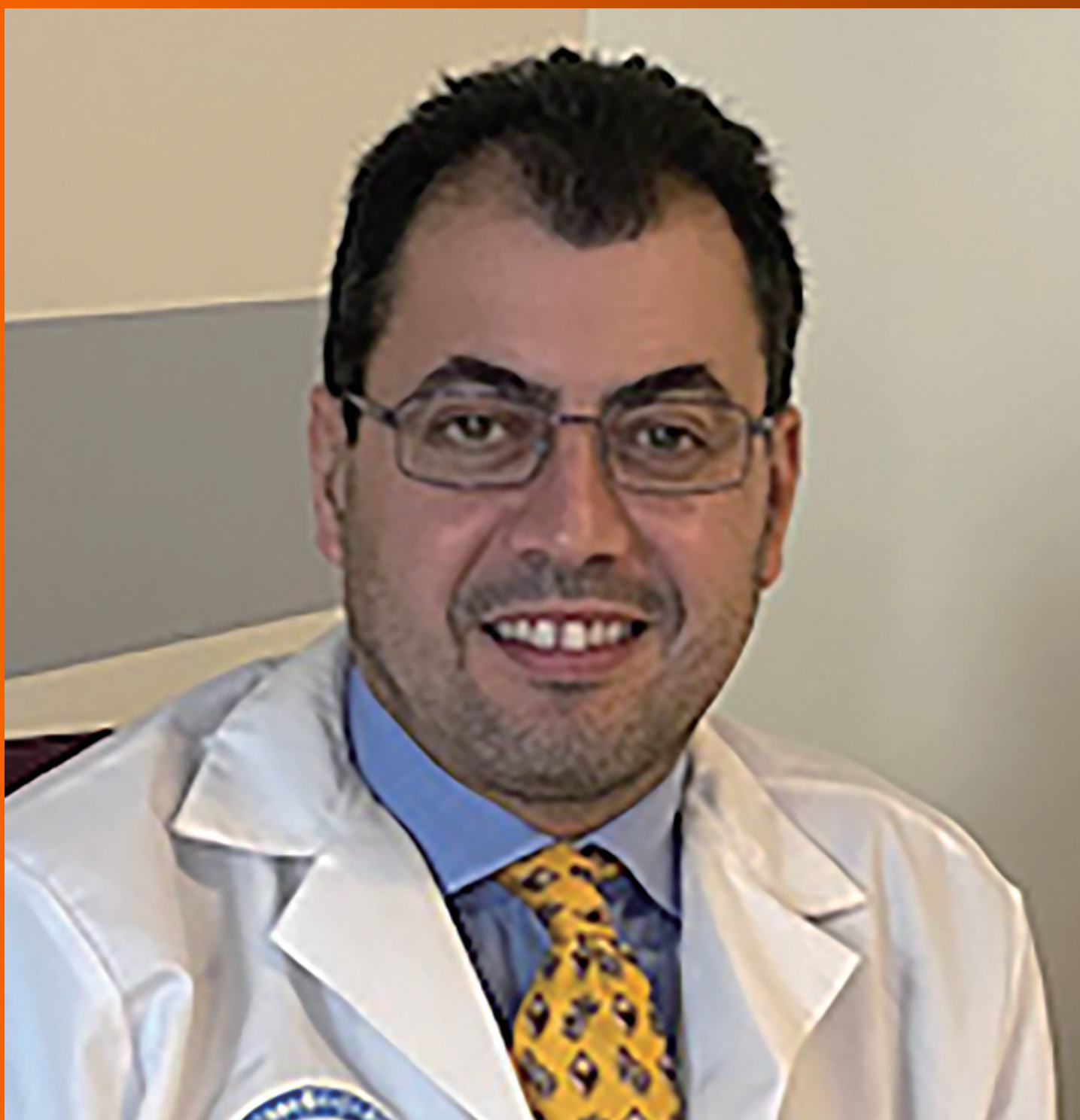


# World Journal of *Gastrointestinal Surgery*

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The primary aim of *World Journal of Gastrointestinal Surgery* (WJGS, *World J Gastrointest Surg*) is to provide scholars and readers from various fields of gastrointestinal surgery with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJGS mainly publishes articles reporting research results and findings obtained in the field of gastrointestinal surgery and covering a wide range of topics including biliary tract surgical procedures, biliopancreatic diversion, colectomy, esophagectomy, esophagostomy, pancreas transplantation, and pancreatectomy, etc.

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Retrospective Study

# Postoperative complications after robotic resection of colorectal cancer: An analysis based on 5-year experience at a large-scale center

Zhi-Xiang Huang, Zhen Zhou, Hao-Ran Shi, Tai-Yuan Li, Shan-Ping Ye

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**Author contributions:** Huang ZX and Ye SP wrote and revised the paper; Ye SP, Li TY designed and proofread the manuscript; Huang ZX, Ye SP, Zhou Z and Shi HR collected the data and conducted the analysis of pooled data.

**Institutional review board statement:** This study was reviewed and approved by the Ethics Committee of the First Affiliated Hospital of Nanchang University.

**Informed consent statement:** Patients were not required to give informed consent to the study because the analysis used anonymous data that were obtained after each patient agreed to treatment by written consent.

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## Abstract

### BACKGROUND

As a common gastrointestinal malignancy, colorectal cancer (CRC) poses a serious health threat globally. Robotic surgery is one of the future trends in surgical treatment of CRC. Robotic surgery has several technical advantages over laparoscopic surgery, including 3D visualization, elimination of the fulcrum effect, and better ergonomic positioning, which together lead to better surgical outcomes and faster recovery. However, analysis of independent factors of postoperative complications after robotic surgery is still insufficient.

### AIM

To analyze the incidence and risk factors for postoperative complications after robotic surgery in patients with CRC.

### METHODS

In total, 1040 patients who had undergone robotic surgical resection for CRC between May 2015 and May 2020 were analyzed retrospectively. Postoperative complications were categorized according to the Clavien-Dindo (C-D) classification, and possible risk factors were evaluated.

### RESULTS

Among 1040 patients who had undergone robotic surgery for CRC, the overall, severe, local, and systemic complication rates were 12.2%, 2.4%, 8.8%, and 3.5%, respectively. Multivariate analysis revealed that multiple organ resection ( $P < 0.001$ ) and level III American Society of Anesthesiologists (ASA) score ( $P = 0.006$ ) were independent risk factors for overall complications. Multivariate analysis



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identified multiple organ resection ( $P < 0.001$ ) and comorbidities ( $P = 0.029$ ) as independent risk factors for severe complications (C-D grade III or higher). Regarding local complications, multiple organ resection ( $P = 0.002$ ) and multiple bowel resection ( $P = 0.027$ ) were independent risk factors. Multiple organ resection ( $P < 0.001$ ) and level III ASA score ( $P = 0.007$ ) were independent risk factors for systemic complications. Additionally, sigmoid colectomy had a lower incidence of overall complications (6.4%;  $P = 0.006$ ) and local complications (4.7%;  $P = 0.028$ ) than other types of colorectal surgery.

## CONCLUSION

Multiple organ resection, level III ASA score, comorbidities, and multiple bowel resection were risk factors for postoperative complications, with multiple organ resection being the most likely.

**Key Words:** Colorectal neoplasms; Surgery; Robot; Complication; Postoperative; Classification; Retrospective studies

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**Core Tip:** This retrospective study of 1040 cases was performed to analyze the incidence and risk factors for postoperative complications after robotic colorectal cancer surgery. The postoperative complications were defined into four types: Overall, severe, local, and systemic complications, and their rates were 12.2%, 2.4%, 8.8%, and 3.5%, respectively. Their independent risk factors were as follows: (1) Overall complications: Multiple organ resection and a level III American Society of Anesthesiologists (ASA) score; (2) Severe complications: Multiple organ resection and comorbidities; (3) Local complications: Multiple organ resection and multiple bowel resection; and (4) Systemic complications: Multiple organ resection and a level III ASA score.

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## INTRODUCTION

As a common malignant tumor of the digestive tract, colorectal cancer (CRC) poses a serious health threat globally. According to the global tumor epidemiology statistics[1, 2] released in 2020 by the International Agency for Research on Cancer of the World Health Organization, approximately 1931600 new cases of CRC and 935200 deaths occurred worldwide in 2020. The incidence and mortality of CRC are ranked third and second among all malignant tumors, respectively[3,4]. Overall, compared with the trend of stabilization or decline in developed countries, the incidence and mortality of CRC in developing countries have been rising slowly in recent years[5,6]. China accounts for 31% of the total number of patients with CRC globally, and 83% of patients in China are at an advanced stage when first diagnosed[1,7].

Surgical resection is the cornerstone of radical intent treatment[3]. Ensuring surgical operation quality is crucial because it is directly related to the patient's survival and quality of life. With the emergence and development of laparoscopy and robotics, minimally invasive surgery (MIS) for CRC can substitute for conventional open surgery with similar or better perioperative and oncologic outcomes[8-10]. However, during laparoscopic surgery, surgeons are faced with challenging conditions, such as a narrow pelvic cavity, anatomical complexity, and restricted surgical view[11]. The da Vinci surgical system, which has several technical advantages, including 3D visualization, elimination of the fulcrum effect, and better ergonomic positioning, overcomes these limitations and is very likely leading to better surgical outcomes and faster recovery than laparoscopic surgery[12,13]. However, because of the lack of high-

quality randomized controlled studies, analysis of independent factors of postoperative complications after robotic surgery is still insufficient[14,15].

Considering the limitations of previous studies and lack of large-scale studies, we analyzed retrospectively more than 1040 cases of short-term postoperative complications after robotic surgery for CRC to assess related risk factors.

## MATERIALS AND METHODS

### *Study population and data collection*

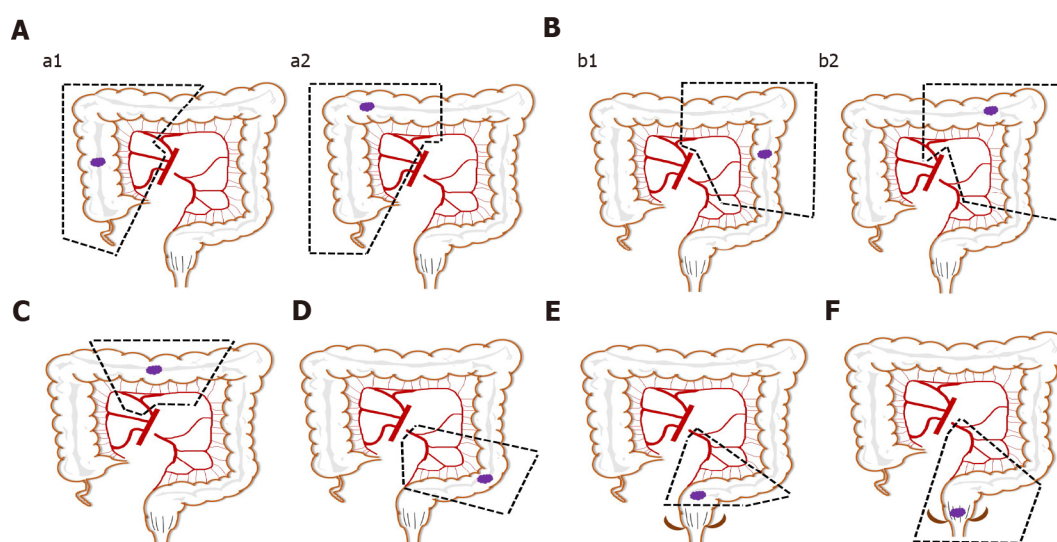
In this retrospective clinical study, we gathered and analyzed the information of 1302 patients who underwent robotic surgery for CRC between May 2015 and May 2020 at the First Affiliated Hospital of Nanchang University, a large-scale center. The inclusion criteria were as follows: (1) Age older than 18 and younger than 80 years; (2) Primary colonic adenocarcinoma confirmed pathologically by endoscopic biopsy; (3) Pathological T1-4N0-2M0 (T: Primary tumor, T1-T4; N: Regional lymph nodes, N0-N2; M: Distant metastasis, M0) at postoperative evaluation according to the 8<sup>th</sup> American Joint Committee on Cancer Cancer Staging Manual[16]; (4) A performance status of 0 or 1 on the Eastern Cooperative Oncology Group scale; (5) American Society of Anesthesiologists (ASA) score I, II, or III; and (6) Written informed consent. The exclusion criteria were as follows: (1) Pregnancy or breastfeeding; (2) Palliative surgery; (3) Emergency surgery due to a complication (bleeding, obstruction, or perforation) caused by CRC; (4) Previous neoadjuvant chemotherapy or radiotherapy; or (5) Recurrence surgery.

Patients who met the diagnostic criteria of related diseases were all subjected to routine preoperative chest X-ray, abdominal ultrasound, tumor markers, abdominal computed tomography, colonoscopy, magnetic resonance imaging, and other examinations to improve the evaluation of the patient's staging and condition. All the patients' medical records were extracted from the prospectively maintained database at the Department of Gastrointestinal Surgery of the First Affiliated Hospital of Nanchang University. This study was approved by the Ethics Committee of the First Affiliated Hospital of Nanchang University.

### *Surgical treatment*

For information regarding surgical principles and procedures, the Chinese expert consensus on robotic surgery for CRC[15] should be referenced. In all cases, the surgical approach was to remove the colon and mesocolon of adjacent organs within the range of resection, cut the tumor-bearing segment, and ligate the origin of the aorta to maximize lymph node dissection (LND) without damaging the visceral fascia layer. The surgeon attempted to secure 10 cm or more for the proximal and distal resection margins (over 5 cm distal margin for rectosigmoid lesions). For colon resection and rectal resection, we followed D3 LND (D3) + complete mesocolic excision principles [17-19] and total mesorectal excision (TME) principles[20-22], respectively.

Different surgical methods were applied to tumors in different areas of invasion, and they have different characteristics (Figure 1). Right hemicolectomy or extended right hemicolectomy cases were included in group A (right colon resection). LND was performed along the superior mesenteric pedicle, including its front side, with high ligation of the ileocolic vessels, middle colic vessels (for hepatic flexure and proximal transverse colon lesion), or right branch of the middle colic vessels (for lesions proximal to hepatic flexure colon). Left hemicolectomy or extended left hemicolectomy cases were included in group B (left colon resection). LND was performed on the origin site of the middle colic vessels (left branch of the middle colic vessels for left hemicolectomy) and the origin site of the left colic artery for complete removal of the mesocolon. Full splenic flexure mobilization was also required for all patients in these cases. For transverse colectomy (group C), LND was only performed on the origin site of the middle colic vessels, and the gastroepiploic vessels were only meticulously dissected, instead of routinely ligated. Sigmoid colectomy (group D) cases required LND only around the inferior mesenteric artery (IMA). The surgical treatment of rectal cancer mainly included low anterior resection (LAR) of rectal cancer (group E) and abdominoperineal resection (group F). Although the scope of resection is different, the scope of LND involves the origin site of IMA. All of the above procedures only involve resection of one bowel segment of the primary tumor, hereinafter referred to as single bowel resection. When at least two primary tumor lesions invaded different parts of the intestine, multiple bowel resection (group G), simultaneous resections of multiple bowel segments of primary tumors, or even (sub-) total colectomy was applied.



**Figure 1** Illustrations describing specific procedures in the lymph node dissection area of six groups. A: Right colon resection; a1: Right hemicolectomy; a2: Extended right hemicolectomy; B: Left colon resection; b1: Left hemicolectomy; b2: Extended left hemicolectomy; C: Transverse colectomy; D: Sigmoid colectomy; E: Low anterior resection; F: Abdominoperineal resection.

Multiple organ resection was performed in cases with peripheral organ tumor invasion or organ diseases requiring surgery.

In our center, there are two types of robotic surgery for CRC: Totally robotic surgery and robot-assisted surgery. Totally robotic surgery uses robotic arms to complete the process of naked intestine, anastomosis, cutting, reinforcement, and removal in the abdominal cavity under the field of endoscopy. Robot-assisted surgery is used to pull out the intestine segment from an additional auxiliary incision after dissection and nakedness by robotic arms in the abdominal cavity, and to complete the process of anastomosis, cutting and reinforcing under direct vision. Surgical procedures for totally robotic CRC resection or robotic-assisted resection have been previously described in detail[6,23]. All robotic surgery procedures were performed by surgeons experienced in laparoscopic surgery for CRC.

### Observation and evaluation parameters

The patients' general demographics data were as follows: Age, sex, body mass index (BMI), history of abdominal surgery, smoking and drinking history, comorbidity (*e.g.*, diabetes, cardiopathy, hypertension, and other basic diseases). The surgical parameters of the patients were as follows: ASA-class, operation time, intraoperative evaluated blood loss, types of colorectal surgery (*e.g.*, right resection, left resection, sigmoid colectomy, rectal resection and multiple bowel resection), types of robotic surgery (*e.g.*, totally robotic or robotic-assisted), number of retrieved lymph nodes, multiple organ resection (cases with peripheral organs tumor invasion or organ diseases requiring surgery), operation number per year. The pathology parameters were as follows: Diameter of the neoplasm, histological type, pathological tumor, node and metastasis (TNM) stage, number of metastatic lymph nodes, lymphovascular invasion, resection margin. The postoperative complications were recorded using the Clavien-Dindo (C-D) classification and divided into local and systemic complications[24,25].

The primary outcomes of the study were postoperative complications. When complications were associated with surgical techniques near the field of operation, such as wounds or anastomosis, they were considered local complications. Complications were classified as systemic when they were not associated with the field of operation, such as pulmonary or hepatic complications. We reviewed morbidity and mortality that occurred during hospitalization after surgery.

### Statistical analysis

All statistical analyses were performed using SPSS, ver.26.0 (IBM Corp., Armonk, NY, United States). Categorical variables were presented as counts and percentages. Normally distributed continuous variables were expressed as mean  $\pm$  SD. Variables with *P* values less than 0.05 in univariate analysis were included in the multivariate analysis. Multivariate analysis was conducted using the logistic regression model to identify independent risk factors for postoperative complications. *P* values less than



0.05 were considered statistically significant.

## RESULTS

### *Patients and surgical outcomes*

**Table 1** shows the patient demographics, baseline pathologic characteristics and perioperative outcomes. Of the 1040 patients, 133 had a history of abdominal surgery, and 239 had other comorbidities, such as diabetes, hypertension, and heart disease. Regarding operative parameters, approximately 12.4% of surgical patients were rated as class III by anesthesiologists using the ASA classification standard. The mean operation time and evaluated blood loss were  $173.6 \pm 51.1$  min and  $108.4 \pm 87.3$  mL, respectively. In total, 235 right colon resections, 88 left colon resections, 11 transverse colectomies, 234 sigmoid colectomies, 369 LARs, and 79 abdominoperineal resections were performed. Multiple bowel resection was applied to 24 cases (2.3%) with multiple cancer foci inside the intestinal tube. The number of totally robotic (507 cases) and robotic-assisted (533 cases) surgeries performed was similar. Thirty-six cases (3.5%) involved multiple organ resection, including seven cases with partial small bowel enterectomy, six cases of oophorocystectomy, four cases of cholecystectomy, three cases of cystectomy, three cases of gastrectomy, three cases of hysterectomy, two cases of pneumonectomy, two cases of adnexectomy, two cases of splenectomy, two cases of nephrectomy, one case of partial hepatectomy, and one case of appendectomy.

Regarding the in-hospital outcomes, the overall complication rate was 12.2%, the severe complication rate was 2.4%, and the mortality rate was 0.4%.

### *Postoperative complications*

The local and systemic complications classified by C-D are shown in **Table 2**. The incidence of local complication was 8.8%, among which anastomotic leakage was the most common, followed by wound problems, intra-abdominal infection, and effusion. Three cases of anastomosis leakage and one case of intra-abdominal bleeding required reoperation under intravenous or inhalation anesthesia. The systemic complication rate was 3.5%, among which hematologic complications were the most common, with severe anemia (13 cases) accounting for the majority, followed by coagulation abnormalities (2 cases). Four patients died after surgery: Three from severe infection leading to shock and one from severe pneumonia resulting in respiratory failure.

Overall complication rates among the five different age groups were similar ( $P = 0.766$ ), as well as when broken down for minor ( $P = 0.750$ ), severe ( $P = 0.091$ ), local ( $P = 0.847$ ), and systemic ( $P = 0.066$ ) complications (**Figure 2**). Considering the trend of the broken line in **Figure 2**, the severe and systemic complication rates generally increased with age, and significant differences were found between the group aged older than 70 years and the other age groups (**Supplementary Table 1**). Postoperative complication rates in subgroups of CRC surgery approaches are outlined in **Figure 3**. The differences in the complication rates were significant among the seven types of colorectal surgery, including the overall ( $P = 0.006 < 0.10$ ) and local ( $P = 0.031 < 0.10$ ) complication rates. These differences may be caused by sigmoid colectomy ( $P = 0.002$  for overall complications and  $P = 0.013$  for local complications) or multiple bowel resection ( $P = 0.020$  for overall complications and  $P = 0.013$  for local complications) (**Supplementary Table 2**). Therefore, in multivariate analysis, we divided the types of colorectal surgery into three categories for comparison – multiple bowel resection, sigmoid colectomy and the other surgery types.

### *Risk factors for complications*

Univariate analyses for overall and severe complications are demonstrated in **Supplementary Table 3**. Multivariate analysis revealed that multiple organ resection ( $P < 0.001$ ) and a level III ASA score ( $P = 0.006$ ) were independent risk factors for overall complications, and multiple organ resection ( $P < 0.001$ ) and comorbidities ( $P = 0.029$ ) were independent risk factors for severe complications (C-D grade III or higher) (**Supplementary Table 4**).

Univariate analyses for local and systemic complications are outlined in **Supplementary Table 5**. For local complications, multiple organ resection ( $P = 0.002$ ) and multiple bowel resection ( $P = 0.027$ ) were identified as independent risk factors. Multiple organ resection ( $P < 0.001$ ) and a level III ASA score ( $P = 0.007$ ) were identified as independent risk factors for systemic complications. Additionally, sigmoid colectomy was identified as an independent protective factor for overall ( $P = 0.006$ ) and local ( $P = 0.028$ ) complications (**Supplementary Table 6**).

**Table 1** Baseline clinicopathologic characteristics and surgical outcomes

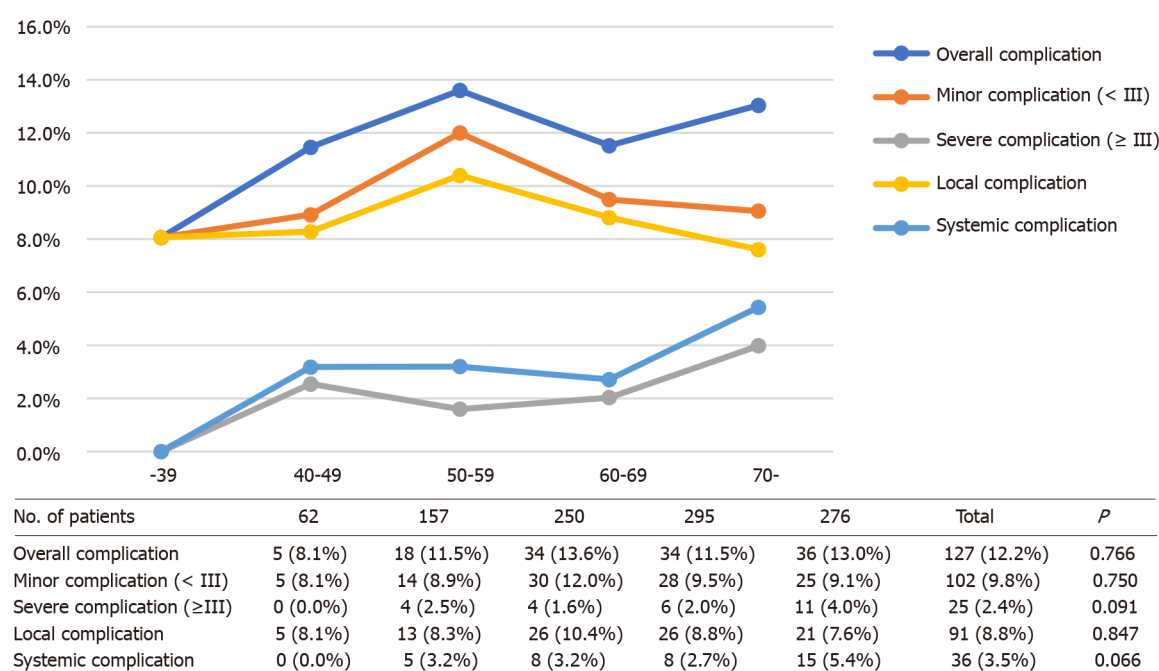
Variables	Total (n = 1040)
Patient demographics	
Age (yr)	60.4 ± 12.4
Sex (male/female)	611/429
BMI (kg/m <sup>2</sup> )	22.5 ± 3.2
With previous abdominal surgery, no. (%)	133 (12.8)
Smoking and drinking history, no. (%)	426 (41.0)
Comorbidity, no. (no/one or more)	239 (23.0%)
Operative parameters	
ASA class, no. (I/II/III)	593/518/129
Operation time (min)	173.6 ± 51.1
Evaluated blood loss (mL)	108.4 ± 87.3
Types of colorectal surgery, no. (right-/left-/transverse-/sigmoid-/LAR/abdominoperineal-/multiple-)	235/88/11/234/369/79/24
Types of robotic surgery, no. (totally robotic/robotic-assisted)	507/533
No. lymph nodes retrieved	17.8 ± 7.5
Multiple organ resection, no. (%)	36(3.5)
Operation number, no. (yr)	
2015/5-2016/5	226 (21.7%)
2016/5-2017/5	226 (21.7%)
2017/5-2018/5	259 (24.9%)
2018/5-2019/5	280 (26.9%)
2019/5-2020/5	311 (29.9%)
Pathology results	
Neoplasm longest diameter, cm	4.5 ± 2.3
Histological type, no. (well or moderately/poorly or undifferentiated)	947/93
pT stage, no. (T1/T2/T3/T4)	107/126/218/589
pN stage, no. (0/1/2)	659/252/129
pTNM stage, no. (I/II/III)	197/462/381
With lymph node metastasis, no. (%)	381 (36.6)
With lymphovascular invasion, no. (%)	423 (40.7)
With positive resection margin, no. (%)	8 (0.8)
In-hospital outcomes	
Time to 1 <sup>st</sup> bowel movement, h	25.4 ± 6.3
Time to 1 <sup>st</sup> first flatus, h	58.6 ± 8.9
Time to 1 <sup>st</sup> liquid diet, h	71.5 ± 9.3
Overall complications, no. (%)	127 (12.2)
Complications, no. (II/III/IV/V)	20/82/15/6/4
Severe complication, no. (C-D grade ≥ III, %)	25 (2.4)
Local complications, no. (%)	91 (8.8)
Systemic complication, no. (%)	36 (3.5)
Mortality, no. (%)	4 (0.4)

Postoperative hospital stay of all patients (d)	7.4 ± 2.3
Postoperative hospital stay of patients without complications (d)	6.5 ± 1.1
Postoperative hospital stay of patients with complications (d)	14.1 ± 5.2

BMI: Body mass index; ASA: American Society of Anesthesiologists; right-, Right colon resection; left-, Left colon resection; transverse-, Transverse colectomy; sigmoid-, Sigmoid colectomy; LAR: Low anterior resection; abdominoperineal-, Abdominoperineal resection; multiple-, Multiple bowel resection; C-D grade: Clavien-Dindo grade; T: Primary tumor; N: Regional lymph nodes; M: Distant metastasis.

**Table 2 Local and systemic complications clarified by Clavien-Dindo classification**

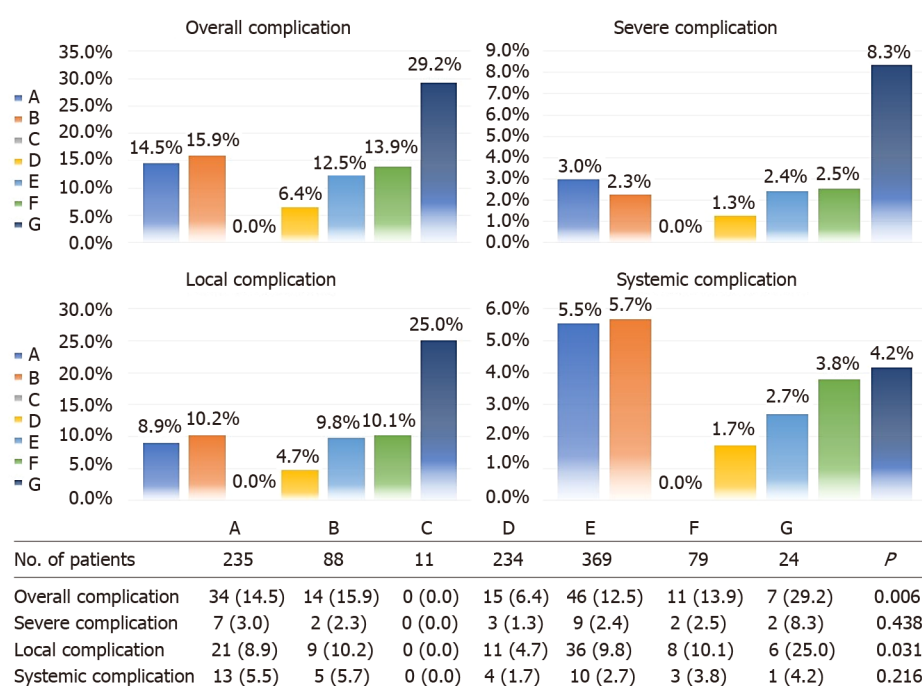
Local complication	Total n (%)	Grade ≥ III	Systemic complication	Total n (%)	Grade ≥ III
Wound problem	14 (1.3)	0 (0.0)	Pulmonary	9 (0.9)	2 (0.2)
Anastomosis leakage	43 (4.1)	9 (0.9)	Hepatic	0 (0.0)	0 (0.0)
Intra-abdominal infection and effusion	12 (1.2)	3 (0.3)	Cardiovascular	2 (0.2)	1 (0.1)
Intra-abdominal bleeding	2 (0.2)	1 (0.1)	Urinary	2 (0.2)	0 (0.0)
Anastomosis bleeding	3 (0.3)	0 (0.0)	Central nervous	2 (0.2)	2 (0.2)
Ileus/motility disorder	9 (0.9)	2 (0.2)	Hematologic	15 (1.4)	0 (0.0)
Infection of presacral space	4 (0.4)	0 (0.0)	Infection	6 (0.6)	5 (0.5)
Others	4 (0.4)	0 (0.0)	Endocrine	0 (0.0)	0 (0.0)



**Figure 2 Postoperative complication rates in different age groups.**

## DISCUSSION

For CRC, MIS is now increasingly accepted and applied. Many clinical trials have shown that short-term outcomes after robotic surgery for CRC are better than those after laparoscopic surgery[26-29]. Robotic surgery is considered more accurate and reliable, reducing trauma and improving the quality of life while ensuring radical resection of the tumor[30,31]. However, the Jayne *et al*[14]'s study, a multicenter randomized clinical trial, found that robotic surgery performed by surgeons with varying robotic experience did not provide clinically important benefits over conventional laparoscopic surgery in the short term. In our study, which only included



**Figure 3** Postoperative complication rates in subgroups of colorectal cancer surgery approaches. A: Right colon resection; B: Left colon resection; C: Transverse colectomy; D: Sigmoid colectomy; E: Low anterior resection; F: Abdominoperineal resection; G: Multiple bowel resection.

patients with malignant disease who had undergone robotic surgery at a single institution, the quality of the surgical procedures was consistently high and the data were sufficiently reliable. Additionally, chief surgeons had completed an initial phase of more than 30 cases[32] before 2015 and could master operations proficiently. Comparing the above two studies, we found that some in-hospital outcomes were numerically superior in our study, such as the mean length of stay (7.3 d *vs* 8.0 d), overall complications (12.2% *vs* 33.1%), and incidence of anastomotic fistula (4.1% *vs* 12.2%). Regarding the huge gap between the two studies, potential reasons may be responsible, such as the limited case volume and inadequate surgical experience that may compromise the quality of surgery[33,34]. A retrospective study[35] of robot-assisted colorectal surgery with the largest sample size worldwide verified the safety and efficacy of robotic techniques and confirmed its clinical advantages, particularly in reducing anastomotic fistulas. The short-term outcomes of our study, a low incidence of anastomoses (approximately 4%), and a short recovery time, were similar to those of this retrospective study except for mortality (0.1%, 6/5389 cases *vs* 0.4%, 4/1040 cases) and morbidity (9%, 487/5389 cases *vs* 12.2%, 127/1040 cases). Analysis of its data found that the incidence of complications that are C-D III or above accounted for 2.4% (129/5389 cases *vs* 25/1040 cases, 2.4%) in all patients. Among patients with CRC suitable for curative resection, compared with conventional laparoscopic surgery, the robotic procedure performed at an experienced medical unit resulted in more favorable clinical outcomes[14,35].

Many researchers have begun to analyze the different significant factors associated with complications after colorectal surgery. Manilich *et al*[33] examined the records of 3552 patients who had undergone colorectal surgery and concluded that BMI, operative time, and chief surgeon were the three most important factors influencing the re-admission rates, rates of transfusions, and surgical site infection. Kirchhoff *et al* [36] found that, of the 20 general background factors analyzed, the following 5 were significant factors for complications following laparoscopic colorectal procedures as an initial report: The surgeon's level of experience, patient age, patient sex, ASA class, and neoplasia. The real world data of 1145 consecutive cases in China[37] revealed that male sex, tumors located in the mid-low rectum, combined organ resection, and clinical T category (cT3-4) were independent risk factors for robotic surgical complications.

In the present study, 21 general background variables were analyzed by univariate analysis, among which 5 were identified as significant factors: Age, comorbidity, ASA class, type of colorectal surgery, and multiple organ resection. Finally, age was excluded from the multivariate analysis of risk factors for all complications. Generally, elderly patients are considered a high-risk population for major abdominal surgery

because of reduced functional reserve and increased comorbidities[38,39]. Some studies[40-43] have confirmed that aging is an independent risk factor for postoperative complications. Additionally, systemic complications are related to the increase in preoperative adverse conditions and comorbidities. We found that only severe and systemic complication rates increased mildly with age. Additionally, postoperative complications in elderly patients (age  $\geq 70$ ) tend to be more severe than those in nonelderly patients. Therefore, during preoperative assessment and postoperative management, medical personnel must focus more on patients aged 70 years and older. The incidence and severity of postoperative complications among elderly patients who had undergone robotic surgery were similar to those who had undergone laparoscopic surgery[44-46].

In our study, multiple organ resection was considered to be a primary independent risk factor for overall, severe, local, and systemic complications after robotic surgery. Chang *et al*[37] reported that combined organ resection was confirmed as an independent risk factor for surgical complications and significantly increased the risk of anastomotic fistula. The conclusions of other studies[47,48] were similar. The complex procedure of intraperitoneal surgery not only poses a challenge to the surgeon but is also a potential risk factor for postoperative complications. Additionally, the complexity of multiple bowel resection makes it an independent risk factor for overall and local complications. Xu *et al*[35] explained that the postoperative complication rate was 8.6% (434/5063 cases) for patients with only primary resection and 16.3% (53/326 cases) for patients with multiple resections. Different types of surgery caused by different tumor locations have different risk degrees for different complications. In a multivariate analysis, we selected sigmoid colectomy as a covariate to further analyze the role of sigmoid colectomy in complications. As expected, sigmoid colectomy was a protective factor for overall and local complications because of clear anatomy and simple operation. Proctectomy was a risk factor for ureteral injuries, but transverse colectomy and right colectomy were protective factors[49]. Therefore, we should focus on different types of complications after different surgeries.

This study has several limitations. First, this retrospective study involved only one single center where experienced surgeons operated on patients. This would limit the promotion to the population of physicians with less experience in robotic resection. Second, this study excluded patients with neoadjuvant therapy, which would limit the universality of our research results. Additionally, selection bias might influence the results, and the follow-up period was relatively short. Thus, the factors identified in this study require confirmation in future research.

## CONCLUSION

The present study demonstrated, in detail, the postoperative complications of robotic surgery treating patients with CRC and identified several independent and significant predictors of the complication rate after robotic CRC surgery. Among them, multiple organ resection was the greatest independent risk factor for complications. We recommend that complex surgical procedures are best performed by experienced surgeons. Additionally, patients' comorbidities should be improved preoperatively, and more attention should be given to follow-up to prevent postoperative complications related to different surgical types.

## ARTICLE HIGHLIGHTS

### Research background

As a common malignant tumor of the digestive tract, colorectal cancer (CRC) poses a serious health threat globally. Robotic surgery for the treatment of CRC is one of the future trends in surgical treatment. With several technical advantages of 3D visualization, elimination of the fulcrum effect, and better ergonomic positioning, the da Vinci surgical system is better than laparoscope and these technical benefits lead to better surgical outcomes and faster recovery. However, it is impossible to accurately explain which factors will affect the complications of robotic surgery because of the lack of high-quality randomized controlled studies.



**Research motivation**

To provide new ideas and directions for reducing complications, through the analysis of incidence and risk factors for postoperative complications after robotic surgery in patients with CRC.

**Research objectives**

To analyze the incidence and risk factors for postoperative complications after robotic surgery in patients with CRC.

**Research methods**

In total, 1040 patients who had undergone robotic surgical resection for CRC between May 2015 and May 2020 were analyzed retrospectively. Postoperative complications were classified as minor complications, severe complications, local complications, and systemic complications, and their possible risk factors were assessed. Variables that were statistically significant ( $P < 0.05$ ) in univariate analysis were included in multivariate analysis. To identify independent risk factors for postoperative complications, the logistic regression model was used in multivariate analysis.

**Research results**

Among 1040 patients who had undergone robotic surgery for CRC, the overall, severe, local, and systemic complication rates were 12.2%, 2.4%, 8.8%, and 3.5%, respectively. Multivariate analysis revealed that multiple organ resection ( $P < 0.001$ ) and a level III American Society of Anesthesiologists (ASA) score ( $P = 0.006$ ) were independent risk factors for overall complications. Multivariate analysis identified multiple organ resection ( $P < 0.001$ ) and comorbidities ( $P = 0.029$ ) as independent risk factors for severe complications (Clavien-Dindo grade III or higher). Regarding local complications, multiple organ resection ( $P = 0.002$ ) and multiple bowel resection ( $P = 0.027$ ) were identified as independent risk factors. Multiple organ resection ( $P < 0.001$ ) and a level III ASA score ( $P = 0.007$ ) were identified as independent risk factors for systemic complications. Additionally, sigmoid colectomy had a lower incidence of overall complications (6.4%;  $P = 0.006$ ) and local complications (4.7%;  $P = 0.028$ ) than other types of colorectal surgery.

**Research conclusions**

The present study demonstrated, in detail, the postoperative complications of robotic procedure to treating patients with CRC, and identified several factors that were independent and significant predictors of the complication rate after robotic CRC surgery. Among them, multiple organ resection was the greatest independent risk factor for complications.

**Research perspectives**

The development of robotic surgery is unstoppable, and the application of robotic surgery to CRC will become more and more widespread. Therefore, research on the risk factors of complications is essential. It will not only provide the possibility to reduce complications in the future but also promote the development of robotic surgery.

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