REVIEW

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Impact of enhanced recovery after surgery on length of stay and pulmonary complications in patients undergoing thoracic surgery: A systematic review and meta-analysis

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ABSTRACT

Introduction: Enhanced Recovery After Surgery (ERAS) protocols are increasingly applied in thoracic surgery to reduce length of stay (LOS) and postoperative pulmonary complications, yet outcomes remain variable. This study aimed to assess the impact of Enhanced Recovery After Surgery (ERAS) on length of stay and postoperative pulmonary complications in patients undergoing thoracic surgery.

Methods: A systematic review and meta-analysis was conducted in accordance with PRISMA guidelines. PubMed, Ovid MEDLINE, EMBASE, and the Cochrane Library were searched through August 2025. Eligible studies included randomized trials and cohort studies reporting postoperative outcomes in thoracic surgery with ERAS versus conventional care. Random-effects models generated pooled estimates.

Results: Eight studies (four randomized controlled trials and four cohort studies; 3.464 patients) were included in the analysis. ERAS protocols were associated with a significantly shorter hospital length of stay (MD −1.81 days, 95% CI −3.10 to −0.52, $p = 0.006$), although moderate heterogeneity was observed ($I^2 = 62\%$). Importantly, two large RCTs consistently demonstrated a reduction in postoperative pulmonary complications (RR 0.49, 95% CI 0.35–0.69, $p < 0.0001$; $I^2 = 0\%$), with PPCs defined as atelectasis, pulmonary infection, or respiratory failure. The risk of bias was judged to be low for RCTs and low to moderate for observational studies. Overall, ERAS implementation was associated with enhanced perioperative recovery and reduced pulmonary morbidity in patients undergoing thoracic surgery.

Conclusion: Enhanced Recovery After Surgery (ERAS) protocols in thoracic surgery are associated with reduced length of stay and pulmonary complications. While the available evidence suggests potential benefits of ERAS implementation, limitations regarding protocol heterogeneity, implementation feasibility, cost-effectiveness, and institutional differences should be considered. Further multicenter randomized controlled trials using standardized ERAS protocols are warranted to confirm these benefits and determine the optimal implementation strategies.

Keywords: Enhanced Recovery After Surgery, length of stay, thoracic surgery.
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INTRODUCTION

Enhanced Recovery After Surgery (ERAS) protocols have been increasingly implemented to improve perioperative outcomes in thoracic surgery. These multimodal, evidence-based pathways encompass preoperative counseling and optimization, opioid-sparing multimodal analgesia, minimally invasive surgical techniques when feasible, early mobilization, and standardized perioperative care to attenuate surgical stress and facilitate recovery. In thoracic surgery, the specialty-adapted pathway, commonly referred to as Enhanced Recovery After Thoracic Surgery (ERATS), incorporates additional elements relevant to pulmonary and thoracic procedures, including nutritional and smoking-cessation optimization, lung-protective anesthesia, standardized chest-tube management, early respiratory physiotherapy, and prompt ambulation. Recommendations from ERAS consensus groups and thoracic surgical societies have incorporated many of these components into practical perioperative pathways for institutional implementation.[1,2]

The principal objectives of ERAS/ERATS pathways in thoracic surgery are to reduce postoperative morbidity, facilitate functional recovery, and shorten hospitalization without compromising surgical or oncologic outcomes when applicable. Previous systematic reviews, meta-analyses, and observational studies have reported associations between ERAS implementation and shorter length of stay,

reduced duration of chest-tube placement, fewer postoperative complications, and improved recovery-related outcomes.[3–5] However, the magnitude and consistency of these benefits have varied across studies, partly because of differences in ERAS pathway composition, degree of protocol adherence, patient populations, surgical procedures, outcome definitions, and institutional resources.

Although several systematic reviews and meta-analyses have previously evaluated ERAS in thoracic surgery, important uncertainties remain. First, the evidence base continues to evolve, particularly with the publication of more recent randomized controlled trials (RCTs), which may provide higher-quality evidence regarding the effectiveness of ERAS compared with observational studies. Second, previous reviews have differed in their inclusion criteria, study populations, ERAS components, and outcome definitions, and some were conducted before the availability of more recent evidence. Therefore, an updated synthesis incorporating contemporary studies is warranted to determine whether the conclusions of earlier reviews remain applicable. Third, pulmonary complications are particularly relevant in thoracic surgery because postoperative respiratory morbidity represents a major determinant of delayed recovery, prolonged hospitalization, and resource utilization. Nevertheless, pulmonary complications have not consistently been evaluated as a specific primary outcome across previous meta-analyses, and the magnitude of their association with ERAS implementation remains less clearly established than overall postoperative morbidity or length of stay.

Furthermore, the relative consistency of treatment effects between randomized and observational evidence remains uncertain. Observational studies may provide valuable information regarding real-world implementation and external validity but are more susceptible to selection bias, confounding, and differences in institutional practice. Conversely, RCTs provide stronger evidence for causal inference but may have more restrictive eligibility criteria and therefore limited generalizability. A systematic evaluation that considers these two sources of evidence separately may provide a more comprehensive assessment of the effectiveness of ERAS in thoracic surgery.

Accordingly, this systematic review and meta-analysis was undertaken to provide an updated synthesis of the available evidence, including recent randomized controlled trials and observational studies, regarding the effects of ERAS protocols in thoracic surgery. In particular, this study evaluates length of stay and postoperative pulmonary complications as clinically relevant outcomes and examines whether the observed effects are consistent between randomized and observational evidence. By incorporating the evolving evidence base and specifically assessing pulmonary complications, this study aims to provide an updated and clinically relevant estimate of the potential benefits of ERAS implementation in thoracic surgery while acknowledging the heterogeneity of protocols and clinical settings.

METHODS

Study Design

This study was designed as a systematic review and meta-analysis conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The review followed the PRISMA extension for systematic reviews of interventions.

Data Sources and Search Strategy

A comprehensive literature search was conducted in PubMed, Ovid MEDLINE, EMBASE, and the Cochrane Library from database inception through August 2025. Search strategies combined controlled vocabulary and free-text terms related to "thoracic surgery" and ("ERAS" OR "Enhanced Recovery After Surgery"). Although the databases were searched from inception, eligibility was restricted to studies published between January 2020 and August 2025. This publication window was selected to focus the review on contemporary ERAS implementation in thoracic surgery, reflecting the increasing standardization and refinement of ERAS/ERATS pathways, perioperative care practices, and minimally invasive surgical approaches during this period. Earlier studies were excluded because differences in ERAS pathway composition, perioperative management, surgical techniques, and implementation standards may limit their comparability with contemporary ERAS protocols. Nevertheless, this restriction may have excluded potentially relevant earlier evidence and is therefore acknowledged as a limitation of the present review. The complete search strategy for each database was documented, and reference lists of included articles were manually screened to identify additional eligible studies.

Eligibility Criteria

Studies were considered eligible if they met the predefined inclusion criteria. We included randomized controlled trials (RCTs), controlled clinical trials (CCTs), and observational studies involving patients undergoing thoracic surgery, including lung resection, thoracotomy, or video-assisted thoracoscopic surgery (VATS). Eligible studies evaluated the implementation of an enhanced recovery after surgery (ERAS) or enhanced recovery after thoracic surgery (ERATS) protocol and compared it with standard perioperative care. The primary outcome of interest was length of hospital stay, while secondary outcomes included pulmonary complications and chest tube duration. Only studies published in English between 2020 and 2025 with freely accessible full-text articles were included. Studies were excluded if they were case reports, conference abstracts, editorials, review articles, or other publication types without original comparative data. Studies without a comparator group were also excluded. In addition, studies were excluded if they did not report at least one of the predefined outcomes relevant to this review, namely length of hospital stay, pulmonary complications, or chest tube duration.

Data Extraction and Quality Assessment

Two independent reviewers extracted data on study characteristics (author, year, study design, population), ERAS interventions, control groups, primary and secondary outcomes, and key findings. Outcomes of interest for meta-analysis included LOS and postoperative pulmonary complications.

Data Synthesis and Statistical Analysis

For continuous outcomes such as length of stay (LOS), mean differences (MD) with 95% confidence intervals were calculated. When studies reported medians (Bang et al. 2024), values were converted to means and standard deviations using established statistical methods. For dichotomous outcomes, including postoperative pulmonary complications (PPCs), risk ratios (RR) with 95% confidence intervals were extracted or derived from available data. Meta-analyses were performed using a random-effects model to account for anticipated heterogeneity across study populations, surgical procedures, and ERAS protocols. Statistical heterogeneity was quantified with the I^2 statistic, with values >50% interpreted as indicating substantial heterogeneity.

RESULTS

Study Selection

The study selection process was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as illustrated in **Figure 1**. A total of 1,280 records were initially identified through four electronic databases: PubMed (n = 521), Ovid (n = 222), Embase (n = 337), and the Cochrane Library (n = 200). After removing 120 duplicate records, 1,160 records underwent title and abstract screening, of which 885 were excluded due to irrelevance to the research objectives. The remaining 275 records were further screened, resulting in the exclusion of 65 non-English studies. Subsequently, 210 reports underwent full-text eligibility assessment, of which 202 were excluded because they were classified as case reports. Ultimately, eight studies met the predefined eligibility criteria and were included in the systematic review and meta-analysis (**Figure 1**).

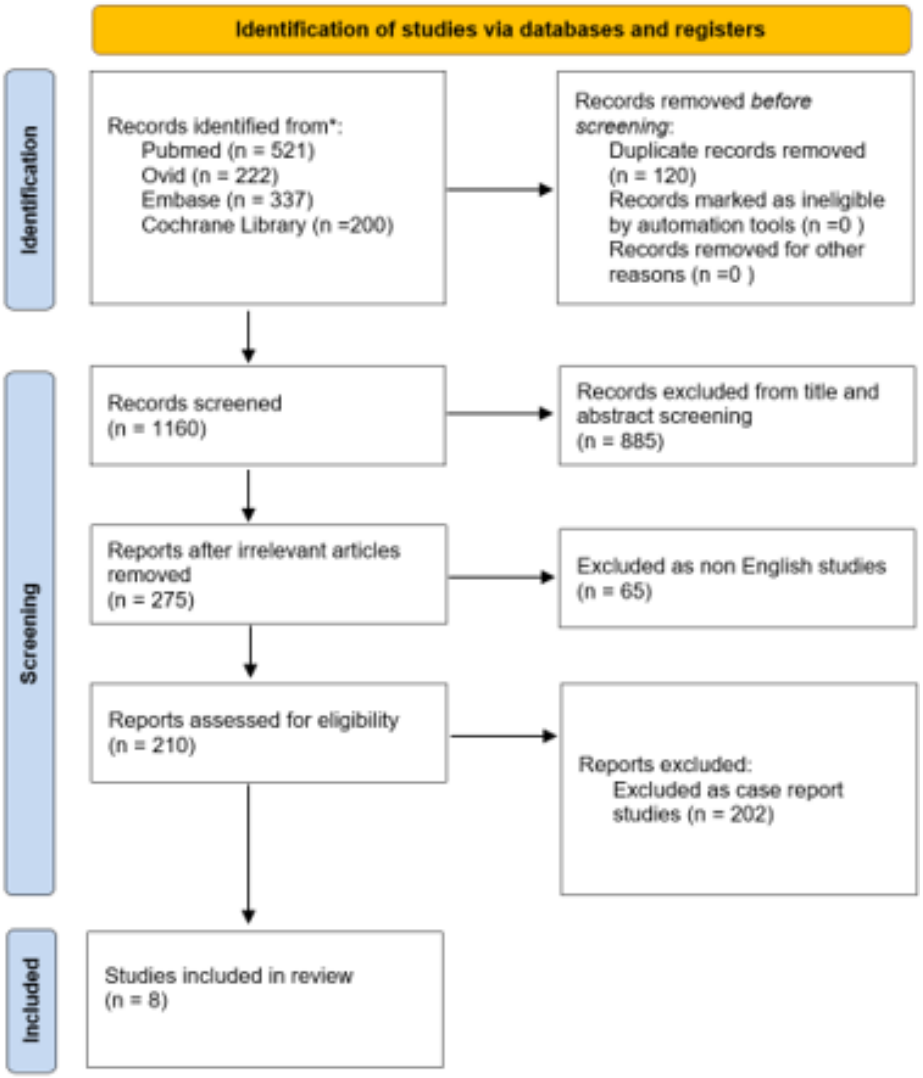


Figure 1. Flow chart of study selection

Description of Included Studies

This systematic review included eight studies comprising four randomized controlled trials (RCTs), two prospective cohort studies, one retrospective cohort study, and one observational single-center study, with a total of 3,464 patients undergoing thoracic surgery. The included studies were predominantly conducted in patients undergoing pulmonary resection for lung cancer, particularly video-assisted thoracoscopic surgery (VATS) lobectomy or other minimally invasive lung resections. Therefore, the applicability of these findings to other thoracic surgical populations, including non-oncologic procedures and open thoracic surgery, may be limited.

The characteristics of the included studies are summarized in Table 1, including study design, sample size, baseline patient characteristics, surgical approach, ERAS protocol components, methods used to assess protocol adherence, follow-up duration, and reported clinical outcomes. Although the core components of ERAS were generally similar across studies, the specific interventions and intensity of implementation varied. Components commonly included preoperative patient education and optimization, multimodal or opioid-sparing analgesia, early mobilization, respiratory physiotherapy, early oral intake, and standardized chest-tube management. However, the measurement and reporting of ERAS adherence were not uniform across studies, with differences in the number of protocol elements assessed and the thresholds used to define adherence.

Among the four RCTs, Ding et al. (2024) evaluated 611 patients undergoing VATS lung resection and reported a lower incidence of postoperative pulmonary complications (PPCs) in the ERAS group compared with routine care (11.5% vs. 22.9%), together with shorter chest-drain duration and length of stay (LOS)[6] Wang et al. (2024), focusing on elderly patients

undergoing thoracic surgery, similarly reported lower PPC rates, shorter chest-tube duration, lower postoperative pain scores, and improved pulmonary function on postoperative day 7 in the ERAS group.[7] Huang et al. (2024) evaluated an ERAS pathway incorporating exercise and nutritional optimization and reported improvements in recovery-related outcomes and pulmonary function. However, no statistically significant difference in postoperative complications was observed.[8] Zhang et al. (2024) evaluated an intensive ERAS pathway in patients undergoing VATS day surgery. They reported earlier mobilization, earlier chest-tube removal, and fewer postoperative complications compared with a less intensive perioperative pathway.[9]

The observational studies generally supported the direction of the findings observed in the RCTs. Stuart et al. (2024), in a multicenter cohort of 960 patients, reported that greater adherence to multiple ERAS components was associated with reductions in overall morbidity, cardiopulmonary complications, and LOS.[10] Similarly, Ni et al. (2021) showed that ERAS shortened hospitalization, chest tube indwelling time, and opioid use while also improving cost-effectiveness in 629 minimally invasive lobectomies.[11] Retrospective analysis by Fryer et al. (2024) revealed decreased LOS and ICU admissions following ERAS adoption, with stable complication and mortality rates.[12] Finally, Bang et al. (2024) observed shorter hospital stays and fewer readmissions in NSCLC patients, although complication and re-operation rates did not significantly differ from standard care. Collectively, these studies provide robust evidence that ERAS is both effective and feasible in improving short-term outcomes after thoracic surgery.[13]

The pooled analysis demonstrated a statistically significant reduction in LOS associated with ERAS implementation. However, substantial between-study heterogeneity was observed (I^2 = 62%), indicating that the magnitude of the reduction varied across studies. This heterogeneity may reflect differences in patient characteristics, surgical procedures, ERAS pathway components,

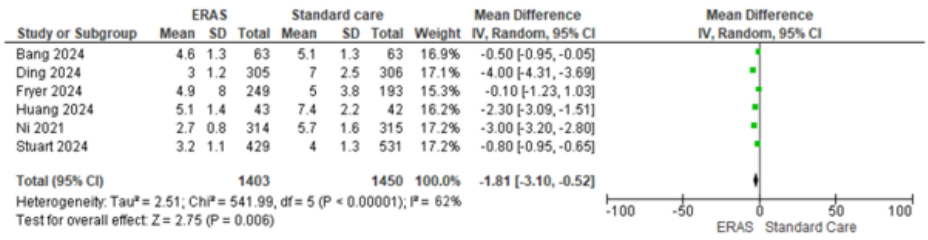


Figure 2. Forest plot of length of stay

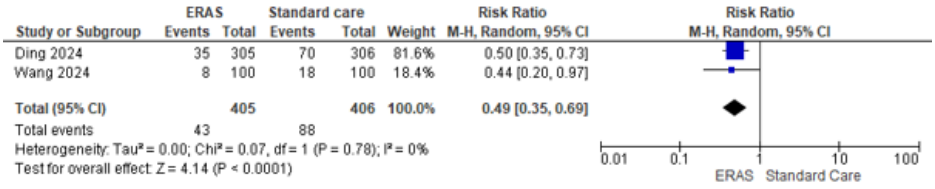


Figure 3. Forest plot of postoperative pulmonary complications

adherence, institutional practices, and discharge criteria. Therefore, although the reduction in LOS appears clinically relevant, the pooled estimate should be interpreted in the context of this moderate-to-substantial heterogeneity.

The meta-analysis of PPCs included only two RCTs. Both studies reported fewer PPCs with ERAS implementation, and the pooled analysis showed a statistically significant reduction in PPCs. However, the limited number of contributing studies and the predominance of lung cancer surgery populations warrant cautious interpretation of this finding. In addition, the definitions and ascertainment methods for PPCs were not completely uniform between the two studies. Consequently, although the direction of effect was consistent, differences in PPC definitions may contribute to variation in the observed effect estimates and limit direct comparability between studies.

Despite low statistical heterogeneity in the PPC analysis (I^2 = 0%), this estimate should not be interpreted as definitive evidence of consistency because it was derived from only two studies. With such a small number of studies, the statistical assessment of heterogeneity has limited precision and may not adequately capture potential clinical or methodological differences between studies.

Overall, the included evidence suggests that ERAS implementation is associated with shorter LOS and may reduce PPCs following thoracic surgery, particularly in patients undergoing minimally invasive pulmonary resection for lung cancer. However, the interpretation of these findings should account for heterogeneity in LOS outcomes, variation in ERAS components and adherence assessment, differences in PPC definitions, and the limited number of RCTs contributing to the PPC analysis.

Length of Stay

A total of six studies comprising 2,853 patients (1,403 in ERAS and 1,450 in standard care) reported postoperative length of stay. The pooled analysis demonstrated that ERAS protocols were associated with a significantly shorter hospital stay compared with standard care (MD −1.81 days, 95% CI −3.10 to −0.52, p=0.006). Statistical heterogeneity was moderate-to-high (I^2 = 62%, p < 0.00001), indicating that the variability in effect estimates across studies was greater than would be expected by chance alone. This heterogeneity may be related to differences in study characteristics, including study design, patient populations, ERAS protocol implementation, and perioperative care practices. In particular, the included studies comprised both prospective randomized and observational designs. Ding et al. (2024) was a prospective randomized controlled study involving 611 patients, whereas Fryer et al. (2024) was a retrospective cohort study. Differences in study methodology and clinical settings may therefore have contributed to the observed variability in treatment effects. Nevertheless, the direction of effect was

Table 1. Comparative analysis of the studies included

No	Author, Year	Study Type / Population	ERAS Intervention	Control Group	Primary Outcome	Key Findings / Results
1	Ding Y et al., 2024	Prospective RCT, VATS lung resection (n=611)	ERAS	Routine care	Postoperative pulmonary complications (PPCs), short-term outcomes, LOS, drain duration	ERAS: earlier oral feeding & mobilization, shorter drain duration (2 vs 5 days), shorter LOS (3 vs 7 days), lower PPCs (11.5% vs 22.9%)
2	Wang Z et al., 2024	RCT, elderly lung cancer patients undergoing thoracoscopic surgery (n=200)	ERAS model with multimodal perioperative care	Routine perioperative management	PPCs, chest tube duration, pain, pulmonary function	ERAS reduced PPCs (8% vs 18%), shorter chest tube duration (2.6 vs 3.9 days), lower pain (2.1 vs 3.8), and better pulmonary function (FVC, FEV1) on day 7
3	Huang L et al., 2024	RCT, thoracoscopic radical lung cancer resection (n=85)	ERAS-based exercise–nutrition management	Routine care	Perioperative recovery indicators, nutritional status, lung function	ERAS improved bowel recovery, earlier ambulation, shorter drainage and LOS; better nutrition (↑ALB, PA, Hb), improved lung function (↑FEV1, MVV, FVC), lower VAS pain; complication rates not significantly different (6.9% vs 11.9%)
4	Zhang H et al., 2024	Pragmatic RCT, VATS day surgery for pulmonary nodules (n=340, PSM adjusted)	Two levels of ERAS protocols	Less intensive ERAS protocol	Recovery indicators, chest tube duration, ambulation, complications, pain, psychological outcomes	Intensive ERAS group had more frequent chest tube removal < 24 h, earlier ambulation, lower complication rates, and no increase in pain compared to less intensive ERAS.
5	Stuart CM et al., 2024	Prospective multi-center cohort, patients undergoing anatomic lung resection (n=960)	Thoracic ERAS protocol	Historical control	Overall morbidity, cardiac, respiratory, infection morbidity, LOS	High adherence (4–5/5 elements) reduced overall morbidity, cardiopulmonary complications, and LOS; infection morbidity not significant
6	Ni H et al., 2021	Cohort, minimally invasive lobectomy (n=629)	ERAS	Routine management	LOS, postoperative complications, chest tube indwelling time (CTIT), postoperative opioid dose (POD), total cost (TC)	ERAS group had shorter LOS, fewer complications, shorter CTIT, reduced POD, and lower TC; additional strategies: single intercostal nerve block, COX-2 inhibitor, early chest tube removal
7	Fryer ML et al., 2024	Retrospective, patients undergoing minimally invasive lung resection (n=442)	ERAS	Pre-ERAS	LOS, postoperative complications, ICU admission, 30-day readmission, mortality	LOS decreased (4 → 3 days), ICU admission decreased (15% → 7.6%), complications & mortality similar, 30-day readmission unchanged
8	Bang HT et al., 2024	Observational single-center, NSCLC patients post-lobectomy (n=197)	ERAS	Routine care	LOS, complications, re-operations, readmissions	LOS shorter (4.6 vs 5.1 days, p=0.01); 30-day readmission lower (1.6% vs 14.3%, p=0.02); complications & re-operations not significantly different

consistent across all included studies, supporting the conclusion that ERAS implementation is associated with a reduction in postoperative hospitalization duration following lung resection surgery (**Figure 2**).

Postoperative Pulmonary Complications

Two randomized controlled trials (Ding et al., 2024; Wang et al., 2024) assessed the effect of ERAS protocols on postoperative pulmonary complications (PPCs). The definition and ascertainment of PPCs were reported separately for each trial, and differences in outcome definitions and assessment methods were considered when interpreting the pooled results. Pooled analysis demonstrated a significant reduction in PPCs among patients managed with ERAS compared with standard perioperative care (RR = 0.49, 95% CI 0.35–0.69, $p < 0.0001$). Statistical heterogeneity was negligible ($I^2 = 0\%$, $p = 0.78$), indicating a consistent direction and magnitude of effect across the two trials. In the trial by Ding et al., PPCs occurred in 11.5% of patients in the ERAS group compared with 22.9% in the control group, whereas Wang et al. reported PPC rates of 8% and 18%, respectively. Despite potential differences in the operational definition and ascertainment of PPCs between trials,

Table 2. NOS risk of bias summary

No	Study	Study Design / Population	NOS Selection (0–4)	NOS Comparability (0–2)	NOS Outcome (0–3)	Total (0–9)	Risk of Bias
1	Stuart CM et al., 2024	Prospective multi-center cohort, n=960, anatomic lung resection	4	2	3	9	Low
2	Ni H et al., 2021	Cohort, n=629, minimally invasive lobectomy	3	1	3	7	Low–Moderate
3	Fryer ML et al., 2024	Retrospective cohort, n=442, minimally invasive lung resection	3	2	2	7	Low–Moderate
4	Bang HT et al., 2024	Observational single-center cohort, n=197, NSCLC post-lobectomy	3	1	2	6	Moderate

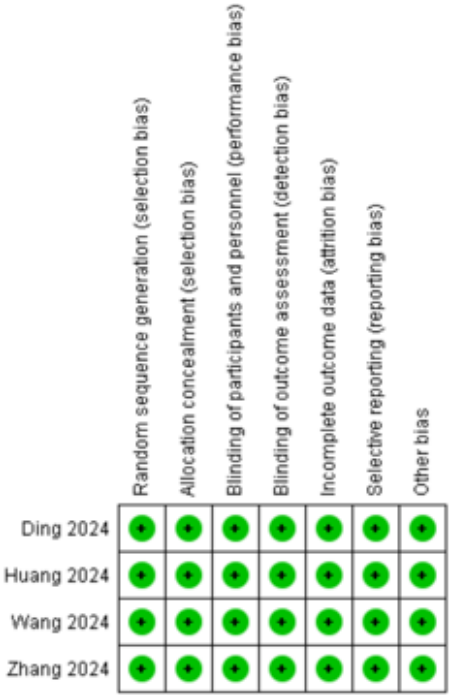


Figure 4. Risk of bias using Cochrane Risk of Bias for RCT

the findings consistently favored ERAS, supporting its association with a lower risk of postoperative pulmonary morbidity following thoracic surgery (**Figure 3**).

Risk of Bias in Included Studies

The risk of bias assessment demonstrated that the methodological quality of the included studies was generally acceptable. Observational and non-randomized controlled studies were assessed using the Newcastle–Ottawa Scale (NOS), with scores ranging from 6 to 9 out of 9. Stuart CM et al. (2024) achieved the maximum score (9/9), reflecting rigorous participant selection, appropriate comparability between groups, and adequate outcome assessment, indicating a low risk of bias.12 Ni et al. (2024), Fryer et al. (2024), and Bang et al. (2024) received NOS scores of 6–7, representing moderate to low–moderate risk of bias, primarily related to limitations in cohort comparability and outcome ascertainment, as well as the retrospective and single-center nature of some studies. Overall, these findings suggest that the observational evidence is reasonably reliable, although residual confounding and selection bias cannot be completely excluded.

For the studies confirmed as randomized controlled trials, risk of bias was assessed using the Cochrane Risk of Bias tool, version 1 (RoB 1). The assessment followed the RoB 1 domains of sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other potential sources of bias. Domain-level judgments were made for each included randomized trial and are presented in Figure 4. Overall, the confirmed randomized controlled trials demonstrated predominantly low risk of bias across the assessed domains. However, individual domains with unclear or high risk were considered in the interpretation of the findings. Collectively, the risk-of-bias assessments provide reasonable confidence in the internal validity of the included evidence. However, the presence of non-randomized studies introduces potential risks of selection bias, confounding, and other methodological limitations, which should be considered when interpreting the pooled estimates.

DISCUSSION

ERAS protocols in thoracic surgery were associated with shorter hospital stay and lower complication rates in our pooled analysis, findings that are consistent with prior syntheses showing meaningful reductions in length of stay and postoperative morbidity after implementation of enhanced recovery pathways. Several thoracic ERAS systematic reviews and meta-analyses have reported similar benefits—reduced LOS, fewer pulmonary complications, and lower readmission in many series—supporting the external validity of our results.[14,15] A systematic review in thoracic surgery demonstrated a mean reduction in length of stay by approximately 3 days, along with fewer pulmonary complications and readmissions.[14]

Implementation of Enhanced Recovery After Surgery (ERAS) pathways in thoracic surgery was associated with clinically meaningful improvements in the early postoperative period. In our pooled analysis, ERAS reduced hospital length of stay and chest-tube duration and—critically—the randomized evidence showed a robust decrease in postoperative pulmonary complications (PPCs). Large RCTs and high-quality cohorts consistently

reported fewer PPCs and shorter LOS after ERAS implementation.[6,9–11] Meta-analytic work in thoracic surgery has reached similar conclusions, reporting reduced LOS and postoperative morbidity after ERAS/ERATS adoption, which supports the external validity of our findings.[14]

Interpretation requires attention to between-study heterogeneity and differences in study design, patient mix, and ERAS content. While pooled LOS and chest-tube estimates favored ERAS, statistical heterogeneity was high—driven largely by variability between large retrospective cohorts and smaller RCTs or single-center matched studies.[11–13] By contrast, PPC outcomes from randomized trials were remarkably consistent (low heterogeneity), strengthening the inference that core ERAS elements (early mobilization, multimodal analgesia with opioid-sparing strategies, protocolized chest-drain management, and targeted respiratory physiotherapy) reduce respiratory morbidity after lung resection. These mechanistic pathways are supported by guideline recommendations and rehabilitation literature emphasizing breathing-exercise and physiotherapy components.[16]

Limitations of the current evidence base temper the strength of causal claims. First, many LOS estimates originate from nonrandomized cohorts and are susceptible to residual confounding and center effects; second, ERAS bundles varied across studies (which complicates attribution to single components); third, outcome reporting (median vs mean, different PPC definitions) was heterogeneous and required statistical harmonization for pooling. Prior systematic reviews similarly call for standardized outcome definitions, core outcome sets, and more multicenter randomized evaluations. Pending such data, the consistent RCT signal for reduced PPCs combined with favorable real-world LOS and chest-tube findings supports considered implementation of ERAS in thoracic surgery, accompanied by local audit, adherence monitoring, and prospective collection of standardized endpoints (including cost and patient-reported outcomes).[14]

CONCLUSION

Enhanced Recovery After Surgery (ERAS) protocols in thoracic surgery are associated with shorter hospital length of stay and fewer postoperative pulmonary complications compared with standard care. Despite heterogeneity in study design, patient populations, and ERAS implementation, the available evidence suggests that ERAS represents a promising perioperative strategy for improving short-term outcomes following thoracic surgery. However, the current evidence remains limited by variability in ERAS components, adherence assessment, and outcome definitions, as well as the limited number of randomized controlled trials evaluating postoperative pulmonary complications. Further multicenter randomized controlled trials using standardized ERAS protocols, adherence measures, and outcome definitions are warranted to confirm the effectiveness and generalizability of ERAS and to determine optimal implementation strategies across diverse thoracic surgical settings.

DISCLOSURES

ETHICAL CONSIDERATION

Not applicable.

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This study received no external funding or financial support from any public, commercial, or not-for-profit funding agencies.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

AUTHOR CONTRIBUTIONS

WK: Conceptualization, methodology, supervision, project administration, and writing–review and editing. B: Investigation, data collection, and writing–original draft. GS: Methodology, data curation, and formal analysis. AU: Literature search, data extraction, and validation. AN: Formal analysis, data interpretation, and visualization. AHLT: Validation, supervision, and writing–review and editing. IHN: Conceptualization, supervision, and critical revision of the manuscript. All authors read and approved the final version of the manuscript.

USE OF ARTIFICIAL INTELLIGENCE

No artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript.

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