Dong *et al. BMC Surgery* (2025) 25:239
https://doi.org/10.1186/s12893-025-02976-9

BMC Surgery

RESEARCH

Open Access

Effect of ERAS pathway nursing on postoperative rehabilitation of patients undergoing gastrointestinal surgery: a meta-analysis

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Abstract

Background This study aimed to systematically evaluate the impact of the Enhanced Recovery After Surgery (ERAS) pathway on postoperative outcomes—including hospital length of stay, complication rates, readmission, reoperation, and mortality—in patients undergoing gastrointestinal surgery, to provide evidence-based guidance for clinical practice.

Methods We systematically searched PubMed, Cochrane Library, Embase, Web of Science and Scopus databases for randomized controlled trials (RCTs) and cohort studies on ERAS pathway in postoperative rehabilitation. Thirteen studies comprising a total of 5,603 patients were included. Literature screening and quality assessment followed the standards of Cochrane Collaboration and Newcastle-Ottawa scales. Statistical analysis was performed using R software to calculate the relative risk (RR), mean difference (MD) with 95% confidence interval (CI), and heterogeneity through the I^2 statistic, with significance set at $P < 0.05$. This systematic review and meta-analysis has been registered in the PROSPERO database (ID: CRD42024608876).

Results The ERAS pathway significantly shortened the postoperative hospital stay (MD = -3.16, 95% CI [-4.10, -2.21], $P < 0.01$) and reduced the incidence of postoperative complications (RR = 0.70, 95% CI [0.58, 0.84], $P < 0.01$). It also significantly reduced the readmission rates (RR = 0.75, 95% CI [0.58, 0.96], $P = 0.02$). However, there was no statistically significant difference in the impact of ERAS pathway on reoperation rate and mortality (RR = 0.59, 95% CI [0.01, 30.14], $P = 0.62$).

Conclusions ERAS protocols are associated with improved postoperative recovery in gastrointestinal surgery, including shorter hospital stays and reduced complication and readmission rates. Although no significant effects were found for reoperation or mortality, the overall evidence supports the broader clinical adoption of ERAS, with a need for further high-quality studies to address remaining uncertainties.

Keywords Enhanced recovery after surgery, Gastrointestinal surgical procedures, Postoperative care, Postoperative complications, Meta-analysis, Systematic review

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Introduction

Enhanced recovery after surgery (ERAS) is a multidisciplinary postoperative care strategy aimed at promoting rapid recovery by optimizing perioperative management measures [1, 2], including anesthesia, surgical techniques, nutritional management, and pain control [3, 4]. ERAS reduces postoperative stress and complications by reducing preoperative preparation, optimizing anesthetic drugs, and encouraging early postoperative activities and dietary recovery [5].

Gastrointestinal (GI) surgeries, such as colorectal and gastric resections, are associated with substantial perioperative risk. In high-risk populations, complication rates can reach up to 80%, and perioperative mortality may be as high as 20% [6]. These adverse outcomes contribute to extended hospitalizations, increased readmission rates, and considerable strain on healthcare systems. ERAS protocols have been widely adopted in elective colorectal and upper GI surgeries and have demonstrated benefits in reducing postoperative complications and hospitalization duration [7, 8]. However, findings remain inconsistent across surgical types and patient populations. For instance, a meta-analysis reported that while ERAS effectively reduced complication rates in obstructive colorectal cancer surgery, its impact on readmissions and reoperations was limited [9]. Similarly, Huang et al. [10]and Catarci et al. [11] found significant variability in ERAS implementation and outcomes, partly due to differences in protocol adherence and study populations.

Despite growing evidence, most existing reviews have focused on specific surgical contexts (e.g., colorectal or gastric surgery) or elective procedures, and lack comprehensive coverage of the broader spectrum of gastrointestinal surgeries, including emergency operations [12–15]. Additionally, prior analyses often included a limited number of studies or did not assess outcomes such as reoperation or mortality in detail [10, 16–18]. Therefore, there remains a clear gap in the literature: a need for an up-to-date, large-scale meta-analysis evaluating the effectiveness of ERAS protocols across diverse gastrointestinal procedures.

This study addresses that gap by systematically evaluating the impact of ERAS on postoperative recovery in patients undergoing gastrointestinal surgery. Following a structured PICO framework, the Population includes adult patients undergoing GI surgery; the Intervention consists of perioperative care based on ERAS protocols; the Comparator is conventional postoperative management; and the Outcomes include hospital length of stay, postoperative complications, readmission rates, reoperation, and mortality. By synthesizing findings across both elective and emergency surgeries, this review aims to clarify the overall clinical value and limitations of ERAS and provide evidence-based guidance for postoperative care in gastrointestinal surgery.

Methods

This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

Literature search

This study systematically searched PubMed, Cochrane Library, Embase, Web of Science, and Scopus databases to collect randomized controlled trials (RCTs), clinical controlled trials, and cohort studies on the ERAS pathway in postoperative rehabilitation of patients undergoing gastrointestinal surgery. The search time range was from the establishment of the database to October 2024, and the language limit was English. The search keywords used a combination of subject terms (MeSH) and free words.

The main search terms are as follows: "Enhanced Recovery After Surgery", "ERAS", "Fast-track surgery" and "Accelerated recovery", "Gastrointestinal surgery", "Digestive surgery", "Gastrointestinal tract surgery", "Colorectal surgery", "Gastric surgery", "Bowel resection", "Intestinal surgery", "Stomach surgery", "Colorectal cancer surgery" and "Abdominal surgery", "Postoperative recovery", "Surgical surgery" recovery", "Post-surgical outcomes", "Postoperative outcomes", "Recovery of function", "Recovery time" and "Postoperative care".

The search strategy was based on a combination of Boolean logical operators (AND, OR), such as: "Enhanced Recovery After Surgery" OR "ERAS" AND "Gastrointestinal surgery" OR "Colorectal surgery" AND "Postoperative recovery" OR "Post-surgical outcomes" AND "Randomized controlled trial" OR "Cohort study". The detailed search strategy for each database was provided in Supplementary Table S1.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) Population: Adult patients (aged ≥ 18 years) undergoing gastrointestinal surgery, including but not limited to patients undergoing surgery for digestive system diseases such as gastric cancer and colorectal cancer; (2) Study Design: Randomized controlled trial (RCT), clinical controlled trials, or cohort studies; (3) Intervention: Implementation of the enhanced recovery after surgery (ERAS) protocol as the primary perioperative nursing or care intervention. To ensure consistency, the ERAS protocol was required to include at least the following core components: preoperative counseling, optimized anesthesia, early oral nutrition, multimodal pain management, and early mobilization; (4) Comparator: Conventional or standard postoperative care without a structured ERAS protocol; (5) Outcomes: At least one outcome indicator related to postoperative rehabilitation, such as length of stay, incidence of postoperative complications, reoperation rate, readmission rate, or mortality; (5) Language and Availability: Full-text articles published in English with accessible and extractable data.

Exclusion criteria were as follows: (1) studies on non-gastrointestinal surgery, or studies on which the type of surgery was unclear or could not be distinguished; (2) studies in which the intervention measures did not clearly comply with the principles of the ERAS pathway; (3) studies with non-original data such as single-group studies, case reports, review articles, commentary articles, conference abstracts, etc.; (4) studies that did not provide the primary outcome measures or had incomplete result data and could not be subjected to meta-analysis; (5) studies that were repeatedly published. If the same study was published multiple times, only the highest quality or latest version was included; and (6) studies with a small sample size (e.g., a sample size of less than 20 cases), serious data bias, or studies that could not be evaluated. Serious data bias refers to significant discrepancies or errors in the data, such as incomplete outcome reporting, selective reporting of results, or missing data that could substantially affect the validity of the study's conclusions.

Data extraction and quality assessment

Two independent reviewers extracted data and assessed study quality based on pre-defined criteria. Any discrepancies were resolved by discussion or adjudication by a third reviewer. The data extraction included the following aspects: (1) Study information: the first author of the study, the year of publication, and the country or region where the study was located; (2) Research subjects: basic characteristics of the patients (age, gender, comorbidities); (3) intervention and control group details (number of participants, type of surgery, ERAS protocol specifics); (4) outcome measures (length of stay, complications, readmission rate, reoperation rate, mortality).

For RCTs, the Cochrane Risk of Bias 2.0 tool was used to evaluate five domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of reported results. Each domain was rated as "low risk", "some concerns", or "high risk" [19].

For cohort studies, the Newcastle-Ottawa Scale (NOS) was used, which assesses quality across three domains: selection (0–4 points), comparability (0–2 points), and outcome assessment (0–3 points), with a maximum score of 9. Studies scoring ≥ 7 points were considered high quality.

Inter-rater reliability between the two reviewers was measured using Cohen's kappa coefficient, yielding a value of $\kappa = 0.84$, indicating strong agreement.

Statistical analysis

All statistical analyses were conducted using R software (version 4.2.2). For dichotomous variables (such as postoperative complication rate), relative risk (RR) and 95% confidence intervals (CI) were calculated. For continuous variables (such as length of stay), mean difference (MD) and 95%CI were used.

Heterogeneity among studies was assessed using the I^2 statistic and Cochran's Q test. When $I^2 > 50\%$, indicating substantial heterogeneity, a random-effect model (DerSimonian and Laird method) was applied. For $I^2 \leq 50\%$, a fixed-effect model (Mantel-Haenszel method) was used, assuming minimal heterogeneity.

Publication bias was evaluated using Egger's test, with p-value < 0.05 indicating potential bias. Funnel plots were also visually inspected for asymmetry. Sensitivity analysis was performed by sequentially removing each individual study to evaluate the robustness of the pooled estimates. All statistical tests were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Literature screening results

A total of 2586 articles were obtained in the initial search, and 2243 articles remained after deduplication. After screening based on the title and abstract, 1985 irrelevant articles were excluded. After further reading of the full text, 245 articles that did not meet the inclusion criteria were excluded again. Finally, 13 studies were included, involving a total of 5603 patients. Figure 1 illustrates the inclusion literature screening process.

Basic characteristics of included studies

A total of 13 studies were included in this study [20–31], including 7 cohort studies and 6 randomized controlled trials, published between 2012 and 2024, with study sample sizes ranging from 86 to 1,001 cases. The age of the patients ranged from 55.7 to 82 years old, and there were some differences in the gender ratio and BMI between the studies, with the BMI range of 22.6 to 25.4 kg/m^2. The main outcome measures included postoperative length of stay, complication rate, readmission rate, reoperation rate, and mortality rate. Most studies reported postoperative length of stay and complication rate, and a few studies involved readmission rate and reoperation rate. The included studies covered gastrointestinal surgery patients from different countries and regions, and the study types included prospective cohort studies and randomized controlled trials. The basic characteristics of the included literature are shown in Table 1.

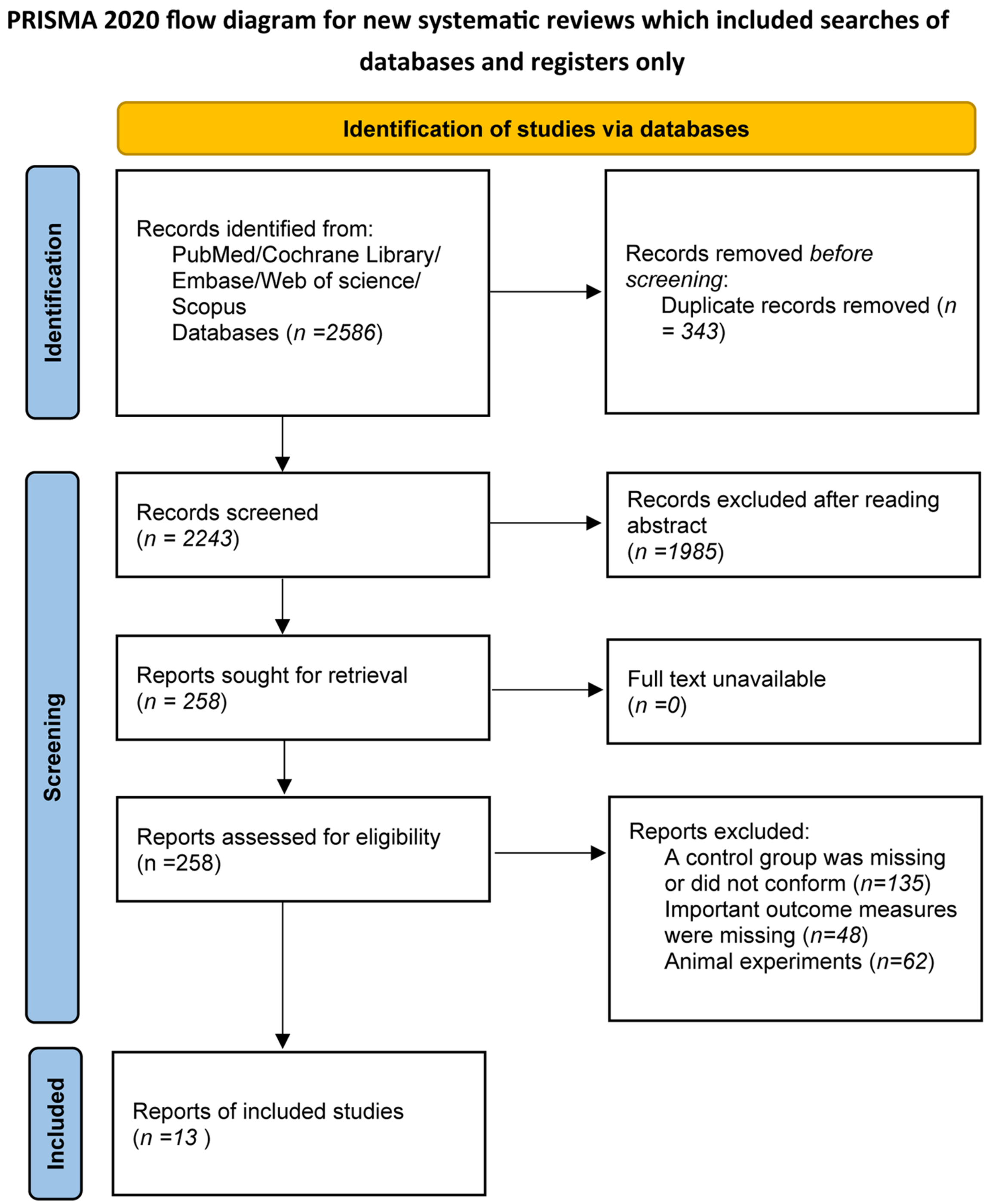

Fig. 1 Flow chart of literature screening process

Literature quality evaluation

For the 6 RCTs [24, 25, 27, 29, 32], the bias risk assessment tool recommended by the Cochrane Collaboration was used for analysis. The results (Table 2) showed that most of the included RCTs showed low risk of bias in terms of random sequence generation, allocation concealment, and outcome data integrity (Supplementary Figure S1). However, there were some concerns regarding blinding, particularly for participants and researchers. This may introduce performance or detection bias, especially for subjective outcomes such as complications and recovery time. Overall, the risk of bias in the RCTs was moderate, as several studies had an unclear risk in areas like outcome assessment blinding and selective reporting.

For 7 cohort studies [20–23, 26, 28, 30, 31], the NOS was used for quality assessment. Table 3 showed that

Table 1 General information of included articles

Author	Year	Study type	Sample size (E/C)	Type of Surgery	ERAS Components	Comparator	Age		Sex (male/female)		BMI (kg/m$^{2)}$		Comorbidity		Outcome Measures
							E	C	E	C	E	C	E	C	
Asklid, D.	2017	Cohort	145/753	Elective colorectal cancer surgery	Goal-directed fluid therapy, early mobilization, limited fasting	Conventional perioperative care	69.3 (12.6)	69.3 (11.5)	51/94	393/360	24.8 (4.3)	25.4 (4.3)	/	/	LOS, Post-op complications, Readmission rate, Mortality
Bellato, V.	2021	Cohort	49/33	Elective cT4 colorectal cancer surgery	Preop counseling, early nutrition, early ambulation, multimodal analgesia	Conventional recovery pathway	69.02 (12.8)	66.51 (10.12)	28/21	18/15	/	/	24 (49)	22 (66.6)	LOS, Post-op complications, Readmission rate, Mortality
Cao, S.	2021	Cohort	85/86	Laparoscopic total gastrectomy (gastric cancer)	Early oral intake, epidural analgesia, early mobilization, reduced drains	Conventional perioperative protocol	70.8 (3.4)	71.4 (3.7)	30/55	32/54	23.1(2.2)	23.3 (2.6)	46 (54.1)	45 (52.3)	LOS, Post-op complications, Readmission rate, Reoperation rate
Han, H.	2024	Cohort	182/131	Elective colorectal cancer surgery (elderly)	Preop education, early ambulation, early feeding, pain management	Traditional postoperative care	72.62 (5.70)	73.61 (6.37)	101/81	131/70	23.05 (3.48)	23.7 9(3.46)	102 (56.0)	74 (56.5)	LOS, Post-op complications, Readmission rate
He, F.	2015	RCT	48/38	Partial laparoscopic hepatectomy (liver cancer)	Short fasting, early diet, early ambulation, low opioids	Standard care without ERAS	56.3 (16.3)	60.4 (20.7)	22/26	18/20	/	/	/	/	LOS, Post-op complications, Readmission rate, Mortality
Jaloun, H. E.	2020	RCT	82/214	Elective colorectal surgery	Preoperative education, early oral feeding, multimodal pain control, early mobilization	Standard care with delayed feeding and traditional mobilization	82 (27.7)	214 (72.3)	44/38	100/114	/	/	/	/	LOS, Post-op complications
Jeong, O.	2021	RCT	219/219	Gastric cancer surgery (laparoscopic/robotic)	Preop counseling, early oral diet, early ambulation, opioid-sparing	Non-ERAS historical control group	61.2 (10.8)	61.9 (11.4)	276/148	111/387	23.2 (3.0)	24.0 (3.8)	197 (46.5)	377 (66.7)	LOS, Post-op complications, Readmission rate, Reoperation rate
Jian, C.	2022	Cohort	464/464	Laparoscopic colorectal cancer surgery	Partial ERAS: early feeding, early walking, no bowel prep	Conventional perioperative management	60.77 (11.61)	58.88 (12.88)	422/228	340/179	23.12 (3.06)	22.64 (3.28)	/	/	LOS, Post-op complications

Table 1 (continued)

Author	Year	Study type	Sample size (E/C)	Type of Surgery	ERAS Components	Comparator	Age		Sex (male/female)		BMI (kg/m$^{2)}$		Comorbidity		Outcome Measures
							E	C	E	C	E	C	E	C	
Kang, S. H.	2018	RCT	46/51	Laparoscopic distal gastrectomy (gastric cancer)	Full ERAS protocol (multimodal pain control, nutrition, minimal drains)	Standard care with delayed oral intake	56.3 (10.4)	54.5 (12.6)	33/13	38/13	23.4 (2.7)	24.3 (2.5)	22 (47.8)	23 (45.1)	LOS, Post-op complications, Readmission rate, Reoperation rate
Loh-siriwat, V.	2021	Cohort	70/279	Stage III colorectal cancer surgery	Full ERAS (early feeding, no bowel prep, ambulation, early discharge)	Traditional recovery protocol	62.1 (13.8)	63.1 (13.0)	40/30	149/130	/	/	/	/	LOS, Post-op complications
Ren, L.	2012	RCT	299/298	Radical resection for colorectal cancer	Reduced fasting, early ambulation, early oral intake, multi-modal analgesia	Traditional postoperative management	61 (21–80)	59 (24–78)	190/108	178/121	22.6(3.4)	22.4 (3.5)	/	/	, Post-op complications
Suth-erasan, M.	2017	Cohort	165/182	Liver resection (hepatectomy)	Preoperative counseling, early feeding, no nasogastric tube, early mobilization	Standard surgical care without ERAS	55.71 (11.32)	58.33 (11.73)	106/59	123/59	/	/	104 (63.0)	103 (56.6)	LOS, Post-op complications, Readmission rate, Mortality
Tida-dini, F.	2022	Cohort	497/504	Colorectal cancer surgery (various types)	Early oral diet, minimal drains, fast-track mobilization, multimodal pain relief	Conventional care prior to ERAS implementation	70 (61–78)	70 (61–79)	319/178	309/194	/	/	233 (46.9)	193 (38.3)	LOS, Post-op complications, Readmission rate

Note: E/C (ERAS/Control); RCT (Randomized Controlled Trial); BMI (Body Mass Index); LOS (Length of Stay); Post-op Complications (Postoperative Complications)

Table 2 Quality evaluation of randomized controlled trials (ROB)

Research	Random sequence generation	Assignment hiding	Blinding (participants and researchers)	Blinding (outcome assessment)	Results Data Integrity	Selective reporting	Other biases	Overall risk of bias
He, F. (2015)	Low bias	Low bias	High bias	Unclear	Low bias	Low bias	Low bias	Moderate bias
Jaloun, H.E. (2020)	Low bias	Unclear	High bias	Unclear	Low bias	Unclear	Low bias	High bias
Jeong, O. (2021)	Low bias	Low bias	High bias	Low bias	Low bias	Low bias	Low bias	Moderate bias
Kang, S.H. (2018)	Low bias	Low bias	High bias	Unclear	Low bias	Low bias	Low bias	Moderate bias
Ren, L. (2012)	Low bias	Low bias	High bias	Unclear	Low bias	Low bias	Low bias	Moderate bias

Table 3 Quality evaluation of cohort study literature (NOS)

Research	Research subject selection (0–4 points)	Comparability between groups (0–2 points)	Result evaluation (0–3 points)	Total score (0–9 points)	Quality Grade
Asklid, D. (2017)	4	1	2	7	high quality
Bellato, V. (2021)	3	1	2	6	Medium quality
Cao, S. (2021)	4	2	3	9	high quality
Han, H. (2024)	4	1	2	7	high quality
Jian, C. (2022)	3	1	2	6	Medium quality
Lohsiriwat, V. (2021)	3	1	2	6	Medium quality
Sutherasan, M. (2017)	3	1	3	7	high quality
Tidadini, F. (2022)	4	1	3	8	high quality

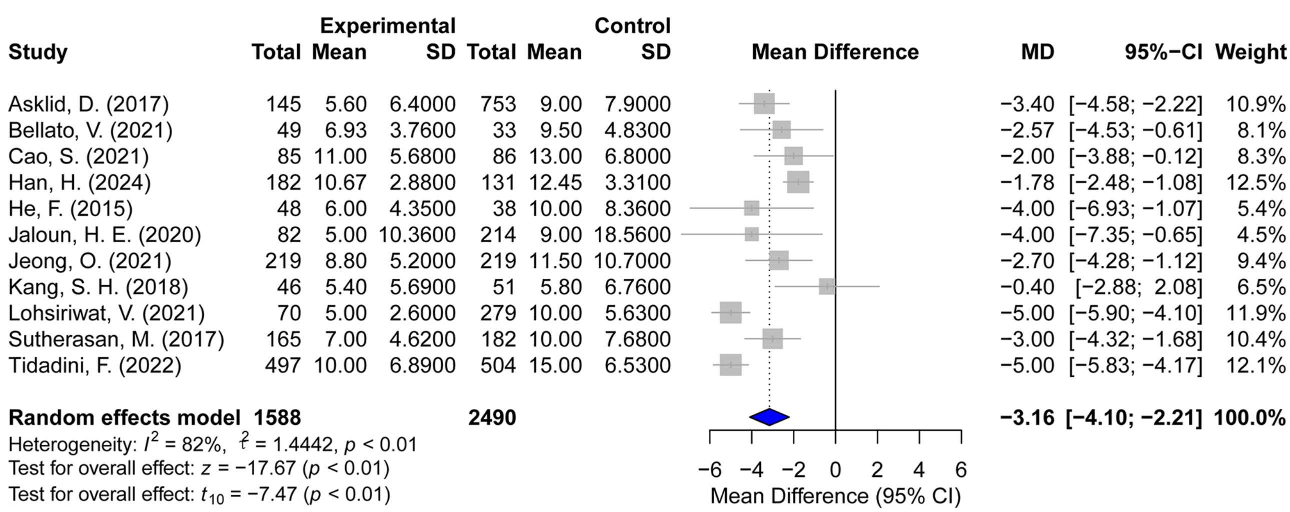

Fig. 2 Forest plot comparing postoperative hospital stay (days) between ERAS and control groups. Squares represent point estimates for individual studies, with horizontal lines indicating 95% confidence intervals. The diamond shows the pooled mean difference (MD) with 95% CI. ERAS: Enhanced Recovery After Surgery

the cohort studies generally had high quality, with most scoring between 7 and 9 points on the NOS. The studies showed well-defined subject selection and sufficient follow-up times. However, a few studies had insufficient control of confounding factors, which slightly decreased their comparability. Despite these minor limitations, most cohort studies were of high quality, contributing reliable data to the meta-analysis.

Main results of meta-analysis

Length of stay (LOS)

A meta-analysis of 11 studies (1,588 ERAS patients and 2,490 controls) showed that the ERAS pathway on postoperative length of stay in patients undergoing gastrointestinal surgery [20–25, 27, 28, 30–32]. A random effects model was used for pooled analysis, and the results (Fig. 2) showed that the postoperative hospital stay of the ERAS group was significantly shorter than that of the control group, with a mean difference (MD) of -3.16 days (95% CI: -4.10 to -2.21, $P<0.01$). This shows that the ERAS pathway can significantly reduce postoperative hospital stay.

Heterogeneity analysis revealed a high level of between-study variability (I^2 = 82%, τ^2 = 1.4442, Q test $P<0.01$). This heterogeneity may be attributed to differences in surgical types, institutional protocols, and varying degrees of ERAS implementation. Nevertheless, the direction of effect was consistent across all studies, and sensitivity analysis confirmed the robustness of the result.

Postoperative complications

Thirteen studies (2,350 ERAS patients and 3,253 controls) [20–32] found that ERAS pathway significantly reduced the incidence of postoperative complications. The incidence of complications in the ERAS group was significantly lower than that in the control group, with a pooled RR of 0.70 (95% CI: 0.58–0.84, $P<0.01$), indicating a 30% relative risk reduction (Fig. 3).

Heterogeneity analysis showed that there was a moderate degree of heterogeneity among the included studies (I^2 = 64%, τ^2 = 0.0455, Q test $P<0.01$), likely due to differences in baseline risk profiles, surgical procedures, and ERAS protocol completeness. Despite this, the CI did not cross 1.0 and all studies favored ERAS, supporting the reliability of this finding.

Readmission rate

Seven studies (1,202 ERAS patients and 1,158 controls) were included to evaluate the impact of the ERAS pathway on postoperative readmission rates [21, 23–25, 27, 30, 31]. The results showed that the ERAS pathway significantly reduced the postoperative readmission rate. The readmission rate in the ERAS group was lower than that in the control group, with a pooled RR of 0.75 (95% CI: 0.58–0.96, $P=0.02$) (Fig. 4). This suggests that the ERAS pathway care intervention can reduce the risk of readmission by approximately 25%.

No heterogeneity was observed among the included studies (I^2 = 0%, τ^2 = 0, Q test $P=0.75$), indicating high consistency in findings and reinforcing the robustness of the result.

Reoperation rate

Three studies (350 ERAS patients and 356 controls) were included to evaluate the impact of ERAS pathway on postoperative reoperation rate [22, 25, 27]. The combined analysis results showed that there was no statistical difference in reoperation rate between ERAS pathway and control group. Significance. The pooled RR was 0.59 (95% CI: 0.01–30.14, $P=0.62$) (Fig. 5). This suggested that the ERAS pathway had a small and statistically insignificant impact on reoperation rates.

Heterogeneity analysis showed that there was a moderate degree of heterogeneity between studies (I^2 = 32%, τ^2 = 0.9527, Q test $P=0.23$), indicating that the differences between the study results can be partially attributed to random error.

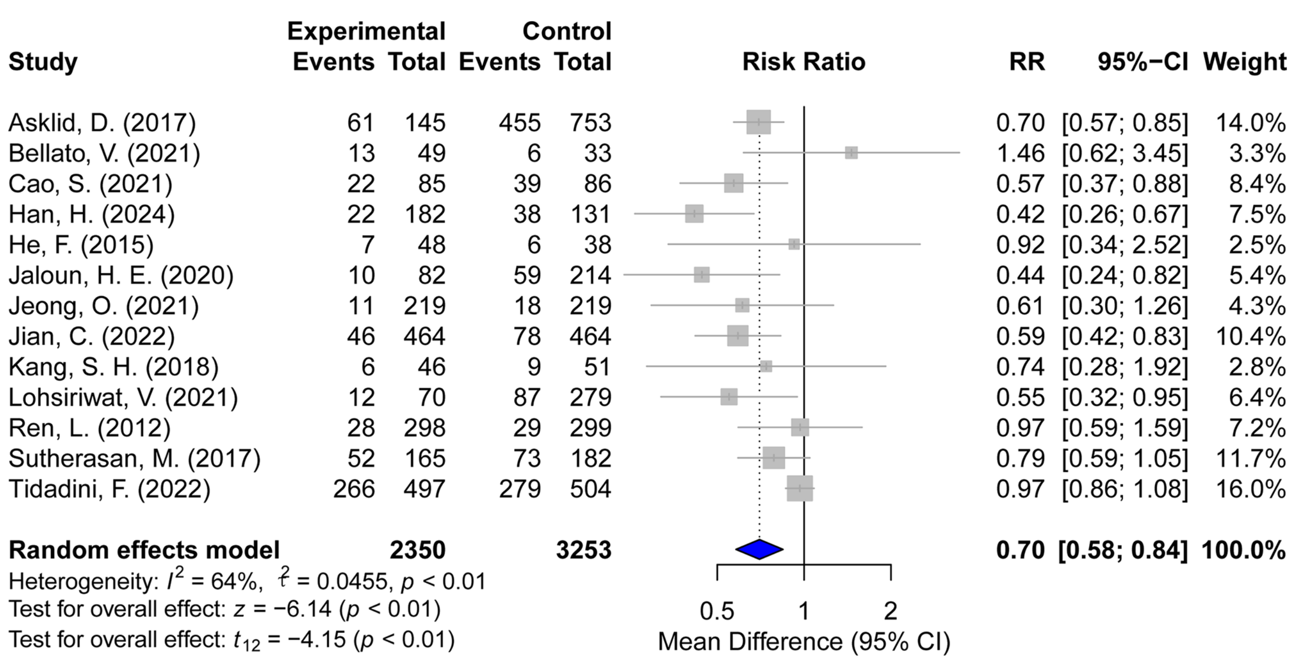

Fig. 3 Forest plot comparing postoperative complication rates between ERAS and control groups. Each square represents the risk ratio (RR) for an individual study, with horizontal lines denoting 95% confidence intervals (CIs). The diamond displays the pooled RR with 95% CI using a random-effects model. The vertical line at RR = 1 indicates no difference between groups. ERAS: Enhanced Recovery After Surgery

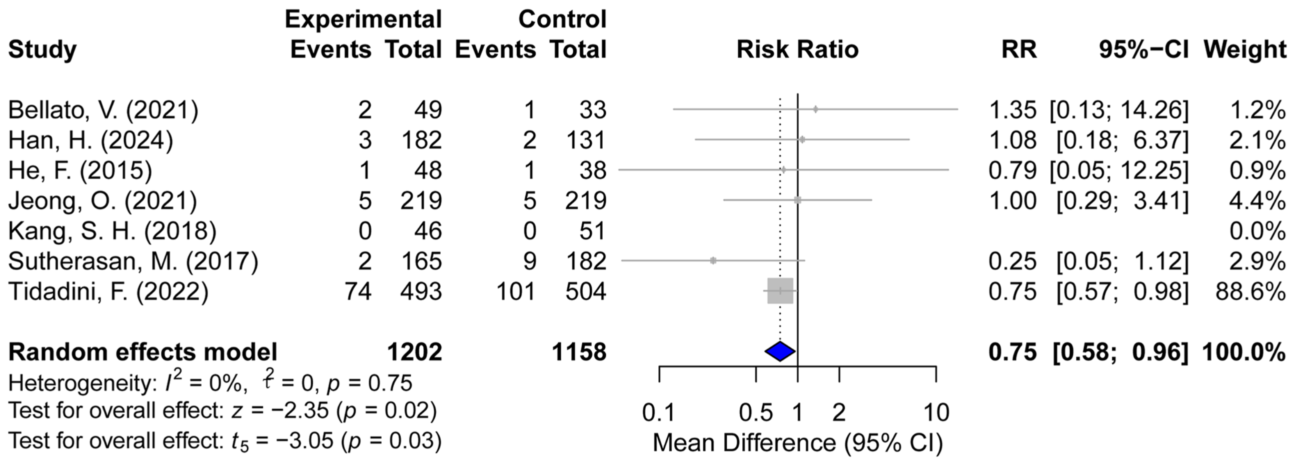

Fig. 4 Forest plot comparing postoperative readmission rates between ERAS and control groups. Each square represents the risk ratio (RR) for an individual study, with horizontal lines denoting 95% confidence intervals (CIs). The diamond displays the pooled RR with 95% CI using a random-effects model. The vertical line at RR = 1 indicates no difference between groups. ERAS: Enhanced Recovery After Surgery

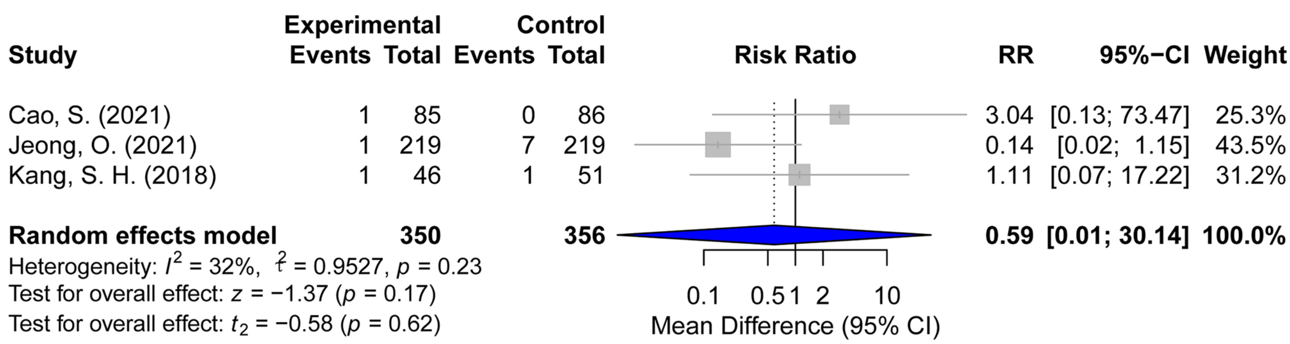

Fig. 5 Forest plot comparing postoperative reoperation rates between ERAS and control groups. Each square represents the risk ratio (RR) for an individual study, with horizontal lines denoting 95% confidence intervals (CIs). The diamond displays the pooled RR with 95% CI using a random-effects model. The vertical line at RR = 1 indicates no difference between groups. ERAS: Enhanced Recovery After Surgery

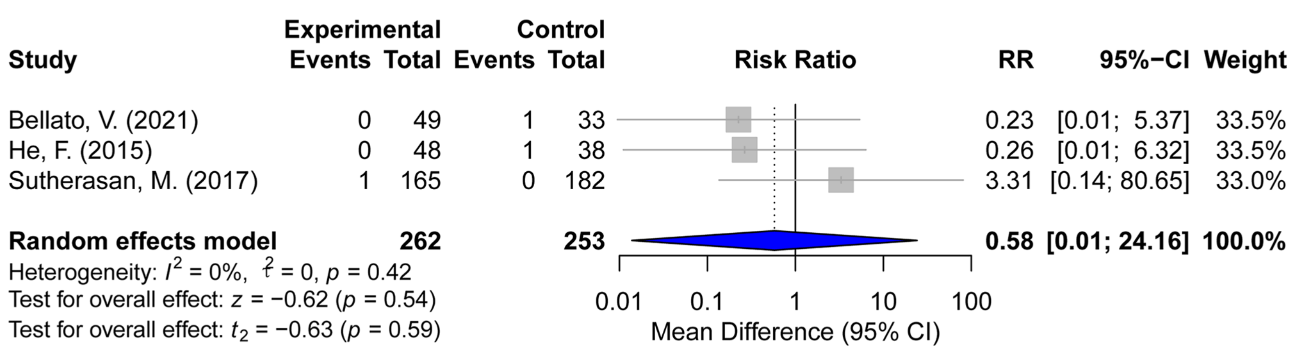

Fig. 6 Forest plot of postoperative mortality of two groups of patients after ERAS pathway nursing intervention

Mortality rate

Three studies (262 ERAS patients and 253 controls) were included to evaluate the impact of the ERAS pathway on postoperative mortality [21, 24, 30]. The combined analysis results showed that there was no significant difference in postoperative mortality between the ERAS pathway and the control group. The pooled RR was 0.58 (95% CI was 0.01–24.16, $P = 0.59$), indicating that the impact of the ERAS pathway on postoperative mortality was not significant (Fig. 6).

Heterogeneity analysis showed that there was no obvious heterogeneity among the studies (I^2 = 0%, τ^2 = 0, Q test $P = 0.42$), indicating that the research results were highly consistent. However, the wide CI suggested imprecision due to small sample size and low event rates. Further large-scale studies are needed to clarify the effect of ERAS on mortality outcomes.

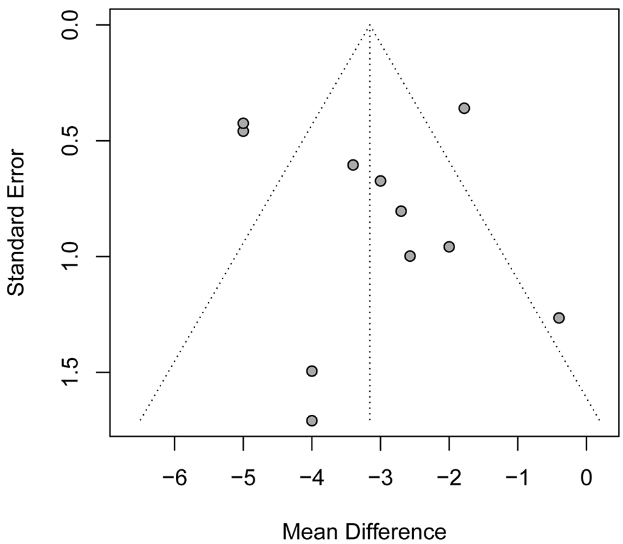

Fig. 7 Funnel plot assessing publication bias for studies reporting postoperative hospital stay. Each point represents an individual study's effect size (mean difference) plotted against its standard error. The vertical line indicates the pooled effect estimate, while the diagonal lines show the expected 95% confidence interval boundaries under the assumption of no publication bias. Symmetrical distribution of points around the pooled estimate suggests minimal publication bias

Publication bias

In addition to evaluating the outcomes of the ERAS pathway, we assessed publication bias using funnel plots and Egger's test. The funnel plot, as shown in Fig. 7, is relatively symmetrical, indicating a low likelihood of publication bias. This suggests that smaller studies with null results have not been disproportionately excluded, supporting the robustness of the meta-analysis results. Egger's test further confirmed this finding, with a p-value of 0.6612, indicating no significant publication bias across the included studies.

Sensitivity analysis

Sensitivity analysis evaluates the impact of a single study on the meta-analysis results by excluding studies one by one. The results (Fig. 8) showed that after excluding any one study, the difference in hospital stay between the ERAS group and the control group was still significant (MD ranged from – 2.91 days to -3.37 days, $P < 0.01$), indicating that the results were robust. Heterogeneity varied slightly across different analyses, with I^2 values ranging from 71 to 84%, but the overall conclusion was not affected, indicating the high robustness and reliability of the analysis.

Discussion

This meta-analysis evaluated the effect of the ERAS pathway on postoperative rehabilitation in gastrointestinal surgery patients. The study found that ERAS pathway significantly shortened postoperative hospital stay and reduced the incidence of postoperative complications and readmission rate. Specifically, ERAS patients had a 3.16-day shorter hospital stay, a 30% reduction in complications, and a 25% reduction in readmissions compared to the control group. However, there was no statistically significant difference in reoperation rate and mortality, suggesting that ERAS enhances recovery and short-term outcomes, its impact on critical adverse events may be more limited.

Our findings are broadly consistent with those of previous meta-analyses but also highlight several nuanced differences [33, 34]. For example, similar to Feng et al. [35],

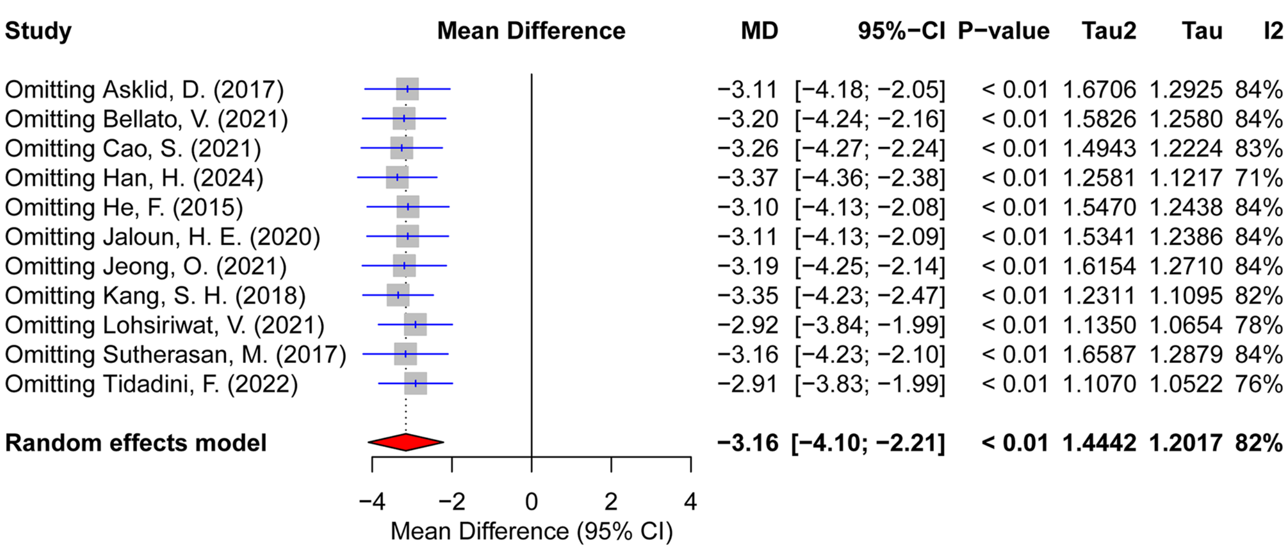

Fig. 8 Sensitivity analysis of hospital stay. Each row represents the pooled risk ratio (RR) when excluding one study sequentially. The central diamond indicates the overall RR with 95% CI from the primary analysis. Horizontal lines show the range of RR estimates after each exclusion, demonstrating robustness of findings

we observed reductions in complications and hospital stay, although our study encompassed a broader range of gastrointestinal procedures. In contrast to Lohsiriwat et al. [36], who focused on emergency colorectal cancer surgeries and reported mortality reduction, our inclusion of mainly elective procedures may explain the lack of mortality benefit. Tan et al. [37] demonstrated ERAS effectiveness in geriatric populations, while our broader age range suggests its applicability across the general adult population. Our findings also align with Li et al. [38], who reported shorter hospital stays and fewer complications in minimally invasive colorectal surgery, supporting ERAS's versatility. However, unlike Li et al. [39], who reported reductions in surgical site infections, our study did not examine specific complication subtypes—highlighting an area for future research. Similarly, Tian et al. [40] reported the benefits of ERAS in laparoscopic distal gastrectomy, which reinforces our conclusion that ERAS protocols improve recovery across different types of gastrointestinal surgeries. While formal subgroup analyses were not performed due to data limitations, qualitative differences were observed across surgical subtypes. For instance, the recovery trajectory and ERAS responsiveness may differ between colorectal and gastric surgeries due to variations in surgical complexity and nutritional management. Such differences may partially explain the variability in effect sizes observed across studies.

Our analysis revealed high heterogeneity, particularly in hospital stay (I^2 = 82%) and complication rate (I^2 = 64%). This variability is likely due to differences in study populations, surgical techniques, and notably, ERAS protocol adherence. In some studies, only partial ERAS protocols were applied—such as early mobilization without early feeding—which may have attenuated the observed effects. Despite this, sensitivity analyses showed consistent findings, supporting the robustness of the results. Additionally, publication bias was unlikely, as evidenced by symmetrical funnel plots and a non-significant Egger's test ($P = 0.6612$).

In terms of complication rate, our finding of a 30% reduction aligns with existing literature suggesting ERAS protocols reduce infection rates and other postoperative complications [41, 42]. The observed effect was consistent across multiple countries and surgical contexts, supporting the generalizability of our findings. However, our study did not find significant reductions in reoperation or mortality, contrasting with Catarci et al. [11], who reported improvements in both outcomes. These discrepancies may be due to broader inclusion criteria in our study, encompassing higher-risk patients and a wider range of surgeries. Additionally, variations in how strictly the ERAS protocols were implemented across different centers may also explain the differing results, as more rigid adherence to the ERAS guidelines tends to yield better outcomes.

Several studies [24, 25, 27, 29, 32] included in our meta-analysis faced methodological limitations, such as the lack of blinding of participants or outcome assessors, which could introduce performance or detection bias. Given the moderate risk of bias across studies, caution is warranted when interpreting subjective outcomes such as complication rates and recovery time. Nonetheless, the consistency of benefit across studies strengthens confidence in the overall effectiveness of ERAS.

Clinically, ERAS protocols have meaningful implications. A study on elderly colorectal cancer patients showed that ERAS protocols reduced hospital stay by 2–3 days, which can improve bed availability and reduce healthcare costs [11]. Additionally, reducing postoperative complications, such as infections and ileus, significantly improves patients' quality of life. In one case series, gastric cancer patients on ERAS had fewer complications and a lower readmission rate, which reduced postoperative anxiety for both patients and families [43]. Moreover, ERAS pathways simplify postoperative care, as demonstrated by a colorectal surgery department where ERAS reduced the need for intensive care in high-risk patients [44]. By integrating multidisciplinary care, ERAS facilitates personalized rehabilitation and optimizes surgical recovery.

Despite the strengths of this meta-analysis, several limitations should be noted. High heterogeneity across studies may impact the reliability of pooled estimates. Differences in ERAS protocol components and adherence levels further contribute to intervention inconsistency. Some studies had small sample sizes or incomplete data, which may reduce the robustness of certain outcomes. Moreover, variability in patient inclusion criteria across studies introduces potential selection bias and limits the generalizability of our findings. Future studies should stratify patients by age, comorbidities, and surgical complexity to determine which subgroups derive the greatest benefit. Large-scale, multicenter randomized controlled trials with standardized ERAS protocols are essential to validate these findings. Furthermore, economic evaluations of ERAS implementation are warranted to assess cost-effectiveness and inform health policy decisions across diverse healthcare settings.

Conclusion

In conclusion, the ERAS pathway appears to offer substantial benefits in reducing postoperative complications, hospital stay, and readmission rates. However, the effectiveness of ERAS can be influenced by variability in protocol implementation, patient characteristics, and surgical complexity. These factors underscore the need for tailored approaches to ERAS application across different clinical settings. Future research should focus on conducting high-quality, multicenter RCTs and on developing standardized, procedure-specific ERAS protocols to minimize variability and improve reproducibility. Additionally, further evaluation of the cost-effectiveness and long-term outcomes of ERAS across diverse healthcare systems is warranted to inform widespread clinical adoption and policy-making.

Abbreviations

ERAS	Enhanced recovery after surgery
RCTs	Randomized controlled trials
RR	Relative risk
MD	Mean difference
CI	Confidence interval
RoB	Risk of Bias Tool
NOS	Newcastle-Ottawa Scale

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-025-02976-9.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3: Risk of bias summary for the included randomized controlled trials. The upper panel presents the overall proportion of studies rated as having low (green), unclear (yellow), or high (red) risk of bias across each domain. The lower panel displays the domain-level judgments for each individual study across seven domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other sources of bias

Acknowledgements
Not applicable.

Author contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Wenxia Jin and Zhebing Qiu. The first draft of this manuscript was written by Fengying Dong and Yan Li and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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

Declarations

Ethics approval and consent of participate
As this study is a systematic review and meta-analysis of previously published studies, ethical approval and informed consent were not required.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 27 November 2024 / Accepted: 27 May 2025

Published online: 02 June 2025

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