Journal of Case Reports and Reviews in Medicine
https://doi.org/10.64978/jcrrm-0122

ISSN: 3069-0749

Research Article

Open Access Full Text Article

Risk Factors for Anastomotic Leakage After Elective Laparoscopic Total Mesorectal Excision for Rectal Cancer: A Single-Center Retrospective Study of 532 Patients

Haibo Luo[1], Yinuo Wang[1*]

[1]Department of Gastrointestinal Surgery, The Second Affiliated Hospital of Kunming Medical University, Kunming, Yunnan, China

[*]**Correspondence:**
Yinuo Wang, MD
Address: No. 374 Dianmian Avenue, Wuhua District, Kunming City, Yunnan Province, China.

Received: May 07, 2026; **Published:** June 23, 2026

How to cite this article:
Luo H, Wang Y. Risk Factors for Anastomotic Leakage After Elective Laparoscopic Total Mesorectal Excision for Rectal Cancer: A Single Center Retrospective Study of 532 Patients. *J Case Rep Rev Med*. 2026;2(2):1-6. doi: https://doi.org/10.64978/jcrrm-0122

Abstract

Background: Anastomotic leakage (AL) is a severe complication after laparoscopic total mesorectal excision (TME) for rectal cancer, yet risk factors specific to this homogeneous surgical setting remain incompletely defined. This study aimed to investigate the incidence and independent risk factors for AL in patients undergoing elective laparoscopic TME for rectal cancer.

Methods: This single-center retrospective cohort study included 532 consecutive patients who underwent elective laparoscopic TME with primary anastomosis for rectal cancer between January 2024 and January 2026. Demographic, clinical, tumor-related, and surgical variables were collected from electronic medical records. Univariate and multivariable logistic regression analyses were performed to identify independent risk factors for AL.

Results: The overall incidence of AL was 12.2% (65/532). Multivariable analysis identified three independent risk factors: diabetes mellitus (OR = 3.20, 95% CI: 1.84–5.58, P < 0.001), smoking history (OR = 2.13, 95% CI: 1.21–3.73, P = 0.008), and advanced tumor stage (III–IV vs. I–II, OR = 1.92, 95% CI: 1.13–3.24, P = 0.015). Age and neoadjuvant chemoradiotherapy were not independently associated with AL in the multivariable model.

Conclusions: Diabetes, smoking history, and advanced tumor stage are independent risk factors for anastomotic leakage after elective laparoscopic TME for rectal cancer. These easily accessible preoperative variables can aid in risk stratification and guide targeted preventive strategies, such as optimizing glycemic control, promoting smoking cessation, and considering diverting stoma in high-risk patients. Prospective multicenter studies are warranted to validate these findings and develop a practical risk prediction tool.

Keywords: anastomotic leakage; mesorectal; rectal cancer; surgery, diabetes; hypertension

Introduction

Colorectal cancer remains one of the most common malignancies worldwide.[1] Total mesorectal excision (TME), introduced by Heald in the 1980s, has become the standard surgical procedure for rectal cancer,[2] significantly reducing local recurrence rates and improving long-term survival.[3] In parallel, laparoscopic TME has gained widespread acceptance due to its advantages of reduced surgical trauma, faster recovery, and shorter hospital stay, with comparable oncological outcomes to open surgery.[4]

Anastomotic leakage (AL) is a devastating complication following rectal cancer surgery.[5] AL not only prolongs hospitalization and increases healthcare costs but also leads to higher rates of reoperation, permanent stoma, and even postoperative mortality.[6] Moreover, a growing body of evidence suggests that AL may compromise long-term oncological outcomes, including increased local recurrence and reduced disease-free survival.[7] Therefore, identifying modifiable and non-modifiable risk factors for AL is of paramount importance for preoperative risk stratification and tailored preventive strategies.

Previous studies have identified several potential risk factors for AL after rectal cancer surgery, including male sex, high body mass index (BMI), diabetes mellitus, smoking, neoadjuvant chemoradiotherapy, low tumor location, and prolonged operative time.[8-10] However, the results have been inconsistent across studies, partly due to heterogeneity in surgical approaches (open vs. laparoscopic), anastomotic techniques, and definitions of AL.[11-13] Furthermore, most existing studies were conducted in mixed cohorts of open and laparoscopic procedures or included both colon and rectal cancers, limiting the applicability of their findings to the specific setting of elective laparoscopic TME for rectal cancer.[13-17]

To date, few studies have focused exclusively on a homogenous cohort of patients undergoing elective laparoscopic TME with primary anastomosis, using standardized surgical techniques and uniform perioperative protocols. Clarifying risk factors in this specific population is essential for developing precise risk prediction tools and guiding clinical decision-making, particularly regarding the selective use of diverting stoma.

In this study, we aimed to investigate the incidence and independent risk factors for anastomotic leakage in a large single-center cohort of patients who underwent elective laparoscopic total mesorectal excision for rectal cancer. We also sought to quantify the strength of association between each potential risk factor and AL, thereby providing evidence-based support for preoperative risk assessment and individualized preventive measures.

Methods

Study Design

This was a single-center retrospective cohort study of patients who underwent elective laparoscopic total mesorectal excision (TME) for rectal cancer at our department between January 2024 and January 2026.

Inclusion criteria were: (1) histologically confirmed rectal adenocarcinoma; (2) elective laparoscopic TME with primary colorectal or coloanal anastomosis; (3) complete clinical and pathological data available.

Exclusion criteria were: (1) conversion to open surgery; (2) primary open surgery; (3) abdominoperineal resection (APR) or Hartmann's procedure (no primary anastomosis); (4) synchronous or metachronous other malignancies; (5) previous colorectal surgery.

A total of 532 consecutive patients met the inclusion criteria and were included in the final analysis. No data were missing for any of the collected variables.

Data Collection

Data were extracted from the hospital's electronic medical records using a standardized data collection form. Demographic and clinical characteristics included age, sex, body mass index (BMI), diabetes mellitus, and smoking history. Preoperative laboratory parameters were obtained from tests performed within 14 days before surgery. Information on neoadjuvant chemoradiotherapy was also recorded.

Tumor-related variables comprised the distance from the tumor to the anal verge (in centimeters), clinical TNM stage according to the AJCC 8th edition (categorized as stage I-II vs. stage III-IV), and circumferential resection margin (CRM) status, where positive was defined as ≤ 1 mm. The duration of surgery (in minutes) was collected as the sole surgical parameter. Postoperatively, the occurrence of anastomotic leakage and its severity grade were documented. All data were double-checked by two independent investigators, and any discrepancies were resolved by consensus.

Outcome Definition

The primary outcome was anastomotic leakage, defined according to the International Study Group of Rectal Cancer (ISREC) criteria: grade A (radiologic evidence without clinical symptoms), grade B (requiring active intervention but no re-laparotomy), and grade C (requiring re-laparotomy). Clinically relevant leakage was defined as grade B or C for sensitivity analysis.[18]

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies (percentages). Univariate logistic regression was first performed to evaluate the association between each potential risk factor and anastomotic leakage. Variables with a P value < 0.10 in the univariate analysis were entered into a multivariable logistic regression model to identify independent risk factors. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). A two-sided P value < 0.05 was considered statistically significant.

All statistical analyses were performed using STATA version 15.0.

Results

Patient Characteristics

A total of 532 patients who underwent elective laparoscopic total mesorectal excision for rectal cancer were included in this study. The mean age was 63.65 ± 10.68 years (range: 28–90 years), with 164 patients (30.83%) aged < 50 years, 190 (35.71%) aged 50–65 years, and 178 (33.46%) aged ≥ 65 years. The cohort comprised 383 male (71.99%) and 149 female (28.01%) patients. The mean BMI was 24.10 ± 3.32 kg/m^2 (range: 18.5-35.0 kg/m^2); 273 patients (51.32%) had a BMI < 24 kg/m^2, 192 (36.09%) had a BMI of 24-28 kg/m^2, and 67 (12.59%) had a BMI ≥ 28 kg/m^2.

Comorbidities included diabetes mellitus in 164 patients (30.83%) and a history of smoking in 156 patients (29.32%). Preoperative laboratory values showed a mean serum albumin level of 40.05 ± 4.76 g/L (range: 28.0–50.0 g/L), with 78 patients (14.66%) having hypoalbuminemia (< 35 g/L). The mean preoperative hemoglobin level was 131.89 ± 12.78 g/L (range: 100.1–169.4 g/L), and 100 patients (18.8%) were classified as anemic (< 120 g/L). Neoadjuvant chemoradiotherapy was administered to 198 patients (37.22%).

Regarding tumor characteristics, the mean distance from the tumor to the anal verge was 4.02 ± 3.44 cm (range: 1.0-15.0 cm); 381 patients (71.62%) had low-lying tumors (< 5 cm from the anal verge), while 151 (28.38%) had tumors ≥ 5 cm. According to clinical staging, 221 patients (41.54%) had stage I–II disease, and 311 (58.46%) had stage III–IV disease. A positive circumferential resection margin was observed in 71 patients (13.35%).

The mean operative duration was 199.11 ± 39.43 minutes (range: 120-296 minutes), with 81 patients (15.23%) having an operative time ≥ 240 minutes. Detailed baseline characteristics stratified by anastomotic leakage status are presented in Table 1.

Table 1. Baseline characteristics and incidence of anastomotic leakage stratified by patient subgroups.

Variable	Group	Total (N=532)	Proportion (%)	Leakage (n)	Leakage rate (%)
Age	< 50	164	30.83	13	7.93
	50-65	190	35.71	22	11.58
	≥ 65	178	33.46	30	16.85
Sex	female	149	28.01	13	8.72
	male	383	71.99	52	13.58
BMI	< 24	273	51.32	33	12.09
	24-28	192	36.09	26	13.54
	≥ 28	67	12.59	6	8.96
Diabetes	no	368	69.17	28	7.61
	yes	164	30.83	37	22.56
Smoking history	no	376	70.68	36	9.57
	yes	156	29.32	29	18.59
Preoperative serum albumin	≥ 35 g/L	454	85.34	45	9.91
	< 35 g/L	78	14.66	20	25.64
Preoperative hemoglobin	No anemia (≥ 120 g/L)	432	81.2	52	12.04
	Anemia (<120 g/L)	100	18.8	13	13
Neoadjuvant chemoradiotherapy	no	334	62.78	26	7.78
	yes	198	37.22	39	19.7
Distance between tumor and anal margin	≥ 5cm	151	28.38	15	9.93
	< 5cm	381	71.62	50	13.12
Tumor staging	I-II	221	41.54	14	6.33
	III-IV	311	58.46	51	16.4
CRM	(-)	461	86.65	54	11.71
	(+)	71	13.35	11	15.49
Duration of surgery	< 240 min	451	84.77	52	11.53
	≥ 240 min	81	15.23	13	16.05

Data are presented as number of patients (n) and proportion (%) for categorical variables, and leakage rate (%) for each subgroup. AL = anastomotic leakage; BMI = body mass index; CRM = circumferential resection margin.

Anastomotic Leakage Incidence

Among the 532 patients included in this study, anastomotic leakage occurred in 65 cases, yielding an overall incidence of 12.2% (95% CI: 9.6%-15.3%) (Table 1).

The incidence of anastomotic leakage varied across different patient subgroups. With respect to age, the leakage rate increased progressively with advancing age: 7.93% in patients under 50 years, 11.58% in those aged 50–65 years, and 16.85% in patients aged 65 years or older. In terms of sex, males had a higher leakage rate than females (13.58% vs. 8.72%) (Table 1).

Regarding metabolic factors, diabetic patients exhibited a markedly higher leakage rate compared with their non-diabetic counterparts (22.56% vs. 7.61%). Similarly, a history of smoking was associated with an elevated leakage rate (18.59% vs. 9.57%). Preoperative hypoalbuminemia (< 35 g/L) was also linked to a substantially higher incidence of leakage (25.64% vs. 9.91%), whereas preoperative anemia (< 120 g/L) showed a comparable leakage rate to those with normal hemoglobin levels (13.00% vs. 12.04%) (Table 1).

In relation to oncologic characteristics, patients who received neoadjuvant chemoradiotherapy experienced a leakage rate of 19.70%, more than double that observed in those who did not (7.78%). Advanced tumor stage (III-IV) was associated with a leakage rate of 16.40%, considerably higher than the 6.33% seen in patients with stage I-II disease. Low-lying tumors (< 5 cm from the anal verge) were associated with a leakage rate of 13.12%, compared with 9.93% for higher tumors. A positive circumferential resection margin was observed in 15.49% of patients, slightly higher than the 11.71% in those with negative margins (Table 1).

Regarding surgical factors, patients with prolonged operative duration (≥ 240 minutes) had a leakage rate of 16.05%, versus 11.53% in those with shorter operations (Table 1).

Univariate Analysis

Univariate logistic regression was performed to evaluate the association between each potential risk factor and anastomotic leakage. The results are summarized in Table 2.

Among demographic variables, age was identified as a significant predictor, with each one-year increase associated with a 3% increase in the odds of anastomotic leakage (OR = 1.03, 95% CI: 1.00-1.05, P = 0.047). Sex showed a trend toward higher risk in males, but this did not reach statistical significance (OR = 1.64, 95% CI: 0.87-3.12, P = 0.128). Body mass index (BMI) was not significantly associated with leakage (OR = 1.00, 95% CI: 0.93-1.08, P = 0.933).

Diabetes mellitus was strongly associated with an increased risk of anastomotic leakage, with diabetic patients having more than three times the odds of leakage compared with non-diabetic patients (OR = 3.54, 95% CI: 2.08-6.02, P < 0.001). Similarly, a history of smoking significantly elevated the risk (OR = 2.16, 95% CI: 1.27-3.66, P = 0.004). Regarding nutritional status, preoperative serum albumin emerged as a protective factor; each 1 g/L increase was associated with an 8% reduction in the odds of leakage (OR = 0.92, 95% CI: 0.87-0.97, P = 0.003). In contrast, preoperative hemoglobin level was not significantly associated with leakage (OR = 1.00, 95% CI: 0.98-1.02, P = 0.839).

Neoadjuvant chemoradiotherapy significantly increased the risk of anastomotic leakage, with treated patients having nearly three times the odds of leakage compared with those who did not receive neoadjuvant therapy (OR = 2.91, 95% CI: 1.71-4.95, P < 0.001). Advanced tumor staging (III-IV) was also a strong predictor, with an OR of 2.48 (95% CI: 1.67-3.70, P < 0.001). The distance between the tumor and the anal margin, analyzed as a continuous variable, was not significantly associated with leakage (OR = 0.96, 95% CI: 0.89-1.04, P = 0.351). Similarly, a positive circumferential resection margin (CRM) did not reach statistical significance (OR = 1.38, 95% CI: 0.68-2.79, P = 0.367).

Duration of surgery, analyzed as a continuous variable, was not significantly associated with anastomotic leakage (OR = 1.01,

95% CI: 1.00-1.01, P = 0.113).

Table 2. Univariate logistic regression analysis of risk factors for anastomotic leakage.

Variable	OR	SE	z	P	95%CI Lower	95%CI Upper
Age	1.03	0.01	1.98	0.047*	1.00	1.05
Sex	1.64	0.54	1.52	0.128	0.87	3.12
BMI	1.00	0.04	0.08	0.933	0.93	1.08
Diabetes	3.54	0.96	4.66	< 0.001*	2.08	6.02
Smoking history	2.16	0.58	2.84	0.004*	1.27	3.66
Preoperative serum albumin	0.92	0.03	-2.99	0.003*	0.87	0.97
Preoperative hemoglobin	1.00	0.01	-0.2	0.839	0.98	1.02
Neoadjuvant chemoradio-therapy	2.91	0.79	3.93	< 0.001*	1.71	4.95
Distance between tumor and anal margin	0.96	0.04	-0.93	0.351	0.89	1.04
Tumor staging	2.48	0.50	4.47	< 0.001*	1.67	3.70
CRM	1.38	0.50	0.9	0.367	0.68	2.79
Duration of surgery	1.01	0.00	1.59	0.113	1.00	1.01

OR = odds ratio; SE = standard error; CI = confidence interval; CRM = circumferential resection margin. *Statistically significant (P < 0.05).

Multivariable Analysis

To identify independent risk factors for anastomotic leakage, variables with a P value < 0.10 in the univariate analysis including age, diabetes, smoking history, preoperative serum albumin, neoadjuvant chemoradiotherapy, and tumor staging were entered into a multivariable logistic regression model. The results are summarized in Table 3 and visualized in Figure 1.

After adjusting for potential confounders, diabetes mellitus remained a strong and significant predictor of anastomotic leakage. Diabetic patients had more than three times the odds of developing leakage compared with non-diabetic patients (OR = 3.20, 95% CI: 1.84-5.58, P < 0.001). Similarly, a history of smoking was independently associated with an increased risk, with an odds ratio of 2.13 (95% CI: 1.21-3.73, P = 0.008). Advanced tumor staging (stage III-IV) also emerged as an independent risk factor, conferring nearly twice the odds of leakage compared with stage I–II disease (OR = 1.92, 95% CI: 1.13-3.24, P = 0.015).

In contrast, age was not significantly associated with anastomotic leakage in the multivariable model (OR = 1.02, 95% CI: 0.99-1.05, P = 0.116). Likewise, neoadjuvant chemoradiotherapy did not retain statistical significance after adjustment (OR = 1.48, 95% CI: 0.73-3.01, P = 0.276).

In summary, in the multivariable logistic regression model adjusting for age, diabetes, smoking history, neoadjuvant chemoradiotherapy, and tumor staging, three factors remained independently associated with anastomotic leakage after laparoscopic total mesorectal excision for rectal cancer: diabetes mellitus (OR = 3.20, 95% CI: 1.84-5.58, P < 0.001), smoking history (OR = 2.13, 95% CI: 1.21-3.73, P = 0.008), and advanced tumor staging (III-IV) (OR = 1.92, 95% CI: 1.13-3.24, P = 0.015). Age and neoadjuvant chemoradiotherapy were not significant in the multivariable model.

Table 3. Multivariable logistic regression analysis of independent risk factors for anastomotic leakage.

Variable	OR	SE	z	P	95%CI Lower	95%CI Upper
Age	1.02	0.01	1.57	0.116	0.99	1.05
Diabetes	3.20	0.91	4.11	< 0.001*	1.84	5.58
Smoking history	2.13	0.61	2.64	0.008*	1.21	3.73
Neoadjuvant chemoradio-therapy	1.48	0.53	1.09	0.276	0.73	3.01
Tumor staging	1.92	0.51	2.42	0.015*	1.13	3.24

Variables with P < 0.05 in univariate analysis were entered into the multivariable model. OR = odds ratio; CI = confidence interval. *Statistically significant (P < 0.05).

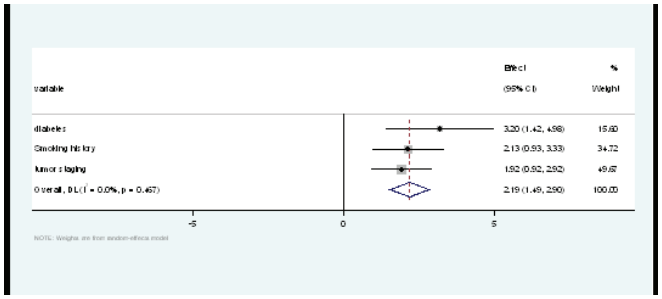

Figure 1. Forest plot of multivariable logistic regression analysis for anastomotic leakage. Odds ratios (ORs) and 95% confidence intervals (CIs) are plotted on a logarithmic scale. Variables with a P value < 0.05 were considered statistically significant. Diabetes mellitus, smoking history, and advanced tumor stage (III–IV) were identified as independent risk factors.

Discussion

In this single-center retrospective cohort of 532 patients undergoing elective laparoscopic total mesorectal excision for rectal cancer, we found an overall anastomotic leakage rate of 12.2%. Multivariable analysis identified diabetes mellitus, smoking history, and advanced tumor stage (III–IV) as independent risk factors for anastomotic leakage. These findings provide clinically useful information for preoperative risk stratification and individualized preventive strategies.

Diabetes mellitus was the strongest risk factor in our study, with diabetic patients having a 3.2-fold increased odds of anastomotic leakage compared with non-diabetic patients. This association is biologically plausible. Chronic hyperglycemia leads to microvascular dysfunction, impaired angiogenesis, and reduced tissue oxygenation, all of which may compromise anastomotic healing.[19-21] Additionally, diabetes is associated with defective collagen synthesis and delayed wound repair. Several previous studies have reported similar findings, although the magnitude of the effect varies across populations.[22-25] Our results reinforce the importance of strict perioperative glycemic control in diabetic patients undergoing rectal cancer surgery.

A history of smoking was independently associated with a 2.13-fold higher risk of anastomotic leakage. Nicotine is a potent vasoconstrictor that reduces mucosal blood flow, while carbon monoxide from cigarette smoke impairs oxygen delivery to tissues.[26] Chronic smoking also increases pulmonary complications, leading to postoperative coughing and elevated intra-abdominal pressure,

which may place tension on the anastomosis.[27] Moreover, smokers often exhibit systemic inflammation and nutritional deficiencies that can impede wound healing. Our findings align with those of previous study, and they underscore the potential benefit of preoperative smoking cessation programs.[27]

Advanced tumor stage (III–IV) emerged as another independent predictor, conferring nearly twice the odds of leakage compared with stage I–II disease. This association may be explained by several factors. Patients with advanced tumors often require more extensive lymphadenectomy, possibly including lateral pelvic lymph node dissection, which increases surgical complexity and operative time.[28] Furthermore, advanced tumors are more likely to have received neoadjuvant chemoradiotherapy, which can induce tissue edema, fibrosis, and microvascular damage, all of which might impair anastomotic healing.[29] Notably, although neoadjuvant therapy was significantly associated with leakage in univariate analysis (OR = 2.91), it lost statistical significance in the multivariable model. This suggests that the effect of neoadjuvant treatment is largely mediated by tumor stage, and the two variables should be interpreted together in clinical practice.

Some variables that have been implicated in previous studies, such as age, BMI, preoperative albumin, tumor distance from the anal verge, and CRM status, were not retained as independent predictors in our multivariable model. The lack of significance for age may reflect the relatively advanced but homogeneous age distribution of our cohort. Preoperative albumin, while significant in univariate analysis, was likely confounded by diabetes and tumor stage, both of which are associated with nutritional status. The distance from the anal verge, often considered a classic risk factor for leakage, did not reach statistical significance in our study. This may be due to the high proportion of low-lying tumors (71.6% < 5 cm) in our cohort, which reduced between-group variation. Alternatively, the expertise of the laparoscopic surgeons at our center may have mitigated the technical challenges of ultralow anastomosis.

Clinical implications of our findings are straightforward. Diabetes, smoking history, and advanced tumor stage are all readily available preoperatively. Patients with one or more of these factors can be identified as high-risk individuals, allowing surgeons to implement targeted preventive measures. These may include optimizing glycemic control, encouraging smoking cessation, considering a diverting stoma (especially for low anastomoses), and enhancing perioperative nutritional support. A simple risk score based on these three variables could be developed in future studies to help guide shared decision-making.

Several limitations of this study should be acknowledged. First, the retrospective design inherently carries the risk of selection and information bias, although the completeness of our data (no missing values) mitigates this concern to some extent. Second, the study is from a single high-volume center, which may limit generalizability to other settings with different surgical volumes or techniques. Third, we did not collect data on certain potentially relevant factors, such as intraoperative indocyanine green fluorescence angiography, the use of mechanical bowel preparation, or the specific type of stapler used. Fourth, because we exclusively studied patients who underwent successful laparoscopic TME without conversion, our findings may not apply to open or converted cases. Fifth, the lack of external validation means our risk estimates should be interpreted cautiously before being applied to other populations.

Despite these limitations, our study has notable strengths. Our work focusing exclusively on elective laparoscopic TME for rectal cancer, with rigorous standardization of the surgical procedure and outcome assessment. The use of the validated ISREC definition for anastomotic leakage ensures comparability with other studies. The complete dataset without missing values further strengthens the reliability of our analyses.

Conclusion

In conclusion, this single-center retrospective study of 532 patients undergoing elective laparoscopic total mesorectal excision for rectal cancer demonstrated that diabetes mellitus, smoking history, and advanced tumor stage (III–IV) are independent risk factors for anastomotic leakage. These three variables are readily available before surgery and can assist clinicians in identifying high-risk patients. Preoperative optimization of glycemic control, smoking cessation, and consideration of a diverting stoma in selected cases may help reduce the risk of this serious complication. Given the retrospective nature and single-center design of this study, prospective multicenter studies are warranted to validate our findings and to develop a practical risk prediction tool for routine clinical use.

Funding

The Second Affiliated Hospital of Kunming Medical University (Grant No. 审-PJ-科-2022-9) (Chinese identifier) Haibo Luo;

Graduate Student Innovation Fund of Kunming Medical University (2025S259) Yinuo Wang.

Conflicts of Interest

None.

References

1. Kwak HD, Ju JK, Lee SY, Kim CH, Kim YJ, Kim HR. Comparison of right-side and left-side colon cancers following laparoscopic radical lymphadenectomy. *J Invest Surg*. 2021;34(2):142-147. doi:10.1080/08941939.2019.1608334.
2. Simo V, Tejedor P, Jimenez LM, et al. Oncological safety of transanal total mesorectal excision (TaTME) for rectal cancer: mid-term results of a prospective multicentre study. *Surg Endosc*. 2021;35(4):1808-1819. doi:10.1007/s00464-020-07579-4.
3. Petropoulou T, Amin S. Robotic rectal cancer surgery with single side-docking technique: experience of a tertiary care university hospital. *J Robot Surg*. 2021;15(1):135-142. doi:10.1007/s11701-020-01087-2.
4. Wang Q, Wang C, Sun DH, Kharbuja P, Cao XY. Laparoscopic total mesorectal excision with natural orifice specimen extraction. *World J Gastroenterol*. 2013;19(5):750-754. doi:10.3748/wjg.v19.i5.750.
5. Hain E, Maggiori L, Zappa M, Prost À la Denise J, Panis Y. Anastomotic leakage after side-to-end anastomosis for rectal cancer: does leakage location matter? *Colorectal Dis*. 2018. doi:10.1111/codi.14005.
6. Liu XH, Wu XR, Zhou C, et al. Conversion is a risk factor for postoperative anastomotic leak in rectal cancer patients: a retrospective cohort study. *Int J Surg*. 2018;53:298-303. doi:10.1016/j.ijsu.2018.01.024.
7. Mege D, Hain E, Lakkis Z, Maggiori L, Prost À la Denise J, Panis Y. Is trans-anal total mesorectal excision really safe and better than laparoscopic total mesorectal excision with

a perineal approach first in patients with low rectal cancer? A learning curve with case-matched study in 68 patients. *Colorectal Dis*. 2018;20(6):O143-O151. doi:10.1111/codi.14238.
8. Law WI, Chu KW, Ho JW, Chan CW. Risk factors for anastomotic leakage after low anterior resection with total mesorectal excision. *Am J Surg*. 2000;179(2):92-96. doi:10.1016/S0002-9610(00)00252-X.
9. Law WL, Chu KW. Anterior resection for rectal cancer with mesorectal excision: a prospective evaluation of 622 patients. *Ann Surg*. 2004;240(2):260-268. doi:10.1097/01.sla.0000133185.23514.32.
10. Peeters KC, Tollenaar RA, Marijnen CA, et al. Risk factors for anastomotic failure after total mesorectal excision of rectal cancer. *Br J Surg*. 2005;92(2):211-216. doi:10.1002/bjs.4806.
11. Aubert M, Mege D, Panis Y. Total mesorectal excision for low and middle rectal cancer: laparoscopic versus transanal approach—a meta-analysis. *Surg Endosc*. 2020;34(9):3908-3919. doi:10.1007/s00464-019-07160-8.
12. Hajibandeh S, Hajibandeh S, Eltair M, et al. Meta-analysis of transanal total mesorectal excision versus laparoscopic total mesorectal excision in management of rectal cancer. *Int J Colorectal Dis*. 2020;35(4):575-593. doi:10.1007/s00384-020-03545-7.
13. Ose I, Perdawood SK. A nationwide comparison of short-term outcomes after transanal, open, laparoscopic, and robot-assisted total mesorectal excision. *Colorectal Dis*. 2021;23(10):2671-2680. doi:10.1111/codi.15809.
14. Peltrini R, Carannante F, Costa G, et al. Oncological outcomes of rectal cancer patients with anastomotic leakage: a multicenter case-control study. *Front Surg*. 2022;9:993650. doi:10.3389/fsurg.2022.993650.
15. Xu F, Li H, Guo C, et al. Incidence and risk factors of surgical complications and anastomotic leakage after transanal total mesorectal excision for middle and low rectal cancer. *J Gastrointest Surg*. 2023;27(2):373-381. doi:10.1007/s11605-022-05546-z.
16. Li Y, Hu G, Zhang J, et al. Nomogram for predicting the probability of rectal anastomotic re-leakage after stoma closure: a retrospective study. *BMC Cancer*. 2024;24(1):834. doi:10.1186/s12885-024-12544-8.
17. Cardelli S, Stocchi L, Merchea A, et al. Multiple robotic stapler firings to transect the rectum are not associated with anastomotic leakage. *Colorectal Dis*. 2025;27(5):e70094. doi:10.1111/codi.70094.
18. Kulu Y, Ulrich A, Bruckner T, et al. Validation of the International Study Group of Rectal Cancer definition and severity grading of anastomotic leakage. *Surgery*. 2013;153(6):753-761. doi:10.1016/j.surg.2013.02.007.
19. Mejía-Rivera S, Pérez-Marroquín SA, Cortés-González R, Medina-Franco H. Contrast-enhanced swallow study sensitivity for anastomotic leak detection in post-esophagectomy patients. *Rev Gastroenterol Mex* (Engl Ed). 2018;83(4):400-404. doi:10.1016/j.rgmx.2017.12.003.
20. Zarzavadjian Le Bian A, Denet C, Tabchouri N, et al. The effect of metabolic syndrome on postoperative outcomes following laparoscopic colectomy. *Tech Coloproctol*. 2018;22(3):215-221. doi:10.1007/s10151-018-1772-7.
21. Alizadeh RF, Li S, Inaba C, et al. Risk factors for gastrointestinal leak after bariatric surgery: MBASQIP analysis. *J Am Coll Surg*. 2018;227(1):135-141. doi:10.1016/j.jamcollsurg.2018.03.030.
22. Kihara S, Mori K, Akagi M. Electron microscopic observation of gastric mucosal capillaries in diabetics—relationship between diabetic micro-angiopathy and complications following gastrectomy. *Gastroenterol Jpn*. 1983;18:181-196. doi:10.1007/BF02774959.
23. Park J, Danielsen AK, Angenete E, et al. Quality of life in a randomized trial of early closure of temporary ileostomy after rectal resection for cancer (EASY trial). *Br J Surg*. 2018;105(3):244-251. doi:10.1002/bjs.10680.
24. Penna M, Hompes R, Arnold S, et al. Incidence and risk factors for anastomotic failure in 1594 patients treated by transanal total mesorectal excision: results from the International TaTME Registry. *Ann Surg*. 2019;269(4):700-711. doi:10.1097/sla.0000000000002653.
25. Gooszen JAH, Goense L, Gisbertz SS, Ruurda JP, van Hillegersberg R, van Berge Henegouwen MI. Intrathoracic versus cervical anastomosis and predictors of anastomotic leakage after oesophagectomy for cancer. *Br J Surg*. 2018;105(5):552-560. doi:10.1002/bjs.10728.
26. Yu F, Li Y, Yang J, Qian J, Li X, Liu C. Prenatal nicotine exposure results in the inhibition of baroreflex sensitivity induced by intravenous injection angiotensin II in the adult male offspring rats. *Cardiovasc Toxicol*. 2017;17(2):200-207. doi:10.1007/s12012-016-9375-x.
27. Verduin WM, Warps AK, van den Helder R, Doodeman HJ, Houdijk APJ. Visceral fat and anastomotic leakage after colon cancer resection. *Dis Colon Rectum*. 2021;64(2):163-170. doi:10.1097/dcr.0000000000001779.
28. Higgins P, Nemeth T, Bennani F, et al. The adequacy of lymph node clearance in colon cancer surgery performed in a non-specialist centre; implications for practice. *Ir J Med Sci*. 2020;189(1):75-81. doi:10.1007/s11845-019-02044-1.
29. Terzi C, Bingul M, Arslan NC, et al. Randomized controlled trial of 8 weeks' vs 12 weeks' interval between neoadjuvant chemoradiotherapy and surgery for locally advanced rectal cancer. *Colorectal Dis*. 2020;22(3):279-288. doi:10.1111/codi.14867.