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ABOUT COVER

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ORIGINAL ARTICLE

Retrospective Cohort Study

Robotic-assisted low anterior resection for rectal cancer shows similar clinical efficacy to laparoscopic surgery: A propensity score matched study

Shen-Xiang Long, Xin-Ning Wang, Shu-Bo Tian, Yu-Fang Bi, Shen-Shuo Gao, Yu Wang, Xiao-Bo Guo

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Abstract

BACKGROUND

Rectal cancer ranks as the second leading cause of cancer-related mortality worldwide, necessitating surgical resection as the sole treatment option. Over the years, there has been a growing adoption of minimally invasive surgical techniques such as robotic and laparoscopic approaches. Robotic surgery represents an innovative modality that effectively addresses the limitations associated with traditional laparoscopic techniques. While previous studies have reported favorable perioperative outcomes for robot-assisted radical resection in rectal cancer patients, further evidence regarding its oncological safety is still warranted.

AIM

To conduct a comparative analysis of perioperative and oncological outcomes between robot-assisted and laparoscopic-assisted low anterior resection (LALAR) procedures.

METHODS
The clinical data of 125 patients who underwent robot-assisted low anterior resection (RALAR) and 279 patients who underwent LALAR resection at Shandong Provincial Hospital Affiliated to Shandong First Medical University from December 2019 to November 2022 were retrospectively analyzed. After performing a 1:1 propensity score matching, the patients were divided into two groups: The RALAR group and the LALAR group (111 cases in each group). Subsequently, a comparison was made between the short-term outcomes within 30 d after surgery and the 3-year survival outcomes of these two groups.

RESULTS
Compared to the LALAR group, the RALAR group exhibited a significantly earlier time to first flatus [2 (2-2) d *vs* 3 (3-3) d, P = 0.000], as well as a shorter time to first fluid diet [4 (3-4) d *vs* 5 (4-6) d, P = 0.001]. Additionally, the RALAR group demonstrated reduced postoperative indwelling catheter time [2 (1-3) d *vs* 4 (3-5) d, P = 0.000] and decreased length of hospital stay after surgery [5 (5-7) d *vs* 7(6-8) d, P = 0.009]. Moreover, there was an observed increase in total cost of hospitalization for the RALAR group compared to the LALAR group [10777 (10780-11850) dollars *vs* 10550 (8766-11715) dollars, P = 0.012]. No significant differences were found in terms of conversion rate to laparotomy or incidence of postoperative complications between both groups. Furthermore, no significant disparities were noted regarding the 3-year overall survival rate and 3-year disease-free survival rate between both groups.

CONCLUSION
Robotic surgery offers potential advantages in terms of accelerated recovery of gastrointestinal and urologic function compared to LALAR resection, while maintaining similar perioperative and 3-year oncological outcomes.

Key Words: Rectal cancer; Robotic surgical procedures; Laparoscopy; Low anterior resection; Clinical efficacy

Core Tip: Robotic surgery is increasingly utilized in the management of rectal cancer. However, only retrospective studies and small-scale clinical trials have reported its perioperative outcomes. In this study, propensity score matching was employed to balance baseline data, thereby enhancing the credibility of the conclusions compared to general retrospective studies. Moreover, it is encouraging that the perioperative results and 3-year oncological outcomes of robotic surgery are similar to those of traditional laparoscopic surgery.

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INTRODUCTION

Rectal cancer ranks as the second leading cause of cancer-related fatalities worldwide[1]. Remarkable advancements have been achieved in the treatment of rectal cancer over recent decades. Since the 1980s, total mesorectal excision (TME) technique has served as the fundamental principle for surgical management of rectal cancer. Initially introduced through open surgery[2], the TME technique has subsequently benefited from laparoscopic techniques and instruments development. Multiple randomized controlled trials have demonstrated that laparoscopic-assisted TME not only matches the quality of tumor resection[3-5], but also yields comparable long-term oncological outcomes[6,7] to traditional open surgery. Nevertheless, surgeons continue to encounter challenges when performing rectal cancer surgery using conventional laparoscopic platforms due to inherent limitations such as reduced instrument flexibility and unstable exposure of the surgical field within a narrow pelvis. Furthermore, establishing noninferiority of laparoscopic-assisted TME compared with open surgery for successful resection remains unresolved[8,9].

In rectal cancer surgery, the robotic digital platform offers distinct technical advantages. It enhances surgical precision through a three-dimensional high-definition field of view, a multi-joint robotic arm, rotatable wrist surgical instruments, tremor filtering, and fluorescence imaging[10,11]. These theoretical benefits suggest that robot-assisted TME may yield superior clinical outcomes compared to laparoscopic-assisted TME.

The objective of this study was to assess the safety and efficacy of robot-assisted low anterior resection (RALAR), with a focus on reporting perioperative and 3-year oncological outcomes for both robotic and laparoscopic surgery.

MATERIALS AND METHODS

Patients

This retrospective cohort study was conducted at the Department of Gastrointestinal Surgery, Shandong Provincial Hospital Affiliated to Shandong First Medical University, and included clinical data from patients who underwent low anterior resection for rectal cancer between December 2019 and November 2022. The inclusion criteria were as follows: (1) Diagnosis of rectal adenocarcinoma; (2) robotic or laparoscopic surgery; (3) low anterior resection; (4) distance from the lower edge of the tumor to the anal edge ≤ 15 cm; and (5) the postoperative pathological TNM stage was I-III. The exclusion criteria were as follows: (1) Preoperative detection of distant metastasis; (2) tumor invasion of adjacent organs; (3) previous history of any other malignant tumors; (4) combined with other organ resections; and (5) preoperative neoadjuvant therapy. The third generation Da Vinci robotic surgical system was utilized in the robotic group.

Data collection

The baseline characteristics encompass the following variables: Gender, age, preoperative hemoglobin level, preoperative albumin level, presence of preoperative intestinal obstruction, comorbidity (including cardiovascular diseases, cerebrovascular disorders, diabetes mellitus, lung diseases, and liver diseases), previous abdominal surgery, history of smoking, height of tumor from anal verge, preventive stoma status, American Society of Anesthesiologists score, classification of New York Heart Association heart function, body mass index (BMI), differentiation grade, maximum tumor diameter, pathological T stage and N stage as well as TNM staging based on AJCC 8th edition criteria for cancer staging purposes, and surgical approach.

The perioperative outcomes encompass the following parameters: Complications within 30 d after surgery and Clavien-Dindo classification[12-14] (All postoperative complications were assessed and classified based on the patient's clinical manifestations, laboratory findings, radiographic results, and treatment modalities), the rate of conversion to laparotomy (Conversion is defined as the transition from robot-assisted or laparoscopic-assisted surgery to open abdominal surgery), approximate intraoperative blood loss, rate of intraoperative blood transfusion, positive rate of distal resection margin, harvested lymph nodes, harvested positive lymph nodes, duration of surgery, intraoperative dose of sufentanil, time to first flatus, time to first fluid diet, postoperative indwelling catheter time, total cost of hospitalization (treatment costs arising from readmission due to complications were not included), postoperative hospital stay, readmission rate within 30 d after surgery(Readmission for adjuvant therapy was not included), and reoperation rate within 30 d after surgery.

Survival outcomes were assessed based on the 3-year overall survival (OS) and 3-year disease-free survival (DFS) rates following surgical intervention. OS was defined as the duration from the date of surgery until the last follow-up visit or death from any cause. DFS referred to the period between surgery and either first recurrence, last follow-up visit, or death from any cause. Local recurrence was determined by radiological or histologic evidence indicating tumor reappearance at the primary site. Distant metastasis denoted the presence of metastatic lesions in organs other than the primary site. Data collection involved telephone interviews and outpatient follow-up visits, with surgery serving as the starting point and death, recurrence, or metastasis as endpoints. Examinations encompassed digital rectal examination, serum tumor markers assessment, colonoscopy, and contrast-enhanced CT scans of chest, abdomen, and pelvis.

Clinical management

The preoperative examination includes routine blood tests, chest and abdominal computed tomography (CT), pelvic magnetic resonance imaging, and colonoscopy. TME is the standard surgical method for rectal cancer, and the surgical technique is carried out as described in previous reports[15,16]. Similar perioperative management was performed as recommended by the Enhanced Recovery After Surgery guidelines[17]. Postoperative oral nutritional supplementation is provided as early as possible, and a liquid diet is resumed early based on the patient's abdominal signs and flatulence. Typically, urinary catheterization is routinely performed 1-3 d after rectal cancer surgery, and the duration should also be individualized based on risk factors (such as male gender, epidural analgesia, and pelvic surgery).

Statistical analysis

The data were analyzed using SPSS 26.0 software. For measurement data conforming to a normal distribution, an independent sample *t*-test was employed; for measurement data and hierarchical data not conforming to a normal distribution, the Mann-Whitney *U* test was utilized; and for count data, either the χ^2 test or Fisher's exact test was applied. A logistic regression model with a caliper value set at 0.02 was used to calculate the propensity score for each patient. The baseline characteristics were utilized as covariates to achieve a 1:1 matching ratio between the RALAR group and the laparoscopic-assisted low anterior resection (LALAR) group. After propensity score matching, paired sample *t*-tests were conducted for measurement data conforming to a normal distribution, McNemar tests were performed for count data, and Wilcoxon tests were employed for measurement data and hierarchical data not conforming to a normal distribution. Univariate logistic regression analysis followed by multivariate logistic regression analysis was conducted to identify risk factors associated with anastomotic leakage. Kaplan-Meier method was used to plot survival curves depicting the 3-year OS rate and 3-year DFS rate after surgery, with between-group differences compared using Log-rank test. A significance level of $P < 0.05$ has been reached, indicating a statistically meaningful difference. mean ± SD values were reported for measurement data conforming to a normal distribution; median and quartile values were provided for measurement data not conforming to a normal distribution; while number and percentage values represented count data.

RESULTS

Patient characteristics

A total of 404 patients were enrolled in this study, with 125 (31%) undergoing RALAR and 279 (69%) undergoing LALAR. Significant differences existed between the two groups prior to matching in terms of patients presenting preoperative intestinal obstruction, liver diseases, height of tumor from anal verge, preventive stoma, and pathological N stage. Propensity score matching was employed to mitigate selection bias and achieve balanced baseline characteristics for both groups (111 patients per group). Table 1 shows the clinical characteristics of the patient.

Perioperative clinical outcomes

The RALAR group exhibited earlier time to first flatus [2 (2-2) d *vs* 3 (3-3) d, P = 0.000] and time to first fluid diet [4 (3-4) d *vs* 5 (4-6) d, P = 0.001], shorter postoperative indwelling catheter time [2 (1-3) d *vs* 4 (3-5) d, P = 0.000] and length of hospital stay after surgery [5 (5-7) d *vs* 7 (6-8) d, P = 0.009], as well as higher total cost of hospitalization [10777 (10780-11850) dollars *vs* 10550 (8766-11715) dollars, P = 0.012] compared to the LALAR group. The rate of conversion to laparotomy did not differ significantly between the RALAR group and the LALAR group (0% *vs* 1.8%, P = 0.498). There were no significant differences observed in the remaining perioperative outcomes between the two groups. Table 2 shows the perioperative results.

Postoperative complications

The overall incidence of postoperative complications was 13.5% in the RALAR group and 12.6% in the LALAR group (P = 1.000). Moreover, the incidence of severe complications (Clavien-Dindo grade ≥ III) was 0.9% in the RALAR group and 3.6% in the LALAR group (P = 0.375). The incidence of each complication and each Clavien-Dindo grade ≥ III complication did not exhibit any significant differences between the two groups. Table 3 shows the postoperative complications.

Subgroup analysis of anastomotic leakage

Univariate logistic regression analysis revealed that BMI ≥ 25 (kg/m^2) and maximum tumor diameter ≥ 6 cm were identified as risk factors for postoperative anastomotic leakage. Subsequently, multivariate logistic regression analysis was conducted on the variables with significant statistical associations in the univariate logistic regression analysis. The results demonstrated that BMI ≥ 25 (kg/m^2) [odds ratio (OR): 2.85; 95% confidence interval (95%CI): 1.23-6.59; P = 0.015] and maximum tumor diameter ≥ 6 cm (OR: 2.81; 95%CI: 1.10-7.15; P = 0.030) independently contributed to the risk of postoperative anastomotic leakage occurrence. Figure 1 depict the risk factor analysis of postoperative anastomotic leakage, while subgroup analyses were performed based on the independent risk factors for this complication. Among patients with BMI ≥ 25 (kg/m^2), there was a respective incidence of anastomotic leakage of 17.8% in the RALAR group and 12.0% in the LALAR group (P = 0.428). In patients with maximum tumor diameter ≥ 6 cm, the incidence of anastomotic leakage was observed to be 28.6% in the RALAR group compared to only 8.3% in the LALAR group (P = 0.330). In summary, although slightly higher incidences of anastomotic leakage were noted in the RALAR group during subgroup analyses, these differences did not reach statistical significance. Table 4 presents detailed findings from subgroup analyses regarding anastomotic leakage.

3-year oncological outcomes

After matching, a total of 10 patients (5 in the RALAR group and 5 in the LALAR group) were lost to follow-up, resulting in a loss rate of 4.5%. However, there was no statistically significant difference observed between the two groups. The median duration of follow-up was 33 months. The 3-year OS rate was 96.4% in the RALAR group and 95.6% in the LALAR group (P = 0.909), indicating no statistically significant difference between the two groups. According to TNM staging, the 3-year OS rate in the RALAR group was 100% in stage I, 100% in stage II, and 91.8% in stage III, while the 3-year OS rate in the LALAR group was 100.0% in stage I, 92.2% in stage II, and 95.0% in stage III. There was no statistically significant difference in the 3-year OS rate at each stage between the RALAR group and the LALAR group. The 3-year OS rate of the two groups was compared in Figure 2A-D. The 3-year DFS rate was 87.7% in the RALAR group and 91.2% in the LALAR group (P = 0.738), with no statistically significant difference between the two groups. According to TNM staging, the 3-year DFS rate in the RALAR group was 96.8% in stage I, 89.6% in stage II, and 78.3% in stage III, while the 3-year DFS rate in the LALAR group was 92.8% in stage I, 92.7% in stage II, and 88.8% in stage III. There was no statistically significant difference in the 3-year DFS rate at each stage between the RALAR group and the LALAR group. The 3-year DFS rate of the two groups was compared in Figure 2E-H.

DISCUSSION

This retrospective cohort study aimed to compare the clinical outcomes of robotic-assisted and LALAR for rectal cancer. Only patients undergoing low anterior resection for rectal cancer were included during the study period. Surgeons' expectations regarding advanced technology may lead to selective application of robotic surgery in more complex cases, such as advanced tumors or abdominoperineal resection for rectal cancer, potentially exacerbating selection bias in the retrospective analysis. To address baseline data imbalance, we performed propensity score matching analysis based on patient clinical characteristics and tumor pathological characteristics after excluding cases of abdominoperineal resection.

Table 1 Baseline characteristics, *n* (%)

Item	Before matching		*P* value	After matching		*P* value
	RALAR, *n* = 125	LALAR, *n* = 279		RALAR, *n* = 111	LALAR, *n* = 111	
Gender			0.871			0.896[1]
Male	76 (60.8)	172 (61.6)		67 (60.4)	65 (58.6)	
Female	49 (39.2)	107 (38.4)		44 (39.6)	46 (41.4)	
Age (yr)	62 (55-68)	63 (54-68)	0.957	62 (55-66)	61 (53-68)	0.761
Preoperative hemoglobin (g/L)	135.0 (123.5-143.5)	134.0 (123.0-145.0)	0.593	131.7 ± 15.7	133.1 ± 17.5	0.510
Preoperative albumin (g/L)	39.5 ± 3.0	39.1 ± 3.2	0.246	39.4 ± 3.0	39.8 ± 3.3	0.430
Preoperative intestinal obstruction	8 (6.4)	44 (15.8)	0.009	8 (7.2)	7 (6.3)	1.000[1]
Comorbidity						
Cardiovascular diseases	48 (38.4)	106 (38.0)	0.938	44 (39.6)	38 (34.2)	0.441[1]
Cerebrovascular disorders	11 (8.8)	38 (13.6)	0.170	10 (9.0)	10 (9.0)	1.000[1]
Diabetes mellitus	16 (12.8)	41 (14.7)	0.613	13 (11.7)	12 (10.8)	1.000[1]
Lung diseases	43 (34.4)	96 (34.4)	0.999	36 (32.4)	38 (34.2)	0.885[1]
Liver diseases	9 (7.2)	8 (2.9)	0.045	4 (3.6)	5 (4.5)	1.000[1]
Previous abdominal surgery	12 (9.6)	33 (11.8)	0.511	11 (9.9)	15 (13.5)	0.523[1]
History of smoking	47 (37.6)	81 (29.0)	0.087	39 (35.1)	36 (32.4)	0.761[1]
Height of tumor from anal verge (cm)	10 (8.0-13.5)	10 (6.0-10.0)	0.005	10 (8.0-12.0)	10 (8.0-12.0)	0.754
Preventive stoma	23 (18.4)	111 (39.8)	0.000	22 (19.8)	23 (20.7)	1.000[1]
ASA score			0.340			0.602
I	0	1 (0.4)		0	0	
II	102 (81.6)	214 (76.7)		90 (81.1)	93 (83.8)	
III	23 (18.4)	64 (22.9)		21 (18.9)	18 (16.2)	
Classification of NYHA heart function			0.837			0.893
I	77 (61.6)	170 (60.9)		67 (60.4)	68 (61.3)	
II	48 (38.4)	106 (38.0)		44 (39.6)	43 (38.7)	
III	0	3 (1.1)		0	0	
BMI (kg/m^2)	24.2 (22.8-25.9)	24.2 (22.1-26.7)	0.780	24.5 ± 2.8	24.6 ± 3.5	0.795
Differentiation			0.053			0.317
Low	3 (2.4)	37 (13.3)		3 (2.7)	4 (3.6)	
Medium	114 (91.2)	218 (78.1)		102 (91.9)	95 (85.6)	
High	8 (6.4)	24 (8.6)		6 (5.4)	12 (10.8)	
Maximum tumor diameter (cm)	4 (3.0-5.0)	4 (3.5-5.0)	0.128	4 (3.0-5.0)	4 (3.0-5.0)	0.693
Pathological T stage			0.693			0.925
Tis	0	2 (0.7)		0	2 (1.8)	
1	10 (8.0)	15 (5.4)		9 (8.1)	7 (6.3)	
2	34 (27.2)	70 (25.1)		32 (28.8)	26 (23.4)	
3	74 (59.2)	185 (66.3)		64 (57.7)	74 (66.7)	
4a	7 (5.6)	7 (2.5)		6 (5.4)	2 (1.8)	
Pathological N stage			0.046			0.534

0	80 (64.0)	154 (55.2)		69 (62.2)	72 (64.9)	
1a	19 (15.2)	38 (13.6)		18 (16.2)	17 (15.3)	
1b	13 (10.4)	38 (13.6)		12 (10.8)	12 (10.8)	
1c	0	7 (2.5)		0	2 (1.8)	
2a	8 (6.4)	19 (6.8)		8 (7.2)	6 (5.4)	
2b	5 (4.0)	23 (8.2)		4 (3.6)	2 (1.8)	
Pathological TNM stage			0.140			0.712
0	0	2 (0.7)		0	2 (1.8)	
I	34 (27.2)	69 (24.7)		31 (27.9)	28 (25.2)	
IIA	43 (34.4)	81 (29.0)		36 (32.4)	41 (36.9)	
IIB	3 (2.4)	2 (0.7)		2 (1.8)	1 (0.9)	
IIIA	9 (7.2)	15 (5.4)		9 (8.1)	5 (4.5)	
IIIB	30 (24.0)	85 (30.5)		28 (25.2)	31 (27.9)	
IIIC	6 (4.8)	25 (9.0)		5 (4.5)	3 (2.7)	

[1]McNemar's test.
RALAR: Robot-assisted low anterior resection; LALAR: Laparoscopic-assisted low anterior resection; ASA: American Society of Anesthesiologists; NYHA: New York Heart Association; BMI: Body mass index.

Table 2 Perioperative outcomes, *n* (%) or median (interquartile range)

	RALAR, *n* = 111	LALAR, *n* = 111	*P* value
Conversion to laparotomy	0	2 (1.8)	0.498[2]
Approximate intraoperative blood loss (mL)	50 (20-50)	50 (30-50)	0.276
Intraoperative blood transfusion	4 (3.6)	3 (2.7)	1.000[1]
Distal resection margin			1.000[2]
Involved	0	1 (0.9)	
Harvested lymph nodes	14 (11-16)	13 (11-17)	0.627
Harvested positive lymph nodes	0 (0-1)	0 (0-1)	0.317
Duration of surgery (min)	187 (160-215)	185 (155-230)	0.977
Intraoperative dose of sufentanil (μg/kg/min)	0.0050 (0.0040-0.0062)	0.0048 (0.0040-0.0064)	0.948
Time to first flatus (d)	2(2-2)	3 (3-3)	0.000
Time to first fluid diet (d)	4 (3-4)	5 (4-6)	0.001
Postoperative indwelling catheter time (d)	2 (1-3)	4 (3-5)	0.000
Total cost of hospitalization (dollars)	10777 (10780-11850)	10550 (8766-11715)	0.012
Length of hospital stay after surgery (d)	5 (5-7)	7 (6-8)	0.009
Readmission within 30 d after operation	1 (0.9)	1 (0.9)	1.000[1]
Reoperation within 30 d after operation	0	1 (0.9)	1.000[2]

[1]McNemar's test.
[2]Fisher's exact test.
RALAR: Robot-assisted low anterior resection; LALAR: Laparoscopic-assisted low anterior resection.

The findings of this study demonstrated that among patients undergoing low anterior resection for rectal cancer, both the RALAR group and the LALAR group exhibited comparable perioperative and 3-year oncological outcomes.

The rate of conversion to laparotomy is a crucial parameter for evaluating the benefits of robotic-assisted radical resection for rectal cancer, as it is believed that the technical advantages of robotics can effectively overcome challenging pelvic anatomy[18] and minimize the need for conversion to laparotomy[19]. Previous studies have demonstrated that

Table 3 Complications within 30 d after surgery, *n* (%)

	RALAR (*n* = 111)					LALAR (*n* = 111)					*P* value	*P* value
	I	II	IIIa	IIIb	Overall	I	II	IIIa	IIIb	Overall	Overall	≥ III
Overall	0	14	1	0	15 (13.5)	3	7	2	2	14 (12.6)	1.000[1]	0.375[1]
Anastomotic leakage	0	12	1	0	13 (11.7)	1	6	0	2	9 (8.1)	0.481[1]	1.000[1]
Anastomotic stenosis	0	0	0	0	0	2	0	0	0	2 (1.8)	0.498[2]	
Intestinal obstruction	0	1	0	0	1 (0.9)	0	2	1	0	3 (2.7)	0.625[1]	1.000[2]
Intraabdominal infection	0	2	0	0	2 (1.8)	0	2	0	1	3 (2.7)	1.000[1]	1.000[2]
Hemoperitoneum	0	0	0	0	0	0	0	1	0	1 (0.9)	1.000[2]	1.000[2]
Pneumonia	0	0	0	0	0	0	2	0	0	2 (1.8)	0.498[2]	
Pulmonary atelectasis	0	0	0	0	0	4	0	0	0	4 (3.6)	0.122[2]	
Venous thrombosis	0	1	0	0	1 (0.9)	0	0	0	0	0	1.000[2]	

[1]McNemar's test.
[2]Fisher's exact test.
RALAR: Robot-assisted low anterior resection; LALAR: Laparoscopic-assisted low anterior resection.

Table 4 Subgroup analysis of anastomotic leakage, *n* (%)

	Anastomotic leakage	*P* value
BMI ≥ 25 (kg/m^2)		0.428
RALAR (*n* = 45)	8 (17.8)	
LALAR (*n* = 50)	6 (12.0)	
Maximum tumor diameter ≥ 6 cm		0.330[1]
RALAR (*n* = 14)	4 (28.6)	
LALAR (*n* = 12)	1 (8.3)	

[1]Fisher's exact test.
RALAR: Robot-assisted low anterior resection; LALAR: Laparoscopic-assisted low anterior resection; BMI: Body mass index.

conversion to laparotomy is associated with inferior long-term oncological outcomes in rectal cancer surgery[20]. Furthermore, conversion to laparotomy leads to increased utilization of intraoperative analgesics[21]. A randomized, unblinded, multicenter study conducted in Denmark revealed that patients undergoing rectal cancer resection using robotic technology required fewer analgesics during surgery and experienced a lower rate of conversion to laparotomy compared to those undergoing traditional laparoscopic surgery[21]. The ROLARR multicenter randomized controlled trial designated the primary endpoint as the conversion rate to laparotomy[22]. In line with our findings, no significant disparity was observed in the rate of conversion to laparotomy between robotic-assisted and laparoscopic-assisted radical resection for rectal cancer in the ROLARR trial. However, subgroup analysis of the ROLARR trial revealed that robotic surgery exhibited a lower incidence of conversion to laparotomy among male patients. Furthermore, two multicenter retrospective cohort studies[23,24] reported that robotic-assisted radical resection for rectal cancer did not significantly mitigate the risk of conversion to laparotomy, which is consistent with our results. In this study, two patients in the LALAR group opted for conversion to laparotomy due to severe abdominal adhesions, while no patient in the RALAR group required conversion to laparotomy. The rate of converting to laparotomy did not exhibit a statistically significant difference between the two groups, thereby failing to demonstrate any advantage of robotic surgery over laparoscopy in terms of conversion rates.

Urogenital dysfunction is considered a significant complication that adversely affects the quality of life in patients following rectal cancer surgery. A prospective controlled study evaluated the urogenital function of patients by International Prostate Symptom Score, International Index of Erectile Function text, Female Sexual Function Index and urodynamic examination, and found that robotic technology was conducive to the early recovery of postoperative urogenital function, which was related to the superiority of robotic surgical technology in identifying and preserving autonomic nerves[25]. Moreover, consistent findings from prospective cohort studies[26] and meta-analyses[27] have shown that male patients undergoing robotic surgery experience improved micturition and erectile function compared to those undergoing traditional laparoscopic rectal cancer surgery. Similarly, our study revealed an earlier removal of catheter in the RALAR group than in the LALAR group, further supporting faster recovery of postoperative urogenital

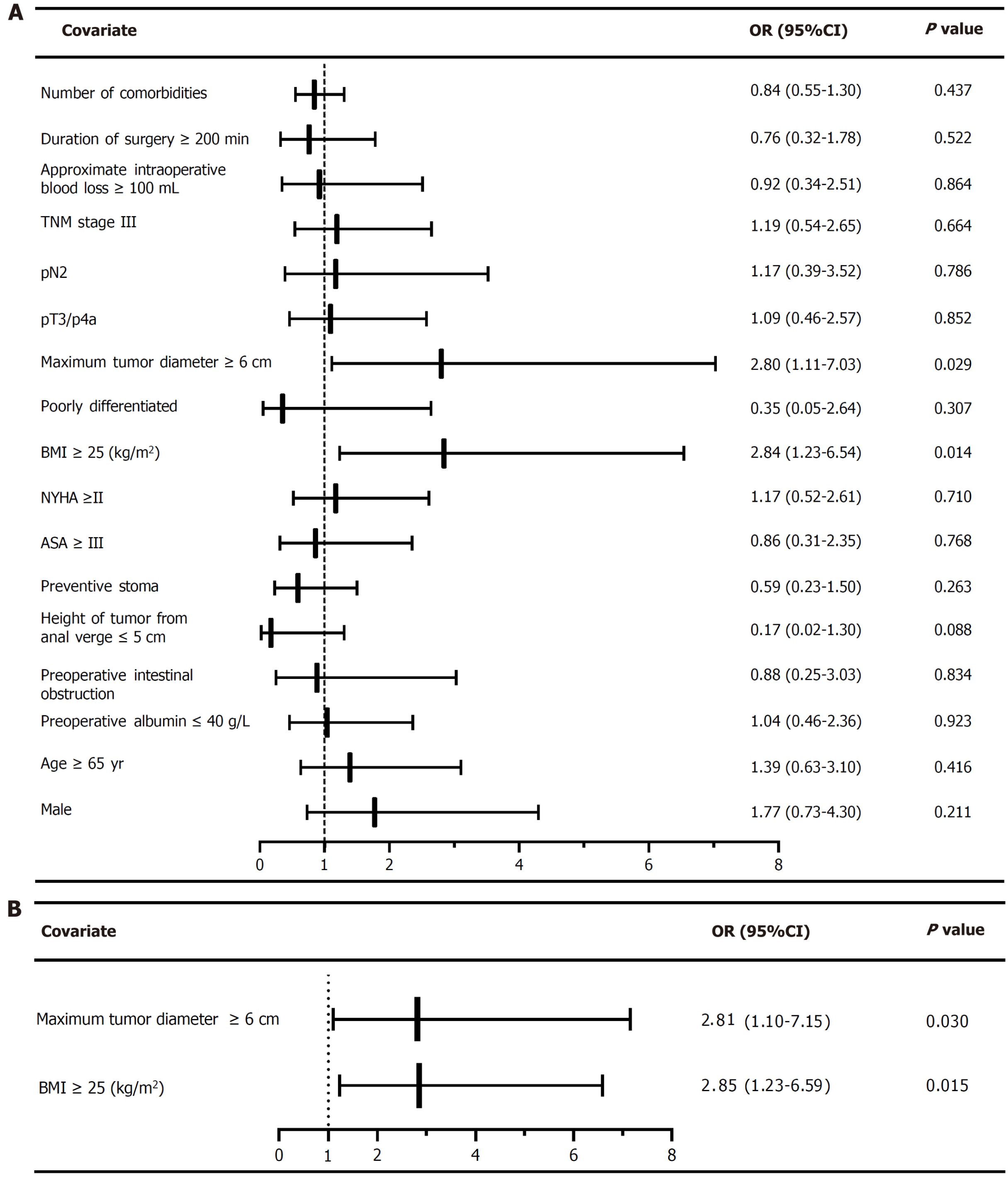

Figure 1 Univariate and multivariate analysis of anastomotic leakage (Clavien-Dindo grade ≥ II). A: Univariate analysis; B: Multivariate analysis. BMI: Body mass index; ASA: American Society of Anesthesiologists. NYHA: New York Heart Association; 95%CI: 95% confidence interval; OR: Odds ratio.

function with robotic surgical technology. However, it is important to note that this study did not include long-term follow-up or evaluation of patients' urogenital function; therefore, these clinically significant results should be interpreted cautiously and confirmed by other high-level evidence.

The faster recovery of gastrointestinal function is a significant advantage of robot-assisted radical resection for rectal cancer[28], as also supported by the findings of this study. However, it is important to address the cost issue, which poses a major barrier to the widespread adoption of robotic technology. Previous studies have highlighted the increased costs associated with robotic surgery[29]. In our preliminary analysis of hospitalization costs, we observed that the total hospitalization costs for patients in the RALAR group were significantly higher compared to those in the LALAR group, primarily due to elevated direct operation expenses. Nevertheless, as robotic surgery becomes more popular and its utilization increases rapidly, there is potential for a decrease in equipment and consumable costs. Furthermore, given that robotic surgery promotes accelerated recovery of gastrointestinal function[28], and reduces postoperative hospital stays [19,29,30], it can help control postoperative expenses and potentially lead to an overall reduction in costs at an acceptable

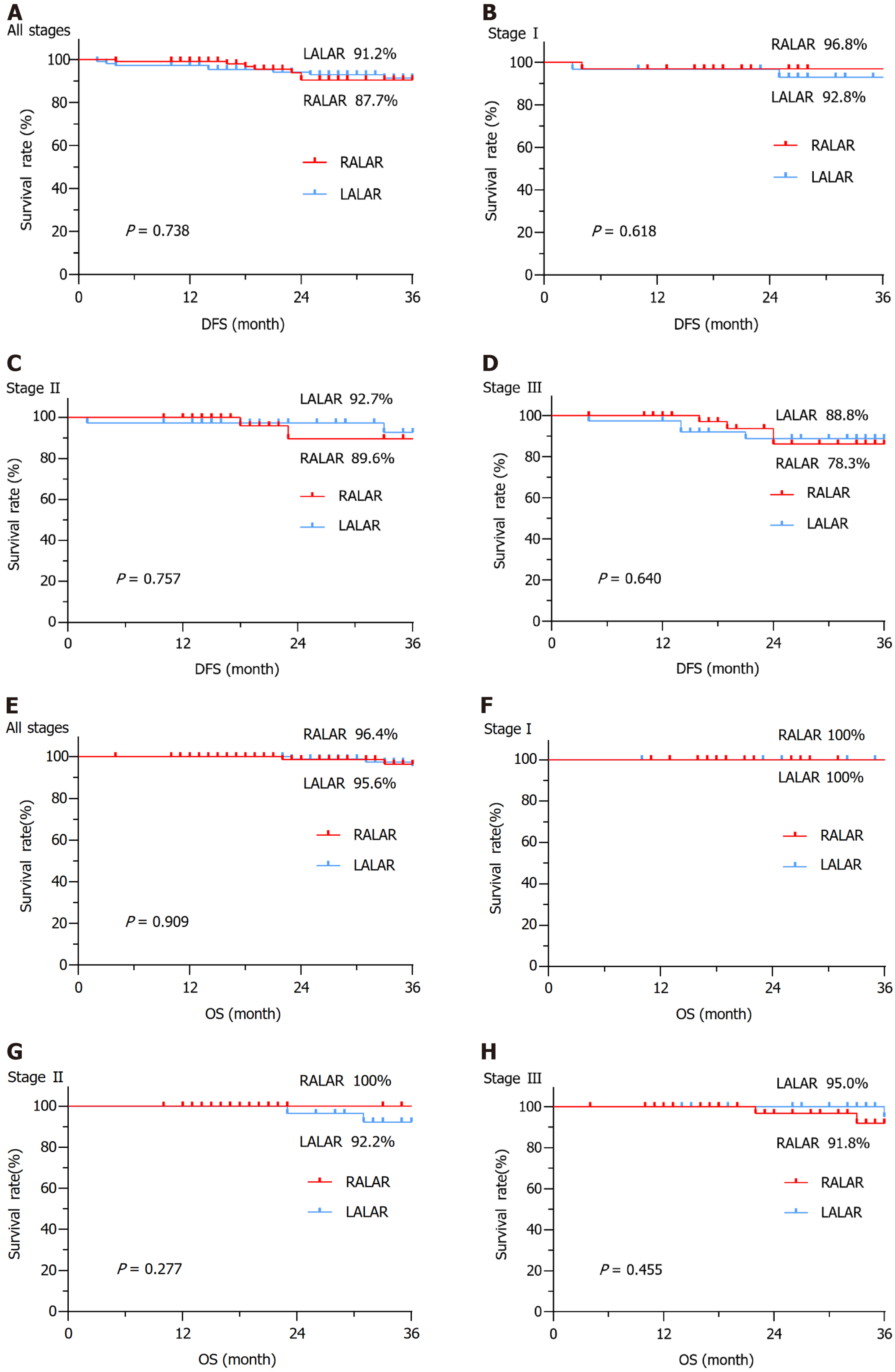

Figure 2 The 3-year overall survival and disease-free survival rate between robotic and laparoscopic surgical procedures. A: Overall survival (OS) rate for all stages in both groups; B: OS rate for stage I in both groups. In stage I, the Log-rank test could not calculate a meaningful statistic or *P* value; C: OS rate for stage II in both groups; D: OS rate for stage III in both groups; E: Disease-free survival (DFS) rate for all stages in both groups; F: DFS rate for stage I in both groups; G: DFS rate for stage II in both groups; H: DFS rate for stage III in both groups. RALAR: Robot-assisted low anterior resection; LALAR: Laparoscopic-assisted low anterior resection; OS: Overall survival.

level.

The incidence of postoperative complications was comparable between the RALAR group and the LALAR group, with no significant difference observed in the occurrence of severe complications. These findings align with previous studies demonstrating similar short-term outcomes for robot-assisted and laparoscopic-assisted radical resection for rectal cancer [19,23,24,30,31]. Anastomotic leakage is a common complication of low anterior resection for rectal cancer. Preventive stoma is considered to be effective in preventing anastomotic leakage[32]. The LASRE trial, a multicenter noninferiority randomized clinical trial for low rectal cancer, demonstrated that the rates of preventive stoma and anastomotic leakage following laparoscopic-assisted radical resection for rectal cancer were 78.8% and 2.5%[5], 81.0% and 3.0% in the ALaCaRT trial[8], 97.6% and 2.1% in the ACOSOG Z6051 trial (a multicenter noninferiority randomized clinical trial for rectal cancer after stage II and III neoadjuvant therapy)[9], and 35% and 13% in the COLOR II trial[3]. Considering the incidence of anastomotic leakage, the risk of reoperation, and patient preference, our hospital's laparoscopic team favors performing preventive stoma during surgery rather than resorting to stoma rerouting post-occurrence. In this study, a statistically significant difference was observed in the rate of preventive stoma between the RALAR group and the LALAR group (18.4% *vs* 39.8%, $P = 0.000$). Following propensity score matching, both the RALAR group (19.8%) and the LALAR group (20.7%) exhibited similar rates of preventive stoma, indicating balanced and comparable baseline data. Furthermore, after matching, there was no significant difference in the incidence of anastomotic leakage between the two groups with rates of 11.7% in the RALAR group and 8.1% in the LALAR group. Due to the theoretical advantages of robotic technology, surgeons are able to have better visualization of the surgical field and operate with increased flexibility in the pelvic cavity, potentially reducing accidental trauma to the intestinal wall. The aforementioned perspective is consistent with a multi-center randomized controlled trial that reported improved macroscopic completeness of specimens in the robotic surgery[28]. Therefore, this study also conducted a subgroup analysis on patients with risk factors for anastomotic leakage (BMI ≥ 25 kg/m^2 and maximum tumor diameter ≥ 6 cm); however, no significant difference in the incidence of anastomotic leakage was observed between the RALAR group and the LALAR group.

In terms of oncology, this study demonstrated comparable 3-year oncological outcomes between robot-assisted and LALAR procedures. Subgroup analysis based on TNM staging revealed no significant differences between the two groups. We compared these findings with previous studies investigating the oncological outcomes of robotic or laparoscopic rectal cancer surgery. Feroci *et al*[30], utilizing data from 2 centers, reported a 3-year OS rate of 90.2% and a 3-year DFS rate of 79.2% for patients undergoing robotic surgery for rectal cancer, while patients undergoing laparoscopic surgery achieved rates of 90.0% and 83.4%, respectively. A multicenter retrospective study conducted by Burghgraef *et al* [33] also reported similar 3-year oncological outcomes. The results of Park *et al*[29] were not inferior to these aforementioned findings, as they observed a 5-year OS rate of 92.8% and a 5-year DFS rate of 81.9% following RALAR. Furthermore, a subgroup analysis of a retrospective study demonstrated that in patients with ypT3-4 tumors who underwent preoperative chemoradiotherapy, the 5-year distant recurrence rate was 44.8% in the laparoscopic group and 9.8% in the robotic group, suggesting potential benefits of robotic surgery for advanced rectal cancer patients with poor response to neoadjuvant chemoradiotherapy[34]. However, considering that distant metastasis is primarily influenced by biological behavior and tumor staging[35], which may not be directly associated with surgical procedure, more robust evidence is still required to substantiate this conclusion.

The retrospective nature of this study was its most significant limitation; therefore, propensity score matching was employed to mitigate confounding from baseline data. Additionally, the evaluation of robotic technique quality should consider the achievement of a radical resection, specifically complete removal of the mesorectum, as circumferential resection margin involvement is a crucial predictor for local recurrence[36] and distant metastasis[37]. Several multicenter retrospective studies have demonstrated comparable specimen quality and circumferential resection margin involvement between robotic-assisted TME and laparoscopic-assisted TME[23,24,30]. However, comprehensive pathological results encompassing circumferential resection margin involvement and integrity of the mesorectum specimen were not available in this study.

In conclusion, this study demonstrated that both techniques yielded satisfactory perioperative and 3-year oncological outcomes. Moreover, robotic techniques exhibited certain advantages in rectal cancer surgery, which warrant further validation through subsequent investigations.

CONCLUSION

The robotic-assisted low anterior resection is a secure surgical technique that not only expedites the recovery of gastrointestinal and urinary function but also demonstrates promising perioperative and 3-year oncological outcomes.

FOOTNOTES

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