# Updated systematic review and meta-analysis for risk predictors of 30-day unplanned readmission following gastric cancer surgery

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**Abstract.** Readmission to hospital is a common occurrence due to adverse post-operative events. The primary objective of the present study was to examine the possible risk predictors for 30-day unplanned readmissions after the surgical treatment of gastric cancer. The secondary aim was to determine the clinical characteristics that are associated with readmission. Studies that reported the risk factors and clinical characteristics of patients with gastric cancer who had an unplanned 30-day post-operative readmission were identified systematically from PubMed, Cochrane Central Register of Controlled Trials, Web of Science and Embase databases, with a final search date of March 30, 2024. A systematic review and meta-analysis were then performed to estimate the risk predictors and relevant clinical characteristics for readmission. A total of 16,154 patients from 12 studies were included in the present study, with 1,736 patients who were readmitted and 14,418 patients who were not readmitted. A higher proportion of patients with an age ≥70 years, cardiovascular comorbidity, Nutritional Risk Screening (NRS) 2002 score ≥3, respiratory diseases, male sex, American Society of Anesthesiologists score ≥3, combined multi-organ resection, greater depth of invasion (T3-4/T1-2), discharge to home with provision of care services, neoadjuvant therapy, post-operative complications or a blood transfusion were found in the readmission group compared with that in the non-readmission group. A meta-analysis was also performed to calculate risk predictors using the results of multivariate regression analyses from the original literature. This identified cardiovascular comorbidity, NRS 2002 score ≥3, pancreatectomy and post-operative complications as risk predictors for 30-day unplanned readmission following surgery for gastric cancer. Therefore, it is recommended that extra attention and support should be given to patients with these high-risk predictors during the perioperative period.

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*Key words:* gastric cancer, meta-analysis, unplanned readmission, risk predictors, gastrectomy

## Introduction

Gastric cancer is the third most common type of tumor in China, with ~480,000 new cases annually (1), and the disease was estimated to account for 4.9% of cancer cases worldwide in 2022 (2). Surgical resection is the mainstay and gold-standard treatment for gastric cancer (3). However, post-operative complications and unplanned readmissions are prevalent among patients with gastric cancer (4). With the advent of enhanced recovery protocols, hospital stays for patients undergoing surgery have been shortened. However, this raises concerns that the discharge of vulnerable patients could lead to unplanned readmissions. According to a previous meta-analysis, individuals with gastric cancer experience readmissions at a higher rate (6.6-8.7%) than those with other types of malignancies (5). Unplanned readmissions have a negative impact on the quality of life and post-operative recovery of patients, and also markedly raise the economic burden of healthcare on patients and their families (6). It was estimated that the medical costs associated with post-operative hospital readmission in the US totaled $17.4 billion in 2004 (7). Clearly, unplanned readmissions impose a high financial burden and increased strain on health insurance and health care providers. It has been reported that unplanned readmission is also associated with increased mortality in patients who undergo gastrectomy (8). Therefore, it is important to identify the risk factors for readmission to enable the rate of readmission after gastrectomy to be reduced.

In 2019, two meta-analyses of original literature were performed to explore the risk predictors of 30-day unplanned readmission after surgery for gastric cancer, both of which included ≤10 articles (5,9). Furthermore, the outcomes of multivariate regression analyses were used to investigate the risk predictors, but these analyses were based on only one to three studies for each predictor (5). Over the subsequent 5 years, updated data and novel articles have emerged. Therefore, an updated systematic review and meta-analysis is required to determine the risk variables for an unplanned 30-day readmission after gastric cancer surgery.

## Materials and methods

*Search strategy.* Relevant studies were found mainly by searching the PubMed (https://pubmed.ncbi.nlm.nih.gov/), Cochrane Central Register of Controlled Trials (https://www.cochranelibrary.com), Web of Science (https://clarivate.com)

and Embase databases (https://www.embase.com/). The main search terms were ('gastric carcinoma' OR 'gastric cancer' OR 'gastrectomy') AND ('readmission' OR 'secondary admission'). The final search was performed on March 30, 2024. Two authors independently reviewed the title and abstract of each citation and obtained the full text of potentially eligible studies. Disagreements were resolved through discussion or with the involvement of the third author. Additionally, the reference lists of all retrieved studies were reviewed to identify any additional eligible studies. The study protocol was registered at PROSPERO (https://www.crd.york.ac.uk/PROSPERO/) (CRD42024537213).

*Inclusion and exclusion criteria*. Inclusion criteria for these studies were as follows: i) Case-control studies, randomized controlled trials or cohort studies in humans; ii) information on 30-day unplanned readmissions following gastric cancer surgery was included; iii) potential causes and risk factors of multivariate analysis were available; and iv) no limitation on surgical methods was imposed. Exclusion criteria: i) Reviews, letters, case reports and conference abstracts; ii) animal experiments, *in vitro* studies and ongoing trials; and iii) required data were lacking.

*Data extraction and quality assessment*. The data were independently retrieved from the included studies by two authors. The information encompassed trial name, publication date, country, study period, number of patients, tumor stage, surgical procedure, surgery plan, and potential causes and risk factors for 30-day readmission. Only causes identified in two or more studies and risk factors reported in the multivariate analysis of two or more articles were included.

Two authors conducted independent assessments. Differences between these two authors were settled by conversation or by seeking the advice of the third author. No exclusions were made based on this. The risk of bias in the eligible studies was comprehensively assessed using the Newcastle-Ottawa Scale (NOS) (10). The NOS has a total of 8 items and a maximum score of 9. Studies with a score <6 were deemed moderate- or low-quality studies.

*Statistical analysis*. The PRISMA statement methodology (11) was utilized to report the systematic reviews and perform the meta-analysis. All categorical variables were non-continuous. Forest plots were automatically generated using Review Manager 5.4 software (Cochrane Collaboration). Odds ratios (ORs), P-values and 95% confidence intervals (CIs) were utilized to assess the significance of differences. $P<0.05$ was considered to indicate a statistically significant result. Heterogeneity evaluation was performed using $I^2$ for the included studies: $I^2$ <50% indicated no significant heterogeneity, while $I^2$ ≥50% denoted heterogeneity. The random effects model was used to analyze and merge the data in forest plots. In addition, ORs with a 95% CI based on multivariate analysis were used to determine the potential risk predictors for 30-day readmission. To clarify the underlying source of heterogeneity, subgroup analyses were performed according to grouping by country, study design and surgical procedure. A 'leave-one-out' influence analysis was also performed to assess the influence of individual studies of the risk predictors by removing one study at a time. Publication bias was evaluated with a funnel plot and Egger's test. The influence analysis and publication bias evaluation were conducted using STATA 16.0 (StataCorp LP).

## Results

*Study selection*. Through a systematic literature search process, a total of 2,569 articles were initially retrieved. After the removal of duplicates followed by the screening of individual titles and abstracts, the full texts of 31 articles were read to assess their eligibility. In total, 19 studies were excluded due to insufficient data, not being on gastric cancer surgery, the gastric cancer being mixed with other tumors, and duplication. Finally, 12 eligible studies (12-23) remained and were included in the present meta-analysis. A flow chart showing the selection of literature according to PRISMA guidelines is shown in Fig. 1.

*Characteristics of studies*. The included studies comprised 10 retrospective case-control studies (12,13,16-23) and two prospective case-control studies (14,15). Two of the retrospective studies (13,16) were multicenter case-control studies from the United States. One study (17) included cases of early gastric cancer only. The present meta-analysis included a total of 16,154 patients, of whom 1,736 were readmitted and 14,418 were not readmitted. Table I displays key characteristics of the included studies. The quality of each study was assessed using the NOS scoring system, and was found to range from 6 to 8, as presented in Table I. Detailed NOS scores are presented in Table SI).

*Preoperative clinical characteristics associated with 30-day readmission*. A total of 12 preoperative clinical characteristics were identified for inclusion in the current meta-analysis (Table II). Of these, five characteristics were found to have a statistically significant association with 30-day readmission, namely, age ≥70 years (OR, 1.58; 95% CI, 1.40-1.79; P<0.00001), cardiovascular comorbidity (OR, 2.00; 95% CI, 1.50-2.66; P<0.00001), a Nutritional Risk Screening (NRS) 2002 score of ≥3 (OR, 2.02; 95% CI, 1.02-3.98; P=0.04), respiratory diseases (OR, 1.46; 95% CI, 1.07-1.99; P=0.02) and male sex (OR, 1.17; 95% CI, 1.03-1.33; P=0.02). By contrast, seven characteristics were found not to have a statistically significant association with 30-day readmission, namely, anemia (OR, 1.06; 95% CI, 0.93-1.21; P=0.40), body mass index (BMI) ≥25 $kg/m^2$ (OR, 1.01; 95% CI, 0.57-1.79; P=0.98), comorbidity (OR, 1.35; 95% CI, 0.86-2.11; P=0.20), diabetes (OR, 1.10; 95% CI, 0.67-1.83; P=0.70), hypertension (OR, 1.23; 95% CI, 0.99-1.52; P=0.06), sarcopenia (OR, 2.08; 95% CI, 0.60-7.20; P=0.25) and smoking history (OR, 1.17; 95% CI, 0.62-2.20; P=0.64). Forest plots for these characteristics are presented in Figs. S1, S2, S3A and S3B.

*Perioperative clinical characteristics associated with 30-day readmission*. Seven factors were found to be significantly different between the readmission and non-readmission groups in the present meta-analysis (Table II). A higher proportion of patients who had an American Society of Anesthesiologists (ASA) score ≥3 (OR, 1.64; 95% CI, 1.23-2.20; P=0.0009), had

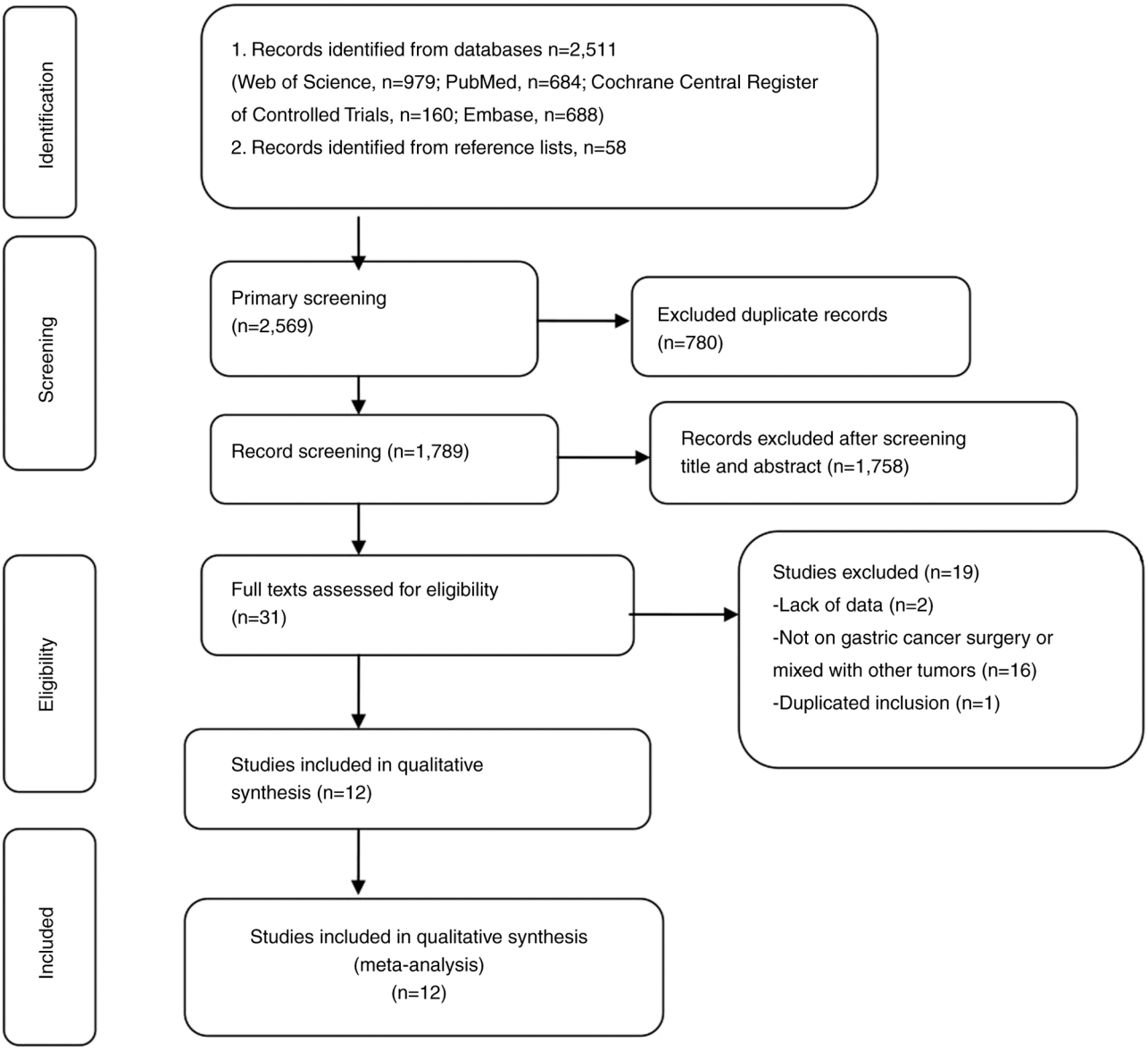


Figure 1. Flow diagram depicting the study selection process for inclusion in the meta-analysis.

undergone combined multi-organ resection (OR, 1.78; 95% CI: 1.32-2.41; P=0.0002) had a high depth of invasion (T3-4/T1-2; OR, 2.05; 95% CI, 1.08-3.88; P=0.03) or were discharged to home with the provision of care services (OR, 1.51; 95% CI, 1.31-1.75; P<0.00001) were identified in the readmission group compared with that in the non-readmission group. In addition, the proportions of patients who received neoadjuvant therapy (OR, 1.65; 95% CI, 1.03-2.67; P=0.04), experienced post-operative complications (OR, 2.70; 95% CI, 1.54-4.74; P=0.0005) or had received blood (OR, 1.27; 95% CI, 1.11-1.44; P=0.0003) were also observed to be higher in the readmission group compared with the non-readmission group. However, no difference between the readmission and non-readmission groups was identified in the following nine characteristics: Complication due to the tumor (OR, 1.76; 95% CI, 0.86-3.60; P=0.12), gastric resection (total/subtotal; OR, 1.25; 95% CI, 0.85-1.82; P=0.25), extent of lymph node dissection ≥D2 (OR, 1.14; 95% CI, 0.73-1.79; P=0.57), history of abdominal surgery (OR, 1.29; 95% CI, 0.74-2.26; P=0.37), laparoscopic surgery (OR, 0.78; 95% CI, 0.45-1.35; P=0.38), duration of surgery ≥210 min (OR, 1.63; 95% CI, 0.67-3.96; P=0.28), pTNM stage (III-IV/I-II; OR, 1.11; 95% CI, 0.81-1.52; P=0.54) and recurrence (OR, 0.99; 95% CI, 0.21-4.63; P=0.98). Forest plots for these analyses are presented in Figs. S3C-E, S4, S5, S6A and S6B).

*Risk predictors for post-operative 30-day unplanned readmission*. Data from multi-factor analyses were incorporated into a meta-analysis to determine independent risk predictors. The results indicated that seven factors were associated with the highest risk of 30-day unplanned readmission. Specifically, cardiovascular comorbidity (OR, 2.57; 95% CI, 1.77-3.71: P<0.00001), NRS 2002 score ≥3 (OR, 2.94; 95% CI, 1.72-5.03; P<0.0001), pancreatectomy (OR, 1.62; 95% CI, 1.17-2.25; P=0.004) and post-operative complications (OR, 2.66; 95% CI, 1.34-5.27; P=0.005) were found to be significant risk factors (Table III). Forest plots for these analyses are presented in Figs. S4, S6C, S6E and S7).

Table I. Key parameters extracted from the included studies.

| First author, year | Country | Study design | Study period | R/T, n | Stage | Surgical procedure | Surgery plan | NOS score | (Refs.) |
|---|---|---|---|---|---|---|---|---|---|
| Kim *et al*, 2012 | Korea | Retro-S | 2003-2008 | 69/461 | I-II | Radical subtotal + G | O + L | 6 | (12) |
| Ahmad *et al*, 2014 | USA | Retro-M | 1995-2001 | 61/418 | I-IV | Curative + G | NA | 7 | (13) |
| Kim *et al*, 2014 | Korea | Pro-S | 2002-2009 | 22/102 | I-II | Radical total + G | O + L | 7 | (14) |
| Zhuang *et al*, 2015 | China | Pro-S | 2013-2014 | 27/376 | I-IV | Curative + G | O + L | 7 | (15) |
| Acher *et al*, 2016 | USA | Retro-M | 2000-2012 | 121/855 | I-IV | Curative + G | NA | 8 | (16) |
| Honda *et al*, 2016 | Japan | Retro-S | 2007-2011 | 21/1461 | I | G | O + L | 6 | (17) |
| Ammori *et al*, 2018 | USA | Retro-S | 2005-2011 | 1195/6985 | NA | G | NA | 6 | (18) |
| Asaoka *et al*, 2019 | Japan | Retro-S | 2010-2016 | 52/1929 | I-IV | Curative + G | O + L | 6 | (19) |
| Ma *et al*, 2019 | China | Retro-M | 2014-2017 | 37/585 | I-II | Curative + G | O + L | 6 | (20) |
| Xiao *et al*, 2018 | China | Retro-S | 2010-2017 | 60/2023 | I-IV | Curative + G | O + L | 7 | (21) |
| Cai *et al*, 2022 | China | Retro-S | 2016-2017 | 43/657 | I-III | Curative + G | O + L | 8 | (22) |
| Chen *et al*, 2023 | China | Retro-S | 2014-2018 | 28/302 | I-III | Curative + G | O + L | 7 | (23) |

R, readmitted patients; T, total patients; NOS, Newcastle-Ottawa Scale; retro, retrospective; pro, prospective; S, single, M, multicenter; G, gastrectomy; O, open surgery; L, laparoscopy; NA, not available; USA, United States.

A substantial degree of heterogeneity ($I^2$=92) was observed in the analysis of the post-operative complications risk factor. Nevertheless, no meta-regression analysis was performed, as the meta-analysis only included four trials. Instead, a sensitivity analysis and random effects model analysis were used (Fig. 2). The results of the meta-analysis appear to be markedly impacted by one study by Ammori *et al* (18), which based on the influence analysis plot, is a source of heterogeneity manifested by the use of various surgical techniques. Therefore, subgroup analyses were performed based on different countries, study designs and surgical procedures (Fig. 3). The forest plots show that heterogeneity decreased most significantly according to study design, followed by surgical procedure. This indicates that differences in study designs could be significant contributors to heterogeneity. Notably, BMI ≥25 kg/m$^2$ (OR, 0.99; 95% CI, 0.32-3.07; P=0.98), male sex (OR, 0.95; 95% CI, 0.83-1.09; P=0.48) and pulmonary comorbidity (OR, 1.08; 95% CI, 0.91-1.28; P=0.38) were not found to be risk factors for the prediction of post-operative 30-day unplanned readmission (Table III).

*Publication bias*. A funnel plot (Fig. 4) was constructed to estimate publication bias, and no obvious bias was observed. In addition, no significant publication bias was identified using the Egger test (P=0.394).

## Discussion

The present meta-analysis exhibits both similarities and differences with the two previously published meta-analyses on the risk factors for readmission after gastric cancer surgery (5,9). Compared with one of the previous meta-analyses (5), the present meta-analysis includes four additional studies (18,20,22,23), and has others in common (12-17,19), while compared with the other (9), the present meta-analysis covers six additional studies (12,14,17,20,22,23), with others in common (13,15,16,18,19,21). Also, only univariate regression analysis results from the original literature were incorporated in one of the prior meta-analyses (9); while the other (5) included data from multivariate regression analyses, some of the risk factors identified by it were only derived from one item of original literature, including longer length of hospital stay, NRS 2002 score ≥3, combined multi-organ resection, laparoscopic vs. open surgery and CRP on post-operative 3-day ≥12. The present meta-analysis differs in that at least two multivariate analysis results from the original literature were included when identifying the risk predictors for readmission. In common with the previous meta-analyses, the present study analyzed age, BMI, cardiovascular comorbidity, diabetes, respiratory diseases, sex, combined multi-organ resection, operation method and post-operative complications. However, it also analyzed other clinical characteristics, including anemia, hypertension, NRS 2002 score, smoking history, sarcopenia, ASA score, tumor-associated complications, depth of invasion, discharge to home with service, the extent of gastric resection, the extent of lymph node dissection, history of abdominal surgery, neoadjuvant therapy, the duration of surgery, pTNM stage, receipt of blood and recurrence.

Post-operative 30-day unplanned readmission after gastric cancer surgery is a concern for patients due to the high mortality rate and additional medical expenses (16,24). Malnutrition is frequent in individuals with gastric cancer, with an incidence of 36-43% (25,26). In patients undergoing major abdominal surgery, preoperative malnutrition is generally associated with an increased risk of post-operative complications, which commonly manifest as anemia, sarcopenia and an NRS 2002 score of ≥3 (27,28). The present meta-analysis confirmed that the proportion of patients with an NRS 2002 score of ≥3 was higher in the readmission group compared with that in the non-readmission group, but no difference between the groups was observed for anemia or sarcopenia. Multiple studies have indicated that post-operative complications are a risk factor

Table II. Meta-analysis of clinical characteristics between patients with and without post-operative 30-day readmission.

A, Pre-operative

| Characteristics | No. of studies | Readmitted, n | Not readmitted, n | Heterogeneity, $I^2$ % | Meta-analysis OR | 95% CI | P-value | Forest plot, Fig. no. | (Refs.) |
|---|---|---|---|---|---|---|---|---|---|
| Age ≥70 years | 3 | 1,240 | 8,097 | 0 | 1.58 | 1.40-1.79 | <0.00001 | S1A | (18,21,23) |
| Anemia | 3 | 1,236 | 7,493 | 0 | 1.06 | 0.93-1.21 | 0.40 | S1B | (17,18,23) |
| BMI ≥25 kg/m$^2$ | 2 | 88 | 2,237 | 0 | 1.01 | 0.57-1.79 | 0.98 | S1C | (21,23) |
| Cardiovascular comorbidity | 5 | 1,442 | 10,204 | 42 | 2.00 | 1.50-2.66 | <0.00001 | S1D | (13,16-19) |
| Comorbidity | 3 | 151 | 2,504 | 35 | 1.35 | 0.86-2.11 | 0.20 | S1E | (12,14,21) |
| Diabetes | 4 | 1,287 | 9,445 | 55 | 1.10 | 0.67-1.83 | 0.70 | S2A | (15,17-19) |
| Hypertension | 4 | 1,401 | 9,830 | 33 | 1.23 | 0.99-1.52 | 0.06 | S2B | (16-19) |
| NRS 2002 score ≥3 | 3 | 98 | 1,237 | 60 | 2.02 | 1.02-3.98 | 0.04 | S2C | (15,2,23) |
| Respiratory diseases | 4 | 1,321 | 9,470 | 17 | 1.46 | 1.07-1.99 | 0.02 | S2D | (13,17-19) |
| Sarcopenia | 3 | 108 | 1,434 | 82 | 2.08 | 0.60-7.20 | 0.25 | S2E | (20,22,23) |
| Sex (male/female) | 11 | 1,680 | 13,866 | 4 | 1.17 | 1.03-1.33 | 0.02 | S3A | (12-19,21-23) |
| Smoking history | 2 | 181 | 2,697 | 74 | 1.17 | 0.62-2.20 | 0.64 | S3B | (16,21) |

B, Peri-operative

| Characteristics | No. of studies | Readmitted, n | Not readmitted, n | Heterogeneity, $I^2$ % | Meta-analysis OR | 95% CI | P-value | Forest plot, Fig. no. | (Refs.) |
|---|---|---|---|---|---|---|---|---|---|
| ASA score ≥3 | 6 | 335 | 5,319 | 0 | 1.64 | 1.23-2.20 | 0.0009 | S3C | (15-17,21-23) |
| Combined multi-organ resection | 3 | 1,333 | 8,530 | 23 | 1.78 | 1.32-2.41 | 0.0002 | S3D | (16,1,21) |
| Complication due to the tumor | 2 | 116 | 3,269 | 68 | 1.76 | 0.86-3.60 | 0.12 | S3E | (17,21) |
| Depth of invasion: (T3-4/T1-2) | 3 | 149 | 2,611 | 64 | 2.05 | 1.08-3.88 | 0.03 | S4A | (13,21,23) |
| Discharge to home with provision of care services | 2 | 1,818 | 4,432 | 0 | 1.51 | 1.30-1.75 | <0.0001 | S4B | (15,18) |
| Extent of gastric resection (total/subtotal) | 8 | 1,474 | 12,502 | 77 | 1.25 | 0.85-1.82 | 0.25 | S4C | (13,15, 17-19,21-23) |
| Extent of lymph node dissection ≥D2 | 3 | 177 | 3,674 | 52 | 1.14 | 0.73-1.79 | 0.57 | S4D | (12,17,19) |
| History of abdominal surgery | 4 | 158 | 3,200 | 21 | 1.29 | 0.74-2.26 | 0.37 | S4E | (15,21-23) |
| Neoadjuvant therapy | 3 | 172 | 4,214 | 0 | 1.65 | 1.03-2.67 | 0.04 | S5A | (13,19,21) |
| Operation method (laparoscopy) | 8 | 357 | 6,995 | 79 | 0.78 | 0.45-1.35 | 0.38 | S5B | (12,14-15, 17,19,21-23) |
| Operation time ≥210 min | 2 | 55 | 683 | 61 | 1.63 | 0.67-3.96 | 0.28 | S5C | (15,23) |
| Post-operative complications | 8 | 1,546 | 11,790 | 91 | 2.70 | 1.54-4.74 | 0.0005 | S5D | (12,14-16, 18,19,21,22) |
| pTNM stage (III-IV/I-II) | 5 | 210 | 5,071 | 8 | 1.11 | 0.81-1.52 | 0.54 | S5E | (15,19,21-23) |
| Receipt of blood | 2 | 1,212 | 7,796 | 0 | 1.27 | 1.11-1.44 | 0.0003 | S6A | (18,21) |
| Recurrence | 2 | 91 | 541 | 0 | 0.99 | 0.21-4.63 | 0.98 | S6B | (12,14) |

All meta-analyses were random. OR, odds ratio; CI, confidence interval; Fig. no., figure number; BMI, body mass index; NRS, nutritional risk score; ASA, American Society of Anesthesiologists.

Table III. Meta-analysis of risk predictors for post-operative 30-day readmission.

| Risk factor | No. of studies | Heterogeneity, $I^2$ % | Meta-analysis | | | Forest plot, Fig. no. | (Refs.) |
|---|---|---|---|---|---|---|---|
| | | | OR | 95% CI | P-value | | |
| BMI (≥25 kg/m$^2$) | 2 | 81 | 0.99 | 0.32-3.07 | 0.98 | S6C | (19,22) |
| Sex (male/female) | 2 | 0 | 0.95 | 0.83-1.09 | 0.48 | S6D | (13,18) |
| Cardiovascular comorbidity | 2 | 0 | 2.57 | 1.77-3.71 | <0.00001 | S6E | (13,16) |
| Pulmonary comorbidity | 2 | 0 | 1.08 | 0.91-1.28 | 0.38 | S7A | (13,18) |
| NRS 2002 score ≥3 | 3 | 0 | 2.94 | 1.72-5.03 | <0.0001 | S7B | (16,22,23) |
| Pancreatectomy | 2 | 11 | 1.62 | 1.17-2.25 | 0.004 | S7C | (16,18) |
| Post-operative complications | 4 | 92 | 2.66 | 1.34-5.27 | 0.005 | S7D | (13,16,18,21) |

All meta-analyses were random. OR, odds ratio; CI, confidence interval; Fig. no., figure number; BMI, body mass index; NRS, nutritional risk score.

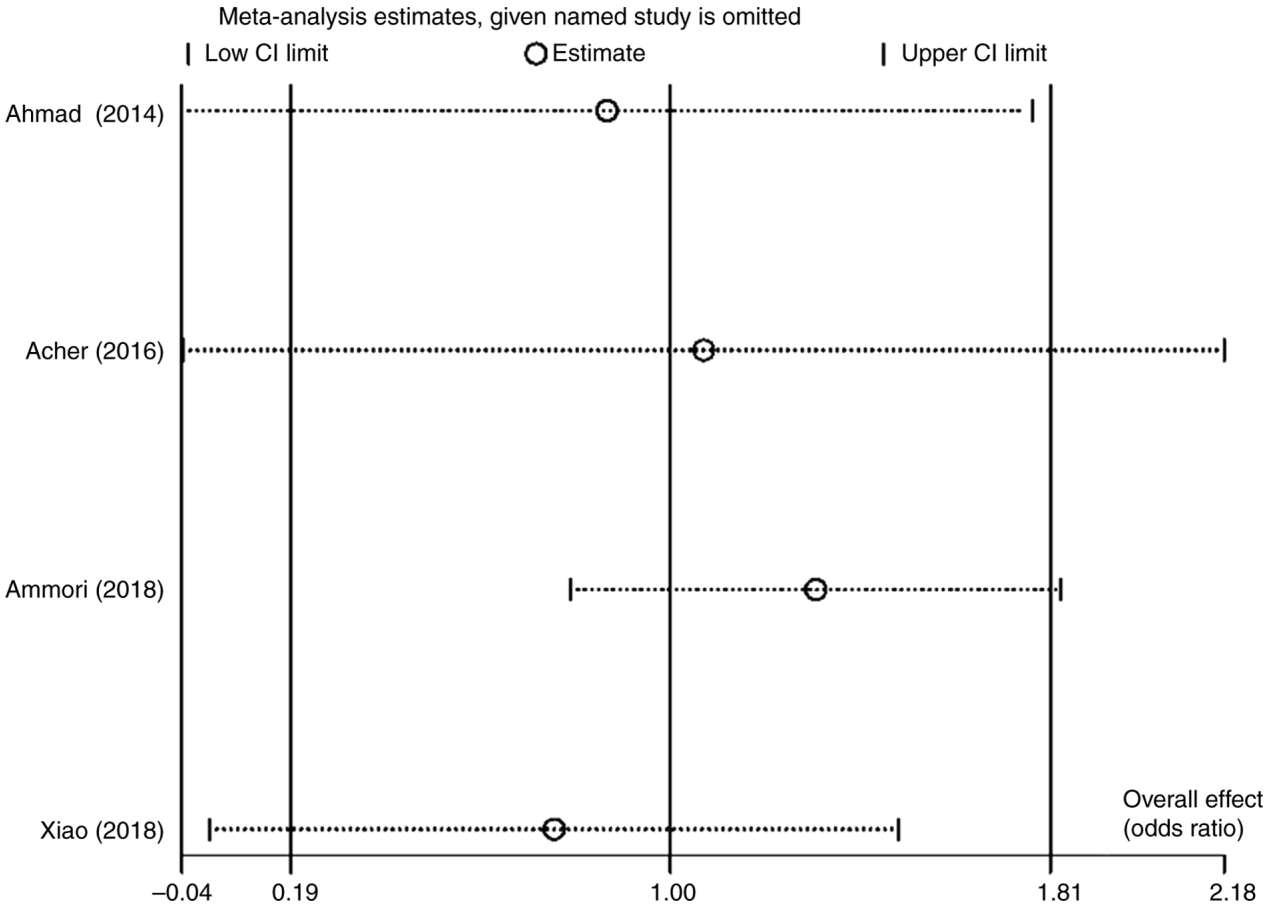


Figure 2. Influence analysis plot for publications on post-operative complications. CI, confidence interval.

for unplanned readmission (12,13,29). Comorbidities can increase the post-operative complication rate, delay discharge time and increase the readmission rate (10,30,31). In the present study, cardiovascular comorbidity and respiratory disease rates were more common in the readmission group compared with those in the non-readmission group. The association between obesity and readmission was also examined. Obesity is frequently associated with diabetes, heart disease and hypertension (32,33). However, the present meta-analysis detected no distinction in the prevalence of obesity, defined as a BMI ≥25, between the readmission and non-readmission groups. Age and sex characteristics were also examined in the current analysis. Readmissions were more common than non-readmissions in ≥70-year-old and male patients. This implies that older male patients, particularly those with respiratory disorders, an NRS 2002 score ≥3 or cardiovascular disease, require more attention, both at home and in the hospital.

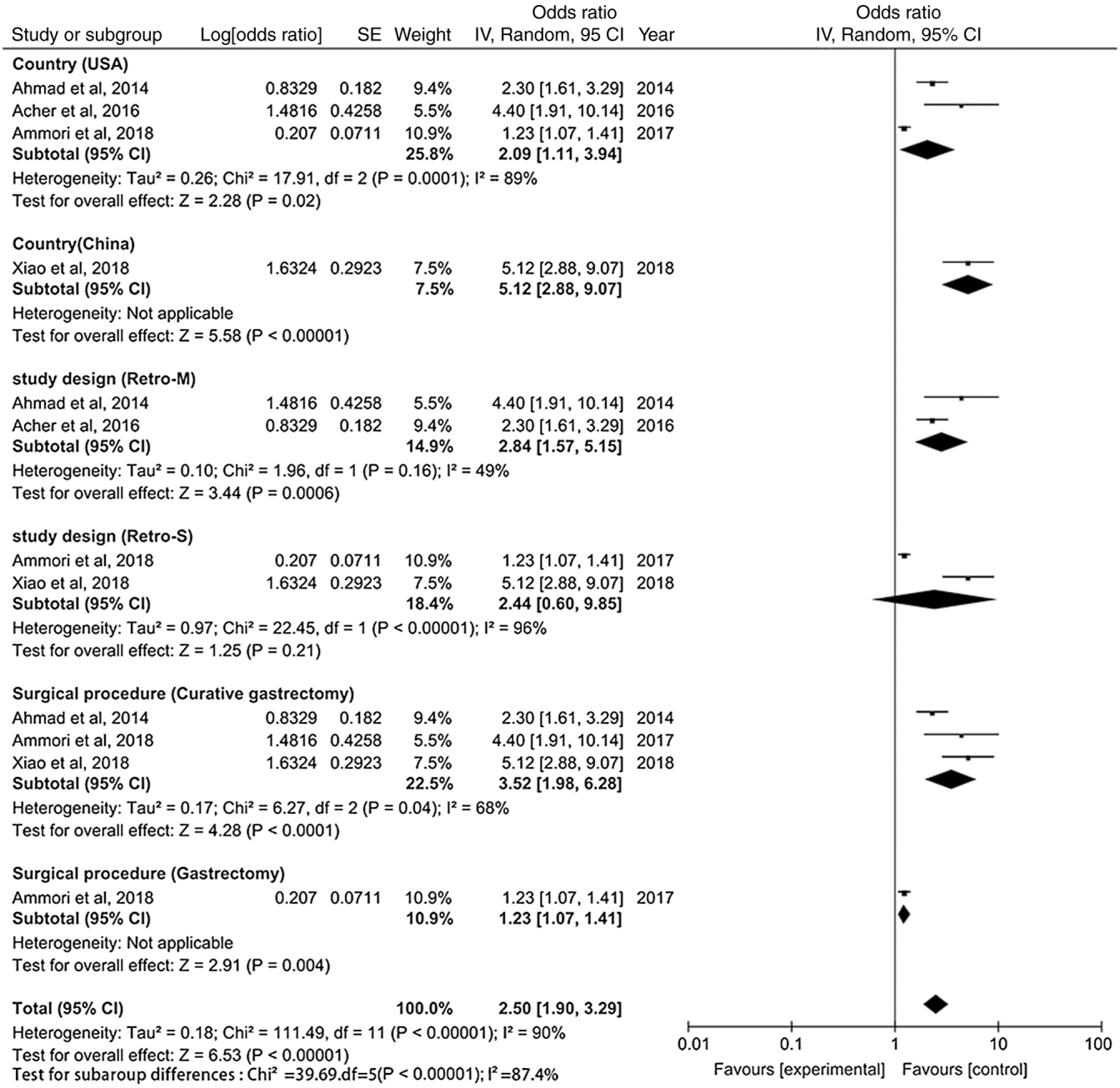


Figure 3. Forest plot for a subgroup analysis of post-operative complications. SE, standard error; CI, confidence interval.

In colorectal cancer, an association between the TNM stage and readmission has been reported (34). The prognosis of gastric cancer is strongly associated with its stage; however, the association between the stage and 30-day readmission after surgery has not yet been established. The results of the present meta-analysis revealed that there was no difference in pTNM stage (III-IV/I-II), but a significant difference in depth of invasion (T3-4/T1-2), between the readmission group and the non-readmission group, which appears to be a paradoxical finding. Additionally, patients in the readmission group were more likely to have undergone combined multi-organ resection. However, no difference between the readmission and non-readmission groups was detected in terms of whether total or subtotal gastric resection was performed, the extent of lymph node dissection, history of abdominal surgery, operation method and the duration of surgery. Therefore, it is speculatively hypothesized that post-operative readmission is not associated with the gastrectomy and lymph node dissection methods, but is associated with combined multi-organ resection. Patients with stage IV gastric cancer are the primary candidates for gastrectomy combined with organectomy, and these patients typically have a poor nutritional status, pyloric blockage, ascites, anemia, more post-operative problems and a worse prognosis. Therefore, it is imperative that patients with stage IV gastric cancer are provided with increased attention and care in order to lower their readmission rates.

Meyer *et al* (35) concluded that patients with higher ASA scores had an elevated risk of cardiovascular complications, as the ASA score represents the preoperative baseline status of the patient. Similarly, in the present study, patients in the

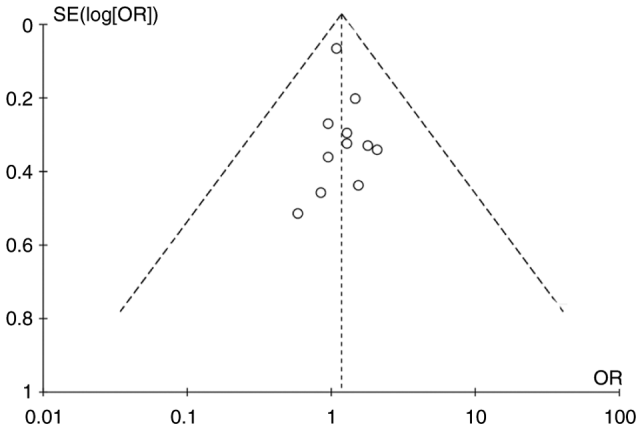


Figure 4. Funnel plot for publication bias. SE, standard error; OR, odds ratio.

readmission group had higher ASA scores than those in the non-readmission group, consistent with findings for cardiovascular complications. Previous studies have indicated that gastrointestinal complications followed by post-operative infectious complications are the most frequent causes of readmission (12,36), and post-operative complications account for a greater proportion of readmissions than tumor-associated complications. It has been reported that being discharged to a non-home facility doubles the probability of readmission, even after adjusting for confounding factors (9). This illustrates the importance of care in the home after discharge from hospital. The current study analyzed patients who were discharged to their own home with or without support services, and the findings indicate that a greater percentage of patients were discharged home with support services in the readmission group compared with the non-readmission group. This outcome is most likely due to patients who are released from the hospital and sent home without any services being sufficiently healed after surgery and in a good physical condition. Patients who have received a blood transfusion are prone to post-operative malnutrition, high post-operative complications and negative survival effects (37). In the present study, blood transfusion was confirmed to be associated with post-operative 30-day unplanned readmission, as was neoadjuvant therapy. A study conducted by Beaudart *et al* (38) found a substantial connection between post-operative 30-day unplanned readmission with malignancy and sarcopenia. However, the present study did not find such an association, which could be since fewer studies were included. Thus, additional clinical research on the association between sarcopenia and readmission is warranted in the future.

The results from multivariate regression analyses in the original literature were incorporated into the present meta-analysis, and the outcomes showed that cardiovascular comorbidity, NRS 2002 score ≥3 and post-operative complications were significant risk predictors of 30-day unplanned readmission following post-operative gastric cancer. These predictors were also found in the two previously published meta-analyses (5,9). Moreover, with the inclusion of additional literature, the present meta-analysis was the first to analyze whether pancreatectomy, BMI, sex and pulmonary comorbidity are risk predictors for readmission. Among these, only pancreatectomy was identified to be a risk predictor. Patients with malnutrition experience higher mortality and complication rates following pancreatectomy (39), and patients with gastric cancer are more likely to suffer from malnutrition than those with other types of cancer. This is because, in addition to factors such as increased protein consumption due to the tumor, cytokines such as TNF-α are released by tumor cells, which can negatively affect certain metabolic pathways in the body (40). Higher metabolic demands and faster tumor cell replication in advanced gastric cancer often translate into increased energy metabolism and a poor nutritional status (41). Malnutrition may affect ~80% of patients with upper digestive tract cancer, and there is sufficient evidence to show that, in patients with cancer, it is an independent risk factor for increased mortality, prolonged hospital stays, post-operative complications and radiotherapy/chemotherapy-induced toxicity (42). Thus, a good nutritional status is highly associated with lower 30-day readmission rates, improved patient recovery and fewer surgical complications in patients with gastric cancer. This indicates that it is crucial to thoroughly analyze the nutritional status of patients before and after surgery, using the NRS 2002 score as a tool for nutritional assessment, to reduce the risk of complications and the 30-day readmission rate.

Ito *et al* (43) demonstrated that intraoperative blood loss (IBL) negatively impacts post-operative complications and long-term survival in patients with gastric cancer who have undergone gastrectomy, and is an independent risk factor for long-term prognosis. Three possible causes of such adverse effects have been proposed: Antitumor immunosuppression, unfavorable post-operative conditions and peritoneal recurrence due to the spillage of cancer cells into the pelvis (44). By contrast, post-operative chemotherapy and radiotherapy have positive effects on the long-term prognosis of patients with gastric cancer after gastrectomy, and both are independent prognostic factors (45,46). It would have been interesting to investigate the relationships of IBL, post-operative chemotherapy and radiotherapy with post-operative 30-day unplanned readmissions for gastric cancer in the present meta-analysis. However, among the 12 studies included in the present meta-analysis, only one study (21) examined the relationship between IBL and 30-day unplanned readmission, and the multivariate analysis results showed that patients with an IBL ≥300 ml exhibited a trend towards a higher incidence of readmission (OR, 1.679; 95% CI, 0.948-2.974), but without statistical significance (P=0.076). Similarly, only the study by Ahmad *et al* (13) reported on the association of post-operative chemotherapy and radiotherapy with 30-day planned readmission, and it found that chemotherapy (P=0.454) and radiotherapy (P=0.113) are not independent risk factors by multivariate analysis. Therefore, in the future, more studies are required to explore the relationships of IBL, post-operative chemotherapy and radiotherapy with 30-day unplanned readmissions after post-operative gastric cancer.

In conclusion, during the perioperative period, patients who are at a high risk of 30-day unplanned readmission following post-operative gastric cancer may be screened out using the identified risk predictors. It is then recommended that these patients should be the focus of additional attention and support to reduce their rate of readmission, improve their prognosis, reduce economic expenditure and lighten the burden on health

insurance providers. However, there are several limitations to the current study. First, most of the 12 studies included in the study were retrospective, and selection bias and quality deviation in these studies are likely to affect the results of the meta-analysis. Second, heterogeneity was consistently detected during the examination of post-operative complications as a risk predictor, and no significant source of heterogeneity was identified, despite influence and subgroup analyses being performed. It is proposed that some heterogeneity may result from variations in the criteria for post-operative complications, the decision-making process for post-operative readmission and the quality of judgment for readmission in the studies. Third, the analysis of risk predictors includes only a small number of publications. A larger number and higher quality of studies are necessary in the future. Fourth, some possible risk factors were not analyzed in this meta-analysis, such as post-operative chemotherapy (13), post-operative radiotherapy (13), renal failure (18) and IBL (21).

In conclusion, the present meta-analysis revealed that cardiovascular comorbidity, NRS 2002 score ≥3, pancreatectomy and post-operative complications are independent risk predictors for 30-day unplanned readmission following gastric cancer surgery. Extra attention and support should be given to those patients with high-risk predictors during the perioperative period.

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**Availability of data and materials**

The data generated in the present study are included in the figures and/or tables of this article.

**Authors' contributions**

JL and SZ were responsible for conceptualization. JL, SZ and XH contributed to data curation, formal analysis, methodology and software. SZ supervised the study. JL and XH wrote the original draft of the manuscript, and SZ reviewed and edited the manuscript. JL and SZ confirm the authenticity of all the raw data. All authors read and approved the final version of the manuscript.

**Ethics approval and consent to participate**

Not applicable.

**Patient consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

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