


Percutaneous endoscopic lumbar discectomy compared with other surgeries for lumbar disc herniation

A meta-analysis

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Abstract

Objective: This meta-analysis was performed to investigate whether percutaneous endoscopic lumbar discectomy (PELD) had a superior effect than other surgeries in the treatment of patients with lumbar disc herniation (LDH).

Method: We searched PubMed, Embase, and Web of Science through February 2018 to identify eligible studies that compared the effects and complications between PELD and other surgical interventions in LDH. The outcomes included success rate, recurrence rate, complication rate, operation time, hospital stay, blood loss, visual analog scale (VAS) score for back pain and leg pain, 12-item Short Form Health Survey (SF12) physical component score, mental component score, Japanese Orthopaedic Association Score, Oswestry Disability Index. A random-effects or fixed-effects model was used to pool the estimate, according to the heterogeneity among the included studies.

Results: Fourteen studies (involving 2,528 patients) were included in this meta-analysis. Compared with other surgeries, PELD had favorable clinical outcomes for LDH, including shorter operation time (weight mean difference, WMD = -18.14 minutes, 95%CI: -25.24, -11.05; $P < .001$) and hospital stay (WMD = -2.59 days, 95%CI: -3.87, -1.31; $P < .001$), less blood loss (WMD = -30.14 ml, 95%CI: -43.16, -17.13; $P < .001$), and improved SF12- mental component score (WMD = 2.28, 95%CI: 0.50, 4.06; $P = .012$) and SF12- physical component score (WMD = 1.04, 95%CI: 0.37, 1.71; $P = .02$). However, it also was associated with a significantly higher rate of recurrent disc herniation (relative risk [RR] = 1.65, 95%CI: 1.08, 2.52; $P = .021$). There were no significant differences between the PELD group and other surgical group in terms of success rate (RR = 1.01, 95%CI: 0.97, 1.04; $P = .733$), complication rate (RR = 0.86, 95%CI: 0.63, 1.18; $P = .361$), Japanese Orthopaedic Association Score score (WMD = 0.19, 95%CI: -1.90, 2.27; $P = .861$), visual analog scale score for back pain (WMD = -0.17, 95%CI: -0.55, 0.21; $P = .384$) and leg pain (WMD = 0.00, 95%CI: -0.10, 0.10; $P = .991$), and Oswestry Disability Index score (WMD = -0.29, 95%CI: -1.00, 0.43; $P = .434$).

Conclusion: PELD was associated with better effects and similar complications with other surgeries in LDH. However, it also resulted in a higher recurrence rate. Considering the potential limitations in the present study, further large-scale, well-performed randomized trials are needed to verify our findings.

Abbreviations: JOA = Japanese Orthopaedic Association Score, LDH = lumbar disc herniation, MCS = mental component score, MED = microendoscopic discectomy, ODI = Oswestry Disability Index, OLM = open lumbar microdiscectomy, PCS = physical component score, PELD = percutaneous endoscopic lumbar discectomy, RR = relative risk, SF12 = 12-item Short Form Health Survey, VAS = visual analog scale, WMD = weighted mean difference.

Keywords: lumbar disc herniation, meta-analysis, percutaneous endoscopic lumbar discectomy

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The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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1. Introduction

Lumbar disc herniation (LDH) is one of the most frequently diagnosed causes of low back pain and is a common cause of radiculopathy.^[1–3] Although most patients with LDH can achieve satisfying clinical and functional outcomes with conservative treatment, a few patients do not respond effectively to conservative treatment and eventually require surgical treatment.^[4,5]

There are several main surgical options: open lumbar microdiscectomy (OLM),^[6] microendoscopic discectomy (MED),^[7,8] minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF),^[9] and percutaneous endoscopic lumbar discectomy (PELD).^[10,11] OLM has been regarded as the most commonly recommended surgical option for recurrent LDH;^[12,13] however, it was associated with several complications, including muscle damage, nerve retraction, and the removal of yellow ligament,^[14,15] which can result in instability and scarring of the epidural space.^[16,17] MED uses a microendoscope for visualization, and the paraspinous muscles are handled by muscle splitting through dilators;^[18] thus, the muscle and soft tissue are minimally injured.^[19] MIS-TLIF is a well-accepted operation method for recurrent LDH. And it has the advantages of less iatrogenic soft tissue injury, lower risk of postoperative radiculitis, and decreased retraction of dural sac.^[20,21] PELD is a more minimally invasive surgery because the posterior column structures are preserved.^[22,23] It has gained interest for its potential advantage in the reduced risk of facet joints injury, fewer postoperative complications, a shorter hospital stay and lower cost.^[24,25] Previous studies have reported that PELD is an effective and safe treatment for LDH.^[26,27] However, whether PELD is superior to other surgical options remains controversial. Thus, we conducted this meta-analysis to compare the clinical, radiologic, and complications of PELD and other surgeries for patients with LDH.

2. Methods

2.1. Literature search strategy

We conducted this meta-analysis in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement guidelines.^[28] Multiple databases, including PubMed, Embase, and Web of Science were systematically searched before February 2018. The structured search strategies were listed as followings: ((“lumbosacral region”[MeSH Terms] OR (“lumbosacral”[All Fields] AND “region”[All Fields]) OR “lumbosacral region”[All Fields] OR “lumbar”[All Fields]) AND disc[All Fields] AND (“hernia”[MeSH Terms] OR “hernia”[All Fields] OR “herniation”[All Fields])) AND (percutaneous[All Fields] AND (“endoscopy”[MeSH Terms] OR “endoscopy”[All Fields] OR “endoscopic”[All Fields]) AND (“lumbosacral region”[MeSH Terms] OR (“lumbosacral”[All Fields] AND “region”[All Fields]) OR “lumbosacral region”[All Fields] OR “lumbar”[All Fields]) AND (“discectomy”[MeSH Terms] OR “discectomy”[All Fields] OR “discectomy”[All Fields])). This search was limited to human subjects, and no language or publication status was imposed. In addition, we also manually searched the reference lists of the included studies and previous review, systematic review and meta-analysis to identify potential studies until no additional articles could be found.

2.2. Inclusion criteria

The inclusion criteria were as follows:

- (1) study design: randomized control trial (RCT), cohort study, or case-control study;
- (2) population: patients who were diagnosed with LDH
- (3) intervention: PELD;
- (4) comparison: other surgical approaches;
- (5) outcome measures: one of the followings: success rate, recurrence rate, complication rate, operation time, hospital stay, blood loss, visual analog scale (VAS) score for back pain and leg pain, 12-item Short Form Health Survey (SF12) physical component score (PCS), mental component score (MCS), Japanese Orthopaedic Association Score (JOA), Oswestry Disability Index (ODI).

2.3. Data extraction

Two independent investigators extracted the following data from the included studies: first author's name, publication year, study design, country, number of patients in each group, patients' characteristics, and outcome data (success rate, recurrence rate, complication rate, operation time, hospital stay, blood loss, VAS scores for back pain and leg pain, JOA, SF12-MCS/PCS, and ODI). If the study did not provide the important data, we would contact the corresponding authors for the missing information.

2.4. Quality assessment

We evaluated the risk of bias in RCTs with the method recommended by Cochrane Collaboration.^[29] Five items, including blinding, method of randomization, allocation concealment, follow-up, and intention-to-treat analysis were used to assess the quality of study.^[29] And each study was classified as high, low, or unclear risk of bias.

We evaluated the methodological quality of non-randomized studies (cohort study, or case-control study) using the modified Newcastle-Ottawa scale.^[30] The total scale of this method was 9 points, and higher point indicated better quality.^[30] Any study was considered to be high quality if the score was more than 5 points.

2.5. Statistical analysis

Two independent investigators used the STATA version 12.0 (Stata Corporation, College Station, TX, USA) to perform the statistical analysis. Success rate, recurrence rate, and complication rate, were treated as dichotomous variables and were expressed as relative risk (RR) with 95% confidence intervals. Operation time, hospital stay, blood loss, back-pain VAS score, leg-pain VAS score, JOA score, and SF12-MCS/PCS, were treated as continuous variables, thus they were expressed as weighted mean difference (WMD) with 95% confidence intervals. Before the data were pooled, Q-statistic and I^2 statistic were used to detect the heterogeneity among the studies, in which a P value $< .10$ or $I^2 > 50\%$ were defined as significant heterogeneity. Pooled estimates were generated by using a fixed-effects model (Mantel-Haenszel method)^[31] or random-effect model (DerSimonian-Laird method),^[32] depending on the heterogeneity among the included studies. When heterogeneity was identified, we conducted sensitivity analysis by omitting one study at each turn to explore the influence of each individual study on the overall risk estimate. We also performed subgroup analysis based on the comparators and duration of following-up to explore the

sources of heterogeneity and the impacts of these variables on the overall estimates. Publication bias was assessed by the Begg^[33] and Egger test.^[34] A 2-tailed P value $<.05$ was considered statistically significant except where a certain P -value had been specified.

2.6. Ethic statement

This is meta-analysis, so ethic approval is not required.

3. Results

3.1. Study selection

We initially retrieved 2,374 relevant publications. Of these, 1,517 records were excluded because of the duplicate records, and 834 were excluded after a review of the title/abstract (Fig. 1). Then 23 potential studies were identified for full-information review. Among them, 9 were excluded because of the following reasons: 3 were a sing-arm study design,^[35–37] 2 were unrelated with our topics,^[38,39]

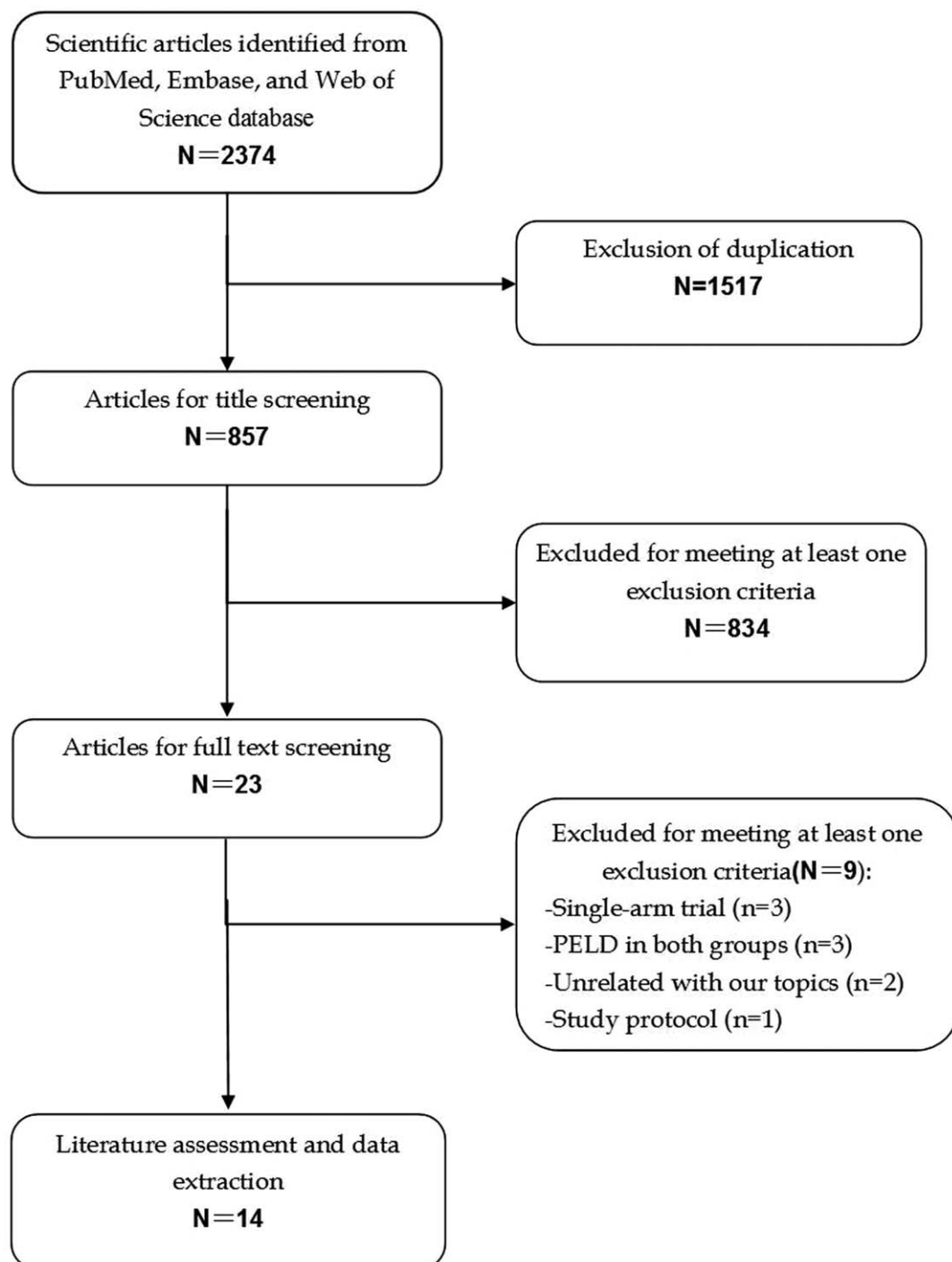


Figure 1. Eligibility of studies for inclusion in meta-analysis.

Table 1
Baseline characteristics of patients in the trials included in the meta-analysis.

Study	Country	Treatment regimen	No. of patients	Male/female	Age (mean \pm SD, yr)	NOS score
Kim MJ ^[44]	Korea	PELD	295	188/107	34.9 (13–83)	6
		OLM	607	392/215	44.4 (17–80)	
Yao Y ^[45]	China	PELD	28	18/10	53.68 \pm 17.7	5
		MIS-TLIF	26	13/13	51.62 \pm 10.04	
		MED	20	11/9	51.05 \pm 16.38	
Lee SH ^[46]	Korea	PELD	30	22/8	39.3 (22–67)	5
		OLM	30	22/8	39.6 (20–64)	
Ahn SS ^[47]	Korea	PELD	32	32/0	22.41 \pm 1.68	6
		OLM	34	34/0	22.18 \pm 1.51	
Rutten S ^[48]	Germany	PELD	45	NR	39 (23–59)	NA
		Microsurgical discectomy	42	NR	39 (23–59)	
Rutten S ^[49]	Germany	PELD	91	NR	43 (20–68)	NA
		Microsurgical discectomy	87	NR	43 (20–68)	
Lee DY ^[50]	Korea	PELD	25	16/9	42 \pm 11.4	5
		OLM	29	22/7	47.7 \pm 12.2	
Mayer MH ^[51]	Germany	PELD	20	12/8	39.8 \pm 10.4	NA
		Microsurgical discectomy	20	14/6	42.7 \pm 10	
Liu C ^[52]	China	PELD	209	110/99	57.2	8
		MIS-TLIF	192	92/100	55.9	
Pan ZM ^[53]	China	PELD	48	26/22	39.5 (22–58)	6
		Fenestration discectomy	58	31/27	42.8 (27–61)	
Yao Y ^[54]	China	PELD	47	34/13	47.91 \pm 14.77	6
		MIS-TLIF	58	42/16	46.76 \pm 12.37	
Chen ZH ^[55]	China	PELD	80	52/28	40.2 \pm 11.4	NA
		MED	73	37/36	40.7 \pm 11.1	
Chang F ^[56]	China	PELD	60	40/20	52.54 \pm 4.12	7
		Open discectomy	50	30/20	36.7 \pm 4.28	
Liu XY ^[57]	China	PELD	60	31/29	36.2 \pm 5.9	7
		Microdiscectomy	69	36/33	34.0 \pm 3.8	
		MED	63	32/31	33.1 \pm 6.7	

MED = microendoscopic discectomy, MIS-TLIF = minimally invasive transforaminal lumbar interbody fusion, NA = not available, NOS = Newcastle-Ottawa, NR = not reported, PELD = percutaneous endoscopic lumbar discectomy, SD = standard deviation.

1 was a study protocol,^[40] and 3 used PELD in both groups.^[41–43] Finally, 14 studies (involving 2,528 patients)^[44–57] met the inclusion criteria, and they were included in this meta-analysis.

3.2. Characteristics of eligible studies

The main characteristics of all eligible RCTs are presented in Table 1. These studies were published between 1993 and 2018. The number of participants per study ranged from 40 to 401. Ten of the included trials in the present study were of cohort design,^[44–47,50,52–54,56,57] and 4 were RCT design.^[48,49,51,55] Among the included studies, four compared PELD with OLM,^[44,46,47,50] three compared PELD with MIS-TLIF,^[45,52,54] three compared PELD with MED,^[45,55,57] three compared PELD with microsurgical discectomy,^[48,49,51] one compared PELD with open discectomy,^[56] and one compared PELD with fenestration discectomy.^[53] Most of the included studies enrolled adult patients with a mean age between 33.1 and 57.2 years, whereas in the study of Ahn SS, et al,^[47] they enrolled young adults with an age between 20–25 years.

Yao Y, et al.^[45] performed a retrospective cohort study, in which three minimally invasive spine surgery approaches (PELD, MIS-TLIF, and MED) were used to treat patients with PELD recurrence.^[45] In that study, the outcome data between each approach were presented, thus, we extracted all these data for estimate pooling. Similarly, in the study conducted by Liu XY, et al.,^[57] they compared the clinical outcomes of PELD, MED,

and microdiscectomy for symptomatic LDH. We also extracted the data for the data analysis.

The median Jada score of the cohort studies was 6 (range from 5 to 8), indicating that these studies were of high quality. The four RCTs were considered as being at high risk of bias because the method for blinding was difficult to perform for the patients and the personnel of outcome assessment.

3.3. Success rate

Seven studies reported the data of success rate.^[44,46–49,51,52] The success rates in the PELD and other surgical intervention groups were 90.1% and 88.0%, respectively. The pooled results indicated that PELD was associated with a comparable success rate with other surgical interventions (RR = 1.01, 95%CI: 0.97, 1.04; $P = .733$) (Fig. 2). The test for heterogeneity was a little significant ($P = .042$, $I^2 = 54.0\%$)

We conducted subgroup analysis based on comparators. The aggregated result showed that PELD had a significantly higher success rate than microsurgical discectomy (RR = 1.11, 95%CI: 1.03, 1.19; $P = .003$), but a similar success rate with OLM (RR = 0.99, 95%CI: 0.94, 1.05; $P = .838$) and MIS-TLIF (RR = 0.96, 95%CI: 0.91, 1.01; $P = .114$) (Fig. 2).

3.4. Recurrence rate

Eight studies reported the data of recurrence rate.^[44,45,47–50,54,56] The recurrence rates in the PELD and other surgical intervention

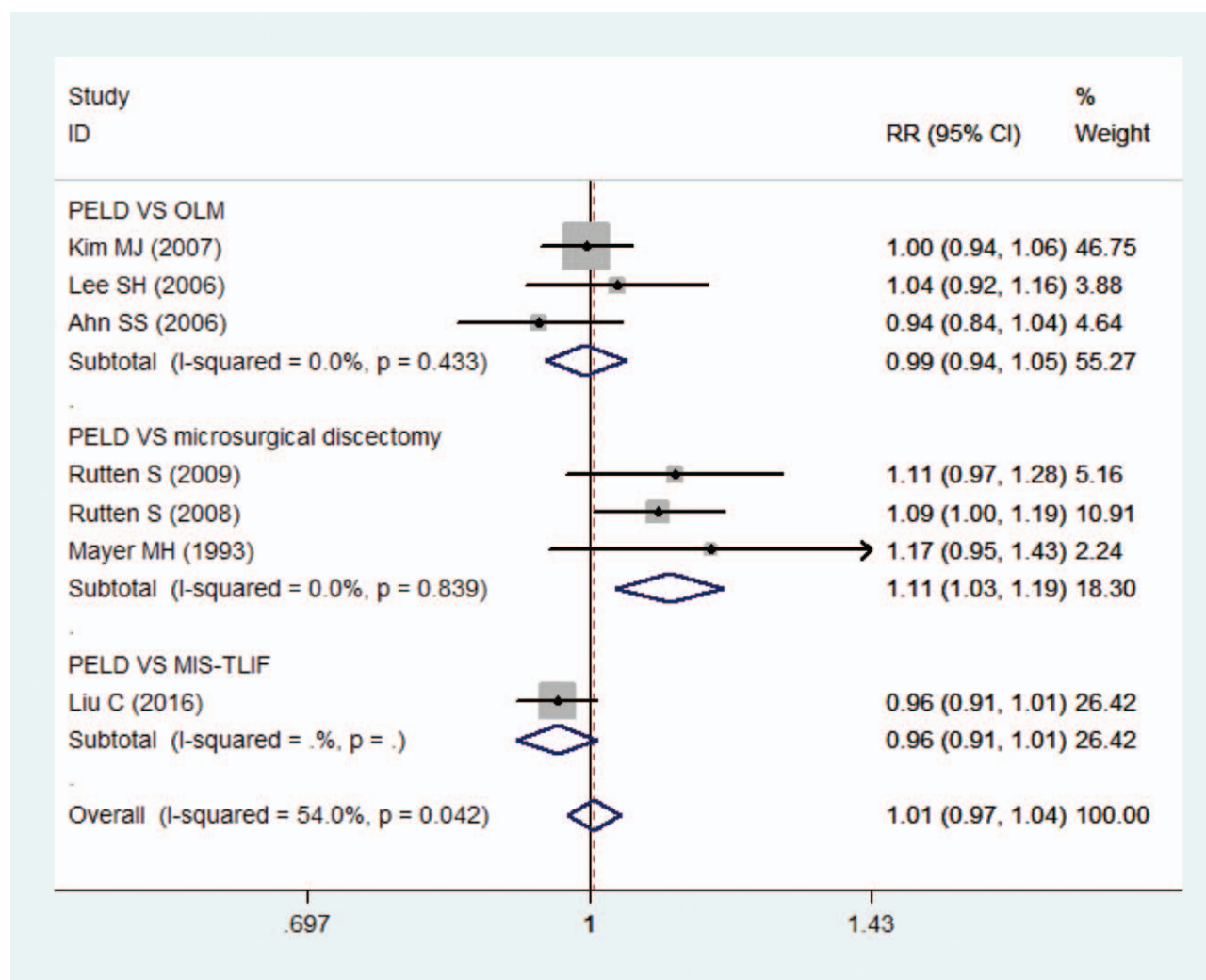


Figure 2. Forest plot showing the comparison between PELD and other surgeries in success rate. PELD=percutaneous endoscopic lumbar discectomy.

groups were 7.57% and 4.38%, respectively. The aggregated results of these studies suggested that PELD was associated with a significantly higher recurrence rate than other surgical interventions (RR=1.65, 95%CI: 1.08, 2.52; $P=.021$) (Fig. 3). The test for heterogeneity was not significant ($P=.22$, $I^2=26.1\%$).

Subgroup analysis based on the comparators showed that PELD had a significantly higher recurrence rate than MIS-TLIF (RR=14.86, 95%CI: 1.99, 111.05; $P=.009$), but a similar recurrence rate with OLM (RR=1.01, 95%CI: 0.56, 1.82; $P=.975$), MED (RR=3.27, 95%CI: 0.96, 11.12; $P=.058$), and microsurgical discectomy (RR=1.22, 95%CI: 0.47, 3.18; $P=.684$) (Fig. 3).

3.5. Complication rate

Ten studies reported the data of complications.^[44,45,47–50,52–55] The complication rates in the PELD and other surgical intervention groups were 6.79% and 6.36%, respectively. The aggregated results of these studies suggested that patients who underwent the PELD had a comparable complication rate with other surgical interventions (RR=0.86, 95%CI: 0.63, 1.18;

$P=.361$) (Fig. 4). The test for heterogeneity was significant ($P=0.024$, $I^2=51.5\%$).

Subgroup analysis based on the comparators showed that patients treated with PELD had a significantly lower complication rate than those treated with microsurgical discectomy (RR=0.29, 95%CI: 0.11, 0.77, $P=.013$), but a similar complication rate than those treated with OLM (RR=1.31, 95%CI: 0.67, 2.58, $P=.399$), MIS-TLIF (RR=1.56, 95%CI: 0.88, 2.78; $P=.130$), MED (RR=0.71, 95%CI: 0.36, 1.38, $P=.707$), and fenestration discectomy (RR=0.30, 95%CI: 0.09, 1.01, $P=.052$) (Fig. 4).

3.6. Operation time

Eleven studies reported the data of operation time.^[44,45,47–51,53,54,56,57] The average operation time in the PELD and other surgical intervention groups were 51.80 and 76.17 minutes, respectively. Pooled estimate suggested that patients who were treated with PELD had 18.14 minutes less of operation time than those treated with other surgeries (WMD=−18.14 minutes, 95%CI: −25.24, −11.05; $P<.001$) (Fig. 5). There was a moderate degree of heterogeneity ($P=.010$, $I^2=54.3\%$).

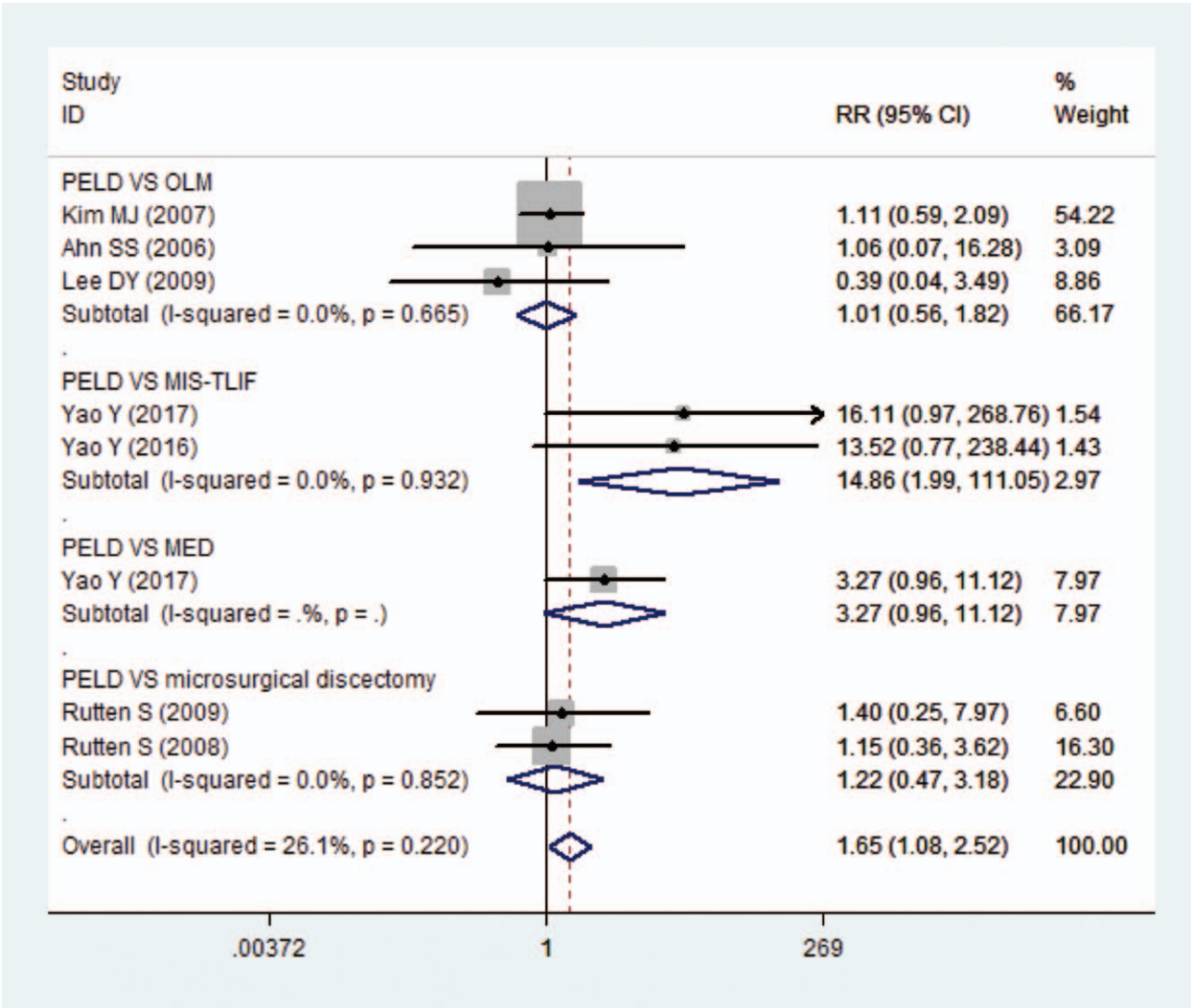


Figure 3. Forest plot showing the comparison between PELD and other surgeries in recurrence rate. PELD=percutaneous endoscopic lumbar discectomy.

Subgroup analysis based on the comparators showed that PELD was associated with a lower operation time than OLM (WMD=−11.66 minutes, 95%CI: −16.70, −6.62; $P<.001$), MIS-TLIF (WMD=−75.23 minutes, 95%CI: −106.06, −44.40; $P<.001$), microsurgical discectomy (WMD=−23.21 minutes, 95%CI: −30.99, −15.43; $P<.001$), and microdiscectomy (WMD=−17.00 minutes, 95%CI: −31.53, −2.47; $P=.022$), but a similar operation time with MED (WMD=−13.55 minutes, 95%CI: −27.11, 0.01; $P=.05$), fenestration discectomy (WMD=−7.20 minutes, 95%CI: −26.29, 11.89; $P=.460$), and open discectomy (WMD=−2.92 minutes, 95%CI: −25.12, 19.28; $P=.797$) (Fig. 5).

3.7. Hospital stay

Six studies reported the data of hospital stay.^[45,47,50,53,54,57] The average time of hospital stay in the PELD and other surgical intervention groups were 5.68 and 9.34 days, respectively. Pooled result showed that patients who underwent PELD had 2.59 days less of hospital stay as compared with those treated with other

surgeries (WMD=−2.59 days, 95%CI: −3.87, −1.31; $P<.001$). The test for heterogeneity was significant ($P=.001$, $I^2=72.1\%$). Thus, we conducted sensitivity analysis to explore the potential source of heterogeneity. When we excluded the trial with outlier,^[47] the pooled result changed slightly (WMD=−2.87 days, 95%CI: −4.18, −1.56; $P<.001$), but the heterogeneity was still present ($P<.001$, $I^2=95.3\%$). When we excluded the study with the small sample size ($N<100$),^[54] the overall estimate changed a little (WMD=−3.70 days, 95%CI: −5.25, −2.15; $P<.001$), but the evidence of heterogeneity was still found among the remaining studies ($P<.001$, $I^2=96.7\%$). When we further excluded any single study individually, the overall estimate and heterogeneity did not change substantially.

Subgroup analysis based on comparators showed that, PELD significantly reduced the length of hospital stay as compared with other surgeries (MIS-TLIF, WMD=−4.98 days, 95%CI: −7.91, −2.05, $P=.001$; MED, WMD=−0.96 days, 95%CI: −1.73, −0.19, $P=.014$; fenestration discectomy, WMD=−5.60 days, 95%CI: −8.93, −2.27, $P=.001$; microdiscectomy, WMD=−1.00 days, WMD=−1.75, −0.25, $P=.009$) except OLM, which

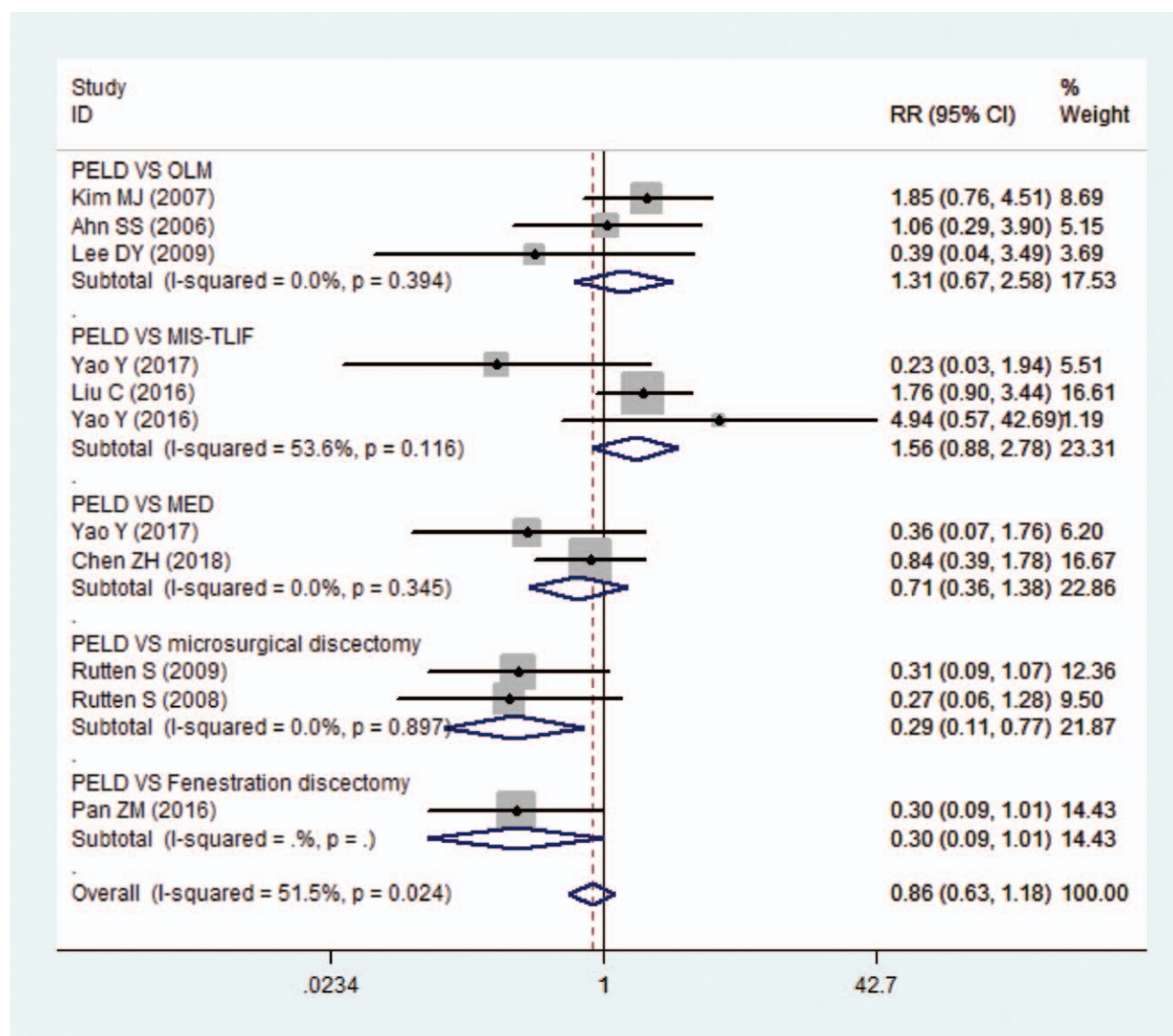


Figure 4. Forest plot showing the comparison between PELD and other surgeries in complication rate. PELD=percutaneous endoscopic lumbar discectomy.

had a similar hospital stay with PELD (WMD = -4.87 days, 95% CI: -9.85, 0.11; $P = .055$).

3.8. Blood loss

Three studies reported the data of blood loss.^[53,56,57] The average blood loss in the PELD and other surgical intervention groups were 12.25 mL and 47.16 mL, respectively. Pooled estimate showed that, patients who underwent PELD had 30.14 mL less of blood loss as compared with those treated with other surgeries (WMD = -30.14 mL, 95% CI: -43.16, -17.13; $P < .001$). There was significant heterogeneity among the included studies. Thus, we performed sensitivity analysis. Exclusion of the trial with outlier^[53] yielded similar result (WMD = -34.26 mL, 95% CI: -48.82, -19.69; $P < .001$), but the heterogeneity was still present ($P = .001$, $I^2 = 84.9\%$). When we excluded the remaining studies individually, the overall estimate and heterogeneity did not alter substantially.

Subgroup analysis based on comparators suggested that, PELD had a significantly less blood loss than other surgeries, and this benefit effect was observed across all the subgroups (fenestration discectomy, WMD = -73.40 mL, 95% CI: -95.86, -50.94, $P < .001$; open discectomy, WMD = -27.21 mL, 95% CI: -41.93, -12.49, $P < .001$; MED, WMD = -18.00 mL, 95% CI: -23.73, -12.27, $P < .001$; microdiscectomy, WMD = -27.18 mL, 95% CI: -27.18, -14.82, $P < .001$).

3.9. Postoperation JOA score

Three studies reported the data of JOA score.^[52,53,57] The average JOA score in the PELD and other surgical intervention groups were 22.68 and 22.66, respectively. Pooled estimate showed that PELD had a similar JOA score than other surgeries (WMD = 0.19, 95% CI: -1.90, 2.27; $P = .861$). The test for heterogeneity was not significant ($P = .982$, $I^2 = 0.0\%$).

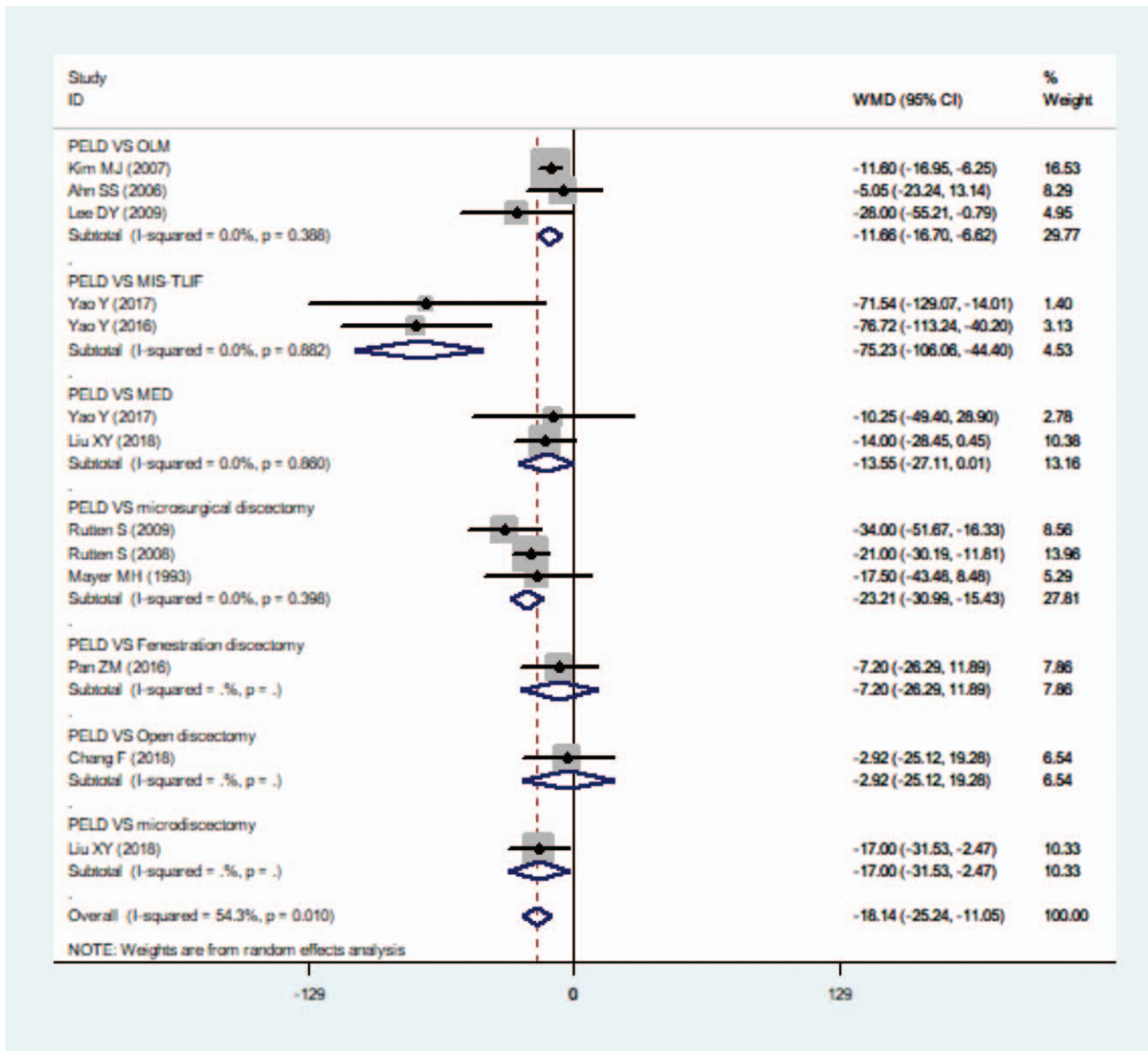


Figure 5. Forest plot showing the comparison between PELD and other surgeries in operation time. PELD=percutaneous endoscopic lumbar discectomy.

Subgroup analysis based on comparators suggested that PELD was associated with a similar postoperation JOA score with other surgeries, and this was observed across all the subgroup analysis (MIS-TLIF, WMD = -0.40, 95%CI: -4.15, 3.35, $P = .834$; fenestration discectomy, WMD = 0.85, 95%CI: -2.30, 4.00, $P = .595$; MED, WMD = -0.20, 95%CI: -6.16, 5.76, $P = .948$; microdiscectomy, WMD = -0.30, 95%CI: -6.02, 5.42, $P = .918$).

3.10. Postoperation VAS score for back pain

Eight studies reported the data of postoperation VAS score for back pain.^[45,47,50,52,54-57] The average VAS score for back pain in the PELD and other surgical intervention groups were 2.46 and 2.71, respectively. Pooled estimate suggested that patients treated with PELD had a similar postoperation VAS score for back pain with those treated with other surgeries (WMD = -0.17, 95%CI:

-0.55, 0.21; $P = .384$). The test for heterogeneity was significant ($P < .001$, $I^2 = 88.3\%$). When we excluded two trials that reported a higher VAS score for back pain in the PELD group,^[50,52] the overall estimate changed substantially (WMD = -0.38, 95%CI: -0.61, -0.16; $P = .001$), but the heterogeneity was still present ($P = .85$, $I^2 = 0.0\%$).

Subgroup analysis based on comparators showed that PELD had a significantly lower VAS score for back pain than open discectomy (WMD = -2.61, 95%CI: -4.0, -1.22; $P < .001$) and microdiscectomy (WMD = -0.50, 95%CI: -0.87, -0.13; $P = .009$), but a similar VAS score with MIS-TLIF (WMD = -0.01, 95%CI: -0.72, 0.70; $P = .974$), MED (WMD = -0.07, 95%CI: -0.32, 0.18; $P = .562$), and OLM (WMD = 0.06, 95%CI: -1.31, 1.42; $P = .936$).

Subgroup analysis based on the duration of following-up showed that patients treated with PELD had a comparable VAS score for back pain with those treated with other surgeries at any

time of the following-up (1 month, WMD = -0.071, 95%CI: -1.201, 1.06, $P = .902$; 3 months, WMD = -0.209, 95%CI: -0.442, 0.025, $P = .080$; 6 months, WMD = -0.337, 95%CI: -0.764, 0.091, $P = .123$; 9 months, WMD = -0.331, 95%CI: -0.985, 0.323, $P = .322$; 12 months, WMD = -0.246, 95%CI: -0.698, 0.207, $P = .287$).

3.11. Postoperation VAS score for leg pain

Seven studies reported the data of postoperative VAS score for leg pain.^[45,47,50,52,54,55,57] The average VAS score for leg pain in the PELD and other surgical intervention groups were 2.99 and 3.03, respectively. The aggregated result showed that patients treated with PELD had a similar VAS score for leg pain with other surgeries (WMD = 0.00, 95%CI: -0.10, 0.10; $P = .991$). The test for heterogeneity was not significant ($P = .996$, $I^2 = 0.0\%$).

Subgroup analysis based on comparators suggested that PELD was associated with a comparable VAS score for leg pain than other surgeries, and this was observed across all the subgroups analysis (MIS-TLIF, WMD = -0.04, 95%CI: -0.19, 0.10, $P = .567$; MED, WMD = 0.08, WMD = -0.06, 0.23, $P = .264$; OLM, WMD = -0.14, 95%CI: -0.69, 0.42, $P = .623$; microdiscectomy, WMD = -0.20, 95%CI: -0.55, 0.15, $P = .268$).

Subgroup analysis based on the duration of following-up showed that patients treated with PELD had a comparable VAS score for leg pain with those treated with other surgeries at any time of the following-up (1 month, WMD = -0.20, 95%CI: -0.23, 0.22, $P = .877$; 3 months, WMD = -0.004, 95%CI: -0.23, 0.22, $P = .971$; 6 months, WMD = -0.069, 95%CI: -0.34, 0.89, $P = .392$; 9 months, WMD = 0.135, 95%CI: -0.104, 0.374, $P = .269$; 12 months, WMD = -0.012, 95%CI: -0.193, 0.169, $P = .895$).

3.12. Postoperation ODI score

Nine studies reported the data of postoperation ODI score.^[45,47,50,52-57] The average ODI score in the PELD and other surgical intervention groups were 18.68 and 19.43, respectively. Pooled result showed that patients who underwent PELD had a similar ODI score with other surgeries (WMD = -0.29, 95%CI: -1.00, 0.43; $P = .434$). The test for heterogeneity was not significant ($P = .996$, $I^2 = 0.0\%$).

Subgroup analysis based on comparators suggested that PELD was associated with a comparable ODI score with other surgical interventions, and this was observed across all the subgroups except open discectomy, which showed a lower ODI score than PELD (MIS-TLIF, WMD = -0.53, 95%CI: -1.56, 0.50, $P = .315$; MED, WMD = 0.65, 95%CI: -0.54, 1.84, $P = 0.285$; OLM, WMD = -1.32, 95%CI: -4.19, 1.54, $P = .300$; fenestration discectomy, WMD = -1.34, 95%CI: -3.89, 1.20, $P = .365$; open discectomy, WMD = -10.81, 95%CI: -19.25, -2.37, $P = .012$; microdiscectomy, WMD = 1.00, 95%CI: -15.79, 17.79, $P = .907$).

Subgroup analysis based on the duration of following-up showed that patients treated with PELD had a significantly lower ODI score than those with other surgeries at 1 month (WMD = -1.37, 95%CI: -2.72, -0.017; $P = .047$), but a comparable ODI score at 3 months (WMD = -2.49, 95%CI: -5.18, 0.19; $P = .068$), 6 months (WMD = -0.49, 95%CI: -1.05, 0.08; $P = 0.092$), 9 months (WMD = 0.27, 95%CI: -0.32, 0.86; $P = .369$), and 12 months (WMD = -0.23, 95%CI: -1.28, 0.81; $P = .662$).

3.13. SF12-MCS

Three studies reported the data of SF12-MCS score.^[45,47,54] The average SF12-MCS score in the PELD and other surgical intervention groups were 29.06 and 27.93, respectively. Pooled estimate suggested that patients treated with PELD had a significantly higher SF12-MCS score than those treated with other surgeries (WMD = 2.28, 95%CI: 0.50, 4.06; $P = 0.012$). The test for heterogeneity was not significant ($P = 0.936$, $I^2 = 0.0\%$).

Subgroup analysis based on comparators showed that the greater SF12-MCS score of PELD was only observed in the comparison with MIS-TLIF (WMD = 2.88, 95%CI: 0.67, 5.10; $P = 0.011$), but not in MED (WMD = 1.15, 95%CI: -1.95, 4.25; $P = 0.468$) and OLM (WMD = 1.64, 95%CI: -9.38, 12.66; $P = 0.771$).

Subgroup analysis based on the duration of following-up demonstrated that, patients treated with PELD had a greater SF12-MCS score than other surgeries at the 1 month (WMD = 4.69, 95%CI: 0.18, 9.55; $P < .001$) and 3 months (WMD = 1.00, 95%CI: 0.28, 4.29; $P = .019$), but a similar SF12-MCS score at the 6 months (WMD = 1.19, 95%CI: -1.34, 3.73; $P = .357$), 9 months (WMD = 0.06, 95%CI: -2.86, 0.57; $P = .549$) and 12 months (WMD = -0.32, 95%CI: -1.74, 1.10; $P = .191$).

3.14. SF12-PCS

Three studies reported the data of SF12-PCS.^[45,47,54] The average SF12-PCS score in the PELD and other surgical intervention groups were 26.61 and 25.95, respectively. The pooled estimate showed that patients who received PELD had a significantly greater SF12-PCS score than those treated with other surgeries (WMD = 1.04, 95%CI: 0.37, 1.71; $P = .02$). The test for heterogeneity was not significant ($P = .015$, $I^2 = 47.8\%$).

Subgroup analysis based on comparators suggested that, the greater SF12-PCS score of PELD was only observed in the comparison with MIS-TLIF (WMD = 2.02, 95%CI: 1.04, 3.01; $P = .002$), but not in MED (WMD = -1.51, 95%CI: -4.07, 1.05; $P = .560$) and OLM (WMD = 0.44, 95%CI: -0.54, 1.42; $P = .934$).

Subgroup analysis based on the duration of following-up showed that, patients treated with PELD had a greater SF12-PCS score than other surgeries at the 1 month (WMD = 3.88, 95%CI: 1.98, 5.78; $P < .001$) and 3 months (WMD = 2.44, 95%CI: 0.46, 4.42; $P = .016$), but a similar SF12-PCS score at the 6 months (WMD = 1.16, 95%CI: -0.17, 2.49; $P = .088$), 9 months (WMD = 0.06, 95%CI: -1.83, 1.96; $P = 0.948$) and 12 months (WMD = -0.08, 95%CI: -1.17, 1.01; $P = 0.888$).

3.15. Publication bias

Publication bias was assessed by using Egger and Begg test. And the results showed that, there was no evidence of significant publication bias among the included studies (Egger test: $t = -0.51$, $P = .463$; Begg test: $Z = 0.47$, $P = .329$).

4. Discussion

The present meta-analysis of 14 trials involving 2,528 patients provided evidence that PELD had favorable clinical outcomes for LDF, including shorter operation time and hospital stay, less blood loss, and improved SF12-MCS and SF12-PCS score.

However, it also was associated with a significantly higher rate of recurrent disc herniation.

In the present study, we found that patients who underwent PELD had a significantly higher recurrence rate than those treated with other surgical interventions. However, in the subgroup analysis based on the comparators, the higher rate of recurrent disc herniation was only observed in the comparison with MIS-TLIF. Yao Y, et al.^[45] performed a retrospective cohort study to compare the outcomes of three minimally invasive spine surgeries (MIS-TLIF, MED, and PELD) in the treatment of recurrent herniation. At the follow-up duration of 12 months, no patients (0.0%) in the MIS-TLIF group, 3 patients (15.0%) in the MED group, and 7 patients (25.0%) in the PELD group developed recurrence.^[45] The recurrence rate in the PELD group was significantly higher than that in the MIS-TLIF group. Similarly, in their another recently published trial,^[54] they also reported a higher recurrence rate of PELD than MIS-TLIF. In that study, the authors enrolled 105 patients who underwent either PELD ($n=47$) or MIS-TLIF ($n=58$) for revision of MED recurrence.^[54] At the 12-month follow-up, patients who underwent PELD had a significantly higher recurrence rate (10.64%) than those treated with MIS-TLIF (0.0%).^[54] The authors attributed the findings to the following reasons: (1) there was some risk factors that were predictive of recurrence in PELD patients. For example, old age, obesity, and Modic change have been identified as significant risk factors for the PELD recurrence.^[58,59] And the 5 patients who experienced recurrence in the PELD group were all relatively old (≥ 60 years old) and obese; thus, they were at high risk of recurrent herniation.^[54] (2) 3 of the 5 patients had herniated fragment that were highly migrated, and this made the surgery more difficult.^[60] The residual fragment would result in unsuccessful surgical outcomes.^[58,61] (3) After the primary MED surgery, the artificial cracks in annulus fibrosus would change the laminate structure, and make the annulus be more easily to delamination.^[54] Based on the damage in annulus fibrosus, the recurrent herniation easily occurred.^[62] Therefore, it is unable for PELD to solve this problem thoroughly, and a through interbody fusion (MIS-TLIF) might be a better choice.^[54]

The success rate in the PELD group and other surgical intervention group were 7.2% and 4.1%, respectively. Although patients treated with PELD achieved a significantly higher success rate than those with other surgeries, the difference between them was not significant. Lee SH, et al.^[46] performed a matched cohort study evaluation of 60 consecutive patients with LDH. Of them, 30 patients were underwent PELD, and 30 were treated with OLM.^[46] At the follow-up duration of 36 months, 96.7% of patients in the PELD group and 93.3% of patients in the OLM group achieved good or excellent results.^[46] For microsurgical discectomy, our result also showed a similar success rate with PELD. Rutten S, et al.^[48] performed a prospective randomized study to compare the clinical outcomes of PELD with microsurgical technique. In that study, 95% of patients with PELD reported subjective satisfaction as compared with 86% of patients with microsurgical technique. However, the difference between them was not significant. In contrast to the lower success rates of OLM and microsurgical discectomy, MIS-TLIF seemed to have a higher success rate than PELD. Liu C, et al.^[52] reported a prospective cohort study of 401 patients with recurrent LDH who were treated with PELD ($n=209$) or MIS-TLIF ($n=192$). At the mean duration follow-up of 46.5 months, the success rate in the two groups was 91.3% and 95.2%, respectively.^[52] MIS-TLIF resulted in a higher success rate than PELD, however, there was no significant difference between them.

Regarding the operation time, the present study demonstrated that patients treated with PELD had 18.14 minutes less of operation time than those with other surgical interventions. However, the reduced operation time of PELD was only observed in the comparison with OLM, MIS-TLIF, microsurgical discectomy and microdiscectomy. Compared with these surgical approaches, PELD had 11.66 minutes, 75.23 minutes, 23.21 minutes, and 17 minutes less of operation time, respectively. Kim MJ, et al.^[44] compared the clinical outcomes of PELD with OLM, and they found the operation time in these two groups was 53.0 ± 13.0 minutes and 64.6 ± 28.7 minutes, respectively ($P < 0.001$). Yao Y, et al.^[45] assessed the three minimally invasive spine surgical approaches (PELD, MIS-TLIF, and MED) for recurrent herniation, and the mean operation time between them was 75.0 ± 31.56 minutes, 146.54 ± 38.07 minutes, and 85.25 ± 41.60 minutes, respectively. PELD had a significantly less operation time than MIS-TLIF, but a comparable operation time with MED.

The functional outcomes were assessed by the VAS scores for back pain and leg pain. Our results suggested that patients treated with PELD had comparable postoperation VAS scores for back pain and leg pain with those treated with other surgeries. Our result was in consistent with the previous findings.^[50,52,54] Yao Y, et al.^[54] reported that the preoperative VAS scores for back pain and leg pain were 5.88 ± 1.24 and 7.05 ± 1.08 in the MIS-TLIF group, 5.92 ± 1.33 and 7.13 ± 1.09 respectively in the PELD group ($P = .888$).^[54] At the follow-up duration of 12 months, the VAS scores significantly reduced in the two groups as compared with preoperative values. However, there was no significant differences between the them in the postoperation VAS scores for back pain and leg pain.^[54] The authors attributed the results to the relatively larger injury of soft tissue and disruption of spinal stability, which were caused by the interbody fusion than discectomy.^[54]

There were several potential limitations in this meta-analysis. First, for some outcomes, the data analysis was based on relatively small number of included studies and sample size; thus, the conclusions about the outcomes should be interpreted with caution. Second, most of the included studies were retrospective cohort study, and the grade evidence was inferior to that of RCTs. Third, despite we performed sensitivity analysis and subgroup analysis to explore the derivation of heterogeneity, no valuable information was found. We thought that some potential reasons may account for the great heterogeneity, including patients' characteristics (age, sex, BMI, type of disc herniation, and surgical segment), duration of follow-up, case definition, and surgical approaches. These factors may have an impact on our results. thus, considering these limitations, caution is advised when interpreting our findings and applying them into the clinical practice.

In conclusion, the present meta-analysis of 14 studies suggested that, PELD was associated with better effects and similar complications with other surgeries in the treatment of LDH. However, it also resulted in a higher recurrence rate. Considering the potential limitations in the present study, further large-scale, well-performed randomized trials are needed to verify our findings.

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