


Security and Radical Assessment in Open, Laparoscopic, Robotic Colorectal Cancer Surgery: A Comparative Study

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Abstract

Purpose: This retrospective study was designed to assess the safety and effectiveness of open, laparoscopic, robotic colorectal cancer surgery. **Methods:** Three hundred patients with colorectal cancer who underwent curative resection in the First Affiliated Hospital of Zhengzhou University between February 2014 and May 2016 were included. Patients were classified into open surgery group, laparoscopic surgery group, and robot-assisted group. **Results:** The blood loss in laparoscopic surgery group was less than that in open surgery group, and the blood loss in robot-assisted group less was than the open surgery group. The number of lymph node dissection in robot-assisted group was significantly larger than that in the open group ($P < .05$). The distance between the lower edge of the tumor group and the distal margin in robotic group was longer than that of the laparoscopic surgery group and the open group ($P < .05$). Three (2.8%) cases of urinary retention occurred in the open surgery group, 4 (3.92%) cases in the laparoscopic surgery group, and 1 (1.1%) case in the robot-assisted group, while 2 (1.87%) cases of sexual dysfunction occurred in the open surgery group, 2 (1.96%) cases in the laparoscopic surgery group, and 1 (1.1%) case in the robot-assisted group. The urinary retention and sexual dysfunction rate did not differ between the 3 groups ($P > .05$), but the minimally invasive group showed a certain advantage over the open group. **Conclusion:** Compared to the traditional open surgery, minimally invasive surgery (especially in robot-assisted group) has advantages such as less intraoperative bleeding, rapid postoperative recovery, and radical cure; open group, laparoscopic surgery group, and robot-assisted group have a similar incidence of postoperative complications, but reduction in the incidence of anastomotic leakage and intestinal obstruction. Robot-assisted group has the potential advantage for pelvic autonomic nerve protection.

Keywords

colorectal cancer, open surgery, laparoscopic surgery, robotic surgery, comparative study, total mesorectal excision

Abbreviations

CRC, colorectal cancer; LAP, laparoscopic surgery group; MRI, magnetic resonance imaging; OS, open surgery group; RAP, robot-assisted group; TME, total mesorectal excision

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Introduction

Colorectal cancer (CRC) is the fifth most common cancer and the third leading cause of cancer-related death in the world.¹ Total mesorectal excision (TME), which involves complete removal of the mesorectal envelope en bloc with the rectum, is considered as a prerequisite procedure because it decreases

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Table 1. Baseline Demographic and Clinical Pathological Features.

	Open (n = 107)	Laparoscopic (n = 102)	Robotic (n = 91)	Statistic Value	P Value ^a
Gender, n (%)				2.905	.234
Male	62 (57.9%)	61 (59.8%)	44 (48.4%)		
Female	45 (42.1%)	41 (40.2%)	47 (51.6%)		
Age (years)	60.22 ± 11.42	59.09 ± 11.61	59.98 ± 13.50	0.249	.780
BMI (kg/m ²)	23.15 ± 1.61	22.73 ± 1.93	22.98 ± 1.90	1.423	.243
TNM stage, n (%) ^b				5.330	.502
I	18 (16.8%)	27 (26.5%)	24 (26.4%)		
II	46 (43.0%)	36 (35.3)	30 (33.0%)		
III	42 (39.3%)	39 (38.2)	36 (39.6%)		
IV	1 (0.9%)	0 (0%)	1 (1.1%)		
Tumor general type, n (%)				4.996	.288
Ulcer	83 (77.6%)	84 (82.4%)	66 (72.5%)		
Mass	22 (20.6%)	17 (16.7%)	25 (27.5%)		
Infiltration	2 (1.9%)	1 (1.0%)	0 (0%)		
Differentiation degree, n (%)				3.333	.504
High	2 (1.9%)	1 (1.0%)	4 (4.4%)		
Media	91 (85.0%)	91 (89.2%)	78 (85.7%)		
Low	14 (13.1%)	10 (9.8%)	9 (9.9%)		
Tumor location, n (%)				8.105	.231
Low rectum	12 (11.2%)	22 (21.6%)	10 (11.0%)		
Media rectum	60 (56.1%)	51 (50.0%)	44 (48.4%)		
High rectum	16 (15.0%)	14 (13.7%)	19 (20.9%)		
Sigmoid	19 (17.8%)	15 (14.7%)	18 (19.8%)		
Tumor size (cm)	4.28 ± 2.11	3.85 ± 1.43	3.98 ± 1.69	1.638	.196
Lymphatic metastasis, n (%)				0.119	.942
Yes	42 (39.3%)	39 (38.2%)	37 (40.7%)		
No	65 (60.7%)	63 (61.8%)	54 (59.3%)		
Distant metastasis, n (%)				1.057	.589
Yes	1 (0.9%)	0 (0%)	1 (1.1%)		
No	106 (99.1%)	102 (100%)	90 (98.9%)		
Perineural invasion, n (%)				4.789	.091
Yes	3 (2.8%)	5 (4.9%)	9 (9.9%)		
No	104 (97.2%)	97 (95.1%)	82 (90.1%)		
Vascular invasion, n (%)				1.580	.454
Yes	4 (3.7%)	5 (4.9%)	7 (7.7%)		
No	103 (96.3%)	97 (95.1%)	84 (92.3%)		
Neoadjuvant chemotherapy, n (%)				0.431	.806
Yes	7 (6.5%)	8 (7.8%)	5 (5.5%)		
No	100 (93.5%)	94 (92.2%)	86 (94.5%)		

Abbreviations: BMI, body mass index; TNM, tumor node metastasis.

^aAll parameters were compared using Pearson χ^2 .

^bClinical cancer staging according to the American Joint Committee on Cancer (7th ed, 2010).

local recurrence to as low as 4% to 6%.²⁻⁴ Due to the confined space in the pelvis and the limitations of existing laparoscopic instruments, conventional laparoscopic surgery for rectal cancer is technically more difficult than colonic resection. Robotic surgery using the da Vinci S surgical system should overcome the limitations of conventional laparoscopic surgery group (LAP).^{5,6} However, it is difficult to conclude whether robot-assisted group (RAP) leads to better outcomes because few studies have directly compared the 3 existing techniques. To the best of our knowledge, we compared the short-term outcomes in patients treated for rectal cancer with open, LAP, or RAP to determine whether the robotic technique offers any advantages compared to other conventional procedures.

Methods

Data Extraction

From November 2014 to August 2016, three hundred consecutive resections for rectal adenocarcinoma were performed by 1 of 3 board-certified colorectal surgeons at First Affiliated Hospital of Zhengzhou University. The disease extent was assessed by clinical examination, colonoscopy, chest radiography, chest and abdominopelvic computed tomography, pelvic magnetic resonance imaging (MRI), endorectal ultrasonography, and computed tomography/positron emission tomography. Patients with clinical stage III or T4 cancers was principally indicated by preoperative chemoradiotherapy (CRT) but was ultimately determined by the surgeon. Pelvic

MRI and/or endorectal ultrasound were applied to assess T stage and lymphonode metastasis of CRC to make sure necessity of preoperative CRT. Besides, MRI was performed to evaluate pelvic organ tissue structure for precision surgical strategy. After 6 months of CRC radical surgery, imaging (computed tomography or MRI) examination was carried out to assess the recurrences or metastasis of CRC to guide treatment. After 12 months of CRC radical surgery, enteroscopy examination was applied to evaluate recurrence situation. Each time, serum tumor markers CEA, AFP, CA-199, CA-724, and CA-125 were detected to assess the treatment effects and recurrences or metastasis of CRC. Exclusion criteria were cancer with intestinal obstruction or perforation, local tumors that were resectable via transanal access, adjacent organ invasion requiring en bloc multiorgan resections, or distant metastasis. Internal review board approval and written informed consent from each patient were obtained. The choice among the 3 different surgical approaches was based on a joint decision by the patients and physicians, and all the patients selected to undergo one of the procedures were suitable for the other 2 surgical approaches. Functional outcome measures such as the International Prostate Symptom Score, International Index of Erectile Function (IIEF), and the Female Sexual Function Index were analyzed to evaluate voiding and sexual function.

Ethics Approval and Consent to Participate

The study was reviewed and approved by the [the First Affiliated Hospital, Zhengzhou university] institutional review board.

Chemotherapy Scheme

Neoadjuvant chemotherapy was carried out in patients with CRC of high-risk II stage and III stage. The first-line adjuvant or neoadjuvant chemotherapy scheme was FOLFOX6 or CapeOX, while the second-line adjuvant chemotherapy scheme was FOLFIRI or CapeOX. Objectively, 40% of patients met the indications for neoadjuvant chemotherapy. However, some patients did not undergo neoadjuvant chemotherapy for multiple reasons, mainly because a few patients refused to accept neoadjuvant chemotherapy.

Outcome Variables

Intraoperative condition and radical degree of operation: (1) Intraoperative condition included surgical time, intraoperative bleeding; radical degree of operation included cleaning lymphatic number and tumor low edge from the incisional margin. (2) Postoperative functional restoration: postexhaust time and posthospital stay. (3) Postoperative complications: urinary dysfunction and sexual dysfunction, incision infection, intestinal obstruction, anastomotic bleeding, anastomotic fistula, thrombosis, and cardiopulmonary complications.

Surgical Technique

All surgeries were performed by the same surgical team. Both the surgeon and the nurse studied and obtained a certificate at the Robinson Training Center, Prince of Wales, Hong Kong. All patients were routinely prescribed for preoperative bowel preparation and treated according to the TME or complete mesocolic excision principles.

A standardized medial to lateral approach was used during the study period. High ligation of the inferior mesenteric artery was performed in most cases, and the inferior mesenteric vein was divided beneath the pancreas. Sharp pelvic dissection was performed using either monopolar coagulation or ultrasonic energy devices. Dissection was performed to the pelvic floor, and an assessment was made whether a double-stapled anastomosis was possible. In the case of a double-stapled anastomosis, the rectum was transected with the endoscopic staplers, and the specimen was retrieved through a suprapubic incision in most cases. An intracorporeal anastomosis was performed with transanal insertion of a circular stapler. The anastomosis was checked by transanal insufflation of air. In the later stage of the study, colonoscopy was performed to assess the integrity of the anastomosis. When the transverse stapler could not be applied with an adequate margin below the tumor, transanal resection and coloanal hand-sewn anastomosis were performed. A diversion stoma was created in patients with neoadjuvant radiation, difficult pelvic dissection, a positive air leakage test, the presence of incomplete doughnuts, or an anastomosis within 5 cm from the anal verge.

The surgical indications are relative. Minimally invasive surgery is particularly beneficial when working in the deep pelvis. However, minimally invasive surgery cannot be applied for cancer with intestinal obstruction or perforation, obesity, and extensive abdominal adhesions.

Statistical Analysis

Physical and clinical pathological variables in the three groups were compared by cross-table analysis using Pearson's χ^2 test and Fisher's exact test with two-sided verification or an unpaired Student's t test and an analysis of variance (ANOVA) test, as appropriate (all $P > 0.05$; Table 1). Potential variables were verified by multivariate analysis using binary logistic regression. Survival outcomes and recurrences were compared using the Kaplan-Meier method with the log-rank test. Statistical significance was set at $P < .05$. All analyses were carried out using the SPSS software (version 21; SPSS Inc, Chicago, Illinois).

Results

Intraoperative Condition and Radical Degree of Operation in Open, LAP, and RAP

The open group, LAP, and RAP were successfully operated. The operation time of open group was longer than that of LAP, and the operation time of RAP was longer than that of open group and LAP ($P < .05$). The blood loss during surgery of LAP

Table 2. Comparison of Intraoperative Situation and Radical Degree in Open, Laparoscopic, and Robotic Surgery.

	Surgical Time, minute	Statistic Value	P Value	Intraoperative Bleeding, mL	Statistic Value	P Value	Cleaning Lymphatic Number	Statistic Value	P Value	LEFIM	Statistic Value	P Value
Open ^a	148.89 ± 23.20	46.826	<0.001	205.74 ± 45.12	155.599	<0.001	10.67 ± 5.62	3.261	0.040	3.60 ± 1.00	3.478	0.032
Laparoscopic ^b	135.41 ± 21.34	4.364	<0.001	146.16 ± 40.36	10.046	<0.001	11.96 ± 10.51	1.111	0.268	3.66 ± 1.31	0.378	0.706
Robotic ^c	169.09 ± 28.12	9.430	<0.001	104.45 ± 35.30	7.600	<0.001	13.53 ± 6.44	1.230	<0.001	3.98 ± 0.88	1.988	0.048
		5.538	<0.001		17.366	<0.001		13.702	<0.001		20.615	<0.001

Abbreviation: LEFIM, the tumor low edge from the incisional margin.

^aLaparoscopic vs Open.

^bRobotic vs Laparoscopic.

^cRobotic vs Open.

was less than the open surgery (OS) group (146.16 ± 40.36 mL vs 205.74 ± 45.12 mL), and the blood loss during surgery of RAP was less than the OS group (104.45 ± 35.30 mL vs 146.16 ± 40.36 mL; $P < .05$). The mean number of retrieved lymph nodes did not differ between the LAP and the RAP ($P = 1.230$), but the mean number of retrieved lymph nodes in the RAP was more than that in the open group ($P < .05$). The mean distal resectionmargin (DRM) did not differ between the open and LA groups ($P > .05$), while it was a little longer in the RAP than in the open and RAP ($P < .05$; Table 2).

Postoperative Outcomes in Open, Laparoscopic, and Robotic Colorectal Cancer Surgery

The mean hospital stay in the LAP and RAP was longer than that in the open group ($P < .05$), and the mean hospital stay in the RAP was longer than that in the LAP ($P < .05$); for the time of postoperative exhaust, the discharge time of the minimally invasive group (laparoscopic group and robot group) was earlier than that of the open group, and the robot group was earlier than that of the endoscopic group, with a statistically significant difference ($P < .05$; Table 3).

Complications in Open, Laparoscopic, and Robotic Colorectal Cancer Surgery

The total postoperative complications of open group, LAP, and RAP were 16.82% (18/107), 12.75% (13/102), and 7.69% (7/91), respectively. There was no significant difference between the 2 groups ($P > .05$). In open group, LAP, and RAP, there were 2 (1.9%) cases, 1 (1%) cases, and 0 case of incision infection respectively, while patients with postoperative intestinal obstruction were 5 (4.7%) cases, 3 (2.9%) cases, and 2 (2.2%) cases, respectively. However, there was no statistically significant difference in incision infection and intestinal obstruction among the 3 groups (all $P > .05$), and the incidence rate in the 3 groups showed a decreasing trend.

Protection of Pelvic Autonomic Nerve

In the neurological protection of the plant, the postoperative voiding dysfunction in the open group, LAP, and RAP was 2.80% (3/107), 3.92% (4/102), and 1.10% (1/91) respectively, and the sexual dysfunction was 1.87% (2/107), 1.96% (2/102), and 1.10% (1/91), respectively. There was no significant difference in urinary function and sexual dysfunction between the 3 groups ($P > .05$), but the minimally invasive group showed a certain advantage compared to the open group.

Discussion

Traditional OS is the classic surgical approach to the treatment of CRC. With the development and popularization of minimally invasive techniques, laparoscopic techniques have

Table 3. The Postoperative Functional Restoration and Complications in Open, Laparoscopic, and Robotic Surgery.

	Open (n = 107)	Laparoscopic (n = 102)	Robotic (n = 91)	Statistic Value	P Value
Postexhaust time, d	3.42 ± 0.52	2.85 ± 0.37	2.52 ± 0.37	111.610 ^a	<.001
				9.095 ^b	<.001
				6.146 ^c	<.001
				3.330 ^d	.001
Posthospital stay, d	13.37 ± 2.06	9.25 ± 2.47	7.26 ± 2.10	197.946 ^a	<.001
				13.114 ^b	<.001
				5.990 ^c	<.001
				2.857 ^d	.005
Postcomplications, n (%)	18 (16.82%)	13 (12.75%)	7 (7.69%)	3.707	.157
Anastomotic bleeding	0	0	0	–	–
Stomal leak	3 (2.80%)	3 (2.94%)	2 (2.20%)	0.114	.944
Incision infection	2 (1.87%)	1 (0.98%)	0 (0%)	1.736	.420
Intestinal obstruction	5 (4.67%)	3 (2.94%)	2 (2.20%)	1.009	.604
Thrombus	1 (0.93%)	0	0	1.810	.405
Cardiopulmonary complications	1 (0.93%)	0	0	1.810	.405
Voiding dysfunction	3 (2.80%)	4 (3.92%)	1 (1.10%)	1.488	.475
Sexual dysfunction	2 (1.87%)	2 (1.96%)	1 (1.10%)	0.260	.878

^aComparison of 3 groups.

^bLaparoscopic versus open.

^cRobotic versus laparoscopic.

^dRobotic versus laparoscopic.

been widely accepted due to the advantages of small trauma, rapid postoperative recovery and postoperative pain, and is gradually replacing traditional OS.^{7,8} The robotic approach has been expected to be relevant to rectal cancer because the robotic interface is specifically suited for procedures in confined space,⁹ while its safety and feasibility in the treatment of rectal cancer are uncertain. Our study aims to compare the 3 surgical approaches for rectal excision in a single institution.

In our study, we demonstrated that RAP has several advantages over the conventional open and laparoscopic approach. First, the 3-dimensional imaging, fixed third-arm retraction, and endowristed movements are particularly beneficial when working in the deep pelvis. Meanwhile, the camera platform is stable because it is operated directly by foot pedal in a console and does not rely on an unstable assistant. Second, robotic surgery system transposes fingers to the instrument tips, eliminates hand tremor, has ambidextrous capability, and can scale motion. Therefore, RAP is more minimally invasive and less bleeding than LAP, and robotic surgery is more suitable for protecting autonomic nerves. The abovementioned advantages of robotic surgery have been reported by multiple centers.¹⁰⁻¹² Third, robotic systems are considered to provide a better operative performance to aid surgeons.^{13,14} As the initial few cases in the robotic group were used to standardize the technique for robotic TME, the mean operating time was longer in RAP.¹⁵

With the development of laparoscopic technology, the absolute indications for CRC surgery will gradually decrease.¹⁶ For example, extended radical surgery of CRC was the absolute indications in the past and it is not indication or called relative indication.¹⁷ There are still some absolute indications, such as serious abdominal adhesion, severe cardiopulmonary disease, and severe hemorrhage.¹⁸

For open CRC surgery, the absolute indications mentioned above will be applied to this type of surgery. However, compared to the abovementioned 2 kinds of minimally invasive surgery, OS is performed through naked eye and more likely to hurt some organizational structures, such as pelvic nerves and blood vessels.¹⁹

Above all, with the development of surgical technology, minimally invasive surgery gradually became popular in treating patients with CRC, especially for robotic surgery.

The mean number of retrieved lymph nodes and the mean DRM are the important criteria for judging whether the tumor will be cured. The number of lymph nodes in the 3 groups of patients was gradually increased, and the number of lymph nodes in LAP and the open group was similar, while the number of lymph node dissection in RAP was significantly higher than that in the open group. Recent study demonstrated that the overall quality of the resected specimen did not differ between the open group and RAP.^{20,21}

Postoperative exhaust time, postoperative hospital stay, is an important indicator of postoperative recovery of patients. Compared to the traditional OS, minimally invasive surgery has the advantages of early postoperative exhaust time and short hospitalization, with minimally invasive surgery patients recovering faster after surgery than OS. Its advantages become more obvious when it is done in the robot technology. There are also literature proving that robotic surgery can shorten hospital stay and accelerate postoperative rehabilitation.²²⁻²⁴ Compared to the traditional open dissection level, laparoscopic surgery has a clearer vision and can effectively protect the blood vessels, with small postoperative incision, which is also conducive to patients with postoperative recovery. As a more advanced laparoscopy, robotic surgery can make the operation more

sophisticated and the patients' postoperative intestinal function and urinary function recovery were faster.

The open group, LAP, and RAP had similar overall postoperative morbidity. The incidence of anastomotic bleeding, thrombus, and cardiopulmonary complications were similar in the 3 groups. In the aspect of postoperative wound infection and intestinal obstruction, due to the smaller sample size, there was no significant difference between the 3 groups, but the proportion of patients with complications decreased gradually. Studies have shown that the incidence of postoperative intestinal obstruction in RAP was lower than that in open group and LAP.^{25,26} We can continue to expand the sample size for further observation and analysis.

The main limitation of the present study is its single center and the relatively small number of patients in the RAP group. Meanwhile, the current study did not include a comparative economic analysis of the 3 surgery procedures. At present, robotic surgery is more expensive than the conventional approach by 25%, the main barrier to popularize adoption of robotic colorectal surgery lies in its high cost.²⁷ In terms of the short-term outcomes, the differences between RAP and LAP might be insufficient to justify the high cost related to the use of new technology. Therefore, long-term oncological and functional outcomes should be evaluated to compare different surgical procedures in a future controlled study.

Conclusions

Our study showed that robot-assisted surgery may be a good alternative to conventional open or laparoscopic surgery for rectal cancer in terms of immediate postoperative recovery and morbidity. However, there was no evidence of clinical benefits to robotic rectal excision compared to the traditional laparoscopic approach when performed by an established laparoscopic colorectal oncologist. In terms of clinical perspective, the effective preservation of autonomic nerves contributes to improving the postoperative quality of life. Although there exists no statistical difference between 3 surgery groups in voiding dysfunction and sexual dysfunction, the robotic surgery has the potential to protect pelvic nerves because of the 3-dimensional view, scale motion, and elimination of hand tremors. Perhaps, the sample size was not big enough or prospective randomized trials are needed to further evaluate the outcomes.

Authors' Note

Written informed consent was obtained for each participant, and the study was reviewed and approved by the [the First Affiliated Hospital, Zhengzhou university] institutional review board.


Declaration of Conflicting Interests


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