Risk Factors for Poor Outcomes Following Minimally Invasive Discectomy: A Post Hoc Subgroup Analysis of 2-Year Follow-up Prospective Data

Zihao Chen1,2,3,*, Lei He1,2,3,*, Lijun Huang1,2,3, Zhongyu Liu1,2,3, Jianwen Dong1,2,3, Bin Liu1,2,3, Ruiqiang Chen1,2,3, Liangming Zhang1,2,3, Peigen Xie1,2,3, Limin Rong1,2,3
1Department of Spine Surgery, The Third Affiliated Hospital of Sun Yat-sen University, Guangzhou, China
2Guangdong Provincial Center for Quality Control of Minimally Invasive Spine Surgery, Guangzhou, China
3Guangdong Provincial Center for Engineering and Technology Research of Minimally Invasive Spine Surgery, Guangzhou, China

Objective: A post hoc subgroup analysis of prospectively collected data from a randomized controlled trial was conducted to identify risk factors related to poor outcomes in patients who underwent minimally invasive discectomy.

Methods: Patients were divided into satisfied and dissatisfied subgroups based on Oswestry Disability Index (ODI), visual analogue scale (VAS) back pain score (VAS-back) and leg pain score (VAS-leg) at short-term and midterm follow-up according to the patient acceptable symptom state threshold. Demographic characteristics, radiographic parameters, and clinical outcomes between the satisfied and dissatisfied subgroups were compared using univariate and multivariate analysis.

Results: A total of 222 patients (92.1%) completed 2-year follow-up, and the postoperative ODI, VAS-back, and VAS-leg were significantly improved after surgery as compared to preoperatively. Multivariate analysis indicated older age (p = 0.026), lateral recess stenosis (p = 0.046), and lower baseline ODI (p = 0.027) were related to poor short-term functional improvement. Higher baseline VAS-back (p = 0.048) was associated with poor short-term relief of back pain, while absence of decreased sensation (p = 0.019) and far-lateral disc herniation (p = 0.004) were associated with poorer short-term relief of leg pain. Lumbar facet joint osteoarthritis was identified as a risk factor for poor functional improvement (p = 0.003) and relief of back pain (p = 0.031). Disc protrusion (p = 0.036) predicted poorer relief of back pain at midterm follow-up.

Conclusion: In this study, several factors were identified to be predictive of poor surgical outcomes following minimally invasive discectomy. (ClinicalTrials.gov number: NCT01997086).

Keywords: Minimally invasive discectomy, Risk factors, Disability, Back pain, Leg pain

INTRODUCTION

Lumbar disc herniation (LDH) is characterized by low back pain and radiating leg pain, and is one of the most costly disorders for society in terms of disability and work absenteeism.1,2 Several randomized controlled trials (RCTs) concluded that surgical treatment provides more effective and rapid pain relief for patients who are surgical candidates.3,4 Currently, conventional microdiscectomy performed with the aid of a microscope is commonly used in Western countries to treat LDH, and is considered to be the gold standard surgical procedure for the condition.4 Over the past 2 decades, minimally invasive spine sur-
gery (MISS) has become increasingly more common, and is effi-
cient and effective for the management of a wide range of spine
disorders.1 Percutaneous transforaminal endoscopic discecto-
y (PTED), also referred to as transforaminal endoscopic lum-
bar discectomy,6 and microendoscopic discectomy (MED), are
2 of the most popular minimally invasive discectomy pro-
dures.5,6

The PTED and MED procedures are considered to be as ef-
fective as microdiscectomy, with the advantages of less surgical
trauma, shorter length of hospital stay, and the potential of fast-
er return to work.8,9 A recent meta-analysis including 18 com-
parative studies reported that both PTED and MED achieve
satisfactory results with high excellent and good outcome rates
(PTED, 92.17%; MED, 91.81%).10 We previously conducted a
RCT examining PTED and MED, and the results showed that
both procedures achieve equivalent and satisfactory outcomes
for the treatment of LDH.11,12

Although favorable surgical outcomes can be achieved in more
than 90% of cases with the aforementioned procedures, there
are factors that may play a role in inferior outcomes. A key to
successful surgical outcomes is proper patient selection; hence
risk factors that predict poor clinical outcomes are useful in
choosing patients who will benefit optimally from minimally
invasive discectomy. Numerous studies have investigated pre-
operative outcome predictors, including sociodemographic,
clinical, radiological, and psychological variables, that are asso-
ciated with postsurgical clinical outcomes in patients undergo-
ing open discectomy.13 To date, only limited retrospective stud-
ies have examined possible risk factors associated with poor
outcomes after minimally invasive discectomy, and no clear
consensus has been achieved.14–18

Thus, the purpose of this study was to analyze the 2-year fol-
low-up data of our RCT in order to identify potential risk fac-
tors related to poor outcomes in patients who underwent mini-
mally invasive discectomy. Identifying factors associated with
poor outcomes will help spine surgeons identify patients most
likely to benefit from the procedure.

MATERIALS AND METHODS

1. Study Design and Inclusion/Exclusion Criteria

We previously conducted a single-center, open-label, RCT to
compare the efficacy and safety of PTED and MED in patients
with LDH for whom surgery was indicated. The study was reg-
istered with the ClinicalTrials.gov database (http://clinicaltrials.
gov), and its registration number is NCT01997086. The clinical
research ethics committee of the Third Affiliated Hospital of
Sun Yat-sen University approved the clinical trial, and all par-
ticipants provided written informed consent.

Patients with radicular pain and signs of radiculopathy, and
an imaging study (magnetic resonance imaging or computed
tomography) showing LDH at the level and side corresponding
to the radicular signs or symptoms were considered potential
participants. The detailed inclusion and exclusion criteria have
been published previously.11,12 All patients included in this
study underwent either PTED or MED.

2. Surgical Interventions

All of the surgeons in the trial were highly experienced, and
all had >3 years of experience performing MISS and had per-
formed a minimum of 200 procedures. They had also received
formal training in PTED and MED, and strictly adhered to stan-
dard operating procedures. The details of PTED or MED pro-
dcedures are described in our prior publications.11,12

3. Outcomes Assessments

Participants were assessed preoperatively, and at 1 week, 1
month, 3 months, 6 months, 1 year, and 2 years postoperatively.
In the current study, we selected clinical outcomes at 3 months
and 2 years postoperatively to represent short-term and mid-
term outcomes, respectively. A research assistant collected base-
line and follow-up data by administering questionnaires via tele-
phone, email, mail, or in person.

Several patient-reported outcome measures (PROMs) were
used to evaluate the effectiveness of the surgical procedures.
The primary outcome measure was Oswestry Disability Index
(ODI) score. Secondary outcomes included scores of the Medi-
cal Outcomes Study 36-item Short-Form Health Survey bodily
pain (SF-36 BP) and physical function (SF-36 PF) scales, Euro-
pean quality of life-5 dimensions (EQ-5D) score, and visual an-
alog scale (VAS) scores for back pain (VAS-back) and leg pain
(VAS-leg).

Patients were divided into satisfied and dissatisfied subgroups
based on ODI score, VAS-back score, and VAS-leg score at
short-term and midterm follow-up, according to the patient ac-
ceptable symptom state (PASS) threshold. PASS is a target score
beyond which patients deem themselves to have attained an ac-
ceptable outcome.19,20 The satisfied subgroup for functional im-
provement was defined as an ODI score less than or equal to
the PASS threshold, ranging from 9.55 to 29.00 according to
baseline scores.20 The satisfied subgroup for relief of back pain
or leg pain was defined as a VAS-back or VAS-leg score ≤2.21
The demographic characteristics, radiographic parameters, and clinical outcomes between the satisfied and dissatisfied subgroups were compared.

### 4. Radiographic Parameters
Preoperative anteroposterior and lateral plain radiographs, dynamic plain radiographs, computed tomography (CT) images, and magnetic resonance (MR) images were prospectively collected. The type and location of disc herniation, Modic change, Pfirrmann disc classification, and adjacent segment degeneration (ASD) in the proximal and distal segments were determined based on MR images. The grade of lumbar facet joint osteoarthritis (LFJOA) and lateral recess stenosis was measured on either CT images or MR images.

Disc degeneration was classified into 5 grades by reviewing lumbar MR images according to the grading system of Pfirrmann et al. In this study, we defined Pfirrmann grade ≥ 3 as disc degeneration. The grading system of Weishaupt et al. is a feasible tool for grading the severity of LFJOA based on CT images or MR images. In this study, LFJOA was defined as Weishaupt grade ≥ 2, and no LFJOA was defined as grade 0 and 1. When there was a difference in the severity of facet joint osteoarthritis between right and left side, the side with the worst grade was used in the analysis. Lateral recess stenosis was defined as a lateral recess measurement of < 3 mm.

### 5. Statistical Analysis
For continuous variables, differences between groups were compared using the Student t-test, whereas the chi-square test was used for categorical variables. Multiple logistic regression analysis was used to identify independent risk factors of poor outcomes. Variables with a value of p < 0.1 by univariate analysis were included in multiple logistic regression models. SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA) was used for all analyses. All p-values were 2-sided, and values < 0.05 were considered to indicate a statistically significant difference.

### RESULTS
Of the 241 patients who were enrolled in our RCT, 119 received PTED and 122 received MED. A total of 222 patients (92.1%) completed the 2-year follow-up, and were included in the current analysis. The dropout rates were low, and were equivalent between treatment groups at each follow-up point. There was no evidence of differential dropout according to the assigned treatment.

The mean age of participants was 41.0 years old, and 40.7% were female. The most common type of disc herniation was paramedian, which accounted for 68% of cases, and L4–5 and L5–S1 were the most operated segments (> 95%). Functional ability and the degree of back pain and leg pain were significantly improved after surgery in both groups, and the magnitude of leg pain relief was greater than that of back pain relief. With respect to all clinical outcomes, there were no differences between the treatment groups at each postoperative follow-up point. Univariate analysis indicated that the surgical technique (PTED or MED) did not impact clinical outcomes at short-term and midterm follow-up.

#### 1. Univariate Analysis of Short-term Outcomes
A total of 68 patients (30.1%) were defined as dissatisfied at 3-month follow-up according to the PASS threshold of ODI score. Although significant improvements in all of the clinical outcomes were seen in both the satisfied and dissatisfied subgroups, the magnitude of improvements was less in the dissatisfied subgroup (Table 1). Based on the results of univariate analysis, statistically significant predictors of inferior improvement in functional outcomes included lower baseline ODI score (p < 0.001), higher baseline SF-36 PF score (p < 0.001), higher baseline SF-36 BP score (p = 0.002), higher baseline EQ-5D score (p < 0.001), lower VAS-leg score (p = 0.005), older age (p = 0.035), negative nerve root tension test (p = 0.012), nonparamedian disc herniation (p = 0.036), nonextrusion (p = 0.036), and lateral recess stenosis (p = 0.010) (Tables 1, 2). Longer symptom duration (p = 0.065) and proximal ASD (p = 0.077), although not statistically significant, showed trends toward dissatisfied functional improvement and were included in multivariate logistic regression models.

According to the PASS threshold of VAS-back score, 24 patients (10.6%) were classified as dissatisfied at 3-month follow-up. Based on the results of univariate analysis, statistically significant predictors of inferior relief of back pain included higher baseline VAS-back score (p < 0.001) and longer symptom duration (p = 0.036) (Tables 1, 2). Predominant back pain symptoms (p = 0.050), absence of decreased sensation (p = 0.066), and absence of myotomal weakness (p = 0.093) showed trends toward dissatisfied relief of back pain (though not significant) and were included in multivariate logistic regression models.

A total of 27 patients (11.9%) were defined as dissatisfied based on the VAS-leg score at 3-month follow-up. Univariate analysis indicated statistically significant predictors of inferior relief of leg pain included predominant back pain symptoms (p = 0.012),
absence of decreased sensation (p = 0.001), absence of myotomal weakness (p = 0.040), and far-lateral disc herniation (p < 0.001) (Tables 1, 2). Higher baseline SF-36 PF score (p = 0.077), higher baseline SF-36 BP score (p = 0.058), higher baseline VAS-back score (p = 0.056), higher body mass index (p = 0.064), and negative nerve root tension test (p = 0.056) showed trends toward dissatisfied relief of leg pain and were included in multivariate logistic regression models.

### 2. Univariate Analysis of Midterm Outcomes

According to the PASS threshold of ODI score, 16 patients (7.2%) were dissatisfied with functional improvement at 2-year follow-up. Comparison of clinical and radiological data between the satisfied and dissatisfied subgroups at midterm follow-up found significant differences between the 2 groups with respect to lower baseline ODI score (p = 0.030), higher baseline SF-36 PF score (p = 0.026), higher baseline SF-36 BP score (p = 0.017), female sex (p = 0.006), and the presence of LFJOA (p < 0.001) (Tables 3, 4). Higher baseline EQ-5D score (p = 0.063), though not significant, was associated with poorer improvement in functional outcomes and was included in multivariate logistic regression models.

According to the PASS threshold of VAS-back score, 9 patients (4.1%) were dissatisfied with relief of back pain at 2-year follow-up. Univariate analysis indicated statistically significant predictors of poorer relief of back pain were higher baseline SF-36 BP score (p = 0.035), female sex (p = 0.019), far-lateral disc herniation (p = 0.017), disc protrusion (p = 0.090), and presence of LFJOA (p = 0.003) (Tables 3, 4). Higher baseline EQ-5D score (p = 0.070), though not significant, was associated with poorer relief of back pain and was included in multivariate logistic regression models.

Only 2 patients (0.9%) were dissatisfied at 2-year follow-up according to the PASS threshold of the VAS-leg score. Due to the small number of patients, it was not possible to conduct univariate analysis or multivariate analysis for relief of leg pain.

### Table 1. Comparison of clinical outcomes between satisfied and dissatisfied subgroups at short-term follow-up by univariate analysis

| Variable          | All patients (n = 226) | Functional improvement | Relief of back pain | Relief of leg pain |
|-------------------|------------------------|------------------------|---------------------|-------------------|
|                   | Satisfied (n = 158)    | Dissatisfied (n = 68)  | Satisfied (n = 202) | Dissatisfied (n = 24) | Satisfied (n = 199) | Dissatisfied (n = 27) |
| ODI score         |                        |                        |                     |                   |
| Baseline          | 45.3 ± 20.1            | 49.6 ± 21.0            | 35.6 ± 13.6         | < 0.001**         | 45.6 ± 20.1         | 43.4 ± 20.5            | 0.615          |
| At 3 months       | 12.3 ± 12.6            | 7.1 ± 6.7              | 24.2 ± 14.8         | < 0.001**         | 10.3 ± 10.4         | 28.7 ± 17.1            | < 0.001**    |
| SF-36 PF score    |                        |                        |                     |                   |
| Baseline          | 51.7 ± 23.8            | 47.8 ± 24.8            | 60.7 ± 18.5         | < 0.001**         | 51.7 ± 23.6         | 51.5 ± 26.3            | 0.967          |
| At 3 months       | 90.3 ± 12.6            | 93.8 ± 6.4             | 82.1 ± 18.3         | < 0.001**         | 92.2 ± 7.7          | 73.8 ± 26.5            | 0.002**       |
| SF-36 BP score    |                        |                        |                     |                   |
| Baseline          | 46.5 ± 19.3            | 43.9 ± 20.3            | 52.5 ± 15.3         | 0.002**           | 46.0 ± 19.6         | 50.5 ± 16.5            | 0.286          |
| At 3 months       | 87.1 ± 14.0            | 91.9 ± 8.7             | 75.9 ± 17.4         | < 0.001**         | 89.8 ± 10.3         | 63.8 ± 19.0            | < 0.001**     |
| EQ-5D score       |                        |                        |                     |                   |
| Baseline          | 0.52 ± 0.23            | 0.48 ± 0.25            | 0.62 ± 0.14         | < 0.001**         | 0.52 ± 0.24         | 0.56 ± 0.15            | 0.365          |
| At 3 months       | 0.90 ± 0.13            | 0.94 ± 0.09            | 0.82 ± 0.18         | < 0.001**         | 0.93 ± 0.10         | 0.72 ± 0.22            | < 0.001**    |
| VAS-back score    |                        |                        |                     |                   |
| Baseline          | 3.96 ± 2.47            | 3.99 ± 2.55            | 3.90 ± 2.31         | 0.815             | 3.80 ± 2.51         | 5.30 ± 1.60            | < 0.001**    |
| At 3 months       | 0.95 ± 1.29            | 0.66 ± 0.92            | 1.63 ± 1.71         | < 0.001**         | 0.60 ± 0.70         | 3.96 ± 1.20            | < 0.001**    |
| VAS-leg score     |                        |                        |                     |                   |
| Baseline          | 5.43 ± 2.00            | 5.67 ± 2.03            | 4.86 ± 1.81         | 0.005**           | 5.42 ± 2.00         | 5.50 ± 2.04            | 0.856          |
| At 3 months       | 0.96 ± 1.43            | 0.51 ± 0.83            | 2.02 ± 1.91         | < 0.001**         | 0.68 ± 1.04         | 3.29 ± 2.07            | < 0.001**    |

Values are presented as mean ± standard deviation.
ODI, Oswestry Disability Index; SF-36 PF, 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale.
*p < 0.1. **p < 0.05.
| Variable | Functional improvement | | Relief of back pain | | Relief of leg pain |
| --- | --- | --- | --- | --- | --- |
| | Satisfied (n = 158) | Dissatisfied (n = 68) | p-value | Satisfied (n = 202) | Dissatisfied (n = 24) | p-value | Satisfied (n = 199) | Dissatisfied (n = 27) | p-value |
| Surgery group, PTED/MED | | | | | | | | | |
| L3/4 or above | 84 (56.9) | 74 (51.4) | 0.056** | 146 (71.9) | 12 (8.2) | 0.001** |
| L4/5 | 41 (26.5) | 37 (54.4) | 0.040** | 77 (37.7) | 42 (20.8) | 0.043** |
| L5/S1 | 117 (74.1) | 39 (56.7) | 0.001** | 19 (70.4) | 14 (69.6) | 0.001** |
| Location of disc herniation | | | | | | | | | |
| Median | 31 (19.6) | 20 (29.4) | 0.001** | 115 (83.8) | 45 (61.3) | 0.001** |
| Paramedian | 77 (49.4) | 35 (53.0) | 0.040** | 63 (41.7) | 45 (61.3) | 0.001** |
| Far lateral | 21 (13.5) | 15 (22.7) | 0.001** | 11 (7.4) | 15 (62.5) | 0.001** |
| Type of disc herniation | | | | | | | | | |
| Bulge | 7 (4.5) | 0 (0) | 0.001** | 5 (3.7) | 2 (8.3) | 0.001** |
| Protrusion | 45 (30.7) | 7 (10.3) | 0.001** | 15 (10.1) | 8 (30.7) | 0.001** |
| Extrusion | 3 (2.5) | 0 (0) | 0.001** | 4 (2.5) | 15 (10.1) | 0.001** |
| Disc degeneration (Pfirrmann grade ≥ 3) | 117 (74.1) | 45 (61.3) | 0.001** | 146 (85.4) | 14 (82.4) | 0.001** |
| Modic change | 41 (26.5) | 37 (54.4) | 0.040** | 115 (83.8) | 45 (61.3) | 0.001** |
| Residue of herniation | 1 (0.6) | 5 (7.6) | 0.001** | 117 (74.1) | 45 (61.3) | 0.001** |
| Recurrence of herniation | 4 (2.5) | 7 (10.3) | 0.001** | 4 (2.5) | 15 (10.1) | 0.001** |
| Reoperation | 7 (4.4) | 7 (10.3) | 0.001** | 7 (4.4) | 7 (10.3) | 0.001** |

Values are presented as mean ± standard deviation or number (%).
PTED, percutaneous transforaminal endoscopic discectomy; MED, microendoscopic discectomy; BMI, body mass index; LFJOA, lumbar facet joint osteoarthritis; ASD, adjacent segment degeneration.
* p < 0.1. **p < 0.05.
at midterm follow-up.

3. Multivariate Analysis of Short-term Outcomes

Multivariate logistic regression modeling for risk factors of poor short-term outcomes in terms of functional improvement, relief of back pain, and relief of leg pain are presented in Table 5. Older age (odds ratio [OR], 1.05; 95% confidence interval [CI], 1.01–1.09; p = 0.026), lateral recess stenosis (OR, 15.54; 95% CI, 1.05–333.33; p = 0.046), and lower baseline ODI score (OR, 0.96; 95% CI, 0.93–0.99; p = 0.027) were found to be statistically significant risk factors for poorer short-term functional improvement. Higher baseline VAS-back score (OR, 1.25; 95% CI, 1.00–1.57; p = 0.048) was the only risk factor associated with poorer short-term relief of back pain. Absence of decreased sensation (OR, 5.13; 95% CI, 1.31–20.1; p = 0.019) and far-lateral disc herniation (OR, 6.06; 95% CI, 1.78–20.6; p = 0.004) were risk factors for poorer short-term relief of leg pain.

4. Multivariate Analysis of Midterm Outcomes

Multivariate logistic regression modeling for risk factors of poorer midterm outcomes in terms of functional improvement and relief of back pain are presented in Table 6. The presence of LFJOA (OR, 8.13; 95% CI, 2.05–32.26; p = 0.003) was the only risk factor for poorer midterm functional improvement. Statistically significant risk factors associated with poorer midterm relief of back pain included the presence of LFJOA (OR, 7.87; 95% CI, 1.21–52.63; p = 0.031) and disc protrusion (OR, 12.7; 95% CI, 1.19–136.3; p = 0.036).

DISCUSSION

Endoscopic spine surgery has become a well-accepted technique, and is the most frequently used method to treat LDH. A recent meta-analysis established the superiority of endoscopic discectomy over microdiscectomy, and concluded that endoscopic discectomy has the potential to take the place of microdiscectomy.

Table 3. Comparison of clinical outcomes between satisfied and dissatisfied subgroups at midterm follow-up by univariate analysis

| Variable               | All patients (n = 222) | Functional improvement |          | Relief of back pain |          |
|------------------------|------------------------|------------------------|----------|---------------------|----------|
|                        | All (n = 206)          | Satisfied              | Dissatisfied (n = 16) | p-value | All (n = 213) | Satisfied (n = 9) | p-value |
| ODI score              |                        |                        |          |                     |          |
| Baseline               | 44.8 ± 19.9            | 45.6 ± 19.8            | 34.4 ± 18.8 | 0.030**             | 45.1 ± 19.8 | 34.4 ± 22.5 | 0.329     |
| At 2 years             | 3.2 ± 7.4              | 1.5 ± 3.2              | 24.8 ± 11.5 | < 0.001**           | 2.2 ± 5.0 | 26.4 ± 14.5 | 0.005**   |
| SF-36 PF score         |                        |                        |          |                     |          |
| Baseline               | 52.1 ± 23.5            | 51.2 ± 23.1            | 64.7 ± 25.1 | 0.026**             | 51.7 ± 23.4 | 62.2 ± 24.5 | 0.189     |
| At 2 years             | 97.5 ± 5.1             | 98.5 ± 2.7             | 84.4 ± 9.6  | < 0.001**           | 98.1 ± 3.7 | 82.8 ± 10.9 | 0.003**   |
| SF-36 BP score         |                        |                        |          |                     |          |
| Baseline               | 46.5 ± 19.0            | 45.7 ± 19.1            | 57.4 ± 14.7 | 0.017**             | 46.0 ± 19.1 | 59.6 ± 13.1 | 0.035**   |
| At 2 years             | 96.0 ± 9.3             | 98.0 ± 5.0             | 70.1 ± 12.7 | < 0.001**           | 97.2 ± 7.1 | 68.0 ± 11.8 | < 0.001** |
| EQ-5D score            |                        |                        |          |                     |          |
| Baseline               | 0.53 ± 0.22            | 0.52 ± 0.23            | 0.63 ± 0.15 | 0.063*              | 0.52 ± 0.22 | 0.66 ± 0.13 | 0.070*    |
| At 2 years             | 0.97 ± 0.07            | 0.99 ± 0.04            | 0.80 ± 0.12 | < 0.001**           | 0.98 ± 0.05 | 0.77 ± 0.12 | < 0.001** |
| VAS-back score         |                        |                        |          |                     |          |
| Baseline               | 3.94 ± 2.42            | 3.96 ± 2.42            | 3.69 ± 2.50 | 0.668               | 3.94 ± 2.42 | 3.89 ± 2.47 | 0.950     |
| At 2 years             | 0.37 ± 0.86            | 0.20 ± 0.50            | 2.56 ± 1.41 | < 0.001**           | 0.23 ± 0.51 | 3.67 ± 0.87 | < 0.001** |
| VAS-leg score          |                        |                        |          |                     |          |
| Baseline               | 5.40 ± 1.92            | 5.40 ± 1.96            | 5.38 ± 1.41 | 0.963               | 5.42 ± 1.92 | 4.78 ± 2.12 | 0.326     |
| At 2 years             | 0.19 ± 0.56            | 0.09 ± 0.31            | 1.44 ± 1.21 | < 0.001**           | 0.15 ± 0.49 | 1.11 ± 1.17 | 0.038**   |

Values are presented as mean ± standard deviation.
ODI, Oswestry Disability Index; SF-36 PF, 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale.
*p < 0.1. **p < 0.05.
Table 4. Comparison of clinical and radiological data between satisfied and dissatisfied subgroups at midterm follow-up by univariate analysis

| Variable                                      | Functional improvement |                     | p-value | Relie of back pain |                     | p-value |
|-----------------------------------------------|------------------------|---------------------|---------|--------------------|---------------------|---------|
|                                               | Satisfied (n = 206)    | Dissatisfied (n = 16) |         | Satisfied (n = 213) | Dissatisfied (n = 9) |         |
| Surgery group, PTED:MED                       | 105 (101)              | 6 (10)              | 0.299   | 107 (106)          | 45                  | 0.734   |
| Age (yr)                                      | 40.4 ± 11.5            | 44.3 ± 9.7          | 0.191   | 40.6 ± 11.4        | 41.0 ± 12.5         | 0.926   |
| Female sex                                    | 77 (37.4)              | 12 (75.0)           | 0.006** | 82 (38.5)          | 7 (77.8)            | 0.019** |
| BMI (kg/m²)                                   | 23.2 ± 3.3             | 23.6 ± 2.9          | 0.927   | 23.1 ± 3.3         | 25.0 ± 3.7          | 0.106   |
| Symptom duration ≥ 12 months                  | 48 (23.3)              | 5 (31.3)            | 0.472   | 49 (23.0)          | 4 (44.4)            | 0.139   |
| Dominant back pain                            | 97 (47.1)              | 9 (56.3)            | 0.480   | 100 (46.9)         | 6 (66.7)            | 0.246   |
| Heavy labor worker                            | 35 (17.0)              | 5 (31.3)            | 0.153   | 38 (17.8)          | 2 (22.2)            | 0.666   |
| Sedentary lifestyle                           | 57 (27.7)              | 3 (18.8)            | 0.567   | 58 (27.2)          | 2 (22.2)            | 0.740   |
| History of smoking                            | 47 (22.8)              | 1 (6.3)             | 0.204   | 47 (22.1)          | 1 (11.1)            | 0.688   |
| History of hypertension                       | 18 (8.7)               | 1 (6.3)             | 0.732   | 18 (8.5)           | 1 (11.1)            | 0.560   |
| History of diabetes                           | 8 (3.9)                | 1 (6.3)             | 0.496   | 9 (4.2)            | 0 (0)               | 0.529   |
| Positive nerve root tension test              | 154 (74.8)             | 10 (62.5)           | 0.282   | 158 (74.2)         | 6 (66.7)            | 0.700   |
| Decreased sensation                           | 79 (38.3)              | 5 (31.3)            | 0.573   | 82 (38.5)          | 2 (22.2)            | 0.324   |
| Myotomal weakness                             | 61 (29.6)              | 5 (31.3)            | 0.890   | 64 (30.0)          | 2 (22.2)            | 0.615   |
| Depressed reflex                              | 66 (32.0)              | 4 (25.0)            | 0.761   | 69 (32.4)          | 1 (11.1)            | 0.279   |
| Surgical segment                              |                         | 0.513               |         |                    | 0.555               |         |
| L3/4 or above segment                         | 4 (1.9)                | 0 (0)               |         | 4 (1.9)            | 0 (0)               |         |
| L4/5                                          | 100 (48.5)             | 10 (62.5)           |         | 104 (48.8)         | 6 (66.7)            |         |
| L5/S1                                         | 102 (49.5)             | 6 (37.5)            |         | 105 (49.3)         | 3 (33.3)            |         |
| Location of disc herniation                   |                         | 0.772               |         |                    | 0.017**             |         |
| Median                                        | 48 (23.3)              | 4 (25.0)            |         | 51 (23.9)          | 1 (11.1)            |         |
| Paramedian                                    | 142 (68.9)             | 10 (62.5)           |         | 147 (69.0)         | 5 (55.6)            |         |
| Far lateral                                   | 16 (8.1)               | 2 (12.5)            |         | 15 (7.0)           | 3 (33.3)            |         |
| Type of disc herniation                       |                         | 0.756               |         |                    | 0.091*              |         |
| Bulge                                         | 33 (16.3)              | 3 (18.8)            |         | 36 (17.1)          | 0 (0)               |         |
| Protrusion                                    | 100 (49.5)             | 9 (56.3)            |         | 102 (48.6)         | 7 (87.5)            |         |
| Extrusion                                     | 69 (34.2)              | 4 (25.0)            |         | 72 (34.3)          | 1 (12.5)            |         |
| Disc degeneration (Pfirrm grade ≥ 3)          | 145 (84.8)             | 13 (92.9)           | 0.697   | 153 (85.5)         | 5 (83.3)            | 0.884   |
| Modic change                                  | 13 (7.6)               | 2 (14.3)            | 0.316   | 14 (7.8)           | 1 (16.7)            | 0.402   |
| LFJOA                                         | 17 (8.4)               | 7 (43.8)            | <0.001**| 20 (9.5)           | 4 (50.0)            | 0.003** |
| Proximal ASD                                  | 73 (42.7)              | 7 (50.0)            | 0.596   | 75 (41.9)          | 5 (83.3)            | 0.110   |
| Distal ASD                                    | 54 (58.1)              | 5 (55.6)            | 0.884   | 57 (58.8)          | 2 (40.0)            | 0.407   |
| Lateral recess stenosis                       | 7 (3.5)                | 0 (0)               | 0.984   | 7 (3.3)            | 0 (0)               | 1.000   |
| Residue of herniation                         | 6 (2.9)                | 0 (0)               | 1.000   | 6 (2.8)            | 0 (0)               | 1.000   |
| Recurrence of herniation                      | 8 (3.9)                | 1 (6.3)             | 0.496   | 9 (4.2)            | 0 (0)               | 1.000   |
| Reoperation                                   | 14 (6.8)               | 1 (6.3)             | 1.000   | 15 (7.0)           | 0 (0)               | 0.883   |

Values are presented as mean ± standard deviation or number (%).
PTED, percutaneous transforaminal endoscopic discectomy; MED, microendoscopic discectomy; BMI, body mass index; LFJOA, lumbar facet joint osteoarthritis; ASD, adjacent segment degeneration.
*p < 0.1. **p < 0.05.
Table 5. Risk factors associated with dissatisfied outcomes at short-term follow-up by multivariate logistic regression analysis

| Factor                                                                 | OR   | 95% CI          | p-value  |
|------------------------------------------------------------------------|------|-----------------|----------|
| Multivariate modeling for dissatisfied functional improvement           |      |                 |          |
| Age                                                                    | 1.05 | 1.01–1.09       | 0.026**  |
| Symptom duration ≥ 12 months                                           | 1.42 | 0.60–3.39       | 0.425    |
| Absence of positive nerve root tension test                           | 1.11 | 0.46–2.68       | 0.822    |
| Location of disc herniation (paramedian vs. median & far-lateral)      | 1.20 | 0.54–2.70       | 0.652    |
| Type of disc herniation (extrusion vs. bulge & protrusion)             | 1.11 | 0.50–2.49       | 0.802    |
| Proximal ASD                                                           | 1.57 | 0.72–3.46       | 0.259    |
| Lateral recess stenosis                                                | 15.54| 1.05–333.33     | 0.046**  |
| Preoperative ODI score                                                 | 0.96 | 0.93–0.99       | 0.027**  |
| Preoperative SF-36 PF score                                            | 1.00 | 0.97–1.03       | 0.925    |
| Preoperative SF-36 BP score                                            | 1.00 | 0.98–1.03       | 0.775    |
| Preoperative EQ-5D score                                               | 10.00| 0.68–142.85     | 0.093    |
| Preoperative VAS-leg score                                             | 0.97 | 0.76–1.24       | 0.814    |
| Multivariate modeling for dissatisfied relief of back pain             |      |                 |          |
| Symptom duration ≥ 12 months                                           | 2.08 | 0.83–5.21       | 0.117    |
| Dominant back pain                                                     | 1.09 | 0.37–3.24       | 0.878    |
| Absence of decreased sensation                                         | 1.97 | 0.67–5.77       | 0.217    |
| Absence of myotomal weakness                                          | 2.57 | 0.71–9.34       | 0.150    |
| Preoperative VAS-back score                                            | 1.25 | 1.00–1.57       | 0.048**  |
| Multivariate modeling for dissatisfied relief of leg pain              |      |                 |          |
| BMI                                                                    | 1.06 | 0.92–1.22       | 0.393    |
| Dominant back pain                                                     | 1.36 | 0.43–4.29       | 0.600    |
| Absence of positive nerve root tension test                            | 2.04 | 0.74–5.63       | 0.168    |
| Absence of decreased sensation                                         | 5.13 | 1.31–20.1       | 0.019**  |
| Absence of myotomal weakness                                          | 2.35 | 0.59–9.27       | 0.224    |
| Location of disc herniation (far-lateral vs. median & paramedian)      | 6.06 | 1.78–20.6       | 0.004**  |
| Preoperative SF-36 PF score                                            | 1.01 | 0.98–1.03       | 0.635    |
| Preoperative SF-36 BP score                                            | 1.02 | 0.99–1.05       | 0.213    |
| Preoperative VAS-back score                                            | 1.21 | 0.93–1.58       | 0.156    |

OR, odds ratio; CI, confidence interval; ASD, adjacent segment degeneration; ODI, Oswestry Disability Index; SF-36 PF, 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale; BMI, body mass index. **p < 0.05.

isclectomy as the gold standard for the treatment of lumbar disc diseases. Numerous studies have investigated correlations between clinical outcomes after discectomy and demographic, clinical, and radiographic variables; however, no clear consensus with respect to risk factors for poorer outcomes has been reached. A recent systematic review that included 40 high-quality studies examined preoperative predictors associated with postoperative outcomes in patients who underwent open lumbar discectomy. The authors concluded that more severe leg pain, better mental health status, shorter symptom duration, and younger age were associated with positive postoperative outcomes, while intact annulus fibrous, longer duration of sick leave, receiving worker’s compensation, and greater severity of baseline symptoms were associated with negative postoperative outcomes. However, only a small number of retrospective studies and studies with a small sample size have examined risk factors for poorer surgical outcomes after minimally invasive discectomy.
Table 6. Risk factors associated with dissatisfied outcomes at midterm follow-up by multivariate logistic regression analysis

| Factor                                      | OR   | 95% CI     | p-value |
|---------------------------------------------|------|------------|---------|
| **Multivariate modeling for dissatisfied functional improvement** |      |            |         |
| Female sex                                  | 3.41 | 0.97–12.05 | 0.057   |
| LFJOA                                       | 8.13 | 2.05–32.26 | 0.003** |
| Preoperative ODI score                      | 0.98 | 0.93–1.03  | 0.394   |
| Preoperative SF-36 PF score                 | 1.01 | 0.97–1.06  | 0.625   |
| Preoperative SF-36 BP score                 | 1.03 | 0.99–1.06  | 0.171   |
| Preoperative EQ-5D score                    | 6.06 | 0.08–500.0 | 0.421   |
| **Multivariate modeling for dissatisfied relief of back pain** |      |            |         |
| Female sex                                  | 9.35 | 0.97–90.91 | 0.053   |
| Location of disc herniation (far-lateral vs. median & paramedian) | 3.07 | 0.34–27.58 | 0.316   |
| Type of disc herniation (protrusion vs. bulge & extrusion) | 12.7 | 1.19–136.3 | 0.036** |
| LFJOA                                       | 7.87 | 1.21–52.63 | 0.031** |
| Preoperative SF-36 BP score                 | 1.02 | 0.96–1.07  | 0.567   |
| Preoperative EQ-5D score                    | 35.7 | 0.06–1000  | 0.269   |

OR, odds ratio; CI, confidence interval; LFJOA, lumbar facet joint osteoarthritis; ODI, Oswestry Disability Index; SF-36 PF, 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions. **p < 0.05.

The purpose of the present study was to identify preoperative factors that predict clinical outcomes after minimally invasive discectomy for the treatment of LDH. There are several advantages of the present study over previous studies. The major advantage is that the data were from a prospective study with relatively large numbers of patients who underwent 2 of the most common minimally invasive discectomy procedures, PTED and MED. Other advantages include the analysis of risk factors based on the presence of functional improvement, back pain relief, and leg pain relief, and analysis of risk factors for poorer outcomes at short-term and midterm follow-up. Notably, patients were divided into satisfied and dissatisfied subgroups in terms of ODI score, VAS-back score, and VAS-leg score according to the PASS threshold. Using the PASS may be more appropriate for defining surgical satisfaction in terms of different PROMs on the individual level, as it is based on the absolute postoperative score rather than the preoperative to postoperative change in score. Hence, the use of high-quality prospective data and the detailed analysis provides useful information for determining which patients are most likely to benefit from the procedures examined.

We found older age, lateral recess stenosis, and lower baseline ODI score were associated with poorer short-term functional improvement following minimally invasive discectomy. Although most studies have found older age to be associated with poorer postoperative outcomes, there have been conflicting results. A prospective study by Wu et al. that included 80 patients who underwent PTED found that older age was associated with inferior outcomes. The results showed that patients older than 40 years tended to have inferior outcomes as compared to younger patients (unfavorable rate 32.7% vs. 10.7%, respectively). A retrospective study by Ahn et al. also reported that patients older than 40 years, and patients with concurrent lateral recess stenosis tended to have worse outcomes following PTED for recurrent LDH. The authors postulated that it is difficult to decompress concurrent lateral recess bony stenosis by PTED, especially of the medial part of the pedicle, because this portion is thicker and harder than the tip of the superior facet.

It is unclear if higher or lower baseline ODI and VAS scores predict poorer postoperative outcomes. Hong et al. and Cook et al. suggested that lower baseline ODI scores and higher baseline VAS-back scores are associated with superior outcomes. However, our data indicated that a lower baseline ODI score was a risk factor for poorer short-term functional improvement and a higher baseline VAS-back score was a risk factor for poorer short-term relief of back pain. These findings are consistent with the results of the Spine Patient Outcomes Research Trial (SPORT), which showed that patients with a lower preoperative ODI score and predominant back pain had a poorer surgical treatment effect. Another prospective study evaluating the outcomes of microdiscectomy also found that patients with predominant back pain had a lower success rate and inferior results.
clinical outcomes.\textsuperscript{35}

The results of the present study indicated that the absence of decreased sensation and far-lateral disc herniation were associated with poorer short-term relief of leg pain; findings that have not been previously reported. Shen et al.\textsuperscript{17} reported that patients who presented with numbness were more likely to have excellent outcomes following PTED, because the presence of numbness may assist in an early and accurate diagnosis of LDH. Direct compression and irritation of the dorsal root ganglion from far-lateral herniation may be the major reason for poorer neural recovery and reduction of leg pain.\textsuperscript{34}

In the current study, the results of univariate and multivariate analysis for the first time identified LFJOA as a risk factor for poorer functional improvement and relief of back pain at 2-year follow-up. Manchikanti et al.\textsuperscript{35} reported that the prevalence of lumbar facet joint pain was 16% (95% CI, 9%–23%) in patients with recurrent pain after various spinal surgical interventions. Bokov et al.\textsuperscript{36} analyzed the reasons for persistent pain syndromes following surgical interventions for LDH, and found that facet joint pain was responsible for 23.1% of cases that underwent microdiscectomy. Although facet joint pain is estimated to be responsible for low back pain in 15%–45% patients, LFJOA has received far less study than other causes of back pain, such as disc degeneration.\textsuperscript{37,38} Fortunately, interest in LFJOA and its effects on low back pain, disability and function has increased in recent years.\textsuperscript{39} Protrusion was another predictor of poorer midterm relief of back pain in this study. The 1-year follow-up results of SPORT also indicated that extrusion and sequestration were more likely to be associated with relief of back pain after surgery than the protrusion.\textsuperscript{40}

A prospective study conducted by Dewing et al.\textsuperscript{33} showed that younger patients with contained disc herniation had significantly worse outcomes than those with sequestered or extruded herniation. Chen et al.\textsuperscript{16} retrospectively reviewed the records of 521 patients who underwent full endoscopic lumbar discectomy, and reported that protrusion was a predictor of poorer outcomes.

The major limitation of the present study is the absence of long-term follow-up results (more than 4 years); hence we could not identify risk factors associated with poorer long-term outcomes. Another limitation is the potential bias raised by asymmetric facet joint osteoarthritis when defining LFJOA based on radiographic assessment. However, asymmetric LFJOA was uncommon in our patients; only 6 cases were identified and defined as LFJOA.

CONCLUSION

Patients with LDH who undergo PTED or MED achieved satisfactory short-term and midterm outcomes in terms of functional improvement and relief of back and leg pain. Older age, lateral recess stenosis, and lower baseline ODI score were associated with poorer short-term functional improvement following minimally invasive discectomy. Higher baseline VAS-back score was associated with poorer short-term relief of back pain, while the absence of decreased sensation and far-lateral disc herniation were associated with poorer short-term relief of leg pain. LFJOA was identified, for the first time, as a risk factor for poor functional improvement and relief of back pain in mid-term follow-up. The protrusion was also a predictor of poorer midterm relief of back pain.

NOTES

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ORCID

Zihao Chen: https://orcid.org/0000-0003-0402-5259
Lei He: https://orcid.org/0000-0001-5390-5282
Lijun Huang: https://orcid.org/0000-0003-0055-9341
Zhongyu Liu: https://orcid.org/0000-0002-2016-2424
Jianwen Dong: https://orcid.org/0000-0001-8196-9742
Bin Liu: https://orcid.org/0000-0001-9295-8176
Ruiqiang Chen: https://orcid.org/0000-0001-7390-8800
Liangming Zhang: https://orcid.org/0000-0003-2282-4687
Limin Rong: https://orcid.org/0000-0003-0373-7393

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