CLINICAL ARTICLE

A Postoperative Phenomenon of Percutaneous Endoscopic Lumbar Discectomy: Rebound Pain

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Objective: After percutaneous endoscopic lumbar discectomy (PELD), most patients with lumbar disc herniation (LDH) experience relief from the typical symptoms of low back and leg pain. However, for a small number of patients, these symptoms are relieved immediately after surgery but aggravated soon after, and then relieved after short-term full rest or conservative treatment. The aim of the study was to demonstrate this short-term recurrent phenomenon, termed rebound pain.

Methods: A retrospective study was conducted on 144 patients who underwent single-segment PELD from May 2017 to June 2020. Postoperative patients were divided into a rebound pain group and a non-rebound pain group. For the former group, general information, symptom characteristics and visual analogue score (VAS) changes in rebound pain were summarized. For both groups, postoperative efficacy was evaluated by recent VAS of low back and leg pain in the remission stage, the Oswestry disability index (ODI) and the modified MacNab criteria at the last follow-up. Logistic regression analysis was used to identify predictors for rebound pain.

Results: The VAS and ODI exhibited significant improvements at the last follow-up of average 15.4 months ($P < 0.001$). The successful outcomes according to the modified MacNab criteria reached 94.4%. A total of 15 patients (10.4%) experienced rebound pain. The typical feature was pain that usually began within 1 month after surgery and lasted for less than 1 month. The symptoms were mainly leg pain with or without low back pain. The range of pain was equal to or less than that before surgery. The symptoms were relieved after conservative treatment. In logistic regression model, postoperative return-to-work time > 45 days was found as a protective factor for rebound pain ($p = 0.031$).

Conclusion: Although rebound pain with multiple characteristics and a short duration had no significant effect on long-term postoperative efficacy, its high incidence often caused unnecessary concern in both patients and doctors. As a result, careful differentiation of rebound pain from other postoperative complications is needed.

Key words: Clinical Outcomes; Complications; Lumbar Disc Herniation; Percutaneous Endoscopic Lumbar Discectomy; Postoperative Pain

Introduction

In recent years, with the promotion of minimally invasive spine surgery, percutaneous endoscopic lumbar discectomy (PELD) has developed rapidly. Due to many benefits, such as less trauma, less bleeding, faster recovery, a shorter hospital stay, and less impact on spinal stability, a large number of PELD cases have accumulated worldwide. Since the yeung endoscopic spine system was invented by Yeung[1] in 1997 and the transforaminal endoscopic spine system was improved by Hoogland[2] in 2006, the clinical efficacy of spinal endoscopy has been comparable to that of conventional open surgery. Several studies have shown that satisfaction with PELD is as high as 90–95%[3–5]. According to a systematic review by Nellensteijn[6], the median overall improvement in leg pain according to visual analogue score (VAS) was 88% (range 65–89%), and that of back pain was 74% (range 13%–84%).

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Received 17 January 2021; accepted 10 May 2021

Orthopaedic Surgery 2021;9999:n/a • DOI: 10.1111/os.13088

A common phenomenon that was observed in clinical practice for patients with lumbar disc herniation and lower limb radicular pain was that most experienced steady symptom improvement after PELD. However, according to clinical observation, for a small number of patients, low back and leg pain was relieved immediately after PELD but aggravated soon after and was then relieved after short-term full rest or conservative treatment. We named this postoperative symptom of low back and leg pain "rebound pain". Gu reported a series of 209 consecutive PELD cases, and 16 of these patients (7.7%) experienced rebound pain one week after surgery[7]. The VAS decreased from 7–10 before surgery to 0–2 immediately after surgery, increased to 5–9 in one week, and then improved in two months. In addition, Huang studied changes of low back and leg pain in 84 patients within 12 weeks after PELD[8]. The VAS showed a downward trend in general but rebounded 2 to 3 weeks after surgery. To date, no specific literature on rebound pain is available. By retrospectively analyzing the recurrence of short-term low back and leg pain in some patients after PELD, the aim of this study was to summarize the incidence rate, characteristics and effects of rebound pain on short-term and long-term outcomes to further explore the pathogenesis and help guide clinical diagnosis and treatment.

Materials and Methods

Patient Selection

We collected 144 patients who underwent PELD from May 2017 to June 2020. As a retrospective study, informed consent was obtained from patients who were willing and eligible to participate. The inclusion criteria were as follows: (i) age between 15 and 50 years old; (ii) definite preoperative symptoms of nerve root pain; (iii) symptoms not relieved after at least 3 months of conservative treatment or severe symptoms despite less than 3 months of conservative treatment; (iv) preoperative diagnosis of single-segment lumbar disc herniation and/or lumbar spinal stenosis characterized by radicular pain with imaging evidence on computed tomography (CT) and magnetic resonance image (MRI); (v) significant improvement of over 50% in postoperative pain level (VAS); and (vi) rebound pain within 3 months after surgery with at least 3 months of follow-up. The exclusion criteria were as follows: (i) concomitant lumbar instability, spondylolisthesis or scoliosis; (ii) preoperative symptoms of severe back pain and mild leg pain; and (iii) organic causes of aggravated postoperative pain, such as incomplete removal or recurrence of a herniated disc, as revealed by re-examination of lumbar MRI or CT after surgery.

Clinical Data and Radiologic Features

According to whether rebound pain occurred, the patients were divided into the rebound pain group and the non-rebound pain group. The baseline data of the two groups are shown in Table 1. The demographic data (e.g., age, sex, BMI, comorbid conditions, smoking status, alcohol use, diagnosis, herniated segment, clinical characteristics, symptom duration, physical examination, return-to-work time) were collected.

According to the preoperative MRI scans, the location of the herniated disc in relation to the pedicles and spinal canal was identified as central, paramedian, foraminal and extraforaminal herniation (Fig. 1A–D)[3]. The type of the herniation was classified as protrusion and extrusion according to the shape of the displaced disc (Fig. 1E, F)[9]. The migrated disc was identified as extruded disc material that was displaced away from the site of extrusion (Fig. 1G)[9]. Modic changes involving the vertebral end plates and marrow reactive changes adjacent to the disc were classified to three types, as seen on MRI[10]. The severity of degenerative changes within the intervertebral disc was assessed by the Pfirrmann grading system[11]. The herniated disc height was calculated as the average height of the anterior, middle and posterior discs. Imaging data of included patients were classified and recorded by the methods described above.

Surgical Technique

According to different percutaneous approaches, PELD can be divided into transforaminal percutaneous endoscopic lumbar discectomy and interlaminar percutaneous endoscopic lumbar discectomy. The choice of different approaches depends on the segment, the direction of the herniated intervertebral disc, the height of the iliac crest, and the requirements for anesthesia[12].

In the transforaminal approach, the patients were given parecoxib sodium and dexmedetomidine initially and then placed in a lateral position on a radiolucent bed with a cushion under the lateral waist to flex the lumbar vertebrae appropriately. Using a C-arm X-ray machine, an oblique line was marked on the anteroposterior fluoroscopic view, and the tip of the superior articular process of the lower vertebral body was marked on the lateral fluoroscopic view. The entrance point was located 10–14 cm lateral to the midline. After local anesthesia consisting of 0.5% ropivacaine +1% lidocaine was administered, an 18-gauge long needle was inserted at the position of the internal edge of the vertebral pedicle on the anteroposterior view and the posterior edge of the intervertebral space on the lateral view. Then, a guiding rod, stepwise-dilating cannulas and a working cannula were introduced along the guiding wire. Disc staining in the cannula, separation of adhesions, removal of the herniated nucleus pulposus and loosening of the nerve roots were all completed under endoscopy. If necessary, the lateral recess can be enlarged using a circular saw and bone chisel to fully relieve compression, ensuring that nerve roots are relaxed, and blood vessels are adequately filled. Finally, the straight leg raise test of the operated leg was carried out. A negative result and good activity of the nerve roots indicated that the decompression was satisfactory, and the operation was complete.

In the interlaminar approach, the patients were submitted to general anesthesia in the prone position with the

TABLE 1 Demographics of included patients

Group	Non-rebound pain (n = 129)	Rebound pain (n = 15)	*P*-value
Age (years)	34.7 ± 8.8	35.5 ± 7.1	0.692
Sex			
male (%)	68 (52.7)	8 (53.3)	0.963
female (%)	61 (47.3)	7 (46.7)	
BMI	22.19 ± 6.23	23.62 ± 4.11	0.537
Diabetes mellitus (%)	12 (9.3)	1 (6.7)	0.736
Hypertension (%)	20 (15.5)	1 (6.7)	0.595
Smoking (%)	36 (27.9)	3 (20.0)	0.73
Alcohol use (%)	15 (11.6)	2 (13.3)	0.846
Diagnosis (%)			
LDH	117 (90.7)	12 (80.0)	0.192
LSS	12 (9.3)	3 (20.0)	
Segment (%)			
L3/4	2 (1.5)	0	0.886
L4/5	69 (53.5)	8 (53.3)	
L5/S1	58 (45.0)	7 (46.7)	
Clinical characteristics			
VAS			
low back	4.71 ± 2.41	4.27 ± 2.49	0.534
leg	6.58 ± 5.28	7.40 ± 1.35	0.161
Nubmness (%)	79 (61.2)	8 (53.3)	0.553
Symptom duration (months)[a]	35.33 ± 37.06	26.87 ± 26.20	0.041
ODI	54.72 ± 21.06	60.99 ± 21.51	0.287
Physical examination (%)			
positive straight leg raise test	67 (51.9)	8 (53.3)	0.918
sensory deficits	53 (41.1)	6 (40.0)	0.936
muscle weakness	24 (18.6)	1 (6.7)	0.426
Location of herniation (%)			
central	43 (33.3)	6 (40.0)	0.849
paramedian	69 (53.5)	7 (46.7)	
foraminal	14 (10.9)	2 (13.3)	
extraforaminal	3 (2.3)	0	
Type of herniation (%)			
protrusion	111 (86.0)	11 (73.3)	0.248
extrusion	18 (14.0)	4 (26.7)	
Migrated herniation (%)	23 (17.8)	1 (6.7)	0.464
Modic changes (%)	58 (45.0)	6 (40.0)	0.714
Pfirrmann grade (%)			
II	5 (3.9)	1 (6.7)	0.662
III	80 (62.0)	8 (53.3)	
IV	41 (31.8)	6 (40.0)	
V	3 (2.3)	0	
Herniated disc height (mm)	8.04 ± 1.64	7.82 ± 1.24	0.546
Return-to-work time (days)[b]	35.8 ± 29.2	29.0 ± 7.9	0.034

Values are presented as the mean ± SD unless otherwise indicated; [a]Symptom duration, the time from the first appearance of symptoms to surgical treatment; [b]Return-to-work time, the time from discharge to return to work; BMI, body mass index; LDH, lumbar disc herniation; LSS, lumbar spinal stenosis; ODI, oswestry disability index; VAS, preoperative visual analogue score.

lower abdomen padded with a cushion. A long needle was inserted 1 cm lateral to the surface projection of the interspinous space. The tip of the needle was located at the lower edge of the intervertebral space and the medial edge of the inferior articular process by a C-arm X-ray machine on the anteroposterior fluoroscopic view. An 18-gauge long needle was inserted into the puncture point, and the guiding wire was advanced into the disc space. The guiding rod, stepwise-dilating cannulas and the working cannula were introduced along the guiding wire. Disc staining was completed under endoscopy, and the annulus fibrosus was cut using a bipolar radiofrequency knife. After removing the herniated nucleus pulposus, loosening the nerve roots and ensuring the decompression effect, the operation was completed. Finally, the activity and muscle strength of the leg were examined after the patient was revived.

Postoperative Management

Patients were asked to restrict activities for 4–6 weeks and wear waist braces for 6 weeks after surgery. A good habit of sitting up sideways must be established within 3–6 months. In addition, a straight leg lifting exercise was performed daily

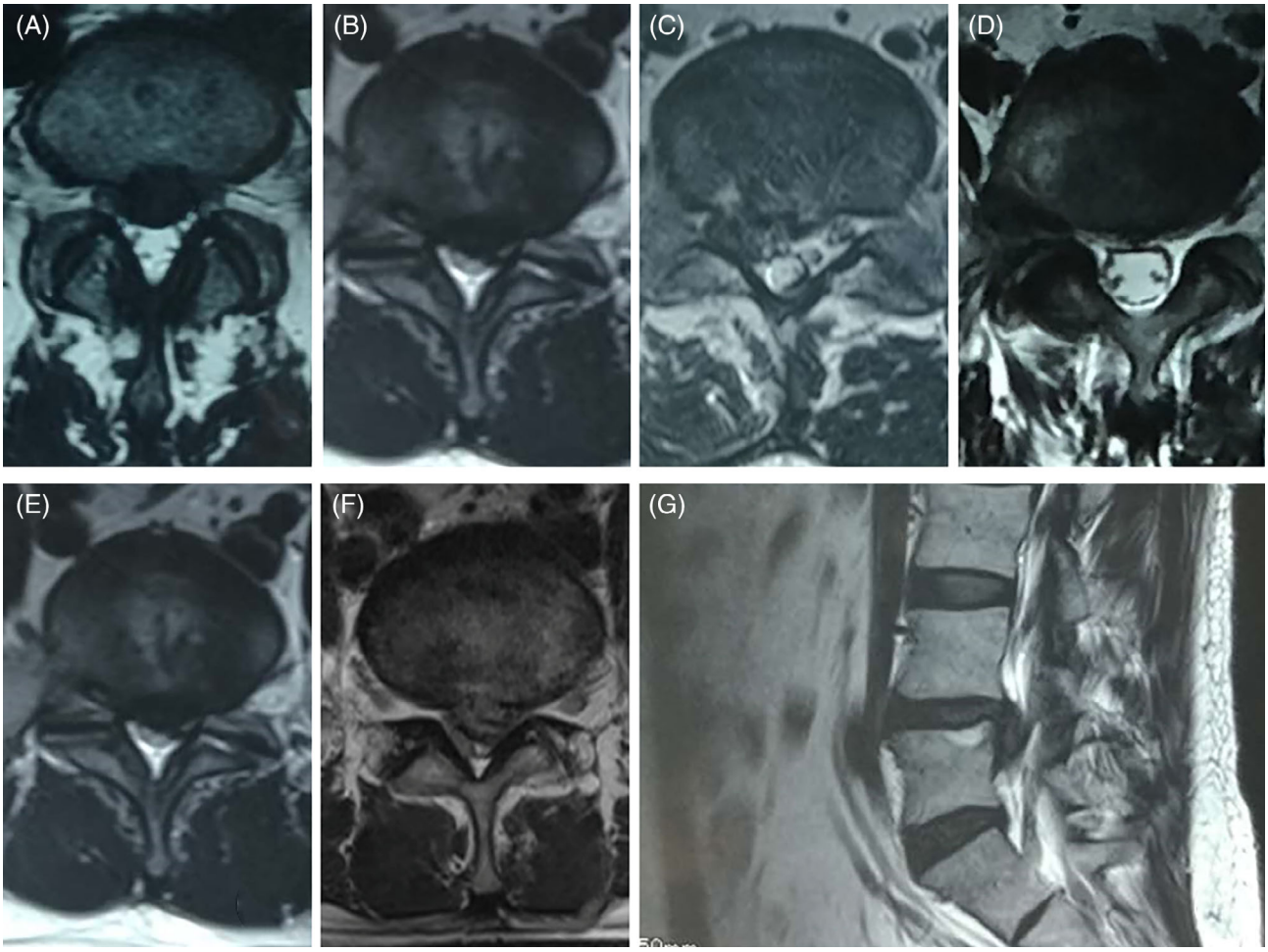

Fig 1 Preoperative magnetic resonance imaging scans. (A) central herniation. (B) paramedian herniation. (C) foraminal herniation. (D) extraforaminal herniation. (E) protrusion. (F) extrusion. (G) migrated herniation.

within 3 weeks, and the "five-point support exercise" was required after 3 weeks (a method of lumbodorsal muscle exercise where the patient, while in the supine position, bends the knees and hips with five support points of the feet, elbows and head and holds the back in an arch shape with the strength of the lumbodorsal muscles for 3–5 seconds each time).

Outcome Assessment

In this study, we set up a respective cohort initially and collected related clinical data of the patients who met the inclusion criteria. Then, regular follow-ups were performed after the surgery. For both rebound pain group and non-rebound pain group, several efficacy indexes were evaluated, including the VAS of low back and leg pain after surgery when the patients felt relief, as well as the VAS, ODI and modified MacNab criteria at long-term follow-ups. The long-term follow-up period was at least 1 year. For the rebound pain group, the general information, symptom characteristics and VAS changes of rebound pain were all summarized. Lumbar MRI was also performed at the second visit.

Visual Analogue Score (VAS)

VAS was used to assess the degree of low back pain and leg pain. A VAS score card was used for evaluation, with the score of 0 for no pain and 10 for the most intolerable pain. Patients was asked to score themselves according to the pain.

Oswestry Disability Index (ODI)

ODI was used to assess patient progress in routine clinical practice. The system includes 10 sections: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life and traveling. For each section of six statements the total score is 5. Final score = (total score/(5 × number of questions answered)) × 100%.

TABLE 2 Comparison of low back and leg pain and functional evaluation in 144 patients

Indexes	VAS back	VAS leg	ODI
T1: Preoperation (n = 144)	4.68 ± 2.48	6.33 ± 2.38	52.65 ± 19.67
T2: Postoperative remission stage (n = 144)	1.14 ± 1.39	1.02 ± 1.24	—
T3: Last follow-up (n = 91)	1.02 ± 1.27	1.01 ± 1.55	9.92 ± 9.51
P-value	VAS back	VAS leg	ODI
T1 *vs*. T2	<0.001	<0.001	—
T1 *vs*. T3	<0.001	<0.001	<0.01
T2 *vs*. T3	0.626	0.564	—

Modified MacNab Criteria

Modified MacNab criteria was used to evaluate the surgical effect. Excellent indicates complete remission of symptoms and normal life. Good indicates mild symptoms with no influence on life. Fair indicates partial remission of symptoms with limited activity. Poor indicates no differences after treatment.

Follow-up Methods

The follow-up methods were as follows: (i) during the outpatient and hospitalization periods, the patients were enrolled in a patient management network platform to record their general information, symptoms and imaging data. Electronic questionnaires were regularly sent to the patients through the network platform, including whether rebound pain occurred, pain characteristics, changes in VAS, and evaluations of efficacy; (ii) in the outpatient period, the patients were followed up, and the curative effect was evaluated; and (iii) telephone follow-ups were performed for the enrolled patients to verify postoperative recovery. Notably, the total response rate for the questionnaires was 70.8% (102/144) due to a close doctor-patient bond established through outpatient visits, the patient management network platform, and a series of systematic management measures for patients ranging from preoperative education to postoperative rehabilitation guidance.

Statistical Analysis

Statistical analysis was carried out using the SPSS ver. 24.0 (IBM Corp., Armonk, NY, USA). The outcomes of measurement data (VAS, ODI) were continuous variables expressed as mean ± standard deviations (SD). Categorical variables were presented as numbers and percentages. Normality of data was examined using the Kolmogorov–Smirnov test. Categorical variables were compared between non-rebound pain and rebound pain group using $\chi 2$ analysis or Fisher exact test, and independent *t*-test for continuous variables. The preoperative and postoperative VAS and ODI scores between the two groups were analyzed using an independent *t*-test. To evaluate the changes of the VAS and ODI in total sample before and after surgery, paired-sample *t*-test was employed. Due to missing data at last follow-up, one-way repeated measures ANOVA was not available for this study. The logistic regression model was used to assess the risk factors of rebound pain. The odds ratios and 95% confidence intervals were generated, and *P* values less than 0.05 were considered statistically significant.

Results

A total of 144 cases that met the inclusion criteria were summarized, including 76 males and 68 females with an average age of 34.7 years. The average follow-up time was 15.4 months. At the last follow-up, 91 patients who were followed for more than 1 year were included in the long-term efficacy evaluation. Most of the cases were single-segment lumbar disc herniation, with a total of 130 patients (91%), including two L3/4 cases, 66 L4/5 cases and 62 L5/S1 cases. A small number of cases (14, 9%) were lumbar spinal stenosis characterized by radicular pain, including 11 L4/5 cases and three L5/S1 cases.

Clinical Improvement

Symptom improvements were as follows (Table 2): (i) VAS of low back pain: 4.68 ± 2.48 preoperatively, 1.14 ± 1.39 at the postoperative remission stage, and 1.02 ± 1.27 at the last follow-up (significant differences were observed between the preoperation and remission stage and between the preoperation and the last follow-up, $P < 0.001$; no significant differences were found between the remission stage and the last follow-up, $P = 0.626$); (ii) VAS of leg and buttock pain: 6.33 ± 2.38 preoperatively, 1.02 ± 1.24 at the postoperative remission stage, and 1.01 ± 1.55 at the last follow-up (significant differences were observed between the preoperation and remission stage and between the preoperation and the last follow-up, $P < 0.001$; no significant differences were found between the remission stage and the last follow-up, $P = 0.564$); and (iii) The ODI was improved from 52.65 ± 19.67 before surgery to 9.92 ± 9.51 at the last follow-up ($P < 0.01$). The overall outcomes of the modified MacNab criteria were excellent in 50 cases (34.7%), good in 86 cases (59.7%), fair in seven cases (4.9%) and poor in one case (0.7%). The percentage of successful outcomes (excellent or good) reached 94.4%.

Rebound Pain Group

In all 144 cases, a total of 15 patients (10.4%), including eight males and seven females with an average age of 35.5 years, experienced recurrence of short-term low back and leg pain, which we called rebound pain. The diagnoses were lumbar disc herniation at L4/5 in six cases and at L5/S1 in seven cases and lumbar spinal stenosis at L4/5 in 1 case. The mean follow-up time was 12.1 months. The modified MacNab criteria at the last follow-up revealed excellent outcomes in three cases, good outcomes in 11 cases and fair outcomes in one case. The percentage of successful outcomes (excellent or good) was 93.3%. When rebound pain occurred, no organic

causes were found by re-examination of MRI, such as the incomplete removal and recurrence of a herniated disc.

The clinical characteristics of rebound pain in 15 patients were summarized as follows (Table 3): (i) most rebound pain occurred within 1 month (73.3%) after surgery; (ii) the duration of rebound pain was within one month in most cases (93.3%); (iii) the locations of rebound pain were divided into simple leg pain and leg + low back pain in nine and six patients, respectively. The range of rebound pain was mostly equal to or less than that of preoperative pain; and (iv) negative or positive straight leg raise test were both recorded during rebound pain. In summary, the symptoms of rebound pain were quite different. The typical feature was that the rebound pain usually began within 1 month after surgery and lasted less than 1 month. The symptoms were mainly leg pain with or without low back pain, with the range of pain equal to or less than that before surgery. The patients in this group did not receive surgical treatment, but the pain can be alleviated through bed rest, NSAID use or physical therapy.

Intergroup Comparison

In this study, changes of pain and functional recovery in the two groups were compared, including the VAS of low back and leg pain preoperatively, at the postoperative remission stage, and at the last follow-up, as well as the ODI preoperatively and at the last follow-up. The results showed no significant differences in short-term and long-term efficacy, indicating that rebound pain did not affect surgical outcomes. Additionally, no significant differences in the preoperative pain degree and functional scores were found between the two groups (Table 4).

Logistic Regression Analyses

In comparing the clinical and radiological data between the rebound pain group and non-rebound pain group, significant differences were found in symptom duration ($P = 0.041$) and return-to-work time ($P = 0.034$) (Table 1). The variables with statistical difference in univariate analysis and those considered to be related to rebound pain were included in binary logistic regression analysis univariate analysis (Table 5). postoperative return-to-work time > 45 days (odds ratio [OR] = 0.10, 95% confidence interval (CI) = 0.01–0.81, $P = 0.031$) was proved as a protective factor for predicting round pain. Sex, age, diagnosis, lumbar segment, clinical characteristics, symptom duration, physical examination and radiological characteristics did not have impact on rebound pain.

Discussion

Status of Research in the Field

Currently, with the accumulation of PELD cases, increasing attention has been directed towards complications, prevention and treatment. This study focused on the phenomenon of short-term recurrent low back and leg pain after PELD, which we named "rebound pain." Rebound pain was previously observed only as an empirical finding by some spinal surgeons with sufficient surgical experience and was even neglected by some surgeons. At present, no relevant literature focusing on this unique phenomenon or definite diagnostic criteria are available, and adequate attention is also lacking. The incidence of rebound pain in this study was 10.4%, which is higher than that of several postoperative complications[13]. Due to the steep learning curve, fully understanding this phenomenon may help surgeons, especially those with limited experience in endoscopic spine surgery, avoid unnecessary stress and overtreatment and determine differential diagnoses. For patients, early notification of the possibility of rebound pain is helpful to alleviate anxiety and ease the fear of recurrence.

Differential Diagnosis

Notably, some complications, such as incomplete removal of a herniated disc, early recurrence, dysesthesia, fiber bundle injury of partial nerve roots and piriformis syndrome must be differentiated[14]. Special caution should be exercised in cases of incomplete removal and recurrence, as these two complications often necessitate secondary surgery. The reoperation rate of PELD ranges from 4.3% to 10.3%, causing substantial trouble for both surgeons and patients[15–18]. In this study, for patients with rebound pain, MRI was performed to exclude organic causes, including residual disc fragments and recurrence. After excluding related complications, conservative treatment and close observation can be adopted. Recently, a study showed that residual disc tissue was observed on postoperative MRI in 16.9% (38/225) of patients who underwent PELD, and only 1.3% (3/225) of patients were symptomatic[19]. Thus, although residual disc fragments with persistent compression were one cause of reoperation, a "watchful waiting" strategy may be an appropriate method for patients with asymptomatic residual disc material[20–23]. Postoperative dysesthesia due to the existing dorsal root ganglion injury is associated with the presence of an inflammatory membrane, and removal or thermal coagulation of "anomalous" furcal nerves in the foramen branching off of the exiting nerve root[24,25]. Dysesthesia usually affects the dermatome of the exiting nerve root, and the range of symptoms is different from that before surgery[26]. Patients with dysesthesia also experience some abnormal sensations, including burning pain, radiating pain and prickling, some of which are similar to rebound pain. However, most causes of dysesthesia are deviation of the cannula and excessive intraoperative manipulation. Thus, dysesthesia usually occurs immediately after surgery and lasts for at least one month[27], while rebound pain occurs after symptoms are significantly relieved. According to a report of 151 cases of PELD under local anesthesia, the incidence of piriformis syndrome after surgery was as high as 40.4%, peaking around the first month[28]. Piriformis syndrome was characterized by pain, prickling, and numbness in the buttock and radiating from the buttock through the posterior thigh to the lower

TABLE 3 general information, symptom characteristics and recovery of patients in the rebound pain group

Case No.	Sex/ Age (years)	Diagnosis / segment	Follow-up period (month)	Rebound pain stage				straight leg raise test	Preoperative VAS		Postoperative remission stage VAS		Rebound pain stage VAS		Last follow-up VAS		Preoperative ODI	Last follow-up ODI	MacNab	Anesthesia	Surgical approach
				Preoperative pain location	pain location	occurrence time (weeks)	duration (weeks)		back	buttock and leg	back	buttock and leg	back	buttock and leg	back	buttock and leg					
1	M/27	LDH L5/S1	16	back, buttock (R), leg (R)	back, buttock (R)	3	1	(+)	6	6	2	1	5	4	3	2	64.44	20.00	good	local	transforaminal
2	F/36	LDH L4/5	15	back, buttock (L), leg (L)	leg (L)	3	1	(−)	5	6	0	2	0	4	0	0	71.11	0.00	excellent	local	transforaminal
3	M/27	LDH L5/S1	12	buttock (R), leg (R)	buttock (R)	3	1	(−)	0	7	0	1	0	4	0	2	46.00	15.00	good	local	transforaminal
4	M/33	LSS L4/5	7	back, buttock (R)	buttock (R)	2	4	(+)	7	9	0	0	0	4	3	0	75.56	35.56	good	local	transforaminal
5	M/47	LSS L4/5	13	back, leg (L)	leg (L)	3	2	(+)	3	6	0	2	0	5	1	2	42.22	12.00	good	local	transforaminal
6	F/44	LSS L4/5	7	buttock (R), leg (R)	buttock (R), leg (R)	12	8	(−)	0	8	1	1	0	4	0	2	31.11	11.11	good	local	transforaminal
7	F/39	LDH L4/5	14	back, buttock (L), leg (L)	back, buttock (L), leg (L)	1–2	1	(+)	2	9	0	3	3	6	0	2	86.67	12.00	good	local	transforaminal
8	M/30	LDH L5/S1	16	back, leg (R)	leg (R)	8	4	(−)	4	7	2	1	2	5	1	2	26.67	13.33	good	general	Interlaminar
9	M/30	LDH L4/5	8	back, buttock (R), leg (R),buttock (L), leg (L)	back, buttock (R), leg (R),buttock (L)	12	4	(−)	6	6	2	1	4	3	2	1	72.00	26.00	good	local	transforaminal
10	F/38	LDH L4/5	14	back, buttock (R), leg (R)	back, buttock (R), leg (R)	1–2	3	(+)	4	6	1	2	2	9	1	1	37.78	13.00	excellent	local	transforaminal
11	M/39	LDH L5/S1	12	back, leg (L)	buttock (L)	8	4	(+)	4	7	4	0	4	6	2	0	60.00	6.00	good	local	transforaminal
12	M/34	LDH L4/5	17	back, leg (R)	back, leg (R), leg (L)	1–2	1	(−)	5	7	2	0	2	3	0	0	66.67	2.00	excellent	local	transforaminal
13	F/46	LDH L5/S1	12	back, buttock (L), leg (L)	buttock (L), leg (L)	3	4	(−)	7	10	3	2	3	7	3	1	98.00	30.00	good	local	transforaminal
14	F/24	LDH L5/S1	10	back, buttock (L), leg (L)	leg (L)	1	4	(+)	6	9	1	0	0	6	1	2	86.67	60.00	fair	general	Interlaminar
15	F/38	LDH L5/S1	9	back, buttock (R), leg (R)	back, buttock (R), leg (R), buttock (L), leg (L)	4	1	(+)	8	8	2	2	5	3	3	2	50.00	22.00	good	general	Interlaminar

TABLE 4 Comparison of efficacy between the rebound pain group and the non-rebound pain group

Group	Preoperation			Postoperative remission stage		Group	Last follow-up		
	VAS back	VAS leg	ODI	VAS back	VAS leg		VAS back	VAS leg	ODI
Rebound pain group (n = 15)	4.20 ± 2.54	6.93 ± 1.67	60.99 ± 21.51	1.47 ± 1.19	1.20 ± 0.94	Rebound pain group (n = 6)	1.50 ± 1.38	1.17 ± 1.98	14.17 ± 10.05
Non-rebound pain group (n = 129)	4.74 ± 2.48	6.26 ± 2.45	51.68 ± 19.29	1.12 ± 1.41	1.00 ± 1.27	Non-rebound pain group (n = 85)	0.99 ± 1.26	1.00 ± 1.58	9.62 ± 9.46
P-value	0.999	0.470	0.506	0.388	0.479	*P*-value	0.906	0.827	0.637

leg, which were similar to rebound pain, in terms of symptoms and timing[29]. A high anxiety state during surgery under local anesthesia was reported to potentially result in muscles with abnormally high tone and tension, which was believed to the cause of postoperative pain.

Analysis of Pathogenesis

In terms of efficacy, this study compared pain intensity and functional evaluations at the last follow-up in both the rebound pain group and the non-rebound pain group. No significant differences were found between the two groups, indicating that postoperative rebound pain is an aggravated symptom in a short term and has no significant effect on long-term efficacy. The pathogenesis is not clear and may be associated with many factors. In PELD surgery, although the nerve roots attain good activity after adhesion release and decompression, they remain in an inflammatory oedematous state due to surgical trauma and self-repair. In addition, the blood supply deficits in the local vasculature may further aggravate inflammatory oedema[8]. Removal of herniated intervertebral disc tissue will result in a cavity filled with blood clots and inflammatory oedema. Organization and absorption require a certain period of time, during which symptoms may become aggravated. Additionally, injuries to the articular surface and capsule during operation, resulting in joint space narrowing and joint instability, may also lead to the aggravation, especially after the resumption of normal activity when the load on the joint increases significantly. In logistic regression analysis, postoperative return-to-work time was found as a protective factor based on the survey indexes. A possible explanation is that returning to work and activity prematurely may increase lumbar loading and stimulate inflammatory responses in the surgical area, contributing to the development of postoperative rebound pain. Maybe because of busy work, the average return-to-work time in the rebound pain group was 29.0 ± 7.9 days, which was much shorter than 6–16 weeks reported in other research[30,31]. It also reminded us that we should be alert to related complications, while achieving enhanced recovery after surgery. Unfortunately, no risk factors were found in this research to facilitate complication prediction. No radiological variable was related to rebound pain, including location and type of herniation, Modic changes and Pfirrmann grade. It supports the hypothesis that rebound pain is associated with inflammatory oedema in recovery stage, rather than disc type, location and character changes. Symptom duration has been considered an important predictor of surgical outcome, although the conclusion is controversial[32,33]. Significant differences in this study were found in univariate analysis, but not in logistic regression analysis. Perhaps more samples of rebound pain could reveal its relationship with symptom duration.

Limitation

Notably, this study is limited by the retrospective, single-centre design and the small sample size, particularly in the

TABLE 5 Logistic regression analyses for risk factors of rebound pain

Risk factors	Model OR	95% CI	*P*-value
Age (years)			
Q1 (≤29)	Reference		
Q2 (>29, ≤36)	2.06	0.45–9.30	0.350
Q3 (>36, ≤42)	1.37	0.29–6.56	0.693
Q4 (>42)	1.42	0.27–7.61	0.680
Sex			
male	Reference		
female	1.03	0.35–2.99	0.965
Diagnosis			
LDH	Reference		
LSS	1.50	0.30–7.45	0.626
Segment			
L3-L5	Reference		
L5-S1	1.07	0.37–3.13	0.904
Clinical characteristics			
VAS (low back)			
Q1 (≤3)	Reference		
Q2 (>3, ≤5)	0.98	0.25–3.92	0.982
Q3 (>5, ≤7)	1.85	0.49–6.97	0.366
Q4 (>7)	0.60	0.06–5.53	0.652
VAS (leg)			
Q1 (≤5)	0	0	0.997
Q2 (>5, ≤7)	1.40	0.39–5.07	0.610
Q3 (>7, ≤8)	0.48	0.08–2.87	0.421
Q4 (>8)	Reference		
Nubmness	0.72	0.25–2.12	0.555
Symptom duration (months)			
Q1 (≤9)	Reference		
Q2 (>9, ≤18)	2.35	0.43–13.00	0.327
Q3 (>18, ≤48)	0.78	0.22–2.82	0.710
Q4 (>48)	2.28	0.41–12.61	0.345
ODI			
Q1 (≤42.67)	Reference		
Q2 (>42.67, ≤53.33)	0.43	0.07–2.52	0.351
Q3 (>53.33, ≤70)	0.75	0.16–3.62	0.720
Q4 (>70)	1.71	0.44–6.70	0.438
Physical examination			
positive straight leg raise test	1.06	0.36–3.01	0.918
sensory deficits	0.96	0.32–2.85	0.936
muscle weakness	0.31	0.04–2.49	0.272
Location of herniation			
central	Reference		
paramedian	0.72	0.22–2.31	0.576
foraminal	0.90	0.16–5.02	0.902
Type of herniation			
protrusion	Reference		
extrusion	1.76	0.50–6.15	0.377
Migrated herniation	0.33	0.41–2.63	0.295
Modic changes	0.82	0.27–2.43	0.715
Pfirrmann grade			
II	Reference		
III	3.75	0.41–34.54	0.243
IV	4.94	0.58–42.37	0.145
V	0.96	0.56–16.27	0.974
Herniated disc height (mm)			
Q1 (≤7.25)	Reference		
Q2 (>7.25, ≤8.58)	0.83	0.23–2.99	0.780
Q3 (>8.58)	0.61	0.16–2.36	0.476
Return-to-work time (days)			
Q1 (≤30)	Reference		
Q2 (>30, ≤45)	0.63	0.18–2.19	0.470
Q3 (>45)[a]	0.10	0.01–0.81	0.031

rebound pain group. Among the 15 patients, only three received PELD through the interlaminar approach. This number is too small to generalize the results that rebound pain is secondary to both approaches. The postoperative neurological and neurophysiological investigations are also necessary to study neuroelectrophysiological changes and have been included in further research. In addition, the follow-up period was too short for a long-term efficacy evaluation. Because of the limited cases of lumbar spinal stenosis in this study, further exploration of the relationship between different lumbar diseases and rebound pain is difficult.

At present, the diagnostic criteria for rebound pain after PELD is still uncertain because of unknown aetiologies, various characteristics and limited cases. The purpose of this study is to present this new view through a single-centre case review. Further large-sample, multicentre and prospective studies are needed. Fully understanding this phenomenon will facilitate appropriate preventive measures, shorten the recovery time, and avoid over-examination and treatment.

Conclusions

In this study, we found that a small number of patients had short-term recurrence of low back and leg pain early after PELD, termed rebound pain, which could be alleviated by adequate rest and conservative treatment. The incidence of this postoperative phenomenon was as high as 10.4%. Rebound pain had no distinctive characteristic symptoms and no significant effects on the postoperative efficacy of PELD. Although rebound pain often indicates "no danger", more attention is still needed.

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