

Article

# Evaluation of Key Risk Factors Associated with Postoperative Complications in Colorectal Cancer Surgery

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**Abstract:** Background: Colorectal surgery remains a cornerstone in the management of colorectal cancer, yet postoperative complications continue to impact surgical outcomes. This study investigates key risk factors influencing morbidity, focusing on patient comorbidities, tumor characteristics, surgical techniques, and anastomotic methods. Methods: A retrospective analysis was conducted on 195 patients who underwent colorectal cancer surgery between January 2021 and December 2024 at the Clinical Hospital of Nephrology “Carol Davila”. Variables analyzed included patient demographics, comorbidities, tumor staging, surgical approach, and postoperative complications. Statistical methods included chi-square tests and multivariate logistic regression (significance threshold:  $p < 0.05$ ). Results: The overall complication rate was 21%, with anastomotic leakage observed in 8.2% of cases. Significant risk factors for morbidity included cardiovascular disease ( $p = 0.001$ ), chronic respiratory failure ( $p = 0.003$ ), and chronic renal failure ( $p = 0.002$ ). Laparoscopic surgery had a lower complication rate (7.1%) than open surgery (28%) ( $p = 0.003$ ). Mechanical anastomosis showed lower complication rates than manual suturing ( $p = 0.009$ ). Left-sided resections were associated with higher morbidity than right-sided procedures ( $p = 0.013$ ). Conclusions: Optimizing colorectal surgery outcomes requires personalized perioperative strategies. Laparoscopic approaches and mechanical anastomosis significantly reduce complications. Further multicenter studies are needed to confirm these findings and enhance surgical guidelines.

**Keywords:** colorectal cancer; postoperative complications; surgical outcomes; colorectal surgery



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## 1. Introduction

Colorectal surgery remains a cornerstone in the management of malignant diseases of the digestive tract [1]. Despite significant advancements in surgical techniques, perioperative care, and oncological therapies, the incidence of postoperative complications continues to be a major concern, with rates reported at approximately 30% [2]. The complexity of colorectal procedures, particularly in oncologic patients, stems from the necessity to re-establish bowel continuity while navigating the challenges of contamination, ischemia, and inflammation. These factors contribute to the heightened risk of morbidity, prolonged hospitalization, and, in severe cases, reintervention [3].

Colorectal cancer, a leading cause of mortality worldwide, poses unique surgical challenges due to the malignancy itself and the physiological burden imposed by tumor growth [4]. According to recent WHO statistics, it ranks second in cancer-related deaths, following lung neoplasia. Surgical resection remains the primary curative approach, yet the presence of systemic inflammation, impaired immune responses, and preoperative treatments such as chemotherapy and radiotherapy complicate the recovery process [5–7].

CRC can develop through inherited genetic mutations (10%), familial clustering (20%), or, most commonly, through sporadic mutations (70%) [8]. The gut microbiota, a diverse ecosystem of microorganisms in the gastrointestinal tract, plays a crucial role in CRC development and prevention [9]. Emerging evidence suggests that an imbalance in gut microbiota, termed dysbiosis, is linked to CRC pathogenesis through mechanisms such as chronic inflammation, oxidative stress, and DNA damage [10,11]. Additionally, the gut microbiota significantly influences postoperative outcomes in colorectal surgery [12]. Patients with balanced intestinal flora demonstrated significantly reduced rates of postoperative complications, such as infections, anastomotic leaks, ileus, incision-site metastasis, and delayed diarrhea, compared to patients experiencing dysbiosis. Moreover, patients receiving optimized bowel preparation and probiotic supplementation had superior wound healing outcomes, improved quality-of-life indicators (such as higher KPS scores and BMI), and shorter recovery periods [13].

Nanotechnology has emerged as a promising approach for improving CRC treatment by enhancing drug delivery, reducing systemic toxicity, and overcoming resistance mechanisms [14]. Nanotechnology enhances postoperative care by improving wound healing and infection prevention. Silver nanoparticles in dressings exhibit strong antimicrobial properties, reducing infections and accelerating healing. Nanostructured hydrogels promote tissue regeneration while minimizing scarring. Nanosensors enable real-time infection detection and intervention. Nanoengineered hydrogels prevent adhesions, reducing complications after surgery. These advancements significantly improve surgical outcomes [15].

In the context of CRC, integrating palliative care early in the treatment process has been associated with extended survival, reduced treatment costs, decreased healthcare-resource utilization, and improved quality of life. For patients with advanced-stage CRC, particularly those with metastatic disease, palliative care plays a crucial role in managing symptoms such as pain, bowel obstruction, and nutritional issues, thereby enhancing patient comfort and well-being [16–18]. Moreover, studies have demonstrated that early integration of palliative care in metastatic CRC patients not only enhances quality of life but also aligns treatment strategies with patient goals, potentially reducing unnecessary interventions and hospitalizations. This holistic approach ensures that treatment decisions are patient-centered, considering individual preferences and values [16–18]. Incorporating palliative care into the management plan for CRC patients, especially those with advanced disease, is essential for providing comprehensive care that addresses both the physical and psychosocial aspects of the illness. Healthcare providers should discuss palliative care options with their patients early in the treatment process to ensure optimal quality-of-life outcomes [16–18].

The occurrence of postoperative complications is multifactorial, influenced by patient-related aspects such as comorbidities, nutritional status, and immunosuppression, as well as tumor-specific features including histopathology, vascularization, and local invasion [19,20]. The surgeon's expertise, intraoperative decision making, and technical precision further determine the overall outcome. Among the most concerning complications, anastomotic leakage represents a critical issue, often leading to peritoneal contamination, septic complications, and the need for additional surgical interventions [21,22]. Despite a meticulous technique, this remains one of the primary contributors to postoperative mortality [23].

Wound healing disorders are another frequent postoperative challenge, predisposing patients to infections, dehiscence, and the subsequent risk of incisional hernias. In addition, intraoperative and postoperative hemorrhage can lead to significant hemodynamic instability, necessitating transfusions and, in extreme cases, surgical revision [24].

Studies have highlighted the role of non-anemic iron deficiency as a potential perioperative risk factor, emphasizing the importance of iron metabolism in surgical recovery and immune function [25]. Additionally, emerging evidence suggests that cyclical and seasonal variations may impact postoperative outcomes, potentially due to fluctuations in hospital workload, environmental conditions, and immune responses [26]. Beyond physiological and biochemical factors, patient demographics and social determinants of health also play a crucial role in surgical recovery. Individuals with disabilities, for instance, face increased barriers to accessing quality surgical care, often leading to higher complication rates and longer hospital stays. These disparities highlight the need for tailored perioperative strategies to ensure equitable surgical outcomes for all patient populations [27]. Furthermore, the integration of minimally invasive techniques, such as laparoscopic and robotic-assisted surgery, has been associated with reduced surgical trauma and enhanced recovery pathways. Innovations in surgical technology, including fluorescence imaging and energy-based dissection tools, continue to refine colorectal cancer surgery, offering promising avenues for improving patient outcomes [28,29].

Beyond the first 30 days postsurgery, complications such as bowel dysfunction, anastomotic strictures, and chronic pain can significantly impair quality of life in the long term. The development of strictures following anastomotic healing often results in obstructive symptoms requiring further intervention. Furthermore, disturbances in bowel motility, particularly following low anterior resection, contribute to complications such as low anterior resection syndrome (LARS), which impacts sphincter function and bowel control [30,31]. The multifactorial nature of complications necessitates a comprehensive approach, incorporating precise surgical execution, rigorous patient selection, and tailored perioperative strategies. A thorough understanding of the risk factors influencing postoperative morbidity is essential for developing preventive measures and ensuring better long-term prognosis.

The objective of our study is to delineate risk factors associated with postoperative complications in colorectal cancer patients undergoing surgical treatment in our clinical setting, aiming to optimize preventive measures and improve long-term patient outcomes.

## 2. Methods

### 2.1. Study Design

We conducted a retrospective study between January 2021 and December 2024, analyzing a cohort of 195 patients diagnosed with colorectal cancer, who were admitted and treated in the Surgery Clinic of the Clinical Hospital of Nephrology Carol Davila Bucharest, Romania. Among them, 49 patients (25.1%) were diagnosed with stage IV disease, while the remaining 146 (74.9%) had stage I–III colorectal cancer, based on TNM classification.

All patients diagnosed with colorectal cancer were included in the study to provide a comprehensive evaluation of postoperative outcomes across a diverse patient population, regardless of disease stage or severity. This approach was chosen to reflect real-world clinical scenarios, where surgical candidates present with varying tumor burdens, comorbidities, and treatment histories. Including all cases, from early-stage to advanced-stage colorectal cancer, allows for a more holistic understanding of surgical risks and postoperative complications. To account for differences in disease severity, subgroup analyses were performed based on tumor staging (TNM classification), surgical approach (open vs. laparoscopic), and anastomotic technique (mechanical vs. manual). This stratification

ensured that variations in severity were systematically assessed, mitigating potential confounding effects while preserving the inclusivity of the study cohort. Several key factors were considered in assessing the impact of risk variables on surgical outcomes, including age, sex, and comorbidities such as cardiovascular disease, diabetes, and chronic kidney disease. Tumor characteristics, particularly anatomical location and morphopathology, were evaluated for their role in surgical complexity and postoperative risks. These factors directly influenced treatment planning and technical challenges during surgery. The type of surgical intervention, whether open or minimally invasive, was analyzed to compare postoperative recovery and complication rates. Additionally, digestive tract continuity was restored using various anastomotic techniques, including manual suturing, linear staplers, and circular staplers. Tumor staging, classified according to the TNM system, was also assessed to determine its association with postoperative complications.

All patients received mechanical bowel preparation and prophylactic antibiotics, except for 32 who required urgent surgical intervention due to obstructive, perforated, or hemorrhagic colorectal cancer. In these cases, immediate surgery was prioritized over preoperative bowel preparation to prevent further deterioration and minimize the risk of septic complications. Preoperative radiotherapy was administered for anorectal malignancies per clinical guidelines, and postoperative care followed standard colorectal surgery protocols.

By integrating these clinical, surgical, and oncological parameters, the study aimed to identify the primary determinants influencing postoperative morbidity and overall treatment success in colorectal cancer surgery.

## 2.2. Data Collection and Statistical Analysis

Patient data were retrospectively collected from medical records of 195 individuals. Statistical analysis included descriptive statistics, chi-square or Fisher's exact tests for categorical variables, and *t*-tests for continuous data. Multivariate logistic regression was applied to identify independent risk factors for postoperative complications. A *p*-value < 0.05 was considered statistically significant.

## 2.3. Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and all applicable ethical regulations. Patient confidentiality was strictly maintained, and all participants were fully informed of their right to withdraw from the study at any time without any adverse consequences. The study protocol and procedures were reviewed and approved by the Ethics Committee of the Clinical Hospital of Nephrology Carol Davila, Bucharest (Approval No. 18, issued on 17 February 2025).

## 3. Results

The mean age of patients who underwent colorectal cancer surgery was 66 years, with an age range spanning from 16 to 91 years. The average body mass index was 27, with a standard deviation of 6.0. The study population exhibited a predominance of male patients, with 119 men and 76 women, yielding a male-to-female ratio of 1.57:1. Furthermore, a substantial proportion of individuals, representing 58% of the cohort ( $n = 113$ ), had an ASA score of 3 or higher, reflecting the presence of significant systemic comorbidities that may impact perioperative risk and postoperative recovery.

Among the 195 patients included in the study, a significant proportion presented with pre-existing medical conditions that could potentially influence surgical outcomes and postoperative recovery. Cardiovascular diseases were the most prevalent comorbidities, affecting 117 patients (60%), with hypertension being the most common diagnosis. Other cardiovascular conditions, including atrial fibrillation, ischemic heart disease, valvular

heart disease, heart failure, and a history of myocardial infarction or stroke, were also frequently encountered. Chronic respiratory failure was documented in 31 patients (16%), further contributing to perioperative risk. Diabetes mellitus was identified in 10 patients (5.3%), a condition known to impair wound healing and increase susceptibility to infections. Additionally, chronic renal failure was present in 17 patients (8.7%), a factor that can complicate fluid balance and perioperative management. A history of malignancy other than colorectal cancer was reported in 16 patients (8.2%).

Another important aspect of our investigation focused on the surgical approach and anastomotic techniques utilized. Among the 195 patients included in the study, 70 underwent laparoscopic procedures, while 125 underwent open surgery, enabling a comparative evaluation of postoperative recovery and complication rates. Digestive tract continuity was re-established in 145 cases through different anastomotic methods, including manual suturing in 9 cases, linear staplers in 43 cases, and circular staplers in 93 cases.

Among the study population, 132 patients (67.7%) had low- to intermediate-grade tumors, while 63 patients (32.3%) presented with high-grade malignancies, indicating a significant proportion of aggressive tumor behavior. Tumor staging was also assessed, with 146 patients (74.9%) diagnosed at stages I–III, reflecting cases with localized or regionally advanced disease, while 49 patients (25.1%) had stage IV disease, characterized by distant metastases and a higher risk of postoperative complications (Table 1).

A total of 195 colorectal cancer surgeries were performed, encompassing a variety of procedures tailored to tumor location. Right hemicolectomy was conducted in 24 cases (12.3%), while left hemicolectomy was performed in 19 cases (9.7%). Sigmoid resections were carried out in 33 patients (16.9%), and rectosigmoid resections in 18 cases (9.2%). Anterior rectal resection was the most frequent procedure, performed in 39 patients (20.0%), followed by rectal extirpation in 16 cases (8.2%). Hartmann's procedure was utilized in 10 cases (5.1%), with subsequent reversal achieved in 9 patients (4.6%). Additionally, stoma confection was necessary for 15 patients (7.7%), and transverse colon resections were completed in 9 cases (4.6%). Other procedures were performed in three patients (1.5%) (Table 2).

Adenocarcinoma was the most frequently encountered histological subtype, being identified in 160 patients, representing 82.1% of the cases.

Among the 195 patients included in the study, postoperative complications were recorded in 41 cases (21%). Wound healing disorders were observed in 11 patients (5.6%), contributing to prolonged recovery and increased morbidity. Bleeding occurred in 11 cases (5.6%), presenting as 2 cases of subcutaneous hematoma, 5 cases of lower gastrointestinal bleeding, and 4 cases of hemoperitoneum. Anastomotic leaks were among the most concerning complications, affecting 16 patients (8.2%). Of these, 10 cases developed stercoral peritonitis, 2 cases led to entero-cutaneous fistulas, and 4 cases resulted in a low-flow anastomotic dehiscence. Evisceration was reported in three patients (1.5%), often requiring surgical intervention. Other complications accounted for six cases (3.1%), including two cases of uroperitoneum and three cases of intraperitoneal abscess formation (Table 3). The average period of hospitalization for the 195 patients was 21 days. For those who experienced postoperative complications, the hospital stay increased to an average of 33 days, representing 57% of cases.

The overall mortality rate was 11.7%, with 23 recorded deaths. Among these, six patients underwent surgical reinterventions for postoperative complications, leading to a 14% mortality rate among those who required additional procedures. Furthermore, four patients required multiple reinterventions due to recurrent postoperative complications, reflecting a complex clinical course that necessitated repeated surgical management.

**Table 1.** Clinicopathological Data.

Parameter	Total (n = 195)	Percentage (%)
Age (Mean ± SD)	66 ± 12 years	
Sex		
Male	119	61.0%
Female	76	39.0%
Comorbidities		
Cardiovascular Disease	117	60.0%
Chronic Respiratory Failure	31	16.0%
Chronic Renal Failure	17	8.7%
Diabetes Mellitus	10	5.3%
History of Other Malignancies	16	8.2%
Type of Cancer		
Adenocarcinoma	182	93.3%
Mucinous Adenocarcinoma	10	5.1%
Other Types	3	1.6%
Tumor Location		
Right Colon	33	16.9%
Left Colon	19	9.7%
Rectosigmoid	18	9.2%
Rectum	55	28.2%
Histological Grade		
Low–Intermediate	70	35.9%
High	125	64.1%
Anastomotic Technique		
Manual Suturing	9	4.6%
Linear Stapler	43	22.1%
Circular Stapler	93	47.7%

The statistical analysis revealed no significant correlation between patient age and the occurrence of postoperative complications. Despite an age range spanning from 36 to 90 years, there was no clear association between advanced age and increased morbidity. Conversely, the statistical analysis confirmed that tumor grade, disease stage, surgical approach, anastomotic technique, and tumor location significantly influenced postoperative outcomes. High-grade tumors were strongly associated with increased complication rates ( $p = 0.004$ ). Similarly, a significant correlation was observed between advanced-stage tumors and postoperative complications ( $p = 0.001$ ), highlighting the increased surgical risk in metastatic disease.

Comorbidities also played a crucial role, with cardiovascular disease ( $p = 0.001$ ), chronic respiratory failure ( $p = 0.003$ ), and chronic renal failure ( $p = 0.002$ ) significantly associated with higher complication rates. However, diabetes mellitus ( $p = 0.109$ ) and a history of other malignancies ( $p = 0.284$ ) were not found to be statistically significant risk factors.

**Table 2.** Surgical procedures.

Surgical Procedure	Number of Patients	Percentage (%)
Right Hemicolectomy	24	12.3
Left Hemicolectomy	19	9.7
Sigmoid Resection	33	16.9
Rectosigmoid Resection	18	9.2
Anterior Rectal Resection	39	20.0
Rectal Extirpation	16	8.2
Hartmann's Procedure	10	5.1
Stoma Confection	15	7.7
Hartmann's Reversal	9	4.6
Transverse Resection	9	4.6
Other Procedures	3	1.5

**Table 3.** Postoperative complications.

Complication	Cases ( <i>n</i> )	Percentage (%)
Total Postoperative Complications	41	21.0
Wound Healing Disorders	11	5.6
Bleeding	11	5.6
Subcutaneous Hematoma	2	1.0
Lower Gastrointestinal Bleeding	5	2.6
Hemoperitoneum	4	2.0
Anastomotic Leaks	16	8.2
Stercoral Peritonitis	10	5.1
Entero-Cutaneous Fistulas	2	1.0
Low-Flow Anastomotic Dehiscence	4	2.0
Evisceration	3	1.5
Other Complications	6	3.1
Uroperitoneum	2	1.0
Intraperitoneal Abscess	3	1.5

Surgical approach and technique had a major impact on complications. Laparoscopic procedures were linked to lower morbidity, with a complication rate of 7.1%, compared to 28% in open surgery ( $p = 0.003$ ). Similarly, mechanical anastomoses demonstrated a lower complication rate (10%) compared to manual suturing (42.1%) ( $p = 0.009$ ).

When analyzing surgical procedures based on tumor location, right-sided colon cancers (right hemicolectomy, transverse resection) demonstrated a lower overall complication rate compared to left-sided colorectal resections (left hemicolectomy, sigmoid resection, rectosigmoid resection, and anterior rectal resection), which are often more technically demanding. Statistical analysis confirmed that left-sided resections were significantly correlated with increased postoperative morbidity ( $p = 0.013$ ). The higher complication rate in left-sided colorectal surgeries is likely due to the complexity of the procedures and the increased risk of anastomotic leakage. Based on these findings, right-sided colon surgery appears to be more favorable in terms of postoperative outcomes, as it is associated



with a lower risk of complications compared to left-sided resections. This emphasizes the importance of individualized surgical planning, taking into account tumor location, disease stage, and patient-specific factors to minimize morbidity and improve recovery in colorectal cancer surgery (Table 4).

**Table 4.** Comparative analysis of factors influencing postoperative complications in colorectal cancer surgery.

Factor	Comparison Groups	Complication Rate	p-Value
Tumor Grade	Low–Intermediate vs. High	Higher in high-grade tumors.	0.004
Tumor Stage	Stage I–III vs. Stage IV	Higher in stage IV.	0.001
Comorbidities	Cardiovascular Disease	Patients with cardiovascular disease have a significantly higher risk of complications.	0.001
	Chronic Respiratory Failure	Chronic respiratory failure significantly increases perioperative risks.	0.003
	Chronic Renal Failure	Chronic kidney disease is significantly correlated with a higher complication rate.	0.002
	Diabetes Mellitus	No statistically significant association between diabetes and postoperative complications.	0.109
	History of Other Malignancies	No significant association between prior malignancies and complications.	0.284
Surgical Approach	Laparoscopic vs. Open	Laparoscopic surgery significantly reduces the complication rate compared to open surgery.	0.003
Anastomotic Technique	Mechanical vs. Manual	Mechanical anastomosis is associated with a significantly lower risk of complications than manual suturing.	0.009
Tumor Location	Right vs. Left Colon	Left-sided tumors have a significantly higher complication rate compared to right-sided tumors.	0.013

#### 4. Discussions

Colorectal cancer remains one of the most frequently diagnosed malignancies worldwide and a leading cause of cancer-related mortality. Despite advancements in surgical techniques, perioperative management, and oncological treatments, postoperative complications remain a significant concern [32]. Factors such as tumor biology, patient comorbidities, surgical approach, and anastomotic techniques influence patient outcomes and the



risk of morbidity [33]. Understanding these risk factors is essential for optimizing surgical strategies and improving postoperative recovery [34].

In our study cohort, patients with stage IV colorectal cancer exhibited a significantly higher complication rate (35.7%) compared to those with earlier-stage disease. This highlights the importance of integrating palliative care early in the treatment continuum for advanced-stage patients. Palliative care interventions, including pain management, nutritional support, and psychological counseling, play a critical role in addressing the complex challenges these patients face. Effective pain management improves comfort, sleep, mood, and overall well-being by reducing the burden of cancer-related pain. Moreover, early integration of palliative care in metastatic colorectal cancer has been shown to enhance quality of life, align treatment strategies with patient goals, and reduce unnecessary interventions and hospitalizations [35].

Our study identified high-grade tumors and stage IV disease as significant predictors of increased postoperative complications. Poorly differentiated tumors exhibited more aggressive behavior, leading to a higher risk of anastomotic failure, local recurrence, and overall surgical morbidity ( $p = 0.004$ ). Similarly, patients with stage IV disease had a significantly higher complication rate compared to those with earlier-stage tumors ( $p = 0.001$ ). These findings align with Gutlic et al. (2024), who reported anastomotic leakage (5.7%) and intra-abdominal infections (3.5%) as major concerns in colorectal cancer patients, particularly those with aggressive tumors [36]. Additionally, Tominaga et al. (2024) highlighted the role of tumor burden in increasing pulmonary complications, reinforcing the idea that advanced-stage disease significantly impacts postoperative morbidity and overall patient recovery [37]. These findings underscore the necessity for heightened perioperative vigilance and tailored management strategies for patients presenting with high-grade and advanced-stage colorectal cancers to mitigate the elevated risk of postoperative complications [38,39].

Patient comorbidities significantly influence postoperative outcomes in colorectal cancer surgery. Our study identified that cardiovascular disease ( $p = 0.001$ ), chronic respiratory failure ( $p = 0.003$ ), and chronic renal failure ( $p = 0.002$ ) were associated with higher complication rates, underscoring the increased perioperative risks posed by these conditions. These findings are consistent with existing literature [37,40]. For instance, some studies have demonstrated that pre-existing chronic kidney disease correlates with elevated rates of pulmonary infections and short-term mortality following colorectal cancer surgery [41,42]. Conversely, our analysis revealed that diabetes mellitus ( $p = 0.109$ ) and a history of other malignancies ( $p = 0.284$ ) did not show statistically significant associations with postoperative morbidity. However, it is important to note that other studies have reported differing results. Some studies indicate that diabetes mellitus is linked to a higher incidence of postoperative complications, including anastomotic leaks and increased readmission rates [43–45]. These discrepancies highlight the necessity for individualized patient assessment and management, considering the complex interplay of comorbidities and their potential impact on surgical outcomes.

The choice of surgical approach remains a key factor in colorectal cancer management. Laparoscopic surgery has been widely reported to offer advantages in terms of reduced postoperative pain, shorter hospital stays, and lower complication rates compared to open surgery [46,47]. Our findings support this, as patients who underwent laparoscopic procedures had a significantly lower complication rate (7.1%) compared to those who had open surgery (28%) ( $p = 0.003$ ). This aligns with Martín-Arévalo et al. (2025), who found that laparoscopic colorectal cancer surgery led to lower rates of anastomotic leakage and overall morbidity. However, their study also noted that institutional factors such as hospital workload fluctuations influenced surgical success rates, suggesting that timing and hospital capacity may indirectly affect postoperative outcomes [48]. These results reinforce the

increasing preference for minimally invasive techniques when feasible, particularly for tumors amenable to laparoscopic resection.

Anastomotic technique also influenced surgical outcomes, with mechanical anastomosis demonstrating a lower complication rate (10%) compared to manual suturing (42.1%) ( $p = 0.009$ ). This aligns with literature suggesting that stapled anastomoses provide more uniform tension distribution and improved healing, reducing the risk of anastomotic dehiscence [45,49]. Given that anastomotic leaks remain one of the most serious complications in colorectal surgery, the selection of a secure and reliable anastomotic technique is paramount in reducing morbidity [49,50].

Tumor location also played a role in postoperative outcomes. Right-sided colorectal surgeries were associated with a lower overall complication rate compared to left-sided resections, which demonstrated a significantly higher morbidity rate ( $p = 0.013$ ). This is consistent with existing data suggesting that left-sided resections, particularly those involving the rectum and sigmoid colon, present technical challenges that increase the risk of anastomotic failure and wound-related complications [51]. The increased bacterial load in the distal colon and the narrower luminal diameter further contribute to higher complication rates in left-sided resections [52]. These variations underscore the complexity of colorectal cancer and suggest that both tumor location and patient-specific factors must be carefully considered when planning surgical interventions to optimize outcomes.

Our study found that the average hospital stay was 21 days, increasing to 33 days for patients with complications, underscoring the burden of postoperative morbidity. The overall mortality rate was 11.7%, with 6 of the 23 total deaths occurring in patients who required surgical reinterventions, resulting in a 14% mortality rate among those with complications requiring further surgery. Additionally, four patients underwent multiple reinterventions due to recurrent postoperative complications, emphasizing the impact of severe morbidity on prolonged hospital stays and increased mortality risk. In comparison, a German multicenter study involving 4146 colorectal cancer patients reported an in-hospital mortality rate of 8.7%, with higher rates observed in older patients and those with significant comorbidities [53]. Another study analyzing 129,196 colonic cancer resections found an overall in-hospital mortality rate of 5.8%, with higher mortality associated with extended colonic resections and surgeries performed in low-volume hospitals [54].

These findings highlight the complex and multifactorial nature of postoperative complications in colorectal cancer surgery, emphasizing the necessity of individualized perioperative risk assessment. Optimizing preoperative patient selection, prioritizing minimally invasive surgical techniques when feasible, and adopting mechanical anastomoses can contribute to improved outcomes by reducing surgical trauma and enhancing recovery. Additionally, proactive postoperative monitoring remains critical, especially for patients with advanced disease, significant comorbidities, or complex left-sided resections, to minimize complications and improve overall survival.

## 5. Limitations of the Study

This study has several limitations that should be acknowledged. First, as a retrospective study, it is inherently subject to selection bias and information bias due to its reliance on pre-existing medical records. The accuracy and completeness of data depend on the documentation quality in patient charts, which may lead to missing or incomplete variables that could influence the interpretation of risk factors. Additionally, the retrospective design limits the ability to establish causal relationships between identified risk factors and postoperative outcomes.

Second, certain clinical variables that could further refine perioperative risk assessment were not available for all patients. For example, detailed nutritional status indicators,

inflammatory markers, and neoadjuvant treatment specifics were not consistently recorded, potentially affecting the assessment of prognostic factors. Moreover, variations in surgical technique, institutional practices, and perioperative care protocols across different settings may limit the generalizability of our findings.

Third, the study did not assess long-term oncological and functional outcomes, such as disease recurrence, quality of life, or bowel function postsurgery. This omission restricts the ability to evaluate the broader impact of postoperative complications beyond the immediate perioperative period. Future prospective, multicenter studies with extended follow-up periods would help validate these findings and provide more robust insights into both short- and long-term postoperative outcomes.

Despite these limitations, this study provides valuable real-world data on postoperative complications in colorectal cancer surgery. The findings reinforce the need for personalized perioperative risk stratification, optimized surgical decision making, and enhanced postoperative monitoring to improve patient outcomes.

## 6. Conclusions

This study highlights the multifactorial nature of postoperative complications in colorectal cancer surgery, emphasizing the impact of tumor stage, patient comorbidities, surgical approach, and anastomotic technique on patient outcomes. The findings demonstrate that high-grade tumors and advanced-stage disease are associated with an increased risk of complications, reinforcing the need for individualized perioperative strategies, particularly in high-risk patients. The lower morbidity rates observed with laparoscopic surgery support its increasing preference in colorectal cancer management, while the reduced anastomotic leakage rates associated with mechanical anastomoses further validate their role in optimizing surgical outcomes.

The prolonged hospital stay and increased mortality rate in our cohort, particularly among patients requiring surgical reinterventions, underscore the importance of early identification and management of postoperative complications. Compared to other studies, institutional factors, perioperative care variations, and differences in patient selection criteria may contribute to the observed discrepancies in outcomes, warranting further investigation. As a retrospective study, inherent limitations such as selection bias, missing clinical variables including nutritional status and inflammatory markers, and the lack of long-term oncologic and functional follow-up must be acknowledged.

Future research should focus on prospective multicenter studies incorporating standardized perioperative management protocols, enhanced recovery after surgery strategies, and long-term follow-up assessments of oncologic and functional outcomes. Further investigations into preoperative optimization, personalized risk stratification, and targeted postoperative monitoring may provide new insights to improve surgical outcomes and reduce postoperative morbidity and mortality.

Moreover, the integration of artificial intelligence and machine learning in colorectal cancer management presents promising advancements in both diagnosis and surgical decision making. AI-driven imaging and histopathological analysis can enhance early detection and staging accuracy, allowing for better risk stratification and treatment planning. Additionally, machine-learning-based predictive models can assist in identifying high-risk patients for postoperative complications, enabling personalized perioperative strategies. Future studies should explore the role of AI and machine learning in colorectal cancer surgery to develop data-driven, adaptive treatment protocols that optimize both short-term recovery and long-term survival.

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