 (8999–14,359)	< 0.001
Anesthesia cost	3609.2 ± 388.6 (3359–5424)	3855.5 ± 311.4 (3207–4259)	< 0.001
Surgical equipment and medical materials cost	3900.0 ± 0.0 (3900–3900)	41,864.2 ± 7684.8 (33333–54,245)	< 0.001

*N* indicates number of patients included in the statistical analysis, LE-ULBD lumbar endoscopic unilateral laminotomy bilateral decompression, MIS-TLIF minimally invasive surgery transforaminal lumbar interbody fusion; healthcare cost was compared in China Yuan (CNY)

and MIS-TLIF were of excellent outcomes for LSS without degenerative spondylolisthesis or deformity, as a result, addition of instrumented fusion to decompression surgery may be not necessary. Therefore, LSS without degenerative spondylolisthesis or deformity could be treated by LE-ULBD. Moreover, endoscopic decompression is of higher technical demand and steep learning curve.

There are some limitations to the present study. First, it is a retrospective, non-randomized controlled cohort study with a small sample size and short follow-up period. There also may be selection bias, as surgeons determined whether decompression alone or decompress with instrumented fusion should be performed. Further prospective, randomized, controlled studies, with larger sample sizes and longer follow-up periods should be conducted to determine the optimal surgical management for patients with LSS. Second, all the patients included were of one-level LSS without degenerative spondylolisthesis or deformity. As a result, further studies should be conducted to compare the clinical outcomes of LE-ULBD and MIS-TLIF for LSS with degenerative spondylolisthesis or deformity. Besides, pre-existing adjacent level degeneration was not evaluated and compared in the present study.

## Conclusion

Both LE-ULBD and MIS-TLIF are safe and effective to treat one-level LSS without degenerative spondylolisthesis or deformity. LE-ULBD was proved to be a more minimally option and of less economic burden compared with MIS-TLIF. Decompression with instrumented fusion may be not necessary for one-level LSS without degenerative spondylolisthesis or deformity.

## Abbreviations

LE-ULBD: Lumbar endoscopic unilateral laminotomy bilateral decompression; MIS-TLIF: Minimally invasive surgery transforaminal lumbar interbody fusion; LSS: Lumbar spinal stenosis; VAS: Visual analog scale; ODI: Oswestry Disability Index.

## Acknowledgements

Not applicable.

## Authors' contributions

WH participated in the design of this study, performed the statistical analysis, and drafted the manuscript. BW carried out the study and collected important background information. WK, XW, YZ and SL collected the clinical data and follow-up details of this study, and SY and CY participated in the study design and helped to draft the manuscript. All authors read and approved the final manuscript.

## Funding

This work was supported by the National Key Research and Development Program of China (2018YFB1105700), the National Natural Science Foundation of China (Grant no. 81904020), and the Natural Science Foundation of Hubei Province (2019CFB305).

## Availability of data and materials

The data sets supporting the conclusion of this article are included in the manuscript. Upon request, raw data can be provided by the corresponding author.

## Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and received approval from the Ethics Committee of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology. Written informed consents to participate were obtained from all the patients.

## Consent for publication

Written informed consents, including the consent for publication of individual details and images were obtained from all the patients.

## Competing interests

The authors declare that they have no competing interests.

Received: 5 August 2020 Accepted: 22 November 2020

Published online: 27 November 2020

## References

- Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. *N Engl J Med*. 2008;358:794–810.
- Deyo RA, Mirza SK, Martin BI, et al. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. *Jama*. 2010;303:1259–65.
- Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonoperative treatment for lumbar spinal stenosis four-year results of the spine patient outcomes research trial. *Spine (Phila Pa 1976)*. 2010;35:1329–38.
- McGrath LB, White-Dzuro GA, Hofstetter CP. Comparison of clinical outcomes following minimally invasive or lumbar endoscopic unilateral laminotomy for bilateral decompression. *J Neurosurg Spine*. 2019;1–9.
- Costa F, Sassi M, Cardia A, et al. Degenerative lumbar spinal stenosis: analysis of results in a series of 374 patients treated with unilateral laminotomy for bilateral microdecompression. *J Neurosurg Spine*. 2007;7: 579–86.
- Mayer HM. A history of endoscopic lumbar spine surgery: what have we learnt? *Biomed Res Int*. 2019;2019:4583943.
- Weiner BK, Walker M, Brower RS, et al. Microdecompression for lumbar spinal canal stenosis. *Spine (Phila Pa 1976)*. 1999;24:2268–72.
- Komp M, Hahn P, Oezdemir S, et al. Bilateral spinal decompression of lumbar central stenosis with the full-endoscopic interlaminar versus



- microsurgical laminotomy technique: a prospective, randomized, controlled study. *Pain Physician*. 2015;18:61–70.
9. Rahman M, Summers LE, Richter B, et al. Comparison of techniques for decompressive lumbar laminectomy: the minimally invasive versus the "classic" open approach. *Minim Invasive Neurosurg*. 2008;51:100–5.
  10. Komp M, Hahn P, Merk H, et al. Bilateral operation of lumbar degenerative central spinal stenosis in full-endoscopic interlaminar technique with unilateral approach: prospective 2-year results of 74 patients. *J Spinal Disord Tech*. 2011;24:281–7.
  11. Kim HS, Paudel B, Jang JS, et al. Percutaneous full endoscopic bilateral lumbar decompression of spinal stenosis through uniportal-contralateral approach: techniques and preliminary results. *World Neurosurg*. 2017;103:201–9.
  12. Katz JN, Lipson SJ, Lew RA, et al. Lumbar laminectomy alone or with instrumented or noninstrumented arthrodesis in degenerative lumbar spinal stenosis. Patient selection, costs, and surgical outcomes. *Spine (Phila Pa 1976)*. 1997;22:1123–31.
  13. Ghogawala Z, Dziura J, Butler WE, et al. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. *N Engl J Med*. 2016;374:1424–34.
  14. Rosenberg WS, Mummaneni PV. Transforaminal lumbar interbody fusion: technique, complications, and early results. *Neurosurgery*. 2001;48:569–75.
  15. Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. *Spine (Phila Pa 1976)*. 2003;28:S26–35.
  16. Peng CWB, Yue WM, Poh SY, et al. Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. *Spine (Phila Pa 1976)*. 2009;34:1385–9.
  17. Lee KH, Yue WM, Yeo W, et al. Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. *Eur Spine J*. 2012;21:2265–70.
  18. Thomas K, Faris P, McIntosh G, et al. Decompression alone vs. decompression plus fusion for claudication secondary to lumbar spinal stenosis. *Spine J*. 2019;19:1633–9.
  19. Försth P, Ólafsson G, Carlsson T, et al. A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med*. 2016;374:1413–23.
  20. Hasan S, McGrath LB, Sen RD, et al. Comparison of full-endoscopic and minimally invasive decompression for lumbar spinal stenosis in the setting of degenerative scoliosis and spondylolisthesis. *Neurosurg Focus*. 2019;46:E16.
  21. Armin SS, Holly LT, Khoo LT. Minimally invasive decompression for lumbar stenosis and disc herniation. *Neurosurg Focus*. 2008;25:E11.
  22. Scholler K, Steingruber T, Stein M, et al. Microsurgical unilateral laminotomy for decompression of lumbar spinal stenosis: long-term results and predictive factors. *Acta Neurochir*. 2016;158:1103–13.
  23. Alimi M, Njoku I Jr, Cong GT, et al. Minimally invasive foraminotomy through tubular retractors via a contralateral approach in patients with unilateral radiculopathy. *Neurosurgery*. 2014;10(Suppl 3):436–47 discussion 446–7.
  24. Machado GC, Ferreira PH, Yoo RJ, et al. Surgical options for lumbar spinal stenosis. *Cochrane Database Syst Rev*. 2016;11:CD012421.
  25. Försth P, Michaëlsson K, Sandén B. Does fusion improve the outcome after decompressive surgery for lumbar spinal stenosis?: a two-year follow-up study involving 5390 patients. *Bone Joint J*. 2013;95-B:960–5.

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Ready to submit your research? Choose BMC and benefit from:**

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

**At BMC, research is always in progress.**

Learn more [biomedcentral.com/submissions](https://biomedcentral.com/submissions)

