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RESEARCH

Long-term functional and prognostic outcomes of robotic intersphincteric resection for treating low rectal cancer: a single-center retrospective study

Yang Bo[1] · Wang Yigao[1] · Zheng Mingye[1] · Jian Zhao[1] · Yongxiang Li[1]

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Abstract

Objective Intraoperative and postoperative data collected from patients with low rectal cancer who had undergone robotic and laparoscopic intersphincteric resection (ISR) procedures were retrospectively analyzed to evaluate factors linked to anastomotic leakage and postoperative recovery of urinary function, bowel control, and long-term prognosis.

Method This single-center study enrolled patients with low rectal cancer who had undergone robotic ISR ($n = 150$) or laparoscopic ISR ($n = 150$) from January 2016 to July 2019.

Result The respective mean tumor distances from the anal margin in the robotic and laparoscopic ISR groups were 3.94 ± 0.48 cm and 5.66 ± 0.47 cm, while the mean times to postoperative catheter removal in these respective groups were 4.9 ± 1.4 days and 5.3 ± 1.6 days ($P = 0.007$). Binary logistic regression analyses indicated that a higher BMI (≥ 25 kg/m^2), diabetes, the absence of left colic artery presentation, T3 pathological T stage, the absence of temporary ileostomy, and DRM (distal resection margin) < 1 cm were linked to a greater likelihood of postoperative anastomotic leakage. Relative to patients in the laparoscopic group, those in the robotic ISR group exhibited better anal and urinary function from 6 months postoperatively, as indicated by a lower frequency of bowel movements, reduced LARS (The Low Anterior Resection Syndrome) severity, and lower IPSS (the International Prostate Symptom Score) scores. Five-year overall and disease-free survival did not differ significantly between the groups.

Conclusion These results highlight the promise of robotic ISR as an approach to managing cases of low and ultra-low rectal tumors, providing a safe and feasible alternative to conventional laparoscopic ISR treatment.

Keywords Robotic surgery · Intersphincteric resection · Low rectal cancer · Bowel function

Introduction

Rectal cancer is a relatively common gastrointestinal tumor [1]. In China, rectal cancer cases frequently include tumors located below the peritoneal reflection, accounting for roughly half of all cases [2]. The precise definition used to define cases of low rectal cancer is somewhat controversial and can vary among reports, but generally included tumors located within 3 cm of the anorectal junction [3]. Owing to the unique anatomical features of the pelvic cavity and the physiological features of these tumors, performing sphincter-preserving surgery in ultra-low rectal cancer cases remains a persistent clinical challenge, prompting significant clinical interest.

In 1994, Schiessel [4] first reported the safe and efficacious implementation of intersphincteric resection (ISR) as a sphincter-preserving approach for treating ultra-low rectal cancer. This procedure has since emerged as a vital approach to preserving anal function in ultra-low rectal cancer. ISR is now established as the best anal-preserving approach to treating low rectal lesions, and can entail the partial, subtotal, or total resection of the internal sphincter or portions of the rectal longitudinal muscle, the extension of the distal incisal margin of the rectum into the anal canal, and coloanal canal anastomosis performed using a stapler or by sewing by hand [5]. Precise intersphincteric dissection is essential when performing the ISR procedure. Operative challenges associated with this procedure include the low position

✉ Yongxiang Li
y18856040554@sina.com

1 Department of General Surgery, The First Affiliated Hospital of Anhui Medical University, 218 Jixi Road, Hefei, China

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of the target tumor and the limited operative field of view within the narrow pelvic cavity, with incomplete visualization contributing to a greater risk of misalignment in the anatomical plane and consequent damage to the nerves and vasculature.

Developments in laparoscopic technology in recent years have led to its application when performing ISR procedures. Laparoscopic ISR procedures are less traumatic and can allow patients to recover more quickly [6–8], all while retaining oncological safety comparable to that associated with abdominal-perineal resection [9]. Laparoscopic ISR, however, remains a technically challenging procedure owing to the narrow pelvic cavity and the consequent restriction of the visual field and 2D range of motion [10]. The Da Vinci Surgical System can be used to overcome many of these technical issues by providing an improved 3D visual field and allowing for the rational utilization of the available surgical space [11, 12]. There have been some reports on the safety and efficacy of robotic ISR in the short term [13–15]. Complications following surgery and the long-term outcomes associated with robotic ISR procedures, however, remain to be fully characterized.

The objective of this investigation was the comparison of the short- and long-term outcomes associated with the laparoscopic ISR and robotic ISR radical resection procedures in cases with low rectal cancer, focusing especially on outcomes pertaining to urogenital and bowel functions.

Method

Study design and participants

This was a retrospective single-center cohort study including patients with low rectal cancer who had undergone treatment via either laparoscopic ISR ($n = 150$) or robotic ISR ($n = 150$) from January 1, 2016, and July 1, 2019. A single team of experienced surgeons who had completed their laparoscopic and robotic ISR learning curves performed all of these procedures. All patients provided informed consent to complete questionnaires for collecting information on urogenital and bowel functional recovery. The ethics committee of The First Affiliated Hospital of Anhui Medical University approved this study.

To be eligible for inclusion, patients had to (1) have a preoperative colonoscopy and biopsy-confirmed diagnosis of rectal adenocarcinoma, (2) have undergone laparoscopic or robotic ISR, (3) exhibit tumors ≤ 6 cm from the anal verge, (4) have undergone stage-appropriate treatment, with stage I (cT1-T2N0M0) patients being eligible to directly undergo surgery whereas stage II or III (cT3N0-2M0) patients first underwent neoadjuvant therapy followed by surgery after tumor downstaging, and (5) exhibit good preoperative anal function.

Patients were excluded if they had (1) undergone preoperative histopathological examination confirming the presence of mucinous adenocarcinoma, signet ring cell carcinoma, or undifferentiated adenocarcinoma, (2) tumors that continued to invade the intersphincteric dissection after neoadjuvant therapy as determined via MRI, or (3) evidence of invasion of the external anal sphincter.

Prior to surgery, the treatment group will evaluate the specific location of the tumor along with the patient's overall health status, including factors such as high BMI, to determine the most suitable surgical approach. Following comprehensive communication and obtaining informed consent from the patient and their family, the surgical procedure will be carried out.

Preoperative and postoperative management

Low rectal cancers in this study were defined as those tumors ≤ 6 cm from the anal verge. The patients received routine preoperative procedures, including digital rectal examination (DRE), pre-treatment colonoscopy, biopsy, pelvic magnetic resonance imaging (MRI), or abdominal pelvic enhanced CT scans. Serum factors such as hemoglobin, albumin, and tumor markers were also determined. Neoadjuvant therapy was provided to patients with locally advanced tumors, with regimens consisting of intravenous oxaliplatin and oral capecitabine. Neoadjuvant radiation was provided as 50 Gy divided into 25 fractions. After two preoperative neoadjuvant treatments, patients were reassessed for surgical indications. Surgical planning was performed through multidisciplinary discussions that included the chief physician from the department of colorectal surgery, radiation and medical oncologists, anesthesiologists, and radiologists. Before surgery, patients were not allowed to consume water or food for 8 h. A clinical nursing specialist documented the postoperative recovery of these patients. Postoperative complications were documented using the Clavien-Dindo classification system.

Surgical procedures

Robotic ISR: (1) After successful anesthetization, patients were positioned in the modified lithotomy position. Routine disinfection, catheterization, and surgical wiping was performed. Pneumoperitoneum establishment was then performed by inserting an 8-mm Trocar ~ 2–3 cm above the right umbilicus. After inserting this Trocar, the robotic arm was positioned at the intersection of the transumbilical plane and a vertical line passing through the left papilla, as well as the left anti-McBurney's point and right McBurney's point. A 12-mm Trocar was then introduced at the intersection of the transumbilical plane and the vertical line passing traversing the right papilla as an auxiliary port. (2) Posterior peritoneal dissection was then performed from the horizontal junction of the mesigmoid and sacral promontory, carefully releasing along the left common iliac artery to achieve exposure of the abdominal aorta. The left colic, sigmoid, and superior rectal arteries were then exposed by dissecting the inferior mesenteric artery ~ 4-cm distal to the bifurcation of the left and right common iliac arteries. The ligation and transection of the superior rectal artery and sigmoid artery were performed, while the ligation or preservation of the integrity of the left colic artery was performed as it entered the Toldt's space, followed by dissection, ligation, and transection of the inferior mesenteric vein. The left ureter and genital vessels were visualized and mobilized within the left lower abdominal wall, followed by lateral dissection of the mesocigmoid from the lateral abdominal wall to where it entered the posterior peritoneum through the plane of the yellow-white borderline (White line of Toldt) where it connects with the medial Toldt's space was performed. (3) The dissection of the sacrorectal ligament was then performed from the abdominal aorta surface, extending into the anterior sacral space with further expansion. The careful dissection of the denonvillier fascia from both the left and right pararectal spaces was performed, making precise incisions ~ 1 cm anterior to the rectovesical pouch and peritoneal reflection. Continued dissection of the mesorectal mesentery was performed until reaching the terminal mesorectal mesentery, extending into the intersphincteric dissection. (4) The pneumoperitoneum was then closed, a disk retractor was used to retract the anus, with placement of a purse-string suture beneath the tumor. An electrotome was then used to incise the intestine below this suture until reaching the sphincter, then ascending through the external sphincter to the upper sphincter to achieve the complete resection of the rectum. The intestinal tube was then sutured, and anastomosis was verified, establishing the pattern of anastomosis intraoperatively. (5) The pneumoperitoneum was then re-established, and two drainage tubes were introduced into the pelvic cavity through the left and right lower abdominal trocar incisions and were secured. (6) The pneumoperitoneum was then evacuated, selecting the right middle abdomen as the stoma site and resecting the end ileum 20 cm proximal to the ileocecal junction.

A similar procedure was also used to perform laparoscopic ISR procedures.

According to the relative position of the tumor to the anal resection line, ISR was categorized into partial, subtotal, and total ISR types. The excision line for partial ISR procedures was above the dentate line, necessitating the excision of only a small portion of the internal anal sphincter. The subtotal ISR resection line was located between the dentate line and the intersphincter groove, necessitating the excision of most of the internal anal sphincter. The total ISR resection line was located within the intersphincteric groove, requiring that the internal anal sphincter be completely excised.

Functional evaluation and postoperative follow-up

The International Prostatic Symptom Score (IPSS) questionnaire was utilized to evaluate patient recovery following surgery. The Wexner and LARS (low anterior resection syndrome score) questionnaires were used to evaluate the recovery of anal function. A specialist nurse followed up with these patients, administering questionnaires at 1, 3, 6, 12, and 24 months postoperatively. Other components of follow-up included postoperative adjuvant therapy, monitoring for metastasis, surveillance for recurrence, and the assessment of survival. Patient prognosis was assessed by specialist nurses at 1, 3, and 5 years postoperatively.

Statistical analysis

Data were analyzed using SPSS 27.0 (NY, USA). Chi-square tests or Fisher's exact test were utilized for comparison of categorical data while continuous data were compared with *t*-tests and Mann–Whitney *U* tests. Data are given as means ± SD or medians and ranges when normally and non-normally distributed, respectively. Risk factors related to postoperative anastomotic leakage (AL) were analyzed with a binary logistic regression approach. Factors capable of predicting the overall survival (OS) and disease-free survival (DFS) of these patients were detected through Cox regression analyses. $P < 0.05$ was used to define significance.

Results

Between January 1, 2016, and July 1, 2019, 300 low rectal cancer patients who were eligible for study inclusion underwent minimally invasive ISR in our colorectal surgical department, including 150 each who underwent robotic ISR and laparoscopic ISR procedures. The baseline preoperative information on the participants is provided in Table 1. The patients in the robotic ISR groups exhibited a significantly lower average distance between the tumor and the anal margin (3.94 ± 0.48 vs 5.66 ± 0.47, $P < 0.001$). No other baseline data differed significantly between these groups, including age, tumor marker levels (CEA, CA19-9), preoperative clinical stage, or preoperative neoadjuvant treatment. Notably, 81 patients (27%) in each group received preoperative neoadjuvant treatment.

Table 1 Clinical characteristics

Baseline data	Robotic ISR ($n=150$)	Laparoscopic ISR ($n=150$)	t/χ^2	*P* value
Gender (*N*, %)				
Male	94 (62.7%)	96 (64%)	0.05	0.811
Female	56 (37.3%)	54 (36%)	7	
Age (years, mean, SD)	58.3 ± 10.4	60.2 ± 10.8	1.542	0.124
BMI (kg/m^2, mean, SD)	23.6 ± 3.2	23.3 ± 3.7	0.771	0.442
Hb (g/L, mean, SD)	126.6 ± 23.4	129.6 ± 16.1	1.257	0.21
Alb (g/L, mean, SD)	42.0 ± 4.4	42.7 ± 3.9	1.497	0.135
CEA (> abnormal, N, %)	25(16.7%)	29(19.3%)	0.361	0.548
CA199 (> abnormal, *N*, %)	14 (9.3%)	10 (6.7%)	0.725	0.395
Diabetes (*N*, %)	15 (10%)	23 (15.3%)	1.928	0.165
ASA classification (*N*, %)				
I	33 (22%)	24 (16%)	1.78	0.409
II	87 (58%)	95 (63.3%)		
III	30 (20%)	31 (20.7%)		
NRS2002 Score (%)				
1 ~ 2	100 (66.7%)	102 (68%)	0.061	0.806
≥ 3	50 (33.3%)	48 (32%)		
Distance from the anal margin (cm, mean, SD)	3.94 ± 0.48	5.66 ± 0.47	31.39	< 0.001
cT stage (*N*, %)				
T1	13 (8.7%)	8 (5.3%)	1.29	0.523
T2	117 (78%)	122 (81.3%)		
T3	20 (13.3%)	20 (13.3%)		
cN stage (*N*, %)				
N0	121 (80.7%)	111 (74%)	3.42	0.18
N1	22 (14.7%)	24 (16%)		
N2	7 (4.7%)	15 (10%)		
cTNM stage (*N*, %)				
I	112 (74.7%)	95 (63.3%)	4.82	0.09
II	9 (6%)	16 (10.7%)		
III	29 (19.3%)	39 (26%)		
Preoperative neoadjuvant therapy (*N*, %)	33 (22%)	48 (32%)	3.805	0.051

Operative, postoperative, and pathological outcomes

Intraoperative, postoperative recovery, complication-related, and pathological data were analyzed in these two patient groups (Table 2). While the robotic ISR group exhibited a longer operative duration, the difference was not significant (253.0 ± 66.4 vs 241.6 ± 77.5, $P > 0.05$). In total, 181 patients (60.3%) underwent left colic artery preservation, including 95 and 86 in the robotic and laparoscopic ISR groups, respectively (63.3% vs 57.3%, $P > 0.05$). Hand-sewn anastomosis was performed for 85 of the participants in the robotic cohort (56.7%) and 71 in the laparoscopic cohort (47.3%) ($P > 0.05$). Temporary ileostomy was not conducted for 41 of the patients in these groups (13.7%). Other intraoperative data including ISR type and intraoperative blood loss were not associated with any show significant differences.

Catheter removal time was markedly shorter in the robotic ISR cohort relative to the laparoscopic ISR cohort (4.9 ± 1.4 vs 5.3 ± 1.6, $P = 0.007$). Postoperative recovery showed no marked differences in terms of postoperative hospitalization, time to leave bed, or postoperative gastrointestinal function recovery time when comparing these groups. The distance between the tumor and the distal margin was markedly less in the robotic ISR cohort than that in the laparoscopic ISR cohort (1.0 ± 0.5 vs 1.3 ± 0.5, $P < 0.001$). Other pathological results, such as tumor differentiation, maximum tumor diameter, number of dissected lymph nodes, vascular and nerve invasion, tumor deposit, and pathological TNM stage, did not differ significantly between the groups.

In total, 64 patients in this study cohort developed postoperative complications, including 34 (22.7%) in the laparoscopic ISR cohort and 30 (20%) in the robotic ISR cohort ($P = 0.573$). Of the patients in the robotic ISR cohort, 8

Table 2 Intraoperative, postoperative recovery, and pathological endpoints

Variables	Robotic ISR ($n=150$)	Laparoscopic ISR ($n=150$)	t/χ^2	*P* value
Type of ISR (N, %)			2.7	0.259
Patrical ISR	36 (24%)	40 (26.7%)		
Substotal ISR	88 (54%)	88 (58.7%)		
Total ISR	33 (22%)	22 (14.7%)		
Operative time (min, mean, SD)	253.0 ± 66.4	241.6 ± 77.5	1.362	0.174
Operative blood loss (ml, mean, SD)	56.3 ± 86.4	53.9 ± 36.5	0.309	0.758
Preserving left colon artery (*N*, %)	95 (63.3%)	86 (57.3%)	1.128	0.288
Anastomotic method (*N*, %)				
Hand-sewn anastomosis	85 (56.7%)	71 (47.3%)	2.618	0.106
Stapler anastomosis	65 (43.3%)	79 (52.7%)		
Temporary ileostomy (*N*, %)	131 (87.3%)	128 (85.3%)	0.254	0.614
Postoperative hospital stay (days, mean, SD)	8.8 ± 3.6	9.4 ± 3.7	1.506	0.133
The leaving bed time (days, mean, SD)	2.3 ± 1.4	2.4 ± 1.1	0.885	0.377
Postoperative gastrointestinal function recovery time (days, mean, SD)	2.9 ± 1.3	3.2 ± 1.7	1.761	0.079
Removal time of urinary catheter (days, mean, SD)	4.9 ± 1.4	5.3 ± 1.6	2.721	0.007
Postoperative complications (*N*)	30 (20%)	34 (22.7%)	0.318	0.573
Anastomotic leakage (%)	10 (6.7%)	14 (9.3%)	0.212	0.807
Incision infection (%)	1 (0.67%)	1 (0.67%)		
Urinary retention (%)	5 (3.3%)	9 (6%)		
urinary tract infection (%)	3 (2%)	1 (0.67%)		
pulmonary infection (%)	4 (2.7%)	4 (2.7%)		
VTE (%)	5 (3.3%)	4 (2.7%)		
intestinal obstruction (%)	2 (1.3%)	1 (0.67%)		
Classification of Clavien-Dindo				
I	12	16	0.695	0.874
II	14	13		
III	3	3		
IV	1	2		
V	0	0		
Classification of anastomotic leakage				
I	2	2	0.171	0.918
II	5	7		
III	3	5		
Ileostomy reversal time (months, mean, SD)	5.2 ± 2.0	5.6 ± 2.4	1.629	0.105
Tumor differentiation (*N*, %)				
High differentiate adenocarcinoma	6 (4%)	9(6%)	1.956	0.376
Moderate differentiate adenocarcinoma	121 (80.7%)	111 (74%)		
Low differentiated adenocarcinoma	23 (15.3%)	30 (20%)		
Maximum tumor diameter (cm, mean, SD)	3.59 ± 1.40	3.74 ± 1.19	1.029	0.305
Number of lymph node dissection (mean, SD)	14.0 ± 3.5	14.4 ± 3.8	1.114	0.266
Distance of tumor from distal margin (mean, SD)	1.0 ± 0.5	1.3 ± 0.5	5.239	< 0.001
Vascular invasion (*N*, %)	52 (34.7%)	61 (41.7%)	1.150	0.284
Nerve invasion (*N*, %)	51 (31%)	48 (32%)	0.136	0.713
Tumor deposit (*N*, %)	18 (12%)	28 (18.7%)	2.568	0.109
No.253 lymph node metastasis (*N*, %)	30 (20%)	26 (17.3%)	0.351	0.553
pT stage (*N*, %)				
Tis	11 (7.3%)	6 (4%)	4.597	0.204
T1	12 (8%)	22 (14.7%)		

Table 2 (continued)

Variables	Robotic ISR ($n = 150$)	Laparoscopic ISR ($n = 150$)	t/χ^2	*P* value
T2	57 (38%)	57 (38%)		
T3	70 (46.7%)	65 (43.3%)		
pN stage (*N*, %)				
N0	108 (72%)	95 (63.3%)	2.959	0.228
N1a ~ c	30 (20%)	36 (24%)		
N2a ~ b	12 (8%)	19 (12.7%)		
pTNM stage (*N*, %)				
I	68 (45.3%)	63 (42%)	3.911	0.142
II	42 (28%)	32 (21.3%)		
III	40 (26.7%)	55 (36.7%)		
Postoperative treatment (*N*, %)				
Adjuvant chemotherapy	72 (48%)	65 (43.3%)	0.683	0.711
Adjuvant radiotherapy	45 (32%)	48 (32%)		
Ileostomy reversal time (months, mean, SD)	5.2 ± 2.0	5.6 ± 2.4	1.629	0.105

(5.3%) experienced urinary retention or urinary tract infection, as compared to 6.67% of patients in the laparoscopic ISR cohort; these differences were not significant. No differences in complication types were observed when comparing these cohorts. The Clavien-Dindo system was applied for classifying complication severity. In the robotic and laparoscopic ISR groups, 86.7% and 85.3% of patients respectively developed grade I–II postoperative complications. Nine patients (3%) across both cohorts required further surgical intervention to treat their complications, including one member of the robotic ISR group and two in the laparoscopic ISR cohort who were postoperatively transferred to the intensive care unit (ICU). Postoperative mortality did not occur in any case.

In total, 24 patients (8%) in both groups developed postoperative anastomotic leakage, including 10 and 14 cases in the robotic ISR and laparoscopic ISR groups, with no significant difference between groups (6.7% vs 9.3%, 0.395). Univariate and multivariate analysis results of factors linked with postoperative anastomotic leakage are shown in Table 3. Binomial logistic regression analyses indicated that elevated BMI (≥ 25 kg/m^2), diabetes, the lack of preservation of the left colic artery, pathological T stage (T3), the absence of temporary ileostomy, and DRM (< 1 cm) were linked to a greater likelihood of postoperative anastomotic leakage.

Table 3 Analyses of urinary function and bowel function

Variables		Postoperative 1 month	Postoperative 3 months	Postoperative 6 months	Postoperative 12 months	Postoperative 24 months
Frequency of bowel movements (times/day)	Robotic ISR	8.9 ± 4.2	8.0 ± 3.8	4.6 ± 2.4	2.6 ± 1.9	1.9 ± 1.4
	Laparoscopic ISR	8.7 ± 4.5	8.2 ± 4.1	7.1 ± 3.8	6.0 ± 3.1	3.9 ± 2.3
	P value	0.781	0.644	< 0.001	< 0.001	< 0.001
Wexner Score (mean, SD)	Robotic ISR	5.0 ± 4.6	3.7 ± 4.3	2.9 ± 3.9	2.1 ± 3.5	1.3 ± 3.1
	Laparoscopic ISR	5.3 ± 4.2	4.6 ± 3.8	4.0 ± 3.5	3.7 ± 3.5	2.8 ± 3.1
	P value	0.634	0.1	0.027	< 0.001	< 0.001
LARS Score (mean, SD)	Robotic ISR	27.0 ± 12.2	26.2 ± 11.6	22.3 ± 11.6	16.9 ± 12.2	10.0 ± 12.6
	Laparoscopic ISR	27.2 ± 12.8	26.6 ± 12.3	25.9 ± 12.1	23.3 ± 13.1	18.4 ± 14.3
	P value	0.927	0.82	0.028	< 0.001	< 0.001
IPSS Score (mean, SD)	Robotic ISR	10.5 ± 4.2	7.2 ± 3.6	5.0 ± 3.1	4.0 ± 2.6	2.3 ± 2.2
	Laparoscopic ISR	9.6 ± 4.1	7.3 ± 3.4	6.0 ± 2.9	4.8 ± 2.9	4.4 ± 2.6
	P value	0.123	0.828	0.01	0.021	< 0.001

Postoperative functional recovery

Bowel movement frequency, Wexner scores, and LARS scores were used to evaluate the postoperative recovery of bowel control function (Table 4). These parameters did not differ significantly between the groups within 3 months of surgery. In general, both groups exhibited gradual decreases in the frequency of bowel movements together with improvements in bowel control function. Significantly better bowel functional recovery was seen in the robotic ISR group relative to the laparoscopic ISR group from 6 months postoperatively, and this advantage was still apparent even at 24 months post-surgery.

IPSS scores were also used to evaluate the postoperative recovery of urinary function, revealing a pattern of functional recovery between these two groups similar to the recovery of bowel function.

Long-term outcomes

In the robotic group, the median follow-up duration was 74 months, whereas in the laparoscopic group, it was 78 months. The 3- and 5-year disease-free survival (DFS) rates in the robotic group were 84.7% and 74.0%, respectively, while the corresponding overall survival (OS) rates were 89.3% and 82.0%. In the laparoscopic group, the 3- and 5-year disease-free survival (RFS) rates were 82.7% and 73.3%, respectively, with OS rates of 89.3% and 78.7% at the same time points ($P > 0.05$). There were no significant differences in disease-free survival or overall survival between the two groups. Patient OS and DFS following surgery are presented in Figs. 1 and 2. No significant differences in either of these survival outcomes were observed between groups. Cox regression analyses indicated that postoperative complications, tumor differentiation, vascular and nerve invasion, a lack of postoperative adjuvant therapy, and positive lymph

Table 4 Univariate and multivariate analysis of postoperative anastomotic leakage

Univariate analysis of postoperative anastomotic leakage (AL)				
Variables	AL group ($n = 24$)	Non-AL Group (n = 276)	χ^2	P value
Age (≥ 70 years)	6 (25%)	56 (20.3%)	0.299	0.585
Gender (male, %)	18 (75%)	172 (62.3%)	1.529	0.216
BMI (≥ 25, %)	16 (66.7%)	86 (31.2%)	12.405	< 0.001
NRS (≥ 3, %)	14 (58.3%)	84 (30.4%)	7.813	0.005
cTNM (I stage, %)	20 (83.3%)	211 (76.4%)	0.591	0.442
Preoperative adjuvant therapy (%)	4 (16.7%)	77(27.9%)	1.413	0.235
Diabetes (%)	13 (54.2%)	25(9.1%)	40.614	< 0.001
Surgical method (robotic ISR, %)	10 (41.7%)	140 (50.7%)	0.725	0.395
Intraoperative bleeding (≥ 50 ml, %)	13 (54.2%)	146 (52.9%)	0.014	0.905
Type of ISR				
Patrical ISR (%)	6 (25%)	70 (25.4%)	4.199	0.123
Substotal ISR (%)	10 (41.7%)	159 (57.6%)		
Total ISR (%)	8 (33.3%)	47 (17.0%)		
Preserving left colon artery (%)	5 (20.8%)	176 (63.8%)	17.007	< 0.001
Hand-sewn anastomosis (%)	16 (66.7%)	140 (50.7%)	2.248	0.134
Temporary Ileostomy (%)	9 (37.5%)	250 (90.6%)	52.725	< 0.001
Maximum tumor diameter (≥ 3 cm, %)	20 (83.3%)	219 (79.3%)	0.217	0.642
pT stage (T3, %)	17 (70.8%)	116 (42.0%)	7.423	0.006
pN stage (N0, %)	13 (54.2%)	190 (68.8%)	2.173	0.140
DRM (< 1 cm, %)	21 (87.5%)	93 (33.7%)	27.131	< 0.001
Binomial logistic regression analysis of postoperative anastomotic leakage				
	Wald	OR	P value	95% CI
BMI (≥ 25 kg/m^2)	4.449	5.419	0.035	1.127 ~ 26.055
NRS (≥ 3)	0.244	1.483	0.310	0.310 ~ 7.094
Diabetes	14.231	79.093	< 0.001	8.165 ~ 766.146
Preserving left colon artery	11.215	0.023	< 0.001	0.002 ~ 0.209
Temporary ileostomy	14.261	0.022	< 0.001	0.003 ~ 0.160
pT stage (T3)	7.393	15.551	0.007	2.151 ~ 112.418
DRM (≥ 1 cm)	10.338	0.041	0.001	0.006 ~ 0.286

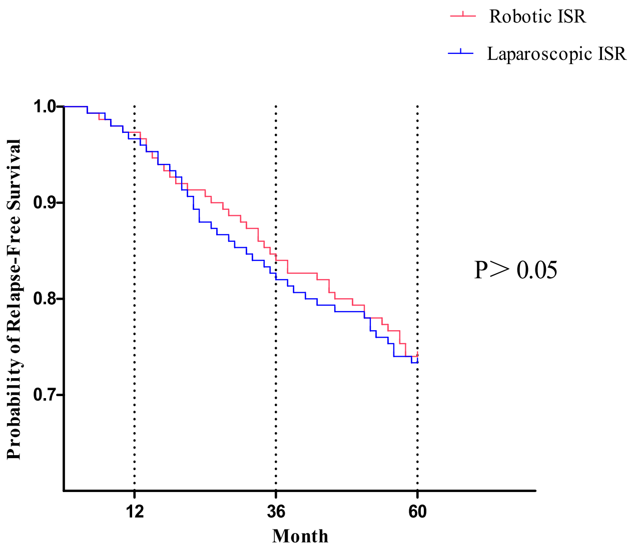

Fig. 1 The 3- and 5-year disease-free survival (DFS) rates in the robotic group were 84.7% and 74.0%, and the 3- and 5-year disease-free survival (DFS) rates in the laparoscopic group were 82.7% and 73.3%, respectively ($P > 0.05$)

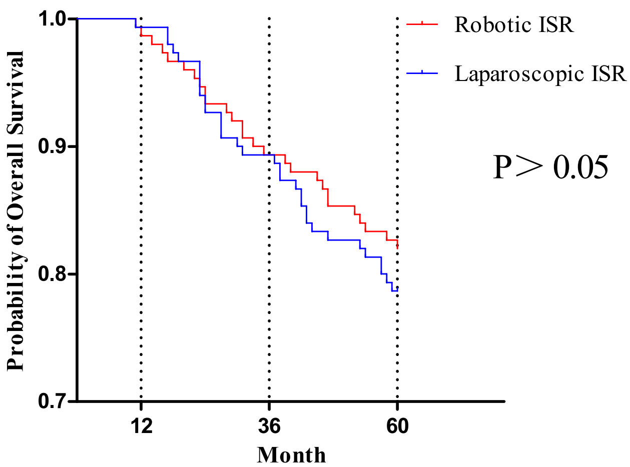

Fig. 2 The 3- and 5-year overall survival (OS) rates in the robotic group were 89.3% and 82.0%, and the 3- and 5-year overall survival (OS) in the laparoscopic group rates were 89.3% and 78.7%, respectively ($P > 0.05$)

nodes (pN +) were significantly associated with postoperative OS (Table 5), and these variables, apart from positive lymph nodes, were also significantly associated with DFS.

Discussion

The advent of ISR has fueled improvements in the rates of anal preservation for low rectal cancer patients. Corresponding studies have revealed that ISR is a suitable clinical approach associated with good short-term oncological safety [9, 16, 17]. Laparoscopic technologies have also been applied in colorectal surgery with increasing frequency. In comparison with laparotomy, laparoscopic surgery can magnify the surgical field of view while causing less trauma and facilitating more rapid postoperative recovery [10]. Some reports have determined that laparoscopic surgical approaches are associated with relatively satisfactory short-term prognostic outcomes when used in the context of ISR treatment [8, 18].

Owing to the technical limitations associated with conventional laparoscopic instruments including their fixed two-dimensional field of view and the lack of an ability to rotate the instrument tip [10], laparoscopic surgery cannot achieve the comprehensive visualization of the pelvic region. When performing ISR, adequately and precisely dissecting the pelvis is essential [19]. For these reasons, there is growing interest in a transition away from laparoscopy in favor of robotic platforms when performing low rectal surgery. Many retrospective studies and meta-analyses have found that utilizing robot-assisted approaches can afford substantial advantages for surgical low rectal cancer management [20–22]. Robotic techniques have the advantage of allowing surgeons to perform procedures that are more intricate, precisely separating the pelvic tissue and completely resecting the mesentery to allow for more rapid postoperative recovery of gastrointestinal function while better preserving pelvic autonomic nerve function and minimizing intraoperative blood loss [21]. Using robotic approaches may thus afford superior outcomes relative to those associated with a laparoscopic approach with respect to the safeguarding of the pelvic nerves and the preservation of anal function, providing rectal cancer patients with better postoperative quality of life. This study is the largest report to our knowledge assessing postoperative functional recovery and long-term prognostic outcomes associated with laparoscopic ISR and robotic ISR.

Here, the tumor location among patients in the robotic group was significantly closer to the anal verge relative to the laparoscopic group. The time to catheter removal was also less in the robotic group. These advantages to robotic ISR may be related to its superior 3D field of view and the advanced seven-degree-of-freedom surgical instruments provided by the robotic platform, allowing for better precision when performing delicate manipulations within the narrow pelvic space such that greater anatomical accuracy could be achieved while minimizing the likelihood of damaging the pelvic vessels and autonomic nerves. The flexible robotic arms used for this procedure allow for the precise separation of the low rectal anatomical structures, facilitating anal preservation for ultra-low rectal cancer. The robotic ISR approach is thus amenable to a smaller anal preservation limit with closer anal proximity as compared to the laparoscopic approach.

Table 5 Cox regression analyses of patient OS and DFS

Univariate and multivariate Cox regression analysis of predictors of OS and DFS								
Variables	Overall survival				Disease-free survival			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Surgical approach: robotic ISR vs laparoscopic ISR	0.960 (0.618 ~ 1.493)	0.858	NA	NA	0.832 (0.499 ~ 1.389)	0.483	NA	NA
Gender: male vs female	1.064 (0.676 ~ 1.677)	0.788	NA	NA	1.105 (0.655 ~ 1.864)	0.709	NA	NA
Age: ≥ 70 years	0.938 (0.542 ~ 1.623)	0.819	NA	NA	0.864 (0.449 ~ 1.663)	0.661	NA	NA
BMI: ≥ 25	1.325 (0.843 ~ 2.082)	0.222	NA	NA	1.457 (0.869 ~ 2.441)	0.153	NA	NA
cTNM stage: III	2.186 (1.383 ~ 3.455)	< 0.001	1.286 (0.775 ~ 2.134)	0.33	1.861 (1.086 ~ 3.191)	0.024	0.997 (0.553 ~ 1.797)	0.992
Preoperative adjuvant therapy	1.385 (0.866 ~ 2.214)	0.174	NA	NA	1.216 (0.699 ~ 2.117)	0.489	NA	NA
CEA: > normal	2.072 (1.275 ~ 3.368)	0.003	1.143 (0.578 ~ 2.261)	0.7	1.828 (1.030 ~ 3.246)	0.039	0.975 (0.527 ~ 1.803)	0.935
CA199: > normal	1.971 (1.042 ~ 3.728)	0.037	0.790 (0.326 ~ 1.911)	0.601	1.341 (0.576 ~ 3.118)	0.496	NA	NA
Type of ISR: total ISR	0.684 (0.362 ~ 1.293)	0.242	NA	NA	0.669 (0.317 ~ 1.409)	0.290	NA	NA
Postoperative complications	3.397 (2.165 ~ 5.322)	< 0.001	1.74 (1.030 ~ 2.936)	0.038	4.884 (2.927 ~ 8.150)	< 0.001	1.873 (1.046 ~ 3.353)	0.035
Tumor differentiation: low differentiated adenocarcinoma	3.421 (2.137 ~ 5.476)	< 0.001	2.135 (1.244 ~ 3.664)	0.006	3.915 (2.307 ~ 6.644)	< 0.001	2.055 (1.131 ~ 3.733)	0.018
Maximum tumor diameter: ≥ 3 cm	1.482 (0.802 ~ 2.740)	0.209	NA	NA	1.275 (0.646 ~ 2.516)	0.484	NA	NA
No.253 lymph node metastasis	8.958 (5.704 ~ 14.070)	< 0.001	1.148 (0.591 ~ 2.229)	0.683	9.822 (5.789 ~ 16.663)	< 0.001	1.090 (0.492 ~ 2.414)	0.833
Distance of tumor from distal margin: < 1 cm	1.050 (0.668 ~ 1.649)	0.832	NA	NA	0.890 (0.523 ~ 1.517)	0.670	NA	NA
Vascular invasion	10.113 (5.752 ~ 17.782)	< 0.001	2.667 (1.373 ~ 5.179)	0.004	16.014 (7.266 ~ 35.297)	< 0.001	3.59 (1.455 ~ 8.860)	0.006
Nerve invasion	10.788 (6.352 ~ 18.321)	< 0.001	3.388 (1.806 ~ 6.357)	< 0.001	24.446 (10.490 ~ 56.968)	< 0.001	6.644 (2.552 ~ 17.295)	< 0.001
Tumor deposit	5.491 (3.487 ~ 8.646)	< 0.001	1.378 (0.791 ~ 2.402)	0.258	6.081 (3.631 ~ 10.184)	< 0.001	1.562 (0.807 ~ 3.024)	0.186
pT stage: T3	4.212 (2.554 ~ 6.947)	< 0.001	1.550 (0.835 ~ 2.879)	0.165	5.590 (2.963 ~ 10.543)	< 0.001	1.595 (0.764 ~ 3.332)	0.214
pN stage: N1 ~ N2	11.044 (6.439 ~ 18.943)	< 0.001	3.77 (1.811 ~ 7.845)	< 0.001	9.461 (5.103 ~ 17.541)	< 0.001	2 (0.806 ~ 4.962)	0.315
Postoperative adjuvant treatment: without adjuvant therapy	2.270 (1.459 ~ 3.533)	< 0.001	2.628 (1.572 ~ 4.392)	< 0.001	1.985 (1.191 ~ 3.307)	0.008	2.109 (1.169 ~ 3.802)	0.013

Robotic ISR surgery has been reported to be longer in duration and associated with less intraoperative blood loss relative to laparoscopic ISR, contributing to accelerated postoperative recovery [23, 24]. These outcomes did not differ significantly between the two cohorts. This may be related to the many years of experience that surgeons at our facility have in the execution of robotic low rectal surgical procedures, leading to more refined surgical techniques such that surgeons have been able to overcome the initial learning curve [25], enabling laparoscopic ISR and robotic ISR procedures can be performed simultaneously. No marked differences in postoperative complications between the cohorts were seen. Postoperative anastomotic leakage affected 8% of the patients in this study, including 9.4% and 6% in the laparoscopic ISR and robotic ISR groups, respectively. Higher BMI, diabetes, a lack of left colic artery-preserving surgery, more extensive tumor invasion, and the lack of a temporary stoma were all markedly linked with the likelihood of postoperative anastomotic leakage. No significant differences in anastomotic leakage rates were observed when comparing surgical approaches, suggesting that left colic artery preservation and routinely preventive ileostomy are both important when performing ISR procedures in an effort to minimize the potential for such leakage.

In this study, robotic ISR outperformed laparoscopic ISR with respect to postoperative recovery, including patient bowel and urinary function. The favorable functional recovery outcomes associated with robotic ISR may be related to improved nerve and anal sphincter preservation mediated by the robotic platform. Several factors have been reported to influence postoperative bowel functional recovery following ISR procedures, including patient age, obesity status, tumor location, preoperative/postoperative adjuvant radiotherapy, psychological factors, social factors, cultural factors, anastomotic leakage, and the duration of stoma maintenance [26–28]. Robot-assisted rectal surgical procedures reportedly yield similar long-term outcomes to those associated with open and laparoscopic rectal surgery [29, 30]. While there have been limited reports of similar prognostic outcomes between robotic ISR and laparoscopic ISR procedures, the sample sizes of these studies have been limited. In the present study, the 5-year OS and DFS rates did not differ markedly between the two cohorts, suggesting that the oncological safety and prognostic outcomes associated with robotic and laparoscopic ISR are similar.

There are several limitations to this study. For one, as a single-center retrospective analysis, the patient selection may have been subject to some degree of bias. Secondly, the study covered a relatively large time period. In addition, no direct attempts to assess anal function were included in this study. The use of questionnaires to gauge bowel and urinary function may have impacted the precision of data pertaining to these functional rehabilitation outcomes. These factors may thus have impacted the accuracy of the conclusions of this study.

In summary, robotic ISR holds promise as a viable approach to managing low and ultra-low rectal tumors, providing a safe and feasible substitute for conventional laparoscopic surgery. Notably, robotic ISR was better than laparoscopic ISR in terms of postoperative functional recovery in this study cohort.

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Authors' contribution Yongxiang Li,Yang bo, Wang yigao, Zheng mingye, Jian Zhao were all involved with the conception and design of the study. Yang bo, Wang yigao and Zheng mingye participated in data acquisition, analysis and interpretation. Yang bo wrote the main manuscript text and also prepared tables 1-4 and figures 1-2. All authors reviewed the manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

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