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Special issue

Endoscopic spine surgery for obesity-related surgical challenges: a systematic review and meta-analysis of current evidence

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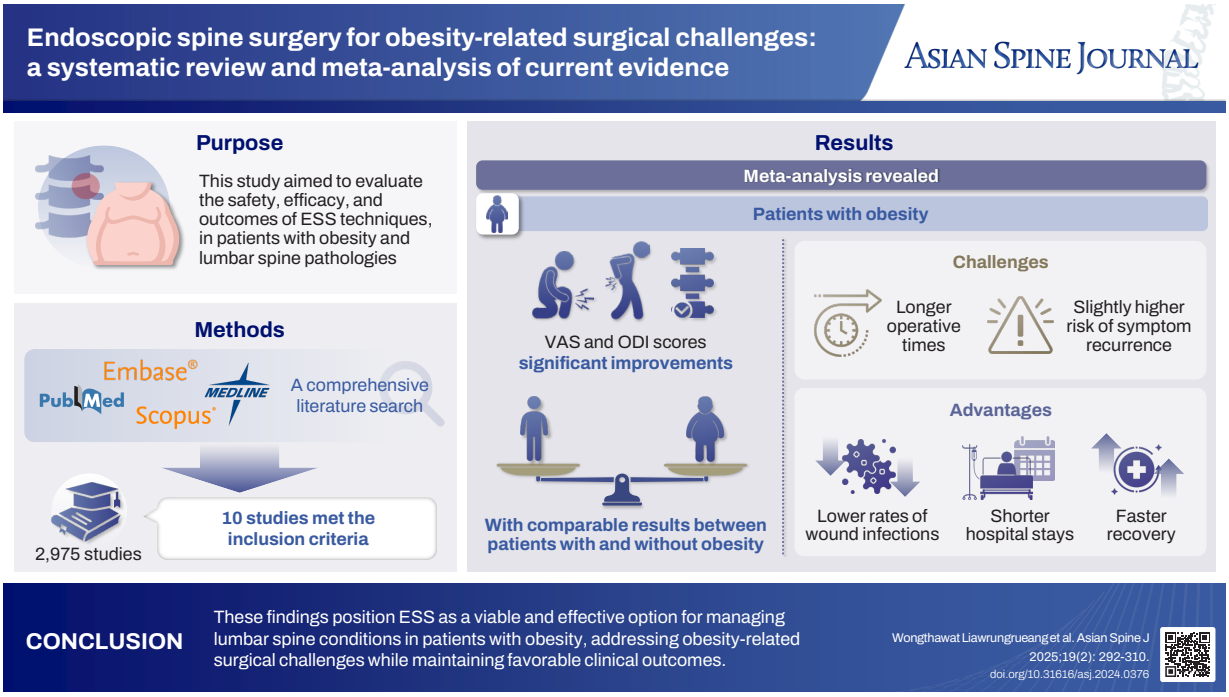

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Obesity presents significant challenges in spinal surgery, including higher rates of perioperative complications, prolonged operative times, and delayed recovery. Traditional open spine surgery often exacerbates these risks, particularly in patients with obesity, because of extensive tissue dissection and larger incisions. Endoscopic spine surgery (ESS) has emerged as a promising minimally invasive alternative, offering advantages such as reduced tissue trauma, minimal blood loss, lower infection rates, and faster recovery. This systematic review and meta-analysis aimed to evaluate the safety, efficacy, and outcomes of ESS techniques, including fully endoscopic and biportal endoscopic lumbar discectomy and decompression, in patients with obesity and lumbar spine pathologies. A comprehensive literature search of the PubMed/Medline, Embase, and Scopus databases yielded 2,975 studies published between 2000 and 2024, of which 10 met the inclusion criteria. The meta-analysis revealed significant improvements in pain relief (Visual Analog Scale) and functional outcomes (Oswestry Disability Index), with comparable results between patients with and without obesity. Patients who are obese experienced longer operative times and have a slightly higher risk of symptom recurrence; however, ESS demonstrated lower rates of wound infections, shorter hospital stays, and faster recovery than traditional surgery. These findings position ESS as a viable and effective option for managing lumbar spine conditions in patients with obesity, addressing obesity-related surgical challenges while maintaining favorable clinical outcomes. However, limitations such as study heterogeneity and the lack of randomized controlled trials highlight the need for further high-quality research to refine ESS techniques and optimize patient care in this high-risk population.

Keywords: Endoscopy; Obesity; Discectomy; Minimally invasive surgical procedures; Treatment outcome

Introduction

The global prevalence of obesity has reached epidemic proportions, with over 650 million adults classified as obese according to the World Health Organization [1,2]. Obesity is a multifactorial condition associated with numerous comorbidities, such as cardiovascular disease, diabetes mellitus, and degenerative musculoskeletal disorders [2,3]. The increasing incidence of obesity poses substantial challenges to spinal surgery because excess body mass complicates operative management and adversely affects surgical outcomes [4]. Patients with obesity are at a greater risk of perioperative complications, including wound infections, prolonged operative times, and extended hospital stays, which contribute to higher morbidity and healthcare costs [5-7]. These challenges are particularly pronounced in traditional open spinal surgery that often requires large incisions, extensive tissue dissection, and prolonged recovery periods [4,8].

Minimally invasive surgical techniques, such as endoscopic spine surgery (ESS), offer a potential solution to the surgical challenges associated with obesity. ESS, which utilizes small incisions and endoscopic visualization for spinal decompression and discectomy, has attracted significant attention because it can minimize tissue trauma, reduce blood loss, and accelerate postoperative recovery. By minimizing the invasiveness of the procedure, ESS has decreased the incidence of perioperative complications commonly associated with open spinal surgery [9-12]. Despite its theoretical advantages, the application of ESS in patients who are obese presents distinct technical and anatomical challenges that have not been comprehensively addressed in the literature. The utility of ESS in obese populations is noteworthy given the disproportionate burden of degenerative spinal diseases in this group. Obesity is a risk factor for lumbar disc herniation and other spinal pathologies; thus, these patients often require surgery [4,13,14]. However, the increased soft tissue mass in patients with obesity complicates surgical access and visualization, potentially prolonging operative times and increasing the risk of complications such as dural tears and infection [13,15,16]. Although ESS has demonstrated positive outcomes in nonobese populations,

its safety and efficacy in patients who are obese remain underexplored. Furthermore, obesity is a potential risk factor for recurrent symptoms following spinal surgery, raising questions about the long-term effectiveness of ESS in this demographic.

This systematic review and meta-analysis analyzed the available evidence on the use of ESS in patients with obesity and lumbar spine pathologies. By evaluating the outcomes of ESS techniques, including fully endoscopic and biportal endoscopic lumbar discectomy (ELD) and decompression, this systematic review aimed to comprehensively evaluate the efficacy, safety, and technical feasibility of ESS in patients who are obese. Given the growing prevalence of obesity and its effect on spinal health, understanding the role of ESS in this patient population is critical to optimizing surgical strategies and improving patient outcomes. The findings will be essential for identifying best practices and refining surgical techniques tailored to the unique anatomical challenges presented by obesity.

Methods

Literature search strategy

In this systematic review, the literature search was conducted across the PubMed/Medline, Embase, and Scopus databases to identify relevant research on the application of ESS in patients with obesity and lumbar spine pathologies. The search included studies published between January 2010 and July 2024. Combinations of Medical Subject Headings were used, and keywords entered in the search included "endoscopic," "spine," "surgery," "obesity," "minimally," "invasive," "lumbar," discectomy," and "decompression." Boolean operators were applied to refine the search, and the reference lists of the included studies were manually reviewed for additional relevant publications. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17].

Inclusion and exclusion criteria

The eligibility criteria for study selection were rigorously defined to ensure the inclusion of high-quality, relevant studies. The following studies that provided quantitative data relevant to the objectives of this review were included: studies that enrolled a sample of patients with a body mass index (BMI) ≥30 kg/m^2 undergoing ESS for lumbar spine pathologies, including but not limited to lumbar disc herniation, lumbar spinal stenosis, or other degenerative lumbar conditions; studies that evaluated the efficacy and safety of ESS techniques, including interlaminar or transforaminal ELD and decompression with fully endoscopic or biportal endoscopic technique; and studies that were published in peer-reviewed journals as original research articles, randomized controlled trials (RCTs), prospective or retrospective cohort studies, and case–control studies. The following studies were excluded: studies that focused on pediatric populations or conditions not involving the lumbar spine (e.g., cervical or thoracic spine pathologies), did not involve ESS as the primary intervention or focused on microscopic or nonendoscopic spinal surgeries (intervention), and were published as narrative reviews, meta-analyses, letters to the editor, conference abstracts, and single case reports (design). Studies focusing exclusively on developing or innovating surgical equipment or surgical learning curves without reporting clinical outcomes were also excluded.

Data extraction

Two independent reviewers conducted the data extraction process. Data were systematically extracted from each study using a standardized data extraction form. The following data points were extracted: study characteristics (authors, year of publication, country, study design, and sample size), patient characteristics (age, sex distribution, BMI, and any relevant comorbidities), surgical characteristics (endoscopic spine surgical technique employed, procedure duration, estimated intraoperative blood loss, and length of hospital stay), and outcome measures, namely, changes in pain intensity (Visual Analog Scale [VAS]), functional outcomes (Oswestry Disability Index [ODI]), complication rates (e.g., infections and dural tears), recurrence rates, and follow-up duration. Any disagreements between the two reviewers regarding data extraction were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted.

Assessment of the risk-of-bias

The risk-of-bias for each study included was systematically evaluated using tools specific to the study design. The risk-of-bias in nonrandomized studies of interventions (ROBINS-I) tool was utilized in nonrandomized studies [18]. This tool assesses potential biases across seven key domains, namely, confounding, participant selection, classification of interventions, deviations from the intended interventions, missing data, mea-

surement of outcomes, and selection of reported results. Each domain was rated as having a low, moderate, serious, or critical risk-of-bias. The Cochrane Risk-of-Bias Assessment Tool 2 was employed for RCTs [19]. This tool evaluates the following five domains: randomization, deviations from the intended interventions, missing outcome data, outcome measurement, and selection of the reported results. Each domain was assessed and categorized into low, some concerns, or high risk of bias. Two reviewers conducted both risk-of-bias assessments independently. Any disagreements were addressed through discussion, and a third reviewer was involved if consensus could not be reached.

Assessment of the meta-analysis and publication bias analysis

The meta-analysis was conducted to evaluate the key outcomes of ESS in patients with and without obesity. A random-effects model was used to account for between-study variability and heterogeneity. The outcomes analyzed included back pain reduction (VAS back), leg pain reduction (VAS leg), functional disability (ODI), and operative time. Heterogeneity was assessed using Cochran's Q test and quantified by the I^2 statistic. Sensitivity analyses were performed to examine the robustness of the results, and subgroup analyses were conducted to account for variations in surgical approaches. For publication bias assessment, funnel plots were generated for each outcome to assess potential publication bias. The symmetry of the funnel plots was evaluated visually, and asymmetry indicated potential publication bias. For outcomes reported by a limited number of studies, caution was exercised in interpreting the funnel plot results. In addition, Egger's regression test was deemed suitable for providing a more quantitative assessment of publication bias. All statistical analyses, including the meta-analysis and publication bias assessment, were performed using Review Manager (RevMan ver. 5.4.1; Cochrane, London, UK) where necessary for advanced bias evaluations. The findings were reported according to the PRISMA guidelines for systematic reviews and meta-analyses.

Ethics statement

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee and Institutional Review Board (IRB) of the University of Phayao (IRB no., HREC-UP-HSST 1.1/045/67).

Results

The initial search across the PubMed/Medline, Embase, and Scopus databases yielded 2,975 studies. After 1,797 duplicate records and studies not published in English were removed, 1,178 articles were screened based on their titles and abstracts. After applying the selection criteria, 1,058 articles were excluded, primarily due to their irrelevance to the topic. A total of 120 full-text articles were retrieved and assessed for eligibility, of which 80 were further excluded because they did not meet the inclusion criteria. Ultimately, 10 studies were included in the final systematic review. The PRISMA flow diagram of the study selection process is shown in Fig. 1.

Study design and publication information

This systematic review included 10 studies published between 2000 and 2024, covering ESS use in patients with obesity and lumbar spine conditions. The studies were conducted in China, South Korea, Greece, United States, and a multinational collaboration (Fig. 2). Of the 10 studies, six were retrospective cohort studies, three were prospective cohort studies, and one was a comparative cohort study involving both prospective and retrospective data. The studies focused on various ESS techniques, such as transforaminal ELD, interlaminar ELD, fully ELD, unilateral biportal endoscopy, and percutaneous ELD. The primary objectives were to evaluate the efficacy and safety of ESS in patients with obesity, assess surgical outcomes, and identify risk factors for complications or recurrence. All the studies highlight the diverse approaches to studying ESS in obese populations, with attention to both perioperative complications and long-term outcomes and functional improvement (Table 1).

Risk-of-bias analysis

All 10 studies were not RCTs and were assessed using the ROBINS-I tool (Cochrane) [18]. The risk-of-bias analyses in Table 2 and Fig. 3 show that most studies had a moderate overall risk-of-bias, primarily due to confounding and participant selection. The study by Yao et al. [20] had a serious risk-of-bias, whereas studies by Kapetanakis [21], Yu et al. [22,23], and Qu et al. [24] exhibited a low risk overall. All studies showed a low risk-of-bias in classifying interventions and outcome measurement, ensuring reliable assessments of the procedures. Despite concerns about missing data

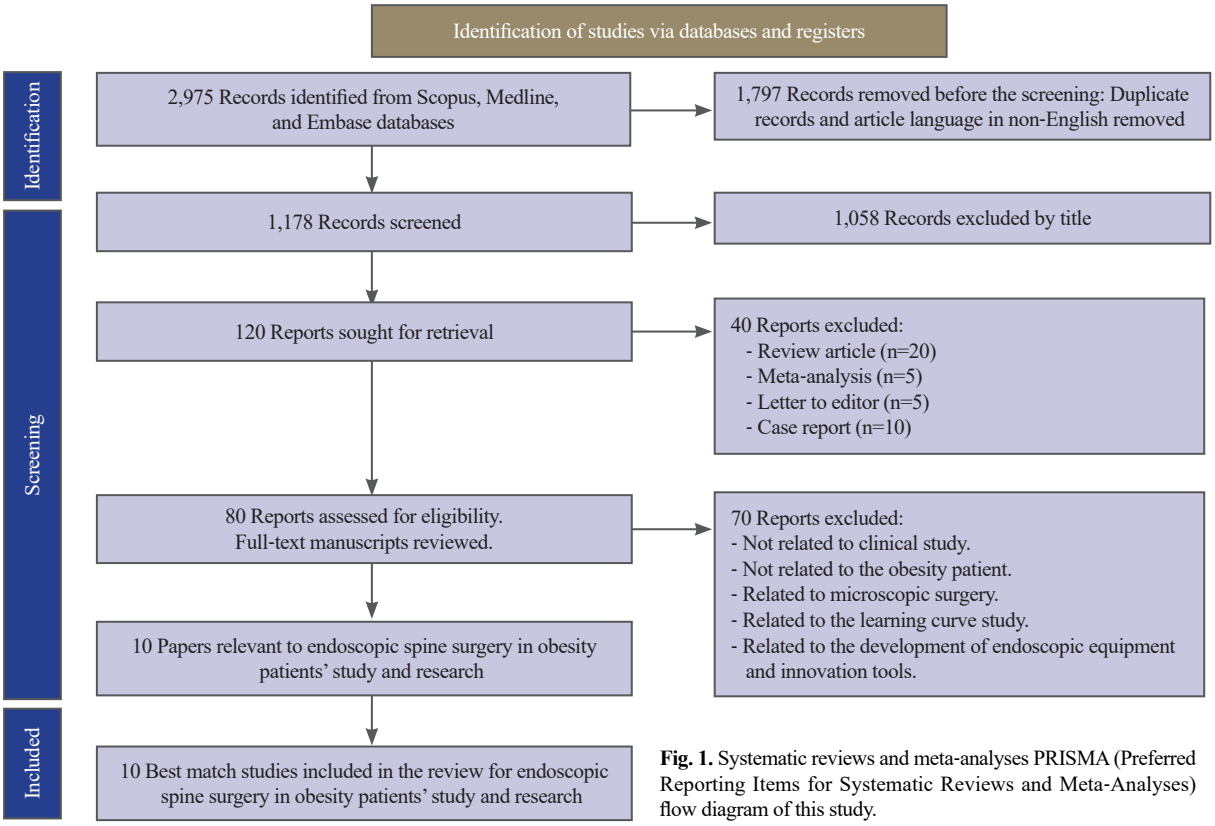

Fig. 1. Systematic reviews and meta-analyses PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of this study.

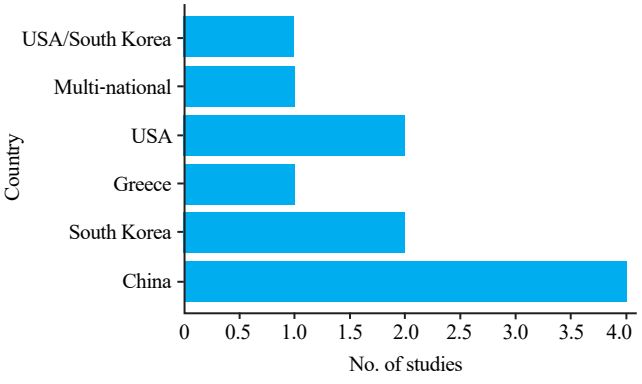

Fig. 2. The distribution of country studies in endoscopic spine surgery related to obesity.

and deviations from the intended interventions, the studies provided a solid basis for evaluating the effectiveness of ESS in patients with obesity.

Surgical outcomes

The studies included in this systematic review encompassed a total of 736 patients, with individual study sample sizes ranging from 30 to 174 patients. The age of the participants varied widely, with most studies reporting a mean age range of 24–61 years, depending on the population and study design. The sex distribution across studies was generally balanced, with male-to-female ratios ranging from approximately 1:1 to 2:1. All patients had a BMI ≥30 kg/m^2, and some studies specifically focused on patients who were morbidly obese (BMI >40 kg/m^2). The overall BMI range spanned from 30 to >40 kg/m^2, reflecting the focus on obese and morbidly obese populations undergoing ESS. The studies highlighted various demographic and clinical characteristics, representing a diverse population of patients with obesity and lumbar spine conditions. A summary of the effectiveness and outcome of ESS for patients with obesity is shown in Table 3.

Pain reduction

All 10 studies consistently reported significant reductions in postoperative pain, as assessed using the VAS. The reductions in pain scores ranged from 50% to 80%, with the participants experiencing substantial pain relief following various ESS procedures, including transforaminal and interlaminar approaches with uniportal and biportal endoscopic decompression. In most studies, pain relief was observed as early as the first follow-up, typically within 1–3 months postoperatively, and these improvements were sustained throughout the follow-up period, which extended up to 24 months. Wang et al. [25] and Kapetanakis et al. [21] reported

Table 1. Demographic data of this systematic review

No.	Authors	Published year	Nationality	Type of study	Title	Objective of study
1	Wang et al. [25]	2016	China	Prospective cohort	Evaluation of transforaminal endoscopic discectomy in treatment of obese patients with lumbar disc herniation	To evaluate the efficacy and safety of TED in obese patients with LDH.
2	Bae & Lee [26]	2016	South Korea	Retrospective cohort	Transforaminal full-endoscopic lumbar discectomy in obese patients	To evaluate the clinical outcomes of transforaminal FELD in obese patients.
3	Yao et al. [20]	2017	China	Retrospective cohort	Risk factors for recurrent herniation after percutaneous endoscopic lumbar discectomy	To identify risk factors for recurrence after successful PELD.
4	Kapetanakis et al. [21]	2018	Greece	Prospective cohort	Percutaneous transforaminal endoscopic discectomy for the treatment of lumbar disc herniation in obese patients: health-related quality of life assessment in a 2-year follow-up	To assess the impact of percutaneous TED on health-related quality of life in obese patients with LDH over a 2-year follow-up period.
5	Wu et al. [27]	2018	China	Retrospective cohort	Percutaneous endoscopic lumbar reoperation for recurrent sciatica symptoms: a retrospective analysis of outcomes and prognostic factors in 94 patients	To evaluate the outcomes and prognostic factors of percutaneous endoscopic lumbar reoperation for recurrent sciatica symptoms.
6	Yu et al. [22,23]	2021	China	Retrospective cohort	Evaluation of full-endoscopic lumbar discectomy in the treatment of obese adolescents with lumbar disc herniation: a retrospective study	To evaluate the safety and efficacy of FELD in obese ALDH.
7	Leyendecker et al. [29]	2023	Multi-National Collaboration	Prospective cohort	Assessing the impact of obesity on full endoscopic spine surgery: surgical site infections, surgery durations, early complications, and short-term functional outcomes	To evaluate the impact of obesity on various aspects of full-endoscopic spine surgery, including surgical site infections, surgery duration, early complications, and short-term functional outcomes.
8	Bergquist et al. [30]	2023	USA	Retrospective cohort	Full-endoscopic technique mitigates obesity-related perioperative morbidity of minimally invasive lumbar decompression	To investigate whether full-endoscopic techniques reduce perioperative morbidity associated with obesity in lumbar decompression surgery.
9	Qu et al. [24]	2023	China	Retrospective cohort	Surgical outcomes of percutaneous endoscopic lumbar discectomy in obese adolescents with lumbar disc herniation	To evaluate the surgical outcomes of PELD in obese ALDH.
10	Olson et al. [28]	2024	USA, South Korea	Comparative cohort (prospective and retrospective)	Does obesity and varying body mass index affect the clinical outcomes and safety of biportal endoscopic lumbar decompression? a comparative cohort study	To determine the impact of obesity and different body mass index categories on outcomes and safety of biportal endoscopic lumbar decompression.

TED, transforaminal endoscopic discectomy; LDH, lumbar disc herniation; FELD, full-endoscopic lumbar discectomy; PELD, percutaneous endoscopic lumbar discectomy; ALDH, adolescents with lumbar disc herniation.

>70% VAS score reductions, with pain relief sustained through the final follow-up. These results demonstrate that ESS effectively alleviates pain in patients with obesity, with outcomes comparable with those in patients without obesity undergoing similar procedures.

Functional improvement

Eight of the included studies reported functional outcomes as measured by the ODI. ODI score reductions ranged from 30% to 70%, indicating a significant improvement in patients' ability to perform daily activities. For instance, Kapetanakis et al. [21] reported an ODI reduction of 65% at the 24-month follow-up, indicating long-term improvements in health-related quality of life in patients with obesity. In most studies, functional improvements were observed within the first 3 months postoperatively, which were sustained over time, reflecting the durability of ESS in restoring physical function. In some cases, such as in the study by Bae and Lee [26], the functional outcomes for patients with obesity were on par with those for patients without obesity, showing no significant differences in ODI reductions between the groups. This finding indicates that ESS offers similar functional recovery for patients with obesity as it does for patients without obesity despite the additional surgical challenges posed by obesity.

Complication and infection rates

Complication rates associated with ESS in patients with obesity were generally low, with rates ranging from 5%

Table 2. Risk of bias analysis using ROBINS-I tool for non-randomized controlled trial studies

Study no.	Authors	Confounding	Selection of participants	Classification of interventions	Deviations from intended interventions	Missing data	Measurement of outcomes	Selection of reported results	Overall risk of bias
1	Wang et al. [25] (2016)	Moderate	Low	Low	Low	Low	Low	Low	Moderate
2	Bae & Lee [26] (2016)	Moderate	Moderate	Low	Moderate	Low	Moderate	Low	Moderate
4	Yao et al. [20] (2017)	Serious	Serious	Low	Moderate	Moderate	Serious	Moderate	Serious
3	Kapetanakis et al. [21] (2018)	Low	Low	Low	Low	Low	Low	Low	Low
5	Wu et al. [27] (2018)	Moderate	Moderate	Low	Moderate	Moderate	Moderate	Low	Moderate
6	Yu et al. [22,23] (2021)	Low	Low	Low	Low	Low	Low	Low	Low
7	Leyendecker et al. [29] (2023)	Moderate	Moderate	Low	Moderate	Low	Low	Low	Moderate
8	Bergquist et al. [30] (2023)	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
9	Qu et al. [24] (2023)	Low	Low	Low	Low	Low	Low	Low	Low
10	Olson et al. [28] (2024)	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate

ROBINS-I, risk-of-bias in nonrandomized studies of interventions.

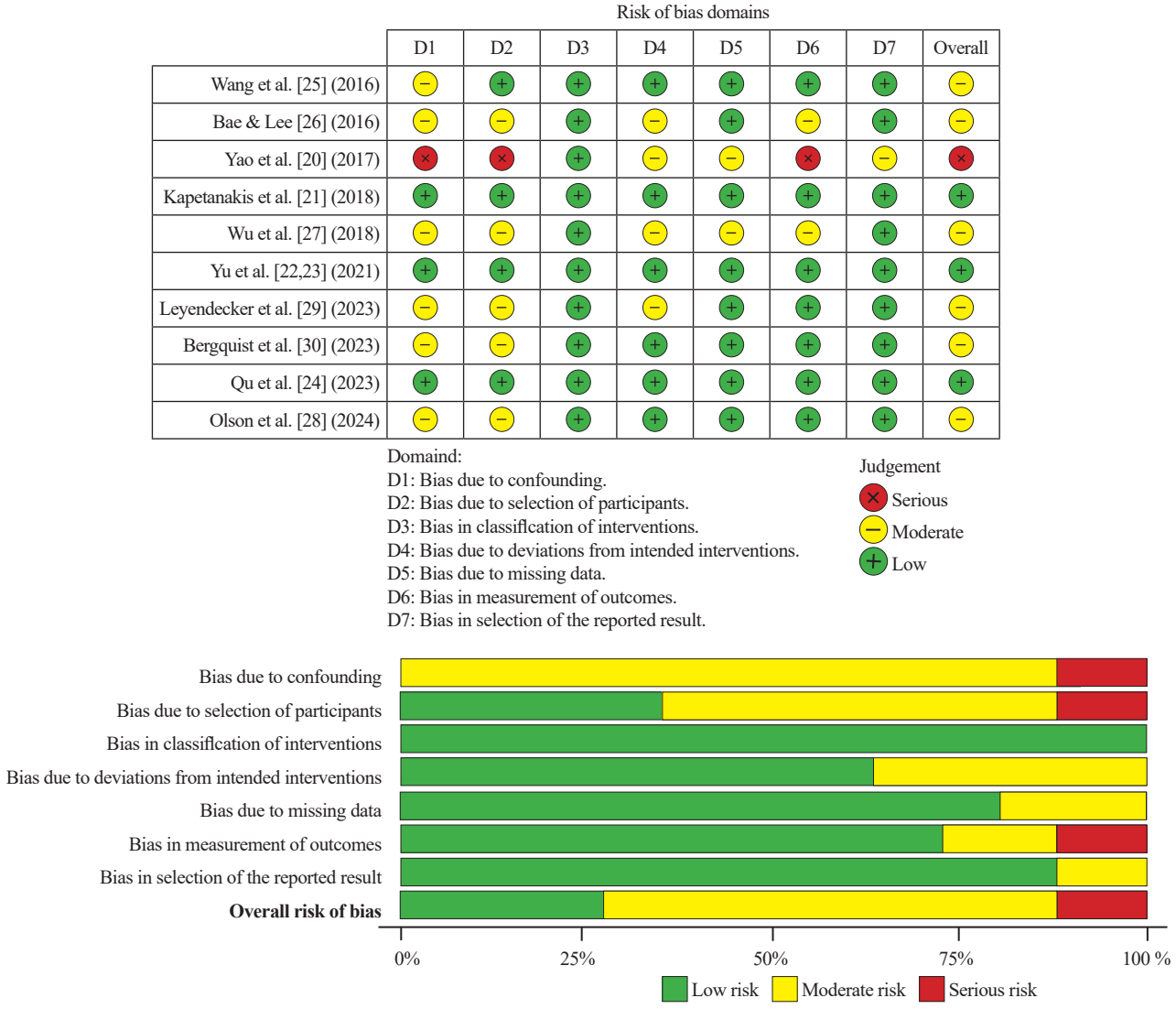

Fig. 3. Risk of bias summary for non-randomized controlled trials, assessed using the risk of bias in non-randomized studies of interventions ROBINS-I tool (Cochrane, London, UK).

Table 3. Summary of the effectiveness and outcome of endoscopic spine surgery for obesity patients

Study no.	Authors	Study group (no. of patients)	Age (yr)	Male:female	BMI (kg/m²)	Operating time (min)	Estimated blood loss (mL)	Length of hospital stay (day)	No. of complications (%)	Infection rate (%)	Last follow-up (mo)	Surgical approach	Outcomes evaluated	Effectiveness	Outcome	Miscellaneous
1	Wang et al. [25] (2016)	69 (all obese)	24–43	35:34	30–40	NS	Minimal	3–5	Abnormal sensations 2 (2.89) and recurrence symptoms 3 (4.34)	0 (0)	12	Transforaminal approach	VAS, JOA, MacNab criteria	Overall, the excellent and good rate was 83.5%. Significant reduction in VAS scores and improved JOA scores.	Effective and safe; recommended for larger, longer-term studies.	- Two cases of temporary postoperative nerve root irritation (full recovery) - Recurrence in 3 cases receive total laminectomy combined with bone grafting internal fixation.
2	Bae & Lee [26] (2016)	48 (21 obese, 27 normal BMI)	Average 37.8 (obese)	14:7 (obese)	>30 (mean BMI was 32.9 in obese)	30–105	Minimal	2–6	Late recurrent herniation 3 (14.28) in obese group	0 (0)	24	Transforaminal approach	VAS, ODI, rehernia-tion	Improved pain and function in both groups, low immediate perioperative complications, some rehernations managed conservatively.	Transforaminal full-endoscopic lumbar discectomy is effective, with low complication rates and manageable rehernia-tion.	- Two patients had tolerable pain and good recovery with conservative treatment. - One patient had recurrent disc herniation underwent open microdiscectomy
3	Yao et al. [20] (2017)	116 (patients with recurrent symptoms following PELD and reoperation)	16–89	63:53	>30	NS	Minimal	NS	NS	0 (0)	3–24	Transforaminal approach	Recurrence rates, risk factors	Obesity identified as a significant risk factor for recurrence post-PELD, highlighting the need for careful patient selection.	PELD is effective but has higher recurrence rates in obese patients.	High recurrence rate associated with central herniation and obesity.

(Continued on the next page)

Table 3. Continued

Study no.	Authors	Study group (no. of patients)	Age (yr)	Male:female	BMI (kg/m²)	Operating time (min)	Estimated blood loss (mL)	Length of hospital stay (day)	No. of complications (%)	Infection rate (%)	Last follow-up (mo)	Surgical approach	Outcomes evaluated	Effectiveness	Outcome	Miscellaneous
4	Kapetanakis et al. [21] (2018)	30 (20 morbid obesity, 10 normal BMI)	57.3±1.8	18:12 (morbid obesity)	>40 (morbid obesity)	NS	Minimal	1–2	0 (0)	0 (0)	24	Transforaminal approach	VAS, SF-36 HRQoL, complications	Significant improvement in HRQoL and pain scores, technical challenges in obese patients noted.	PTED is generally effective and safe; some technical challenges noted.	Obese patients required more surgical adjustments, but outcomes were positive overall.
5	Wu et al. [27] (2018)	94	30–51	67:27	≥30 (obese)	55–100	Minimal	1–8 for PELD group	Report 50% risk of recurrence symptom in BMI ≥28 kg/m2	0 (0)	18	Transforaminal approach	MacNab criteria and recurrence rates	Good to excellent outcomes in most patients, with obesity linked to higher recurrence rates.	Effective for recurrent sciatica symptoms; careful monitoring required for obese patients.	The obese patients is high risk for recurrence symptoms.
6	Yu et al. [22,23] (2021)	108 (28 obese, 80 non-obese)	15–21	26:4 (obese)	>30 (obese)	42.5–77.5	Approximately 5 mL	2–3	Recurrence symptoms: 1 (3.6)	0 (0)	12	FELD (transforaminal and interlaminar approach)	VAS, ODI, MacNab criteria, recurrence rates	Significant improvement in pain and function, low recurrence rates, comparable outcomes in obese and non-obese adolescents.	Safe and effective for obese adolescents, similar to non-obese peers.	One case (3.6%) in the obese group had a recurrence at the same lumbar disc, and FELD was performed again in our hospital after 1 year postoperatively.

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Table 3. Continued

Study no.	Authors	Study group (no. of patients)	Age (yr)	Male:female	BMI (kg/m²)	Operating time (min)	Estimated blood loss (mL)	Length of hospital stay (day)	No. of complications (%)	Infection rate (%)	Last follow-up (mo)	Surgical approach	Outcomes evaluated	Effectiveness	Outcome	Miscellaneous
7	Leyendecker et al. [29] (2023)	118 (53 obese, 65 non-obese)	55.5±14.7 (obese)	30:23 (obese)	>30 (mean BMI=37.1)	91.2±57.7 (per level) (obese)	Minimal (9.7±16.8 mL) (obese)	NS	Dural tear: 1 (1.9) (obese)	0 (0) (obese)	3	Full-endoscopic spine surgery in obese (discectomy: 27 [50.9%], LE-ULBD: 20 [37.7%], endo-TLIF: 4 [7.5%], foraminotomy: 2 [3.8%])	Surgical site infections, surgery duration, complications, functional outcomes (VAS and ODI)	Low infection and complication rates, longer surgery durations in obese patients, similar functional outcomes across groups.	Safe for obese patients; low complication rates and effective outcomes.	No significant increase in early complications, indicating the safety of full-endoscopic techniques.
8	Bergquist et al. [30] (2023)	174 (74 obese, 100 non-obese)	61.5±1.6	44:30 (obese)	>30 (obese)	70.0±1.7 (obese)	Minimal (NS)	0–3 (97.2) and >3 (2.8) in obesity group	Perioperative (obese): 6 (8.1): 1 epidural hematoma, 1 CSF, 3 urinary retention, 1 UTI	1 UTI without wound infection	24.5±2.4	Full-endoscopic ULBD (LE-ULBD)	Preparation time, operative time, pain medication use, functional outcomes	Longer preparation time for obese patients, no significant difference in operative time or complications, similar functional outcomes.	Effective in managing obesity-related challenges, ensuring comparable outcomes.	Obese vs. non-obese patients no difference of perioperative complications and revision surgery rate
9	Qu et al. [24] (2023)	51 (19 obese, 32 normal)	16.5±2.6	7:12 (obese group)	37.2±3.1	101.9±9.0 (obese group)	Minimal (NS)	3.3±0.5 (obese group)	Revision surgery: 1 in PTED group (NS)	0 (0)	12	PTED 15; PIED 4	Operative time, fluoroscopy exposures, time to ambulation, VAS, ODI, SF-36	Obese adolescents required longer operative time and more fluoroscopy, but achieved similar clinical outcomes as normal-weight peers.	PELD is effective and safe for obese adolescents, despite increased operative demands.	Effective and safe for obese adolescents, with similar outcomes despite increased perioperative demands.

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Table 3 Continued

Study no.	Authors	Study group (no. of patients)	Age (yr)	Male:female	BMI (kg/m²)	Operating time (min)	Estimated blood loss (mL)	Length of hospital stay (day)	No. of complications (%)	Infection rate (%)	Last follow-up (mo)	Surgical approach	Outcomes evaluated	Effectiveness	Outcome	Miscellaneous
10	Olson et al. [28] (2024)	84 (26 normal, 35 overweight, 23 obese)	60.0±16.4 (total)	Overweight: 29:6, obese 19:6	Normal BMI: 18.0–24.9), overweight (BMI 25.0–29.9), and obese (BMI >30.0)	Overweight 133±48 and obese 128±47	Overweight: 25–86 mL and obese 7–61 mL (total drain output)	NS	Postoperative Radiculitis: overweight 5 (14) and obese 5 (22)	0 (0)	12	Biportal endoscopic lumbar decompression	VAS, ODI, postoperative complications, ASA scores	Significant improvement in pain and function across all BMI categories, no increase in complications for obese patients.	Safe and effective across different BMI categories, suitable for obese patients. Recurrent was 0% in overweight and obese.	Obesity is not a risk factor for increased perioperative complications with biportal spinal endoscopy and has similar clinical outcomes and safety profile as compared to patients with normal BMI.

BMI, body mass index; NS, not specified; VAS, Visual Analog Scale; JOA, Japanese Orthopedic Association; ODI, Oswestry Disability Index; PELD, percutaneous endoscopic lumbar decompression; SF-36, 36-Item Short Form Survey; HRQoL, health-related quality of life; FELD, full-endoscopic lumbar discectomy; ULBD, unilateral laminotomies for bilateral decompression; LE-ULBD, lumbar endoscopic ULBD; TLIF, transforaminal lumbar interbody fusion; CSF, cerebrospinal fluid; UTI, urinary tract infection; PTED, percutaneous transforaminal endoscopic discectomy; PIED, percutaneous interlaminar endoscopic discectomy; ASA, American Society of Anesthesiologists.

to 10% across the included studies. The most frequently reported complications were nerve root irritation, dural tears, and wound infections. For example, Wu et al. [27] reported a 7% complication rate, including transient nerve root irritation that resolved without long-term sequelae. Similarly, Yao et al. [20] reported a 5% complication rate, which included dural tears and recurrence of herniation that were successfully managed with conservative treatment or revision surgery. The infection rates in all studies were significantly lower with ESS, with infection rates reported between 0%. This is particularly relevant for patients with obesity, who are typically at a higher risk for wound infections in open procedures. For instance, Olson et al. [28] and Leyendecker et al. [29] noted that the ESS-associated reduced tissue disruption significantly minimized postoperative infections in patients with obesity. Overall, these findings highlight the safety profile of ESS, with a low incidence of serious complications, making it a viable option for patients with obesity.

Operative time and recovery

Operative times for ESS in patients with obesity were longer than those without it, with the average duration ranging from 90 to 180 minutes depending on the complexity of the procedure and extent of obesity. Bae and Lee [26] and Yu et al. [22,23] reported longer operative times in patients with obesity, attributing this to the technical challenges of navigating through thicker soft tissues and the increased difficulty of visualizing anatomical landmarks. Despite these longer operative times, ESS was associated with shorter hospital stays, typically ranging from 2 to 4 days, compared with the 5–7 days commonly reported for open surgeries. Qu et al. [24] found that adolescents with obesity who were undergoing ESS for lumbar disc herniation had an average hospital stay of 3 days, significantly shorter than those undergoing traditional open procedures. In addition, Bergquist et al. [30] reported that despite longer preparation and operative times in patients with obesity, recovery was generally faster, with most patients able to resume normal activities within a few weeks postoperatively. These findings indicate that despite the longer operative time for ESS in patients with obesity, its minimally invasive nature leads to quicker postoperative recovery and shorter hospital stays, which may contribute to reduced healthcare costs and improved patient satisfaction.

Recurrence rates

Four studies reported symptom recurrence, particularly following percutaneous endoscopic lumbar decompression (PELD), with recurrence rates ranging from 3% to 14%. Obesity was identified as a significant risk factor for recurrence. Yao et al. [20] reported that patients with a higher BMI were more likely to experience recurrent herniation, with a recurrence rate of 14%, the highest among the included studies. Recurrences were primarily observed within the first postoperative year and were often related to factors such as central herniation and inadequate decompression. However, most recurrences were successfully managed with revision surgery or conservative treatment, and the long-term outcomes remained favorable for most patients. Wang et al. [25] in 2016 reported a 4.34% recurrence rate, and all recurrences were effectively treated with revision surgery. Although recurrence is a concern in patients with obesity undergoing ESS, it does not significantly affect the overall effectiveness of the procedure, particularly when managed appropriately.

Meta-analysis and publication bias analysis

In this study, only some articles with complete data can be included in the meta-analysis and publication bias analysis. The meta-analysis and publication bias analysis revealed that ESS offers comparable functional outcomes for patients with and without obesity despite some differences in operative time and pain relief. Although publication bias was minimal for ODI and VAS leg pain, potential biases in VAS back pain and operative time highlight the need for further high-quality studies with broader representation. To assess the outcomes of ESS in patients with and without obesity, a meta-analysis focusing on the following key clinical parameters was conducted: back pain (VAS back), leg pain (VAS leg), functional disability (ODI), and operative time. Three studies have reported on VAS back pain. The pooled mean difference (MD) was 0.51 (95% confidence interval [CI], 0.04–0.98; p=0.03), significantly favoring the nonobese group. Heterogeneity was high (I^2=88%, p=0.0002), reflecting the variability among the included studies (Fig. 4A). Three studies analyzed VAS leg pain. The pooled MD was 0.95 (95% CI, 0.56–1.34; p<0.00001), indicating significantly better outcomes in the nonobese group. Heterogeneity was substantial (I^2=83%, p=0.003) (Fig. 4B). Three studies reported functional outcomes measured by the ODI, and the pooled MD was −0.17 (95% CI, −1.74 to 1.40; p=0.83), indicating no significant difference between the obese and nonobese groups. Heterogeneity was moderate (I^2=58%, p=0.09) (Fig. 4C). Three studies reported operative times, with a pooled MD of 6.11 minutes (95% CI, 4.40–7.82; p<0.00001), which was significantly longer in the obese group. High heterogeneity was observed (I^2=90%, p<0.0001), likely due to the technical challenges associated with obesity (Fig. 4D). Although the obese group experience longer operative times and slightly less pain relief than the nonobese group, functional outcomes (ODI) are comparable between the groups.

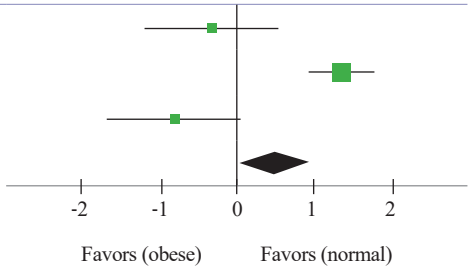
For each outcome, funnel plots were generated to evaluate the potential for publication bias in the included studies (Fig. 5). The funnel plot for VAS back pain exhibited asymmetry, suggesting the potential for publication bias. Smaller studies with less precise estimates may have influenced the pooled results (Fig. 5A). The funnel plot for the VAS leg pain was relatively symmetric, indicating a low likelihood of publication bias. However, the limited number of studies warrants careful interpretation (Fig. 5B). The funnel plot for the ODI was also relatively symmetric, proposing minimal publication bias. The distribution of studies supports the robustness of the findings for functional outcomes (Fig. 5C). The funnel plot for the operative time demonstrated asymmetry, indicating potential publication bias (Fig. 5D). This may be due to the overrepresentation of studies reporting longer operative times in the obese group.

Discussion

This systematic review evaluated the safety and efficacy of ESS in patients with obesity and lumbar spine conditions. The findings demonstrate that ESS offers significant benefits for this population, with substantial pain reduction and improved functional outcomes [26,31,32]. Despite the obesity-related surgical challenges such as increased operative time and a slightly elevated risk of recurrence, ESS provided comparable long-term outcomes to patients without obesity, supporting its role as a minimally invasive alternative to traditional open surgery [10,22,23]. The lower complication and infection rates observed across the studies further highlight ESS as a viable and potentially superior option for managing lumbar spine disorders in patients with obesity. One of the key advantages of ESS identified in this review is its lower complication rates, particularly in terms of wound infections, than traditional open spine surgery [10,22,26]. Patients with obesity undergoing open surgery are at a higher risk of

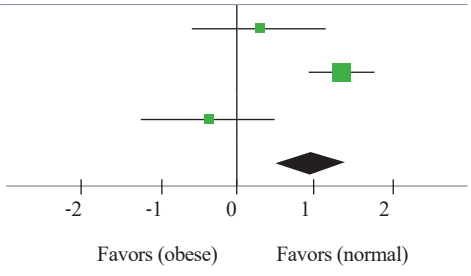
A

Study or subgroup	Obese Mean±SD	Total	Normal Mean±SD	Total	Weight (%)	Mean difference IV, fixed, 95% CI
Bae et al. [26] (2024)	1.6±2.3	21	2±1.1	27	19.3	–0.40 (–1.47 to 0.67)
Kapetanakis et al. [21] (2018)	1.72±1.18	20	0.4±0.52	10	59.2	1.32 (0.71 to 1.93)
Leyendecker et al. [29] (2023)	2±2.5	65	2.9±3	53	21.5	–0.90 (–1.91 to 0.11)
Total (95% CI)		**106**		**90**	**100.0**	**0.51 (0.04 to 0.98)**
Heterogeneity: χ^2=17.05, df=2 (p=0.0002); I^2=88%						
Test for overall effect: Z=2.13 (p=0.03)						



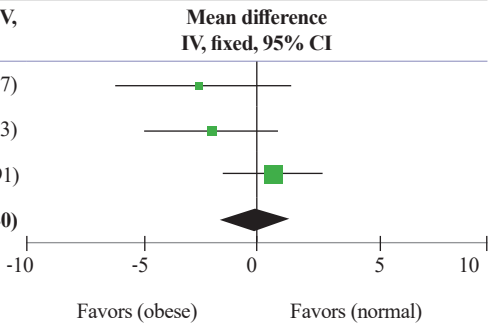
B

Study or subgroup	Obese Mean±SD	Total	Normal Mean±SD	Total	Weight (%)	Mean difference IV, fixed, 95% CI
Bae et al. [26] (2024)	1.4±1.7	21	1±1.4	27	18.8	0.40 (–0.50 to 1.30)
Kapetanakis et al. [21] (2018)	2.22±0.65	20	0.8±0.63	10	65.0	1.42 (0.94 to 1.90)
Leyendecker et al. [29] (2023)	1.6±2.5	65	1.9±2.8	53	16.2	–0.30 (–1.27 to 0.67)
Total (95% CI)		**106**		**90**	**100.0**	**0.95 (0.56 to 1.34)**
Heterogeneity: χ^2=11.47, df=2 (p=0.003); I^2=83%						
Test for overall effect: Z=4.78 (p<0.00001)						



C

Study or subgroup	Obese Mean±SD	Total	Normal Mean±SD	Total	Weight (%)	Mean difference IV, fixed, 95% CI
Bae et al. [26] (2024)	7.8±11.3	21	11±4.1	27	9.6	–3.20 (–8.27 to 1.87)
Leyendecker et al. [29] (2023)	8.8±8.2	65	11.3±9.9	53	22.2	–2.50 (–5.83 to 0.83)
Yu et al. [22,23] (2021)	8.29±4.97	28	7.28±2.13	80	68.2	1.01 (–0.89 to 2.91)
Total (95% CI)		**114**		**160**	**100.0**	**–0.17 (–1.74 to 1.40)**
Heterogeneity: χ^2=4.74, df=2 (p=0.09); I^2=58%						
Test for overall effect: Z=0.21 (p=0.83)						



D

Study or subgroup	Obese Mean±SD	Total	Normal Mean±SD	Total	Weight (%)	Mean difference IV, fixed, 95% CI
Bergquist et al. [30] (2023)	146.8±7.1	74	141.7±4	4	90.7	5.10 (3.30 to 6.90)
Olson et al. [28] (2014)	111±43	26	128±47	47	0.5	-17.00 (-42.34 to 8.34)
Qu et al. [24] (2023)	101.9±9	19	84.3±11	11	8.9	17.60 (11.86 to 23.34)
Total (95% CI)		**119**		**151**	**100.0**	**6.11 (4.40 to 7.82)**
Heterogeneity: χ^2=19.79, df=2 (p<0.0001); I^2=90%						
Test for overall effect: Z=7.00 (p<0.00001)						

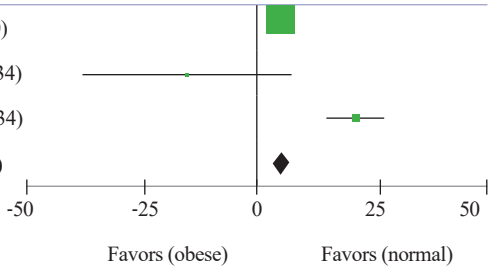


Fig. 4. Forest plot comparison of Visual Analog Scale (VAS) back **(A)**, VAS leg **(B)**, Oswestry Disability Index (ODI) **(C)**, and operative time **(D)** in obese and non-obese patients undergoing endoscopic spine surgery. SD, standard deviation; IV, inverse variance; CI, confidence interval; df, degree of freedom.

postoperative wound infections because of the larger incisions and increased tissue trauma. In contrast, the smaller incisions and less invasive nature of ESS contribute to significantly lower infection rates, with rates ranging from 0% to 3% [22,23,26,33]. This finding aligns with the existing data suggesting that minimally

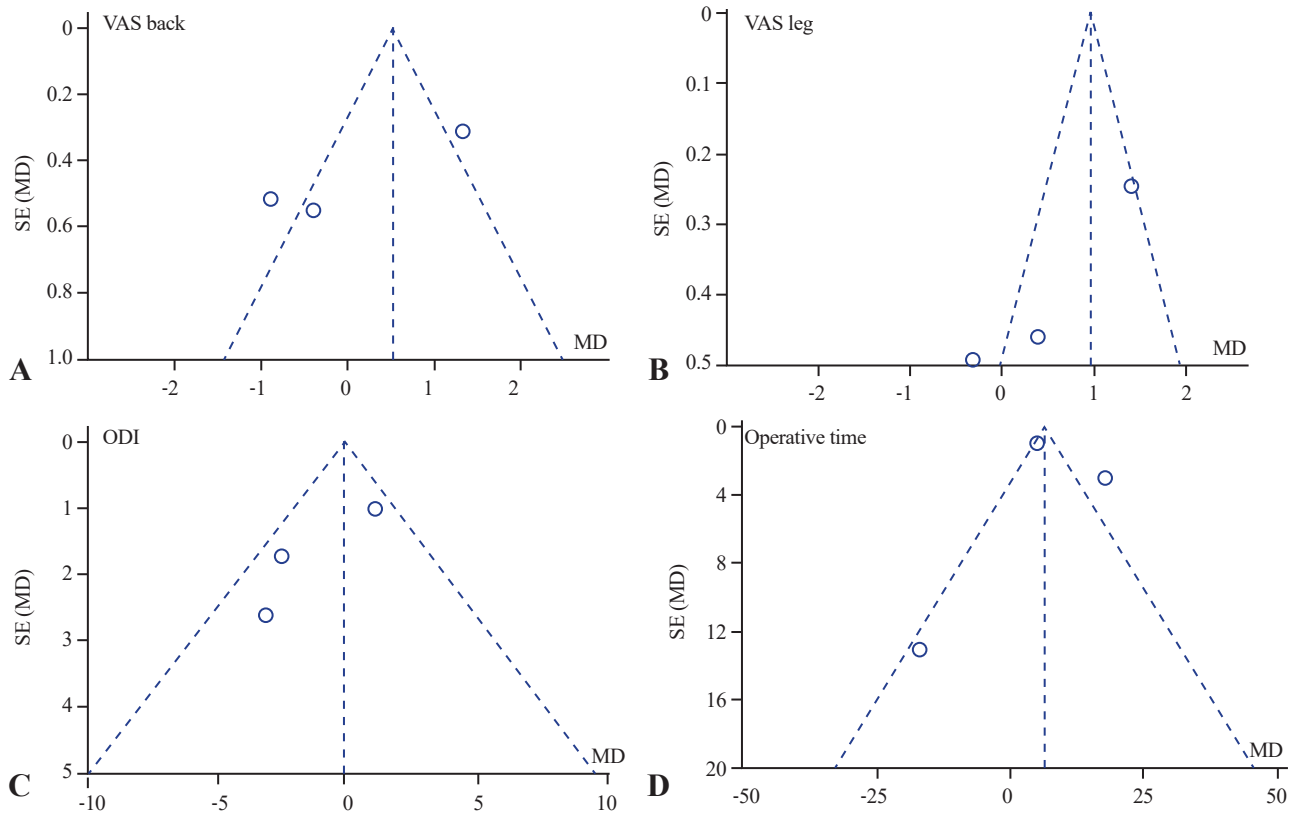


Fig. 5. Funnel plot of publication bias for Visual Analog Scale (VAS) back **(A)**, VAS leg **(B)**, Oswestry Disability Index (ODI) **(C)**, and operative time **(D)**. SE, standard error; MD, mean difference.

invasive techniques reduce the risk of surgical site infections, which is important in patients with obesity in whom wound healing can be compromised.

The effect of obesity on surgical outcomes complicates spinal surgery due to factors such as increased soft tissue, difficulty in accessing anatomical structures, and prolonged operative times. This review confirmed that operative times were generally longer for patients with obesity undergoing ESS, with procedures lasting between 90 and 180 minutes [22,27,29]. Despite these extended durations, the outcomes were not negatively affected. As measured by the ODI, the functional improvements and significant reductions in VAS scores indicate that ESS can effectively manage lumbar spine conditions in the obese group, providing outcomes similar to those observed in the nonobese group [28].

Several studies have reported symptom recurrence, particularly following PELD; the overall recurrence rates were relatively low, ranging from 3% to 14% [22,23,26,27]. Obesity was identified as a potential risk factor for recurrence, which is consistent with previous studies that highlight the increased biomechanical stress on the spine in individuals with obesity [34]. However, most recurrences were managed conservatively or with revision surgery and did not significantly affect the overall efficacy of ESS. The low rates of major complications, including dural tears and nerve root irritation, further support the safety profile of ESS in patients with obesity [24,28]. Furthermore, in this systematic review, the author performed a multimetric comparison across studies on ESS for patients with obesity. The bar chart represents the size of the study groups (Fig. 6), whereas the overlaid line plots show the complication rates, operative times, length of hospital stay, age, and BMI. The visualization highlights correlations and patterns, such as the relationship between higher BMI, age, and complication rates. This report provides an integrated overview, enhancing the understanding of patient demographics and outcomes across the reviewed studies (Fig. 6).

ESS has demonstrated efficacy and safety in patients with obesity, and specific technical challenges must be considered [9,31,35]. The increased soft tissue mass in the obese group can make access to the spinal structures more difficult, potentially leading to longer operative times and the need for specialized instruments [10,12]. Moreover, surgeons must account for the altered anatomy in patients with obesity, which

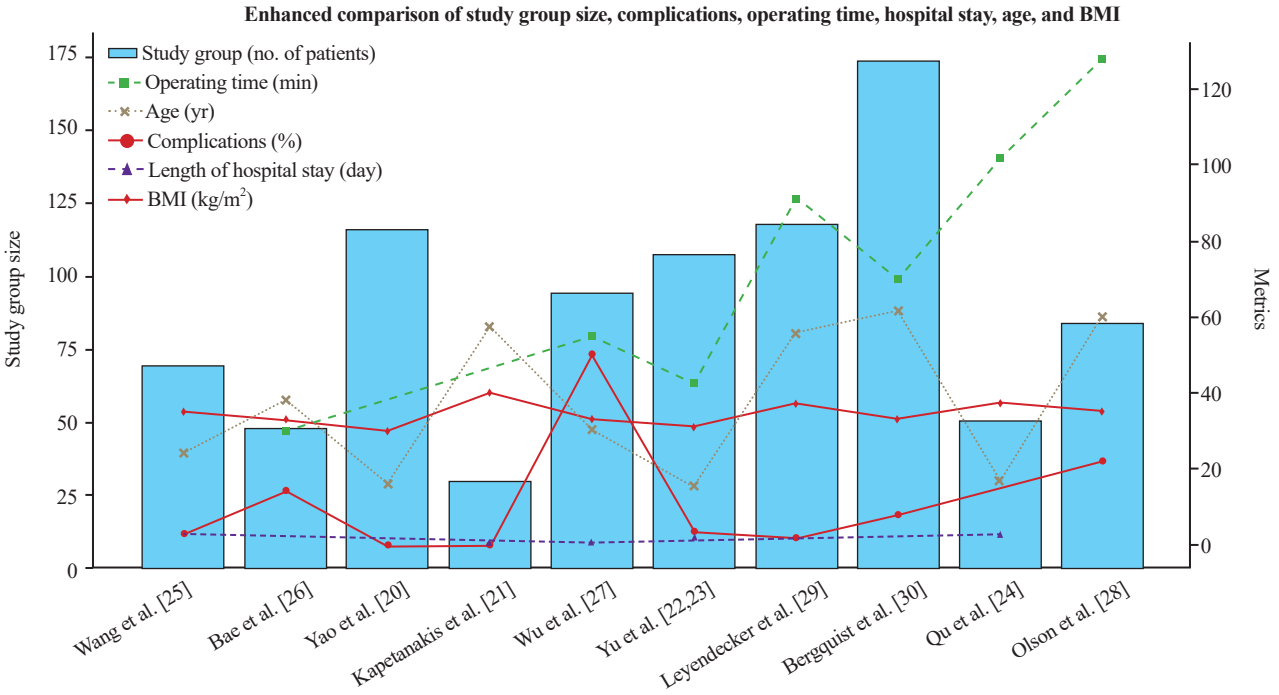


Fig. 6. Comparison chart of study metrics in endoscopic spine surgery for obese patients. BMI, body mass index.

may require adjustments in positioning and the use of extended-length instruments. These factors underscore the importance of surgical expertise and preoperative planning to optimize outcomes in this patient population [28,31,36]. Despite these challenges, the results of this review indicate that ESS remains a highly effective option for patients with obesity when performed by experienced surgeons [24,28,37].

The findings of this review have important clinical implications. Given the rising global prevalence of obesity and the associated increase in spinal disorders, surgical approaches that can mitigate the risks associated with obesity are increasingly needed. ESS, with its minimally invasive nature and favorable safety profile, offers an attractive alternative to traditional open surgery, particularly in reducing perioperative complications and enhancing faster recovery. Clinicians should consider ESS as a primary surgical option for patients with obesity and lumbar spine pathologies, particularly for those at high risk for wound complications or extended hospital stay [24,28,38,39].

The recent review by Jitpakdee et al. [9] compared uniportal and biportal ESS approaches, highlighting their distinct advantages and limitations. The uniportal approach, with a single incision and minimal muscle dissection, is better suited for transforaminal access and requires a rigid working channel but involves a steeper learning curve and higher instrument costs. It offers precision in discectomy with minimal muscle injury and enhanced visualization for fusion; however, it lacks independent instrument maneuverability. Conversely, the biportal approach involves greater maneuverability and a shorter learning curve but necessitates triangulation skills and is less suitable for transforaminal procedures. It excels in complex decompression tasks, such as contralateral sublaminar decompression, is preferred for multilevel stenosis, and enables superior visibility during fusion [9]. Overall, the approaches have unique strengths that make them suitable for different procedural needs and surgeon preferences. Biportal endoscopic surgery has potential advantages for degenerative spinal disease. A recent meta-analysis study by He et al. [40] reported that uniportal techniques often result in shorter operative times and less intraoperative blood loss, whereas biportal approaches offer superior dural sac expansion and greater instrument maneuverability, which can be advantageous in patients with obesity where visibility and access can be challenging because of excess soft tissue. Given the rapid advancements in both techniques, further studies comparing these approaches are crucial. Specifically, studies focusing on patients with obesity would help clarify which technique provides the best balance of efficiency, safety, and clinical outcomes.

Although patients with obesity experienced slightly less improvement in pain relief (VAS back and leg) and

had significantly longer operative times, the findings of our meta-analysis reveal that ESS provides comparable functional outcomes (ODI) to patients with and without obesity. These findings highlight the efficacy of ESS in addressing the unique challenges posed by obesity while maintaining positive clinical outcomes. However, the high heterogeneity in most outcomes underscores the variability in surgical techniques, patient populations, and methodologies, indicating the need for more standardized approaches in future research. Publication bias analysis, as indicated by funnel plots, showed minimal bias for ODI and VAS leg pain; however, potential biases were noted in VAS back pain and operative time. These findings emphasize the importance of cautious interpretation of the results and the need for broader, high-quality studies to validate the outcomes and address the limitations of this meta-analysis.

The study limitations should be considered to provide context for the findings. First, the included studies exhibited significant heterogeneity in terms of surgical methods, patient populations, and outcome measures. Some were single-arm studies that focused on endoscopic techniques, whereas others compared endoscopic surgery with different surgical modalities, making a comprehensive meta-analysis challenging despite our efforts to account for variability through subgroup analyses. Second, the body of literature specifically addressing ESS in patients with obesity is limited, and no RCTs have been conducted, which constrains the generalizability of the findings. Future research should focus on developing specialized technologies and instruments designed to address the unique anatomical challenges associated with obesity. Preoperative protocols aimed at optimizing patient selection and preparation could further improve

Table 4. Summary of the advantages and strategies of endoscopic spine surgery for obese patients for current and future practice

Category	Advantages	Current strategies	Future strategies
Minimally invasive approach	- Reduced tissue damage, resulting in less postoperative pain and quicker recovery. - Smaller incisions reduce risk of wound infections, especially important in obese patients.	- Use of smaller incisions and specialized instruments to minimize tissue disruption. - Employing precise endoscopic visualization to target affected areas.	- Develop more advanced endoscopic instruments tailored for obese patients to enhance precision. - Further refine techniques to reduce the risk of infection and complications, leveraging smaller incisions and better visualization.
Pain management	- Significant reduction in postoperative pain, leading to decreased need for narcotics. - Improved pain management due to targeted approach.	- Preoperative planning and use of nerve monitoring to avoid unnecessary nerve manipulation.	- Implement enhanced pain management protocols specific to endoscopic techniques, reducing reliance on narcotics.
Reduced blood loss	- Minimal blood loss compared to traditional open surgeries, reducing the need for blood transfusions.	- Use of advanced coagulation tools and techniques during surgery.	- Continue to innovate on blood conservation strategies during endoscopic procedures.
Shorter hospital stays	- Faster recovery and reduced hospital stays, leading to cost savings and reduced healthcare burden.	- Early mobilization protocols post-surgery to enhance recovery.	- Develop standardized recovery pathways that optimize discharge times without compromising patient safety.
Lower complication rates	- Lower rates of complications such as wound infections and surgical site infections compared to open surgery.	- Adherence to strict sterile protocols and minimally invasive techniques to reduce infection risks.	- Invest in ongoing training and education for surgeons on infection control specific to endoscopic procedures in obese patients.
Effective for recurrence prevention	- Effective in reducing recurrence rates when patient selection and surgical techniques are optimized.	- Careful patient selection and preoperative imaging to identify suitable candidates for endoscopic surgery.	- Develop risk stratification tools to better identify patients at risk for recurrence and tailor surgical approaches accordingly.
Technical feasibility	- High success rates in obese patients when performed by experienced surgeons.	- Use of high-definition endoscopic cameras and instruments to enhance visualization and precision.	- Encourage widespread training programs and certifications in endoscopic spine surgery techniques to ensure a high level of surgical skill.
Patient satisfaction	- High rates of patient satisfaction due to less postoperative pain, faster recovery, and cosmetic benefits from smaller incisions.	- Incorporate patient feedback into surgical planning and postoperative care to enhance outcomes.	- Develop patient education programs focused on the benefits and realistic expectations of endoscopic surgery.
Enhanced postoperative outcomes	- Significant improvement in pain relief and functional outcomes, evidenced by VAS and ODI scores.	- Regular follow-up and monitoring of clinical outcomes using standardized tools like VAS, ODI, and SF-36.	- Implement long-term outcome tracking and quality improvement initiatives to continuously refine surgical techniques and patient care protocols.
Adaptability for future innovations	- The full-endoscopic technique is adaptable to future technological advancements, making it a sustainable surgical approach.	- Stay updated with the latest advancements in endoscopic technology and integrate them into practice.	- Invest in research and development to explore novel endoscopic tools and methods, such as robotics and AI-assisted surgery, to further improve outcomes in obese patients.

VAS, Visual Analog Scale; ODI, Oswestry Disability Index; SF-36, 36-Item Short Form Survey; AI, artificial intelligence.

outcomes [41]. In addition, long-term follow-up studies are needed to evaluate the durability of ESS outcomes, particularly concerning recurrence rates and the progression of degenerative spinal conditions. Finally, integrating advanced technologies such as robotic-assisted surgery and augmented reality into ESS may enhance its precision and overall effectiveness in this high-risk population. A summary of the advantages and strategies of ESS for patients with obesity is presented in Table 4.

Conclusions

ESS is a viable and effective option for patients with obesity, offering reduced perioperative morbidity and favorable functional outcomes. Adapting ESS techniques to address the unique challenges of obesity can significantly enhance surgical safety and patient recovery. Further large-scale, multicenter studies with long-term follow-up are warranted to confirm these findings and refine techniques for broader application in this high-risk population.

Key Points

- Endoscopic spine surgery (ESS) is a safe and effective alternative for obese patients, offering significant pain relief, functional improvement, and lower complication rates compared to traditional open surgery.
- Obese patients experience longer operative times but benefit from shorter hospital stays, reduced infection rates, and faster recovery, making ESS a favorable option for managing lumbar spine conditions.
- Meta-analysis confirms comparable functional outcomes (Oswestry Disability Index) between obese and non-obese patients, despite slightly higher recurrence rates in obese individuals.
- Heterogeneity among studies and potential publication bias highlight the need for high-quality randomized controlled trials to further validate ESS efficacy in obese populations.
- Future research should focus on optimizing ESS techniques by integrating robotic assistance, augmented reality, and patient-specific surgical planning to improve outcomes in obese patients.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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