Revision Surgery after Percutaneous Endoscopic Transforaminal Discectomy Compared with Primary Open Surgery for Symptomatic Lumbar Degenerative Disease

Jin-qian Liang, MD*, Chong Chen, MD*, Hong Zhao, MD

Department of Orthopaedic Surgery, Peking Union Medical College Hospital, Chinese Academy of Medical Science, Peking Union Medical College, Beijing, China

Objective: To evaluate the clinical outcome of reoperation after percutaneous endoscopic lumbar discectomy (PELD) as compared with primary spinal decompression and fusion.

Methods: A retrospective study from December 2014 to December 2017 was conducted at Peking Union Medical College Hospital and comprised 39 patients with symptomatic lumbar degenerative disease (LDD): 13 post-PELD who underwent reoperation (revision surgery group) and 26 who received primary spinal decompression and fusion (primary open surgery group). The two groups were compared regarding: operative time, blood loss, transfusion, hospitalization, postoperative visual analog scale (VAS) scores, Oswestry Disability Index (ODI) scores, Japanese Orthopedic Association (JOA) improvement rate, and postoperative complications. The Mann–Whitney U-test was applied to analyze continuous parameters, and the χ²-test for categorical parameters. Fisher’s exact test was used for small data subsets.

Results: There was no statistically significant difference between the two groups in mean age (52.7 years vs 52.9 years), gender ratio (6 men-to-7 women vs 12 men-to-14 women), body mass index, medical history, preoperative diagnosis, or surgical spine level (P > 0.05). The mean operative time of the revision surgery group was significantly longer than that of the primary open surgery group (160.0 min vs 130.2 min, P < 0.05). The revision surgery group also had a significantly higher mean estimated blood loss, postoperative drainage, and length of hospital stay (P < 0.05). However, no significant differences were found between the two groups in terms of hemoglobin and hematocrit values, preoperatively and postoperatively. The rate of transitional neurological irritation was higher in the revision surgery group (61.5% vs 3.8%; P < 0.05), as was intraoperative durotomy and cerebrospinal fluid leakage (30.8% vs 3.8%, P < 0.05). At 1 month, the VAS and ODI scores of the primary open surgery group were significantly better than those of the revision surgery group, while the improvement in JOA scores was similar. After 6 and 12 months’ follow-up, the VAS and ODI scores and the rates of JOA improvement were comparable.

Conclusion: Patients with LDD who received primary spinal decompression and fusion experienced lower rates of perioperative complications and shorter hospitalization compared with patients who underwent revision surgery after PELD, but the clinical outcomes at the last follow-up of both groups were satisfactory.

Key words: Lumbar degenerative disease; Lumbar surgery; Percutaneous endoscopic lumbar discectomy; Reoperation

Address for correspondence Hong Zhao, MD, Department of Orthopaedic Surgery, Peking Union Medical College Hospital, Chinese Academy of Medical Science, Peking Union Medical College, No. 1 Shuai Fu Yuan, Wang Fu Jing Street, Beijing, China 100730 Tel: 0086-10-69152813; Fax: 0086-10-69152800; Email: zhaohongyisheng@126.com

*Jin-qian Liang and Chong Chen contributed equally to this project and manuscript preparation.

Disclosure: The authors declare that they have no competing interests.

Received 2 March 2019; accepted 20 June 2019
Introduction

Symptomatic lumbar degenerative disease (LDD) presents as low back pain and limited physical activity that is due to abnormal motion or compression of neurovascular structures. LDD may be further characterized by stenosis of the spinal canal, herniated discs, and degenerative changes in the posterior arch. In the United States, surgical treatment for LDD has increased more than twofold in recent years (2000–2009), and a variety of innovative surgical techniques have been introduced. Worldwide, 266 million patients are diagnosed with LDD and low back pain per year, and low-income and middle-income countries have three times the incidence rate compared to high-income countries. Thus, how to best address lumbar degenerative disease and finding appropriate methods for treatment remain global issues.

Percutaneous endoscopic lumbar discectomy (PELD) is a promising minimally invasive alternative to primary open surgery. Results of PELD have been encouraging for treatment of lumbar disc herniation using an endoscopic posterolateral transforaminal approach, which can decrease the risk of repeated damage to the posterior and paraspinal structures, making it less traumatic than traditional open surgery, with less bleeding and faster postoperative recovery. Meanwhile, PELD combined with 3-D traction after surgery could provide more satisfied decompression and reduce hospital stay.

However, the recurrence of herniation after PELD has been the cause of great concern for many clinicians. A nationwide sample cohort study in South Korea analyzed the long-term reoperation rates for lumbar herniated intervertebral disc disease. The cumulative incidence of reoperation for PELD was 16% at 10-year follow-up, which was not very different to that for other surgical techniques like open discectomy, laminectomy or fusion. However, open surgery was the most commonly used technique for reoperation.

The epidemiological prevalence and related risk factors of recurrent herniation after PELD are unclear. Cheng et al. reported that after PELD percutaneous endoscopic discectomy (PELD group), 68 patients had homolateral real recurrent herniation (homolateral herniations at the same level), and recurrence was significantly more common than for other reoperative surgical techniques (70.6% in PELD group, 47.1% in microendoscopic discectomy [MED] group, and 37.8% in open group). A retrospective review performed on patients who had undergone PELD, including 10 228 patients with 1 year of follow-up, indicated that approximately 4.3% of cases were unsuccessful. The main reasons were incomplete removal of herniated discs and recurrence. Kim et al. (2007) point out that elderly patients, larger body mass index (BMI), and the presence of Modic change were more frequent in the recurrent group. Yao et al. (2017) reach a similar conclusion and state that obesity with BMI ≥25 kg/m² is the most significant risk factor for recurrence after PELD. Older age (≥50 years old), limited experience of the surgeon (<200 cases), treatment period, and central location of herniation were also closely associated with recurrent herniation after successful PELD. The overall mean interval until revision was 18.9 months (8.1 months in the PELD group vs 19.7 months in the MED group vs 33.1 months in the open group, P < 0.01).

Revision surgery is needed for most patients who suffer from recurrent low back pain or lower limb symptoms after PELD, if conservative treatment fails to relieve the patient’s symptoms. However, few studies have evaluated the clinical outcomes of reoperation surgery after PELD, relative to primary open surgery, for treating symptomatic LDD. Outcomes of revision lumbar open surgery tend to be worse than the initial procedure when there is a dural tear, nerve root injury, and other complications, which may be due to epidural or nerve root scarring from the first surgery.

Therefore, this retrospective study evaluated the clinical outcome of reoperation after PELD as compared with primary spinal decompression and fusion. The aim of the present study was to provide surgeons with: (i) insight for treating recurrent low back pain or lower limb symptoms for patients with LDD after PELD; (ii) useful and practical guidance regarding the perioperative clinical strategy for revision surgery after PELD; (iii) a summary of perioperative complications and discussion of how to avoid them.

Patients who had PELD and underwent reoperation were defined as the revision surgery group and those who received primary spinal decompression and fusion were defined as the primary open surgery group. We compare two groups with regard to operative time, blood loss, transfusion, hospitalization, postoperative visual analog scale (VAS) scores for low-back and leg pain, Oswestry Disability Index (ODI) scores, Japanese Orthopedic Association (JOA) improvement rate, and postoperative complications.

Patients and Methods

Patient Demographics

Each patient provided informed consent for participation in the study. This retrospective study was conducted in accordance with the Declaration of Helsinki (Ethical Principles for Medical Research Involving Human Subjects) and was approved by the Ethics Committee of the Peking Union Medical College Hospital.

From December 2014 to December 2017, the inclusion criteria for the reoperation surgery group were as follows: (i) patients previously with symptomatic LDD who underwent PELD; (ii) patients who presented with recurrent low back pain or lower limb symptoms due to lumbar disc herniation, lumbar spinal stenosis, or both lumbar disc herniation and spinal stenosis; (iii) MRI findings of re-herniation at the site of the previous PELD surgery; (iv) conservative treatment failed to relieve the recurrent pain; and (v) received open revision surgery. Exclusion criteria: (i) congenital lumbar scoliosis, spinal stenosis, or other deformities; (ii) lumbar infection or tumor; (iii) serious osteoporosis; and (iv) lumbar spondylolisthesis. Finally, 13 patients were included.
The control group (primary open surgery group) comprised 26 patients from our database who had received primary open surgical treatment for spinal decompression and fusion during the same period and had the same surgeons for the treatment of LDD. The patients in the primary open surgery group were just matched with the revision surgery group for gender ratio, age, and surgical spine levels. The demographic and clinical data for both groups included BMI, histories of cardiovascular disease, smoking, and hypertension, spine surgery level, and diagnosis.

**Surgical Procedures**
The surgeries were performed under general anesthesia; the patients were placed prone on a radiolucent operating table; a midline skin incision was made; the paravertebral muscles were divided and the surgery was cautious not to tear the dura mater; laminotomy or laminectomy was performed, and then discectomy with or without fusion; the incision was closed in layers after adequate nerve root decompression.

**Clinical Assessment**
Each participant was asked to complete three quality-of-life questionnaires before surgery and at each follow-up.

**Oswestry Disability Index**
The ODI is one of the principal condition-specific outcome measures used in the management of spinal disorders17. For each section of six statements, the total score is 5 (the first statement is marked with the score “0” and the last statement is marked as “5”). If more than one box is marked in each section, the highest score is taken. If all 10 sections are completed, the score is calculated as follows: total scored/50 (total possible score) × 100%. If one section is missed (or not applicable), the score is calculated as: total scored/45 (total possible score) × 100%. Therefore, the final score may be summarized as: [total score/(5 × number of questions answered)] × 100%. Rounding the percentage to a whole number is suggested for convenience. We defined that: 0%–20% means mild; 21%–40% means moderate; 41%–60% means severe; 61%–80% means very severe; and 80%–100% means patients with very exaggerated symptoms.

**Visual Analogue Scale**
The VAS score system is used in the social and behavioral sciences to measure low back pain and leg pain18. The VAS pain scoring standard (scores from 0 to 10) was as follows: 0 means painless; 1–3 means mild pain that the patient could endure; 4–6 means the patient was in pain that could be endured and was able to sleep; and 7–10 means the patient had intense pain and was unable to tolerate the pain.

**Japanese Orthopedic Association**
The JOA score was used to evaluate the neurological function of patients with lumbar degeneration and treatment effectiveness19. The system consists of four subsections, including 14 categories with overall headings of subjective symptoms, clinical signs, restriction of activities of daily living, and bladder function. The highest possible total score from categories for a normal person is 29 points. Therefore, the treatment improvement rate = [(post-treatment score – pre-treatment score)/(29 – pre-treatment score)] × 100%; and ≥ 75% means excellent, 50%–74% means good, 25%–49% means fair, and 0%–24% means poor.

The patients were followed at 1, 6, and 12 months postoperatively. In addition, operative time, estimated blood loss, length of hospital stay, and complications were documented.

**Statistical Analysis**
SPSS version 20.0 (Chicago, IL, USA) was used to compare the demographic data and clinical outcomes between the groups. The Mann–Whitney U-test was applied to analyze continuous parameters, and the χ2-test for categorical parameters. Fisher’s exact test was used for small data subsets (n < 5). P < 0.05 was considered statistically significant.

**Results**

**Demographic Data**
The revision surgery group included 13 patients and the primary open surgery group included 26 patients (Table 1). Between the two groups there was no statistically significant differences in mean age (52.7 years vs 52.9 years; P > 0.05) or gender ratio (6 men-to-7 women vs 12 men-to-14 women; P > 0.05). There were also no significant differences in BMI scores, medical history, preoperative diagnosis, or surgical spine level (P > 0.05).

**Clinical Outcomes**
The mean operative time of the revision surgery group was significantly longer than that of the primary open surgery group in Table 2 (160.0 min vs 130.2 mins, P < 0.05). The revision surgery group also had a significantly higher mean estimated blood loss (317.69 mL vs 250.12 mL, P < 0.05), postoperative drainage (354.85 mL vs 232.00 mL, P < 0.05), and length of hospital stay (9.46 days vs 7.69 days, P < 0.05). However, no significant differences were found between the two groups in terms of hemoglobin and hematocrit values, preoperatively and postoperatively.

**Visual Analogue Scale**
There were no differences between the groups with regard to preoperative VAS mean scores (6.9 vs 6.9, P > 0.05). At the 1-month follow-up, the VAS scores of the primary open surgery group were significantly better than those of the revision surgery group (2.2 vs 3.7, P < 0.05). At the 6-month and 12-month follow-ups, the VAS scores of the two groups were not significantly different (2.5 vs 2.7 in 6-month, 1.5 vs 1.6 in 12-month, P > 0.05) (Fig. 1A).
Oswestry Disability Index
There were no differences between the groups in preoperative ODI scores (60.1% vs 61.5%, P > 0.05), but at the 1-month follow-up, the ODI scores of the primary open surgery group were better than those of the revision surgery group (25.5% vs 36.6%, P < 0.05). There were no differences in the ODI scores between the groups at the 6-month and 12-month follow-ups (14.7% vs 16.3% in 6-month, 8.8% vs 9.5% in 12-month, P > 0.05) (Fig. 1B).

Japanese Orthopedic Association
As for JOA improvement rate, there were no differences between the two groups at the 1-month (52.0% vs 58.1%, P > 0.05), 6-month (82.6% vs 88.9%, P > 0.05), and 12-month follow-up (90.8% vs 94.0%, P > 0.05) (Fig. 1C).

Postoperative Complications
No nerve root injury or cauda equina syndrome was observed (Table 3). However, transient nerve root irritation (numbness, weakness, and pain) was found in 61.5% (8 of 13) of patients in the revision surgery group, compared with 3.8% (1 of 26) in the primary open surgery group (P < 0.001, Fig. 2). These patients were treated with oral gabapentin and mecobalamin and improved within 3 months postoperatively (Fig. 3). Of the 13 patients in the revision surgery group, 4 (30.8%) were found to have a thecal sac tear with cerebrospinal fluid leakage (Fig. 4). However, only 1 patient (3.8%) was noted in the primary open surgery group (P < 0.05). No significant differences were found in terms of infections, cardiac complications, or urinary retention.

### TABLE 1 Demographic characteristics and surgery-related factors of reoperation group and primary open surgery group

| Demographic         | Group A | Group B | P value |
|---------------------|---------|---------|---------|
| Subjects (cases)    | 13      | 26      | —       |
| Age (years, mean ± SD) | 52.69 ± 15.93 | 52.85 ± 14.83 | 0.976 |
| Gender (cases [%])  | Male 6 (46.2) | 12 (46.2) | 1.000 |
|                     | Female 7 (53.8) | 14 (53.8) | |
| BMI (kg/m², mean ± SD) | 26.38 ± 3.29 | 24.67 ± 3.10 | 0.120 |
| Coronary disease (cases [%]) | 1 (7.7) | 1 (3.8) | 0.608 |
| Hypertension (cases [%]) | 6 (46.2) | 6 (23.1) | 0.141 |
| Diabetes mellitus (cases [%]) | 2 (15.4) | 3 (11.5) | 0.735 |
| Diagnosis (cases [%]) | LDH 6 (46.2) | 12 (46.2) | 0.791 |
|                     | LSS 1 (7.7) | 6 (23.1) | |
|                     | LDH & LSS 6 (46.2) | 8 (30.8) | |
| Surgical level (cases [%]) | L5–S1 2 (15.4) | 4 (15.4) | 0.736 |
|                     | L4–L5 7 (53.8) | 10 (38.5) | |
|                     | L4–S1 2 (15.4) | 4 (15.4) | |
|                     | L5–S1 2 (15.4) | 8 (30.8) | |

Group A, reoperation group; Group B, primary open surgery group. BMI, body mass index; LDH, lumbar disc herniation; LSS, lumbar spinal stenosis.

### TABLE 2 Operative and post-operative features of reoperation for post-PELD group and primary open surgery group

| Demographic         | Group A | Group B | P value |
|---------------------|---------|---------|---------|
| Subjects (cases)    | 13      | 26      | —       |
| Levels fused (n, mean ± SD) | 1.31 ± 0.48 | 1.31 ± 0.47 | 1.000 |
| Operative time (min, mean ± SD) | 160.0 ± 26.14 | 130.23 ± 25.61 | 0.003 |
| Operative EBL (mL, mean ± SD) | 317.69 ± 56.70 | 250.12 ± 102.96 | 0.034 |
| Transfusion (U/patient, mean ± SD) | 0.31 ± 0.75 | 0.08 ± 0.39 | 0.213 |
| Allogenic blood transfusion (cases [%]) | 2 (15.4) | 1 (3.8) | 0.202 |
| Postoperative drainage (mL, mean ± SD) | 354.85 ± 234.62 | 232.00 ± 124.76 | 0.038 |
| Hemoglobin (g/dL, mean ± SD) | Baseline 13.46 ± 15.93 | 13.77 ± 1.27 | 0.804 |
|                     | Day 1 postoperative 12.24 ± 2.04 | 12.11 ± 1.52 | 0.828 |
|                     | Discharge 11.85 ± 2.31 | 12.30 ± 1.42 | 0.464 |
| Hematocrit (% mean ± SD) | Baseline 40.39 ± 4.64 | 39.93 ± 3.70 | 0.738 |
|                     | Day 1 postoperative 36.14 ± 5.07 | 35.20 ± 4.08 | 0.536 |
|                     | Discharge 35.37 ± 7.01 | 35.74 ± 3.76 | 0.829 |
| Length of stay (days, mean ± SD) | 9.46 ± 3.41 | 7.69 ± 1.85 | 0.041 |

Group A, reoperation group; Group B, primary open surgery group. EBL, estimated blood loss.
The recurrence rate after PELD is reportedly as much as 7.4%–22. Revision surgery is very important for patients with symptomatic LDD who fail to recover through conservative therapy. However, few studies have evaluated the clinical outcome of open revision surgery for recurrent symptoms after PELD, relative to primary open surgery.

Challenging for Revision Surgery

Revision surgery is far more challenging than primary surgery. Epidural or perineural scar tissue can be a troublesome issue that can disturb dissection during a posterior approach, increasing the risk of dural tear or nerve injury.\textsuperscript{23} The incidence of intraoperative incidental durotomy is as high as 20.0% in patients receiving repeated open lumbar surgery.\textsuperscript{24,25} The rate of recurrent herniation after PELD was reported as 3.6%, which may be related to age (>50 years) and obesity.\textsuperscript{26} Ebeling \textit{et al.}\textsuperscript{27} reported a complication rate of 13.0% after repeated discectomy, among which dural tears and infections are the most common problems. Yao \textit{et al.}\textsuperscript{28} investigated minimally invasive spine surgeries for recurrent herniation and reported that the complication rates were 3.9%, 10%, and 14.3% in patients receiving, respectively, transforaminal lumbar interbody fusion, microendoscopic discectomy, and PELD. Consistent with these previous studies, the present study showed that the perioperative complication rate of patients who underwent repeated open surgery for PELD recurrence was higher than that of patients who underwent primary spinal decompression and fusion. Therefore, we believe patients and their family members should be routinely informed of the high risk of perioperative complications when planning open revision surgery after PELD. To prevent perioperative neurologic complications, patients scheduled for reoperation should be routinely encouraged to take steroid agents such as methylprednisolone or dexamethasone.

Ahn \textit{et al.}\textsuperscript{29} found that minimally invasive revision lumbar discectomy may be associated with increased operative time, longer hospital stay, and postoperative narcotic utilization, compared with the primary surgery. Longer operative time may also make a wide variety of complications more likely. Kim \textit{et al.}\textsuperscript{30} conducted a study with a large cohort (4588 patients) who underwent single-level lumbar fusion and found that prolonged operative time was associated with increased risk for overall, medical, and surgical complications, superficial surgical site infection, and postoperative transfusions. Consistent with these reports, in the present study the operative time and the duration of hospitalization of patients in the reoperation post-PELD group

| Complications                  | Reoperation group (n = 13) | Control group (n = 26) | P value$^*$ |
|-------------------------------|---------------------------|------------------------|-------------|
| Neurological deficiency       | 8 (61.5)                  | 1 (3.8)                | 0.000       |
| CSF leakage                   | 4 (30.8)                  | 1 (3.8)                | 0.035       |
| Incision infection            | 2 (15.4)                  | 1 (3.8)                | 0.253       |
| Urinary tract infection       | 2 (15.4)                  | 1 (3.8)                | 0.253       |
| Pneumonia                     | 1 (7.7)                   | 1 (3.8)                | 1.000       |
| Cerebrovascular accident      | 1 (7.7)                   | 0 (0)                  | 0.333       |

Note: Total number of patients in these composites is not the sum of individual complications because some patients had more than one complication. $^*$ Fisher exact test; CSF, cerebrospinal fluid.
were significantly longer than for primary surgery. Thus, we presume that longer operative time may be an important risk factor affecting the prognosis and overall complications of revision surgery. Strategies to reduce operative time and further investigations of risk factors are needed.

High-volume blood loss leads to more autologous or allogenic blood transfusions, with attendant risks of transfusion reactions and infections. A study by Yoshihara and Yoneoka\textsuperscript{31} using data from the National Inpatient Sample found that revision spinal fusion was an independent risk factor for allogenic blood transfusion. Basques\textit{ et al.}\textsuperscript{32} compared the short-term morbidity of revision and primary posterior lumbar fusions and reported that the former had a significantly higher rate of blood transfusion. In contrast, in the present study, the rates of allogenic blood transfusion were similar between the revision and primary surgery groups. This may be because the number of fused levels was relatively few. Therefore, we emphasize that surgeons should

Fig. 2 Clinical imaging from 1 representative patient (female, 39 years old) more than 5 years after percutaneous endoscopic lumbar discectomy (PELD) (L4–L5), who complained of lumbago and left lower limb extremity pain for approximately 7 months. (A) X-ray images of lumbar vertebrae anteroposterior and lateral position plain films showed no spondylolisthesis. (B) T2-weighted sagittal (left) and axial (right) preoperative MRI of the lumbar spine showed the L4–L5 disc herniation on the same segment of PELD. (C) The X-ray imaging indicated that the location of the internal fixator was excellent. On the third postoperative day, the acupuncture feeling on the left lower extremity was slightly reduced, and recovered in 2 weeks.

Fig. 3 A patient (male, 78 years old) who received PELD (L4–L5) 4 months previously and had lumbago and bilateral lower limb pain and intermittent claudication. (A) X-ray images of lumbar vertebrae anteroposterior and lateral position plain films showed scoliosis and severe degeneration. (B) Preoperative MRI showed that sagittal (left) and axial (right) of the lumbar spine there was severe lumbar spinal stenosis, especially in L4–L5. During the surgery, we discovered that severe lateral recess stenosis of the L4–L5, adhesion between scar tissue and dural and hard to be separated. (C) The X-ray imaging indicated that the location of the internal fixator was excellent but after 1 postoperative day, the numb feeling on the bilateral lower extremity reappearance, which recovered in 2 months.
be aware of the potential risk in these procedures. In particular, effective strategies to minimize blood loss during revision lumbar fusion are important.

In the current study, at the last follow-up there were no significant differences between the two groups regarding functional outcomes, as reflected by VAS scores, ODI scores, and JOA improvement rates. However, at the 1-month follow-up, the VAS and ODI scores of the primary open surgery group were significantly better than those of the revision surgery group, although the JOA improvement rates were similar. The lack of difference in JOA improvement may be a result of no patient suffering severe neurological damage. Compared with the revision surgery group, patients in the primary open surgery group experienced earlier recovery, perhaps because of transient nerve root irritation or cerebrospinal fluid leakage in the former. The lack of difference in functional outcomes at the last follow-up may be the result of all patients having recovered completely from any complication. Therefore, the final functional outcomes of the patients who underwent reoperative surgery after PELD were satisfactory.

**Limitations**

This study is limited in that the patients’ lifestyle and family history were not recorded. We also did not investigate the effects of spinal deformity on the outcomes of the respective surgeries. In addition, this is a retrospective study, and financial factors and preoperative medications may have influenced the length of stay in hospital, as has been reported elsewhere. Finally, all patients were relatively young, and these findings may not be applicable to elderly, more comorbid patients.

**Conclusions**

The present study provides an important perspective on the management of recurrence after PELD with open revision surgery. Compared with primary open surgery, post-PELD revision was associated with a higher perioperative complication rate and longer hospital stay. However, the patients’ functional outcomes at the last follow-up were satisfactory. The disadvantages of reoperation should be carefully balanced against the potential advantages, and patients should be fully informed.

**References**

1. Wang HW, Hu YC, Wu ZY, et al. Minimally invasive transforaminal lumbar interbody fusion and unilateral fixation for degenerative lumbar disease. Orthop Surg, 2017, 9: 277–283.
2. Yoshihara H, Yoneoka D. National trends in the surgical treatment for lumbar degenerative disc disease: United States, 2000 to 2009. Spine J, 2015, 15: 265–271.
3. Ravindra VM, Senglaub SS, Rattani A, et al. Degenerative lumbar spine disease: estimating global incidence and worldwide volume. Global Spine J, 2018, 8: 784–794.
4. Xu BS, Liu Y, Xu HW, Yang Q, Ma XL, Hu YC. Intervertebral fusion with mobile microendoscopic discectomy for lumbar degenerative disc disease. Orthop Surg, 2016, 8: 241–245.
5. Gu YT, Cui Z, Shao HW, Ye Y, Gu AQ. Percutaneous transforaminal endoscopic surgery (PTES) for symptomatic lumbar disc herniation: a surgical technique, outcome, and complications in 209 consecutive cases. J Orthop Surg Res, 2017, 12: 25.
6. Ruetten S, Komp M, Merk H, Godolias G. Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-
endoscopic interlaminar and transforaminal versus microsurgical revision.
J Spinal Discord Tech, 2009, 22: 122–129.
7. Jang JS, An SH, Lee SH. Transforaminal percutaneous endoscopic discectomy in the treatment of foraminal and extraforaminal lumbar disc herniations. J Spinal Discord Tech. 2006, 19: 338–343.
8. Kafadar A, Kaharaman S, Akbörü M. Percutaneous endoscopic transforaminal lumbar discectomy: a critical appraisal. Minim Invasive Neurosurg, 2006, 49: 74–79.
9. Hu D, Fei J, Chen G, Yu Y, Lai Z. Treatment for lumbar spinal stenosis in elderly patients using percutaneous endoscopic lumbar discectomy combined with postoperative three-dimensional traction. Expert Rev Med Devices, 2019, 16: 317–323.
10. Kim CH, Chung CK, Choi Y, et al. The long-term reoperation rate following surgery for lumbar herniated intervertebral disc disease: a Nationwide sample cohort study with a 10-year follow-up. Spine (Phila Pa 1976), 2019. https://doi.org/10.1097/BRS.0000000000003065.
11. Cheng J, Wang H, Zheng W, et al. Reoperation after lumbar disc surgery in two hundred and seven patients. Int Orthop, 2013, 37: 1511–1517.
12. Choi KC, Lee JH, Kim JS, et al. Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10,228 cases. Neurosurgery, 2015, 76: 372–380 discussion 380–371; quiz 381.
13. Kim JM, Lee SH, Ahn Y, Yoon DH, Lee CD, Lim ST. Recurrence after successful percutaneous endoscopic lumbar discectomy. Minim Invasive Neurosurg, 2007, 50: 82–85.
14. Yao Y, Liu H, Zhang H, et al. Risk factors for recurrent herniation after percutaneous endoscopic lumbar discectomy. World Neurosurg, 2017, 100: 1–6.
15. Chen HC, Lee CH, Wei L, Lui TN, Lin TJ. Comparison of percutaneous endoscopic lumbar discectomy and open lumbar surgery for adjacent segment degeneration and recurrent disc herniation. Neurol Res Int, 2015, 2015: 791943: 1–5.
16. Le H, Sandhu FA, Fessler RG. Clinical outcomes after minimal-access surgery for recurrent lumbar disc herniation. Neurosurg Focus, 2003, 15: E12.
17. Fairbank JC, Pynsent PB. The Oswestry disability index. Spine (Phila pa 1976), 2000, 25: 2940–2952 discussion 2952.
18. Wewers ME, Lowe NK. A critical review of visual analogue scales in the measurement of clinical phenomena. Res Nurs Health, 1990, 13: 227–236.
19. Zheng CF, Liu YC, Hu YC, et al. Correlations of Japanese Orthopaedic association scoring systems with gait parameters in patients with degenerative spinal diseases. Orthop Surg, 2016, 8: 447–453.
20. Ruetten S, Komp M, Merk H, Godilas G. Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. Spine (Phila Pa 1976), 2008, 33: 931–939.
21. Choi KC, Kim JS, Kang BU, Lee CD, Lee SH. Changes in back pain after percutaneous endoscopic lumbar discectomy and annuloplasty for lumbar disc herniation: a prospective study. Pain Med, 2011, 12: 1615–1621.
22. Hoogland T, Schubert M, Miklitz B, Ramirez A. Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases. Spine (Phila Pa 1976), 2006, 31: E890–E897.
23. Ahn Y, Lee SH, Park WM, Lee HY, Shin SW, Kang HY. Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: surgical technique, outcome, and prognostic factors of 43 consecutive cases. Spine (Phila Pa 1976), 2004, 29: E326–E332.
24. Choi KB, Lee DY, Lee SH. Contralateral reherniation after open lumbar microdiscectomy: a comparison with ipsilateral reherniation. J Korean Neurosurg Soc, 2008, 44: 320–326.
25. Morgan-Hough CV, Jones PW, Eisenstein SM. Primary and revision lumbar discectomy. A 16-year review from one centre. J Bone Joint Surg Br, 2003, 85: 871–874.
26. Yin S, Du H, Yang W, Duan C, Feng C, Tao H. Prevalence of recurrent herniation following percutaneous endoscopic lumbar discectomy: a meta-analysis. Pain Physician, 2018, 21: 337–350.
27. Ebeling U, Kalbarcy H, Reuten HJ. Microsurgical reoperation following lumbar disc surgery. Timing, surgical findings, and outcome in 92 patients. J Neurosurg, 1989, 70: 397–404.
28. Yao Y, Zhang H, Wu J, et al. Comparison of three minimally invasive spine surgery methods for revision surgery for recurrent herniation after percutaneous endoscopic lumbar discectomy. World Neurosurg, 2017, 100: 641–647.e641.
29. Ahn J, Tabaraee E, Bohl DD, Aboushaala K, Singh K. Primary versus revision single-level minimally invasive lumbar discectomy: analysis of clinical outcomes and narcotic utilization. Spine (Phila Pa 1976), 2015, 40: E1025–E1030.
30. Kim BD, Hsu WK, De Oliveira GS Jr, Saha S, Kim JY. Operative duration as an independent risk factor for postoperative complications in single-level lumbar fusion: an analysis of 4588 surgical cases. Spine (Phila Pa 1976), 2014, 39: 510–520.
31. Yoshihara H, Yoneoka D. Predictors of allogeneic blood transfusion in spinal surgery for pediatric patients with idiopathic scoliosis in the United States, 2000–2009. Spine (Phila Pa 1976), 2014, 39: 1860–1867.
32. Basques BA, Diaz-Collado PJ, Geddes BJ, et al. Primary and revision posterior lumbar fusion have similar short-term complication rates. Spine (Phila Pa 1976), 2016, 41: E101–E106.
33. Neatherlin JS, Brilhart B, Henry JJ. Factors determining length of hospitalization for patients having laminectomy surgery. J Neurosci Nurs, 1988, 20: 39–41.