

RESEARCH

Open Access



Risk factors for unplanned 31-day readmission after surgery for colorectal cancer patients: a meta-analysis

Nan Qu¹, Tiantian Li¹, Lifeng Zhang^{1,2}, Xingyu Liu¹ and Liping Cui^{3*}

Abstract

Background The high incidence of unplanned readmissions within 31 days after colorectal cancer surgery remains a significant challenge. However, the identified risk factors for these readmissions are inconsistent across the literature. This study aims to perform a comprehensive meta-analysis to estimate the incidence of unplanned readmissions and systematically identify the factors associated with this risk, providing robust evidence for targeted interventions to reduce readmission rates.

Methods This study was conducted in accordance with the PRISMA guidelines. All study steps, including study selection, data extraction, and quality assessment, were independently performed by two authors, with any disagreements resolved through consultation with a third author. A comprehensive search for published studies was conducted across the following databases up to January 2025: VIP Journal Database, Wanfang Data, CNKI, SinoMed, PubMed, Embase, Web of Science, and the Cochrane Library. Statistical analyses were performed using RevMan 5.4 and Stata 17.0, with a p-value of less than 0.05 considered statistically significant.

Results This meta-analysis identified several significant risk factors associated with unplanned readmission during this period ($P < 0.05$), including age (OR = 1.13), postoperative complications (OR = 1.87), tumor stage (TNM $\geq$ III) (OR = 2.01), tumor site in the rectum (OR = 1.64), stoma creation (OR = 1.70), Complicated diabetes (OR = 1.56), Charlson Comorbidity Index (CCI) (OR = 1.27), blood transfusion (BT) (OR = 1.24), Length of hospital stay (LOS) (OR = 1.65), and surgical approach (OR = 1.22). Notably, female (OR = 0.85) was identified as a protective factor against unplanned readmission.

Conclusion The unplanned readmission rate within 31 days after colorectal cancer surgery was 11.73%. Current evidence suggests that age, postoperative complications, TNM $\geq$ III, tumor site in the rectum, stoma creation, complicated diabetes, Charlson Comorbidity Index (CCI), blood transfusion (BT), length of hospital stay (LOS), and surgical approach are significant risk factors for unplanned readmission. Conversely, female has been identified as a protective factor. To mitigate these risks and reduce readmission rates, healthcare professionals should implement targeted educational and clinical interventions.

Keywords Colorectal cancer, Unplanned readmission, Risk factors, Meta-analysis

*Correspondence:

Liping Cui
sxtyslj-1@163.com

Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Introduction

Colorectal cancer (CRC) refers to a primary malignant tumor originating from the epithelium of the large intestine, encompassing both colon and rectal cancers [1]. It is one of the most common malignant tumors of the digestive system, with its development influenced by various factors such as genetic, physiological conditions, behavioral habits, lifestyle, and underlying diseases [2]. According to the latest GLOBOCAN data released by the International Agency for Research on Cancer (IARC), more than 1.9 million new cases of CRC were diagnosed worldwide in 2022, with over 900,000 deaths. This makes CRC the second most common cancer globally in terms of incidence and the third leading cause of cancer-related deaths [3, 4]. Historically, the incidence of CRC in China was relatively low compared to developed countries in Europe and North America [5]. However, in recent decades, with rapid economic development and significant changes in dietary patterns and lifestyle habits, the incidence and mortality rates of CRC have risen sharply. In 2022 alone, China reported 517,100 new cases and 240,000 deaths due to CRC, making it the second most common malignancy and placing a heavy burden on both families and society [6]. The prevention and treatment of CRC currently face significant challenges.

The management of CRC includes surgical resection, chemotherapy, radiotherapy, and neoadjuvant therapy. Among these, surgery remains the primary and preferred treatment for patients with CRC [7]. However, postoperative instability and susceptibility to various risk factors make these patients prone to developing a range of complications, such as postoperative intestinal obstruction, anastomotic leakage, bleeding, surgical site infections, and septic shock [8]. These complications can significantly increase the risk of unplanned readmission (UR) after discharge.

Unplanned readmission (UR) refers to the re-hospitalization of patients shortly after discharge for the same condition, typically due to factors such as inadequate discharge planning, disease-related complications, and insufficient medical or nursing care [9]. Studies have shown that the 31-day UR rate is particularly high in patients undergoing CRC surgery, with reported rates reaching as high as 20.5% [10]. Frequent UR not only jeopardizes patient health and quality of life but also places substantial burdens on families, healthcare systems, and society [11]. Furthermore, a study by Singh et al. found that patients experiencing UR within 31 days after CRC surgery have a significantly lower 3-year survival rate, underscoring the long-term impact of early readmission on patient outcomes [12].

Existing strategies to reduce postoperative readmissions primarily focus on improving postoperative care,

early identification of complications, and optimizing discharge planning [13]. For example, some studies have implemented personalized care pathways to closely monitor high-risk patients after discharge, while others have explored the role of multidisciplinary care teams in reducing postoperative complications [14]. Despite these efforts, UR within 31 days post-surgery remains a significant issue. The gaps in current practices, particularly the inconsistency in identifying key risk factors, highlight the need for further research.

There are varying reports in the literature on factors associated with UR within 31 days postoperatively in CRC patients. Some studies have indicated that postoperative complications are the primary cause of UR [15, 16], while others have found that LOS is positively correlated with the incidence of UR [17, 18]. Additionally, several studies have suggested that preoperative comorbidities, tumor location, tumor stage, and surgical approach are important risk factors for UR within this period [19, 20]. However, there remains a lack of robust evidence regarding the effect of these potential risk factors. Therefore, further verification of these risk factors is essential. This study conducts a meta-analysis to evaluate the incidence and risk factors of UR within 31 days after CRC surgery, providing robust evidence for early identification of high-risk patients and the development of effective prevention strategies.

Methods

A meta-analysis was conducted following a predefined protocol in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [21] (Supplementary Material 1). The search protocol was prospectively registered with PROSPERO (CRD42024499642). Institutional Review Board approval was waived as the study used only anonymized data from previously published literature.

Literature retrieval

Four major Chinese databases were searched: VIP Journal Database, Wanfang Data, CNKI, SinoMed. The search period covered from the inception of the databases to January 2025. The keywords used were "colorectal cancer, colon cancer, colorectal adenocarcinoma, colorectal tumor; readmission, rehospitalization, unplanned readmission, unplanned rehospitalization; influencing factors, risk factors, danger factors, high-risk factors, associated factors". Four major English databases were searched: Web of Science, PubMed, Cochrane Library, and Embase. The keywords included "Colorectal Neoplasms*, Colorectal Tumor*, Colorectal Cancer*, Colorectal Carcinoma*, Patient Readmission, Rehospitalizations, Unplanned

Readmission, Thirty-Day Readmission, 30-Day Readmission, Hospital Readmissions; Risk Factors, Risk, Relative Risk, predictor*, predictive*, recurrence, protective factor". No language restrictions were applied. A combination of subject terms, keywords, and free words was used to search the databases and merge the search results. The search strategy is outlined in Supplementary Material 2.

Inclusion criteria and exclusion criteria

Inclusion criteria: (1) The study design was a case-control or cohort study; (2) The study population consisted of patients aged ≥ 18 years, diagnosed with CRC through endoscopy or pathology, and who underwent surgical treatment; (3) The study focused on the incidence of UR and associated risk factors within 31 days after CRC surgery; (4) Studies were required to provide multivariate analysis results, including odds ratios (OR) and 95% confidence intervals (CI) for readmission risk factors. (5) Only studies published from 2000 to the present were included, ensuring relevance to contemporary clinical practices.

Exclusion criteria: (1) Studies involving non-CRC patients or those that failed to clearly distinguish CRC from other types of cancer, as well as studies focusing on readmissions occurring more than 31 days postoperatively; (2) Case reports, reviews, commentaries, preprints, conference abstracts, unpublished studies, animal studies, and in vitro studies, as well as studies that did not provide complete data; (3) Duplicate studies; (4) Studies that did not explicitly report UR or only reported planned readmissions, as well as studies that did not analyze influencing factors or merely described readmission rates; (5) Studies with incomplete data or data that could not be extracted, as well as studies with low methodological quality (Newcastle–Ottawa Scale score < 4); (6) Studies published in languages other than English or Chinese.

Literature screening and data extraction

All included studies were imported into NoteExpress software. Two researchers (QN, LT) independently performed the literature search, screening, and data extraction. The consistency of the quality assessment was measured using the Kappa statistic (0.79), indicating substantial agreement. Any discrepancies between the two reviewers were first discussed. If a consensus could not be reached, a third independent reviewer (ZL) made the final decision. The extracted data included the first author, publication year, study region, study design, sample size, number of UR, number of non-UR, UR incidence, and associated risk factors.

Study risk of bias assessment

The Newcastle–Ottawa Scale (NOS) was used to assess the quality of the included studies [22]. This scale evaluates case-control and cohort studies based on three dimensions: the selection of the study population, the comparability between groups, and the assessment of exposure or outcomes. Study quality is classified into three levels: low quality (0–3 stars), moderate quality (4–6 stars), and high quality (7–9 stars) [23]. Each study was independently assessed by two reviewers (QN, LT), and any disagreements were resolved through discussion. If necessary, a third reviewer (ZL) was consulted for arbitration. The quality assessment results of the included studies are presented in the results section.

Statistical analysis

Statistical analysis will be conducted using RevMan 5.4 software, with the UR rate within 31 days post-CRC surgery as the effect size. The incidence rate will be calculated with a 95% CI. Risk factors will be expressed as OR with their corresponding 95% CI, provided that data from at least three studies are available for pooling. For factors reported in only one or two studies, a descriptive analysis will be conducted, summarizing their findings qualitatively without statistical pooling. Heterogeneity will be assessed using the I^2 statistic: when $I^2 < 50\%$ and $P > 0.05$, indicating low heterogeneity, a fixed-effect model will be applied; when $I^2 > 50\%$ and $P \leq 0.05$, indicating high heterogeneity, a random-effects model will be used [24]. For factors with high heterogeneity, subgroup analyses will be conducted to explore its sources. Sensitivity analyses will also be performed using a systematic leave-one-out method to evaluate the stability of the results.

Egger's test ($\alpha = 0.05$) will be conducted using Stata 17.0 software to assess publication bias in studies with at least 10 articles. A P -value greater than 0.05 suggests a low likelihood of publication bias. If bias is detected, the trim-and-fill method will be applied to evaluate the stability of the results after bias correction.

Results

Literature search results

A total of 801 studies were initially identified, including 702 English articles and 99 Chinese articles. After removing duplicates, 256 studies remained. Screening the titles and abstracts yielded 74 articles, from which those not meeting the inclusion criteria or with unusable data were excluded. Ultimately, 15 studies (12 in English, 3 in Chinese) were included. The literature screening process and results are shown in Fig. 1.

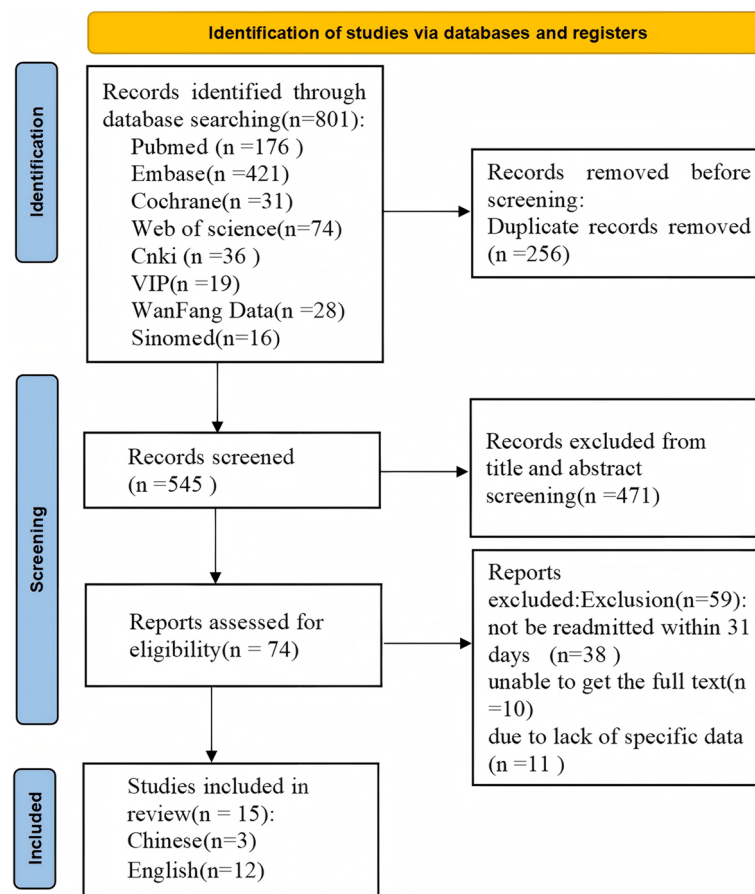


Fig. 1 Flow chart of the literature screening process

Characteristics and risk of bias assessment of included studies

A total of 15 studies were included, comprising 13 cohort studies and 2 case–control studies, with a combined sample size of 693,917 patients. Among them, 63,906 CRC patients experienced UR within 31 days post-surgery, involving 26 potential risk factors. The overall quality of the included studies ranged from moderate to high. According to the NOS assessment, 11 studies (73%) were rated as high quality (7–9 stars), while 4 studies (27%) were rated as moderate quality (4–6 stars). The basic characteristics and quality assessment of the included studies are summarized in Table 1, with detailed quality evaluation results provided in Supplementary Material 3.

Meta-analysis results

The incidence of UR within 31 days after CRC surgery

A total of 15 studies examined the incidence of UR within 31 days following CRC surgery. Meta-analysis revealed substantial heterogeneity across the included studies ($I^2 = 100\%$, $P < 0.001$). Using a random-effects model for the pooled analysis, the overall UR rate was estimated at

11.73% (95% CI, 9.46%–14.00%). The reported UR rates varied widely, with the highest incidence reaching 20.50% (95% CI, 20.11%–20.89%) and the lowest at 5.13% (95% CI, 3.96%–6.29%) (Fig. 2).

Risk factors for UR within 31 days after CRC surgery

This meta-analysis identified several factors associated with 31-day UR after CRC surgery. Significant risk factors included age (OR = 1.13, 95% CI [1.03, 1.25]), post-operative complications (OR = 1.87, 95% CI [1.32, 2.65]), TNM $\geq$ III (OR = 2.01, 95% CI [1.73, 2.33]), tumor site: rectum (OR = 1.64, 95% CI [1.19, 2.26]), stoma creation (OR = 1.70, 95% CI [1.06, 2.71]), CCI (OR = 1.27, 95% CI [1.21, 1.34]), BT (OR = 1.24, 95% CI [1.09, 1.41]), LOS (OR = 1.65, 95% CI [1.58, 1.72]), and surgical approach (OR = 1.22, 95% CI [1.01, 1.47]). Female was identified as a protective factor (OR = 0.85, 95% CI [0.83, 0.87]), while disseminated tumor showed no significant association with UR risk (OR = 1.05, 95% CI [0.77, 1.45]) (Table 2). The forest plot is shown in Supplementary Material 4.

Heterogeneity analysis revealed substantial variability ($I^2 > 70\%$) in age, postoperative complications, tumor

Table 1 Basic characteristics and methodological quality assessment of included studies [10], [16], [18], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36]

Researcher	Year	Nation	Study Type	Sample size(n)			Incidence	Risk factor	NOS
				Total	UR	Non-UR			
Li [25]	2023	China	case-control	480	26	454	5.42%	①②⑤⑥⑩ ②⑤	7
D'Souza [26]	2023	New Zealand	Cohort study	701	105	595	15.10%	①③⑤	7
Chen [27]	2022	China	case-control	1383	71	1312	5.13%	①② ①③⑦⑬	9
Clausen [10]	2022	Denmark	Cohort study	40782	8360	32422	20.50%	⑬⑯⑰⑱⑳ ㉑	8
M.S. Alyabisi [28]	2022	America	Cohort study	356	49	307	13.76%	㉓㉔	8
M.Alyabisi [29]	2021	America	Cohort study	315	62	253	19.68%	⑦㉑	7
He [30]	2020	China	Cohort study	315	37	278	11.70%	③④⑭⑮	8
Chung [31]	2020	Korea	Cohort study	229	24	205	10.50%	②④⑪⑫	7
Tatar [32]	2019	America	Cohort study	7337	871	6466	11.80%	⑨⑬⑯⑱⑳	6
O'Connell [33]	2019	Ireland	Cohort study	246	31	215	12.60%	⑤⑱	7
Mazrou [34]	2017	America	Cohort study	69222	7476	61746	10.80%	⑤⑨㉒	6
Pucciarelli [16]	2017	Italy	Cohort study	345074	20808	324266	6.00%	③⑤⑦⑬⑳ ㉕	6
Kelly [18]	2014	America	Cohort study	33033	3731	29302	11.00%	④⑥⑧⑨ ⑫⑬⑰⑱	8
Lucas [35]	2014	America	Cohort study	44822	5502	39320	12.30%	⑥㉕㉖	6
Schneider [36]	2012	America	Cohort study	149622	16753	130408	11.20%	①⑦⑧⑳㉕㉖	7

Note: ①Postoperative complications; ②TNM staging; ③Tumor location: rectum; ④Duration of surgery; ⑤Stoma creation; ⑥Diabetes; ⑦CCI; ⑧Perioperative transfusion; ⑨Disseminated tumor; ⑩Hypoproteinemia; ⑪Pulmonary disease; ⑫Liver disease; ⑬Length of hospital stay; ⑭10% weight loss in the past six months; ⑮Readiness for discharge; ⑯Smoking; ⑰American Society of Anesthesiologists (ASA) score; ⑱Surgical method; ⑲Surgical site infection; ⑳BMI (kg/m²): 25-30; ㉑Intestinal obstruction or perforation; ㉒Unplanned intubation; ㉓Distant metastasis; ㉔General ward (non-ICU) admission; ㉕Age; ㉖Gender

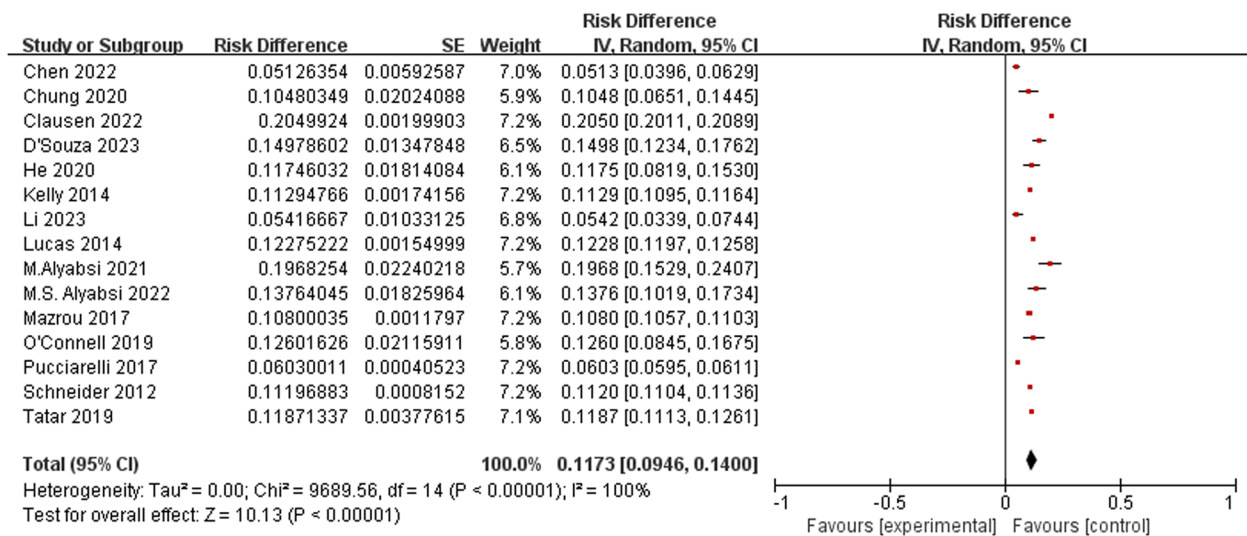


Fig. 2 Forest plot of the UR incidence within 31 days after CRC surgery

Table 2 Heterogeneity test and meta-analysis results of risk factors for UR within 31 days after CRC surgery

Risk Factors	Study Number	Heterogeneity		Effect Model	OR	95%CI	Z	P
		I² (%)	P					
Age	4[16, 25, 35, 36]	89%	< 0.001	Random	1.13	[1.03, 1.25]	28.33	0.01
Female	4[16, 35, 36]	26%	0.26	Fixed	0.85	[0.83, 0.87]	16.92	< 0.001
Postoperative complications	5[10, 25–27, 36]	93%	< 0.001	Random	1.87	[1.32, 2.65]	3.54	0.0004
TNM ≥ III	3[25, 27, 31]	10%	0.33	Fixed	2.01	[1.73, 2.33]	9.26	< 0.001
Tumor site: rectum	4[10, 16, 26, 30]	74%	0.008	Random	1.64	[1.19, 2.26]	3.04	0.002
Disseminated tumor	3[18, 32, 34]	91%	< 0.001	Random	1.05	[0.77, 1.45]	0.32	0.75
Stoma creation	4[16, 25, 26, 33, 34]	97%	< 0.001	Random	1.70	[1.06, 2.71]	2.21	0.03
Complicated diabetes	3[18, 25, 35]	96%	< 0.001	Random	1.56	[1.00, 2.42]	1.95	0.05
CCI	4[10, 16, 29, 36]	71%	0.02	Random	1.27	[1.21, 1.34]	8.89	< 0.001
BT	3[10, 18, 36]	86%	0.001	Random	1.24	[1.09, 1.41]	3.23	0.001
LOS	3[10, 16, 18]	7%	0.34	Fixed	1.65	[1.58, 1.72]	22.82	< 0.001
Surgical approach	5[10, 16, 18, 29, 32]	94%	< 0.001	Random	1.22	[1.01, 1.47]	2.09	0.04

CCI: Charlson Comorbidity Index; BT: blood transfusion; LOS: length of hospital stays

site: rectum, stoma creation, complicated diabetes, CCI, BT, and surgical approach, necessitating the use of a random-effects model. For TNM ≥ III (I² = 10%, P = 0.33), length of stay (I² = 7%, P = 0.34), and female (I² = 26%, P = 0.26), a fixed-effects model was applied, indicating more stable results (Table 2).

Sensitivity analysis

Sensitivity analysis for UR incidence

A leave-one-out sensitivity analysis was conducted for studies with I² > 50% and at least two included studies. The 31-day UR rate for CRC patients ranged from 11.51% to 12.23%, aligning closely with the overall UR rate of

11.73%. This indicates that the meta-analysis results are stable.

Sensitivity analysis UR risk factors

A sensitivity analysis was conducted for highly heterogeneous risk factors associated with UR within 31 days after CRC surgery. The results showed a significant reduction in heterogeneity (I² < 50%) for age, postoperative complications, tumor site: rectum, stoma creation, complicated diabetes, CCI, BP, and surgical approach. Consequently, a fixed-effects model was applied (Table 3). The forest plot is shown in Supplementary Material 5.

Table 3 Sensitivity analysis of the influencing factors of UR within 31 days after CRC surgery

Risk factors	Excluding studies	Before excluding			After excluding		
		Model	OR (95%CI)	P	Model	OR (95%CI)	P
Age	2[25, 35]	Random	1.13 [1.03, 1.25]	0.01	Fixed	1.04 [1.01, 1.08]	0.02
Postoperative complications	2[26, 27]	Random	1.87 [1.32, 2.65]	< 0.001	Fixed	1.17 [1.14, 1.20]	< 0.001
Tumor site: rectum	1[16]	Random	1.64 [1.19, 2.26]	0.002	Fixed	1.84 [1.44, 2.34]	< 0.001
Stoma creation	2[33, 34]	Random	1.70 [1.06, 2.71]	0.03	Fixed	1.68 [1.62, 1.75]	< 0.001
Complicated diabetes	1[18]	Random	1.56 [1.00, 2.42]	0.05	Fixed	1.95 [1.73, 2.20]	< 0.001
CCI	2[10, 29]	Random	1.27 [1.21, 1.34]	< 0.001	Fixed	1.29 [1.26, 1.32]	< 0.001
BP	1[36]	Random	1.24 [1.09, 1.41]	0.001	Fixed	1.32 [1.23, 1.41]	< 0.001
Surgical approach	2[16, 29]	Random	1.22 [1.01, 1.47]	0.04	Fixed	1.24 [1.17, 1.31]	< 0.001

Subgroup analysis

Subgroup analysis for UR incidence

We conducted subgroup analyses based on Age, gender, study period, study type, geographic region, and sample size. The results showed that Age, study type and region significantly influenced the 31-day UR rate after CRC surgery ($P < 0.05$). The UR rate was 5.20% (95% CI: 4.20%–6.21%) in case–control studies and 12.77% (95% CI: 10.32%–15.22%) in cohort studies. By region, the UR rates were 7.70% (95% CI: 4.86%–10.54%) in Asia, 13.05% (95% CI: 1.43%–24.66%) in Europe, 11.62% (95% CI: 11.09%–12.16%) in North America, and 14.98% (95% CI: 12.34%–17.62%) in Oceania.

For gender and sample size, differences in UR rates were observed but were not statistically significant ($P > 0.05$). The incidence of UR was 5.67% (95% CI: 3.75%–7.60%) in patients aged < 60 years, while it was 11.48% (95% CI: 8.92%–14.03%) in patients aged > 60 years. The UR rates for male and female patients were 13.33% (95% CI: 10.61%–15.84%) and 13.93% (95% CI: 11.01%–16.84%), respectively. Based on sample size, the UR rates were 12.54% (95% CI: 8.77%–16.31%) for ≤ 1000 , 8.52% (95% CI: 1.92%–15.12%) for 1000–10000, and 12.01% (95% CI: 8.52%–15.50%) for > 10,000 (Table 4). The forest plot is shown in Supplementary Material 6.

Table 4 Subgroup analysis results of UR incidence within 31 days after CRC surgery

Subgroup analysis	Study Number	Heterogeneity Test		Effect Model	Incidence(95%CI)	P
		I ² (%)	P			
Age						$P = 0.0004$
< 60	5[16, 25, 27, 30, 31]	83	$P < 0.001$	Random	5.67% (3.75%–7.60%)	
> 60	11[10, 16, 18, 25–27, 31, 32, 34–36]	100	$P < 0.001$	Random	11.48% (8.92%–14.03%)	
Gender				Random		0.87
Male	15[10, 16, 18, 25–36]	100%	$P < 0.001$	Random	11.80% (9.42%–14.18%)	
Female	15[10, 16, 18, 25–36]	100%	$P < 0.001$	Random	11.52% (9.19%–13.86%)	
Study Type						$P < 0.001$
Case–control	2[25, 27]	0	$P = 0.81$	Random	5.20% (4.20%–6.21%)	
Cohort study	13[10, 16, 18, 26, 28–36]	100	$P < 0.001$	Random	12.77% (10.32%–15.22%)	
Region						$P = 0.004$
Asia	4[25, 27, 30, 31]	83	$P = 0.0006$	Random	7.70% (4.86%–10.54%)	
Europe	3[10, 16, 33]	100	$P < 0.001$	Random	13.05% (1.43%–24.66%)	
North America	7[18, 28, 29, 32, 34–36]	92	$P < 0.001$	Random	11.62% (11.09%–12.16%)	
Oceania	1[26]	-	-	Random	14.98% (12.34%–17.62%)	
Sample size						$P = 0.57$
≤ 1000	7[25, 26, 28–31, 36]	89	$P < 0.001$	Random	12.54% (8.77%–16.31%)	
1000–10000	2[27, 32]	99	$P < 0.001$	Random	8.52% (1.92%–15.12%)	
> 10,000	6[10, 16, 18, 33–35]	100	$P < 0.001$	Random	12.01% (8.52%–15.50%)	

Subgroup analysis for UR risk factors

Subgroup analysis was conducted for risk factors with $I^2 > 50\%$ to explore the sources of heterogeneity. The results indicated that sample size, Source of the sample, and surgical approach were the primary sources of heterogeneity for various risk factors. Detailed results are presented in Table 5. The forest plot is shown in Supplementary Material 7.

Descriptive analysis

Single study showed that hypoproteinemia, pulmonary disease, liver disease, a 10% weight loss in the past six months, readiness for discharge, smoking, American Society of Anesthesiologists (ASA) score, surgical site infection, BMI (kg/m²) of 25–30, intestinal obstruction or perforation, unplanned intubation, and admission to a general ward (non-ICU) were all significantly associated with UR within 31 days after CRC surgery (all $P < 0.05$).

Publication bias

Publication bias was assessed using Egger's test for meta-analyses that included at least 10 studies. The results indicated no significant publication bias across different analyses, including the overall meta-analysis, age > 60 subgroup, male and female subgroups, and cohort studies ($P > 0.05$). As shown in Fig. 3, the funnel plots for these analyses appeared symmetrical. Detailed results of Egger's test are provided in Supplementary Material 8. For other risk factors with fewer than 10 included studies, the power to detect publication bias was limited; thus, funnel plots and Egger's test were not conducted.

Discussion

Current status of 31-day UR after CRC surgery

UR within 31 days after CRC surgery remains a significant global challenge. This meta-analysis identified an overall UR rate of 11.73% within 31 days postoperatively, which is comparable to the 14% reported by Tsai et al. [37] and the 8.1% reported by Jiang et al. [38].

A subgroup analysis based on age showed that patients aged > 60 had a higher incidence of UR compared to those aged < 60 . This difference may be attributed to the reduced postoperative recovery capacity in elderly patients, a higher prevalence of chronic diseases, an increased risk of complications, and a decline in functional status, leading to greater postoperative care needs [39]. Additionally, older patients may have lower tolerance to perioperative treatment and a prolonged recovery process [40], further increasing the risk of readmission.

A subgroup analysis based on study design revealed that cohort studies generally reported higher UR rates than case-control studies. This discrepancy may stem from the more extensive and comprehensive data sources in cohort studies, which provide a more accurate estimate of the overall population's UR levels. In contrast, case-control studies may be subject to selection bias and incomplete information, potentially leading to an underestimation of UR rates [41]. Therefore, future assessments of UR should carefully consider the impact of study design to enhance the comparability and generalizability of findings.

From a geographical perspective, UR rates in Oceania, Europe, and North America were generally higher than those in Asia. One possible explanation is that Western countries have a higher prevalence of obesity and

Table 5 Subgroup analysis results of UR risk factors within 31 days after CRC surgery

Risk factors	Subgroup	Study Number	Heterogeneity Test		Effect Model	OR (95%CI)
			I^2 (%)	P		
Postoperative complications	Sample size					
	< 1000	2[25, 26]	25	0.25	Fixed	1.77 [1.34, 2.33]
	1000–10000	1[27]	-	-	-	7.32 [4.36, 12.30]
	> 10,000	2[10, 36]	0	0.61	Fixed	1.17 (1.14–1.20)
Tumor site	Source of the sample					
	Single-center Study	2[26, 30]	0	0.36	Fixed	2.22 (1.58, 3.11)
	National Database Study	2[10, 16]	0	0.33	Fixed	1.28 (1.24, 1.32)
Stoma creation	Source of the sample					
	Single-center Study	3[25, 26, 33]	36	0.21	Fixed	2.15 [1.66, 2.78]
	National Database Study	2[16, 34]	99	< 0.001	Random	1.18 [0.58, 2.38]
Surgical approach						
	Open	4[10, 18, 29, 32]	50	0.11	Fixed	1.24 [1.17, 1.32]
	Laparoscopic	1[16]	-	-	-	0.94 [0.90, 0.98]

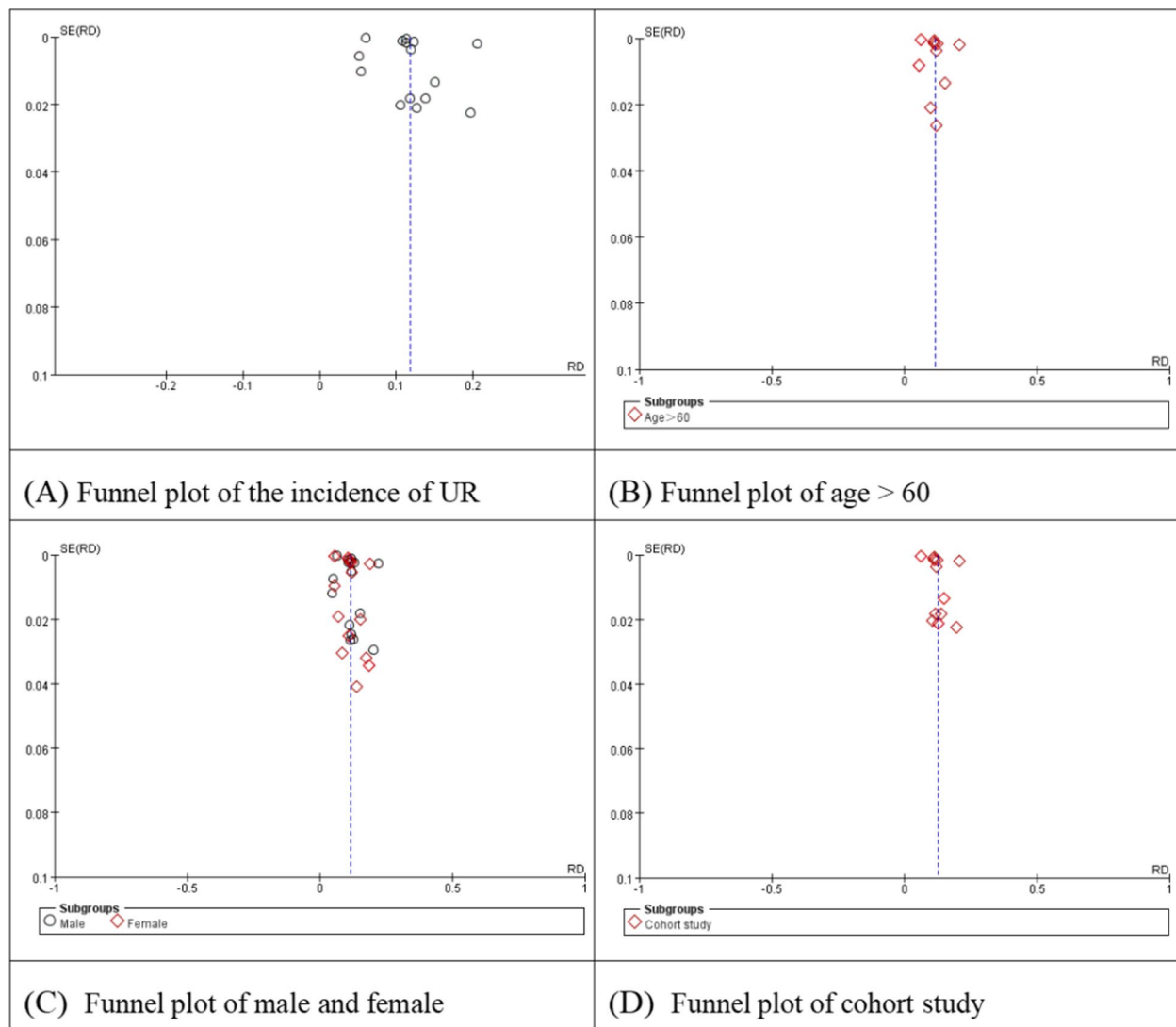


Fig. 3 Funnel plots assessing publication bias: (A) overall incidence of UR, (B) age > 60 subgroup, (C) male and female subgroups, and (D) cohort study subgroup. RD: Risk Difference; SE(RD): standard Error of the Risk Difference

diabetes, both of which are well-documented risk factors for postoperative complications and increased UR risk [42]. In contrast, certain Asian countries exhibit dietary patterns and lifestyles that are more conducive to metabolic health, which may mitigate postoperative complications and reduce readmission rates. Additionally, postoperative follow-up tends to be more stringent in Western countries, where patients are regularly evaluated and readily admitted for further treatment. Conversely, in some Asian countries, limited healthcare resources or differing healthcare-seeking behaviors may lead patients to self-manage mild complications or delay seeking medical attention, potentially contributing to lower or underestimated UR rates. Therefore, clinical strategies should

be tailored to the specific characteristics of each region. In areas with higher UR rates, strengthening chronic disease management, implementing dietary improvements, and enhancing perioperative health interventions may help reduce the risk of postoperative complications and further lower the likelihood of UR. Conversely, in regions where UR rates may be underestimated, improving follow-up systems and ensuring better access to postoperative health monitoring can help patients enhance their ability to prevent risks and enable timely interventions to avoid adverse outcomes due to delayed treatment. Furthermore, this study found that sex, study year, and sample size did not have a significant impact on the 31-day UR rate following CRC surgery.

Factors influencing 31-day UR after CRC surgery

Age

Age has been identified as a significant factor influencing UR within 31 days after CRC surgery. Although substantial heterogeneity was observed in the pooled analysis, sensitivity analysis confirmed that the results remained stable, reinforcing the reliability of this association. Pucciarelli et al. [16] suggested that age was not significantly associated with the rate of UR within 30 days after surgery, a finding that may be closely related to the quality of postoperative management and nursing care. However, studies by Li et al. [25], Schneider et al. [36], and Lucas et al. [35] reached contrasting conclusions, identifying age as a critical factor influencing UR. Notably, the age distribution of participants in Li et al.'s [25] study was broad, while Schneider et al. [36] and Lucas et al. [35] primarily focused on participants around 75 years old. This difference in sample characteristics may be the main reason for the heterogeneity in the study outcomes. Given these findings, future research should further investigate the differences in UR risk among patients of different age groups to provide more precise guidance for clinical practice.

The risk of UR after surgery is significantly increased in elderly patients undergoing colorectal procedures, primarily due to factors such as geriatric frailty, polypharmacy, impaired postoperative recovery, and inadequate post-discharge care [43]. American Society of Colon and Rectal Surgeons (ASCRS) recommends a stratified intervention strategy, including preoperative comprehensive geriatric assessment to screen for frailty, intraoperative adjustments based on individual risk, and enhanced postoperative specialist follow-up and family support [44]. American College of Cardiology emphasize the importance of cardiovascular risk assessment in elderly patients undergoing non-cardiac surgery to reduce the incidence of postoperative cardiovascular events and UR [45]. Additionally, enhanced recovery after surgery (ERAS) protocols tailored for elderly colorectal cancer patients, such as modified fasting regimens and stepwise pain management, combined with prehabilitation interventions, have been shown to significantly improve postoperative recovery and reduce UR rates [46]. Therefore, multidisciplinary interventions and personalized management strategies are essential for minimizing the risk of postoperative UR in elderly colorectal cancer patients.

Female

This study found that female patients had a lower risk of UR compared to male patients. Existing evidence suggests that this sex-based disparity is likely influenced by a combination of socio-behavioral factors and biological mechanisms. On the one hand, Zhang et al. suggested

that women, as primary caregivers in daily life, tend to develop superior self-management knowledge and skills [47]. Female patients generally exhibit higher adherence to medical advice—including medication compliance, wound care, and dietary recommendations—leading to a reduced incidence of postoperative complications [48] and, consequently, a lower UR risk. On the other hand, biological mechanisms may also play a role. Research indicates that estrogen exerts immunomodulatory effects, potentially mitigating surgical stress and inflammatory responses by suppressing pro-inflammatory cytokines (e.g., TNF- α and IL-6), thus promoting postoperative recovery [49, 50]. In contrast, androgens may negatively affect tissue repair by suppressing macrophage activity [51]. However, the precise biological mechanisms underlying these sex differences remain unclear and warrant further investigation to elucidate their impact on postoperative outcomes and UR.

Based on the findings of this study and existing evidence highlighting gender differences, it is recommended to implement postoperative management strategies that balance universal applicability with gender sensitivity. In clinical practice, standardized discharge guidance should be provided to all patients, while tailored interventions should address gender-specific risk factors. For male patients, emphasis should be placed on enhancing self-management skills through visual educational tools and peer support mechanisms to improve caregiving proficiency and adherence. For female patients, attention should be given to caregiving burden and mental health to prevent care omissions resulting from overconfidence or fatigue. Additionally, clinical monitoring should incorporate gender-related biomarkers (e.g., inflammatory factors) to guide individualized interventions. Future research should employ gender-stratified study designs to further validate the effectiveness of these measures and establish a more precise gender-specific management system.

Diabetes and CCI

This study found that diabetes patients had a significantly higher risk of UR. Rattan et al. [52] reported that postoperative complications such as wound infections, delayed healing, and metabolic disorders are more common in diabetes patients, which may be important contributors to the increased risk of UR. Although the meta-analysis revealed substantial heterogeneity, the sensitivity analysis confirmed the robustness of the results. The source of this heterogeneity may be related to factors such as glycemic control levels or treatment strategies. However, due to the lack of detailed reporting on these factors in the original studies, further analysis could not be conducted.

In this study, a higher CCI score was associated with an increased risk of UR, likely due to reduced postoperative recovery capacity, a higher likelihood of complications, and prolonged hospital stays. However, the meta-analysis of CCI exhibited high heterogeneity. Sensitivity analysis indicated that the results were relatively stable, and further investigation suggests that variations in the baseline disease spectrum across studies may contribute to this heterogeneity, as certain comorbidities may have a greater impact on UR risk than others. Additionally, preoperative optimization strategies—such as prehabilitation programs, perioperative blood glucose management, and nutritional interventions—may also influence the association between CCI and UR. However, reporting of these factors was inconsistent across studies, and some studies did not account for them, making it difficult to accurately assess their impact. Future research should aim to explore the independent contributions of different types of comorbidities to UR risk while also considering the potential influence of preoperative optimization strategies.

For colorectal surgery patients with multiple chronic conditions and diabetes, clinical guidelines recommend a multidisciplinary comprehensive intervention approach to reduce the risk of UR. The ASCRS advises conducting a thorough preoperative risk stratification assessment and collaborating with endocrinology specialists to optimize glycemic control, ensuring HbA1c levels are within the ideal range. Intraoperatively, minimally invasive techniques should be prioritized, with enhanced blood glucose monitoring. Postoperatively, structured discharge management and specialized follow-up care are emphasized [44]. For patients with multiple comorbidities or significant functional impairment, a multimodal prehabilitation program may be considered before elective surgery. A meta-analysis of 35 studies involving 3,402 patients undergoing major abdominal surgery demonstrated that prehabilitation significantly reduces overall postoperative complications, including pulmonary and cardiac complications [53]. Therefore, strengthening a multidisciplinary approach is essential for optimizing perioperative management in patients with diabetes and a high comorbidity burden.

Tumor stage

This study found that $TNM \geq III$ is an independent risk factor for UR within 31 days after CRC surgery. This finding is consistent with the results of QUINTANA et al. [54]. Patients with advanced TNM stages tend to have deeper tumor infiltration and more severe involvement of adjacent organs, often requiring more complex surgical procedures, such as extended resection or multiorgan resection. These procedures result in greater surgical

trauma, slower postoperative recovery, and a higher incidence of complications. Additionally, patients with a higher tumor burden may experience disease progression or recurrence within a short period, necessitating readmission for further treatment, which contributes to an increased UR rate.

To mitigate this risk, the National Comprehensive Cancer Network (NCCN) and the ASCRS recommend a multidisciplinary intervention strategy. Preoperatively, emphasis is placed on optimizing nutritional status, enhancing functional reserves, and determining the optimal timing for individualized neoadjuvant therapy. Intraoperatively, a preference for minimally invasive surgical techniques is advocated. Postoperatively, systematic follow-up and early identification and management of complications are prioritized [55, 56]. Notably, incorporating the ERAS protocol into the comprehensive management of these patients has been shown to further reduce the risk of postoperative unplanned readmission [46]. These evidence-based interventions provide valuable guidance for clinical practice.

Tumor site

This study found that rectal cancer patients have a higher risk of UR compared to colon cancer patients, consistent with the findings of Doumouras et al. [57]. Their study highlighted that the deeper anatomical location of the rectum, its rich pelvic neurovascular structures, and the increased surgical complexity contribute to a higher incidence of anastomotic leakage (AL), pelvic infections, bowel obstructions, and stoma-related complications in rectal cancer patients. These complications, in turn, increase the likelihood of UR. Notably, patients with low rectal cancer who undergo low anterior resection (LAR) or abdominoperineal resection (APR) are at an elevated risk of AL and bowel dysfunction [58]. AL, in particular, can lead to severe infections requiring reoperation [59], while bowel dysfunction affects nutritional intake and quality of life, further increasing the risk of UR.

Although this meta-analysis exhibited a high degree of heterogeneity, sensitivity analysis confirmed the stability of the results, further supporting the conclusion that rectal cancer patients are more likely to experience UR. The heterogeneity may primarily stem from differences in data sources. The studies by Pucciarelli et al. [16] and Johan et al. [10] were based on national databases, whereas those by He et al. [30] and D'Souza et al. [26] were single-center studies, with the latter reporting a significantly higher UR risk. A possible explanation is that national databases encompass large sample sizes, broad coverage, and extended study periods, incorporating data from multiple medical institutions with varying patient management practices, which may lead to an

underestimation of UR rates. In contrast, single-center studies focus on a single hospital, where follow-up tends to be more rigorous, and postoperative management and readmission events are recorded in greater detail, potentially resulting in higher observed UR rates.

The ASCRS recommends a multilayered intervention strategy to reduce the risk of UR in rectal cancer patients [44]. First, a multidisciplinary team should develop an individualized treatment plan preoperatively, routinely considering a protective stoma for patients undergoing low anastomosis (< 5 cm). Second, standardized total mesorectal excision techniques should be employed intraoperatively, with reinforcement measures for the anastomosis considered when necessary. Finally, a structured postoperative management plan, including pelvic floor rehabilitation and early complication monitoring, should be implemented. These measures can help minimize complications, promote recovery, and ultimately reduce the risk of UR.

Stoma creation

This study confirms that stoma creation is an important factor influencing UR in CRC patients. Although the heterogeneity of the meta-analysis is relatively high, sensitivity analysis indicates that the results remain stable. Previous studies have shown that patients undergoing stoma creation may experience complications such as retraction, stenosis, leakage, and skin irritation [60]. These issues not only affect patients' adaptability and quality of life but may also lead to infections, electrolyte imbalances, or malnutrition, thereby increasing the risk of UR. Additionally, some patients may lack sufficient stoma care experience or professional guidance after discharge, resulting in functional abnormalities or improper management, ultimately necessitating UR [61].

The high heterogeneity in the meta-analysis may be attributed to differences in data sources. D'Souza et al.'s [25, 26, 33] study was based on single-center data, while Mazrou et al.'s [16, 34] study utilized data from a national database. Such differences in data sources may contribute to increased heterogeneity between studies and affect result comparability. Furthermore, Mazrou's [34] study primarily examined the impact of stoma creation on UR within 0–5 days, suggesting that stoma creation might reduce the risk of early UR. In contrast, Pucciarrelli's [16] study analyzed stoma creation's effect on UR within 31 days, identifying it as a significant risk factor for UR within 31 days post-CRC surgery. Differences in study design and follow-up duration may further amplify heterogeneity, leading to inconsistencies in the conclusions regarding stoma creation's impact on UR. Future research should further investigate the impact of stoma creation on UR at different time points to clarify its role

in early and late readmissions. Additionally, adopting multicenter study designs and establishing standardized data collection and analysis frameworks could enhance the comparability and generalizability of results, providing more robust evidence for clinical practice.

In clinical practice, UR related to stomas are primarily caused by complications and difficulties in self-management. The ASCRS recommends a three-tiered intervention strategy to mitigate this risk: (1) preoperative multidisciplinary assessment, including precise stoma site marking and risk evaluation with the involvement of a stoma therapist; (2) intraoperative preference for minimally invasive techniques, such as laparoscopy, to reduce surgical trauma; and (3) postoperative implementation of standardized management protocols, including structured education (covering complication recognition and stoma care techniques), early follow-up within seven days, and remote monitoring [44]. Studies have shown that implementing a clinical pathway incorporating stoma output monitoring and dedicated follow-up nurses can reduce dehydration-related UR among stoma patients from 15.5% to 0% [62]. Furthermore, the adoption of the ERAS protocol has been found to lower the 30-day dehydration-related UR from 9% to 3.9% [63].

Surgical approach

This study indicates that the surgical approach is a significant risk factor for postoperative UR. Specifically, Pucciarrelli et al. [16] found that laparoscopic surgery serves as an independent protective factor, significantly reducing the incidence of UR. Similarly, Clausen et al. [10, 16, 29, 32] reported that patients undergoing open surgery faced a higher risk of UR compared to those receiving laparoscopic surgery. The heterogeneity observed in this meta-analysis may be attributed to variations in how different studies define surgical approaches. Extensive clinical research evidence suggests that minimally invasive surgery (MIS) has significant clinical value in the field of colorectal surgery. According to the guidelines jointly developed by the ASCRS, high-quality randomized controlled trials and large-scale clinical data analyses have demonstrated that laparoscopic surgery offers several perioperative advantages, including reduced intraoperative blood loss, improved postoperative pain management, accelerated recovery of bowel function, and shortened hospital stays [44].

Notably, the application of MIS has been shown to significantly reduce the overall incidence of complications, particularly in lowering the risk of surgical site infections (SSI) and other wound-related complications, which may help decrease the likelihood of UR [64]. Existing evidence indicates that integrating MIS—especially laparoscopic surgery—with the ERAS protocol can produce a

synergistic effect, a concept supported by studies such as the LAFA trial [65]. Therefore, when carefully selecting appropriate candidates and ensuring that the surgical team possesses the necessary technical expertise, the combined approach of MIS and ERAS can be considered one of the preferred strategies for optimizing perioperative management in colorectal surgery patients, potentially further reducing the risk of UR.

Blood transfusion

This study found that perioperative BT was closely associated with an increased risk of UR within 31 days after CRC surgery. However, inconsistencies in BT timing across different studies may contribute to the heterogeneity observed in our analysis. Some studies focus on perioperative BT [10], while others include BT administered upon admission or before discharge [18, 36]. Due to the lack of detailed data on BT timing and frequency in the included studies, we were unable to further analyze their specific effects.

An international study reported that CRC patients who received BT had a higher likelihood of UR within 31 days postoperatively than those who did not [66]. Multiple mechanisms may explain the association between BT and UR risk. This may be attributed to BT-induced immunosuppression, as the infusion of plasma or whole blood can reduce the number and activity of macrophages and natural killer cells, thereby weakening the body's ability to fight infections. This increased susceptibility to postoperative infections is considered a major contributor to UR [67]. Additionally, BT may impair bone marrow function, inhibit new blood cell production, and delay tissue repair, further prolonging postoperative recovery. Some studies have also suggested that BT might promote the survival of residual tumor cells, potentially increasing the risk of cancer recurrence [68]. Despite growing evidence linking BT to a higher risk of UR, research on this topic remains limited in China. Future studies should further investigate the impact of different BT timings, blood components, and BT frequencies on UR risk and explore strategies to mitigate these risks.

Restrictive transfusion strategies and patient blood management (PBM) can effectively reduce the risk of UR. To minimize transfusion-related adverse outcomes, the American Association of Blood Banks (AABB) recommends a restrictive transfusion threshold ($Hb \leq 7$ g/dL) for hemodynamically stable patients [69]. This approach emphasizes preoperative optimization (such as using iron supplements or erythropoiesis-stimulating agents to correct anemia), intraoperative blood loss reduction (e.g., through minimally invasive techniques and tranexamic acid), and postoperative monitoring. The ACS and ERAS guidelines further support a multimodal PBM approach,

including preoperative anemia screening, intraoperative autologous BT, and early postoperative mobilization [46, 70]. These combined interventions can reduce the need for transfusions, improve postoperative recovery, and ultimately decrease the risk of UR.

length of stay

This study demonstrates a significant association between LOS and the risk of UR in postoperative CRC patients. Patients with prolonged LOS tend to have more severe conditions, undergo more complex surgeries, experience slower recovery, and face a higher likelihood of complications, all of which contribute to an increased risk of UR. This trend aligns with previous research [71], which reported UR rates of 7% for patients with $LOS \leq 3$ days, 9.8% for those with LOS of 4–5 days, 13.2% for those with LOS of 6–7 days, and as high as 14.9% for patients with $LOS \geq 8$ days.

In clinical practice, the ERAS protocol has been widely adopted and shown to effectively shorten LOS, reduce postoperative complications, and improve recovery outcomes [72]. A Cochrane review found that, compared with traditional perioperative management, the ERAS protocol is associated with a lower overall complication rate and a shorter LOS [73]. The ASCRS guidelines also recommend early postoperative mobilization with a gradual increase in activity to promote recovery and reduce LOS [44]. However, while ERAS enables some patients to be safely discharged within 3–5 days postoperatively, older patients, those with multiple comorbidities, or those experiencing delayed recovery may still require prolonged hospitalization, further increasing their UR risk. Therefore, future research should focus on optimizing perioperative management within the ERAS framework, particularly by developing individualized intervention strategies for high-risk populations. By ensuring patient safety while minimizing LOS, these strategies could help reduce UR rates [74].

Postoperative complications

Our study indicates that patients experiencing postoperative complications have a significantly higher risk of UR compared to those without complications. Sensitivity analysis confirmed the robustness of this association, while further subgroup analysis identified sample size variation as a primary source of heterogeneity. However, even after accounting for heterogeneity, postoperative complications remained a significant predictor of UR, consistent with existing literature. Lawson et al. [75] reported that bowel obstruction and surgical site infections are among the most common postoperative complications, with an increasing number of complications correlating with a higher UR risk. Similarly, Orcutt et al.

[76] highlighted that postoperative immunosuppression increases susceptibility to infections, which may delay recovery, prolong hospital stays, and ultimately elevate the likelihood of UR. However, the included studies did not provide a detailed classification of postoperative complications, despite the fact that different types of complications may have varying impacts on patient outcomes. This lack of specificity may represent another important source of heterogeneity. Therefore, future research should further stratify postoperative complications to delineate their specific contributions to UR risk. Additionally, large-scale, multicenter studies are needed to explore how the severity, management strategies, and recovery trajectories of complications influence UR rates, thereby improving the accuracy and clinical applicability of findings.

In clinical practice, optimizing perioperative management, particularly in preventing and addressing high-risk complications such as infections and intestinal obstruction, is a key strategy for reducing the incidence of UR after surgery. The ASCRS emphasizes the importance of preventing surgical site infections (SSI) in clinical practice and recommends implementing evidence-based SSI prevention bundles. Studies have demonstrated that these comprehensive interventions effectively reduce the incidence of SSI in patients undergoing colorectal surgery [77]. A 2018 RCT demonstrated that an enhanced SSI prevention bundle—comprising antibiotic peritoneal lavage, triclosan-coated sutures to inhibit bacterial growth, and mupirocin ointment for additional infection control—reduced SSI rates from 16 to 4% [78]. Furthermore, a study from Finland highlighted the role of preoperative bowel preparation combined with oral antimicrobial agents in reducing not only overall postoperative complications but also SSI and anastomotic leakage in colorectal cancer patients, ultimately lowering the risk of postoperative readmission [79]. Beyond infection control, early recovery of bowel function is crucial in preventing postoperative intestinal obstruction. A meta-analysis showed that early oral intake within 24 h postoperatively, compared to delayed feeding, significantly promotes the recovery of gastrointestinal function [80]. A review further highlighted several effective interventions for enhancing gastrointestinal recovery and preventing postoperative intestinal obstruction. These include coffee consumption and chewing gum to stimulate gut motility, probiotic supplementation to support gut microbiota, minimally invasive surgery to reduce surgical trauma, and Daikenchuto—a traditional Japanese herbal medicine composed of dried ginger, ginseng, and zanthoxylum fruit—known for its prokinetic and anti-inflammatory effects [81]. These measures not only

improve patient outcomes but also shorten hospital stays, ultimately reducing the risk of unplanned readmission.

Limitations

This study has several limitations. First, we searched only four Chinese and four English databases, which may have led to the omission of relevant studies, thereby limiting the comprehensiveness of the literature coverage. Second, our meta-analysis was based on 13 cohort studies and 2 case–control studies, and the differences in study design may have introduced confounding factors, potentially affecting the accuracy of the results. Third, the number of included studies for certain influencing factors was relatively small (< 10), resulting in limited statistical power and potential instability in the Meta regression results. Therefore, this study did not adopt this method. Fourth, the influencing factors analyzed in different studies varied, making it impossible to merge certain variables, which may have limited the comprehensiveness of our assessment. Future research should expand the scope of literature retrieval, include more high-quality studies, and refine the classification of influencing factors to enhance the robustness and reliability of the analysis.

Conclusion

In conclusion, UR within 31 days after CRC surgery not only significantly increases the healthcare burden but may also prolong the recovery period and negatively impact the patient's quality of life. The occurrence of postoperative UR is the result of multiple contributing factors; therefore, healthcare providers need to systematically assess patient risks and develop targeted intervention strategies. In clinical practice, special attention should be given to high-risk groups, including patients with postoperative complications, those with TNM stage $\geq$ III, patients with rectal, those undergoing stoma procedures, diabetic patients, individuals with an elevated CCI, patients requiring BT during hospitalization, those with LOS, those undergoing open surgery, and elderly patients. By establishing risk alert systems, optimizing perioperative management protocols, and implementing individualized interventions, the incidence of postoperative UR can be effectively reduced, thereby improving short-term outcomes and enhancing overall healthcare quality.

Abbreviations

CRC	Colorectal cancer
UR	Unplanned readmission
CCI	Charlson Comorbidity Index
BT	Blood transfusion
LOS	Length of hospital stays
NOS	Newcastle-Ottawa Scale
RD	Risk Difference
SE (RD)	Standard Error of the Risk Difference

LAR	Low anterior resection
APR	Abdominoperineal resection
AL	Anastomotic leakage
ASCRS	American Society of Colon and Rectal Surgeons
ERAS	Enhanced recovery after surgery
MIS	Minimally invasive surgery
SAGES	Society of American Gastrointestinal and Endoscopic Surgeons
PBM	Patient blood management
ACS	American College of Surgeons
SSI	Surgical site infections
RCT	Randomized controlled trial

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12876-025-03872-5>.

Supplementary Material 1.
Supplementary Material 2.
Supplementary Material 3.
Supplementary Material 4.
Supplementary Material 5.
Supplementary Material 6.
Supplementary Material 7.
Supplementary Material 8.

Acknowledgements

Not applicable.

Authors' contributions

Qu Nan: Conceptualization, Methodology, Software, Data Curation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project Management; Li Tiantian, Zhang Lifeng, Liu Xingyu: Conceptualization, Methodology, Investigation, Resources, Data Management, Writing – Review & Editing, Visualization, Project Management; Cui Liping: Conceptualization, Methodology, Investigation, Resources, Data Management, Writing – Review & Editing, Project Management. All authors reviewed the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability

All data supporting the findings of this study are available within the paper and its Supplementary Information.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹School of Nursing, Shanxi University of Chinese Medicine, Jinzhong 030619, China. ²Third Hospital of Shanxi Medical University, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Taiyuan 030032, China. ³Department of Nursing, Third Hospital of Shanxi Medical University, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Taiyuan 030032, China.

Received: 19 December 2024 Accepted: 9 April 2025

Published online: 23 April 2025

References

- Dekker E, Tanis PJ, Vleugels JLA, Kasi PM, Wallace MB. Colorectal cancer. *Lancet*. 2019;394(10207):1467–80.
- Patel SG, Karlitz JJ, Yen T, Lieu CH, Boland CR. The rising tide of early-onset colorectal cancer: a comprehensive review of epidemiology, clinical features, biology, risk factors, prevention, and early detection. *Lancet Gastroenterol Hepatol*. 2022;7(3):262–74.
- Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, Jemal A. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin*. 2024;74(3):229–63.
- Global cancer burden growing, amidst mounting need for services. *Saudi Med J*. 2024;45(3):326–7.
- Parkin DM, Bray F, Ferlay J, Pisani P. Global cancer statistics, 2002. *CA Cancer J Clin*. 2005;55(2):74–108.
- Han B, Zheng R, Zeng H, Wang S, Sun K, Chen R, Li L, Wei W, He J. Cancer incidence and mortality in China, 2022. *J Natl Cancer Cent*. 2024;4(1):47–53.
- [Chinese Protocol of Diagnosis and Treatment of Colorectal Cancer (2023 edition)]. *Zhonghua Wai Ke Za Zhi* 2023, 61(8):617–644.
- You S: Meta-analysis of Risk Factors for Postoperative Complications Following Laparoscopic Colorectal Cancer Surgery. Master's candidate. . 2016.
- Pons-Suñer P, Arnal L, Signol F, Caballero Mateos MJ, Valdivieso Martínez B, Perez-Cortes JC. Prediction of 30-day unplanned hospital readmission through survival analysis. *Heliyon*. 2023;9(10): e20942.
- Clausen J, Hansen HF, Walbech JS, Gögenur I. Incidence and clinical predictors of 30-day emergency readmission after colorectal cancer surgery – A nationwide cohort study. *Colorectal Dis*. 2023;25(2):222–33.
- Damle RN, Cherng NB, Flahive JM, Davids JS, Maykel JA, Sturrock PR, Sweeney WB, Alavi K. Clinical and financial impact of hospital readmissions after colorectal resection: predictors, outcomes, and costs. *Dis Colon Rectum*. 2014;57(12):1421–9.
- Singh PP, Hill AG. Fast-track elective colectomy: single-surgeon experience of 100 consecutive cases. *N Z Med J*. 2013;126(1369):8–15.
- Granda-Cameron C, Behta M, Hovinga M, Rundio A, Mintzer D. Risk Factors Associated with Unplanned Hospital Readmissions in Adults with Cancer. *Oncol Nurs Forum*. 2015;42(3):E257–268.
- Kehlet H. Fast-track surgery—an update on physiological care principles to enhance recovery. *Langenbecks Arch Surg*. 2011;396(5):585–90.
- Curtis NJ, Noble E, Salib E, Hipkiss R, Meachim E, Dalton R, Allison A, Ockrim J, Francis NK. Does hospital readmission following colorectal cancer resection and enhanced recovery after surgery affect long term survival? *Colorectal Dis*. 2017;19(8):723–30.
- Pucciarelli S, Zorzi M, Gennaro N, Gagliardi G, Restivo A, Saugo M, Barina A, Rugge M, Zuin M, Maretto I, et al. In-hospital mortality, 30-day readmission, and length of hospital stay after surgery for primary colorectal cancer: A national population-based study. *Eur J Surg Oncol*. 2017;43(7):1312–23.
- Wick EC, Shore AD, Hirose K, Ibrahim AM, Gearhart SL, Efron J, Weiner JP, Makary MA. Readmission rates and cost following colorectal surgery. *Dis Colon Rectum*. 2011;54(12):1475–9.
- Kelly KN, Iannuzzi JC, Aquina CT, Probst CP, Noyes K, Monson JR, Fleming FJ. Timing of discharge: a key to understanding the reason for readmission after colorectal surgery. *J Gastrointest Surg* 2015, 19(3):418–427; discussion 427–418.
- He Yuhua YJ, Jiang Lili.: Research Progress on Unplanned Readmissions After Colorectal Cancer Surgery. *Nursing Research* 2019, 33(02):290–293.
- Justiniano CF, Temple LK, Swanger AA, Xu Z, Speranza JR, Cellini C, Salloum RM, Fleming FJ. Readmissions With Dehydration After Ileostomy Creation: Rethinking Risk Factors. *Dis Colon Rectum*. 2018;61(11):1297–305.
- Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372: n71.

22. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol.* 2010;25(9):603–5.
23. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analyses. [http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm]
24. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page M J, & Welch V A. : *Cochrane Handbook for Systematic Reviews of Interventions*, Version 6.3 edn: Cochrane; 2022.
25. Li Qin SX, Zhang Yan, et al.: Analysis of the Situation and Influencing Factors of Unplanned Readmission in Patients after Colorectal Cancer Surgery. *Chinese and Western Medicine Nursing (Chinese and English)* 2023, 9(01):124–126.
26. D'Souza J, Eglinton T, Frizelle F. Readmission prediction after colorectal cancer surgery: A derivation and validation study. *PLoS ONE.* 2023;18(6):e0287811.
27. Chen J, Xu L, Wu X, Li X. Analysis of Risk Factors for Unplanned Readmission in Colorectal Cancer Patients Post-Surgery Based on Logistic Regression and Decision Tree Models. *Nurs J.* 2022;29(02):1–6.
28. Alyabisi MS, Alqarni AH, Almutairi LM, Algarni MA, Alshammari KM, Almutairi A, Alselaime NA. The 30-day hospital readmission and mortality after surgery in colorectal cancer patients. *BMC Gastroenterol.* 2022;22(1):434.
29. Alyabisi M, Charlton M, Meza J, Islam KMM, Soliman A, Watanabe-Galloway S. Comparison of Urban-Rural Readmission Rates After Colorectal Cancer Surgery: Findings From a Privately Insured Population. *Cancer Control.* 2021;28:10732748211027168.
30. He Yuhua YJ, Jiang Lili: Analysis of Factors Influencing Unplanned Readmission within 30 Days of Discharge for Colorectal Cancer Patients Under Enhanced Recovery After Surgery Mode. *Chinese Journal of General Surgery Basic and Clinical* 2021, 28(10):1334–1339.
31. Chung JS, Kwak HD, Ju JK. Thirty-Day Readmission After Elective Colorectal Surgery for Colon Cancer: A Single-Center Cohort Study. *Ann Coloproctol.* 2020;36(3):186–91.
32. Tatar C, Benlice C, Delaney CP, Holubar SD, Liska D, Steele SR, Gorgun E. Modified frailty index predicts high-risk patients for readmission after colorectal surgery for cancer. *Am J Surg.* 2020;220(1):187–90.
33. O'Connell EP, Healy V, Fitzpatrick F, Higgins CA, Burke JP, McNamara DA. Predictors of Readmission Following Proctectomy for Rectal Cancer. *Dis Colon Rectum.* 2019;62(6):703–10.
34. Al-Mazrou AM, Suradkar K, Mauro CM, Kiran RP. Characterization of Readmission by Day of Rehospitalization After Colorectal Surgery. *Dis Colon Rectum.* 2017;60(2):202–12.
35. Lucas DJ, Ejaz A, Bischof DA, Schneider EB, Pawlik TM. Variation in readmission by hospital after colorectal cancer surgery. *JAMA Surg.* 2014;149(12):1272–7.
36. Schneider EB, Hyder O, Brooke BS, Efron J, Cameron JL, Edil BH, Schulick RD, Choti MA, Wolfgang CL, Pawlik TM: Patient readmission and mortality after colorectal surgery for colon cancer: impact of length of stay relative to other clinical factors. *J Am Coll Surg* 2012, 214(4):390–398; discussion 398–399.
37. Tsai TC, Joynt KE, Orav EJ, Gawande AA, Jha AK. Variation in surgical-readmission rates and quality of hospital care. *N Engl J Med.* 2013;369(12):1134–42.
38. Guangqing J: Preliminary Analysis of High-risk Factors Associated with Unplanned Readmission after Colorectal Cancer Surgery. master 2022.
39. Jin Z, Yan W, Hui W, Yin Z, Xiaoxu Z, Zhiyuan Z, Dejing X, Xin Z, Liuli Z: Construction of a Comprehensive Health Management Program for Elderly Postoperative Colorectal Cancer Patients. *Chinese General Practice* 2024, 27(21):2600–2606+2616.
40. Mingfen C, Xuemei F, Ying L, Yuanyuan S. The correlation between preoperative frailty assessment and postoperative complications in elderly patients with colorectal cancer. *Chin J Gerontol.* 2022;42(20):5133–6.
41. Song JW, Chung KC. Observational studies: cohort and case-control studies. *Plast Reconstr Surg.* 2010;126(6):2234–42.
42. Harborg S, Kjærgaard KA, Thomsen RW, Borgquist S, Cronin-Fenton D, Hjorth CF. New Horizons: Epidemiology of Obesity, Diabetes Mellitus, and Cancer Prognosis. *J Clin Endocrinol Metab.* 2024;109(4):924–35.
43. Khan S, Kaltenmeier C, Hrebinko K, Nassour I, Hoehn RS, Medich DS, Zureikat A, Tohme S. Readmission After Surgical Resection for Colon and Rectal Cancers: A Retrospective Cohort Study. *Am Surg.* 2022;88(6):1118–30.
44. Irani JL, Hedrick TL, Miller TE, Lee L, Steinhagen E, Shogan BD, Goldberg JE, Feingold DL, Lightner AL, Paquette JM. Clinical practice guidelines for enhanced recovery after colon and rectal surgery from the American Society of Colon and Rectal Surgeons and the Society of American Gastrointestinal and Endoscopic Surgeons. *Surg Endosc.* 2023;37(1):5–30.
45. Thompson A, Fleischmann KE, Smilowitz NR, de Las FL, Mukherjee D, Aggarwal NR, Ahmad FS, Allen RB, Altin SE, Auerbach A, et al. 2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol.* 2024;84(19):1869–969.
46. Gustafsson UO, Scott MJ, Hubner M, Nygren J, Demartines N, Francis N, Rockall TA, Young-Fadok TM, Hill AG, Soop M, et al. Guidelines for Perioperative Care in Elective Colorectal Surgery: Enhanced Recovery After Surgery (ERAS[®]) Society Recommendations: 2018. *World J Surg.* 2019;43(3):659–95.
47. Yuehong Z, Yifan L. Influence Factors of Self-management Behaviors of Patients with Colorectal Cancer after Ostomy Surgery and Their Correlation with Self-efficacy and Coping Styles. *General nursing.* 2021;19(02):257–60.
48. Chuying Z, Guofen Z, Yuting Z, Qian G, Xuli Z, Hui L, Jianfang H. Effects of health education nursing on postoperative complications and psychological state of patients with open fracture of lower limb. *Clinical Medical Research and Practice.* 2025;10(02):129–32.
49. Klein SL, Flanagan KL. Sex differences in immune responses. *Nat Rev Immunol.* 2016;16(10):626–38.
50. Straub RH. The complex role of estrogens in inflammation. *Endocr Rev.* 2007;28(5):521–74.
51. Gilliver SC, Ashcroft GS. Sex steroids and cutaneous wound healing: the contrasting influences of estrogens and androgens. *Climacteric.* 2007;10(4):276–88.
52. Rattan R, Parreco J, Lindenmaier LB, Yeh DD, Zakrisson TL, Pust GD, Sands LR, Namias N. Underestimation of Unplanned Readmission after Colorectal Surgery: A National Analysis. *J Am Coll Surg.* 2018;226(4):382–90.
53. Bundred JR, Kamarajah SK. Re: "Critical appraisal on the impact of preoperative rehabilitation and outcomes after major abdominal and cardiothoracic surgery: A systematic review and meta-analysis"-Counting rules are critical. *Surgery.* 2020;168(6):1179.
54. Quintana JM, Anton-Ladislao A, Lázaro S, Gonzalez N, Bare M, de Larrea NF, Redondo M, Briones E, Escobar A, Sarasqueta C, et al. Predictors of readmission and reoperation in patients with colorectal cancer. *Support Care Cancer.* 2020;28(5):2339–50.
55. Vogel JD, Felder SI, Bhama AR, Hawkins AT, Langenfeld SJ, Shaffer VO, Thorsen AJ, Weiser MR, Chang GJ, Lightner AL, et al. The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for the Management of Colon Cancer. *Dis Colon Rectum.* 2022;65(2):148–77.
56. NCCN Clinical Practice Guidelines in Oncology: Colon Cancer [<https://www.nccn.org/guidelines/guidelines-detail?category=1&id=1421>]
57. Doumouras AG, Tsao MW, Saleh F, Hong D. A population-based comparison of 30-day readmission after surgery for colon and rectal cancer: How are they different? *J Surg Oncol.* 2016;114(3):354–60.
58. Dulskas A, Kavaliauskas P, Pilipavicius L, Jodinskas M, Mikalonis M, Samalavicius NE. Long-term bowel dysfunction following low anterior resection. *Sci Rep.* 2020;10(1):11882.
59. van Workum F, Talboom K, Hannink G, Wolhuis A, de Lacy BF, Lefevre JH, Solomon M, Frasson M, Rotholtz N, Denost Q, et al. Treatment of anastomotic leakage after rectal cancer resection: The TENTACLE-Rectum study. *Colorectal Dis.* 2021;23(4):982–8.
60. Qian Z, Xing W, Yun LJ. Nursing progress of stoma-related complications in rectal cancer patients with permanent colostomy. *Integrated Traditional Chinese and Western Medicine Nursing (Chinese and English).* 2023;9(09):196–8.
61. Danielsen AK, Soerensen EE, Burcharth K, Rosenberg J. Impact of a temporary stoma on patients' everyday lives: feelings of uncertainty while waiting for closure of the stoma. *J Clin Nurs.* 2013;22(9–10):1343–52.
62. Nagle D, Pare T, Keenan E, Marcet K, Tizio S, Poylin V. Ileostomy pathway virtually eliminates readmissions for dehydration in new ostomates. *Dis Colon Rectum.* 2012;55(12):1266–72.

63. Gonella F, Valenti A, Massucco P, Russolillo N, Mineccia M, Fontana AP, Cucco D, Ferrero A. A novel patient-centered protocol to reduce hospital readmissions for dehydration after ileostomy. *Updates Surg.* 2019;71(3):515–21.
64. Braga M, Frasson M, Zuliani W, Vignali A, Pecorelli N, Di Carlo V. Randomized clinical trial of laparoscopic versus open left colonic resection. *Br J Surg.* 2010;97(8):1180–6.
65. Vlug MS, Wind J, Hollmann MW, Ubbink DT, Cense HA, Engel AF, Gerhards MF, van Wagenveld BA, van der Zaag ES, van Geloven AA, et al. Laparoscopy in combination with fast track multimodal management is the best perioperative strategy in patients undergoing colonic surgery: a randomized clinical trial (LAFA-study). *Ann Surg.* 2011;254(6):868–75.
66. Kumar M, Sahu RS, Kumar M, Gupta R. Comment on “Perioperative Blood Transfusions Are Associated With Worse Overall Survival But Not Disease-Free Survival After Curative Rectal Cancer Resection: A Propensity Score-Matched Analysis.” *Dis Colon Rectum.* 2022;65(5): e337.
67. Waymack JP, Alexander JW. Blood transfusions as an immunomodulator—a review. *Comp Immunol Microbiol Infect Dis.* 1986;9(2–3):177–83.
68. Jagoditsch M, Pozgainer P, Klingler A, Tschmelitsch J. Impact of blood transfusions on recurrence and survival after rectal cancer surgery. *Dis Colon Rectum.* 2006;49(8):1116–30.
69. Tobian AA, Heddle NM, Wiegmann TL, Carson JL. Red blood cell transfusion: 2016 clinical practice guidelines from AABB. *Transfusion.* 2016;56(10):2627–30.
70. Camazine MN, Hemmila MR, Leonard JC, Jacobs RA, Horst JA, Kozar RA, Bochicchio GV, Nathens AB, Cryer HM, Spinella PC. Massive transfusion policies at trauma centers participating in the American College of Surgeons Trauma Quality Improvement Program. *J Trauma Acute Care Surg.* 2015;78(6 Suppl 1):S48–53.
71. Azimuddin K, Rosen L, Reed JF 3rd, Stasik JJ, Riether RD, Khubchandani IT. Readmissions after colorectal surgery cannot be predicted. *Dis Colon Rectum.* 2001;44(7):942–6.
72. Group EC. The Impact of Enhanced Recovery Protocol Compliance on Elective Colorectal Cancer Resection: Results From an International Registry. *Ann Surg.* 2015;261(6):1153–9.
73. Spanjersberg WR, Reurings J, Keus F, van Laarhoven CJ. Fast track surgery versus conventional recovery strategies for colorectal surgery. *Cochrane Database Syst Rev* 2011(2):Cd007635.
74. Biondi A, Mele MC, Agnes A, Lorenzon L, Cintoni M, Rinninella E, Marincola G, D’Ugo D, Gasbarrini A, Persiani R. Feasibility of discharge within 72 hours of major colorectal surgery: lessons learned after 5 years of institutional experience with the ERAS protocol. *BJS Open* 2022, 6(1).
75. Lawson EH, Hall BL, Louie R, Ettner SL, Zingmond DS, Han L, Rapp M, Ko CY. Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. *Ann Surg.* 2013;258(1):10–8.
76. Orcutt ST, Li LT, Balentine CJ, Albo D, Awad SS, Berger DH, Anaya DA. Ninety-day readmission after colorectal cancer surgery in a Veterans Affairs cohort. *J Surg Res.* 2016;201(2):370–7.
77. Shogan BD, Vogel JD, Davis BR, Keller DS, Ayscue JM, Goldstein LE, Feingold DL, Lightner AL, Paquette IM. The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for Preventing Surgical Site Infection. *Dis Colon Rectum.* 2024;67(11):1368–82.
78. Jaffe TA, Meka AP, Semaan DZ, Okoro U, Hwang C. Papin Jt, Mullard A, Campbell DA, Englesbe MJ. Optimizing Value of Colon Surgery in Michigan. *Ann Surg.* 2017;265(6):1178–82.
79. Koskenvuo L, Lunkka P, Varpe P, Hyöty M, Satokari R, Haapamäki C, Lepistö A, Sallinen V. Morbidity After Mechanical Bowel Preparation and Oral Antibiotics Prior to Rectal Resection: The MOBILE2 Randomized Clinical Trial. *JAMA Surg.* 2024;159(6):606–14.
80. Herbert G, Perry R, Andersen HK, Atkinson C, Penfold C, Lewis SJ, Ness AR, Thomas S. Early enteral nutrition within 24 hours of lower gastrointestinal surgery versus later commencement for length of hospital stay and postoperative complications. *Cochrane Database Syst Rev* 2019, 7(7):Cd004080.
81. Iskander O. An outline of the management and prevention of postoperative ileus: A review. *Medicine (Baltimore).* 2024;103(24): e38177.

Publisher’s Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.