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Impact of enhanced recovery after surgery (ERAS) on surgical site infection and postoperative recovery outcomes: a retrospective study of 1276 cases

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This retrospective observational study aimed to evaluate the incidence of surgical site infection (SSI) in the era of enhanced recovery after surgery (ERAS) and the effect of ERAS on postoperative outcomes. Totally 1,276 patients (565 in ERAS group and 711 in non-ERAS group) who underwent operations at the department of general surgery during 2017–2021 were included. Risk factors were identified via logistic regression analysis and meta-analysis of all relevant published studies was performed. Subsequently, propensity score matching was used to match different risk factors. Overall, 40 patients were diagnosed with SSI, and the pooled incidence of SSI was 3.13%. In total, 14 (2.48%) and 26 (3.66%) patients in the ERAS and non-ERAS groups, respectively, were diagnosed with SSI ($P = 0.230$). Among patients for whom the ERAS protocol was adopted, 7 independent risk factors of SSI were identified. After propensity score matching, in patients without SSI, the number of hospital days was significantly lower in the ERAS group than in the non-ERAS group (2 [2, 5] vs. 3 [2, 7], $P = 0.005$), whereas in patients with SSI, the number of hospital days was similar between the ERAS and non-ERAS groups. ERAS had no effect on the incidence of SSI but could significantly accelerate the discharge of uninfected patients. In the era of ERAS, SSI incidence was affected by the type of surgery; number of postoperative hospital days; type of incision; serum hemoglobin, total protein, and albumin levels; and antibiotic prophylaxis. Furthermore, these results will significantly affect the implementation of the ERAS protocol and optimal preoperative management.

Keywords Enhanced recovery after surgery, Surgical site infection, Risk factor, Meta-analysis, Propensity score matching

Enhanced recovery after surgery (ERAS) is a multimodal perioperative care program used to reduce postoperative physical and psychological stress to accelerate recovery[1]. This program covers the entire surgical process and has been reported to reduce recovery time for several types of surgery, including thyroid and parathyroid[2], colorectal[3], and breast cancer surgeries[4]. However, because most centers have only recently implemented the protocol, its effect on postoperative complications, particularly surgical site infections, remains unclear[5].

Surgical site infection (SSI) is defined as an infection of the incision, operated organ, or related cavity occurring after surgery[6]. According to the World Health Organization, it is the most common healthcare-associated infection in developing countries, accounting for 11.8% of all infections[7]. Notably, SSI has also led to considerable financial burden. Moreover, even in the USA, the incidence of SSI is approximately 5%, prolonging the length of hospital stay by 9.7 days and incurring an additional cost of $700 million per year[8]. Surgeries performed in general departments appear to be associated with a high incidence of SSI, and in most institutions,

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the ERAS protocol is primarily used in thyroid, breast, gastrointestinal, duct, liver, and pancreatic surgeries[9–11]. Thus, there is a need for an in-depth analysis of SSI incidence and ERAS implementation.

Given this background, the present study aimed to estimate the incidence of SSI upon the implementation of ERAS. Moreover, it aimed to evaluate the influence of ERAS on postoperative outcomes.

Methods

Study design as well as inclusion and exclusion criteria

This retrospective analysis was performed by randomly selecting patients who underwent surgery at the Department of General Surgery, Shanghai Ninth People's Hospital, in 2017–2021. Detailed information was collected from 1526 patients, and 1276 patients remained after exclusion based on the following exclusion criteria: surgery performed under endoscopy, multiple surgeries for non-infectious reasons, and pre-existing infection before surgery. The identification of pre-existing infection was made by Danhua Yao, who has 15 years of experience in SSI management, based on medical history records and pre-surgery laboratory tests. The study was approved by the Ethics Committee in Shanghai Ninth People's Hospital and the informed consent was waived by the Institutional Review Board (Approval No.: SH9H-2023-T266-1). Moreover, the study was registered with the Chinese clinical trial registry (ChiCTR2400081217). All methods were performed in accordance with the Declaration of Helsinki.

Definition of SSI and confirmation of SSI cases

The presence of SSI was confirmed by the scores obtained for the need for Additional treatment, the presence of Serous discharge, Erythema, Purulent exudate, and Separation of the deep tissues, the Isolation of bacteria, and the duration of inpatient Stay (ASEPSIS)[12]. The grade of the wound was scored according to the signs or symptoms of infection, as documented in the electronic medical records. Information regarding bacterial culture results, postoperative antibiotic use, inpatient days, and postoperative treatment of the incision were used to assign additional points. Notably, the item "inpatient time > 14 days" was defined as the postoperative inpatient time of > 14 days, as reported in a previous study[13]. A score of > 20 was considered to indicate SSI. Further, the scores were grouped into five categories [satisfactory (0–10), disturbance of healing (11–20), minor SSI (21–30), moderate SSI (31–40), and severe SSI (> 40)].

ERAS implementation

The ERAS protocols were implemented at the Department of General Surgery, Shanghai Ninth People's Hospital, from the end of 2018 to the middle of 2019. The components of the ERAS protocol include preadmission education, early discharge planning, carbohydrate loading, no bowel prep, antibiotic prophylaxis, prewarming, active warming during the operation, opioid-sparing technique, avoidance of prophylactic NG tubes & drains, avoidance of urinary catheterization, goal-directed perioperative fluid management, pain & nausea management, early oral nutrition, early ambulation, postoperative wound care, early catheter removal, and defined discharge criteria.

Data collection

Two researchers (Baohong Wang and Jingyan Huang) investigated the electronic medical records and microbial culture reports of patients in terms of their demographic characteristics, lifestyle, comorbidities, surgery-related data, and laboratory biomarkers.

The detailed data obtained for each patient were as follows: diagnosis; age; sex; weight; comorbidities (hypertension, diabetes mellitus, and chronic heart disease); and history of allergic reactions to drugs, surgery, and hormone use.

Surgery-related data included preoperative hospital stay (between admission and operation), surgery type (emergent or selective), incision type (According to the incision classification defined by the National Academy of Sciences, the incisions were categorized as type I (clean), type II (clean-contaminated), type III (contaminated), and type IV (dirty). Non-type I incision referred to the collective group of type II, type III, and type IV incisions in our study) and postoperative drainage[14]. Information regarding antibiotic use included prophylactic use of antibiotics (drug name, dosage, route, and juncture) and postoperative use of antibiotics (drug name, daily dosage, and duration).

Furthermore, data regarding the following laboratory biomarkers were collected: preoperative white blood cell (WBC) count, neutrophil (NEUT) count, C-reactive protein (CRP) level, hemoglobin level, total protein (TP) level, albumin (ALB) level, alanine aminotransferase (ALT) level, aspartate transaminase (AST) level, serum total bilirubin (STB) level, conjugated bilirubin level, blood glucose level, serum urea level, creatinine level, and uric acid level. If multiple laboratory biomarkers were recorded during the preoperative period, the biomarkers measured at the closest preoperative date were selected. Postoperative WBC count, NEUT count, CRP level, and procalcitonin level were also evaluated.

Moreover, the following items related to SSI were recorded: signs or symptoms of infection, postoperative treatment of the incision, bacterial culture results, and postoperative fever.

Statistical analysis

Continuous data were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR) and were evaluated consistently by Student's t test or Mann–Whitney U test, when appropriate. Categorical data were expressed as numbers and percentages and were analyzed by chi-squared or Fisher's exact test, when appropriate.

Logistic regression analysis was used to determine the independent risk factors of SSI. The propensity scores were calculated using a logistic regression model with the following factors as covariates: age, surgery type, incision type, WBC, TP, ALB, and antibiotic prophylaxis, and 1:1 (ERAS to non-ERAS) matching (matched without replacement) with a caliper of 0.01 SD of the estimated logit was performed. The cutoff value of an absolute standardized mean difference above which a meaningful imbalance is indicated is 0.200. The Kaplan–Meier estimator was used to investigate the incidence of SSI. The interval included in the survival statistics was from the day of surgery until the end of follow-up (90 days after surgery).

Meta-analysis

Literature search strategy

A literature search was performed in the databases PubMed and EMBASE from inception of the databases until May 20, 2022. The following search string was used in PubMed without language restrictions: ("SSI"[Title/Abstract] OR "surgical site infection"[Title/Abstract] OR "surgical site infections"[Title/Abstract]OR "surgical wound infection"[Title/Abstract]OR "surgical wound infections"[Title/Abstract] OR "wound infection"[Title/Abstract] OR "wound infections"[Title/Abstract]) AND ("general surgery"[Title/Abstract] OR "general surgeries"[Title/Abstract]) AND ("risk factor"[Title/Abstract] OR "risk factors"[Title/Abstract] OR "prognostic factor"[Title/Abstract] OR "prognostic factors"[Title/Abstract] OR "epidemiologic factor"[Title/Abstract] OR "epidemiologic factors"[Title/Abstract]).

Eligibility criteria

Studies were enrolled in this meta-analysis based on the following eligibility criteria: (1) studies involving patients aged > 18 years; (2) retrospective cohort studies, case–control studies, or prospective investigations assessing risk factors for SSI at a general surgery department; (3) studies reporting estimates of odds ratios (ORs), relative risks, or hazard ratios with their corresponding 95% confidence intervals (CIs) or enough data to calculate them; and (4) studies published in English. Conversely, studies published for the same study population or duplicate studies were excluded from this systematic review. In the event of disagreements between the two reviewers regarding whether a study met the inclusion criteria, a consensus was reached by a joint review.

Screening and data extraction

All articles identified by our search underwent preliminary screening of their titles and abstracts to determine relevance and adherence to the eligibility criteria. Data were extracted independently from the selected studies by two reviewers, including the authors, year of publication, country in which the study was performed, study type, number of cases, study period, SSI rate, and related risk factors. Any discrepancies were resolved through discussion among the authors.

Evaluation of research quality

The research quality of studies was assessed using the Newcastle–Ottawa Scale (NOS). Studies with an NOS score of ≥ 7 were considered to be of high quality; studies with scores of 4–6 were considered to be of moderate quality, and studies with scores of < 4 were considered to be of poor quality.

Statistics

Statistical analyses were performed using Review Manager, version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The 95% CI and OR were calculated. Both the fixed-effects model and random-effects model were considered, depending on the heterogeneity of the included studies. To assess the heterogeneity between studies, both Cochrane's Q statistic and I^2 statistic were used. Heterogeneity was considered statistically significant when $P < 0.05$ or $I^2 > 50$. If heterogeneity was observed, data were analyzed using a random-effects model. Conversely, a fixed-effects model was used when there was no heterogeneity. Additionally, to assess potential publication bias, a funnel plot and Egger test were used. A two-tailed P-value of < 0.05 was considered statistically significant.

Results

The data of 1,526 patients who underwent surgeries at the department of general surgery were retrieved from their electronic medical records. Overall, 1,276 patients (565 in the ERAS group and 711 in the non-ERAS group) remained after exclusion based on the procedure presented in Fig. 1. Basic demographic data of the included patients are presented in Table 1. Among the included patients, 40 were diagnosed with SSI, and the pooled incidence of SSI was 3.13%. The highest rate of SSI was among those undergoing gastrointestinal surgery (GS, 8.72%), followed by those undergoing bile duct, liver, and pancreatic surgeries (DLP, 1.90%); herniorrhaphy (1.82%); and thyroid and breast surgeries (TB, 0.46%). The $\chi 2$ values within TB, DLP and GS were 1.818 ($P = 0.178$), 2.219 ($P = 0.136$) and 0.199 ($P = 0.656$) respectively, indicating that no significant difference was found among these surgery types. Moreover, 14 (2.48%) patients in the ERAS group were diagnosed with SSI, whereas 26 (3.66%) patients in the non-ERAS group were diagnosed with SSI, and there were no significant differences between the two groups ($P = 0.230$).

Antibiotics given after surgery were also investigated (Table 2). Overall, 197 patients (34.87%) in the ERAS group and 266 patients (37.41%) in the non-ERAS group were given antibiotics after surgery ($P = 0.347$). The ERAS group had a lower median rate of personal defined daily doses (DDDs), although the difference was not statistically significant ($P = 0.438$). However, the rate of antibiotics use density (AUD) was higher in the ERAS group.

Risk factor analysis

Logistic regression analysis was performed (Table S1). In the ERAS group, gastrointestinal surgery (OR = 9.652, 95% CI = 1.236–74.371; $P = 0.031$), longer hospital stay after surgery (OR = 1.132, 95% CI = 1.077–1.19; $P < 0.001$), non-type I incision (OR = 20.472, 95% CI = 2.659–157.623; $P = 0.004$), lower serum hemoglobin

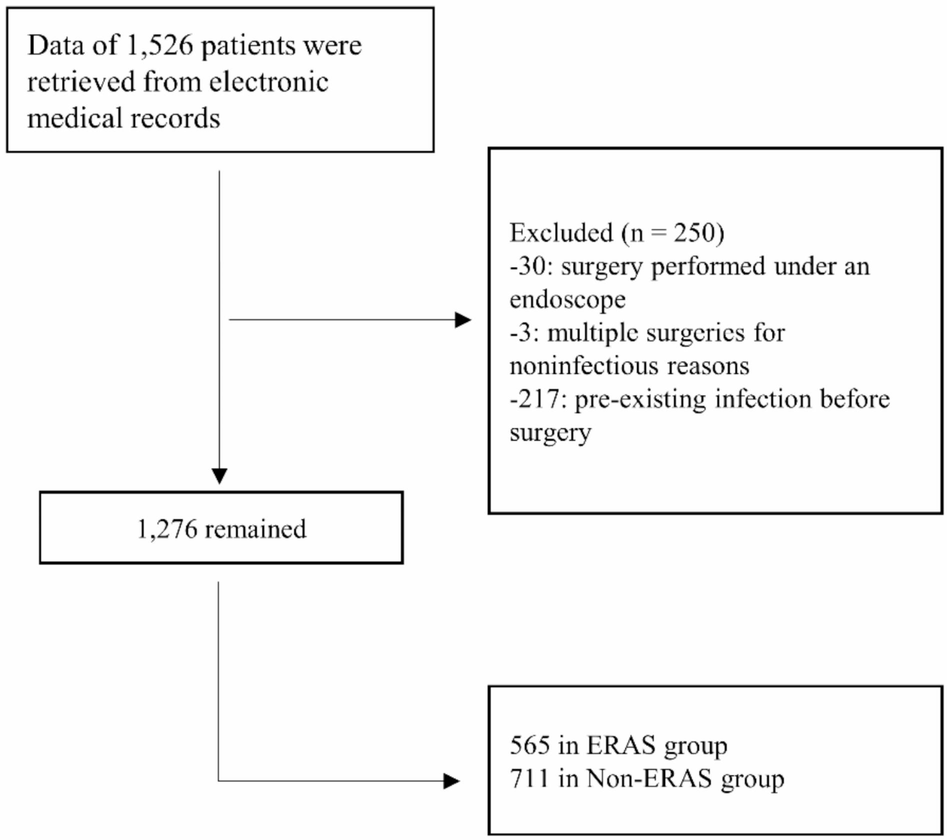

Fig. 1. Flow diagram of collection and selection of data from patents.

(OR = 0.972, 95% CI = 0.948–0.996; $P = 0.024$), lower serum TP (OR = 0.919, 95% CI = 0.852–0.992; $P = 0.03$), lower serum albumin (OR = 0.864, 95% CI = 0.776–0.962; $P = 0.008$), and antibiotic prophylaxis (OR = 4.986, 95% CI = 1.543–16.114; $P = 0.007$) were thought to be independent risk factors of SSI. Gastrointestinal surgery (OR = 4.104, 95% CI = 1.342–12.552; $P = 0.013$), longer hospital stay after surgery (OR = 1.193, 95% CI = 1.129–1.261; $P < 0.001$), non-type I incision (OR = 4.735, 95% CI = 1.878–11.940; $P = 0.001$), lower serum albumin (OR = 0.899, 95% CI = 0.827–0.978; $P = 0.013$), and antibiotic prophylaxis (OR = 4.108, 95% CI = 1.832–9.212; $P = 0.001$) were also identified as independent risk factors of SSI in the non-ERAS group. However, patients aged between 65 and 74 years old (OR = 4.945, 95% CI = 1.286–19.020; $P = 0.02$) and patients with a higher WBC count (OR = 1.385, 95% CI = 1.033–1.856; $P = 0.029$) in the non-ERAS group were more prone to SSI. Moreover, lower serum hemoglobin and lower serum TP were not thought to be independent risk factors of SSI in the non-ERAS group.

Meta-analysis

Given that the incidence of SSI was low in our study, a meta-analysis of risk factors for SSI in general departments was conducted to identify more risk factors and reduce bias.

Characteristic	ERAS group ($n=565$)	Non-ERAS group ($n=711$)	*P*-value
Female sex [n (%)]	307 (54.34%)	408 (57.38%)	0.276
Age (years) (mean ± SD)	54.96 ± 16.64	57.29 ± 17.49	0.051
Weight (mean ± SD)	63.48 ± 12.69	64.52 ± 15.47	0.117
Antibiotic prophylaxis [n (%)]	194 (34.34%)	208 (29.25%)	0.052
Diabetes [n (%)]	60 (10.62%)	74 (10.41%)	0.903
Hypertension [n (%)]	148 (26.19%)	193 (27.14%)	0.552
WBC count (10^9/L) (mean ± SD)	5.50 ± 1.40	5.68 ± 1.44	0.864
Hb (g/L) (mean ± SD)	129.44 ± 18.06	129.85 ± 17.13	0.602
Neutrophil percent (%) (mean ± SD)	58.29 ± 9.68	58.28 ± 8.65	0.738
ALB (g/L) [median (IQR)]	43 [39, 46]	43 [40, 46]	0.478
ALT (U/L) [median (IQR)]	15 [12, 23.5]	17 [12, 29]	0.229
AST (U/L) [median (IQR)]	19 [16, 23.5]	20 [17, 26]	0.016
STB (μmol/L) [median (IQR)]	12 [9, 15]	12 [9, 15]	0.972
UCB (μmol/L) [median (IQR)]	4 [3, 5]	4 [3, 5]	0.056
Serum glucose (mmol/L) (mean ± SD)	5.41 ± 1.55	5.35 ± 1.27	0.952
Serum urea (mmol/L) (mean ± SD)	5.12 ± 1.69	5.32 ± 2.05	0.41

Table 1. Demographic characteristics of the patients. ERAS, enhanced recovery after surgery; SD, standard deviation; WBC, white blood cell; hb, hemoglobin; ALB, albumin; IRQ, interquartile range; ALT, alanine aminotransferase; AST, aspartate aminotransferase; STB, serum total bilirubin; UCB, unconjugated bilirubin.

	ERAS group ($n=565$)	Non-ERAS group ($n=711$)	*P*-value
Antibiotics used after surgery [n (%)]	197 (34.87%)	266 (37.41%)	0.347
Personal DDDs* [median (IQR)]	3.33 [1.54, 6.67]	4 [2, 6.67]	0.438
AUD†	76.47	67.35	–

Table 2. Antibiotic consumption after surgery. *DDDs $= \sum \left(\frac{drug\ specification \times amount}{defined\ daily\ dose}\right)$. †AUD $=\frac{DDDs \times 100}{inpatient\ days}$. ERAS, enhanced recovery after surgery; DDDs, defined daily doses; AUD, antibiotics use density.

Characteristics of studies

Combined search strategies resulted in 157 abstracts. Further, all identified abstracts were checked and full texts of 39 articles were reviewed in depth. In total, 118 studies were excluded during abstract review, whereas 24 studies were excluded during full-text review (Fig. 2).

A total of 15 eligible studies were finally included in our meta-analysis, including 12 prospective investigations and 3 retrospective studies. The basic characteristics of the enrolled studies are summarized in Table 3. As shown in Table S2, according to the NOS checklist, 11 studies with scores of ≥ 7 were considered to be of high quality, and the remaining 4 studies were of medium quality with 5 or 6 points.

Analysis of risk factors (Table S3, Figs. 3 and 4)

Overall, nine risk factors were assessed in our meta-analysis. A funnel plot and Egger's test were used to evaluate potential publication bias, which indicated no significant publication bias among all of the included studies.

Maleness Eight studies involving male patients were included in our analysis, with nine prospective investigations and one retrospective study. The overall OR was 1.25 (95% CI = 0.99–1.58; $P=0.06$) with heterogeneity ($P=0.02$ and $I^2=57\%$), indicating that there was no significant relationship between maleness and SSI.

Diabetes Five studies included in our research were related to diabetes, and all of them were prospective investigations. The overall OR was 2.17 (95% CI = 1.73–2.74; $P<0.00001$) with no significant heterogeneity ($P=0.33$, $I^2=12\%$), which showed a strong relationship between diabetes and SSI.

Anemia Only two prospective investigations included in our studies were related to anemia. The overall OR was 1.63 (95% CI = 0.50–5.28; $P=0.41$) and significant heterogeneity was observed during the analysis ($P<0.0001$, $I^2=95\%$).

Smoking Five studies, including four prospective investigations and one retrospective study, were related to smoking. The overall OR for smoking was 1.54 (95% CI = 1.25–1.90; $P<0.0001$) with mild heterogeneity ($P=0.13$, $I^2=43\%$), indicating that there was a relationship between smoking and SSI.

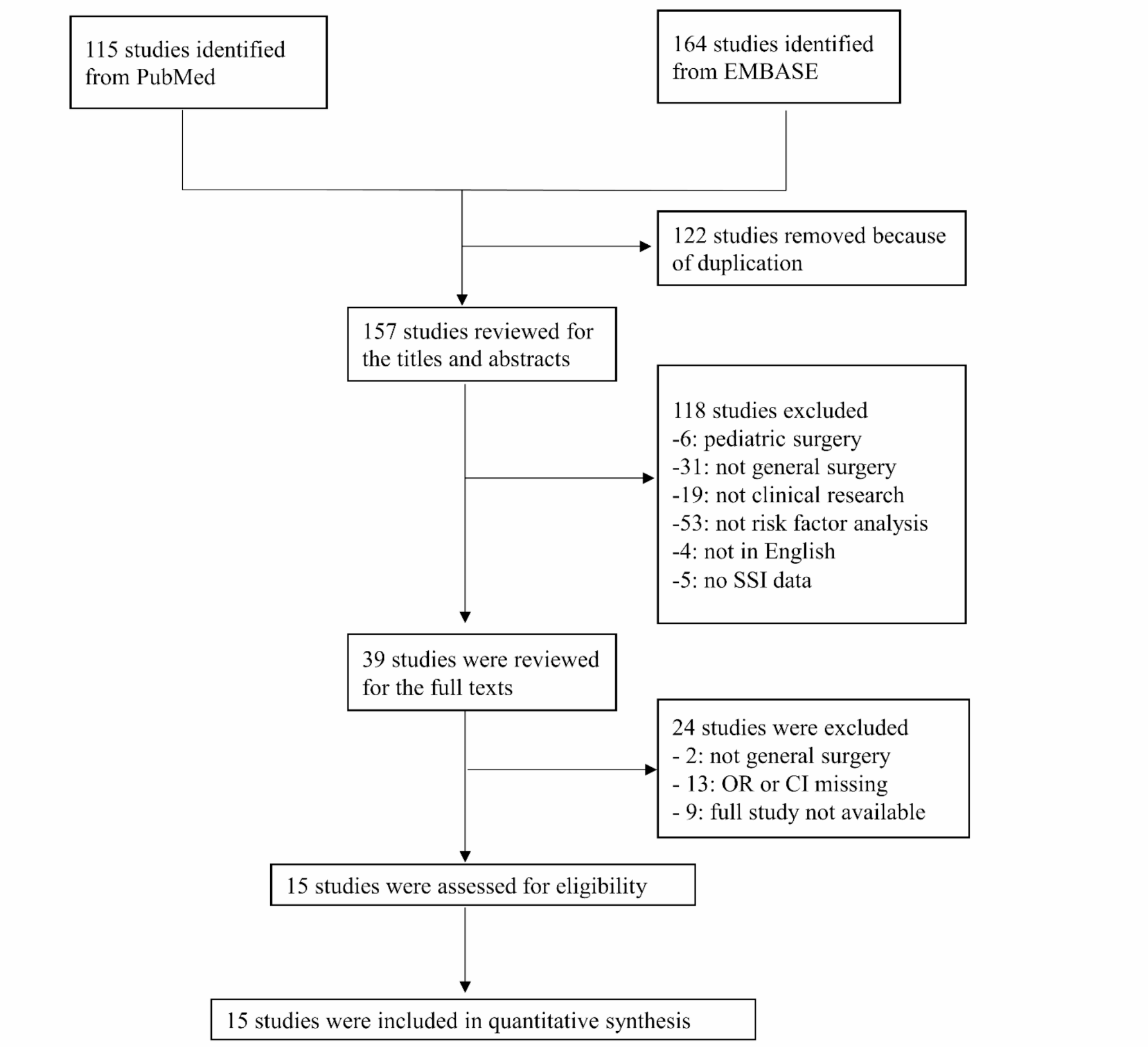

Fig. 2. Flow diagram of the meta-analysis and selection processes.

Transfusion Four prospective investigations and one retrospective study were related to transfusion. The overall OR was 2.06 (95% CI = 1.41–3.02; $P = 0.0002$), with considerable heterogeneity ($P = 0.0003$, $I^2 = 79\%$). This showed that transfusion might be an indicator of SSI.

Lower serum albumin levels Three studies included in our work were related to lower serum albumin. Two of them were retrospective studies and only one was a prospective investigation. The overall OR for lower serum albumin was 1.91 (95% CI = 1.47–2.50; $P < 0.00001$) and a little heterogeneity ($P = 0.50$, $I^2 = 0$) was observed. This showed that lower serum albumin might be a risk factor of SSI.

Drainage A total of four studies related to drainage were included in our analysis, with three prospective investigations and one retrospective study. The overall OR was 2.66 (95% CI = 1.98–3.58; $P < 0.00001$) with heterogeneity ($P = 0.03$, $I^2 = 66\%$), indicating a significant relationship between drainage and SSI.

Non-type I incision In our study, nine studies, including seven prospective investigations and two retrospective studies, were related to the type of incision. Owing to the differences in the analysis of higher classes of incision (some studies analyzed type II and III incisions separately, whereas some considered type II and III incisions as a single risk factor in the analysis), our analysis included data on only type II incision or the combination of type II and III incisions. The overall OR was 3.44 (95% CI = 2.03–5.82; $P < 0.00001$) with significant heterogeneity ($P < 0.00001$, $I^2 = 87\%$). Accordingly, type II and III incisions may be considered the predictors of SSI.

Study	Country	Year	No.	Study type	Study period	SSI rate (%)
Kasatpibal et al.[30]	USA	2017	4078	Retrospective	2012–2015	0.4
Alp et al.[31]	Turkey	2014	3859	Prospective	2005–2009	10.8
Fiorio et al.[32]	Italy	2006	2972	Prospective	2002	5.2
Misha et al.[33]	Ethiopia	2021	251	Prospective	2019	21.1
Haridas et al.[34]	USA	2008	5952	Retrospective	2000–2006	5.04
Junker et al.[35]	Switzerland	2012	6283	Prospective	2000–2001	4.7
Elbur et al.[36]	Sudan	2013	540	Prospective	2010	10.9
Mekhla et al.[37]	India	2019	100	Prospective	2016–2017	39
Isik et al.[38]	Turkey	2015	4690	Retrospective	2003–2009	4.09
Petrosillo et al.[39]	Italy	2008	4665	Prospective	2002	5.2
Hung et al.[40]	Vietnam	2011	4413	Prospective	2009	5.5
Lindsjö et al.[41]	India	2015	1581	Prospective	2011–2013	6.5
Pishori et al.[42]	Pakistan	2003	3788	Retrospective	1997–1999	10.5
Medina-Cuadros et al.[43]	Spain	1996	1483	Prospective	1992–1994	10.5
Alp et al.[44]*	Turkey	2014	800	Prospective	2011	15.2

Table 3. General characteristics of the included studies. *This article will be represented as Alp et al. (2014a) in the following analysis. SSI, surgical site infection.

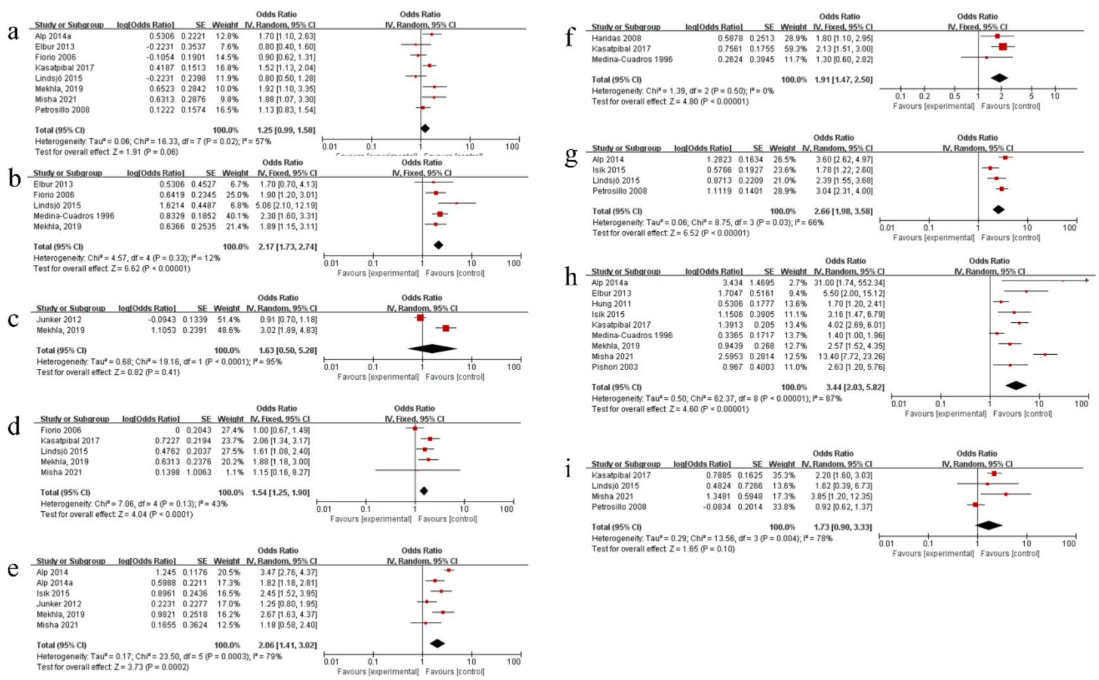

Fig. 3. Forest plot for risk factors, including male (**a**), diabetes (**b**), anemia (**c**), smoking (**d**), transfusion (**e**), lower serum albumin (**f**), drainage (**g**), non-type I incision (**h**) and antibiotic prophylaxis (**i**). CI = confidence interval; df = degree of freedom; IV = inverse variance;

Antibiotic prophylaxis There were three prospective investigations and one retrospective study related to antibiotic prophylaxis in our study. No significant relationship was found between antibiotic prophylaxis and SSI, with an overall OR of 1.73 (95% CI = 0.90–3.33; $P = 0.10$) and significant heterogeneity ($P = 0.004$, $I^2 = 78\%$).

Propensity score matching

Based on the results of logistic regression analysis and meta-analysis, nine risk factors were considered in propensity score matching (i.e., age, surgery type, incision type, diabetes, WBC count, hemoglobin level, TP level, ALB level, and antibiotic prophylaxis). Furthermore, 1:1 propensity score matching provided two fuzzy-matched populations of 358 patients with similar preoperative characteristics (Table 4). After matching, the

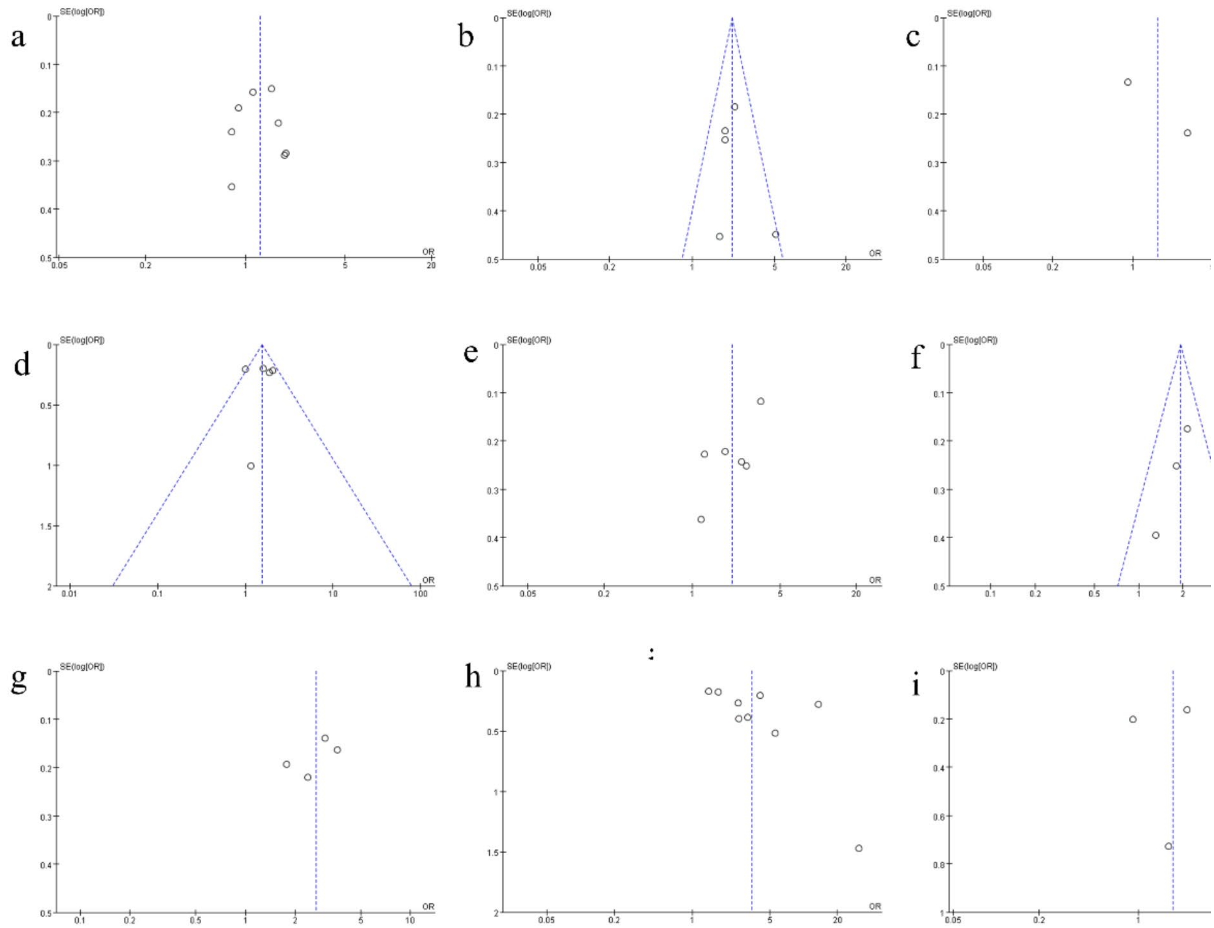

Fig. 4. Funnel plot for risk factors, including male (**a**), diabetes (**b**), anemia (**c**), smoking (**d**), transfusion (**e**), lower serum albumin (**f**), drainage (**g**), non-type I incision (**h**) and antibiotic prophylaxis (**i**). SE = effect size.

Characteristic	ERAS group (n = 358)	Non-ERAS group (n = 358)	P-value
65–74 years old [n (%)]	69 (19.27%)	59 (16.48%)	0.38
Gastrointestinal surgery [n (%)]	78 (21.79%)	79 (22.07%)	0.928
Diabetes [n (%)]	42 (11.73%)	40 (11.73%)	0.814
Type 2 incision [n (%)]	110 (30.72%)	116 (32.40%)	0.629
WBC count (10^9/L) (mean ± SD)	5.60 ± 1.38	5.60 ± 1.42	0.773
Hb (g/L) (mean ± SD)	130.05 ± 18.49	130.01 ± 16.94	0.697
TP (g/L) (mean ± SD)	69.96 ± 6.51	70.30 ± 6.77	0.826
ALB (g/L) (mean ± SD)	42.53 ± 4.62	42.74 ± 4.49	0.886

Table 4. Characteristics after propensity score matching. ERAS, enhanced recovery after surgery; WBC, white blood cell; hb, hemoglobin; ALB, albumin; TP, total protein.

SSI rate was 2.80% and 3.98% in the ERAS and non-ERAS groups, respectively, with no significant differences between the two groups (P = 0.534). Similarly, no significant difference was observed in the cumulative incidence of SSI between ERAS and Non-ERAS group (P = 0.690, Table S4, Fig. 5). Moreover, the personal DDDs (4 [1.71, 6.67] vs. 4 [2, 7], P = 0.183) were similar between the two groups (Table 5) ,while AUD in ERAS group was higher than Non-ERAS group(72.56 vs. 69.47).

There were significantly fewer postoperative hospitalized days in the ERAS group (3 [2, 6] vs. 3 [2, 7], P = 0.004). Moreover, patients in the ERAS group without SSI showed significantly fewer hospital days (2 [2, 5]

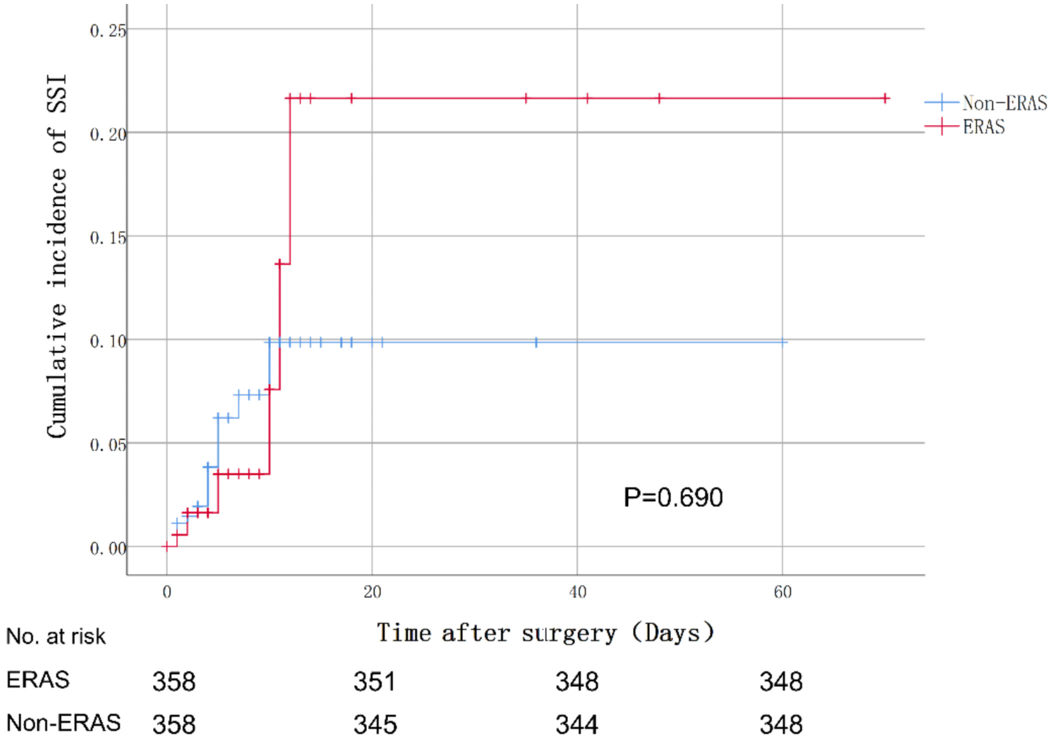

Fig. 5. Kaplan–Meier estimates of incidence of SSI in ERAS and Non-ERAS groups.

	ERAS group	Non-ERAS group	*P*-value
SSI incidence [n (%)]	2.80%	3.98%	0.534
Postoperative hospitalized days [median (IQR)]	3 [2, 6]	3 [2, 7]	0.004
Personal DDDs [median (IQR)]	4 [1.71, 6.67]	4 [2, 7]	0.183
AUD	72.56	69.47	–

Table 5. Outcomes after propensity score matching. ERAS, enhanced recovery after surgery; DDDs, defined daily doses; AUD, antibiotics use density.

vs. 3 [2, 7], $P=0.005$) than patients in the non-ERAS group without SSI, while a significant difference was solely noticed between patients with SSI in the ERAS and non-ERAS groups (20.5 [17, 32] vs. 16.5 [9, 23], $P=0.341$).

Discussion

In this retrospective observational study, SSI incidence was maintained at 3.13%. The rate was lower than the pooled SSI rate of 14.1% in low- and middle-income countries as reported by the World Health Organization[2]. Although the SSI rate in ERAS appeared to be a slightly lower than that in the non-ERAS group, no significant difference was found, indicating that the implementation of ERAS had no effect on SSI incidence. Notably, the ERAS and non-ERAS groups even showed more similar SSI rates after matching. This matches the findings in surveys conducted by Gronnier et al.[15] and Joliat et al.[16], which verified that ERAS had no independent impact on SSI in colonic and pancreatic surgery, respectively. Interestingly, according to Kaplan–Meier analysis, it seems that patients in Non-ERAS group were more likely to get SSI in the first few days after surgery, while those in ERAS group became more susceptible with duration of follow-up.

The ERAS protocol applied in the present study successfully reduced the length of postoperative hospital stay, and this finding is similar to those of previous studies[17,18]. Moreover, as indicated by the results of our study, a significant difference was noted between the ERAS and non-ERAS groups solely in uninfected patients. Conversely, no significant difference was identified between the two groups among infected patients. This indicates that the implementation of the protocol accelerated the discharge of uninfected patients. However, although no significant difference was identified among infected patients, in the ERAS group, patients with SSI tended to have longer postoperative hospital stays. This could potentially result from the avoidance of unnecessary procedures, minimization of prescriptions for medications such as opioids or steroids, and the implementation of early enteral nutritional support[19,20]. Moreover, the length of the postoperative hospital stay was remarkably affected by SSI. Therefore, delayed discharge due to SSI could not compensate for the reduced length of stay due to ERAS.

There were some differences between the risk factors identified in our study and previous studies[15,16]. For example, more risk factors, such as lower serum hemoglobin, TP, and albumin levels, were identified in our study. In addition, different risk factors were identified between the ERAS and non-ERAS groups. This could be attributed to the variation of protocol, which has been mentioned by Chorath et al.[2], and compliance with the protocol. Moreover, based on the geriatric assessment and personalized prehabilitation in ERAS, it could be assumed that age was not an independent risk factor for SSI[21]. Furthermore, given that both acute and chronic inflammatory processes can cause neutrophilia, prehabilitation in ERAS could contribute to better SSI prevention[22].

Six risk factors were identified by meta-analysis, among which diabetes, lower ALB, and non-type I incision were also found by our risk factor analysis. The impact of lower albumin on SSI has been reported recently[23]. Our study further confirmed that lower albumin before surgery was a crucial risk factor that was even more important than lower TP. The possible pathophysiological mechanism could be as follows. Although albumin synthesis increases in SSI patients, oxidation and scavenging of albumin are upregulated. Meanwhile, albumin serves as an intracellular amino acid donor for cell proliferation at a high rate in SSI. Consequently, the breakdown of albumin is increased in SSI, leading to decreased albumin mass despite potentially increased synthesis[24].

Surprisingly, patients with type II incision were more prone to SSI than those with type III incision in our study. This is counterintuitive because it has been well recognized that type III incision has a higher risk of SSI. However, it is understandable because most of the patients with type III incision had undergone cholecystectomy or appendicectomy. These surgeries have been confirmed to be associated with a lower risk of SSI than surgeries like gastrectomy or enterectomy, which were classified as involving type II incisions[7]. Moreover, antibiotics were used preoperatively in most of patients with type III incisions, which heightened the difficulty for doctors in charge to diagnose SSI[25].

The reduced hospital days significantly affect the surveillance of antibiotic consumption. After propensity score matching, the ERAS group showed a lower personal DDDs, while its AUD was nearly 5% higher than non-ERAS group. However, since various measures to reduce AUD in hospitals have been implemented these years, the effect of ERAS on AUD might be underestimated. This result reminds us that AUD might not be the most appropriate measure of antibiotics consumption in the era of ERAS.

ASEPSIS score has been used to identify SSIs after breast surgery[26], groin surgery[27], and colorectal surgery[28] and it has been shown to have a 95.7% inter-rater agreement between surgeons[29]. This is the first time that the ASEPSIS score has been used in China to evaluate SSI associated with general surgeries. The ASEPSIS score was found to be convenient and efficient to use in our study and a retrospective study showed its objectivity and practicability to make accurate wound surveillance feasible at a lower cost. However, more research is needed internationally to investigate whether the ASEPSIS score could be a practical scoring method for the assessment of surgical wounds at other sites.

Nevertheless, there are still some limitations in our research. Firstly, the required postoperative observation period is 30 days according to the ASEPSIS score; however, most of the patients examined in our study were discharged within 30 days, and the follow-up was difficult unless the patients were readmitted for disturbed wound healing. Therefore, the patients were not observed for 30 days; thus, the incidence of SSI might have been underestimated. Another limitation of our study is the lack of deep investigation into a single disease. This is potentially attributable to the small sample size and low SSI rate, which have resulted in a scarcity of infected patients across several diseases. While meta-analysis has aided in identifying additional risk factors, we acknowledged that some of the studies included were not recently published, emphasizing the need for more researches to clarify the correlation between ERAS and SSI.

In conclusion, although the present study confirmed that the implementation of ERAS had no impact on the incidence of SSI. We still discovered a novel idea that the implementation of ERAS considerably accelerated the discharge of uninfected patients, whereas it did not affect the discharge of infected patients, which means the implementation of ERAS should be encouraged. In the future, more researches are expected to provide insights into specialized surgeries, such as biliary tract surgeries or pancreatic surgeries, enabling optimal and accurate perioperative management. Not only in general surgery, other fields, like urology surgery, should be paid attention. Furthermore, researches on the impact of specific measurement within ERAS protocol, where digital instruments or artificial intelligence models could be involved, will also make a profound difference to the evaluation of ERAS protocol and personalized perioperative management.

Data availability

The dataset used in this study are currently not permitted for public release by the Institutional Review Boards. Data requests pertaining to the manuscript will be made to the first author (Baohong Wang;1004597232@qq.com).

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Author contributions

In this study, B.W., Y.W. and J.H. designed the method, and drafted the manuscript. P.W., Y.H., Z.Z, L.Z, D.Y and C.Y. collected and checked the dataset. D.Y. participated in the drawing of the figures. Y.L. revised the manuscript and coordinated and supervised the whole work. Authors were involved in critical revisions of the manuscript, and have read and approved the final version.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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