Systematic Review

Percutaneous Endoscopic Lumbar Discectomy for Calcified Lumbar Disc Herniation: A Retrospective Cohort Study, Systematic Review and Meta-Analysis

Guozhong Zhou, MD[1,2], Zhi Liang, MS[2], Fucun Gao, MS[2], Liqing Zhao, BS[2], Hongbing Gao, BS[2], Guoqing Xiao, BS[2], Jiang Xu, BS[2], Xuesong Chen, BS[2], and Chao Song, BS[2,3]

From: [1]Department of Science and Research, Anning First People's Hospital Affiliated to Kunming University of Science and Technology, Kunming, Yunnan Province, China; [2]Department of Pain Medicine, Anning First People's Hospital Affiliated to Kunming University of Science and Technology, Kunming, Yunnan Province, China; [3]Department of Medical Imaging, Anning First People's Hospital Affiliated to Kunming University of Science and Technology, Kunming, Yunnan Province, China

Address Correspondence:
Chao Song, BS
No. 2 Ganghe South Rd
Anning City, Kunming, Yunnan Province, China
E-mail: chaoge6870@163.com

Disclaimer: G Zhou and Z Liang contributed equally to this work. This work was supported by the Talent Project of Kunming Health Science and Technology (NO. 2022-SW [Leading Talents]-001, to CS), the Special Project "Spring City Plan" Famous Doctor (NO. C202012016, to CS).

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 06-18-2023
Revised manuscript received: 07-20-2023
Accepted for publication: 08-29-2023

Free full manuscript:
www.painphysicianjournal.com

Background: Calcified lumbar disc herniation (CLDH) is a subtype characterized by calcification, leading to increased surgical complexity. Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive technique, but its effectiveness and complications in CLDH patients remain to be fully evaluated.

Objective: To assess the effectiveness and complications of PELD in treating CLDH patients.

Study Design: A retrospective cohort study combined with a systematic review and meta-analysis.

Setting: Department of Pain Medicine, an affiliated hospital of a university.

Methods: Data from patients who underwent PELD in our department between March 2020 and May 2021 were collected. Forty CLDH patients were included in the study group, and equally matched cases with uncalcified lumbar disc herniation (UCLDH) served as controls. A systematic search was conducted on October 5, 2022, using EMBASE, PubMed, Cochrane Library, the China Biology Medicine disk, the China National Knowledge Infrastructure, and the Wanfang databases, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A random-effects model was used to calculate pooled results.

Results: Eighty patients were included in the retrospective cohort, and 41 studies were included in the meta-analysis. Both the retrospective cohort and meta-analysis consistently showed a significant decrease in visual analog scale (VAS) and Oswestry Disability Index (ODI) scores in the CLDH group after the operation. In the retrospective cohort, the excellent or good rate according to the MacNab classification was 85%, with no reported complications. The meta-analysis revealed a pooled excellent or good rate of 91.8% and a low complication rate of 2.9%. Combining the findings from our retrospective cohort and meta-analysis, we observed that the CLDH group had longer operation times and slightly higher postoperative ODI scores compared to the UCLDH group.

Limitations: Small sample size and lack of long-term follow-up in the retrospective cohort, as well as limited inclusion of comparative studies in the meta-analysis.

Conclusion: PELD is an effective and safe treatment option for CLDH patients. In comparison to UCLDH patients, CLDH patients may experience longer operation times and slightly slower functional recovery than those with UCLDH.

Key words: Calcification, lumbar disc herniation, percutaneous endoscopic lumbar discectomy, effectiveness, complication

Pain Physician 2024: 27:E1-E15

Lumbar disc herniation (LDH) is the most common type of intervertebral disc degenerative disease (1,2). The main symptoms of LDH include severe leg pain and lower limb numbness and weakness (3,4). CLDH is a subtype of LDH with calcification on the herniated area (5). Patients with CLDH often have a longer course of disease, hard intervertebral disc cartilage, severe vertebral degeneration, and severe adhesion to the thecal sac and narrow lamina space, which increases surgical difficulty and may cause iatrogenic injuries, such as nerve root injury and dural tear (6,7).

Percutaneous endoscopic lumbar discectomy (PELD), with the advantages of a short incision, less trauma, little intraoperative blood loss, and fast postoperative recovery, is a minimally invasive surgical procedure for LDH (7). However, for CLDH, conventional endoscopic techniques have difficulties in removing the calcification (5). In recent years, rapid advances in spinal endoscopic techniques and surgical equipment have improved the feasibility of endoscopic treatment of CLDH. For example, ultrasonic osteotomes are a type of instrument based on piezoelectric high-frequency mechanical vibration, which has selective bone-cutting properties with preservation of adjacent soft tissue (8). Under the microscope, circular sawing can effectively remove bone tissue when it is perpendicular to or angled with the bone surface; The dynamic drilling technology under a spinal endoscope not only has the above functions, but can also polish the bone tissue on the horizontal plane.

Previous studies have assessed the effectiveness and complication of PELD in the treatment of CLDH patients (3-8). However, the small sample sizes available in previous studies hampered their interpretability. Therefore, we evaluated the effectiveness and complication of PELD in the treatment of CLDH patients through a retrospective cohort study combined with a systematic review and meta-analysis.

Methods

Retrospective Cohort Study

Patients and Data Collection

Our retrospective cohort study was approved by the Ethics Committee of Anning First People's Hospital Affiliated with Kunming University of Science and Technology (approval number: 2021-018-01). We retrospectively recruited consecutive patients according to the following inclusion criteria: 1) patients primarily complained of radicular pain of unilateral leg; 2) nerve root compression sign including positive Lasègue sign, sensory or movement disorder of the lower limbs and reflex abnormalities of knee or ankle; 3) imaging data confirmed the presence of single-level LDH and excluded other spinal diseases, such as lumbar spondylolisthesis or lateral recess stenosis; 4) patients managed with conservative measures for at least 3 months and agreed to receive surgical treatment. The exclusion criteria were the following: 1) lumbar instability and severe spinal stenosis; 2) severe cardiopulmonary disease and coagulation dysfunction; 3) with a history of spinal infection, tumor, or surgery.

Data from patients who underwent PELD in our department between March 2020 and May 2021 were collected. Forty CLDH patients were included in the study group, and 40 age-, gender-, and body mass index (BMI)-matched cases with UCLDH served as controls. All patients were followed for more than 6 months through outpatient or telephone consultation.

Surgical Procedure

All the procedures were performed with the patient under local anesthesia and deep nerve trunk anesthesia. The patient was placed in a prone position on a radiolucent table. A position pad was placed under the abdomen of the patient to bend the spine forward to maximize the height of the posterior edge of the intervertebral space. Feedback from the patient during the entire procedure was monitored to avoid damaging the neural structures. According to the position of the herniated nucleus pulposus and calcification on computed tomography and magnetic resonance imaging of the patient's lumbar spine, and their relative position with the nerve root, the appropriate surgical method was selected. Both methods used the peak technique to treat calcified tissue. For foraminoplasty during percutaneous endoscopic transforaminal discectomy (PETD), limited polishing of the ventral side of the articular process was performed to achieve the formation of intervertebral foramen. Subsequently, the extruded or sequestered herniation was removed, and the base of calcification was exposed. The second intracannula foraminoplasty was performed and targeted on the peak of the calcification. Finally, a suitable manipulation angle was obtained for the removal of the calcification. For percutaneous endoscopic intralaminar discectomy (PEID), laminotomy and facetectomy were performed. The lateral side of the nerve root was exposed and gently pushed to the medial side, the extruded or se-

questered herniation was removed, and the ruptured intervertebral disc annulus fibrosus was located along the protrusion and effectively decompressed in the intervertebral space. Subsequently, a wider laminotomy or facetectomy was performed until the peak of calcification was freely exposed. With a wider interlaminar window, the tension on the nerve root decreased.

Outcome Assessment

We analyzed the outcomes based on demographic data, perioperative data, the Visual Analog Scale (VAS), Oswestry Disability Index (ODI), MacNab classification, and complication rate.

Statistical Analysis

Data were statistically analyzed using the IBM SPSS 23 program. The normal distribution of variables was tested by the Shapiro-Wilk test. Normal distribution variables which were compared between the 2 groups were tested using the independent Student's t-test. Non-normal distribution variables and ordinal categorical variables were tested using the Mann–Whitney U test. Unordered categorical variables were compared through Pearson's chi-squared test or Fisher's exact test. The threshold for statistical significance was set at $P < 0.05$.

Systematic Review and Meta-Analysis

Search Strategy and Study Selection

The systematic review was conducted according to the PRISMA guidelines (9). We searched EMBASE, PubMed, Cochrane Library, the China Biology Medicine disk, the China National Knowledge Infrastructure, and the Wanfang databases on October 5, 2022. The English key words were "lumbar disc herniation" and "calcified." The Chinese key words were "椎间盘突出" and "钙化." Reference lists of relevant articles were manually checked for other potentially relevant papers.

The inclusion criteria were as follows: 1) observational studies in which CLDH patients were treated with PELD; 2) the outcome variables were at least one of the following: VAS, ODI, MacNab classification, and complication rate.

The exclusion criteria were as follows: 1) surgical decompression procedure but without removing intervertebral disc; 2) fewer than 10 patients; 3) follow-up period was less than 6 months; 4) abstracts, reviews, case reports, and animal studies.

Two investigators (GZZ and ZL) independently screened article titles and abstracts retrieved from the literature search. The full texts of potentially eligible studies were further assessed for final inclusion. A third investigator (CS) cross-checked extracted data; disagreements were resolved through consensus.

Data Extraction and Quality Assessment

Information on patient demographics, mean surgery time, hospitalization time, follow-up time, VAS general, VAS back/leg, ODI, McNab classification, and complication rates was extracted from each study. Two investigators (GZZ and ZL) independently extracted data from individual studies. Full texts of those potentially eligible studies were further assessed for final inclusion. A third investigator (CS) cross-checked extracted data; disagreements were resolved through consensus.

A modified version of the Newcastle-Ottawa Scale (NOS) was used to assess the quality of each study. Studies with NOS scores of 1–3, 4–6, and 7–9 were considered low, intermediate, and high quality, respectively. Two investigators (GZZ and ZL) independently assessed the methodological quality of a quarter of the studies, and the third investigator (CS) independently reviewed those assessments. Disagreements were resolved through consensus.

Outcomes

The primary outcome was to evaluate the effectiveness and complications of PELD in treating CLDH patients. The secondary outcomes included comparing the effectiveness and complications of PELD between the CLDH and UCLDH groups, comparing the 2 surgical approaches (PETD and PEID) within the PELD technique, and comparing PELD with open surgery in the treatment of CLDH patients.

Data Analysis

A random-effects model was used to calculate pooled results with a 95% CI. The mean difference (MD) was used as the effect index for continuous variables, while the risk difference (RD) was utilized for dichotomous variables. I^2 statistic was used to assess the heterogeneity of included studies, with $I^2 > 50\%$ suggesting significant heterogeneity. Publication bias was assessed using a funnel plot and Egger's test. All P values were 2-sided, and the threshold for statistical significance was set at $P < 0.05$. This meta-analysis was conducted using the "meta" package in R statistical software version 3.4.3.

Results

Retrospective Cohort

Baseline Characteristics and Perioperative Data

The baseline data of the 2 groups is summarized in Table 1. There was no statistical difference in age, gender, BMI, operation segment, and follow-up time between CLDH and UCLDH groups.

Perioperative data is shown in Table 1. The mean duration of the operation for the CLDH group (62.73 ± 13.58 min) was longer than that for the UCLDH group (57.88 ± 11.00 min); however, no statistical significance was observed (P = 0.083). The average hospitalization days for the CLDH group (5.58 ± 1.48 days) was significantly shorter than that for the UCLDH group (6.35 ± 1.58 days) (P = 0.026).

Table 1. *Demographic data, perioperative data, effectiveness and complication of CLDH group and UCLDH group in retrospective cohorts.*

	CLDH (n = 40)	UCLDH (n = 40)	*P*-value
Demographic data			
Age (mean ± SD, years)	46.784 ± 15.40	49.53 ± 13.65	0.401
Gender			
Men n (%)	26 (65.0)	21 (52.5)	0.364
Women n (%)	14 (35.0)	19 (47.5)	
BMI (mean ± SD)	24.41 ± 3.51	24.83 ± 3.37	0.594
Segments			
L3-4 n (%)	1 (2.5)	1 (2.5)	0.901
L4-5 n (%)	21 (52.5)	23 (57.5)	
L5-S1 n (%)	18 (45.0)	16 (40.0)	
Disease duration (mean ± SD, month)	20.35 ± 18.24	24.53 ± 20.81	0.343
Perioperative data			
Operation time (mean ± SD, min)	62.73 ± 13.58	57.88 ± 11.00	0.083
Hospitalization time (mean ± SD, days)	5.58 ± 1.48	6.35 ± 1.58	0.026
Effectiveness of operation			
VAS data*			
Preoperative (mean ± SD)	5.58 ± 0.59	5.88 ± 0.82	0.065
Discharge (mean ± SD)	1.45 ± 0.64	1.43 ± 0.78	0.876
1-month (mean ± SD)	1.10 ± 0.49	1.53 ± 1.18	0.038
3-month (mean ± SD)	1.00 ± 0.82	1.43 ± 1.17	0.064
6-month (mean ± SD)	0.98 ± 0.86	1.55 ± 1.06	0.009
ODI data			
Preoperative (mean ± SD)	71.01 ± 7.17	70.48 ± 7.24	0.743

Assessment of the Effectiveness and Complications

The average preoperative VAS score of the CLDH group was 5.58 ± 0.59, and it decreased to 1.45 ± 0.64 at discharge and continually dropped to 0.98 ± 0.86 6-months after the operation. The VAS score of the UCLDH group dropped from 5.88 ± 0.82 to 1.43 ± 0.78 at discharge and continually dropped to 1.55 ± 1.06 6-months after surgery. There was no statistical difference in the VAS before surgery between the 2 groups; however, the VAS score of the CLDH group was lower than that of the UCLDH group after surgery (Table 1).

The average preoperative ODI score of the CLDH group was 71.01 ± 7.17, and it decreased to 23.40 ± 5.00 immediately and continually dropped to 16.59 ± 3.10 6-months after the operation. The ODI score of the UCLDH group dropped from 70.48 ± 7.24 to 20.02 ± 4.93 immediately and continually dropped to 14.98 ± 2.59 6-months after surgery. There was no statistical difference in the VAS before surgery between the 2

Table 1 cont. *Demographic data, perioperative data, effectiveness and complication of CLDH group and UCLDH group in retrospective cohorts.*

	CLDH (n = 40)	UCLDH (n = 40)	*P*-value
Postoperative (mean ± SD)	23.40 ± 5.00	20.02 ± 4.93	0.003
1-month (mean ± SD)	19.37 ± 4.89	17.07 ± 3.23	0.015
3-month (mean ± SD)	17.92 ± 3.52	16.05 ± 2.85	0.011
6-month (mean ± SD)	16.59 ± 3.10	14.98 ± 2.59	0.013
MacNab classification data			
Excellent n (%)	33 (82.5)	31 (77.5)	0.377
Good n (%)	1 (2.5)	4 (10.0)	
Fair n (%)	6 (15.0)	5 (12.5)	
Excellent or good n (%)	34 (85)	35 (87.5)	0.377
Complication n (%)	1 (2.5)	0 (0)	0.314

Note: CLDH, calcified lumbar disc herniation; UCLDH, uncalcified lumbar disc herniation; ODI: Oswestry disability index; VAS: visual analog scale; BMI, body mass index.

groups ($P > 0.05$); however, the ODI score of the CLDH group was higher than that of the UCLDH group after surgery ($P < 0.05$).

Of the 40 CLDH patients, 35 (85%) patients considered the treatment effect as excellent or good 6-months after surgery. The excellent or good rate of the UCLDH group was 87.5%, and there was no statistical significance between the 2 groups.

One patient had a recurrence of disc herniation for the CLDH group, and there were no complications recorded in the UCLDH group.

Systematic Review and Meta-Analysis

During the screening process, a comprehensive search yielded a total of 1,241 full-text articles, which were subsequently reviewed (Fig. 1). After a thorough assessment, 40 relevant studies (3,5-8,10-44) were deemed suitable for inclusion in the analysis. Additionally, our retrospective cohort study was incorporated, resulting in a total of 41 studies being considered. These studies collectively encompassed a sample size of 2,012 individuals and met the eligibility criteria for further analysis. Among the included studies, 39 originated from China, while 2 were conducted in South Korea. Table 2 provides an overview of the characteristics of the included studies. It is noteworthy that all studies, comprising 26 with moderate quality and 15 with high quality, were retained for the analysis (Fig. 2).

Primary Analysis

We assessed the effectiveness and complications of PELD in treating CLDH. The pooled operation time was 68.88 min (95% CI 63.23 to 75.01 min, $I^2 = 99\%$), and the pooled hospitalization time was 4.16 days (95% CI 3.55 to 4.88 days, $I^2 = 99\%$) (Table 3). The postoperative VAS score was significantly lower than the preoperative score (pooled MD = -4.30 [95% CI -4.66 to -3.94, $I^2 = 98\%$]), and the VAS score continued to decline within one year after the operation. Similarly, the postoperative ODI score was significantly lower than the preoperative score (pooled MD = -42.26 [95% CI -45.28 to -39.25, $I^2 = 97\%$]), and the ODI score continued to decline within one year after the operation.

The pooled excellent or good rate in MacNab classification was 91.8% (95% CI 89.9 to 93.6%, $I^2 = 0\%$), and the pooled complication rate was 2.9% (95% CI 1.7 to 4.3%, $I^2 = 42\%$). The most common complication was postoperative dysesthesia, with a pooled rate of 0.3% (95% CI 0.1 to 0.8%, $I^2 = 14\%$) (Table 3).

Secondary Outcomes

In the comparison between CLDH group and

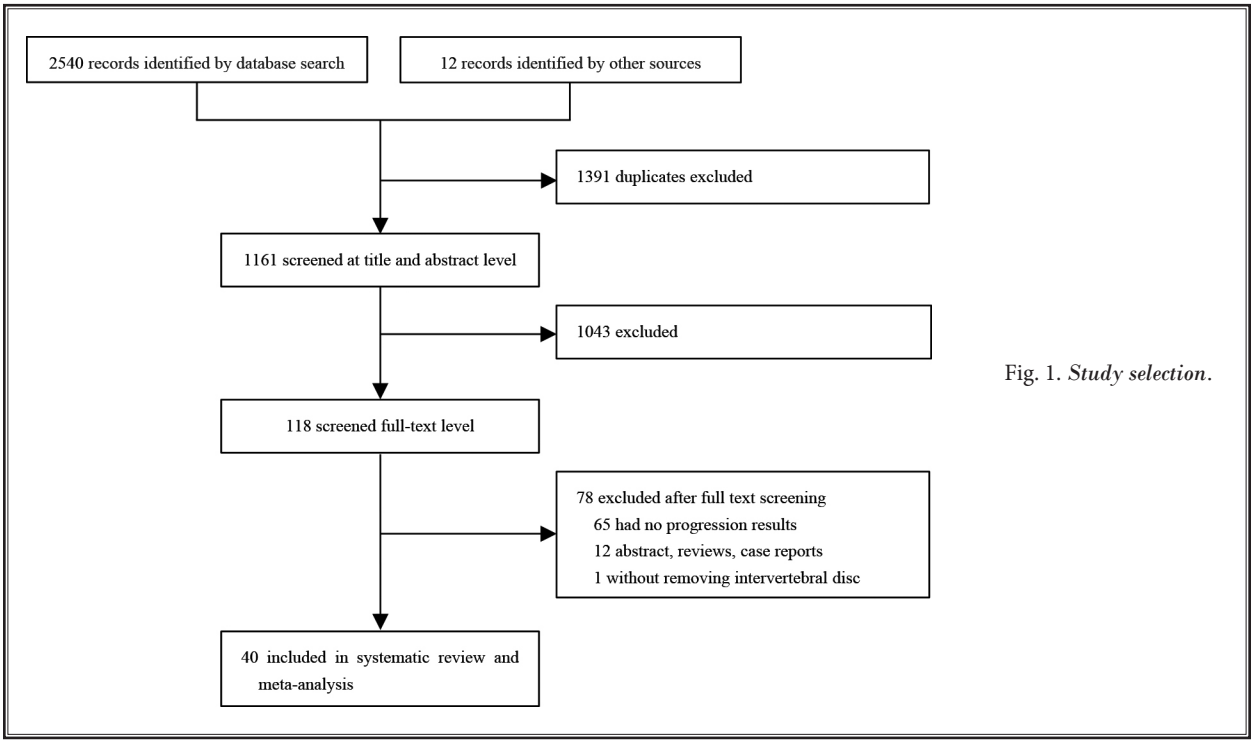

Fig. 1. *Study selection.*

Table 2. *Detailed individual study characteristics in the meta-analysis.*

	Area	Study design	Age	Male (%)	Surgical Level	Sub-group	Partic-ipants (n)	Preopera-tive VAS	3 months VAS	6 months VAS	Preop-erative ODI	3 months ODI	6 months ODI	MacNab excellent + good	Compli-cation
Cai et al 2021 (10)	China	NS	28.7 ± 3.3	75.0	L4-S1	All	20	5.8±0.8	1.1±0.3	NS	57.3±10.1	12.5±3.0	NS	19	0
Chen et al 2014 (3)	China	Retrospective	31.1 ± 9.2	78.0	L4-S1	All	41	7.2±2.7	NS	NS	54.5±18.7	NS	NS	NS	3
Chen et al 2019 (7)	China	Retrospective	46.9 ± 6.9	61.5	L4-S1	PEID	13	5.8±1.5	NS	NS	58.2±15.2	NS	NS	NS	1
Chen et al 2019 (7)	China	Retrospective	45.5 ± 7.5	70.4	L4-S1	PETD	27	5.9±1.7	NS	NS	57.6±17.0	NS	NS	NS	2
Cheng et al 2021 (11)	China	Retrospective	37.1 ± 6.3	58.3	L5-S1	PEID	24	7.6±0.9	2.2±0.5	1.8±0.4	70.8±9.8	NS	19.4±4.0	22	2
Cheng et al 2021 (11)	China	Retrospective	37.8 ± 10.7	55.6	L5-S1	PETD	18	7.5±0.9	2.4±0.7	1.9±0.6	71.1±12.5	NS	22.0±5.4	16	2
Cheng et al 2022 (12)	China	Retrospective	38.6 ± 8.8	60.7	L5-S1	All	28	7.5±0.9	2.2 ± 0.6	1.7 ± 0.5	69.3±9.9	23.9±4.0	20.2±3.8	26	2
Deng et al 2017 (13)	China	NS	43.1 ± 8.6	65.0	L4-S1	CLDH	20	6.9±0.7	1.9±0.5	1.2±0.4	60.2±3.2	12.0 ±1.3	6.8 ±1.0	18	1
Deng et al 2017 (13)	China	NS	40.8 ± 8.9	55.0	L4-S1	ULDH	20	6.3±0.6	1.5±0.5	0.9±0.7	54.6±2.3	9.2±1.6	5.1 ±1.2	19	0
Fang et al 2017 (14)	China	NS	37.1 ± 8.2	66.7	L4-S1	Open surgery	18	7.5±1.2	NS	4.0±0.3	NS	NS	NS	16	NS
Fang et al 2017 (14)	China	NS	37.0 ± 8.3	58.8	L4-S1	PEID	17	7.5±1.2	NS	3.0±0.2	NS	NS	NS	16	NS
He et al 2019 (15)	China	NS	68.3 ± 6.1	59.6	L3-S1	All	46	7.7±1.2	NS	2.0±0.3	78.3±8.2	NS	24.3±4.0	40	4
Huang et al 2017 (16)	China	NS	48.2 ± 8.3	65.4	NS	Open surgery	26	7.3±0.3	NS	NS	69.7±1.4	NS	NS	NS	NS

Table 2 cont. *Detailed individual study characteristics in the meta-analysis.*

	Area	Study design	Age	Male (%)	Surgical Level	Sub-group	Partic-ipants (n)	Preopera-tive VAS	3 months VAS	6 months VAS	Preop-erative ODI	3 months ODI	6 months ODI	MacNab excellent + good	Compli-cation
Huang et al 2017 (16)	China	NS	48.6 ± 8.5	57.7	NS	PEID	26	7.4±0.3	NS	NS	70.2±1.5	NS	NS	NS	NS
Huang et al 2021 (17)	China	Retrospective	48.8 ± 16.4	58.8	L2-S1	All	68	6.4±1.2	NS	NS	60.1±13.1	NS	NS	NS	2
Jiao et al 2018 (18)	China	Retrospective	Mean: 41.9	61.9	L4-S1	All	21	6.2±1.5	NS	NS	NS	NS	NS	21	1
Kim et al 2018 (6)	South Korea	Retrospective	43.7 ± 11.2	54.8	L2-S1	All	31	8.2±0.6	NS	NS	NS	NS	NS	NS	4
Li YM et al 2020 (19)	China	NS	54.2 ± 3.7	60.5	NS	PEID	43	5.6±1.8	1.8±0.5	NS	NS	NS	NS	NS	0
Li YM et al 2020 (19)	China	NS	54.5 ± 3.6	67.4	NS	PETD	43	5.9±1.5	1.9±0.6	NS	NS	NS	NS	NS	0
Li CY et al 2020 (20)	China	NS	31.0 ± 9.1	44.7	NS	All remove	27	7.3±1.5	2.0±0.7	NS	86.6±4.8	15.2±3.4	NS	26	0
Li CY et al 2020 (20)	China	NS	32.3 ± 7.9	44.7	NS	Partial remove	20	7.2±1.1	1.8±0.7	NS	85.5±3.9	14.7±3.3	NS	19	0
Li J et al 2014 (21)	China	NS	37.0 ± 13.0	75.0	L4-S1	Open surgery	28	7.4±0.3	3.5±0.1	3.0±0.1	69.8±1.3	33.5±1.5	32.5±2.9	26	2
Li J et al 2014 (21)	China	NS	35.7 ± 13.0	71.4	L4-S1	PEID	28	7.4±0.3	3.0±0.1	3.2±0.2	70.2±1.6	32.8±1.4	33.3±1.4	27	2
Lin et al 2017 (22)	China	NS	Mean: 48.0	60.0	L4-S1	All	15	7.8±0.7	2.0±0.5	1.5±0.5	82.5±5.0	24.1±3.5	22.4±2.5	14	0
Lu et al 2017 (23)	China	Retrospective	Mean: 55.0	58.0	L3-S1	All	34	3.2±1.5	NS	NS	48.7±14.3	NS	NS	31	0
Qiu et al 2019 (24)	China	NS	56.9 ± 7.2	48.9	NS	Open surgery	45	6.8±0.8	NS	NS	74.2±10.9	NS	NS	NS	4

Table 2 cont. *Detailed individual study characteristics in the meta-analysis.*

	Area	Study design	Age	Male (%)	Surgical Level	Sub-group	Partic-ipants (n)	Preopera-tive VAS	3 months VAS	6 months VAS	Preop-erative ODI	3 months ODI	6 months ODI	MacNab excellent + good	Compli-cation
Qiu et al 2019 (24)	China	NS	56.5 ± 7.7	56.0	NS	PEID	50	6.7 ± 0.8	NS	NS	73.3 ± 11.4	NS	NS	NS	2
Sang et al 2018 (25)	China	Retrospective	Mean: 42.6	34.2	L5-S1	All	38	3.2 ± 0.4	NS	NS	74.6 ± 11.1	NS	NS	NS	3
Shin et al 2020 (26)	South Korea	Retrospective	NS	NS	L2-S1	All	43	6.2 ± 2.3	NS	1.7 ± 0.9	55.4 ± 23.0	NS	16.4 ± 9.8	NS	4
Wang CL et al 2022 (27)	China	Retrospective	42.4 ± 12.7	56.3	NS	All	32	4.1 ± 1.0	NS	NS	53.7 ± 11.8	NS	NS	29	NS
Wang H et al 2021 (5)	China	Retrospective	49.6 ± 16.2	56.5	L4-S1	CLDH	46	9 (5–10)	1 (0–3)	1 (0–3)	NS	NS	NS	44	1
Wang H et al 2021 (5)	China	Retrospective	51.5 ± 16.1	56.4	L4-S1	ULDH	55	8 (6–10)	1 (0–3)	1 (0–3)	NS	NS	NS	52	3
Wang LB et al 2021 (28)	China	NS	51.7 ± 12.5	64.7	L2-S1	All	17	5.5 ± 1.4	NS	NS	65.2 ± 10.3	NS	NS	15	0
Wang YB et al 2020 (29)	China	Retrospective	56.9 ± 13.0	58.0	L3-S1	All	143	6.9 ± 1.4	NS	2.8 ± 1.0	65.4 ± 12.0	NS	28.2 ± 7.8	NS	NS
Wang XQ et al 2020 (30)	China	NS	54.2 ± 4.3	61.3	L4-S1	Open surgery	31	4.7 ± 0.7	NS	NS	NS	NS	NS	NS	2
Wang XQ et al 2020 (30)	China	NS	53.8 ± 4.5	65.6	L4-S1	PEID	32	4.7 ± 0.5	NS	NS	NS	NS	NS	NS	1
Wang et al 2018 (31)	China	Retrospective	Rang: 32-73	55.8	L3-S1	All	52	7.2 ± 1.1	NS	2.8 ± 1.3	84.9 ± 6.4	NS	18.9 ± l3.3	49	1
Wen et al 2015 (32)	China	NS	Mean: 54.5	56.3	L3-S1	All	48	6.3 ± 0.2	2.0 ± 0.2	1.1 ± 0.1	NS	NS	NS	44	2

Table 2 cont. *Detailed individual study characteristics in the meta-analysis.*

	Area	Study design	Age	Male (%)	Surgical Level	Sub-group	Partic-ipants (n)	Preopera-tive VAS	3 months VAS	6 months VAS	Preop-erative ODI	3 months ODI	6 months ODI	MacNab excellent + good	Compli-cation
Wu et al 2017 (33)	China	Retrospective	31.0 ± 4.0	60.0	L4-S1	All	20	6.3 ± 2.5	0.9 ± 0.3	NS	NS	NS	NS	NS	NS
Xu et al 2016 (34)	China	Retrospective	36.0 ± 7.8	66.7	L4-S1	CLDH	30	NS	NS	NS	NS	NS	NS	27	NS
Xu et al 2016 (34)	China	Retrospective	35.9 ± 6.5	60.0	L4-S1	ULDH	30	NS	NS	NS	NS	NS	NS	29	NS
Yan et al 2019 (35)	China	NS	38.1 ± 8.1	61.1	L3-S1	Open surgery	18	7.0 ± 0.3	NS	3.9 ± 0.3	NS	NS	NS	16	1
Yan et al 2019 (35)	China	NS	38.2 ± 7.2	65.0	L3-S1	PEID	20	6.9 ± 1.2	NS	3.3 ± 0.5	NS	NS	NS	19	0
Yin et al 2017 (36)	China	NS	Mean: 49.0	55.2	L2-S1	PEID	31	9.4 ± 0.6	NS	NS	NS	NS	NS	27	NS
Yin et al 2017 (36)	China	NS	Mean: 49.0	55.2	L2-S1	PETD	36	9.2 ± 0.7	NS	NS	NS	NS	NS	32	NS
Yu et al 2020 (8)	China	Retrospective	38.0 ± 2.3	64.0	L4-S1	All	25	6.4 ± 1.0	1.6 ± 0.9	0.8 ± 0.7	64.5 ± 8.5	19.8 ± 8.1	13.4 ± 4.3	23	1
Yuan et al 2018 (37)	China	NS	36.0 ± 8.2	80.0	L5-S1	All	15	7.8 ± 0.6	2.1 ± 0.2	1.9 ± 0.1	68.4 ± 5.7	31.9 ± 3.8	32.1 ± 5.3	13	0
Yuan et al 2022 (38)	China	Retrospective	49.9 ± 14.5	40.0	L1-S1	CLDH	50	NS	NS	NS	67.4 ± 13.3	20.4 ± 8.8	11.0 ± 6.3	47	1
Yuan et al 2022 (38)	China	Retrospective	53.2 ± 15.3	40.7	L1-S1	ULDH	54	NS	NS	NS	67.7 ± 14.4	19.6 ± 7.8	10.7 ± 5.8	50	0
Zhang et al 2020 (39)	China	NS	47.8 ± 9.7	57.1	L4-S1	All	18	6.2 ± 1.0	2.4 ± 0.2	NS	65.4 ± 8.3	21.1 ± 2.1	NS	15	1
Zhao et al 2019 (40)	China	NS	42.1 ± 10.2	63.0	L5-S1	All	27	7.6 ± 0.3	2.0 ± 0.5	NS	61.2 ± 7.32	2.8 ± 4.3	NS	NS	2

Table 2 cont. *Detailed individual study characteristics in the meta-analysis.*

	Area	Study design	Age	Male (%)	Surgical Level	Sub-group	Participants (n)	Preoperative VAS	3 months VAS	6 months VAS	Preoperative ODI	3 months ODI	6 months ODI	MacNab excellent + good	Complication
Zhong et al 2015 (41)	China	NS	36.9±13.0	76.0	L4-S1	Open surgery	25	7.3±03	3.5±0.1	3.0±0.3	69.8±1.3	33.5±1.5	32.5±2.9	23	NS
Zhong et al 2015 (41)	China	NS	35.7±13.0	72.0	L4-S1	PETD	25	7.4±0.3	3.0±0.1	3.1±0.2	70.2±1.6	32.8±1.4	33.3±1.4	24	NS
Zhou et al 2022 (42)	China	Retrospective	Mean: 52.6	61.5	NS	All	26	7.5±1.3	3.2±0.5	3.8±0.4	75.8±11.4	19.2±2.4	14.9±3.1	NS	2
Zhu et al 2019 (43)	China	NS	45.2±6.4	60.0	NS	Open surgery	40	NS	NS	NS	NS	NS	NS	20	NS
Zhu et al 2019 (43)	China	NS	46.5±5.3	47.5	NS	PEID	40	NS	NS	NS	NS	NS	NS	32	NS
Zou et al 2019 (44)	China	NS	41.0±18.4	57.4	NS	All	68	6.2±2.5	NS	NS	69.9±9.6	NS	NS	NS	1
Present study 2022	China	Retrospective	46.8±15.4	65.0	L3-S1	CLDH	40	5.6±0.6	1.0±0.8	1.0±0.9	71.0±7.2	17.9±3.5	16.6±3.1	34	0
Present study 2022	China	Retrospective	49.5±13.7	52.5	L3-S1	ULDH	40	5.9±0.8	1.4±1.2	1.5±1.1	70.5±7.2	16.1±2.9	15.0±2.6	35	1

Note: Four studies reported VAS scores of the back and leg [12,19,23,28], and only VAS scores of the back were retained for analysis. PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy; CLDH, calcified lumbar disc herniation; UCLDH, uncalcified lumbar disc herniation.; NS, not specified.

UCLDH group, the operation time (MD = 6.67 min [95% CI 4.45 to 8.90 min]) and postoperative ODI score (3 months MD = 2.37 [95% CI 1.52 to 3.21]) of CLDH group were higher than those of UCLDH group. In the comparison between PETD and PEID in treating CLDH patients, the operation time of PETD was shorter than that of PEID (MD = -14.93 min [95% CI -22.35 to -7.51] min). In the comparison between PELD and open surgery in treating CLDH patients, the intraoperative blood loss, hospitalization time, postoperative VAS score, and ODI score of the PELD group were lower than those of the open surgery group (Table 4).

Egger's test was set as a parameter in publication bias detection. There was no evidence of publication bias found in the comparison between postoperative VAS score and preoperative VAS score (P = 0.0774), in the calculation of excellent or good rate in MacNab classification (P = 0.5169), and in the calculation of complication rate (P = 0.9674). However, publication bias was found in the comparison between postoperative ODI score and preoperative VAS score (P = 0.0213).

Discussion

In this study, we evaluated the effectiveness and complication of PELD in the treatment of CLDH patients through a retrospective cohort study combined with a systematic review and meta-analysis. We included 80 patients and 41 studies and found that PELD was effective and safe in treating CLDH patients. To the best of our knowledge, this is the first meta-analysis on this topic,

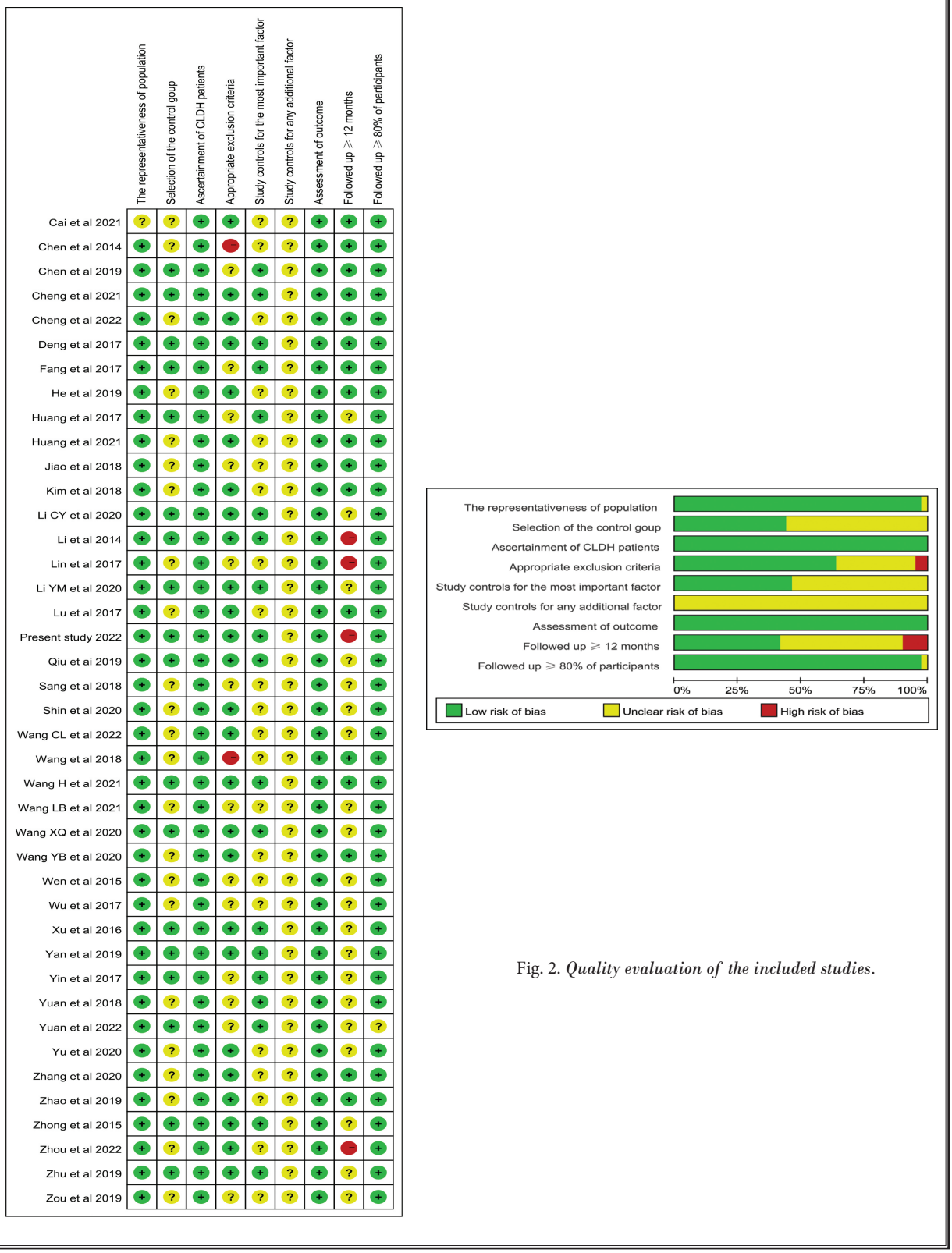

Fig. 2. *Quality evaluation of the included studies.*

Table 3. *Assessment of effectiveness and complication of PELD in treatment of CLDH patients in the meta-analysis.*

	Studies (n)	Patients (n)	Pooled ES (95% CI)	I^2 (%)
Operation time (min)	33	1211	68.88 (63.23 to 75.01)	99
Hospitalization time (days)	21	716	4.16 (3.55 to 4.88)	99
VAS data				
Postoperative vs preoperative (MD)	19	550	-4.30 (-4.66 to -3.94)	98
3-month vs preoperative (MD)	19	490	-4.82 (-5.05 to -4.59)	93
6-month vs preoperative (MD)	18	623	-4.95 (-5.28 to -4.63)	97
12-month vs preoperative (MD)	13	398	-5.30 (-6.38 to -4.22)	99
ODI data				
Postoperative vs preoperative (MD)	13	366	-42.26 (-45.28 to -39.25)	97
3-month vs preoperative (MD)	14	344	-50.10 (-56.45 to -43.76)	99
6-month vs preoperative (MD)	15	558	-49.18 (-53.99 to -44.37)	99
12-month vs preoperative (MD)	14	460	-57.78 (-63.30 to -52.27)	97
Macnab classification				
Excellent (%)	29	843	69.7 (66.6 to 72.8)	75
Good (%)	29	843	20.9 (18.2 to 23.7)	73
Fair (%)	28	803	6.3 (4.7 to 8.1)	0
Poor (%)	28	803	0.7 (0.2 to 1.4)	13
Excellent or good (%)	29	843	91.8 (89.9 to 93.6)	0
Complication				
Total complication (%)	37	1202	2.9 (1.7 to 4.3)	42
Recurrent disc herniation (%)	37	1202	0.2 (0.0 to 0.5)	0
Postoperative dysesthesia (%)	37	1202	0.3 (0.1 to 0.8)	14
Nerve root injury (%)	37	1202	0.2 (0.0 to 0.5)	0
Dural tear (%)	37	1202	0.2 (0.0 to 0.5)	0

Note: PELD, percutaneous endoscopic lumbar discectomy, CLDH, calcified lumbar disc herniation; ES, effect size; ODI, Oswestry disability index; VAS, Visual analog scale; MD, mean differences.

which provides a reliable result and a more extensive application of the analysis of results.

Both in our retrospective cohort and meta-analysis, the VAS and ODI scores in the CLDH group were continually decreased after the operation. The excellent or good rates in the MacNab classification in the retrospective cohort and meta-analysis were 85% and 91.8%, respectively. Additionally, no complications were observed in our retrospective cohort, and only 2.9% of CLDH patients had complications in our meta-analysis. Dural tears and nerve root injury are worrisome since severe vertebral degeneration and severe adhesion to the thecal sac are common in CLDH patients (5,34). However, in our 41 included studies, the complication rate of dural tears was reported to range from 0% to 7.7%, and the pooled complication rate of dural tears was only 0.2%. The complication rate of nerve root injury was reported to range from 0% to 6.7%, and the pooled complication rate of nerve root injury was only 0.2%. Therefore, our results revealed that PELD was an effective and safe method in the treatment of CLDH patients.

In the comparison between the CLDH and UCLDH groups, there was no difference in the hospitalization time, VAS score, and MacNab classification. However, the operation time in the CLDH group was longer than that in the UCLDH group, with a pooled MD of 6.67 min (95% CI 4.45 to 8.90). The ODI score after surgery in the CLDH group was higher than that in the UCLDH group, with a pooled MD of 2.37 (95% CI 1.52 to 3.21) 3-months after surgery, and 1.59 (95% CI 1.01 to 2.18) 6-months after surgery. Calcification of the intervertebral discs is always accompanied by a chronic pathological process (34), including severe adhesion to the thecal sac, which may explain the longer operation time and slower functional recovery after surgery.

Although our meta-analysis showed no difference in the total complication rate between the groups, dural tears and dysesthesia seem to be more common in the CLDH group, and recurrent cases seem to be more com-

Table 4. *Comparison of the perioperative data, effectiveness, and complication CLDH versus UCLDH, PEID versus PETD, and PELD versus open surgery in the meta-analysis.*

	Studies (n)	Patients (n)	Pooled ES (95% CI)	I^2 (%)
CLDH VS UCLDH				
Operation time (MD, min)	5	186/190	6.67 (4.45 to 8.90)	0
Hospitalization time (MD, days)	2	70/70	-0.36 (-1.11 to 0.40)	68
VAS data				
Preoperative (MD)	2	60/60	0.14 (-0.74 to 1.02)	91
3-month (MD)	2	60/60	0.05 (-0.86 to 0.96)	91
6-month (MD)	2	60/60	-0.10 (-1.00 to 0.80)	91
ODI data				
Preoperative (MD)	3	110/114	2.35 (-1.82 to 6.53)	81
3-month (MD)	3	110/114	2.37 (1.52 to 3.21)	13
6-month (MD)	3	110/114	1.59 (1.01 to 2.18)	0
Macnab excellent or good (RD)	5	186/199	-0.01 (-0.06 to 0.04)	0
Total complication (RD)	4	156/169	-0.00 (-0.04 to 0.03)	0
PEID VS PETD				
Operation Time (MD, min)	3	107/101	-14.93 (-22.35 to -7.51)	84
Hospitalization time (MD, days)	3	107/101	0.07 (-0.29 to 0.44)	0
VAS data				
Preoperative (MD)	5	151/164	0.09 (-0.09 to 0.26)	0
3-month (MD)	3	107/101	-0.14 (-0.35 to 0.06)	0
6-month (MD)	2	64/58	-0.010 (-0.36 to 0.16)	0
ODI data				
Preoperative (MD)	3	77/85	3.58 (-1.61 to 8.77)	53
3-month (MD)	2	83/83	-0.20 (-1.84 to 1.45)	59
6-month (MD)	2	64/58	-0.26 (-4.34 to 3.82)	85
Macnab excellent or good (RD)	3	85/64	-0.01 (-0.10 to 0.08)	0
Total complication (RD)	4	110/98	-0.00 (-0.04 to 0.04)	0
PEID VS Open surgery				
Operation Time (MD, min)	7	213/218	-3.30 (-11.07 to 4.46)	95
Hospitalization time (MD, days)	6	168/168	-2.46 (-4.13 to -0.79)	99
Intraoperative blood loss (MD, ml)	6	186/182	-30.34 (-40.28 to -20.40)	99
VAS data				
Preoperative (MD)	6	173/178	0.06 (-0.03 to 0.14)	0
1-day (MD)	4	124/129	-0.50 (-0.24 to -0.76)	96
6-month (MD)	3	71/70	-0.22 (-0.68 to 0.25)	99
ODI data				
Preoperative (MD)	4	124/129	0.39 (0.06 to 0.85)	0
1-day (MD)	4	124/129	-3.10 (-4.50 to -1.70)	88
6-month (MD)	3	71/70	-2.03 (-7.19 to 3.13)	98
Macnab excellent or good (RD)	4	111/110	0.09 (-0.03 to 0.22)	63
Total complication (RD)	3	104/110	-0.03 (-0.10 to 0.03)	0

Note: PELD, percutaneous endoscopic lumbar discectomy; PEID, percutaneous endoscopic interlaminar discectomy; PETD, percutaneous endoscopic transforaminal discectomy; CLDH, calcified lumbar disc herniation; UCLDH, uncalcified lumbar disc herniation; ES, effect size; ODI, Oswestry disability index; VAS, Visual analog scale; MD, mean differences; RD, Risk Difference.

mon in the UCLDH group. In the study by Xu et al (34), one case of dural tear was observed in 30 CLDH patients, and none was observed in 30 UCLDH patients. Similarly, in the study by Deng et al (13), one case of dural tear was observed in 20 CLDH patients, and none was observed in 20 UCLDH patients. In our retrospective cohort, one recurrent case was observed in 40 UCLDH patients, and none was observed in 40 CLDH patients. Similarly, in the study by Wang H et al (5), one recurrent case was observed in 55 UCLDH patients, and none was observed in 46 CLDH patients. The adhesion between the calcifica-

tion and the nerve root or dura increases the possibility of iatrogenic injury. However, calcified intervertebral discs are more stable than noncalcified intervertebral discs; therefore, the probability of recurrence is reduced.

In the comparison between PETD and PEID in treating CLDH patients, we found that the operation time of the PETD group was significantly longer than that of the PEID group, with an MD of 14.93 min (95% CI 7.51 to 22.35 min). Two previous meta-analyses compared the performance between PETD and PEID in treating LDH patients and found similar results that the PETD group had longer operation time than the PEID group (45,46). PETD involves accessing the disc herniation through the transforaminal approach, which requires additional time for navigating the neural structures and reaching the target site. On the other hand, PEID utilizes an intralaminar approach, which may provide more straightforward access to the disc herniation, resulting in shorter operation times. These findings align with previous meta-analyses conducted on lumbar disc herniation patients, suggesting that the choice of surgical approach can influence the duration of the procedure.

Limitation

There are some limitations to our study. First, the retrospective cohort had a small sample size. Second, long-term follow-up results were lacking owing to the retrospective design of the study. Third, the meta-analysis only included retrospective studies with small sample sizes. Fourth, only a few comparative studies were included in the meta-analysis, therefore, some results need further confirmation.

Conclusion

PELD is an effective and safe treatment option for CLDH patients. In comparison to UCLDH patients, CLDH patients may experience longer operation times and slightly slower functional recovery than those with UCLDH.

Author Contributions

XSC and CS initiated the project and were responsible for protocol design. ZL collected the data from a retrospective study. ZL and GZZ performed the literature review, collected the data, assessed the quality of studies, and analyzed the data. FCG, LQZ, HBG, GQX, JX, XSC, and CS interpreted the data. GZZ and ZL wrote the initial draft of the manuscript. All authors were responsible for the critical revision of the manuscript and provided important intellectual content. All authors approved the final version of the manuscript submitted for publication.

References

1. Deyo RA, Mirza SK. Clinical Practice. Herniated lumbar intervertebral disk. *N Engl J Med* 2016; 374:1763-1772.
2. Costăchescu B, Niculescu AG, Teleanu RI, et al. Recent advances in managing spinal intervertebral disc degeneration. *Int J Mol Sci* 2022; 23:6460.
3. Cheng ZX, Zheng YJ, Feng ZY, et al. Chinese association for the study of pain: Expert consensus on diagnosis and treatment for lumbar disc herniation. *World J Clin Cases* 2021; 9:2058-2067.
4. Wong T, Patel A, Golub D, et al. Prevalence of long-term low back pain after symptomatic lumbar disc herniation. *World Neurosurg* 2023; 170:163-173.e1.
5. Wang H, Zhou T, Gu Y, et al. Evaluation of efficacy and safety of percutaneous transforaminal endoscopic surgery (PTES) for surgical treatment of calcified lumbar disc herniation: A retrospective cohort study of 101 patients. *BMC Musculoskelet Disord* 2021; 22:65.
6. Kim HS, Adsul N, Ju YS, et al. Full endoscopic lumbar discectomy using the calcification floating technique for symptomatic partially calcified lumbar herniated nucleus pulposus. *World Neurosurg* 2018; 119:500-505.
7. Chen Y, Wang JX, Sun B, et al. Percutaneous endoscopic lumbar discectomy in treating calcified lumbar intervertebral disc herniation. *World Neurosurg* 2019; 122:e1449-e1456.
8. Yu L, Wen JK, Wang S, et al. Removal of calcified lumbar disc herniation with endoscopic-matched ultrasonic osteotome - Our preliminary experience. *Br J Neurosurg* 2020; 34:80-85.
9. Moher D, Shamseer L, Clarke M, et al.Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; 4:1.
10. Cai X, Yu PF, Li YW, et al. Clinical study of percutaneous transforaminal endoscopic discectomy in the treatment of calcified lumbar disc herniation in adults. *Journal of Cervicodynia and Lumbodynia* 2021; 42:203-206.
11. Cheng YP. Comparative study of the percutaneous endoscopic interlaminar approach and transforaminal approach for calcified lumbar disc herniation [dissertation]. *Ji Lin University* 2021.
12. Cheng Y, Zhang Q, Li Y, et al. Percutaneous endoscopic interlaminar discectomy for L5-S1 calcified lumbar disc herniation: A retrospective study. *Front Surg* 2022; 9:998231.
13. Deng ZB. The clinical study treatment of special types of lumbar disc herniation with percutaneous endoscopic interlaminar discectomy [dissertation]. *Nanchang University* 2017.
14. Fang SB, Zhong HF, Chen RC. Efficacy analysis of medium and long-term percutaneous transforaminal endoscopic discectomy in the treatment of calcified lumbar disc herniation. *China Modern Medicine* 2017; 24:80-85.
15. He ZY, Wang DX. Endoscopic discectomy via minimally invasive

interlaminar approach for the treatment of senile calcified lumbar disc herniation. *Journal of Cervicodynia and Lumbodynia* 2019; 40:648-652.

16. Huang GB. Clinical observation on minimally invasive treatment of calcified lumbar disc herniation by percutaneous endoscopic approach. *Journal of Baotou Medicine* 2017; 41:10-11.
17. Huang W, Jiang XH, Liu PT, et al. Diagnosis and treatment of calcified lumbar disc herniation and lumbar disc herniation with posterior edge separation of the vertebral body. *Orthopaedics* 2021; 12:14-18.
18. Jiao LB, Wu Y, Zhang B. Clinical application of percutaneous foraminoscopy in calcified lumbar disc herniation. *Journal of Cervicodynia and Lumbodynia* 2018; 39:634-636.
19. Li YM, Sun HD, Li Q, Zhong R. Effects of minimally invasive percutaneous interlaminar approach on nerve root separation rate and calcification clearance rate in patients with lumbar disc herniation. *Medical Innovation of China* 2020; 17:49-52.
20. Li CY, Liu Y, Yan BR, et al. Application of percutaneous spinal endoscopy in calcified lumbar disc herniation. *Chinese Journal of Pain Medicine* 2020; 26:66-68.
21. Li J, Fu Q. An analysis of short-term clinical outcomes of percutaneous endoscopic interlaminar approach for calcified lumbar disc herniation. *Chinese Journal of Bone and Joint* 2014; 3:597-598.
22. Lin WB. The analysis of the clinical effect for patients with calcified lumber disc herniation in percutaneous full-endoscopic interlaminar approach [dissertation]. *Zunyi Medical University* 2017.
23. Lu CX. Relationship between the operative effect of Lumbar Disc Herniation and TESSYS typing method [dissertation]. *Chengde Medical College* 2017.
24. Qiu JR, Yan GH, Ge Y, et al. Percutaneous transforaminal endoscopic nucleus pulpectomy for single-segment calcified lumbar disc herniation. *Chinese Journal of Difficult and Complicated Cases* 2019; 18:586-589.
25. Sang PM, Zhang M, Chen BH, et al. PEID in the treatment of lumbar disc herniation with free prolapse and calcification. *Chinese Journal of Bone and Joint Injury* 2018; 33:290-291.
26. Shin SH, Bae JS, Lee SH, et al. Transforaminal endoscopic discectomy for hard or calcified lumbar disc herniation: A new surgical technique and clinical outcomes. *World Neurosurg* 2020; 143:e224-e231.
27. Wang CL, Si ZB, Zuo CH, et al. Comparison of percutaneous endoscopic lumbar discectomy for patients with lumbar disc herniation of lateral recess stenosis type and calcification type. *Journal of Clinical and Experimental Medicine* 2022; 21:621-624.
28. Wang LB, Li JJ, Zhu LF, et al. Percutaneous spinal endoscopy for treatment of calcified lumbar disc herniation. *Orthopedic Journal of China* 2021; 29:1597-1600.
29. Wang YB. Clinical study of percutaneous endoscopic transforaminal discectomy in the treatment of calcified lumbar disc herniation [dissertation]. *Henan University* 2017.
30. Wang XQ, Xia HT, Li J. Effect of percutaneous foraminoscopic nucleus pulpectomy on patients with single level calcified lumbar disc herniation. *Henan Medical Research* 2020; 29:3915-3916.
31. Wang ZZ, Cui B, Tian DY, et al. Clinical effect of percutaneous endoscopic lumbar discectomy in the treatment of lumbar disc herniation and calcification. *Journal of Regional Anatomy and Operative Surgery* 2018; 27:32-35.
32. Wen ZJ. The evaluation of percutaneous transforaminal endoscopic discectomy using TESSYS technology in the treatment of calcified lumbar disc herniation [dissertation]. *Binzhou Medical University* 2015.
33. Wu XD, Wang ZC, Ye XJ, et al. Percutaneous endoscopic transforaminal discectomy for the treatment of calcified intervertebral lumbar disc herniation. *Journal of Spinal Surgery* 2017; 15:146-149.
34. Xu DB, Chen ZQ, Zhao YC, et al. The clinical results of percutaneous endoscopic interlaminar discectomy (PEID) in the treatment of calcified lumbar disc herniation: A Case-control study. *Pain Physician* 2016; 19:69-76.
35. Yan GH, Qiu JR, Ge SJ. Efficacy analysis of percutaneous transforaminal endoscopic discectomy in the treatment of single segment calcified lumbar disc herniation. *Journal of Modern Medicine and Health* 2019; 35:1136-1142.
36. Yin L, Dong ZJ, Wang SL, et al. The comparative effectiveness of two different approaches in the treatment of calcified lumbar disc herniation by percutaneous transforaminal endoscopic discectomy. *Chinese Journal of Pain Medicine* 2017; 23:277-282.
37. Yuan TY, Zhang J, Liu QY. Treatment of calcified L5S1 lumbar disc herniation with percutaneous endoscopic interlaminar discectomy: A report of 15 cases and literature review. *Journal of Jilin University* 2018; 44:615-619.
38. Yuan AL, Shen X, Chen B. Treatment of calcified lumbar disc herniation by intervertebral foramen remolding: a retrospective study. *J Pain Res* 2022; 15:1719-1728.
39. Zhang WB, Liu SP, Liu R, et al. Percutaneous endoscopic foraminal approach for the treatment of lumbar disc herniation with posterior calcification. *Journal of Clinical Orthopaedics* 2020; 23:348-351.
40. Zhao JL. Treatment of 27 cases of L5-S1 calcified lumbar disc herniation by percutaneous endoscopic surgery. *The Journal of Cervicodynia and Lumbodynia* 2019; 40:520-522.
41. Zhong HF, Zeng LM, Liu N, et al. Vertebral plate into the path between the skin and minimally invasive treatment technique of calcification type lumbar intervertebral disc protrusion. *China Modern Medicine* 2015; 22:87-89.
42. Zhou J, Cheng ZW, Ma C, et al. Treatment of calcified lumbar disc herniation with total endoscopic nucleus pulpectomy via percutaneous lamina space approach. *Chinese Journal of Bone and Joint* 2022; 37:65-67.
43. Zhu HZ. Clinical effect of total endoscopic surgery via interlaminar approach in the treatment of calcified lumbar disc herniation. *Henan Medical Research* 2019; 28:3303-3304.
44. Zou J, Yu WH, Bai D. The efficacy and safety of PETD in the treatment of calcified lumbar disc herniation. *Heilongjiang Medical Journal* 2019; 32:708.
45. Jitpakdee K, Liu Y, Kotheeranurak V, et al. Transforaminal versus interlaminar endoscopic lumbar discectomy for lumbar disc herniation: A systematic review and meta-analysis. *Global Spine J* 2023; 13:575-587.
46. Huang Y, Yin J, Sun Z, et al. Percutaneous endoscopic lumbar discectomy for LDH via a transforaminal approach versus an interlaminar approach: A meta-analysis. *Orthopade* 2020; 49:338-349.