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Robotic versus laparoscopic rectal resection surgery: Short-term outcomes and complications: A retrospective comparative study

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ABSTRACT

Background: The safety of robotic-assisted surgery (RAS) remains a concern. This study aimed to compare the complications after RAS versus laparoscopic-assisted surgery (LAS) for rectal cancer using the Clavien–Dindo classification and to identify risk factors related to the complications.

Method: Between March 2010 and June 2016, 556 rectal cancer patients who underwent successful RAS and 1029 patients who received LAS were enrolled in this study. The complications were graded according to the Clavien-Dindo classification, and the possible risk factors related to the complications were analyzed.

Results: The overall postoperative complication rate was 14.9%, with a 5% rate of severe complications that were classified as grade III or above in RAS group compared with 17.1% and 4.4% in LAS group. However, no significant difference was found ($P = 0.608$). A high ASA score was identified as an independent risk factor for overall and severe complications in both groups. The use of more than 3 staples in each operation and the anastomotic site of the anal verge at less than 5 cm were independent risk factors for complications.

Conclusions: RAS for rectal cancer is technically safe and it does not significantly improve the complication rate. The incidence of overall complications is still related to tumor location, the general condition of the patients, and the surgical approach.

1. Introduction

Colorectal cancer is one of the most common digestive system malignancies worldwide [1]. The preferred treatment for colorectal cancer is radical surgery, and minimally invasive surgery options for colorectal diseases were introduced in 1991 [2]. Laparoscopic surgery (LAS) for rectal cancer is gradually becoming increasingly popular and has become the new standard treatment [3,4]. LAS provides better vision and operational flexibility in a narrow pelvic space compared with open surgery; therefore, laparoscopic treatment is more conducive to lower rectal cancer than open surgery [5]. However, this technology suffers from limitations, including ergonomic discomfort for the surgeon, a decreased range of instrument movement, 2-dimensional vision, unavoidable physiological tremors, and unstable camera platforms [5], thus hindering the promotion of LAS.

The emergence of robotic surgical systems is expected to help overcome these technical drawbacks. Robotic-assisted surgery for use in colorectal cancer was first reported in 2002 [6]. Since then, many studies have been conducted on the use of robotic-assisted rectum surgery [7–9]. The Da Vinci® surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) provides a stable 3-dimensional visualization. The convenient movements of the robotic arm (7° of freedom, 180° articulation, and 540° rotation) provide advantages, such as reduced physiological tremors, superior dexterity, and far greater ergonomic comfort [10,11].

The short-term outcomes of RAS for rectal cancer compared with LAS surgery have been confirmed in several studies [12,13]. However, reports focusing on the complications of robotic surgery in rectal cancer are lacking. Most of these reports do not consider the severity of each complication or classify it by criteria of the specification. Moreover, large sample research works and systematic analysis are lacking.

In our center, we have completed more than 600 robotic-assisted rectal cancer surgeries since 2010 and more than 1000 conventional laparoscopic surgeries in the same time period. We carried out a retrospective analysis of patients who were undergoing laparoscopic or robotic-assisted radical resection for rectal cancer, focusing on complications based on large samples, assessing the complications of robotic surgery using the Clavien–Dindo classification, and identifying related risk factors.

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Table 1
Eligibility criteria.

Inclusion Criteria
Age older than 20 and younger than 90 years
Primary rectal adenocarcinoma confirmed pathologically by endoscopic biopsy preoperation
cT < 4a, and circumferential margin > 1 mm confirmed by MRI in subgroups tumor below peritoneal reflection
Rectal tumor was R0 resected
ASA class I, II, or III
Written informed consent
Exclusion Criteria
Clinical or radiological evidence of metastatic spread
Severe mental disorder
Other malignant disease within the past 5 years
Cerebral vascular accident in past 3 months
Ahead of discharged patients

2. Materials and methods

From March 2010 to June 2016, more than 600 patients underwent RAS for rectal cancer using the da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) in our center. We included 556 robotic resections and compared them to 1029 laparoscopic resections from the same time period. Eligibility criteria are listed in Table 1.

Each patient was diagnosed with rectal adenocarcinoma preoperatively by colonoscopy examination and then confirmed by biopsy. Tumor staging should be classified by computed tomography (CT) and magnetic resonance imaging (MRI). Endoscopic ultrasonography was not routinely used. RAS or LAS was selected by the patients after providing informed consent following an explanation of the advantages, disadvantages, and all possible outcomes of RAS and LAS in detail. RAS was technically feasible and more beneficial than LAS if the tumor was located within a confined space, such as in rectal cancer; however, the disadvantages were higher cost and longer operation time (including docking time) than LAS [14], the main differences were shown as table list to patients. All of the 6 surgeons were certified of professional robotic surgical training and experienced on laparoscopic or robotic total mesorectal excision (TME) operation. All clinical and intraoperative data were collected. The results of the pathological data were classified according to the new TNM classification of American Joint Committee on Cancer (AJCC 8th edition) [15]. Postoperative complications were recorded and graded using the Clavien–Dindo classification [16]. This study was approved by the ethics committee of the First Affiliated Hospital of Third Military Medical University, PLA. All participants provided written agreement allowing the use of their clinical records.

2.1. Surgical procedures

TME was employed in most cases. The robot was a three-armed Da Vinci Si surgical system. The patients were positioned in a head-low position, and the layout of the trocars and total mesorectal excision steps of RAS were the same as that in our previous report [17]. After separation of the rectum, the robotic arms were undocked, the specimen was extracted through a 3–5 cm oblique minilaparotomy at the left lower quadrant in anterior resection cases, and then end-to-end anastomosis was completed using standard double stapling laparoscopy. For specimen retrieval through the perineal wound, the appropriate ostomy point was selected at the left lower quadrant, and colostomy was completed for abdominoperineal resection (APR) cases. The specimen was matched in the TME pathologic assessment (smooth surface, without incisions, defects or cracks of all mesorectal tissue) with photo evidence. We adopted transanal specimen extraction and colo-anal hand-sewn anastomosis in intersphincteric resection cases. Diverting ileostomies were performed simultaneously as previously described [17]. Additionally, diverting ileostomies were generally performed upon a surgeon's decision during the operation when the following criteria were met as discussed in our previous report [17]. The Hartmann approach performs sigmoid end colostomy at the left lower quadrant and reserves the distal rectum and anal canal.

2.2. Outcome measurements for surgical safety analysis

All complications were classified by pathogenesis. A specific complication was diagnosed on the basis of clinical evidence and auxiliary examination. Wound problems included wound healing, infection, dehiscence, and hernias. Abdominal inflammation, adjacent viscera damage, fistula, and anastomosis-related complications were confirmed by CT scans, ultrasonography, endoscopy, or angiography. Infection complications were confirmed by microbiological culture results. The severity of postoperative complications was assessed according to the Clavien-Dindo classification, with grade III or above considered to be a severe complication. Anastomotic leak was defined as an anastomotic event requiring surgical intervention or interventional radiology, including pelvic abscesses without radiological evidence of leakage and early rectovaginal fistulas [18]. The observation period was 30 days after surgery.

2.3. Statistical analysis

The $\chi 2$ test or Fisher exact test was used for comparisons of categorical variables, and a Student *t*-test or Wilcoxon signed rank test was used for comparisons of continuous variables. Univariate and multivariate logistic regression analyses were used to evaluate the risk factors that could affect postoperative complications. All statistical calculations were conducted using the statistical software SPSS19.0 for Windows (SPSS, Inc., Chicago, IL, USA). P values of less than 0.05 were considered statistically significant.

3. Results

3.1. Patient characteristics and surgery outcomes

The patient characteristics and pathology of the two groups are presented in Table 2. A total of 556 patients in RAS group and 1029 patients in LAS group were enrolled. No significant differences were noted in age, gender, BMI, histology, ASA, Tumor location, pT stage and pTNM stage between the two groups. The compliance rates of patient clinical-pathological characteristics were similar in both groups. The surgical outcome is presented in Table 3. In RAS group, a high anterior resection, low anterior resection (LAR), APR, and Hartmann operation were performed in 221 (39.7%), 191 (34.4%), 131 (23.6%), and 13 (2.3%) cases, and the corresponding data in LAS group were 491 (43.1%), 331 (29.8%), 269 (23.6%), and 40 (3.5%) cases, respectively. Among them, the LAR group that received RAS included 3 patients (0.5%) using the partial intersphincteric resection approach versus 10 patients (0.8%) in the LAS group. A total of 6 (1.0%) patients in the RAS group and 22 (1.9%) patients in LAS group underwent diverting ileostomies ($P = 0.196$) according to our criteria [17] (surgical procedures, step 10d). No significant approach difference was observed.

The mean surgical time of the RAS group was 37 min longer than that of the LAS group (222 v 185 min; $P < 0.01$) because RAS requires more time to dock and to dismantle the mechanical arms. The mean docking time was 17 min (range: 12–29 min). The longer operating time for RAS than LAS likely resulted from the initial learning curve. Conversion to open surgery was required in 6 cases (1.1%) that used RAS and 23 cases (2%) that used LAS, with no significant differences ($p = 0.161$). The mean number of harvested nodes in RAS group was 1.2 more than that of the LAS group (14.9 vs. 13.7, $P < 0.01$). No intraoperative complications occurred in either group. The mean distal margin from the anal verge was not significantly different between the

Table 2
Patient clinical and pathologic characteristics at baseline.

Patient charactaristics	Robotic assistant surgery (n = 556)				Laparoscopic surgery (n = 1139)				
	No.	%	Mean	SD	No.	%	Mean	SD	*P*
Age, years			57.0	11.9			58.0	11.8	0.111
Sex									0.921
male	347	62.4			708	62.2			
female	209	37.6			431	37.8			
BMI, kg/m2			23.3	3.1			23.0	3.1	0.093
ASA classification, n									0.206
1-2	542	97.5			1097	96,3			
3	14	2.5			42	3.7			
Tumor location, n									0.315
Above peritoneal reflection	238	42.8			517	45.4			
Below peritoneal reflection[a]	318	57.2			622	54.6			
Mean distance from anal (cm)			7.4	4.2			7.3	3.3	0.163
Distance from anal < 10 cm	396	71.2			772	67.8			0.083
Previous abdominal surgery									
No	487	87.6			965	84.8			0.114
Yes	69	12.4			174	15.2			
Preoperative distant metastasis	22	3.9			62	5.4			0.113
Preoperative adjuvant chemotherapy	15	2.7			44	3.8			0.219
Tumor size (cm)			4.4	2.3	4.2	2.6			0.873
CRM(+)	11	2.0			29	2.5			0.295
Pathologic T stage									0.49
< = T2	180	32.4			332	29.1			
T3	299	53.8			621	54.5			
T4a	70	12.6			174	15.3			
T4b	7	1.3			12	1.1			
Metastatic lymph node			1.5	3.2			1.4	3.1	0.842
pTMN stage									0.172
I	147	26.4			255	23.7			
II	199	35.8			429	37.1			
III	188	33.8			391	34.2			
IV	22	4			64	5.1			
Histology									0.886
Well/moderately differentiated	496	89.2			1022	89.7			
Others	60	10.8			117	10.3			

[a] Include parallel to peritoneal reflection.

two groups (3.6 cm vs. 3.5 cm, P = 0.152). The recovery course, the mean number of days until the first flatus, number of days eating a liquid diet, and the duration of hospitalization after the operation were not significantly different in both groups (all P > 0.05).

3.2. *Postoperative complications*

Table 4 shows all of the complications within 30 days postoperatively. No significant difference was found in the overall complication rate of 14.9% in RAS group and 17.1% in LAS group (P = 0.252). Among the complications, one patient died of multiple organ failure as a result of cardiovascular accident in LAS group. Wound problems,

Table 3
Surgical outcomes.

Outcome	Robotic assistant surgery (n = 556)				Laparoscopic surgery (n = 1139)					
	No.	%	mean	SD	No.	%	Mean	SD		*P*
Type of resection										0.16
HAR	221	39.7			491	43.1				
LAR (ISR)	191	34.4			339	29.8				
ISR	*3*	*0.5*			*10*	*0.8*				
APR	131	23.6			269	23.6				
Hartmann	13	2.3			40	3.5				
Ileostomy	6	1			22	1.9				0.196
Median operative time, min	222		222	57			185	54		< 0.01
Docking time, min			17	8.5			–	–		–
Blood loss (ml)			67.5	34.3			74	32.5		0.171
Intraoperative blood transfusion	20	3.6			48	4.2				0.543
Number of harvested nodes			14.9	5.3			13.7	5.9		< 0.01
Conversion	6	1.1			23	2.0				0.161
Distal margin from anal Verge (cm)			3.6	3.2			3.5	2.7		0.152
Time to first flatus, days			2.5	1.3			2.7	0.9	0.171	
Time to first liquid intake, days			2.7	0.9			2.8	1.0	0.093	
Length of postoperative hospital stay			11.4	5.7			10.9	4.1	0.067	

Table 4
Complications within 30 days postoperatively for RALS and LS Groups.

Postoperative complications	Robotic assistant surgery (n = 556)		Laparoscopic surgery (n = 1139)		P
	No	Rate(%)	No	Rate(%)	
Overall	83	14.9	195	17.1	0.252
Wound problem	20	3.6	68	5.2	0.039
Urinary tract infection	2	0.4	5	0.4	> 0.05
Urinary retention	1	0.2	1	0.1	> 0.05
Stress ulcer	0	0	1	0.1	> 0.05
Pulmonary	10	1.8	29	2.5	0.335
Liver dysfunction	2	0.4	3	0.3	> 0.05
Intraluminal bleeding	1	0.2	2	0.2	> 0.05
Intra-abdominal abscess	1	0.2	1	0.1	> 0.05
Intestinal fistula	0	/	1	0.1	> 0.05
Injury of urinary system	1	0.2	5	0.4	> 0.05
Infection via catheter	4	0.7	5	0.4	> 0.05
Ileus	7	1.3	9	0.8	> 0.05
Cerebrovascular	1	0.2	0	0	> 0.05
Enterocolitis	0	0	4	0.4	> 0.05
Cardiac	0	0	3	0.3	> 0.05
Anastomosis leakage	28	6.8	46	5.5	0.379
Anastomosis bleeding	2	0.5	5	0.6	> 0.05
Others[a](fever)	3	0.5	7	0.6	> 0.05
Clavien-Dindo classification					0.385
I	16	2.9	56	4.9	
II	39	7.0	89	7.8	
IIIa	9	1.6	18	1.6	
IIIb	6	1.1	16	1.4	
IVa	8	1.4	10	0.9	
IVb	5	0.9	5	0.4	
V	0	0	1	0.1	
Severe grade (III-V)	28	5	50	4.4	0.551

[a] e.g Unexplained transient fever.

pulmonary complications, anastomosis leakage, and bleeding were the most common complications. The RAS group showed a significantly lower incidence of wound problems (3.6% vs. 5.2%, P = 0.039) compared with the LAS group. A total of 28 patients (6.8%) in RAS group (412 cases) and 46 patients (5.5%) in LAS group (830 cases) experienced anastomotic leakages, with no statistically significant difference between the two groups (p = 0.379). All complications were classified using the Clavien-Dindo classification, and the distribution of severity was similar between the two groups (P = 0.385). We emphasize that 7 patients in the RAS group and 15 patients in the LAS group experienced more than two complications, but only the high-grade complications were listed. With the severe complications classified as grade III or above, no statistically significant difference was observed between the two groups (5% vs. 4.4%, P = 0.551). Furthermore, 11 patients (2%) experienced a repeat of anesthesia surgery in RAS group, which included 8 anastomotic leakages cases, 2 anastomotic bleeding, and 1 internal hernia. Twenty (1.8%) patients in LAS group experienced second operation, which included 13 anastomotic leakage patients, 2 anastomotic bleeding patients, 2 disruption of wound case patients, 2 urinary tract trauma patients, and 1 intra-abdominal abscess patient. The rates (P = 0.748) of repeat surgery were not significantly different between the two groups.

3.3. *Risk factors for postoperative complications*

The results of the analysis of risk factors are shown in Tables 5 and 6. Our results suggest that the risk factors for complications in both groups were similar. Overall and severe complications after RAS or LAS correlated significantly with ASA score (1–2 or ≥3, all $P < 0.05$) and with the number of linear cut staples (1–3 or ≥4, all $P < 0.05$) that were used for a transected rectum. Given that the number of staples used in APR and Hartmann subgroups was less than those that were used on patients who required one-stage anastomosis, we specifically excluded patients who underwent colostomy. In 412 patients in RAS subgroup and 830 patients in LAS subgroup who underwent anastomosis, including ileostomy patients, the number of linear cut staples and the ASA score also affected the incidence of overall and severe complications in both groups (all $P < 0.05$). Moreover, the anastomotic site from the anal verge was also related to the complications (< 5 or ≥5 cm) in both subgroups (all $P < 0.05$). Factors with significant differences ($P < 0.05$) in the univariate analysis were selected as covariables in the multivariate logistic regression analysis. We further confirmed that a high ASA score was the independent risk factor for a high postoperative complication rate in the RAS group (overall: odds ratio 6.051; 95% CI, 1.875–19.529; P = 0.009; severe: odds ratio 17.097; 95% CI, 4.279–68.305; $P < 0.001$) and LAS group (overall: odds ratio 3.156; 95% CI, 1.658–6.003; $P < 0.001$; severe: odds ratio 5.91; 95% CI, 2.578–13.549; $P < 0.001$). In subgroups of patients with stage one anastomoses, the multivariate logistic regression analysis also identified that the number of linear staples was ≥4 in RAS group (overall: odds ratio 2.646; 95% CI, 1.371–5.102; P = 0.004; severe: odds ratio 4.049; 95% CI, 1.645–9.901; P = 0.002) and the LAS group (overall: odds ratio 5.296; 95% CI, 3.026–9.268; $P < 0.001$; severe: odds ratio 4.322; 95% CI, 1.867–9.997; P = 0.001). Moreover, anastomoses from anal verge < 5 cm were also independent predictors of a high postoperative overall and severe complication rate in RAS group (overall: odds ratio 2.295; 95% 1.557–5.496; P = 0.001; severe: odds ratio 4.762; 95% CI, 1.583–14.327; P = 0.005) and the LAS group (overall: odds ratio 3.609; 95% 2.385–5.462; $P < 0.001$; severe: odds ratio 6.032; 95% CI, 2.603–13.976; $P < 0.001$).

4. Discussion

Robotic procedures may induce less blood loss, technical feasibility for lateral lymph node dissection, low intraoperative conversion rate [4,19,20], long operation time, and high cost. However, concerns for postoperative complications are less, which usually leads to increased length of hospital stays and increased painful patient experiences. The rate of complication is also an important indicator for measuring the operative quality. In our study, we adopted the well-standardized system known as the Clavien–Dindo classification to analyze the rate of complications and the influencing factors.

The distribution of patient characteristics showed no difference between the two groups. Compared with other centers, the composition of the patients included the following features: 1) more middle or low tumor location (distance from anal verge < 10 cm in the RAS group (71.2%) vs. the LAS group (67.8%); 2) more cases with clinical stage II or III (RAS group 69.6% vs. LAS group 71.3%); and (3) somewhat lower ratio of neoadjuvant chemoradiotherapy in our center (2.7% in the RAS group and 3.8% in the LAS group). In our study, only those who were suspected or confirmed with existing positive CRM by a preoperative MRI underwent neoadjuvant therapy, and the patients who were included in this study mainly exhibited stages T1, 2 and 3, fitting this criteria. Only 59 patients underwent preoperative chemoradiotherapy in our series. The low ratio of chemoradiotherapy was due to poor compliance and high cost in Western China. The latest ESMO guideline shows a low risk of local recurrence if the surgeon routinely carries out good-quality TME and removes the mesorectal nodes [21] for mid- or low locally advanced rectal cancers.

In the present study, the overall and severe complication (graded Clavien-Dindo III–IV) rates were 14.9% and 5% in RAS group, which was similar to the LAS group (17.1% and 4.4%), respectively. Recently, Park et al. an overall morbidity of 29.3% and a severe complication morbidity of 9.8% in the RAS group in a case-match study (n = 82) [10]. Baek et al. reported that the postoperative overall complication rate was 22.0% in a case-matched study [20]. Shiomi et al. reported

Table 5
Univariate analysis of risk factors.

Variables	Robotic assistant surgery (n = 556)				Laparoscopic surgery (n = 1139)			
	Complications (%)	p	Severe complications[a] (%)	p	Complications (%)	p	Severe complications (%)	p
Age (years)		0.812		0.644		0.783		0.213
< 65	65/421 (15.4)		23/421 (5.5)		127/732 (17.3)		28/732 (3.8)	
≥65	22/135 (16.3)		6/135 (4.4)		68/407 (16.7)		22/407 (5.4)	
Sex		**0.301**		0.052		0.72		0.981
male	55/340 (16.2)		22/340 (6.5)		119/708 (16.8)		31/708 (4.4)	
female	28/216 (13)		6/216 (2.8)		76/431 (17.6)		19/431 (4.4)	
BMI		0.233		0.516		0.458		0.363
< 25	57/394 (14.5)		19/394 (4.8)		143/859 (16.6)		35/859 (4.1)	
≥25	30/162 (18.5)		10/162 (6.1)		52/280 (18.6)		15/280 (5.4)	
ASA score		**0.004**		< 0.001		< 0.001		< 0.001
1–2	81/542 (14.9)		25/542 (4.6)		179/1097 (16.3)		42/1097 (3.8)	
≥3	6/14 (42.3)		4/14 (28/6)		16/42 (38.1)		8/42 (19.1)	
Previous abdominal surgery		0.526		0.817		0.863		0.062
No	78/487 (16)		25/487 (5.1)		166/965 (17.2)		47/965 (4.9)	
Yes	6/69 (8.7)		2/69 (2.9)		29/174 (16.7)		3/174 (1.7)	
TNM stage		0.243		0.12		0.493		0.541
I-II	59/346 (17.1)		22/346 (6.4)		113/685 (16.5)		28/685 (4.1)	
III-IV	28/210 (13.3)		7/210 (3.3)		82/454 (18.1)		22/454 (4.8)	
Operation time (min)		0.461		0.688		0.308		0.927
< 240	57/383 (14.9)		19/383 (5)		160/962 (16.6)		42/962 (4.4)	
≥240	30/173 (17.3)		10/173 (5.8)		35/177 (19.8)		8/177 (4.5)	
Blood loss		0.054		0.216		0.587		0.836
< 100	70/483 (14.5)		23/483 (4.8)		183/1078 (17)		47/1078 (4.4)	
≥100	17/73 (23.3)		6/73 (8.2)		12/61 (19.7)		3/61 (4.9)	
Staple		0.034		**0.001**		< **0.001**		**0.001**
1–3	67/488 (13.8)		19/488 (3.9)		169/1074 (15.7)		42/1074 (3.9)	
≥4	16/68 (23.5)		9/68 (13.2)		26/65 (40)		8/65 (12/3)	

Subgroups with one-stage anastomosis(LAR and HAR)								
Variables	**Robotic assistant surgery (n = 412)**				**Laparoscopic surgery (n = 830)**			
	Complications (%)	**p**	**Severe complications[a] (%)**	**p**	**Complications (%)**	**p**	**Severe complications (%)**	**p**
ASA score		**0.025**		0.09		< 0.001		< 0.001
1–2	48/402 (11.9)		19/402 (4.7)		179/1097 (16.3)		42/1097 (3.8)	
≥3	4/10 (40)		2/10 (20)		16/42 (38.1)		8/42 (19)	
Anastomotic from anal verge (cm)[a]		0.001		0.002		< 0.001		< 0.001
< 5	39/208 (18.8)		17/208 (8.2)		81/345 (23.5)		28/345 (8.1)	
≥5	15/204 (7.4)		4/204 (2)		38/485 (7.8)		7/485 (1.4)	
Staple		0.003		**0.001**		< **0.001**		< **0.001**
1–3	36/347 (10.4)		12/347 (3.5)		94/771 (12.2)		27/771 (3.5)	
≥4	16/65 (24.6)		9/65 (13.8)		25/59 (42.4)		8/59 (15.6)	

[a] Severe ≥ IIIa.

that the overall complication rate of RAS was 19.4%, including 2.7% severe complications [22]. As suggested above, the complication rate of our study was similar to the rates reported herein. David Jayne et al. reported on a multicenter randomized trial (ROLARR) about the outcome of robotic-assisted versus conventional laparoscopic rectal cancer resection and found that 15.0% exhibited an intraoperative complication, 14.8% in the conventional laparoscopic group and 15.3% in the robotic-assisted laparoscopic group (unadjusted risk difference = −0.5% [95% CI, −6.0%–7.0%]) did not differ significantly, which shows a relatively increased morbidity because the enrolled cases involved a high proportion of neoadjuvant therapy and low tumor location [23]. To match the study, we looked at data on the statistics of the subgroups that were in clinical stage II or III, within 12 cm from the anal verge, and with a severe complication rate (5.9% in RAS group vs. 3.5% in LAS group). Therefore, the overall and severe complication rates of RAS in our center were acceptable and comparable to LAS in this study.

The major complication from rectal cancer surgery is the anastomotic problem. Clinically significant anastomotic leakage occurs in 5%–20% of cases [19]. A previous randomized clinical trial reported that the overall clinical anastomotic leak rate was 7% (3% for clinically important grade III–IV leaks) [24]. Our results included 21 cases of anastomotic leakages and 2 cases of anastomosis bleeding in the RAS group, and 8 cases of anastomotic leakage and 2 anastomotic bleeding patients needed repeats of the anesthesia surgery (2.4% for C-D grade > III). The overall anastomotic problem rate was 6.3% (46 anastomotic leakages and 5 anastomotic bleeding cases) in the LAS group and 2.2% of patients (14 anastomotic leakages and 2 anastomotic bleeding cases) should be cured with secondary surgery (C–D grade > III). Our results showed no difference in the rate of anastomosis or secondary surgery between the two groups ($p > 0.05$).

We then performed univariate and multivariate analyses to investigate the risk factors that correlate with complications. ASA score was associated with overall and severe complications. An ASA score of 3 reflected the existence of preoperative medical comorbidities as reported in previous studies [25,26].

We further analyzed patients who completed one-stage anastomosis. The location of anastomosis can be divided into high or low, which can affect the short-term outcome [22,27]. The division of the lower distal rectum was difficult, which means more linear staples were used

Table 6
Multivariate analysis of risk factors.

		Overall complications (%)			Severe complications (%)		
	Variables	OR	95% CI	*p*	OR	95% CI	*p*
Robotic assistant surgery (n = 556)	ASA score			0.009			< 0.001
	1–2	1			1		
	≥3	6.051	1.875–19.529		17.097	4.279–68.305	
Laparoscopic surgery (n = 1139)	ASA score			< 0.001			< 0.001
	1–2	1			1		
	≥3	3.156	1.658–6.003		5.91	2.578–13.549	
Subgroups with one-stage anastomoses							
Robotic assistant surgery (n = 412)	Anastomotic from anal verge (cm)			0.001			0.005
	≥5	1			1		
	< 5	2.295	1.557–5.496		4.762	1.583–14.327	
Laparoscopic surgery (n = 830)	Anastomotic from anal verge (cm)			< 0.001			< 0.001
	≥5	1			1		
	< 5	3.609	2.385–5.462		6.032	2.603–13.976	
Robotic assistant surgery (n = 412)	Staple			0.004			0.002
	1–3	1			1		
	≥4	2.646	1.371–5.102		4.049	1.645–9.901	
Laparoscopic surgery (n = 830)	Staple			< 0.001			0.001
	1–3	1			1		
	≥4	5.296	3.026–9.268		4.322	1.867–9.997	

especially in the narrow pelvis of Asian males. Thus, both the location of the anastomosis and the number of linear cut staples was correlated with complication morbidity. In RAS and LAS groups, the multivariate logistic regression analysis results showed that a distance of less than 5 cm from the anastomosis to the anal verge increased the overall and severe risk. Shiomo et al. [28] reported that clinically significant anastomotic leakage occurred in 5%–20% of cases. Our anastomosis leakage morbidity was similar to other reports on RAS [29]. The use of 4 linear staples or more increased the overall and severe morbidity in RAS and LAS groups. The high number of residual nails and the angle produced between each section may increase the risk of anastomotic problem, abdominal pelvic infection, and even sepsis. The application of additional sutures after stapled anastomosis to reduce the incidence of anastomotic complication was common, but the operation was difficult with a middle-low anastomosis location in LAS [30]. Robotsewing may make this operation easy; however, reports on the use of this technique in rectal surgery are lacking.

Our study possessed some limitations. 1) The study was a retrospective analysis and was not in accordance with the principle of random grouping. 2) Results were limited to patients' morbidity within 30 days postoperatively. 3) The neoadjuvant treatment rate of patients with cT3 tumor was lower than that at other centers, so comparing our results with those from other literature was not entirely appropriate. 4) Finally, objective parameters, such as pelvic nerve-sparing, evaluation of urinary and sexual function, and patients' defecation scores, to measure other benefits of minimally invasive surgery were not included in our study. Factors, such as difference in experience of each surgeon and laboratory examination, were not incorporated into our analysis. Despite these limitations, we found that the differences between RAS and LAS were negligible. Further prospective clinical trials are necessary.

In conclusion, robotic-assisted LAS in patients with rectal cancer can be as safely performed as LAS and was not found to increase the rate of complications.

Author contribution

Tang bo and Li chuan contributed equally to this work, Tang bo and Yu peiwu performed the experiment conception and design. Tang bo and Li chuan performed the research and retrieved the data. Li chuan, Zhang chao, Luo huaxing and Liu hongchang, performed the data collection and analysis. Tang bo and Li chuan did the paper writing. All authors read and approved the final manuscript.

Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

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References

[1] E. Van Cutsem, F. Costa, Progress in the adjuvant treatment of colon cancer: has it influenced clinical practice? J. Am. Med. Assoc. 294 (21) (2005) 2758–2760.
[2] M. Jacobs, J.C. Verdeja, H.S. Goldstein, Minimally invasive colon resection (laparoscopic colectomy), Surg. Laparosc. Endosc. 1 (3) (1991) 144–150.
[3] H.J. Bonjer, C.L. Deijen, G.A. Abis, M.A. Cuesta, M.H. van der Pas, E.S. de Lange-de Klerk, A.M. Lacy, W.A. Bemelman, J. Andersson, E. Angenete, J. Rosenberg, A. Fuerst, E. Haglind, A randomized trial of laparoscopic versus open surgery for rectal cancer, N. Engl. J. Med. 372 (14) (2015) 1324–1332.
[4] P.J. Guillou, P. Quirke, H. Thorpe, J. Walker, D.G. Jayne, A.M. Smith, R.M. Heath, J.M. Brown, Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial, Lancet 365 (9472) (2005) 1718–1726.
[5] A. Shiomi, Y. Kinugasa, T. Yamaguchi, S. Tsukamoto, H. Tomioka, H. Kagawa, Feasibility of laparoscopic intersphincteric resection for patients with cT1-T2 low rectal cancer, Dig. Surg. 30 (4–6) (2013) 272–277.
[6] P.A. Weber, S. Merola, A. Wasielewski, G.H. Ballantyne, Telerobotic-assisted laparoscopic right and sigmoid colectomies for benign disease, Dis. Colon Rectum 45 (12) (2002) 1689–1694 discussion 1695-6.
[7] P. Bianchi, W. Petz, G. Spinoglio, D. Belotti, E. Bertani, M.G. Zampino, C. Crosta, R. Lazzari, B. Andreoni, [Robotic rectal resection in rectal cancer: short term results in a monocentric prospective study], Minerva Chir. 66 (6) (2011) 527–535.
[8] D.S. Keller, L. Hashemi, M. Lu, C.P. Delaney, Short-term outcomes for robotic colorectal surgery by provider volume, J. Am. Coll. Surg. 217 (6) (2013) 1063-9 e1.
[9] M. Hara, K. Sng, B.E. Yoo, J.W. Shin, D.W. Lee, S.H. Kim, Robotic-assisted surgery for rectal adenocarcinoma: short-term and midterm outcomes from 200 consecutive cases at a single institution, Dis. Colon Rectum 57 (5) (2014) 570–577.
[10] J.S. Park, G.S. Choi, K.H. Lim, Y.S. Jang, S.H. Jun, Robotic-assisted versus laparoscopic surgery for low rectal cancer: case-matched analysis of short-term outcomes, Ann. Surg. Oncol. 17 (12) (2010) 3195–3202.
[11] A. Valverde, N. Goasguen, O. Oberlin, M. Svreck, J.F. Flejou, A. Sezeur, H. Mosnier, R. Houdart, R.M. Lupinacci, Robotic versus laparoscopic rectal resection for sphincter-saving surgery: Pathological and short-term outcomes in a single-center analysis of 130 consecutive patients, Surg. Endosc. (2017).
[12] M.C. Kim, G.U. Heo, G.J. Jung, Robotic gastrectomy for gastric cancer: surgical

techniques and clinical merits, Surg. Endosc. 24 (3) (2010) 610–615.
[13] P.P. Bianchi, C. Ceriani, A. Locatelli, G. Spinoglio, M.G. Zampino, A. Sonzogni, C. Crosta, B. Andreoni, Robotic versus laparoscopic total mesorectal excision for rectal cancer: a comparative analysis of oncological safety and short-term outcomes, Surg. Endosc. 24 (11) (2010) 2888–2894.
[14] S.Y. Park, G.S. Choi, J.S. Park, H.J. Kim, W.H. Choi, J.P. Ryuk, Robotic-assisted transabdominal intersphincteric resection: a technique involving a completely abdominal approach and coloanal anastomosis, Surg. Laparosc. Endosc. Percutaneous Tech. 23 (1) (2013) e5–10.
[15] M.R. Weiser, AJCC 8th edition: colorectal cancer, Ann. Surg. Oncol. 25 (6) (2018) 1454–1455.
[16] P.A. Clavien, J. Barkun, M.L. de Oliveira, J.N. Vauthey, D. Dindo, R.D. Schulick, E. de Santibanes, J. Pekolj, K. Slankamenac, C. Bassi, R. Graf, R. Vonlanthen, R. Padbury, J.L. Cameron, M. Makuuchi, The Clavien-Dindo classification of surgical complications: five-year experience, Ann. Surg. 250 (2) (2009) 187–196.
[17] B. Tang, C. Zhang, C. Li, J. Chen, H. Luo, D. Zeng, P. Yu, Robotic total mesorectal excision for rectal cancer: a series of 392 cases and mid-term outcomes from A single center in China, J. Gastrointest. Surg. 21 (3) (2017) 569–576.
[18] E. Espin, M.A. Ciga, M. Pera, H. Ortiz, Oncological outcome following anastomotic leak in rectal surgery, Br. J. Surg. 102 (4) (2015) 416–422.
[19] Y. Yang, F. Wang, P. Zhang, C. Shi, Y. Zou, H. Qin, Y. Ma, Robot-assisted versus conventional laparoscopic surgery for colorectal disease, focusing on rectal cancer: a meta-analysis, Ann. Surg. Oncol. 19 (12) (2012) 3727–3736.
[20] S.J. Baek, S.H. Kim, J.S. Cho, J.W. Shin, J. Kim, Robotic versus conventional laparoscopic surgery for rectal cancer: a cost analysis from a single institute in Korea, World J. Surg. 36 (11) (2012) 2722–2729.
[21] R. Glynne-Jones, L. Wyrwicz, E. Tiret, G. Brown, C. Rodel, A. Cervantes, D. Arnold, Rectal cancer: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up, Ann. Oncol. 28 (suppl_4) (2017) iv22–iv40.
[22] A. Shiomi, Y. Kinugasa, T. Yamaguchi, H. Tomioka, H. Kagawa, Robot-assisted rectal cancer surgery: short-term outcomes for 113 consecutive patients, Int. J. Colorectal Dis. 29 (9) (2014) 1105–1111.
[23] D. Jayne, A. Pigazzi, H. Marshall, J. Croft, N. Corrigan, J. Copeland, P. Quirke, N. West, T. Rautio, N. Thomassen, H. Tilney, M. Gudgeon, P.P. Bianchi, R. Edlin, C. Hulme, J. Brown, Effect of robotic-assisted vs conventional laparoscopic surgery on risk of conversion to open laparotomy among patients undergoing resection for rectal cancer: the ROLARR randomized clinical trial, J. Am. Med. Assoc. 318 (16) (2017) 1569–1580.
[24] A.R. Stevenson, M.J. Solomon, J.W. Lumley, P. Hewett, A.D. Clouston, V.J. Gebski, L. Davies, K. Wilson, W. Hague, J. Simes, Effect of laparoscopic-assisted resection vs open resection on pathological outcomes in rectal cancer: the ALaCaRT randomized clinical trial, J. Am. Med. Assoc. 314 (13) (2015) 1356–1363.
[25] H. Qu, Y. Liu, D.S. Bi, Clinical risk factors for anastomotic leakage after laparoscopic anterior resection for rectal cancer: a systematic review and meta-analysis, Surg. Endosc. 29 (12) (2015) 3608–3617.
[26] T. Akiyoshi, M. Ueno, Y. Fukunaga, S. Nagayama, Y. Fujimoto, T. Konishi, H. Kuroyanagi, T. Yamaguchi, Incidence of and risk factors for anastomotic leakage after laparoscopic anterior resection with intracorporeal rectal transection and double-stapling technique anastomosis for rectal cancer, Am. J. Surg. 202 (3) (2011) 259–264.
[27] H. Kagawa, Y. Kinugasa, A. Shiomi, T. Yamaguchi, S. Tsukamoto, H. Tomioka, Y. Yamakawa, S. Sato, Robotic-assisted lateral lymph node dissection for lower rectal cancer: short-term outcomes in 50 consecutive patients, Surg. Endosc. 29 (4) (2015) 995–1000.
[28] A. Shiomi, M. Ito, N. Saito, T. Hirai, M. Ohue, Y. Kubo, Y. Takii, T. Sudo, M. Kotake, Y. Moriya, The indications for a diverting stoma in low anterior resection for rectal cancer: a prospective multicentre study of 222 patients from Japanese cancer centers, Colorectal Dis. 13 (12) (2011) 1384–1389.
[29] J.M. Kwak, S.H. Kim, J. Kim, D.N. Son, S.J. Baek, J.S. Cho, Robotic vs laparoscopic resection of rectal cancer: short-term outcomes of a case-control study, Dis. Colon Rectum 54 (2) (2011) 151–156.
[30] K. Maeda, H. Nagahara, M. Shibutani, H. Ohtani, K. Sakurai, T. Toyokawa, K. Muguruma, H. Tanaka, R. Amano, K. Kimura, K. Sugano, T. Ikeya, Y. Iseki, K. Hirakawa, Efficacy of intracorporeal reinforcing sutures for anastomotic leakage after laparoscopic surgery for rectal cancer, Surg. Endosc. 29 (12) (2015) 3535–3542.