Outcomes after decompressive laminectomy for lumbar spinal stenosis: comparison between minimally invasive unilateral laminectomy for bilateral decompression and open laminectomy

Clinical article

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Object. The development of minimally invasive surgical techniques is driven by the quest for better patient outcomes. There is some evidence for the use of minimally invasive surgery for degenerative lumbar spine stenosis (LSS), but there are currently no studies comparing outcomes with matched controls. The object of this study was to compare outcomes following minimally invasive unilateral laminectomy for bilateral decompression (ULBD) to a standard “open” laminectomy for LSS.

Methods. The authors conducted a prospective, 1:1 randomized trial comparing ULBD to open laminectomy for degenerative LSS. The study enrolled 79 patients between 2007 and 2009, and adequate data for analysis were available in 54 patients (27 in each arm of the study). Patient demographic characteristics and clinical characteristics were recorded and clinical outcomes were obtained using pre- and postoperative Oswestry Disability Index (ODI) scores, visual analog scale (VAS) scores for leg pain, patient satisfaction index scores, and postoperative 12-Item Short Form Health Survey (SF-12) scores.

Results. Significant improvements were observed in ODI and VAS scores for both open and ULBD interventions ($p < 0.001$ for both groups using either score). In addition, the ULBD-treated patients had a significantly better mean improvement in the VAS scores ($p = 0.013$) but not the ODI scores ($p = 0.055$) compared with patients in the open-surgery group. ULBD-treated patients had a significantly shorter length of postoperative hospital stay (55.1 vs 100.8 hours, $p = 0.0041$) and time to mobilization (15.6 vs 33.3 hours, $p < 0.001$) and were more likely to not use opioids for postoperative pain (51.9% vs 15.4%, $p = 0.046$).

Conclusions. Based on short-term follow-up, microscopic ULBD is as effective as open decompression in improving function (ODI score), with the additional benefits of a significantly greater decrease in pain (VAS score), postoperative recovery time, time to mobilization, and opioid use.
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KEY WORDS • degenerative • laminectomy • lumbar • stenosis • minimally invasive surgery

AQUIRED degenerative lumbar spinal stenosis (LSS) is the most common indication for lumbar spine surgery in the elderly.^{5,23,28} Degenerative changes, including intervertebral disc bulge, ligamentum flavum hypertrophy/calcification, and/or facet joint hypertrophy, cause neural compression in the vertebral canal, lateral recess, or intervertebral foramen, resulting in pain, impaired function, and decreased quality of life.^{8,23} Surgical treatment of LSS is currently recommended after failure of conservative medical therapy; however, the optimal

procedure is still debated.^{12,20,28} The traditional approach is an open laminectomy, medial facetectomy, and foraminotomy,^{3,6,15} which involves wide muscle retraction and extensive removal of posterior spinal structures.¹³ While open decompressions have a variable success rate,¹⁸ the extensive bony and muscular disruption has adverse consequences, including flexion instability, muscle weakness and/or atrophy, and failed back surgery syndrome.^{2,4,13,15,25}

As central neural compression occurs primarily at the interlaminar window, there is a trend toward minimally invasive surgery (MIS).²¹ Since the microendoscopic tubular-retractor system for microdiscectomy (METRx-MD, Medtronic Sofamor Danek) became adapted for

Abbreviations used in this paper: IV = intravenous; LSS = lumbar spinal stenosis; MIS = minimally invasive surgery; ODI = Oswestry Disability Index; PSI = patient satisfaction index; SF-12 = 12-Item Short Form Health Survey; ULBD = unilateral laminectomy for bilateral decompression; VAS = visual analog scale.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.

treating spinal stenosis,^{13,18,27,30} microendoscopic decompressive laminotomy has become a suitable alternative to conventional decompression.³⁰ The aim of MIS is to achieve adequate neural decompression while decreasing iatrogenic tissue trauma and postoperative spinal instability.^{2,26} Minimally invasive surgical approaches involve muscle-splitting techniques to access the spine, leaving intact the midline structures that support muscles and ligaments²⁶ and decreasing intraoperative blood loss and postoperative pain.¹⁷ One such recently described MIS technique is unilateral laminectomy for bilateral decompression (ULBD).^{13,16,24} Preoperative and postoperative MR images obtained in a patient with LSS treated with ULBD are shown in Fig. 1.

In theory, the reduction of tissue trauma by minimization of the access to the spine should be of benefit for the patient. However, the advantages of ULBD over open laminectomies are not well characterized in the literature.^{13,20} The majority of studies prior to 1992 had major deficits in design and analysis, preventing comparisons and clear conclusions from being made.² A review of the current literature reveals a lack of studies directly comparing ULBD and open laminectomies, with most studies on ULBD lacking a control group or focusing on developing novel procedures.

The purpose of this study was to compare standard open laminectomy with the novel minimal access muscle-splitting ULBD approach in regard to efficiency, safety, and clinical outcome.

Methods

Patient Selection

The study protocol was approved by the Northern Hospital Network Human Research Ethics Committee

Fig. 1. Preoperative (left) and postoperative (right) MR images demonstrating the efficacy of the ULBD approach. The preoperative image shows severe canal stenosis characterized by broad-based disc bulge, ligamentum flavum hypertrophy, and hypertrophic facet joints. The image obtained 4 weeks after ULBD shows effective decompression of the canal. Note the defect in the thoracolumbar fascia and small residual paraspinal muscle edema indicating the slightly lateral approach.

All patients signed a written informed consent and underwent surgery performed by a single senior neurosurgeon (R.J.M.) with extensive experience in lumbar spine surgery and minimally invasive spine surgery.

Inclusion in the study required: 1) symptomatic LSS with radiculopathy (defined as well-localized lower-limb pain, weakness, or numbness), neurogenic claudication (defined as poorly localized back or lower-limb heaviness or numbness, with reduced tolerance for standing or ambulation), or urinary dysfunction; and 2) radiologically confirmed LSS (confirmed by either MRI or CT myelogram), caused by degenerative changes (facet joint hypertrophy, ligamentum flavum hypertrophy, and/or broad-based disc bulge); and 3) canal stenosis at a maximum of 2 levels (that is, 1- or 2-level canal stenosis only). Patients were excluded if they: 1) were to undergo a concomitant fusion or instrumentation placement; 2) had had previous lumbar surgeries at the same level; 3) were to undergo lumbar laminectomy involving discectomy; 4) had spondylolisthesis of any grade or degenerative scoliosis; or 5) had evidence of instability on dynamic radiographs.

A total of 79 patients fulfilled all inclusion criteria between 2007 and 2009 and were assigned to either open decompressive laminectomy or microscopic ULBD in a 1:1 split according to their sequence of presentation (Fig. 2). The block randomization technique (1:1) was chosen to provide a balance in the overall numbers for the study, as the patient numbers were relatively small. All pre- and postoperative data were collected by an independent observer and analyzed by an independent statistician not involved in operations or patient care. The observer and statistician were blinded to treatment group by the use of reference numbers.

Patient Evaluation

The surgical outcomes assessed were the preoperative to postoperative changes in leg/back pain and disability/function, patient satisfaction with the procedure, and postoperative quality of life. Pain was measured according to a self-assessment 10-point visual analog scale (VAS) for leg pain only. Physical and mental health symptoms were measured using the Oswestry Disability Index (ODI)⁹ and 12-Item Short Form Health Survey (SF-12, version 1) questionnaire. Patient satisfaction with the procedure was measured using a patient satisfaction index (PSI) questionnaire. The ODI, SF-12, and PSI questionnaires were completed at the final postoperative visit. The SF-12 determined differences in postoperative overall health status and quality-of-life between groups and was scored according to the method of Ware and colleagues (1995).²⁹ Our PSI questionnaire was an early version of the North American Spine Society (NASS) Outcome Questionnaire with possible scores of 1–4 (Table 1); scores of 1 and 2 were considered to indicate “satisfied/good,” and scores of 3 or 4 were considered to indicate “dissatisfied/poor.” All patients were contacted pre- and postoperatively for completion of the standardized questionnaires containing the ODI, VAS, SF-12, and PSI. A total of 54 patients completed all data points and therefore were included for data analysis.

Duration of postoperative hospital stay, time to mobilization, postoperative analgesic use, complication rates,

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Fig. 2. CONSORT (Consolidated Standards of Reporting Trials) flow diagram. In total, 68.4% of the originally randomized 79 patients were included in the study. Based on template available at <http://www.consort-statement.org/consort-statement/flow-diagram>.

and baseline patient characteristics were prospectively collected. Duration of postoperative hospital stay was determined in hours from the time patients entered recovery until discharge. Time to mobilization was determined in hours from the time patients entered recovery until the medical notes documented they were able to “sit-to-stand” or “mobilize with supervision.”

To compare total postoperative opioid usage, we converted opioid doses into intravenous (IV) morphine equivalent units (mg) with an equianalgesic dose table (Table 2).¹⁴ Equianalgesic dose tables list opioid doses that have been adjusted for potency and bioavailability to produce approximately the same analgesia, standardized to 10 mg of parenteral morphine. To decrease the difference in means of total opioid consumption between the groups, we used the highest value in the equianalgesic dose range in our conversions to IV morphine equivalent units.

Data Analysis

Statistical analysis was performed independent of all authors, with version 2.6.2 of the R program (R Foundation for Statistical Computing). All values were expressed as mean $\pm$ standard deviation with a 68% confidence interval. Normality assumption was tested with a normal quantile plot. A 2-sample t-test and chi-square tests were performed to determine statistical differences in baseline

demographics, preoperative clinical characteristics, and study outcomes between groups. Preoperative to postoperative ODI and VAS changes within each group were analyzed with paired t-tests. A p value less than 0.05 was considered statistically significant.

Surgical Technique

All procedures were performed under general anesthesia in a standardized manner on a Jackson spinal table with Wilson frame support, with the patient’s hips and knees flexed to reduce lordosis of the lumbar spine. Methylprednisolone (Depo Medrol) was irrigated over the inflamed dura mater and nerve roots, and paraspinal muscles were injected with bupivacaine (Marcain) for postoperative pain relief before closure of the fascia and skin.

Technique 1: Conventional Laminectomy. The skin was incised horizontally over a length of 8–10 cm in the midline. The lumbodorsal fascia was incised vertically over a distance of 8–10 cm. The paraspinal musculature was detached from the spinous process and laminae in a subperiosteal fashion and bilaterally retracted. Decompression was performed using standard techniques to remove the spinous process, lamina, and ligamentum flavum, along with partial medial facetectomy (limited to one-third of the facet joint) and rhizolysis of the traversing nerve

TABLE 1: Patient satisfaction index used in this study

Score	Options
1	Surgery met my expectations
2	I did not improve as much as I had hoped but I would undergo the same operation for the same results
3	Surgery helped but I would not undergo the same operation for the same outcome
4	I am the same or worse as compared to before surgery

TABLE 2: Equianalgesic doses of narcotics*

Opioid	Equianalgesic	
	Parenteral	Oral
morphine	10 mg	20–30 mg
oxycodone	15 mg	15–30 mg
methadone	2.5–10 mg	5–20 mg
codeine	120–150 mg	200–250 mg
oxymorphone	1 mg	10–15mg
fentanyl	50–200 µg	NA
tramadol	100–110 mg	100–200 mg
hydromorphone	1.5 mg	3.75–7.5 mg

* Based on Anderson et al.,¹ Knotkova et al.,¹⁴ and Patanwala AE, Doby J, Waters D, et al.: Opioid conversions in acute care. *Ann Pharmacother* 41:255–266, 2007. NA = not applicable.

roots (that is, the nerve roots that exit at the vertebral level below the surgical level). Hemostasis was performed using a combination of bipolar diathermy and Gelfoam (Fig. 3C). Copious antibiotic irrigation of the exposed tissues was performed at the completion of each case.

Technique 2: Minimally Invasive ULBD. The incision level was marked slightly lateral (0.5–1 cm) to the midline and a radio-opaque marker was inserted. Anteroposterior and lateral radiographs obtained with a C-arm imaging system confirmed the level of canal and/or nerve compression. Following operative field preparation and a 0.25% bupivacaine-adrenaline injection, a 2.5- to 3-cm skin and thoracolumbar fascial incision was made. A

FIG. 3. Schematic illustration of a normal lumbar canal (A), lumbar canal stenosis (B), a standard “open” laminectomy with bilateral muscle dissection (C), and unilateral MIS decompression with minimal bone resection and soft tissue disruption (D). Copyright Ralph J. Mobbs. Published with permission.

minimally invasive retractor system was placed to retract the musculature. An 18-mm tubular retractor was placed creating a surgical corridor and exposing the laminae/inter-spinous space at the affected level (Fig. 3D).

Muscle and other soft tissue covering the adjacent lamina and medial facet was resected using a long-tipped cautery. Unilateral laminectomy was performed with a 3-mm high-speed round bur, exposing the ligamentum flavum. Facet hypertrophy was treated by thinning down the lamina and medial facet, and the laminectomy was enlarged with microangled curettes and 2-mm Kerrison rongeurs. For removal of the hypertrophied ligamentum flavum, a nerve-hook or small-angled curette was used to determine its position over the dura prior to dissection. Medium-sized Kerrison rongeurs were used to remove the flavum medially toward the spinolaminar junction, decompressing the ipsilateral recess. Following inspection of the thecal sac and affected nerve roots, a medial ipsilateral facetectomy was performed, allowing contralateral microscopic visualization, contralateral flavum dissection, and if necessary, a contralateral foraminotomy. Hemostasis was achieved with a bipolar cautery and thrombin-soaked Gelfoam pledgets. Following antibiotic irrigation, the retractors were removed.

Results

Demographic and Clinical Data

The study enrolled 79 patients between 2007 and 2009, and adequate data for analysis were available in 54 patients (27 in each arm of the study). Fifteen patients did not return for long-term follow-up, and their cases were therefore excluded from the data analysis. Patients were contacted to request the reasons for failure to return, and concerns related to travel distance were cited as the most common reasons for failure to return. Nine patients withdrew from the study following randomization. The mean age at the time of surgery was 65.8 years in the open laminectomy group and 72.7 years in the ULBD group. It should be noted that the younger mean age in the open laminectomy group represents a potential bias toward more positive outcomes for that group. Significant differences in demographic and clinical characteristics of the groups included age at time of surgery, follow-up time, and the number of patients presenting with radiculopathy (Table 3). There was no significant difference between the 2 groups with respect to baseline VAS or ODI scores. The mean preoperative VAS scores were 7.9 ± 1.4 and 7.5 ± 2.1 in the open laminectomy and ULBD groups, respectively ($p = 0.50$). The mean preoperative ODI score was 46.6 ± 18.9 in the open laminectomy group and 51.4 ± 19.4 in the ULBD group ($p = 0.39$).

Complications and Repeated Surgery

One conventionally treated patient developed postoperative right foot drop and a second conventionally treated patient developed a postoperative hematoma leading to suboptimal decompression. Both complications resolved spontaneously. Additionally, one patient from each group suffered an intraoperative dural tear without further sequelae.

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TABLE 3: Summary of clinical and demographic characteristics

Characteristic	Open-Surgery Group (n = 27)	ULBD Group (n = 27)	p Value
mean age at time of op (yrs) $\pm$ SD	65.8 $\pm$ 14.3	72.7 $\pm$ 10.4	0.046
male/female ratio	1:1	1:5	0.58
mean follow-up time (mos) $\pm$ SD	44.3 $\pm$ 15.0	36.9 $\pm$ 4.3	<0.001
level treated (no. of patients [%])			
L2–3	4 (14.8)	1 (3.7)	0.16
L3–4	8 (29.6)	5 (18.5)	0.34
L4–5	21 (77.8)	23 (85.2)	0.48
L5–S1	3 (11.1)	0 (0)	0.075
symptoms (%)			
low-back pain	66.7	40.7	0.056
radiculopathy	88.9	66.7	0.050
neurogenic claudication	59.3	66.7	0.57
urinary dysfunction	11.1	3.7	0.30
comorbidities (%)			
smoker	18.5	25.9	0.51
obesity	25.9	29.6	0.76
hypertension	55.6	55.6	1
cardiac disease	40.7	33.3	0.57
respiratory disease	33.3	18.5	0.21
Type 2 diabetes	3.7	18.5	0.083
depression	11.1	22.2	0.27

Clinical Outcomes

Analysis of mean preoperative and postoperative ODI and VAS leg pain scores showed statistically significant postoperative improvements in ODI and VAS within each group (Fig. 4). In addition, the mean improvement in VAS scores was significantly greater in the ULBD group than in the open laminectomy group. Although the mean improvement in ODI scores was greater in patients treated with ULBD, there was no significant difference between groups (Table 4). Analysis of SF-12 Mental and Physical Component Summary scores showed no significant difference between groups (Table 4).

Patient satisfaction index (PSI) scores were available for 53 of the 54 patients (27 in the ULBD group and 26 in the open-surgery group). The percentage of patients who were satisfied (score of 1 or 2) was greater in the ULBD group (85%) than in the open-surgery group (62%), but this difference was not statistically significant ($p = 0.26$). The percentage of patients who were dissatisfied (score of 3 or 4) was greater in the open-surgery group (38%) than in the ULBD group (15%), but this difference was not statistically significant ($p = 0.11$).

The average time to mobilization and average length of postoperative hospital stay were significantly shorter for the ULBD group (Fig. 5). The mean blood loss was significantly greater in the open-surgery group (110 ml) than in the ULBD group (40 ml). The average total number of IV morphine equivalent units consumed was significantly smaller in the ULBD group, with a significantly higher percentage of patients (52%) not using any opioids in this group than in open-surgery group (15%) ($p = 0.46$).

One patient in the ULBD group and 3 in the open-surgery required a reoperation due to failure of symptom relief. Reoperations included a decompression at a new lumbar level, repeat nerve decompression due to postoperative scar entrapment, and repeat laminectomy due to recurrent or residual stenosis. There was no significant difference in reoperation rates between groups ($p = 0.18$).

Discussion

Although treating degenerative LSS with open decompression can achieve good-to-excellent outcomes in 64% of patients,²⁸ the extensive disruption of posterior bony and muscular structures can lead to flexion instability, paraspinal muscle weakness and atrophy, and a large dead space producing an ideal medium for bacterial colonization or scar formation around the nerve and dura.^{5,6,11,15} These complications lead to chronic pain and failed back surgery syndrome,¹⁵ which is of particular concern as degenerative LSS is most common in the elderly who have multilevel involvement and more severe degrees of stenosis.¹⁹

Therefore, there is a trend toward limiting midline and contralateral resection without compromising neural decompression.^{6,18,19} Previous studies have associated ULBD with a reasonable operative time,^{18,22} less blood loss and narcotic use than with open decompression,¹³ and good long-term outcomes.¹⁶

However, a literature search reveals a lack of studies directly comparing ULBD to open laminectomies. Apart from the comparative studies by Ikuta et al.,¹⁰ Thomé et al.,²⁵ Khoo and Fessler,¹³ and Rahman et al.,²² most studies analyzing ULBD lack a conventionally treated control

Fig. 4. Clinical status assessment. Graph showing pre- and postoperative mean VAS scores (left) and ODI scores (right) for both the open laminectomy (black) and ULBD (gray) groups. **Significant difference, $p < 0.001$.

group. Also, since the recent incorporation of operating microscopes into endoscopic approaches, few studies have compared microscopic approaches to open surgery.

Patient Characteristics

Significant differences in clinical and demographic characteristics included the mean follow-up time, age at time of surgery, and the number of patients presenting with radiculopathy. The mean duration of follow-up was higher in the open-surgery group than in the ULBD group (44.3 vs 36.9 months). This is a limitation in our study, as increasing evidence suggests that outcomes deteriorate over time,^{4,25} with success rates falling from 82% at 1 year to 68% at 4 years in the study by Mariconda et al.¹⁵

While the age at time of surgery was significantly higher in the ULBD group than in the open-surgery group (72.7 vs 65.8 years) the literature remains contradictory as to whether age predicts outcome.^{23,27,28,30} If age does predict outcome, higher age is likely to predict worse outcome, and in this study the older group had a better outcome despite age.

Clinical Outcomes

Previous studies have shown that ULBD can sig-

TABLE 4: Comparison of mean improvement in ODI, VAS (leg pain), and SF-12 scores between groups*

Score	Open-Surgery Group	ULBD Group	p Value
ODI	17.8 ± 15.4	28.6 ± 27.7	0.055
VAS (leg pain)	3.9 ± 2.9	5.6 ± 2.5	0.013
SF-12 PCS	40.2 ± 9.9	40.1 ± 10.8	0.52
SF-12 MCS	47.1 ± 9.8	50.2 ± 10	0.14

* Means presented ± SD. MCS = Mental Component Summary; PCS = Physical Component Summary.

nificantly improve ODI and VAS scores (range of mean follow-up 7 months–5.4 years);^{4–6,8,12,19,23} however, none of these studies had a conventionally treated control group for comparison. In our study, both MIS and open approaches resulted in significant improvements in function (ODI score) and leg pain (VAS score). In addition, the MIS approach achieved a significantly greater improvement in leg pain (VAS score) than did the open approach. However, neither approach was clearly superior in improving function (ODI score) or quality of life (SF-12 scores). Furthermore, neither approach was clearly associated with a higher success or satisfaction rate. While a greater percentage of patients in the ULBD group (85% vs 62%) felt they had a good outcome, the difference was not statistically significant. Disparities in study outcome measures and length of follow-up made comparing our success and satisfaction rates to findings reported in the literature difficult.

Postoperative Course

Our study demonstrates several benefits of microscopic ULBD in the postoperative course. As most patients with LSS are elderly and have numerous preoperative comorbidities, decreasing postoperative hospital stay, time to mobilization, and postoperative pain and disability can significantly decrease patient morbidity. Longer hospital stays and delayed recovery are associated with more postoperative complications, such as deep vein thrombosis, urinary tract infections, cardiopulmonary problems, pulmonary embolism, ileus, and prolonged narcotic use as well as with increased cost of care.^{2,11,13} Therefore, in our study, the significantly shorter average time to mobilization (15.6 vs 33.3 hours) and average duration of postoperative hospital stay (55.1 vs 100.8 hours) for patients in the ULBD group compared with those in the conventionally treated group were advantageous. Review of previously published studies showed values for

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Fig. 5. Measures of postoperative recovery for the open laminectomy (black) and ULBD (gray) procedures. Postoperative length of stay (A), time to mobilization (B), and opioid use (C) differed significantly between groups. * $p < 0.01$. ** $p < 0.001$.

mean postoperative hospital stay ranging from 42 to 80 hours^{4,8,13,23} and from 45 to 172 hours^{7,11,13} for ULBD-treated and conventionally treated patients, respectively.

Opioids have unwanted side effects that may require additional medications and unnecessarily prolong hospital stay.¹ Therefore, decreasing opioid requirements avoids these complications and allows for less complicated recovery, increased patient comfort, and faster return to normal activities of daily living.⁵ In our study, the mean value of total IV morphine equivalent units consumed was significantly smaller in ULBD-treated patients (9.3 vs 42.8 morphine equivalent units). While this could be due to the significantly longer mean postoperative stay in the conventionally treated group, a significantly larger proportion of patients in the ULBD group did not use any opioids at all (52% vs 15%). This is supported by Khoo and Fessler's 2002 study¹³ in which open-surgery patients required almost 3 times the amount of narcotics as patients treated with microendoscopic decompressive laminotomy (73.7 vs 31.8 morphine equivalent units, respectively) after adjusting for length of stay. While we cannot definitively state that patients treated with MIS consume fewer morphine equivalent units, we can conclude they are more likely to not use any opioids, suggesting that ULBD is associated with less postoperative pain and discomfort.

Disadvantages of ULBD

Possible disadvantages of MIS techniques include: 1) higher complication rates due to difficulty manipulating instruments through a small portal, especially in cases requiring contralateral access,²⁵ resulting in more significant dural sac retraction and a higher possibility of dural tears;¹⁹ 2) higher recurrence and reoperation rates due to minimal exposure leading to inadequate decompression;^{14,17,26} and 3) increased operation time due to the steep learning curve.²¹

However, our study showed no significant difference in complication and reoperation rates between ULBD-treated and conventionally treated patients. This could be accounted for by our study's short duration of follow-up, as reoperation rates increase in the long term^{8,16} when

bony regrowth occurs in an inadequate decompression.¹⁰ Additionally, the procedures in this study were performed by a single senior surgeon with extensive experience using both minimally invasive and open techniques, thus reducing the impact of the learning curve for ULBD.

Study Limitations

Our study's limitations lie in its small sample size and short length of follow-up. Because outcomes worsen in the long term,^{15,27} clear conclusions about between-group differences in ODI, VAS, PSI, and SF-12 scores and long-term complication and reoperation rates cannot be made.

In addition, our analysis of opioid consumption is also limited. Our conversions are based on equianalgesic dose ratios, and there is controversy over which ratios are correct,¹⁴ as opioid potency is affected by patient age, sex, and race. Furthermore, to prove that the higher consumption of opioids by conventionally treated patients was not due to the longer postoperative stay, analgesic use beyond the discharge date should be recorded in future studies.

Undoubtedly, our study findings need to be validated by a long-term randomized control trial. Our study's strengths include having a control group, a lack of learning-curve bias (because the same senior neurosurgeon performed all operations), and similarity of baseline characteristics in the 2 groups.

Conclusions

In the short and medium term, microscopic ULBD is more effective than standard open decompression for decreasing leg pain and equally effective in improving function. Additional benefits of the ULBD approach include significantly shorter postoperative hospital recovery time and time to mobilization, with less postoperative pain and postoperative opioid use.

Disclosure

The authors report no conflict of interest concerning the mate-

rials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Mobbs. Acquisition of data: Mobbs, Li, Sivabalan, Raley. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Rao. Study supervision: Mobbs.

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