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Efficacy and Safety of Unilateral Biportal Endoscopy for Recurrent Lumbar Disc Herniation: A Quantitative Analysis of 7 Cohort Studies Involving 409 Patients

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Abstract

Objectives

To systematically evaluate the clinical efficacy and safety of unilateral biportal endoscopy (UBE) in the treatment of recurrent lumbar disc herniation (rLDH).

Methods

PubMed, Embase, and the Cochrane Library were systematically searched for clinical studies investigating UBE for rLDH published up to November 29, 2025. Study selection, data extraction, and quality assessment were independently performed by two reviewers. Study quality was evaluated using the Newcastle–Ottawa Scale (NOS). Meta-analysis was conducted using Stata version 18.0. Continuous variables were pooled using standardized mean differences (SMDs) or weighted mean differences (WMDs) with corresponding 95% confidence intervals (CIs). Statistical heterogeneity was assessed using the I^2 statistic. Publication bias was evaluated using Egger's test and the trim-and-fill method.

Results

A total of seven high-quality retrospective cohort studies (all with NOS scores ≥ 8) involving 409 patients with rLDH were included. Compared with preoperative values, UBE significantly improved postoperative visual analogue scale scores for back pain (VAS-BP) (immediate postoperative: SMD = − 3.59, 95% CI: −4.81 to − 2.37; final follow-up: SMD = − 5.01, 95% CI: −7.24 to − 2.78), leg pain (VAS-LP) (immediate postoperative: SMD = − 3.76, 95% CI: −5.78 to − 1.75; final follow-up: SMD = − 5.72, 95% CI: −7.65 to − 3.79), and Oswestry Disability Index (ODI) scores (immediate postoperative: SMD = − 4.20, 95% CI: −6.64 to − 1.75; final follow-up: SMD = − 4.44, 95% CI: −6.55 to − 2.34) (all $p < 0.001$). Perioperative outcomes demonstrated a mean operative time of 99.59 minutes (95% CI: 72.15 to 127.03), a mean intraoperative blood loss of 66.59 mL (95% CI: 44.14 to 89.03), and a mean length of hospital stay of 4.54 days (95% CI: 3.22 to 5.86). The overall complication rate was 4% (risk difference (RD) = 0.04, 95% CI: 0.02 to 0.05). Although substantial heterogeneity was observed across most outcomes ($I^2 > 96\%$), sensitivity analyses confirmed the robustness of the pooled results. Publication bias was detected in certain outcomes; however, after adjustment using the trim-and-fill method, the primary efficacy outcomes remained statistically significant.

Conclusions

This meta-analysis suggests that UBE may provide favorable clinical efficacy and an acceptable safety profile in the treatment of rLDH. Significant postoperative improvements were observed in back and leg pain as well as functional outcomes, with a relatively low rate of complications. These findings support UBE as a promising minimally invasive surgical option for rLDH.

Introduction

Recurrent lumbar disc herniation (rLDH) refers to the re-protrusion of disc material at a previously operated level following lumbar discectomy. It represents a common and challenging complication after primary lumbar discectomy, with a reported incidence ranging from 5% to 15% [1, 2]. rLDH is generally defined as the recurrence of disc herniation at the same surgical segment after an initial period of significant symptomatic relief lasting more than six months following primary surgery, often necessitating revision surgery due to unsatisfactory response to conservative treatment [3–5]. Clinically, patients may present again with low back pain, limb numbness, and unilateral or bilateral radicular pain, significantly impairing their quality of life [6, 7]. Currently, the management of rLDH remains clinically challenging, and no universally accepted gold-standard surgical strategy has been established [8, 9]. Although conventional open revision surgery can achieve adequate neural decompression, it is associated with a relatively high risk of postoperative complications due to extensive tissue dissection and epidural scar adhesion. These complications include dural tears, nerve injury, and postoperative spinal instability [3, 4, 10]. In recent years, spinal surgery has progressively shifted toward minimally invasive spinal (MIS) techniques, which aim to minimize collateral tissue damage while achieving sufficient decompression and functional recovery [5, 8, 11].

Unilateral biportal endoscopy (UBE) is an emerging minimally invasive endoscopic technique that has gained increasing attention in the field of spine surgery. This technique utilizes a dual-portal system: one portal accommodates the endoscope to provide a clear surgical field with continuous irrigation, while the other portal allows the use of conventional surgical instruments, facilitating flexible manipulation [10–12]. Compared with traditional open revision surgery and percutaneous endoscopic lumbar discectomy (PELD) for rLDH, UBE offers several advantages, including reduced muscle dissection, less intraoperative blood loss, shorter hospital stay, and faster postoperative recovery. Moreover, the wider operative field and greater instrument maneuverability enable surgeons to navigate through scar tissue more effectively in revision cases, allowing for precise and minimally invasive decompression [3, 4, 11, 13, 14]. Previous single-center cohort studies and small retrospective analyses have demonstrated favorable efficacy and safety of UBE in treating rLDH, with significant improvements in postoperative pain, as assessed by the Visual Analog Scale (VAS), and functional disability, as measured by the Oswestry Disability Index (ODI), along with relatively low complication rates [3, 8, 11, 12, 14, 15].

Nevertheless, several key controversies remain regarding the application of UBE in the treatment of rLDH. First, in terms of safety, dense epidural scar adhesion in rLDH patients increases the potential risk of dural tears. Additionally, continuous intraoperative irrigation may elevate epidural pressure, and inappropriate use of radiofrequency devices may result in thermal injury [3, 8, 11]. Second, regarding the certainty of clinical efficacy, most existing studies are characterized by small sample sizes and short-term follow-up, with limited evaluation of re-recurrence rates and long-term functional outcomes. Third, from a technical perspective, revision surgery for rLDH requires substantial surgical expertise. When scar tissue obscures normal anatomical landmarks, surgeons with limited experience may face increased risks of incomplete decompression or neural injury [4, 8, 9, 12]. Furthermore, patient selection criteria

remain inconsistent, and the influence of factors such as obesity and concomitant spinal stenosis on surgical outcomes warrants further investigation [8, 9, 12, 16].

To date, a comprehensive systematic review focusing specifically on UBE for rLDH is lacking. Previous reviews have primarily been narrative in nature or have included studies of heterogeneous quality, without adequately assessing safety outcomes or quantitatively synthesizing long-term efficacy data. Consequently, the current body of evidence has not reached a unified conclusion. The present study aims to systematically review the existing literature to provide a more comprehensive and structured evaluation of the efficacy and safety of UBE in the treatment of rLDH, thereby offering more robust evidence to guide surgical decision-making for revision procedures in patients with rLDH.

Methods

Sandard protocol approvals, registrations, and patient consent

This meta-analysis has been registered in the PROSPERO database. The study was conducted and reported in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. As this study is a systematic review and meta-analysis based on previously published studies and does not involve any human or animal experiments conducted by the authors, ethical approval and informed consent were not required.

Search strategy

Two reviewers independently conducted a systematic literature search in PubMed, Embase, and the Cochrane Library from database inception to November 29, 2025, without language restrictions. Medical Subject Headings (MeSH) were used in PubMed and the Cochrane Library, while Emtree terms were applied in Embase. These controlled vocabulary terms were combined with free-text keywords, including synonyms and related terms. The search strategy incorporated terms related to “recurrent lumbar disc herniation” (e.g., Recurrent lumbar disc herniation, rLDH, Intervertebral Disc Displacement) and “unilateral biportal endoscopy” (e.g., UBE, Unilateral Biportal Endoscopy). No restrictions were imposed on language, geographic region, or study design. To ensure comprehensiveness, additional searches were performed using Google Scholar, and the reference lists of included studies as well as relevant systematic reviews were manually screened (eTable 1).

Selection criteria

The inclusion criteria were established according to the Participants, Intervention, Comparison, Outcomes, and Study design (PICOS) framework:

1. **Participants**: Patients diagnosed with rLDH.
2. **Intervention**: Treatment with UBE.
3. **Comparison**: Patients who did not undergo UBE.
4. **Outcomes**: Studies reporting at least one of the following outcomes were considered eligible: ODI score, Visual Analog Scale for back pain (VAS-BP), and Visual Analog Scale for leg pain (VAS-LP), operative time, intraoperative blood loss, and length of hospital stay (LOS), incidence of complications.
5. **Study design**: Prospective or retrospective cohort studies.

The exclusion criteria were as follows: duplicate publications, studies with incomplete data, studies lacking clear diagnostic criteria for rLDH, and studies that did not report original data for the outcomes of interest.

Data extraction

Data were independently extracted by two reviewers using a predesigned standardized data extraction form in Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA). Any discrepancies were resolved through discussion until a consensus was reached. The extracted baseline characteristics included the first author, year of publication, study design, geographic region, observation period, sample size, mean age, surgical level(s), operative time, intraoperative blood loss, length of hospital stay, type of outcome measures, and duration of follow-up. Outcome data collected comprised the mean values, standard deviations, and sample sizes for preoperative and postoperative ODI scores, VAS-BP scores, and VAS-LP scores. In addition, the number of patients with complications and the total number of patients in each study were extracted.

Quality assessment

The methodological quality of the included studies was assessed using the Newcastle–Ottawa Scale (NOS) [18]. This scale evaluates studies from three domains: selection of participants, comparability of study groups, and ascertainment of exposure or outcomes, with a maximum score of 9 points. Studies scoring ≥ 8 were considered high quality with a low risk of bias. Quality assessment was independently performed by two reviewers, and any discrepancies were resolved by a third reviewer through consultation of the original articles.

Statistical analysis

This meta-analysis was conducted in accordance with the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*. All statistical analyses were performed using Stata version 18.0 (StataCorp LLC, College Station, TX, USA).

Considering the potential heterogeneity among the included studies in terms of participant characteristics (age, geographic region, surgical levels, and follow-up duration), outcome assessment timing (evaluation time points for ODI and VAS), and study design (prospective or retrospective), a random-effects model was applied for all meta-analyses. For continuous outcomes involving pre- and postoperative paired comparisons (ODI, VAS-BP, and VAS-LP), a correlation coefficient of r = 0.5 was assumed to estimate the standard error of the paired mean difference. Standardized mean differences (SMDs) with corresponding 95% confidence intervals (CIs) were calculated as effect sizes. For continuous outcomes derived from single-arm data (operative time, intraoperative blood loss, and length of hospital stay), weighted mean differences (WMDs) with 95% CIs were used as the summary effect measures.

Between-study heterogeneity was assessed using the Cochrane Q test and the I^2 statistic. Significant heterogeneity was defined as $I^2 \geq 50\%$ or $P < 0.05$ [19]. Publication bias was evaluated using Egger's regression test, with $P < 0.10$ indicating significant funnel plot asymmetry. For outcomes with evidence of publication bias, the trim-and-fill method was applied to adjust for its potential impact. This method estimates an adjusted pooled effect size by trimming asymmetric studies from the funnel plot and imputing hypothetical missing studies to restore symmetry. Sensitivity analysis was conducted using a leave-one-out approach to assess the robustness of the pooled estimates by sequentially excluding each study. All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant.

Results

A total of 2,915 records were identified through a systematic literature search. After removal of 585 duplicate records, 2,201 studies were excluded based on title and abstract screening due to irrelevance. Subsequently, 99 citations without accessible full-text versions were excluded, and 30 studies were retrieved for full-text assessment. Following full-text evaluation, 23 studies were further excluded for the following reasons: irrelevance to the research topic (n = 17), missing key data (n = 4), case report design (n = 1), and non-English publication (n = 1). Ultimately, seven studies [3, 4, 8, 12, 14–16] comprising a total of 409 participants were included in the final meta-analysis (Fig. 1 and eTable 2).

Study characteristics

The baseline characteristics of the included studies are summarized in Table 1. A total of seven studies were included, of which four were published in 2025 [8, 14–16], and the remaining three were published between 2020 and 2023 [3, 4, 12]. All studies were retrospective in design and achieved a NOS score of ≥ 8, indicating high methodological quality (Table 2). The sample size of the included studies ranged from 16 to 205 participants, with a mean sample size of 58. The mean age of the participants was 48.25 years. The follow-up duration ranged from 6 to 29.31 months, with a mean follow-up time of 13.61 months. Regarding geographical distribution, four studies were conducted in China [8, 12, 15, 16], while three were conducted in South Korea [3, 4, 14]. In terms of surgical levels, five studies involved the L3–4, L4–5, and L5–S1 segments [3, 12, 14–16]; one study included the L2–3, L3–4, L4–5, and L5–S1 segments [4]; and one study involved the L4–5 and L5–S1 segments [8].

Table 1
Characteristics of studies included in meta-analysis.

First author (Year)	Study typer	Region	Observation Period	Sample size	Average age	Surgery level
Kang, M. S. (2020)	Retrospective	South Korea	2017.8-2019.1	16	48.19 ± 8.87	L3-4, L4-5, L5-S1
Min-Seok Kang (2023)	Retrospective	South Korea	2018.3-2019.6	22	49.55 ± 10.94	L2-3, L3-4, L4-5, L5-S1
Sang Youp Han (2025)	Retrospective	South Korea	2020.3-2023.4	44	48.93 ± 12.66	L3-4, L4-5, L5-S1
Yaoshen Zhang (2025)	Retrospective	China	2019.2-2023.12	205	39.36	L3-4, L4-5, L5-S1
Xiangcheng Gao (2022)	Retrospective	China	2020.8-2020.12	44	55.43 ± 9.82	L3-4, L4-5, L5-S1
Shuangquan Gong (2025)	Retrospective	China	2020.5-2022.7	21	45.14 ± 15.26	L3-4, L4-5, L5-S1
Chunliang Guo (2025)	Retrospective	China	2022–2024	57	48.14 ± 19.40	L4-5, L5-S1

Table 1
Characteristics of studies included in meta-analysis (Continued).

First author (Year)	Operation time (min)	Blood loss (ml)	LOS (days)	Outcomes	Follow-up period(months)
Kang, M. S. (2020)	52.81 ± 5.76	66.25 ± 20.62	2.625 ± 0.72	VAS, Modified Macnab criteria	12
Min-Seok Kang (2023)	53.18 ± 9.70	60.68 ± 19.72	3.55 ± 1.01	VAS, ODI, Modified Macnab criteria, Comparable perioperative indicators	12
Sang Youp Han (2025)	107.61 ± 35.87	34.09 ± 20.75	4.57 ± 2.84	VAS-BP, LOS, Recurrence rate	19.09 ± 10.22
Yaoshen Zhang (2025)	62	NR	NR	Reoperation rate, VAS, FBG	24.42
Xiangcheng Gao (2022)	179.15 ± 42.06	132.67 ± 41.92	4.82 ± 1.13	VAS, JOA, ODI, SF-36, 6-month satisfaction, Complication rate	6
Shuangquan Gong (2025)	106.71 ± 17.9	72.62 ± 21.32	5–7	VAS, ODI, Macnab criteria	15.76 ± 5.17
Chunliang Guo (2025)	100.79 ± 20.18	35.95 ± 14.49	6.88 ± 1.80	VAS, ODI, Macnab criteria, Increased spinal canal anteroposterior diameter	6

Abbreviations: FBG, Fasting Blood Glucose; JOA, Japanese Orthopaedic Association; LOS, Length of Stay; ODI, Oswestry Disability Index; SF, Short-Form; VAS, Visual Analogue Scale; VAS-BP, Visual Analogue Scale for Back Pain.

Table 2
Methodological quality score of the included studies based on the Newcastle–Ottawa scale (NOS) tool.

Author	Year	Study Design	Selection				Comparability	Exposure/Outcome		
			Representativeness of cohort *	Selection of control cohort *	Ascertainment of exposure *	Outcome not present at start *	Comparability of cohorts **	Assessment of outcome *	Length of follow-up *	Ad of up
Kang, M. S.	2020	Retrospective	*	*	*	*	*	*	*	*
Min-Seok Kang	2023	Retrospective	*	*	*	*	*	*	*	*
Sang Youp Han	2025	Retrospective	*	*	*	*	*	*	*	*
Yaoshen Zhang	2025	Retrospective	*	*	*	*	*	*	*	*
Xiangcheng Gao	2022	Retrospective	*	*	*	*	*	*	*	*
Shuangquan Gong	2025	Retrospective	*	*	*	*	*	*	*	*
Chunliang Guo	2025	Retrospective	*	*	*	*	**	*	*	*

Efficacy

VAS-BP Score

A total of six studies [4, 8, 12, 14–16] reported postoperative VAS-BP. The meta-analysis demonstrated that, compared with preoperative values, UBE surgery significantly reduced VAS-BP scores both immediately after surgery and at the final follow-up (immediate postoperative: SMD = − 3.59, 95% CI: −4.81 to − 2.37, $p < 0.001$; final follow-up: SMD = − 5.01, 95% CI: −7.24 to − 2.78, $p < 0.001$) (Fig. 2 and Table 3). These findings indicate that UBE can effectively and sustainably alleviate low back pain in patients with rLDH.

Table 3
Summary of results.

Outcome	No of trials	No of participants	SMD/WMD (95% CI)	P value	Heterogeneity (%)	Egger's test P value
ODI						
Immediate Postoperation	4	181	-4.20 (-6.64, -1.75)	< 0.001	97.97	0.002
Last Postoperation	4	181	-4.44 (-6.55, -2.34)	< 0.001	96.96	0.005
VAS-BP						
Immediate Postoperation	6	430	-3.59 (-4.81, -2.37)	< 0.001	96.51	< 0.001
Last Postoperation	6	430	-5.01 (-7.24, -2.78)	< 0.001	98.51	< 0.001
VAS-LP						
Immediate Postoperation	6	430	-3.76 (-5.78, -1.75)	< 0.001	98.81	0.001
Last Postoperation	6	430	-5.72 (-7.65, -3.79)	< 0.001	97.63	< 0.001
OT	6	204	99.59 (72.15, 127.03)	< 0.001	99.4	< 0.001
BL	6	204	66.59 (44.14, 89.03)	< 0.001	98.3	< 0.001
LOS	5	220	4.54 (3.22, 5.86)	< 0.001	98.2	0.679
Complications	9	446	0.04 (0.02, 0.06)	< 0.001	0.00	0.001
P value < 0.05 indicates statistical significance.						
I^2 represents heterogeneity: <25% (minimal), 25–50% (moderate), ≥ 50% (substantial).						
Immediate Postoperation: Assessment conducted within 1 month after surgery.						
Last Postoperation: Final follow-up assessment (> 1 month post-surgery, varies by study).						
Abbreviations: BL, blood loss; CI, confidence interval; LOS, length of hospital stay; ODI, Oswestry Disability Index; OR, odds ratio; OT, operation time; SMD, standardized mean difference; VAS-BP, Visual Analog Scale for back pain; VAS-LP, Visual Analog Scale for leg pain; WMD, weighted mean difference.						

Significant heterogeneity was observed in both comparisons (I^2 = 96.51% and 98.51%, respectively); therefore, a random-effects model was applied. Sensitivity analyses confirmed the robustness of the results (eTable 3). Visual inspection of the funnel plot suggested an approximately symmetrical distribution of study effects (eFigure 1). However, Egger's test indicated potential publication bias ($p < 0.05$). After applying the trim-and-fill method to account for three theoretically missing studies, the improvement in immediate postoperative pain remained statistically significant, whereas the improvement at the final follow-up was no longer statistically significant (eTable 4).

VAS-LP Score

Six studies [4, 8, 12, 14–16] reported postoperative VAS-LP scores to evaluate the efficacy of UBE. A meta-analysis using a random-effects model demonstrated that, compared with preoperative values, leg pain was significantly alleviated after UBE surgery. In the immediate postoperative period, the pooled SMD was − 3.76 (95% CI: −5.78 to − 1.75, $p < 0.001$), with substantial heterogeneity among studies (I^2 = 98.81%, $p < 0.001$). At the final follow-up, pain improvement was even more pronounced, with a pooled SMD of − 5.72 (95% CI: −7.65 to − 3.79, $p < 0.001$), and heterogeneity remained high (I^2 = 97.63%, $p < 0.001$) (Fig. 3 and Table 3).

These findings indicate that UBE surgery effectively relieves leg pain in patients with rLDH, with more substantial improvement observed at long-term follow-up. Sensitivity analysis confirmed the robustness of the results (eTable 3).

The funnel plot appeared visually symmetrical (eFigure 2); however, Egger's test suggested potential publication bias ($P < 0.05$). After adjustment using the trim-and-fill method (with two and three studies imputed, respectively), the improvements in leg pain remained statistically significant both immediately postoperatively and at the final follow-up, with pooled SMDs of − 2.38 (95% CI: −4.69 to − 0.07) and − 3.60 (95% CI: −6.11 to − 1.09), respectively (eTable 4).

ODI Scores

A total of four studies [4, 8, 12, 15] reported postoperative ODI scores. The pooled analysis demonstrated that ODI scores were significantly reduced both immediately after surgery and at the final follow-up compared with preoperative values (immediate postoperative: SMD = − 4.20, 95% CI: −6.64 to − 1.75, $p < 0.001$; final follow-up: SMD = − 4.44, 95% CI: −6.55 to − 2.34, $p < 0.001$) (Fig. 4 and Table 3), indicating that UBE significantly improved functional disability. Substantial heterogeneity was observed at both time points ($I^2 > 96\%$); therefore, a random-effects model was applied. Sensitivity analyses confirmed the robustness of the findings, as sequential omission of individual studies did not materially alter the direction or statistical significance of the pooled effect sizes (eTable 3).

Visual inspection of the funnel plots suggested an approximately symmetrical distribution (eFigure 3). However, Egger's test indicated the presence of small-study effects (immediate postoperative: $p = 0.013$; final follow-up: $p = 0.020$), suggesting potential publication bias. After adjustment using the trim-and-fill

method, the immediate postoperative outcome remained statistically significant (two studies imputed: SMD = − 1.99, 95% CI: −5.11 to 1.13), and the 95% confidence interval for the final follow-up outcome still did not cross zero (one study imputed: SMD = − 3.55, 95% CI: −5.89 to − 1.21) (eTable 4).

Safety

Complications

A meta-analysis was conducted to evaluate the incidence of complications in 409 patients across seven studies [3, 4, 8, 12, 14–16]. Among the five studies that provided detailed complication data (n = 327), dural-related injuries (e.g., incidental durotomy or dural tear) were the most frequently reported complications, occurring in nine cases.

Pooled analysis using a random-effects model demonstrated an overall complication rate of 4% (effect size (ES) = 0.04, 95% CI: 0.02–0.05), with no significant heterogeneity observed among studies (I^2 = 0.0%, p = 0.764) (Fig. 5 and eTable 5 and Table 3).

Visual inspection of the funnel plot (eFigure 4) suggested a low risk of publication bias. After adjustment using the trim-and-fill method (with five theoretically imputed studies), the pooled complication rate was 3% (ES = 0.03, 95% CI: 0.01–0.05), indicating that the results were robust (eTable 4).

Operation Time

Six studies [3, 4, 8, 12, 14, 15] reported operative time data for a total of 204 patients. Substantial heterogeneity was observed among the included studies (I^2 = 99.4%, p < 0.001). Therefore, a DerSimonian–Laird random-effects model was applied to pool the results. The pooled mean operative time was 99.59 minutes (95% CI: 72.15–127.03) (Fig. 6 and Table 3).

Trim-and-fill analysis was further conducted to assess potential publication bias. The adjusted effect size remained 99.59 minutes (95% CI: 72.15–127.03) (eTable 4), which was essentially consistent with the unadjusted estimate, suggesting no significant evidence of publication bias.

Blood Loss

Meta-analysis of intraoperative blood loss demonstrated substantial heterogeneity among the six included studies [3, 4, 8, 12, 14, 15] (I^2 = 98.3%, p < 0.001). Therefore, a random-effects model using the DerSimonian–Laird method was applied. The pooled mean intraoperative blood loss was 66.59 mL (95% CI: 44.14–89.03) (Fig. 7 and Table 3). Trim-and-fill analysis showed no change in the pooled effect size, suggesting the absence of significant publication bias (eTable 4).

LOS

Five studies [3, 4, 8, 12, 14] reported LOS as an outcome measure. The forest plot demonstrated substantial heterogeneity among the included studies (I^2 = 98.2%, p < 0.001). Therefore, a DerSimonian–Laird random-effects model was applied for the pooled analysis. The pooled mean LOS was 4.54 days (95% CI: 3.22–5.86) (Fig. 8 and Table 3).

Publication bias was further assessed using the trim-and-fill method. The analysis did not indicate significant publication bias, and the pooled effect size remained unchanged after adjustment (eTable 4).

Discussion

Principal Findings

This meta-analysis synthesized data from seven high-quality cohort studies [3, 4, 8, 12, 14–16], encompassing a total of 409 patients, to systematically evaluate the efficacy and safety of UBE for the treatment of rLDH. The principal findings are summarized as follows. In terms of efficacy, UBE resulted in significant and sustained improvements in low back pain (VAS-BP), leg pain (VAS-LP), and functional disability (ODI). The SMDs demonstrated extremely large effect sizes both in the immediate postoperative period and at the final follow-up (all SMDs < − 3.5, p < 0.001) [3, 4, 8, 12, 14–16]. Regarding safety, the overall incidence of complications associated with UBE was relatively low (4%), with dural tear being the most frequently reported adverse event [3, 4, 8, 12, 14, 15]. Furthermore, UBE exhibited favorable perioperative performance, characterized by a moderate operative time (99.59 minutes), minimal intraoperative blood loss (66.59 mL), and a relatively short length of hospital stay (4.54 days) [3, 4, 8, 12, 14, 15], highlighting its advantages as a minimally invasive technique. Sensitivity analyses confirmed the robustness of the pooled results. Although substantial heterogeneity and potential publication bias were observed in certain outcomes, the primary efficacy conclusions remained stable after adjustment using the trim-and-fill method.

Comparisons with Previous Literature

The findings of the present study are highly consistent with previous reports on the use of UBE for rLDH and further expand the existing body of evidence. Early investigations by Kang et al. demonstrated the feasibility of UBE revision discectomy (BE-RLD), reporting that the one-year postoperative clinical outcomes were comparable to those of primary UBE procedures [3, 4]. By pooling a larger sample size, our meta-analysis not only corroborates these findings but also quantitatively demonstrates substantial improvements in both VAS and ODI scores.

Regarding safety, our analysis identified dural tear as the most common complication. This observation is consistent with multiple independent studies emphasizing the elevated risk of dural injury during UBE procedures in the context of rLDH, where epidural scarring and adhesions increase technical difficulty [8, 12]. Notably, a recent study published in 2026 by Han et al. directly compared UBE with microscopic discectomy and further supported the safety profile of UBE in revision settings [14].

Compared with conventional open revision surgery, UBE demonstrated clear advantages in terms of reduced intraoperative blood loss and shorter hospital stay in our study. These findings are in agreement with those reported by Gao et al. in their investigation of UBE-assisted transforaminal lumbar interbody fusion (UBE-TLIF), highlighting the minimally invasive benefits of the UBE technique [12]. However, in contrast to endoscopic studies focusing on primary lumbar disc herniation, revision surgery for rLDH exhibits substantially greater heterogeneity [16], underscoring the necessity and clinical relevance of the present study.

Potential Mechanisms

The advantages of UBE in the treatment of rLDH may be attributed to its unique technical design, which renders it particularly suitable for the complex anatomical environment encountered in revision surgery. Its biportal configuration—comprising an independent viewing portal and a working portal—combined with continuous saline irrigation, provides a clearer surgical field and greater maneuverability compared with single-portal endoscopic techniques when addressing dense epidural adhesions formed after primary surgery [8, 12, 14]. These technical characteristics facilitate precise adhesiolysis and adequate neural decompression while minimizing neural manipulation, which may represent one of the key mechanisms underlying the significant postoperative improvement in functional outcomes, as reflected by the ODI scores [3, 4].

Furthermore, UBE is performed through two small incisions, thereby avoiding extensive paraspinal muscle dissection and prolonged retraction. This minimally invasive approach may mechanistically explain the reduced postoperative pain, faster recovery, and decreased intraoperative blood loss associated with the procedure [8]. Previous studies have demonstrated that serum creatine phosphokinase (CPK) and C-reactive protein (CRP) levels recover more rapidly following minimally invasive surgery [3], providing biochemical evidence supporting the reduced tissue trauma associated with UBE.

Zhang et al. identified risk factors for reherniation, including obesity and hyperglycemia, highlighting the importance of the biomechanical environment in the prognosis of rLDH [16]. In this context, the precise decompression achieved by UBE may contribute to optimizing the local biomechanical conditions, thereby potentially improving clinical outcomes.

Implications for Clinical Practice and Future Studies

The findings of the present study provide important implications for clinical practice. UBE can be considered an effective and safe minimally invasive revision option for rLDH, particularly for patients who prioritize rapid recovery and reduced surgicaltrauma [20]. Its clear visual feedback and flexible instrumentation offer distinct advantages for performing safe dissection within scar tissue, where anatomical planes are often obscured [21].

Nevertheless, several issues warrant careful consideration. First, although short-term outcomes appear favorable, long-term efficacy—particularly the results at final follow-up—seems susceptible to publication bias, and thus their robustness should be interpreted with caution [15, 16]. Second, the substantial heterogeneity observed among studies suggests that factors such as patient selection and technical variations (e.g., whether annular repair is performed) may significantly influence clinical outcomes [15]. Future research should aim to clarify the optimal indications for UBE. For instance, as highlighted by Zhang et al. [16], patients with obesity (body mass index (BMI) > 25.775 kg/m²) or poor glycemic control—both associated with a higher risk of recurrence—may require individualized decision-making, and in some cases, fusion procedures should be considered [22].

Accordingly, future investigations should focus on the following aspects: (1) conducting large-scale, multicenter prospective randomized controlled trials to directly compare the long-term efficacy and cost-effectiveness of UBE with other revision techniques, such as microsurgical discectomy and minimally invasive fusion procedures; (2) establishing standardized criteria for patient selection and technical protocols; and (3) exploring adjunctive strategies, including annular repair and the application of biomaterials, to further reduce the risk of recurrenc [15, 23].

Strengths

This meta-analysis possesses several methodological strengths that enhance the validity of its conclusions. First, to the best of our knowledge, this is the first quantitative synthesis specifically designed to evaluate the efficacy and safety of unilateral biportal endoscopy (UBE) for recurrent lumbar disc herniation (rLDH), thereby addressing a significant gap in the current literature. Second, this study was conducted with rigorous methodology. The review protocol was prospectively registered, and the entire process adhered to the PRISMA and MOOSE reporting guidelines. We performed a comprehensive and systematic literature search and included only high-quality cohort studies (Newcastle–Ottawa Scale score ≥ 8), thereby minimizing the risk of bias originating from the primary studies. Third, robust statistical approaches were employed to ensure the reliability of the findings. A random-effects model was applied a priori to account for anticipated clinical heterogeneity. The stability of the key outcomes—including significant improvements in back pain, leg pain, and functional disability—was confirmed through sensitivity analyses. Furthermore, the robustness of the primary efficacy outcomes was supported by trim-and-fill analyses adjusting for potential publication bias.

Limitations

The interpretation of our findings should be considered in light of several limitations. First, the evidence base consisted exclusively of retrospective cohort studies. In the absence of randomized controlled trials, causal inferences cannot be definitively established, and the observed associations may be influenced by unmeasured or residual confounding factors. Second, substantial statistical heterogeneity was observed across most outcome measures. This heterogeneity likely reflects variations in surgical expertise, technical details, patient selection, and duration of follow-up. Although a random-effects model was used, the presence of heterogeneity may still compromise the precision of the pooled effect estimates. Third, this quantitative synthesis is constrained by the relatively small number of included studies (n = 7) and the limited overall sample size (n = 409), particularly for functional outcomes. Moreover, the mean follow-up duration of 13.6 months is insufficient to evaluate the long-term durability of treatment effects, including the critical endpoint of re-

recurrence. Finally, this analysis relied on study-level aggregated data, which precluded more in-depth investigations, such as subgroup analyses or meta-regression, to explore sources of heterogeneity or to identify specific patient subgroups that may derive the greatest benefit from this technique.

Conclusions

This meta-analysis suggests that UBE may provide favorable clinical efficacy and an acceptable safety profile in the treatment of rLDH. Significant postoperative improvements were observed in back and leg pain as well as functional outcomes, with a relatively low rate of complications. These findings support UBE as a promising minimally invasive surgical option for rLDH.

Declarations

Disclosure statement

The authors declare no potential conflicts of interest.

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Author contributions:

Study concept and design (ML, JH, ZZ); Acquisition of data (JH, WL, YT, XL, WL, PL, YZ, ZL, ZZ); Analysis and interpretation of data (ML, JH); Drafting of the manuscript (ML, JH, WL, ZZ); Critical revision of the manuscript for important intellectual content (all authors); Study supervision (ML, ZZ, XZ).

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Data availability statement

Data included in article/supplementary material/referenced in article.

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Figures

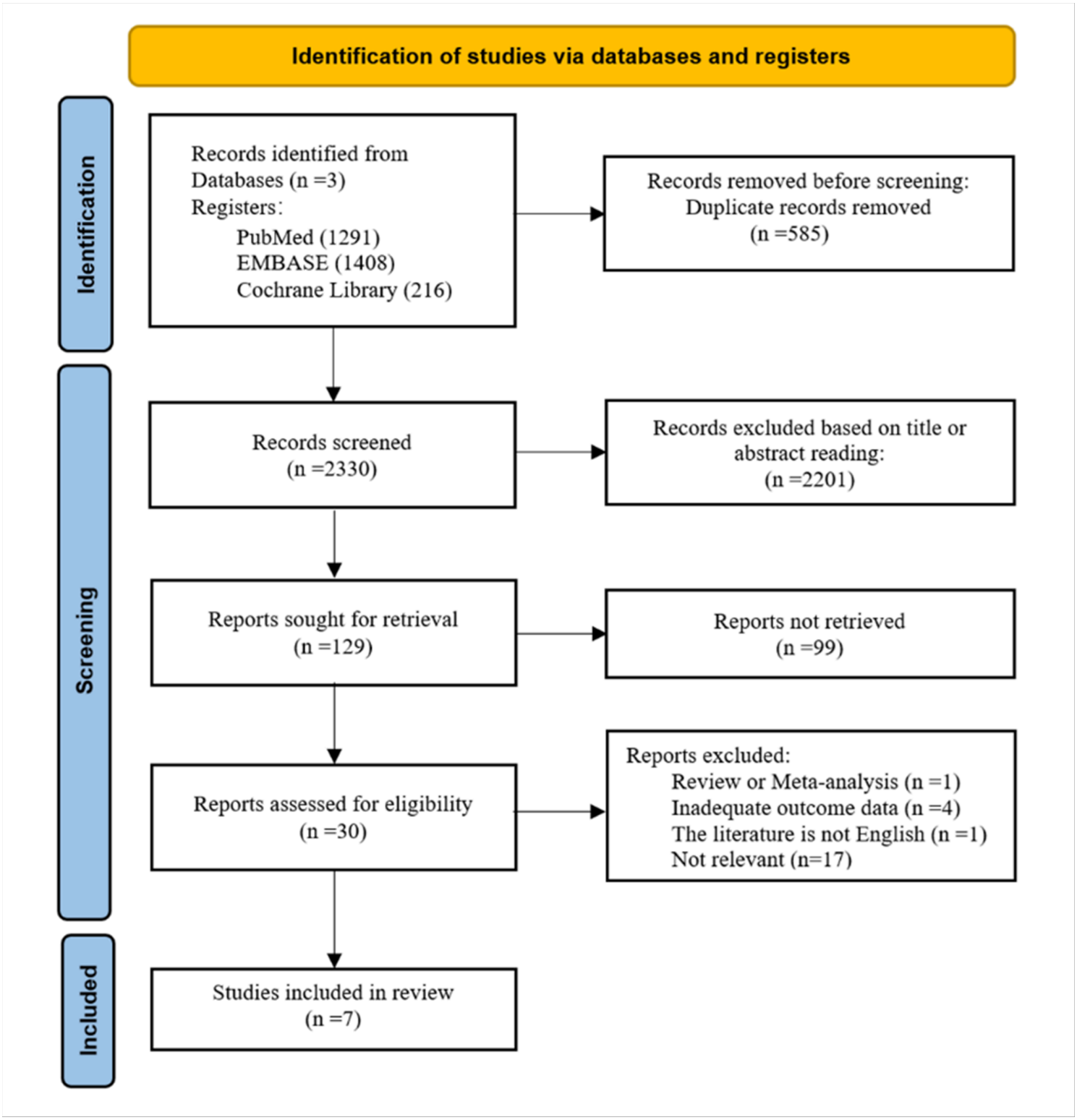


Figure 1

Flow diagram of the study selection process.

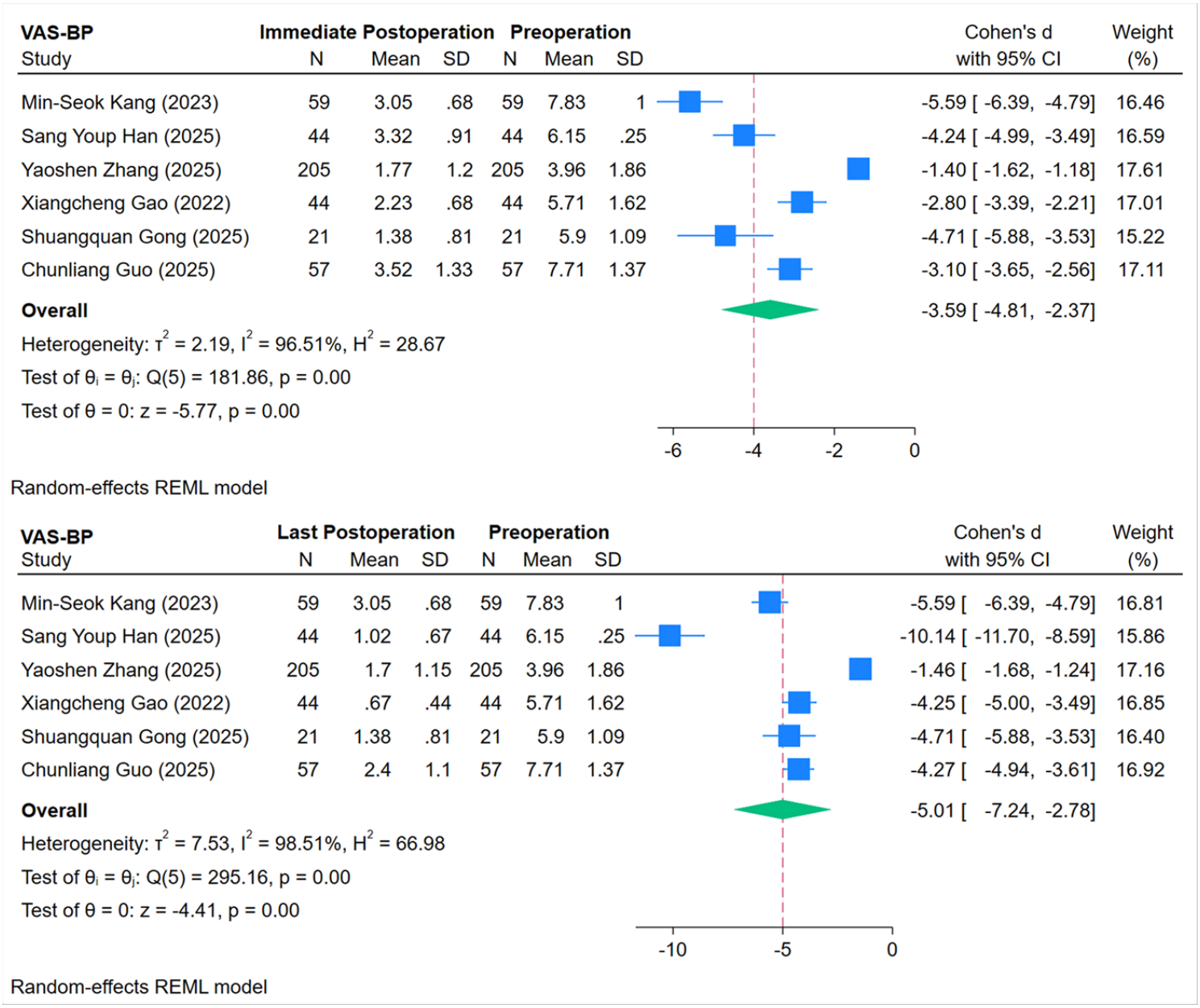


Figure 2

Forest plot comparing pooled VAS-BP scores between preoperative, immediate postoperative, and final follow-up assessments across studies.

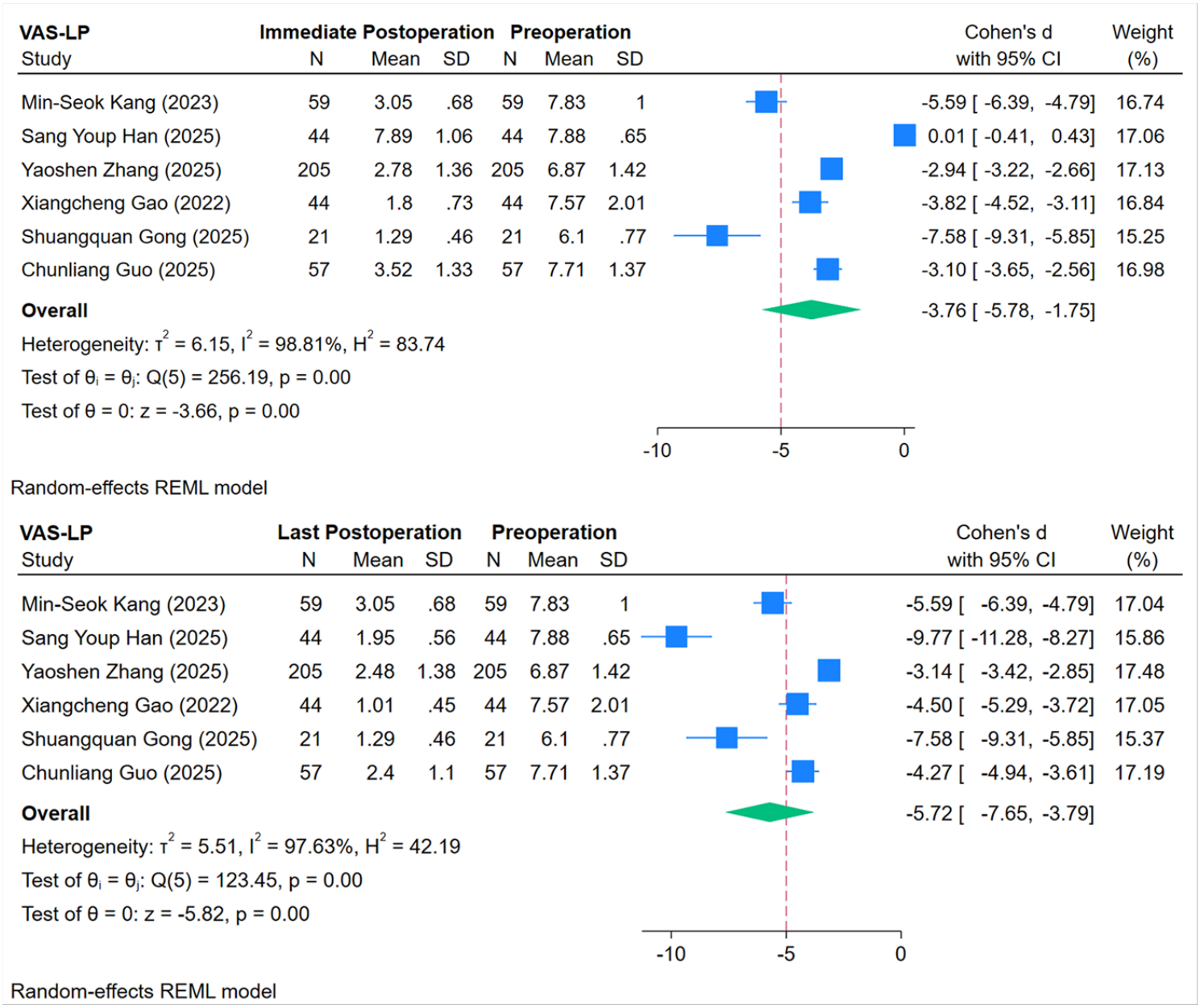


Figure 3

Forest plot comparing pooled VAS-LP scores between preoperative, immediate postoperative, and final follow-up assessments across studies.

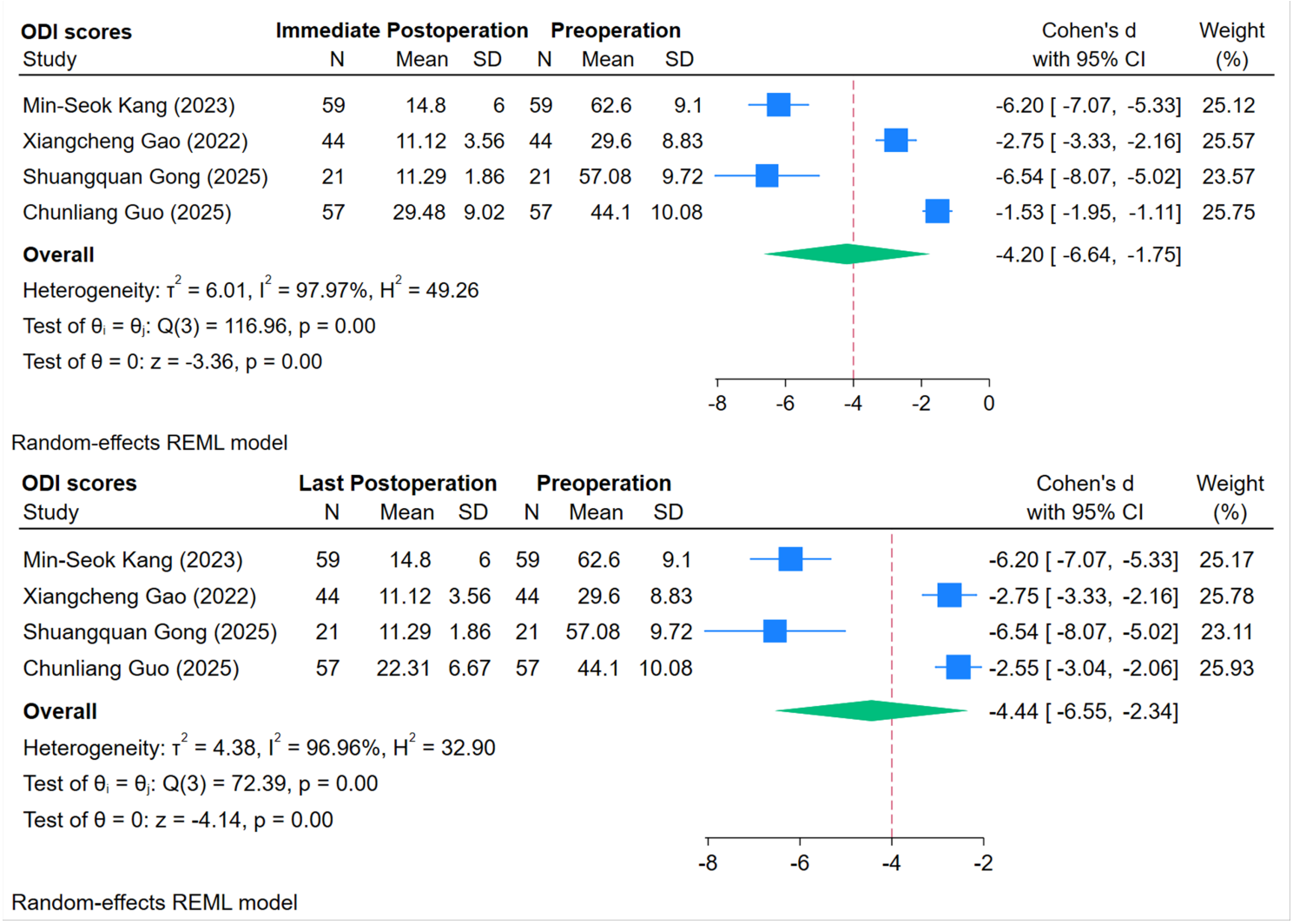


Figure 4

Forest plot comparing pooled ODI scores between preoperative, immediate postoperative, and final follow-up assessments across studies.

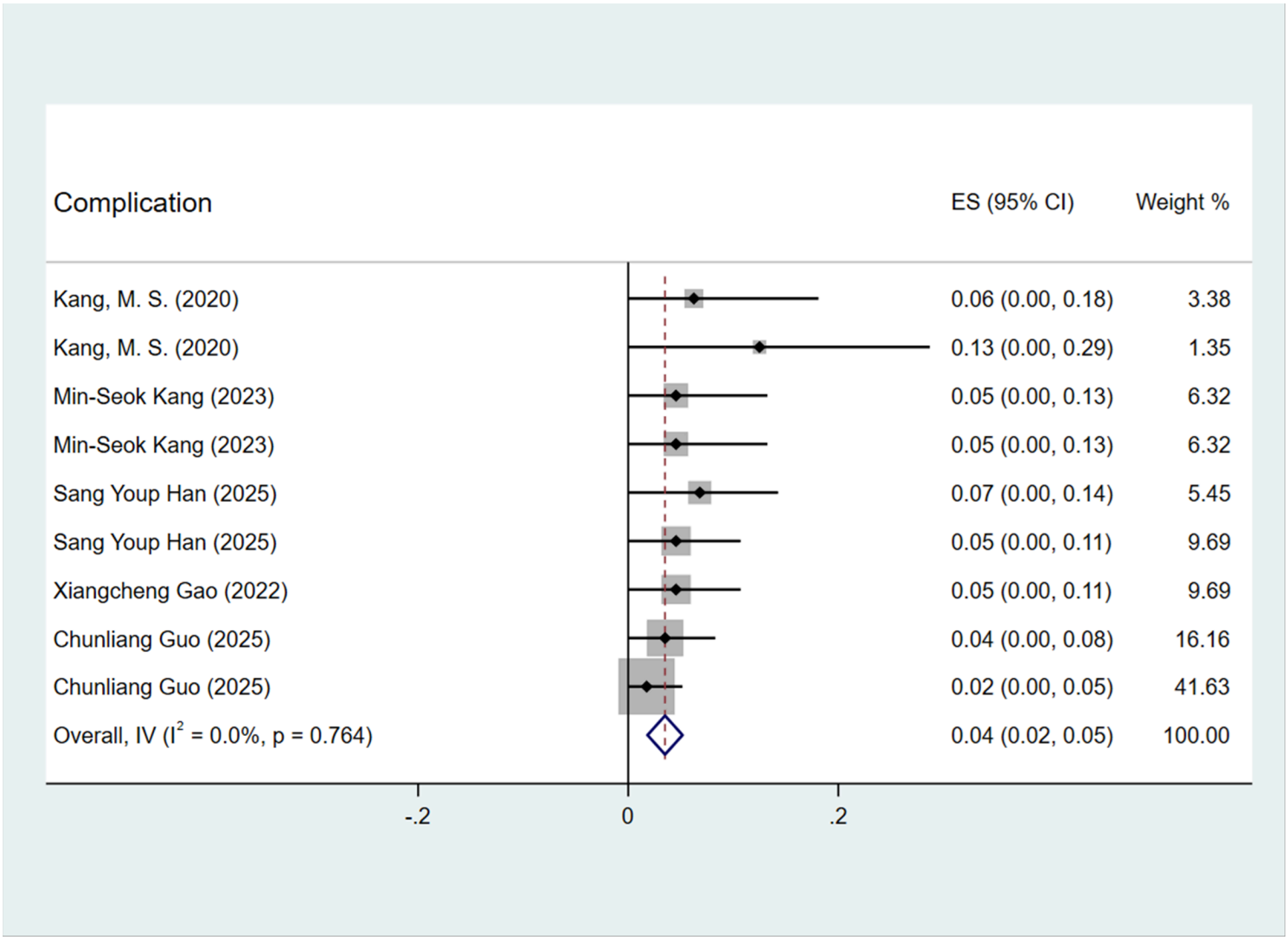


Figure 5

Forest plot showing the pooled incidence of complications across the included studies.

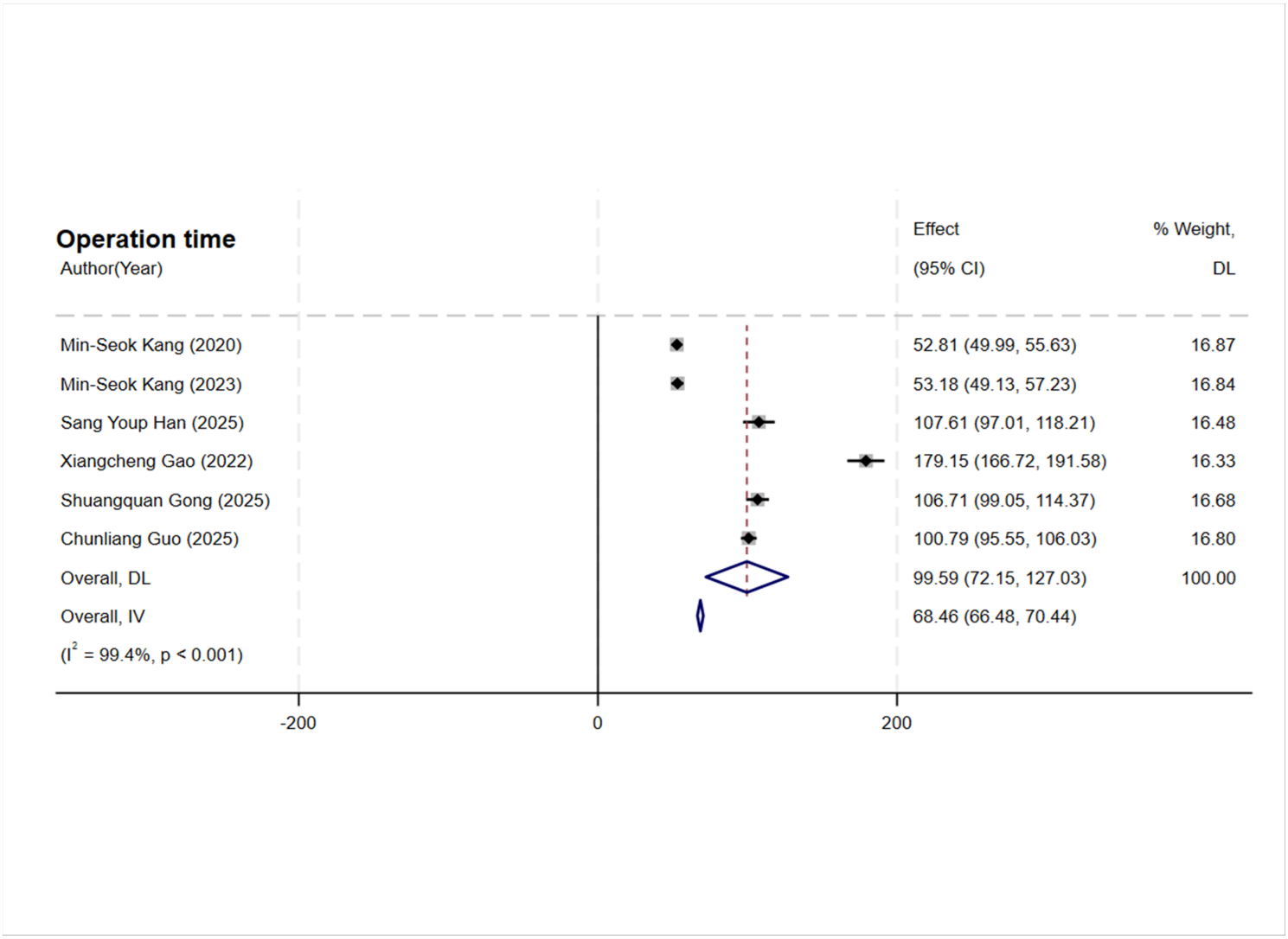


Figure 6

Forest plot of pooled operative time across the included studies.

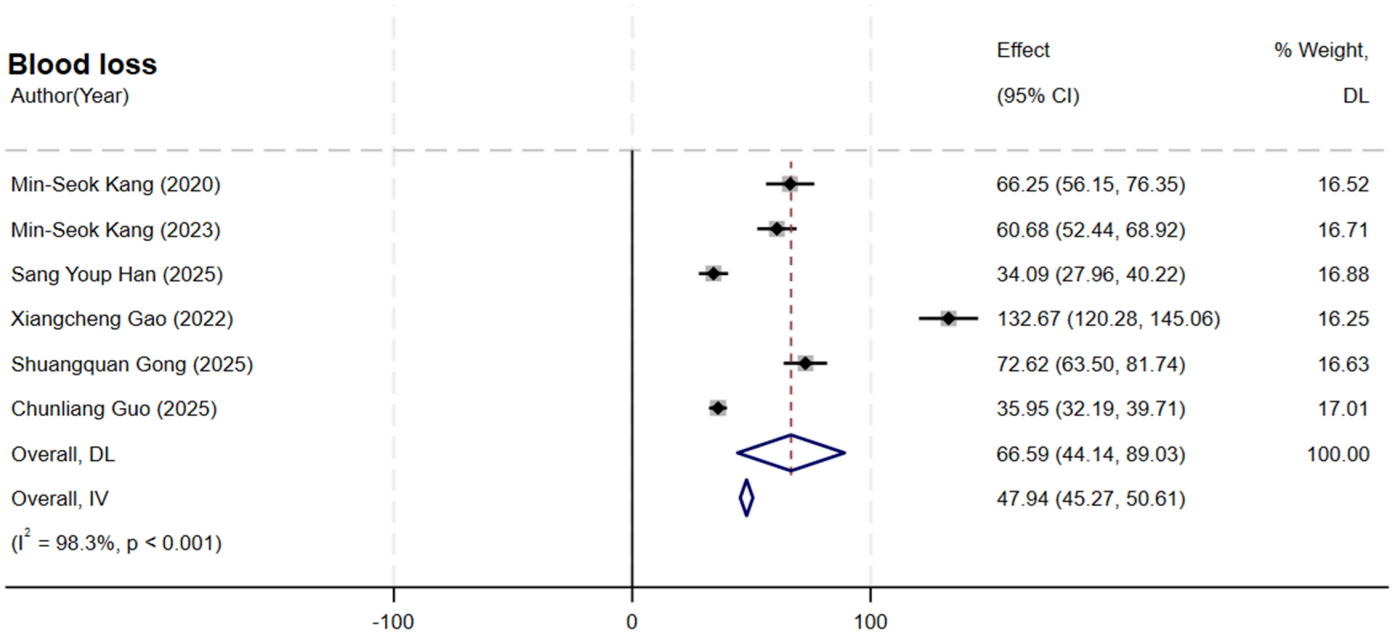


Figure 7

Forest plot of pooled intraoperative blood loss across the included studies.

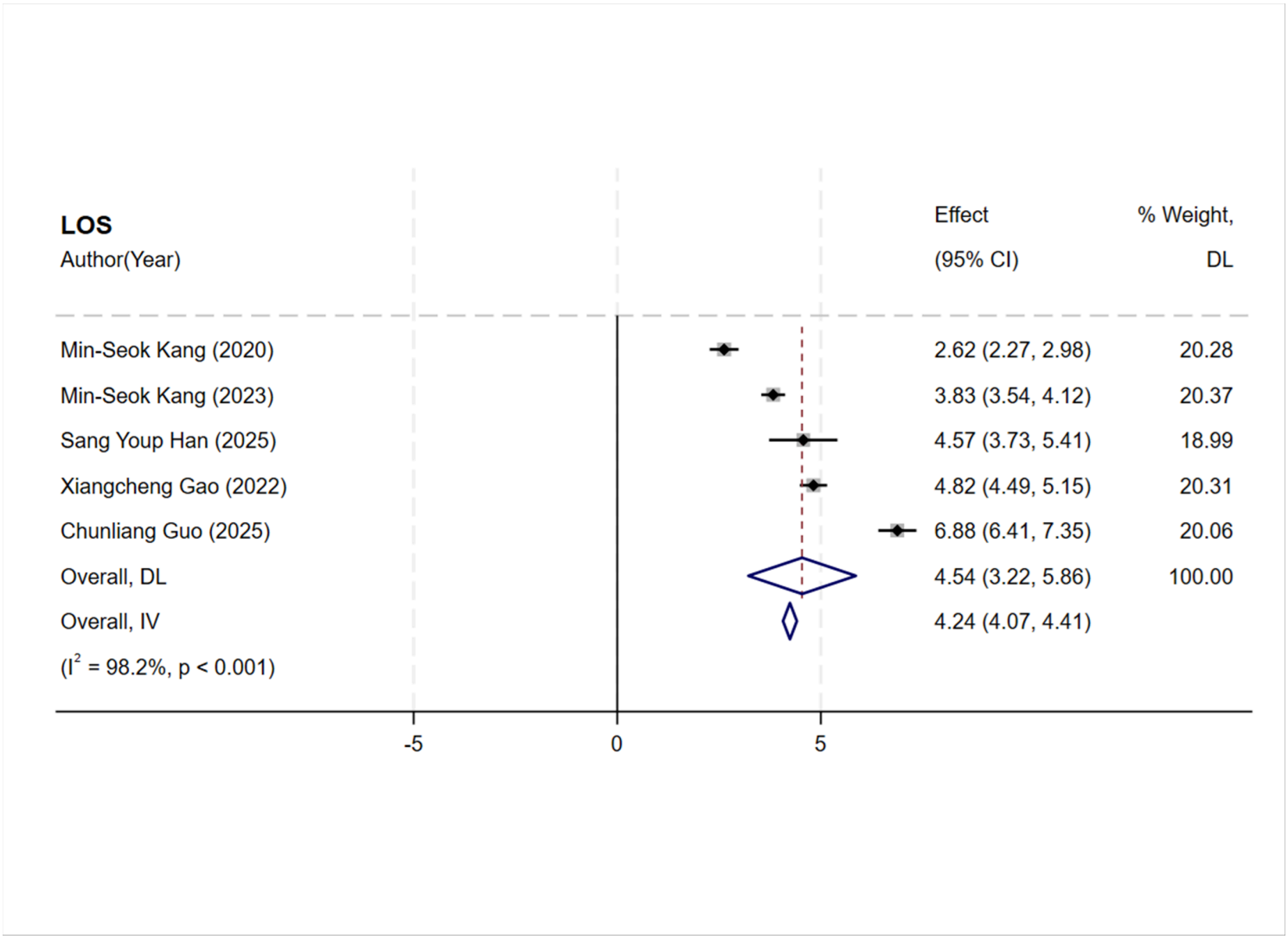


Figure 8

Forest plot of pooled length of hospital stay across the included studies.

Supplementary Files

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- SupplementaryMaterial.docx