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Robotic right colectomy versus laparoscopic right colectomy in patients with right colon cancer: a comparative study

Engeng Chen[1], Wei Zhang[1] and Li Chen[1*]

Abstract

Background The study aimed to compare the clinical outcomes of robotic right colectomy (RRC) versus laparoscopic right colectomy (LRC) in patients diagnosed with right colon cancer, given the increasing adoption of robotic surgical techniques and their potential benefits in oncologic surgery.

Methods This retrospective comparative study included patients who underwent right colectomy at Sir Run Run Shaw Hospital, College of Medicine, Zhejiang University, between January 2019 and May 2022. The primary outcomes measured were the number of lymph nodes harvested. Key secondary outcomes included the operation time, intraoperative blood loss, postoperative complications, hospitalization costs, overall survival (OS), and disease-free survival (DFS). Data were analyzed using multivariable Cox proportional hazards regression to adjust for potential confounders.

Results A total of 225 patients (aged 65.23 ± 11.45, 108 males) with right colon cancer were included, with 100 (44.4%) patients underwent RRC. Patients who underwent RRC had significantly more lymph nodes harvested (27.69 ± 12.59 vs. 24.43 ± 9.42, $P = 0.028$), and incurred higher total hospitalization costs compared to those with LRC (9.68 ± 7.12 vs. 5.28 ± 1.23 ten-thousand-yuan, $P < 0.001$). The OS and DFS were comparable between RRC and LRC (both $P > 0.05$) within a median follow-up of 27 (range, 9–44) months. Multivariable cox proportional hazards regression showed that patients underwent RRC had significantly higher risk for all-cause death compared with those underwent LRC [hazards ratio (HR) = 2.303, 95% confidence intervals (CI): 1.625–3.265, $P < 0.001$].

Conclusion Patients underwent RRC seemed to have significantly more numbers of lymph nodes harvested and higher risk for all-cause death and higher hospitalization costs compared with those underwent LRC. These findings suggest a need for careful consideration of the benefits and risks associated with robotic versus laparoscopic right colectomy in clinical practice.

Trial registration Not applicable.

Keywords Robotic right colectomy, Laparoscopic right colectomy, Outcome, Lymph node yield, Comparative study

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Introduction

Colon cancer is the fifth most common cancer in the world, with an estimated 1,148,515 new cases in 2018 and causing 576,858 deaths [1] and in China, colon cancer ranks fourth [2]. Right colectomy is the standard surgical treatment for malignant tumors of the right colon [3, 4]. Laparoscopic right hemicolectomy (LRC) is mainly performed by large-volume centers and has been proven safe and feasible [5–7]. However, laparoscopic surgery has limitations such as loss of the three-dimensional visual field, limited range of motion of the surgical instruments, and hand tremors of the operator. The Da Vinci robotic surgical system is specifically designed to address the limitations of laparoscopic surgery by providing a more stable three-dimensional vision, advanced vibration elimination technology, and a significantly expanded range of motion for surgical instruments [8, 9]. Studies found that robotic right colectomy (RRC) had several potential advantages, including reduced blood loss, fewer complications, lower wound infection rates, fewer conversions to open surgery, faster bowel function recovery, and shorter hospital stays but requires more operative time than LRC [10–13]. However, the advantages of RRC versus LRC were still uncertain. This study aimed to compare the outcome of RRC and LRC in patients with right colon cancer.

Methods

Study design and participants

This retrospective comparative study included patients with right colon cancer at Sir Run Run Shaw Hospital, College of Medicine, Zhejiang University between January 2019 and May 2022. Compared to traditional open surgery, minimally invasive surgery offers several advantages, including reduced surgical trauma, enhanced postoperative recovery, and improved visualization of the surgical field, without compromising oncological prognosis [14–16]. Therefore, our center routinely utilizes laparoscopic or Da Vinci robotic-assisted approaches for colorectal cancer surgeries. Patient allocation to these surgical methods is determined following comprehensive discussions with patients and their families, during which they are thoroughly informed about the potential risks and benefits of each technique, with careful consideration of the associated financial implications. Inclusion criteria: (1) patients with right colon adenocarcinoma, and (2) underwent LRC or RRC. Exclusion criteria: (1) recurrence of colorectal cancer, (2) metastasis, (3) complicated with other tumors, (4) underwent radiotherapy or chemotherapy, (5) postoperative pathology showed melanoma, neuroendocrine carcinoma, or non-adenocarcinoma, (6) with permanent or prophylactic stoma, (7) pregnant, (8) serious complications such as severe heart, lung, liver, and kidney diseases, or (9) incomplete data. In this study, laparoscopic right hemicolectomy was performed using a standard five-port technique (including a camera port for observation, the primary surgeon requires one 12 mm main operating port and one 5 mm auxiliary operating port, while the first assistant needs two 5 mm operating ports), while robotic right hemicolectomy utilized a Da Vinci robotic system with similar port placements (Four 8 mm robotic arm ports and a 12 mm auxiliary port for the first assistant). Both procedures adhered to oncological principles, including complete mesocolic excision (CME) and high vascular ligation. Each surgery was performed by a team of three surgeons, with one lead surgeon experienced in either laparoscopic or robotic techniques, who had completed the system training provided by the Da Vinci robotic company and obtained certification. Seven attending surgeons at our department and each of them has performed over 50 Da Vinci robotic colorectal cancer surgeries. This study was approved by the Ethics Committee of Sir Run Run Shaw Hospital, College of Medicine, Zhejiang University. The requirement for informed consent was waived by the committee due to retrospective features.

Data collection and definition

Demographic characteristics were collected, including age, sex, preoperative body mass index (BMI), preoperative carcinoembryonic antigen (CEA) levels, tumor site, American Society of Anesthesiologists (ASA) grade, tumor pathological stage, and pathological differentiation degree. The colonic lesions were measured by electronic colonoscopy. Operation was performed in both groups based on the principle of CME+CVL. The standard resection margin for a radical right hemicolectomy includes the small intestine extending 10 cm from the ileocecal junction to the mid-transverse colon. After the specimens were macroscopically examined by the operating room physician, each specimen was sent for pathological examination. All specimens of patients with right colon cancer were examined by colorectal cancer pathologists at Sir Run Run Shaw Hospital. The pathological stage of the tumor was determined according to the eighth edition of the American Joint Committee on Cancer (AJCC).

Outcomes

The primary outcome was the number of lymph nodes harvested. Secondary outcomes focused on key clinical parameters, including operation time, intraoperative blood loss, postoperative complications (graded>II according to the Clavien-Dindo classification), hospitalization costs, overall survival (OS), and disease free survival (DFS). Other secondary outcomes such as exhaust time, fluid intake duration, drainage tube removal time, and hospitalization days were recorded but not

emphasized in the analysis to maintain focus. The operation time referred to the time from the establishment of the pneumoperitoneum to the end of abdominal closure. Intraoperative blood loss was calculated based on the total amount of blood collected in the suction bottle before the abdominal irrigation plus the total amount of blood in the gauze. The total amount of blood in the gauze was determined as the weight of the wet gauze minus the weight of the dry gauze and the amount of blood in the gauze was calculated as 1 g equals 1 ml. OS was defined as the time from surgery to all-cause death, and DFS was defined as the time from surgery to recurrence. For patients without OS or DFS events, the follow-up was censored at the last follow-up. The postoperative complications were evaluated according to the Clavien-Dindo complication classification, including abdominal infection, intestinal obstruction, pulmonary embolism, chylous leakage, and incision infection. The postoperative complications grade > II were recorded [17].

Statistical analysis

All data were analyzed using SPSS 23.0 (IBM, Armonk, NY, USA). The continuous variables were described as means ± standard deviations and analyzed using Student's t-test. The categorical variables were described as n (%) and analyzed using the chi-square test. DFS and OS were calculated using the Kaplan-Meier method and evaluated by the log-rank test. Multivariable cox proportional hazards regression was used to estimate the relative all-cause mortality risk associated with RRC vs. LRC. Two-sided P-values < 0.05 were considered statistically significant.

Results

A total of 225 patients (aged 65.23 ± 11.45, 108 males) with right colon cancer were included, with 100 (44.4%) patients underwent RRC (Fig. 1). Patients who underwent RRC were older than those underwent LRC (67.13 ± 13.11 vs. 63.62 ± 12.43 years, $P=0.041$) (Table 1). Patients who underwent RRC had significantly more lymph nodes harvested (27.69 ± 12.59 vs. 24.43 ± 9.42, $P=0.028$), and higher total hospitalization costs than that with LRC (9.68 ± 7.12 vs. 5.28 ± 1.23 ten-thousand-yuan, $P<0.001$). No significant differences were found in operation time, intraoperative blood loss, or postoperative complication rates between the two groups (Table 2). The OS and DFS were comparable between RRC and LRC ($P=0.3784$ and $P=0.4386$) within a median follow-up of 27 (range, 9–44) months (Fig. 2). However, multivariable Cox regression

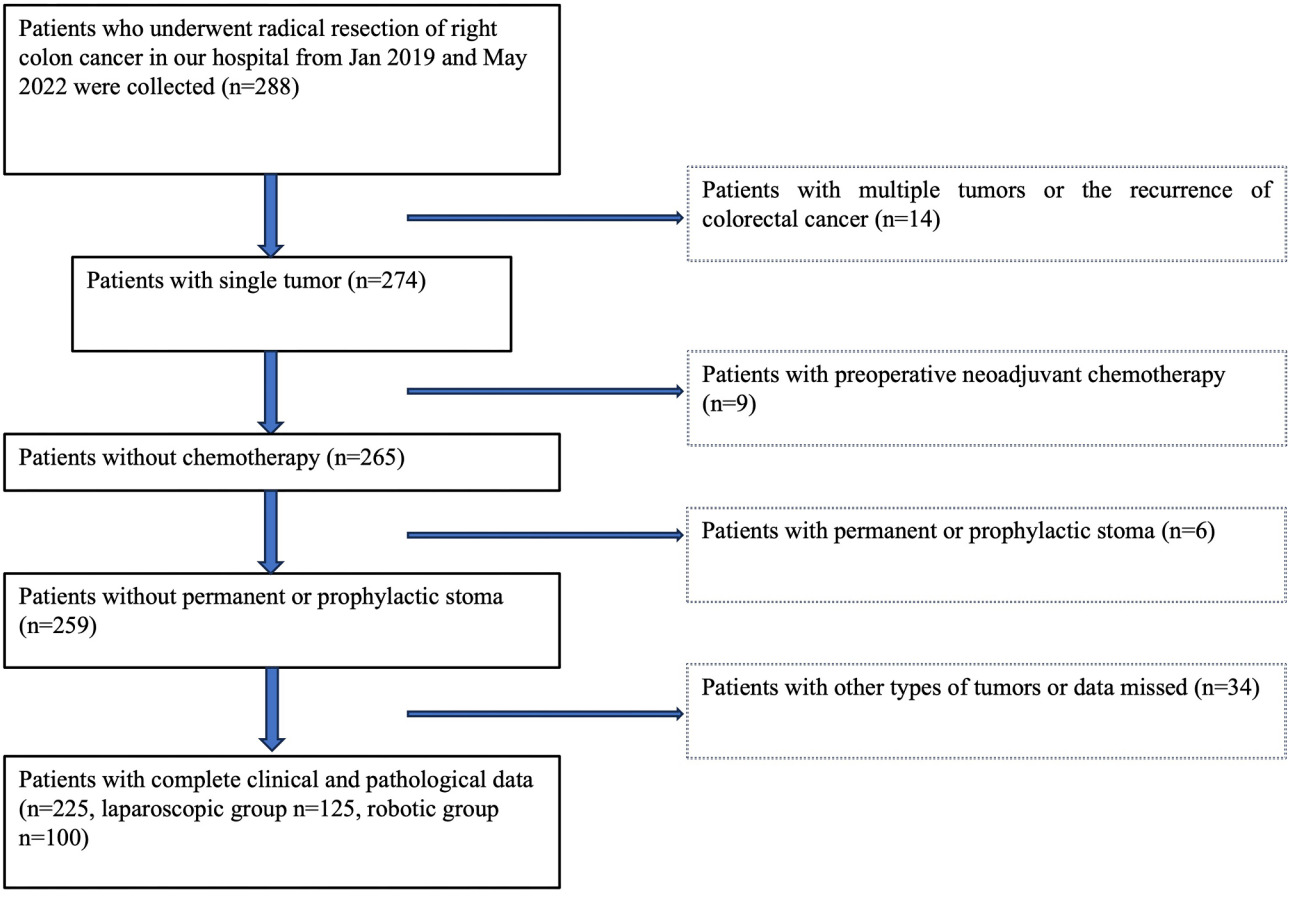

Fig. 1 Patients' flowchart

Table 1 Baseline characteristics

Variable	LRC (*n* = 125)	RRC (*n* = 100)	*P**
Age (years)	63.62 ± 12.43	67.13 ± 13.11	0.041
Male	55 (44.00%)	53 (53.00%)	0.179
Body mass index (kg/m^2)	23.07 ± 4.85	22.64 ± 3.96	0.478
Preoperative CEA (ng/ml)	11.16 ± 45.64	12.34 ± 23.68	0.815
Tumor site			0.958
Ileocecal part	18 (14.40%)	28 (28.00%)	
Ascending colon	43 (34.40%)	27 (43.00%)	
Hepatic flexure	64 (51.20%)	45 (27.00%)	
ASA grade (No, %)			0.696
I-II	53 (42.40%)	45 (45.00%)	
III-IV	72 (57.60%)	55 (55.00%)	
Tumor pathological stage			> 0.999
I	24 (19.20%)	16 (16.00%)	
II	62 (49.60%)	51 (51.00%)	
III	39 (31.20%)	33 (33.00%)	
Pathological differentiation degree			0.062
Low	33 (10.40%)	38 (38.00%)	
Moderate and high	92 (73.60%)	62 (62.00%)	

RRC: robotic right colectomy, LRC: laparoscopic right colectomy

***P: The continuous variables were described as means ± standard deviations and analyzed using Student's t-test. The categorical variables were described as n (%) and analyzed using the chi-square test**

Table 2 Outcomes

Variables	LRC (*n* = 125)	RRC (*n* = 100)	*P**
Postoperative pathological			
Total number of lymph node yield	24.43 ± 9.42	27.69 ± 12.59	0.028
Total number of positive lymph nodes	1.45 ± 3.47	2.31 ± 6.70	0.214
Intraoperative situation			
Operation time (min)	168.40 ± 34.93	171.7 ± 38.70	0.499
Intraoperative blood loss (ml)	64.80 ± 88.20	52.80 ± 20.00	0.184
Postoperative recovery			
Exhaust time (day)	3.75 ± 1.56	3.81 ± 1.21	0.769
Fluid intake time (day)	4.59 ± 2.13	4.21 ± 1.47	0.132
Drainage tube removal time (day)	8.44 ± 3.06	8.03 ± 2.89	0.309
Hospitalization days	9.90 ± 3.76	9.81 ± 4.04	0.857
Total hospitalization cost (Ten thousand yuan)	5.28 ± 1.23	9.68 ± 7.12	< 0.001
Complications	19 (15.20%)	18 (18.00%)	0.773
Abdominal infection	10 (8.00%)	12 (12.00%)	
Intestinal obstruction	3 (2.40%)	2 (2.00%)	
Pulmonary embolism	1 (0.80%)	1 (1.00%)	
Chylous leakage	4 (3.20%)	3 (3.00%)	
Incision infection	1 (0.80%)	1 (1.00%)	

RRC: robotic right colectomy, LRC: laparoscopic right colectomy

***P: The continuous variables were described as means ± standard deviations and analyzed using Student's t-test. The categorical variables were described as n (%) and analyzed using the chi-square test**

showed that patients who underwent RRC had a significantly higher risk for all-cause death compared with those who underwent LRC (HR = 2.303, 95% CI: 1.625–3.265, $P < 0.001$) (Table 3and Fig. 3).

Discussion

In the present study, we observed that patients undergoing RRC exhibited a significantly higher lymph node harvest and incurred greater hospitalization costs compared to those undergoing LRC. Intriguingly, despite the increased lymph node yield, RRC was associated with a

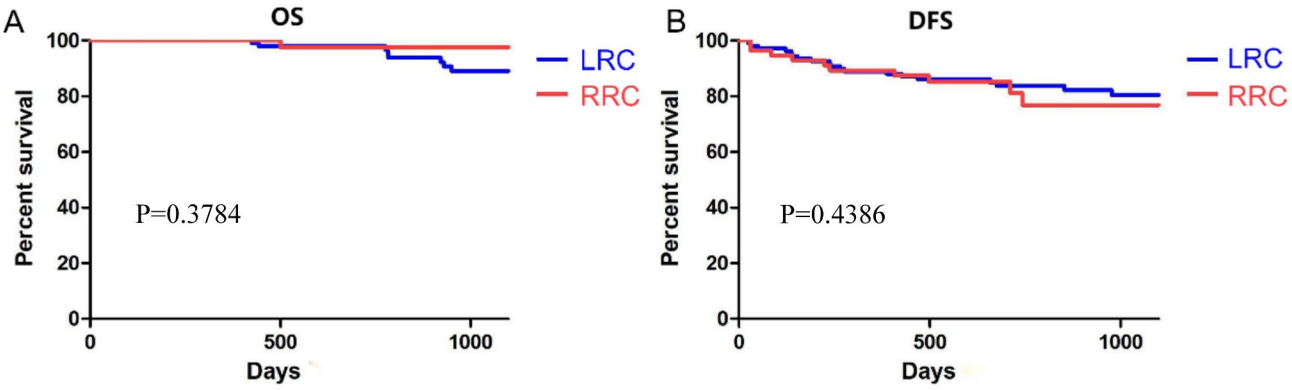

Fig. 2 Overall survival (OS) and disease-free survival (DFS). (**A**) OS. (**B**) DFS

Table 3 Multivariable cox proportional hazards regression

	No. of patients	Adjusted model*		
		HR	95% CI	P
Sex				
Female	74 (44.0)	Ref		
Male	94 (56.0)	0.922	0.659–1.291	0.638
Age				
< 60 yr	50 (29.8)	Ref		
≧ 60 yr	118 (70.2)	1.168	0.826–1.651	0.381
Tumor pathological stage				
I	28 (16.7)	Ref		
II	84 (50.0)	0.640	0.408–1.002	0.051
III	56 (33.3)	0.740	0.443–1.236	0.250
Pathological differentiation				
Low	49 (29.2)	Ref		
Moderate and high	119 (70.8)	1.458	1.000-2.127	0.050
Surgery type				
LRC	112 (66.7)	Ref		
RRC	56 (33.3)	2.303	1.625–3.265	< 0.001

HR: hazard ratio; CI: confidence interval; RRC: robotic right colectomy; LRC: laparoscopic right colectomy

*Adjusted for age, sex, tumor pathological stage, pathological differentiation

higher risk of all-cause mortality in the multivariate analysis, while OS and DFS remained comparable between the two groups during a median follow-up of 27 months.

The cornerstone of curative colon cancer surgery lies in adhering to the principles of CME and D3 lymphadenectomy, which entail en bloc resection of the tumor-bearing colon segment along with its mesentery and associated lymphovascular structures [18–20]. Our finding of a greater lymph node retrieval in the RRC group aligns with prior studies. Waters et al. reported a higher lymph node harvest in RRC across 15 studies involving 831 RRC and 3,241 LRC patients [11], corroborating our results. Similarly, Formisano et al. highlighted the advantages of RRC in facilitating CME and intracorporeal anastomosis [13]. The enhanced dexterity and three-dimensional visualization offered by robotic systems may contribute to a more meticulous dissection and thorough lymphadenectomy [21].

Despite these technical advantages, the lack of a corresponding improvement in OS and DFS raises critical questions. Several factors may account for this discrepancy. First, the median follow-up period of 27 months may be insufficient to capture long-term survival benefits, as colorectal cancer often requires extended observation to detect differences in oncological outcomes. The potential impact of increased lymph node harvest on staging accuracy and adjuvant therapy decisions may not translate into immediate survival advantages within this timeframe. Second, both RRC and LRC adhere to oncological surgical principles, potentially reducing the survival impact of the increased lymph node yield in RRC. The phenomenon of stage migration resulting from more accurate staging might not significantly influence survival if both surgical approaches effectively achieve complete tumor resection.

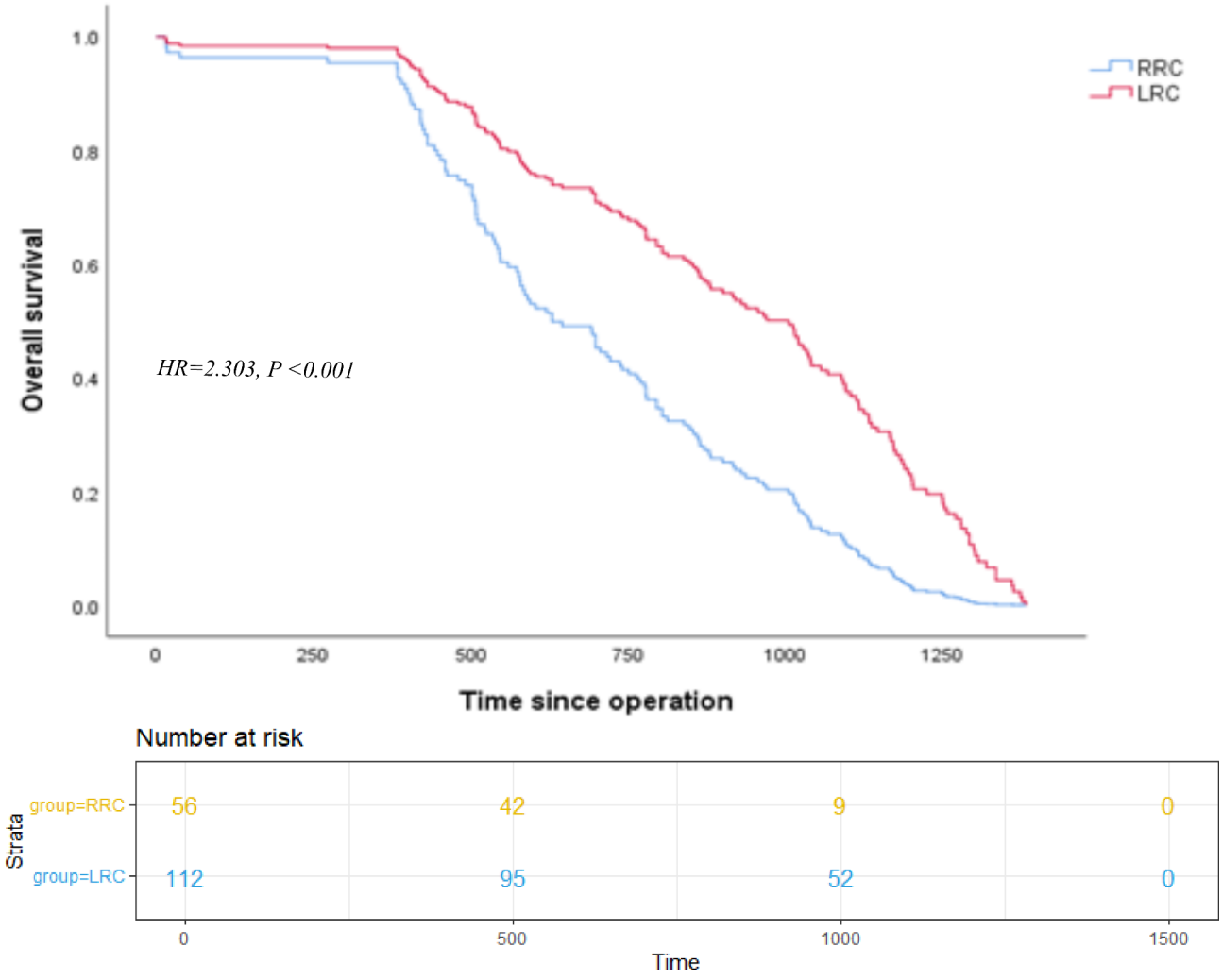

Fig. 3 Multivariable cox proportional hazards regression for overall survival

The unexpected finding of a higher all-cause mortality risk associated with RRC warrants careful consideration. Several potential explanations merit discussion. The adoption of robotic surgery is relatively recent in our institution, and the proficiency of surgeons performing RRC may vary due to the learning curve inherent in mastering robotic techniques [22]. Studies have demonstrated that surgical expertise significantly influences patient outcomes, with complication rates decreasing as surgeons gain experience.

Moreover, the selection of surgical modality was determined through discussions with patients and their families, considering potential risks, benefits, and financial implications. This approach may introduce selection bias, as patients opting for RRC could possess different baseline characteristics or comorbidities not fully captured in our data [23]. It is plausible that patients with more advanced disease or complex anatomies were preferentially allocated to RRC, perceiving the robotic approach as offering superior technical advantages. Such an inherent selection of higher-risk cases could confound the association between RRC and increased mortality.

Additionally, the higher hospitalization costs observed in the RRC group might reflect more intensive perioperative management or a greater incidence of postoperative complications, factors that could adversely affect patient outcomes. While our study did not find significant differences in operative times, intraoperative blood loss, or postoperative complication rates between RRC and LRC, other studies have reported prolonged operative durations for RRC [10], which could contribute to increased morbidity and mortality due to extended anesthesia exposure and surgical stress.

The similarity in OS and DFS between the two groups, despite the higher lymph node harvest in RRC, emphasizes the complexity of surgical oncology outcomes. Spinoglio et al. reported no significant differences in OS or 5-year DFS between RRC and LRC in a cohort of

202 patients [8], aligning with our findings. Conversely, Mirkin et al. observed higher 5-year OS rates with RRC in stage II and III colon cancer patients [24]. These discrepancies highlight the influence of factors such as sample size, follow-up duration, patient demographics, tumor characteristics, and surgical expertise on survival outcomes.

Our study has inherent limitations. Being a single-center retrospective analysis, the findings may lack generalizability to broader populations. The relatively small sample size and short median follow-up period constrain the ability to draw definitive conclusions regarding long-term survival benefits. Furthermore, the potential for unmeasured confounding variables and selection bias, due to patient-determined surgical choices, may influence the observed associations.

Conclusion

In conclusion, while RRC offers technical advantages such as enhanced lymph node harvest, these do not necessarily translate into improved long-term survival and may be accompanied by increased mortality risk. These findings suggest that the benefits of robotic assistance must be carefully weighed against potential risks, and highlight the importance of surgical expertise and patient selection in optimizing outcomes. Prospective, multicenter randomized controlled trials with extended follow-up are essential to validate these observations and elucidate the role of robotic surgery in the management of right colon cancer.

Abbreviations

(RRC) Robotic right colectomy
(LRC) Laparoscopic right colectomy
(BMI) Bbody mass index
(CEA) Carcinoembryonic antigen
(ASA) American Society of Anesthesiologists
(AJCC) American Joint Committee on Cancer
(OS) Overall survival
(DFS) Disease-free survival

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Author contributions

All authors have read and approved the manuscript.Conceptualization: LCData curation: LC, EGCFormal analysis: LC, WZ, EGCMethodology: LC, EGCResources: LC, EGC, WZSoftware: LC, EGCWriting – original draft: LCWriting – review & editing: LC, EGC.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to protecting individual patient privacy but are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was carried out after the protocol was approved by the ethics committee of Sir Run Run Shaw Hospital Zhejiang University College of Medicine. I confirm that all methods were performed in accordance with the relevant guidelines. All procedures were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments, and informed consent was obtained from all participants.

Consent for publication

Written consent was obtained from patients for the patient's personal or clinical data, along with any identifying images to be published in this study.

Competing interests

The authors declare no competing interests.

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