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Short- and long-term outcomes of totally robotic versus robotic-assisted right hemicolectomy for colon cancer

A retrospective study

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Abstract

Totally robotic right hemicolectomy (TRRH) is a novel alternative surgical method used for the treatment of colon cancer. The aim of this study was to compare both the short-and long-term outcomes of TRRH and robotic-assisted right hemicolectomy (RARH) for the treatment of colon cancer.

We performed a 1:2 matched propensity score analysis. We then retrospectively analyzed all procedures (64 cases TRRH and 128 cases RARH) carried out by a single surgeon between December 4, 2014 and June 20, 2018 at a large center. Both short-and long-term surgical outcomes were compared between 2 different groups.

Based on the propensity score matching, we selected 64 patients that had undergone TRRH treatment and 128 patients who had undergone RARH treatment. The preoperative clinical–pathological characteristics were well matched between the 2 groups. We observed no significant differences between the 2 groups in postoperative pathological outcomes. The mean operative time was found to be significantly longer in the TRRH group compared to the RARH group (168.2 ± 9.1 minutes vs 153.4 ± 7.4 minutes, $P = .034$). The mean operative incision length was found to be significantly longer in the TRRH group than in the RARH group (4.5 ± 0.6 cm vs 6.9 ± 1.1 cm, $P = .023$). Postoperative pain score (visual analog scale at day 1) was found to be significantly lower in the TRRH group than in the RARH group (2.9 ± 1.3 vs 4.1 ± 2.1, $P = .005$). The time to pass flatus was observed to be statistically lower in the TRRH group ($P = .042$). We observed 3 twists of mesentery in the RARH group, while none were observed in the TRRH group ($P < .050$). Both the 3-year overall survival (TRRH [91.6%] vs RARH [89.2%], $P = .467$) and the 3-year disease-free survival (TRRH [81.4%] vs RARH [78.2%], $P = .551$) were determined to be comparable between the 2 groups studied here.

We show that TRRH is a safe and feasible treatment option for colon cancer patients in terms of both short- and long-term outcomes. High-volume, randomized, controlled trials with sufficient follow-up studies will need to be carried out in order to confirm this rationale.

Abbreviations: PSM = propensity score matching, RARH = robotic-assisted right hemicolectomy, TRRH = totally robotic right hemicolectomy.

Keywords: colon cancer, right hemicolectomy, robotic surgery

1. Introduction

Robotic techniques are now widely used in minimally invasive abdominal surgery. In the case of colorectal surgery, it is used for anterior resections, left colectomies, and right colectomies.[1–3] However, the advantages associated with this technique compared to standard laparoscopy techniques have yet to be fully defined.[4–6] Specifically, the current literature concludes that robotic right colectomy is feasible, safe, and adequate for oncology purposes.[7,8] However, the clear advantages to justify a longer operation duration and higher costs of this procedure in comparison to standard laparoscopy techniques have yet to be fully described.[9,10]

The most common robotic-assisted procedure involves intracorporeal dissection, intracorporeal ligation of vessels, and extracorporeal anastomosis through a small laparotomy wound. However, bowel exteriorization for the anastomosis is a challenging procedure in obese patients.[11–14] In addition, bowel exteriorization limits the extraction site location and could function to compromise bowel alignment following extraction. Intracorporeal anastomosis represents an alternative approach

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that could function to alleviate some of the technical problems that are associated with extracorporeal anastomosis. However, there exists very few data regarding the short- and long-term outcomes following intracorporeal anastomosis in right-sided colon cancer patients. Therefore, we used the propensity score-matched analysis in order to exclude the bias of each patient assigned to different study groups. The goal of this study was to understand whether the use of the totally robotic right hemicolectomy (TRRH) method with intracorporeal anastomosis possesses any advantages over the robotic-assisted right hemicolectomy (RARH) method with extracorporeal anastomosis.

2. Materials and methods

2.1. Patient

This retrospective clinical study was approved by the institutional review board and Ethics Committees of The First Affiliated Hospital of Nanchang University. All patients in this study were enrolled from the prospectively maintained database at the Department of Gastrointestinal Surgery. We used propensity score-matched analysis in order to eliminate the bias of each patient assigned to a different study group. Patients in this cohort study were grouped according to the 1:2 ratio based on the following parameters: age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status, tumor location, tumor long diameter, prior abdominal surgery, pTNM stage, and preoperative serum-carcinoembryonic antigen (s-CEA). In the analysis, 192 patients from December 4, 2014 to June 20, 2018 were included. The entire cohort was comprised of 64 and 128 patients who underwent TRRH and RARH, respectively. Identical inclusion and exclusion criteria were used for both groups.

The inclusion criteria used for this study were as follows:

(1) histologically confirmed adenocarcinoma by colonoscopy and pathological biopsy;
(2) depth of invasion confined to pT1, pT2, pT3, or pT4a;
(3) no distant metastasis or invasion to adjacent organs;
(4) no combination with another malignancy;
(5) no emergency operation; and
(6) no preoperative chemotherapy or radiation therapy was performed.

Exclusion criteria:

(1) acute intestinal obstruction or perforation, and so on. that required emergency surgery;
(2) distant metastasis or intraoperative presence of implant metastasis;
(3) multiple organ resection and nonradical resection.

Both TRRH and RARH were carried out using CME.[15–17] Pathological stages were classified according to the eighth edition of the American Joint Committee on Cancer TNM Staging System for colorectal cancer. This study was approved by the institutional review board of the First Affiliated Hospital of Nanchang University.

The following parameters were statistically analysed:

(1) pathological parameters, including surgical specimen length, proximal resection margin, distal resection margin, negative surgical margin, pathologic T-category, pathologic N-category, differentiation, lymphovascular invasion, perineural invasion, and number of retrieved lymph nodes.
(2) Relevant parameters of recent surgical results, including operative time, estimated blood loss, postoperative pain score (visual analog scale [VAS] at day 1), length of operative incision, conversion to open surgery, time to mobilization, time to pass flatus, return to liquid diet, hospitalization, total cost, complications (anastomotic leakage, bleeding, wound infection, deep vein thrombosis, postoperative transfusion, arrhythmia, urinary retention, ileus, and intra-abdominal abscess), reoperation, hospital readmission, and mortality.
(3) total survival time of 3 years and 3 years tumor-free survival time.

2.2. Definitions

Right-sided colon cancer was defined as cancer localized at the cecum (CE), ascending colon (AC), hepatic flexure (HF), or proximal transverse colon (TC).[18] The term anastomotic leakage was used to define all conditions having clinical or radiologic anastomotic dehiscence, with or without the requirement for surgical revision. Any bleeding has been considered if blood transfusions were required. Pain was classified as the need for extra analgesia for moderate to severe pain in the postoperative period.

Overall survival was calculated as the time from the operation date to the date of death from any cause. Disease-free survival was calculated as the time from the operation date to the date of either recurrence or metastasis.[19] In this study, patients with a high-risk stage II or stage III tumor were recommended to receive postoperative adjuvant chemotherapy using 5-fluorouracil-based regimens. The final follow-up was carried out in June 2018.

2.3. Surgeon background

All procedures carried out in the present study were performed by the same surgeon (T-Y Li), who had carried out greater than 1000 cases of robotic gastrointestinal surgery since December 2014.

2.4. Surgical procedures

For information regarding surgical procedures, refer to the guide.[20] The modus operandi used between the 2 groups was almost identical, with the exception of digestive tract reconstruction. Surgical treatment for patients in both groups used the medial-to-lateral approach right hemicolectomy with complete mesocolic excision, and was carried out by the same surgical group. Installation of the robotic operation system was carried out using the following reference, including the surgical position, number, and location of trocar (Fig. 1). The operating procedure was completed with exposure of the operative filed, division of vessels, mobilization of the ascending colon, mobilization of the hepatic flexure of colon, and mobilization of the side peritoneum.

Anastomosis of the 2 groups:

(1) TRRH: The terminal ileum was placed close to the transverse colon, and the ultrasound knife was used to cut a 1 cm hole into the 2 intestinal walls. Using the A hole as a passage way, a 45-mm linear stapler (Ethicon) was put in to generate a side-to-side antiperistaltic ileocolic anastomosis. Next, another 45-mm linear stapler was used to cut off the broken ends of the terminal ileum and the transverse colon at the same time. The anastomosis was intermittently reinforced using vicryl sutures (Fig. 2). Finally, the R2 incision was lengthened, and the specimen was removed using a plastic bag (Fig. 3).

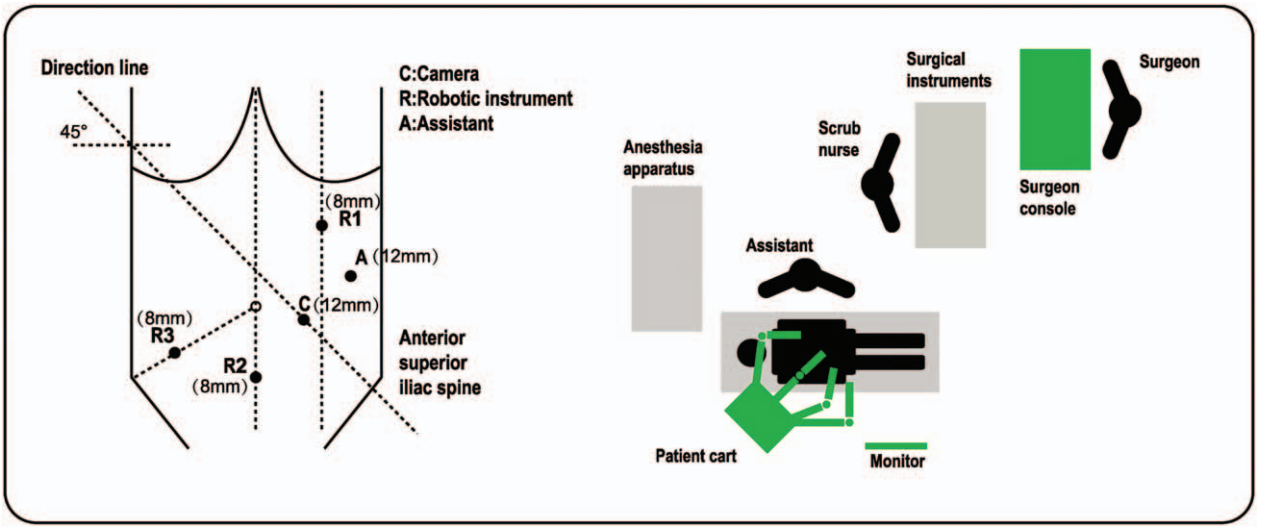

Figure 1. Trocar location and operating room setup for robot-assisted radical resection of right-sided colon cancer.

(2) RARH: A 6 to 8 cm incision was made around the umbilical cord along the midline. A 75-mm linear stapler (Ethicon) was used to generate a side-to-side antiperistaltic ileocolic anastomosis, and another one was used to cut off the broken ends of the terminal ileum and the transverse colon at the same time. The anastomosis was intermittently reinforced using vicryl sutures. The drain was inserted in through R3 (Fig. 3). The defect between the mesentery and the mesocolon following ileocolic anastomosis was not closed in either group.

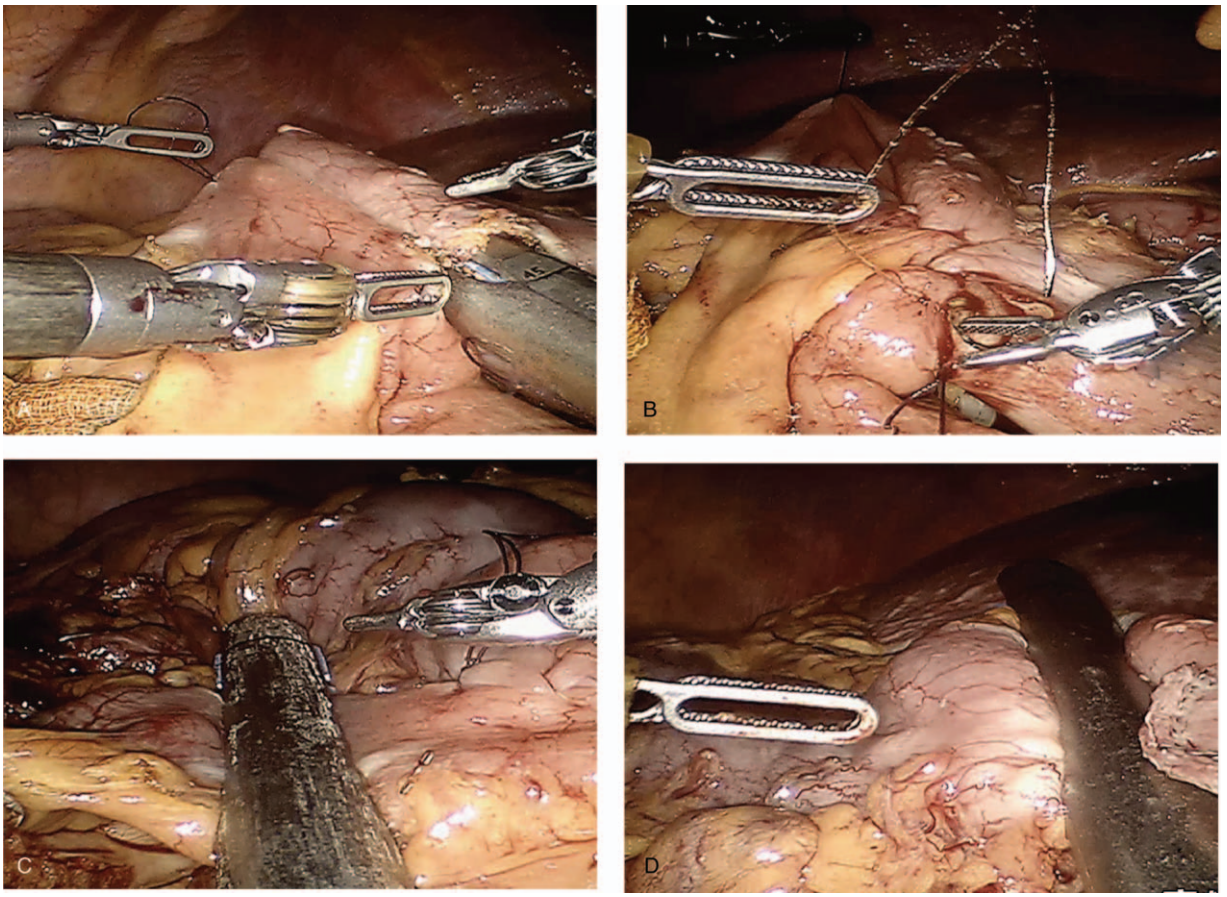

Figure 2. Anastomosis of totally robotic right hemicolectomy. A: Stapled ileocolic anastomosis; B: Hand-sewing of enterotomy after stapler removal; C: Transected terminal ileum; D: Transected terminal transverse colon.

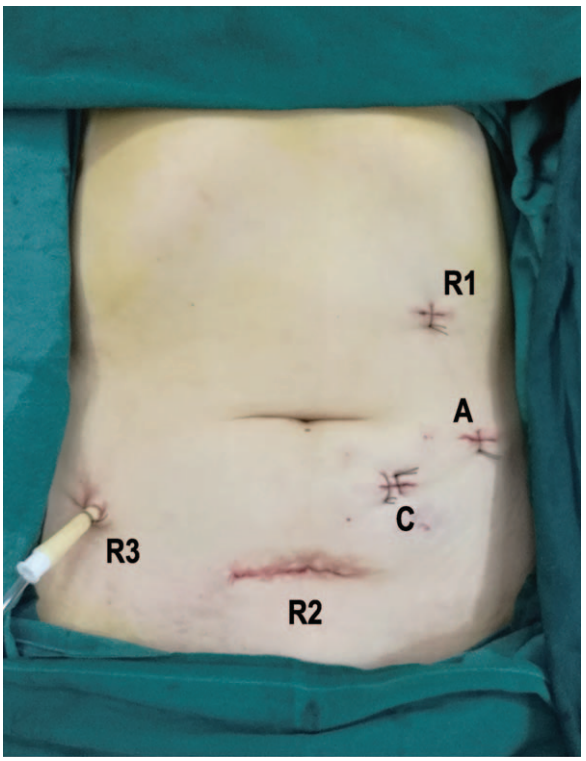

Figure 3. Placement of the trocars: R1-3, robotic instrument ports (8 mm); C, camera ports (12 mm); A, assistant ports (12 mm).

2.5. Statistical analysis

All statistical analyses were carried out using SPSS version 22.0 (SPSS Inc, Chicago, IL). Continuous variables are presented as means ± standard deviations and variables with non-normal distributions are reported as the median (range). Physical and clinicopathological parameters in the 2 groups were compared using a cross-table analysis using Pearson χ^2 test or Fisher exact test with 2-sided verification, along with the Mann–Whitney *U*-test. Survival data were analyzed using the Kaplan–Meier method and compared using the log-rank test. Statistical tests were 2-sided and *P* values less than .05 were considered to be statistically significant.

3. Results

3.1. Clinical–pathological characteristics

Based on one-to-two propensity score matching (PSM), we selected a total of 64 patients who underwent TRRH and a total of 128 patients who underwent RARH. Table 1 depicts the clinical–pathological data regarding the propensity score-matched patients (n = 192). Following PSM, the patient distributions were observed to be well balanced between the TRRH and RARH groups. There was no significant difference observed in terms of age, gender, BMI, ASA physical status, tumor length diameter, prior abdominal surgery, pTNM stage, and preoperative s-CEA between the 2 groups. The tumor location was divided into 4 different sites: CE, AC, HF, and TC. No differences were observed in tumor location between the 2 groups.

3.2. Pathological features

The TRRH and RARH groups were not observed to differ in their patterns of surgical specimen length, pathological stage, differentiation, negative surgical margin, lymphovascular, and perineural invasion (Table 2). The mean length of the proximal resection margin was found to be significantly greater than that of the distal resection margin in the case of both groups ($P = .009$). The mean number of retrieved lymph nodes was 18 ± 7 and 16 ± 6 in the TRRH and the RARH group, respectively ($P = .279$). A total of 96% of the TRRH group and 93% of the RARH group were observed to have greater than 12 lymph nodes in the specimen ($P = .147$).

Table 1

Clinical–pathological characteristics.

Parameters	TRRH n = 64	RARH n = 128	*P*-value*
Gender,male/female	34/30	75/53	.471
Age†, yr	60 ± 11	58 ± 13	.689
BMI‡, kg/m^2	23.2 (17–35)	24.7 (18–32)	.423
ASA physical status, I/II/III/IV	16/42/6/0	28/85/15/0	.819
Tumour location, CE/AC/HF/TC	5/36/7/6	15/72/23/18	.630
Tumour long diameter† cm	4.8 ± 1.9	4.6 ± 1.6	.774
Prior abdominal surgery	6	15	.210
Stage§, I/II/III/IV	9/40/15/0	18/73/37/0	.709
Preoperative s-CEA†, ng/ml	4.6 ± 5.3	5.4 ± 9.5	.652

ASA = American Society of Anesthesiologists, BMI = body mass index, CE/AC/HF/TC = cecum/ascending colon/hepatic flexure/transverse colon, RARH = robotic-assisted right hemicolectomy, s-CEA = serum-carcinoembryonic antigen, SD = standard deviation, TRRH = totally robotic right hemicolectomy.

* All parameters were compared using Fisher exact test with 2-sided verification or Pearson χ^2 test and Mann–Whitney *U*-test.

† mean ± SD.

‡ Median (range) value expressed.

§ Pathologic staging according to the American Joint Committee on Cancer (8th ed., 2017).

3.3. Short-term outcomes

Table 3 depicts the results of the short-term outcomes. With the exception of 58 patients (TRRH, n = 18, RARH, n = 40) who underwent an extended right hemicolectomy and CME, all other patients had undergone a right hemicolectomy and CME.

The mean operative time was determined to be significantly longer in the TRRH group compared to the RARH group

Table 2

Pathological outcomes.

Parameters	TRRH n = 64	RARH n = 128	*P*-value*
Surgical specimen length†, cm	36.7 ± 9.6	38.2 ± 12.3	.412
Proximal resection margin‡, cm	25.6 (8–63)	28.2 (9–69)	.123
Distal resection margin†, cm	11.8 ± 4.8	10.4 ± 4.1	.758
Negative surgical margin	64	128	
Pathologic T-category§, 1/2/3/4a	3/8/43/10	12/15/81/20	.724
Pathologic N-category§, 0/1/2	42/17/5	85/36/7	.812
Differentiation,WD/MD/PD/M	8/40/10/6	15/72/29/12	.718
Lymphovascular invasion+	27	52	.358
Perineural invasion+	22	47	.371
No.of retrieved lymph nodes†	17 ± 7	16 ± 6	.279

RARH = robotic-assisted right hemicolectomy, SD = standard deviation, TRRH = totally robotic right hemicolectomy, WD/MD/PD/M = well differentiated/ moderately differentiated/poorly differentiated/ mucinous.

* All parameters were compared using Pearson χ^2 test and Mann–Whitney *U*-test.

† mean ± SD.

‡ Median (range) value expressed.

§ Pathologic staging according to the American Joint Committee on Cancer (8th ed., 2017).

Table 3

Short-term outcomes.

Parameters	TRRH n = 64	RARH n = 128	*P*-value*
Operative time†, min	178.2 ± 9.1	153.4 ± 7.4	**.034**
Estimated blood loss†, ml	85.2 ± 17.5	88.9 ± 19.3	.147
Postoperative pain score† (VAS at day 1)	2.9 ± 1.3	4.1 ± 2.1	**.005**
Length of operative incision†, cm	4.5 ± 0.6	6.9 ± 1.1	**.023**
Conversion to open surgery	0	0	
Time to mobilization†, h	24.2 ± 3.1	26.5 ± 3.8	.271
Time to pass flatus†, h	54.6 ± 5.9	61.5 ± 6.2	**.042**
Return to liquid diet†, h	74.6 ± 7.1	77.2 ± 7.3	.071
Hospitalization†, d	7.5 ± 1.6	7.4 ± 1.5	.358
Total cost†, $	9886.7 ± 561.2	9450.9 ± 495.8	.134
Complication‡	12	22	.148
Reoperation‡	1	2	.752
Hospital readmission‡	0	1	.289
Mortality‡	0	0	

RARH = robotic-assisted right hemicolectomy, SD = standard deviation, TRRH = totally robotic right hemicolectomy, VAS = visual analog scale.

Bold are the statistically significant results.

* All parameters were compared using Fisher exact test with 2-sided verification or Pearson χ^2 test and Mann–Whitney *U*-test.

† mean ± SD.

‡ ≤1 mo of surgery.

Table 4

Complications.

Parameters	TRRH n = 64	RARH n = 128	*P*-value*
Anastomotic leakage	1	1	>.050
Twist of mesentery	0	3	<**.050**†
Wound infection	4	9	>.050
Others‡	6	10	>.050

RARH = robotic-assisted right hemicolectomy, TRRH = totally robotic right hemicolectomy.

Bold are the statistically significant results.

* All parameters were compared using Fisher exact test with 2-sided verification or Pearson χ^2 test.

† Immediate redo anastomosis in the surgery.

‡ Deep vein thrombosis, postoperative transfusion, arrhythmia, urinary retention, ileus, intra-abdominal abscess, bleeding.

(168.2 ± 9.1 minutes vs 153.4 ± 7.4 minutes, $P = .034$). However, estimated blood loss was observed to be similar in the TRRH group compared to the RARH group (85.2 ± 17.5 ml vs 88.9 ± 19.3 ml, $P = .147$). Interestingly, the mean length of the operative incision was observed to be significantly longer in the TRRH group compared to the RARH group (4.5 ± 0.6 cm vs 6.9 ± 1.1 cm, $P = .023$). On the other hand, postoperative pain score (VAS at day 1) was found to be significantly lower in the TRRH group compared to the RARH group (2.9 ± 1.3 vs 4.1 ± 2.1, $P = .005$).

The time to pass flatus was observed to be statistically reduced in the TRRH group ($P = .042$). While it was not found to be statistically significant, a lower return to liquid diet (74.6 ± 7.1 hours vs 77.2 ± 7.3 hours) was observed among patients that had undergone TRRH surgery. There were no significant differences observed in the time to mobilization, hospitalization, total cost, or mortality.

Postoperative complications were observed to occur in 12 patients in the TRRH group and in 22 patients in the RARH group ($P = .148$) (Table 4). We observed 3 twists of mesentery in the RARH group and none in the TRRH group. One patient in this study required readmission for conservative treatment of a surgical site infection following RARH. No readmission of patients was required in the TRRH group ($P = .289$). Two patients in the RARH group underwent reoperation due to surgical complications (1 case of anastomosis leak and 1 cases of bleeding). One patient in the TRRH group underwent reoperation due to anastomosis leak.

3.4. Follow-up result

In this study, a total of 5 patients (7.8%) in the TRRH group and 9 patients (7.0%) in the RARH group were lost before follow up. The median follow-up duration was 27 months (range 2–41 months) for the TRRH group and 29 months (range 3–42 months) for the RARH group ($P = .414$). The 3-year overall survival was determined to be 91.6% in the TRRH group and 89.2% in the RARH group ($P = .467$) (Fig. 4A). The 3-year disease-free survival was determined to be 81.4% in the TRRH group and 78.2% in the RARH group ($P = .551$) (Fig. 4B).

4. Discussion

Both the use and the potential benefits associated with the robotic da Vinci Surgical System in right hemicolectomy are far from being fully understood. Current literature regarding this area is primarily limited to the analysis of series and case reports.[7–10] In addition, the majority of the series are nonhomogeneous due to the fact that they include both patients with benign diseases and malignancies.[5,11] Anastomotic technique-specific data related to robotic right-sided colon surgery is lacking. This study represents the first study carried out that reports short- and long-term results following totally robotic and robotic-assisted side-to-side ileocolonic anastomosis in right hemicolectomy for the treatment of colon cancer.

The average operative time (which includes docking time) of the TRRH group was found to be significantly longer compared to that of the RARH group (178.2 + 9.1 minutes vs 153.4 + 7.4 minutes, $P = .034$). This could be related to the unskilled intracorporeal anastomosis technology in the early stage of operation. Following 15 cases of TRRH surgery, the time of intracorporeal anastomosis was significantly shortened. However, the time to pass flatus in the TRRH group was found to be significantly shorter compared to that of the RARH group (54.6 + 5.9 hours vs 61.5 + 6.2 hours, $P = .042$). This could be due to the fact that in TRRH, there is less interference to the intestine, and the exposure time of the intestine to air is relatively short. However, there no statistically significant difference was observed between the 2 groups in the time of first return to liquid diet and hospitalization ($P > .05$).

In addition, we observed statistically significant differences between the totally robotic and the robotic-assisted techniques in both the length of operative incision (4.5 ± 0.6 cm vs 6.9 ± 1.1 cm) and postoperative pain score (VAS at day 1) (2.9 ± 1.3 vs 4.1 ± 2.1). The incision was made only for specimen extraction with the totally robotic technique. This has the benefit of less retraction or tension being placed on the wound compared to attempting to introduce a large hand or forearm into the abdomen or to externalizing the specimen for resection or anastomosis. One explanation for the decreased pain demonstrated in our study could simply be the smaller incision that was used in the totally robotic technique at approximately 4 to 5 cm versus that in the robotic-assisted approach at 7 to 9 cm.

Significant percentages of anastomotic complications (twists) have been described with the use of extracorporeal anastomosis

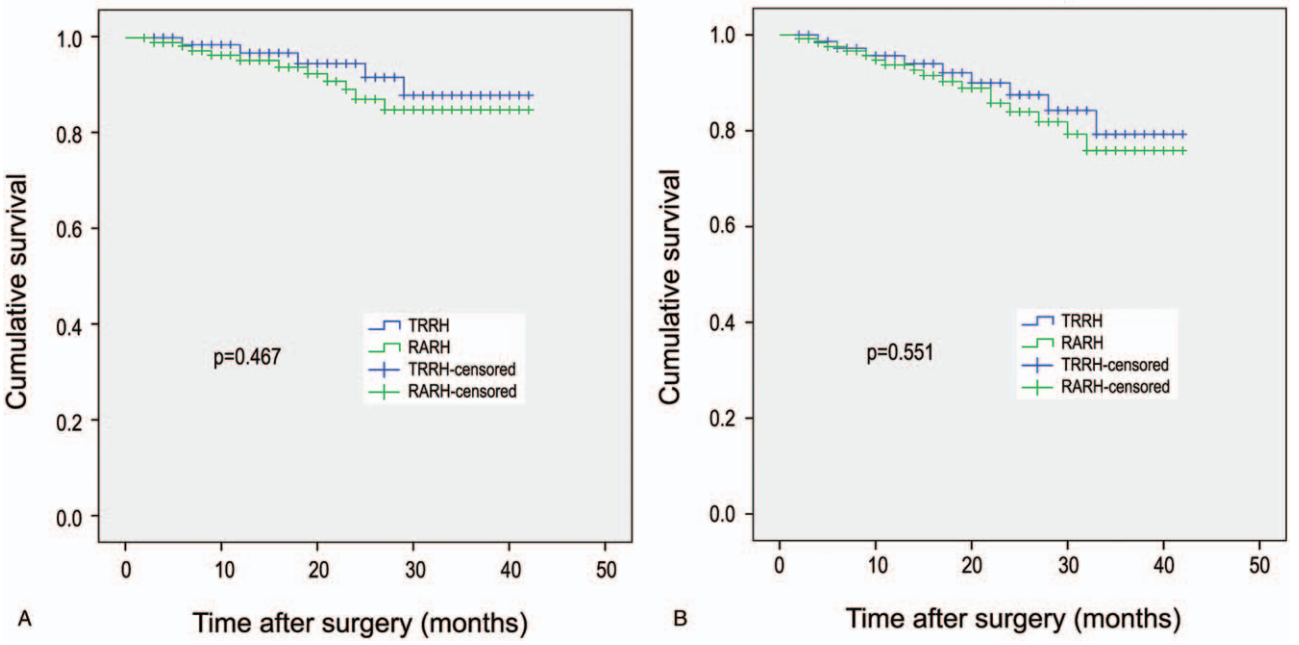

Figure 4. Survival outcomes. A: Cumulative overall survival rate during a 3-year interval in the TRRH and RARH groups (91.6% vs 89.2%, $P = .467$; Log-rank test); B: Cumulative disease-free survival rate during a 3-year interval in the in the TRRH and RARH groups (81.4% vs 77.2%, $P = .551$; Log-rank test). RARH = robotic-assisted right hemicolectomy, TRRH = totally robotic right hemicolectomy.

technique.[21,22] The twist of the mesentery is a well-known and well-described event that can occur when extracorporeal anastomosis is carried out without direct vision of the bowel orientation. The results described in this study agree with those described in other studies. We observed 3 twists of mesentery in the RARH group, and none in the TRRH group.

To date, there have been few studies aimed to compare long-term survival outcomes of TRRH and RARH. The results described in this study suggest that there exists no significant difference in the 3-year overall survival and the disease-free survival of TRRH and RARH. However, the time of follow-up used in this study was relatively short. Therefore, it could be assumed that the prognosis is similar in both groups. Further work will be carried out to continue to follow up this data in order to obtain more comprehensive and accurate data.

In comparison with RARH ileocolic anastomosis, TRRH ileocolic anastomoses were found to have the following potential advantages[13,23]:

(1) the creation of the anastomosis in full view could function to reduce unrecognized twisting of mesentery;
(2) anastomosing away from the abdominal wall could function to reduce wound infection rates;
(3) the shorter surgical incision resulted in reduced postoperative pain and a lower incision infection rate;
(4) because the surgeon's hand does not enter the abdominal cavity and touch the intestine, adhesive bowel obstruction rates could be reduced; and
(5) there is no requirement for the mobilization of the transverse colon to reach the abdominal wall, allowing for anastomosing in the abdominal cavity.

The following potential disadvantages[13,23]:

(1) surgeon must be skilled in the art of intra-abdominal suture and knotting;
(2) the longer operative time increases indirect cost and could potentially result in higher complication rates;
(3) allowing anastomosing in the abdominal cavity could result in increased intra-abdominal infection rates.

This study possesses some limitations.

(1) it was a retrospective cohort study which depended on medical record documentation;
(2) it was a small study, and the operation was carried out by a single experienced surgeon in 1 medical center;
(3) the findings described here may lack generalizability due to the relatively short median follow-up time.

In conclusion, results from this study suggest that TRRH with CME represents a technically feasible and safe procedure that yields comparable short- and long-term outcomes to RARH. However, studies examining long-term effects in prospective randomized multicenter clinical trials must be carried out.

Author contributions

Conceptualization: Dongning Liu, Jieming Li, Taiyuan Li.
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Supervision: Taiyuan Li.
Validation: Jieming Li.
Writing – original draft: Jieming Li.
Writing – review and editing: Dongning Liu.
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