



OPEN Comparison of robotic assisted and laparoscopic radical resection for rectal cancer with or without left colic artery preservation

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The preservation of the left colic artery (LCA) during rectal cancer resection remains a topic of controversy, and there is a notable absence of robust evidence regarding the outcomes associated with LCA preservation. And the advantages of robotic-assisted laparoscopy (RAL) surgery in rectal resection remain uncertain. The objective of this study was to assess the influence of LCA preservation surgery and RAL surgery on intraoperative and postoperative complications of rectal cancer resection. Patients who underwent laparoscopic (LSC) or RAL with or without LCA preservation resection for rectal cancer between April 2020 and May 2023 were retrospectively assessed. The patients were categorized into two groups: low ligation (LL) which with preservation of LCA and high ligation (HL) which without preservation of LCA. A one-to-one propensity score-matched analysis was performed to decrease confounding. The primary outcome was operative findings, operative morbidity, and postoperative genitourinary function. A total of 612 patients were eligible for this study, and propensity score matching yielded 139 patients in each group. The blood loss of the LL group was significantly less than that of the HL group (54.42 ± 12.99 mL vs. 65.71 ± 7.37 mL, $p < 0.001$). The urinary catheter withdrawal time in the LL group was significantly shorter than that in the HL group (4.87 ± 2.04 d vs. 6.06 ± 2.43 d, $p < 0.001$). Anastomotic leakage in the LL group was significantly lower than that in HL group (1.44% vs. 7.91% , $p = 0.011$). The rate of urinary dysfunction and sexual dysfunction in LL group is both significantly lower than HL group. Blood loss and number of harvested lymph nodes (LNs) of both RAL subgroups in LL and HL groups were significantly more than that in LSC subgroups. The anastomotic leakage in the RAL subgroup of HL group was significantly lower than that in LSC subgroup (0% vs. 14.89% , $p = 0.018$). LCA preservation surgery for rectal cancer may help reduce the blood loss, urinary catheter withdrawal time, the rate of anastomotic leakage and ileus, and postoperative genitourinary function outcomes. RAL can reduce the probability of blood loss and improve harvest LNs in patients with rectal cancer.

Keywords Rectal cancer, Left colic artery, High ligation, Low ligation, Inferior mesenteric artery, Robotic-assisted laparoscopy

In rectal cancer surgery, the optimal level for ligating the inferior mesenteric artery (IMA) remains a subject of debate. Surgeons must choose between a high ligation (HL) at the IMA's origin near the aorta and a low ligation (LL) below the left colic artery (LCA) origin¹. Notably, HL at the IMA origin may increase the risk of anastomotic leakage². Consequently, many surgeons opt for LL, which involves preserving the LCA while ligating the IMA after dissecting the surrounding lymph nodes³. The complexity of rectal cancer surgery escalates with the tumor's proximity to the sphincter muscle and the depth of its aboral position⁴. There are two main approaches to handling the IMA during rectal cancer resection: either preserving the LCA and ligating the IMA after its bifurcation or directly ligating the IMA root without LCA preservation⁵.

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In recent years, minimally invasive surgery has gained significant traction⁶. However, studies comparing the effectiveness of robotic-assisted and laparoscopic resections for rectal cancer are still limited. Robotic-assisted systems offer numerous advantages, such as enhanced comfort and maneuverability, tremor and motion filtration via computer systems, high-definition 3D binocular vision with magnification options, fluorescence capabilities, and a stable, surgeon-operated camera platform. These features represent a significant advancement in surgical technology⁷.

In our study, we analyzed data from patients who underwent rectal cancer resection at the Department of Gastrointestinal Surgery of Northern Jiangsu People's Hospital. We aimed to explore the perioperative outcomes of low ligation and high ligation resections for rectal cancer, comparing subgroups of robotic-assisted and laparoscopic surgeries.

Methods

All methods of our research were performed in accordance with the relevant guidelines and regulations by Declaration of Helsinki. We identified that the Ethics Committee of Northern Jiangsu Province People's Hospital approved this research, including any relevant details. Informed consent was obtained from each patient preoperatively.

Patients

Inclusion criteria⁸: (1) 18 years of age and over; (2) low anterior resection for rectal cancer; (3) postoperative pathological diagnosis of rectal adenocarcinoma; and (4) informed consent signed prior to surgery.

Exclusion criteria⁸: (1) recurrent rectal cancer; (2) emergency surgery; (3) preoperative and intraoperative detection of distant organ metastases or extensive implantation metastases in the abdominal cavity; (4) palliative surgery; (5) a postoperative pathology report that showed residual cancer cells at the proximal or distal resection margin; (6) no standard chemotherapy for tumor-node-metastasis (TNM) staging II or III after surgery; (7) synchronous colorectal carcinoma and other organ tumors; and (8) incomplete case data.

As displayed in Fig. 1, based on these criteria, we retrospectively reviewed medical records of patients who underwent rectal cancer surgery at Northern Jiangsu People's Hospital from April 2020 to May 2023. Out of 1,164 cases, 612 met the inclusion criteria. Of these, 462 cases involved low ligation (LL) preserving the LCA (LL group), with 202 undergoing robotic-assisted laparoscopy (LL-RAL subgroup) and 260 undergoing laparoscopy (LL-LSC subgroup). The remaining 150 cases involved high ligation (HL) without preserving the LCA (HL group), with 70 undergoing robotic-assisted laparoscopy (HL-RAL subgroup) and 80 undergoing laparoscopy (HL-LSC subgroup).

Surgical procedure.

All patients underwent total mesorectal excision or partial mesorectal excision with D3 lymph node dissection while preserving the sphincter. In the HL group, the IMA was ligated and divided 2 cm from its origin (Fig. 2), and the inferior mesenteric vein was divided below the pancreatic margin. In the LL group, the LCA was identified and preserved while performing low ligation of the IMA (superior hemorrhoidal artery) (Fig. 2). Lymphadenectomy proceeded medially along the IMA to 2 cm from the aorta. After tumor resection, the bowel proximal to the pubic symphysis was checked to ensure tension-free condition. Splenic flexure mobilization was performed if necessary. To reconstruct the gastrointestinal tract, an end-to-end colorectal anastomosis was made, and a diverting ileostomy was added based on the surgeon's evaluation of the anastomosis quality.

Evaluation of genitourinary function

Postoperative urinary and sexual functions were assessed 6 to 12 months after surgery through interviews and questionnaires. Each patient, along with a partner, completed a questionnaire about bladder and sexual sensations. Urinary function was evaluated based on incontinence, retention, pollakiuria, and residual urine volume, and dysfunction was classified into four grades⁹: (I) normal function, no urination trouble; (II) mild dysfunction, pollakiuria, residual urine volume ≤ 50 mL; (III) moderate dysfunction, urination possible most times, residual urine volume > 50 mL, rare self-catheterization; and (IV) severe dysfunction, usual self-catheterization for incontinence or retention.

Erectile function was assessed using the International Erectile Dysfunction Index-5 (IIEF-5) questionnaire¹⁰: (I) normal erectile function, score > 11 ; (II) reduced erectile function, score 8–11, lower rigidity than preoperative; (III) loss of erectile function, score < 8 , no erection. Ejaculatory function was evaluated with an ejaculation function score¹⁰: (I) normal ejaculation; (II) abnormal ejaculation, few or retrograde; (III) loss of ejaculation function, no ejaculation. Categories II and III in erectile and ejaculatory functions were defined as sexual dysfunctions.

Statistical analyses

A one-to-one propensity score-matched (PSM) analysis was performed using IBM SPSS 22.0, with a caliper of 0.02 to reduce confounding. Patients were grouped based on variables such as age, sex, BMI, ASA classification, tumor location, TNM stage, and surgical approach (laparoscopic or robotic). Out of 612 eligible patients, PSM yielded 139 patients in each group.

To control confounding, subgroup analyses were conducted based on the presence or absence of a protective ileostomy. Continuous variables with a normal distribution are presented as mean \pm standard deviation and analyzed using Student's t-test. Categorical variables were compared using the chi-square test or Fisher's exact test. A p-value of < 0.05 was considered statistically significant. Statistical analysis was performed using IBM SPSS Statistics, version 22.

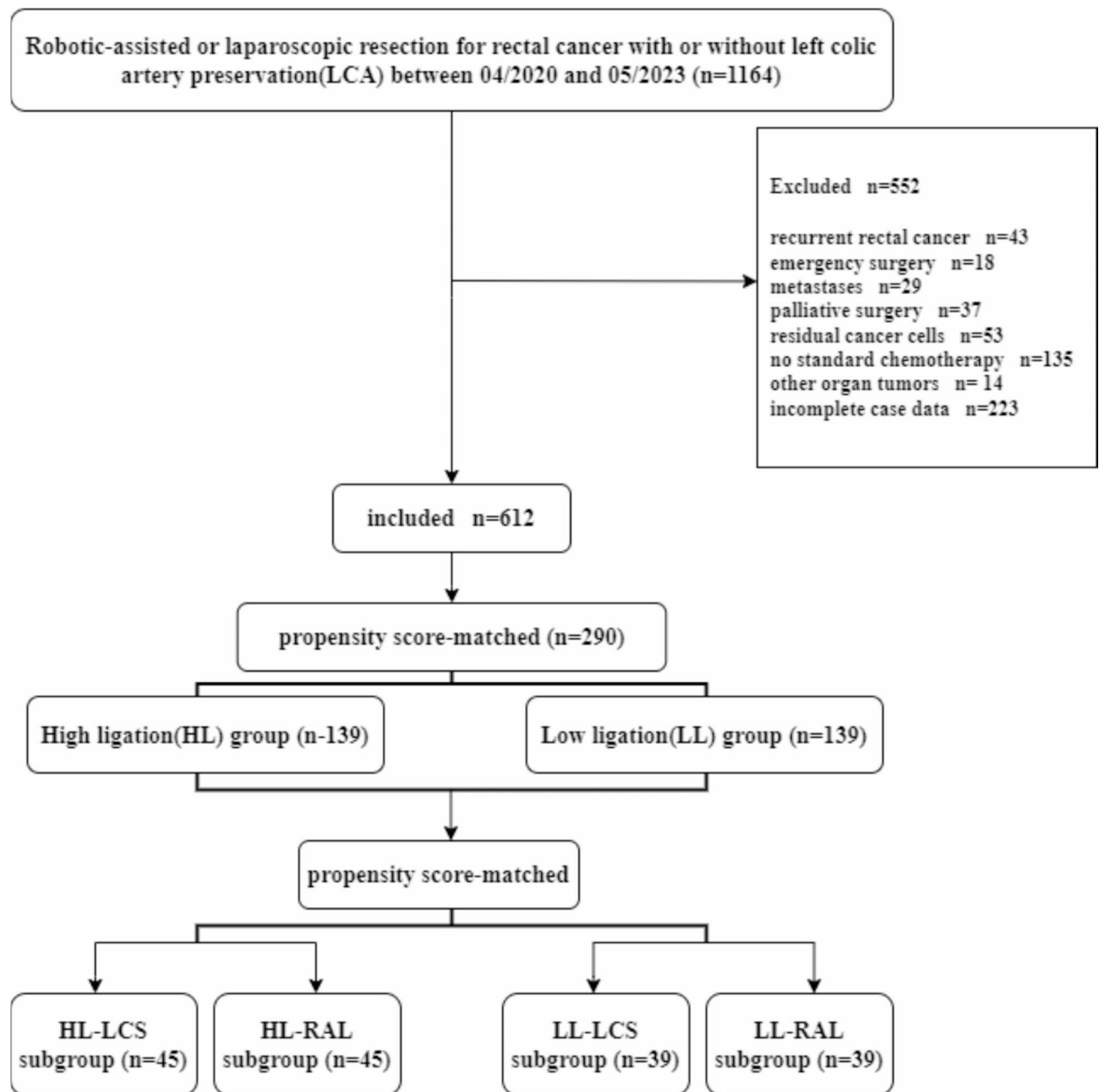
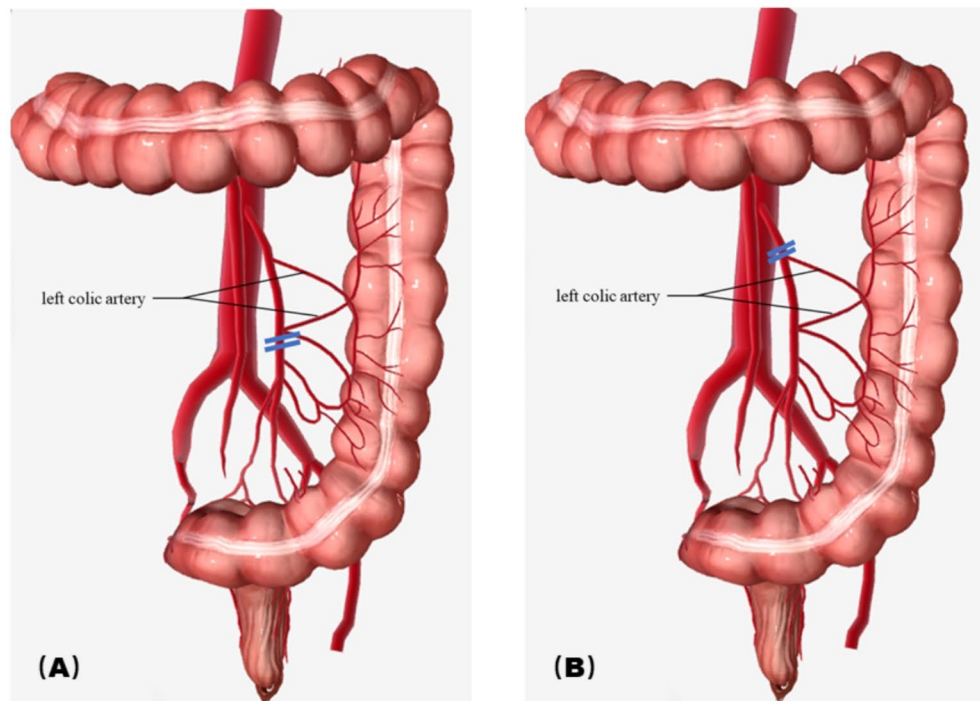


Fig. 1. Flowchart of the study.

Results

Patient clinical characteristics

A total of 612 rectal cancer patients were included in this study, consisting of 245 men (40.0%) and 367 women (60.0%). Among these patients, 462 (74.5%) were in the LL group, and 150 (24.5%) were in the HL group. Table 1 provides the clinicopathological characteristics of the two groups. Post-propensity score matching (PSM), there were no significant differences between the two groups in terms of age, sex, BMI, history of abdominal surgery, cardiopulmonary disease, diabetes, preoperative smoking, preoperative malnutrition, ASA classification, tumor TNM staging, tumor size, surgical approach, distance between tumor and anus, and degree of tumor



* The anatomical diagrams of the gastrointestinal tract and blood vessels were sourced from online database *BioDigital Human* (<https://human.biodigital.com>).

Fig. 2. Schema of resection for rectal cancer with (A, LL group) and without (B, HL group) preservation of the left colic artery (LCA).

differentiation. Both the LL and HL groups were further divided into LSC and RAL subgroups. Tables 2 and 3 present the clinicopathological characteristics of the LL and HL subgroups post-second PSM scoring.

Operative findings

Table 4 summarizes the operative findings between the LL and HL groups. The LL group exhibited significantly less blood loss compared to the HL group (54.42 ± 12.99 mL vs. 65.71 ± 7.37 mL, $p < 0.001$). Urinary catheter withdrawal time was shorter in the LL group (4.87 ± 2.04 days vs. 6.06 ± 2.43 days, $p < 0.001$). There was no significant difference in operation time (128.67 ± 26.03 min vs. 130.86 ± 8.64 min, $p = 0.346$), number of harvested lymph nodes (18.81 ± 2.89 vs. 19.54 ± 4.85 , $p = 0.126$), or number of positive lymph nodes (5.71 ± 1.10 vs. 5.50 ± 1.64 , $p = 0.215$) between the LL and HL groups. Similarly, no significant differences were observed in time to flatus (2.03 ± 0.79 days vs. 2.17 ± 0.57 days, $p = 0.099$), time to regular diet (3.76 ± 1.01 days vs. 4.01 ± 1.52 days, $p = 0.105$), and postoperative hospital stay (7.35 ± 2.24 days vs. 7.96 ± 3.44 days, $p = 0.077$).

As presented in Table 5, in the LL group, the RAL subgroup had significantly longer operation times than the LSC subgroup (132.69 ± 25.94 min vs. 117.41 ± 24.55 min, $p = 0.009$), but less blood loss (50.13 ± 12.3 mL vs. 58.1 ± 10.73 mL, $p = 0.003$), and more harvested lymph nodes (19.67 ± 3.13 vs. 17.69 ± 2.61 , $p = 0.003$). No significant differences were found in the number of positive lymph nodes (5.54 ± 1.07 vs. 5.46 ± 1.29 , $p = 0.776$), time to flatus (1.95 ± 0.79 days vs. 2.21 ± 0.73 days, $p = 0.142$), time to regular diet (3.59 ± 0.88 days vs. 3.79 ± 0.92 days, $p = 0.318$), or postoperative hospital stay (6.95 ± 2.01 days vs. 7.74 ± 2.30 days, $p = 0.109$).

	Entire cohort		X ² /t	P	PSM cohort		X ² /t	P
	HL (n = 150)	LL (n = 462)			HL (n = 139)	LL (n = 139)		
Age, years	63.93 ± 6.75	65.47 ± 7.95	-2.125	0.034	63.99 ± 6.86	63.85 ± 6.98	0.173	0.862
Sex, n (%)			4.491	0.034			2.944	0.086
Male	49(32.67)	196(42.42)			47(33.81)	34(24.46)		
Female	101(67.33)	266(57.58)			92(66.19)	105(75.54)		
BMI(kg/m ²)	25.53 ± 3.24	24.55 ± 2.62	3.721	0.000	25.44 ± 3.21	24.81 ± 2.65	1.775	0.077
Abdominal Surgery History(%)			6.031	0.014			0.026	0.873
No	121(80.67)	409(88.53)			115(82.73)	116(83.45)		
Yes	29(19.33)	53(11.47)			24(17.27)	23(16.55)		
Cardiopulmonary Diseases History(%)			2.455	0.117			0.585	0.444
No	97(64.67)	330(71.43)			90(64.75)	96(69.06)		
Yes	53(35.33)	132(28.57)			49(35.25)	43(30.94)		
Diabetes History(%)			0.507	0.476			0.101	0.751
No	125(83.33)	396(85.71)			116(83.45)	114(82.01)		
Yes	25(16.67)	66(14.29)			23(16.55)	25(17.99)		
Preoperative pyloric obstruction(%)			5.202	0.023			0.432	0.511
No	126(84.00)	419(90.69)			119(85.61)	115(82.73)		
Yes	24(16.00)	43(9.31)			20(14.39)	24(17.27)		
Preoperative smoking(%)			0.277	0.599			0.101	0.751
No	124(82.67)	373(80.74)			114(82.01)	116(83.45)		
Yes	26(17.33)	89(19.26)			25(17.99)	23(16.55)		
Preoperative malnutrition(%)			6.099	0.014			0.852	0.356
No	123(82)	414(89.61)			116(83.45)	110(79.14)		
Yes	27(18)	48(10.39)			23(16.55)	29(20.86)		
Preoperative neoadjuvant chemotherapy(%)			7.022	0.008			0.081	0.776
No	139(92.67)	450(97.40)			132(94.96)	133(95.68)		
Yes	11(7.33)	12(2.60)			7(5.04)	6(4.32)		
ASA classification, n (%)			6.153	0.046			0.340	0.844
I	71(47.33)	246(53.25)			70(50.36)	66(47.48)		
II	38(25.33)	133(28.79)			34(24.46)	38(27.34)		
III	41(27.33)	83(17.97)			35(25.18)	35(25.18)		
Tumor TNM staging			6.218	0.101			0.563	0.905
I	39(26)	169(36.58)			37(26.62)	37(26.62)		
II	37(24.67)	109(23.59)			33(23.74)	35(25.18)		
III	58(38.67)	145(31.39)			53(38.13)	48(34.53)		
IV	16(10.67)	39(8.44)			16(11.51)	19(13.67)		
surgical approach			0.397	0.528			0.058	0.81
laparoscopic	80(53.33)	260(56.28)			75(53.96)	73(52.52)		
robotic	70(46.67)	202(43.72)			64(46.04)	66(47.48)		
Tumor size (cm)	3.36 ± 1.19	3.20 ± 1.07	1.546	0.123	3.35 ± 1.19	3.38 ± 1.03	-0.255	0.799
Distance between tumor and anus (cm)	8.30 ± 2.31	8.65 ± 2.51	-1.499	0.135	8.29 ± 2.32	8.46 ± 2.57	-0.600	0.549
Tumor location(%)			3.245	0.197			0.244	0.885
Lower (≤ 5 cm)	30(20.00)	83(17.97)			28(20.14)	29(20.86)		
Middle (5.1–10 cm)	64(42.67)	168(36.36)			57(41.01)	53(38.13)		
Upper (10.1–15 cm)	56(37.33)	211(45.67)			54(38.85)	57(41.01)		
Degree of tumor differentiation(%)			2.309	0.315			0.241	0.886
low	27(18.00)	81(17.53)			24(17.27)	26(18.71)		
middle	78(52.00)	212(45.89)			70(50.36)	66(47.48)		
high	45(30.00)	169(36.58)			45(32.37)	47(33.81)		

Table 1. Comparison of general information before and after matching between HL and LL group.

Furthermore, as detailed in Table 6, in the HL group, the RAL subgroup also had longer operation times than the LSC subgroup (132.28 ± 7.61 min vs. 128.00 ± 9.07 min, $p = 0.015$), less blood loss (63.40 ± 6.85 mL vs. 66.68 ± 6.59 mL, $p = 0.020$), and more harvested lymph nodes (20.98 ± 4.99 vs. 18.53 ± 4.33 , $p = 0.013$). No significant differences were noted in the number of positive lymph nodes (5.80 ± 1.47 vs. 5.30 ± 1.88 , $p = 0.187$),

	Entire cohort		X ² /t	P	PSM cohort		X ² /t	P
	LL-LCS	LL-RAL			LL-LCS	LL-RAL		
Age, years	65.19 ± 7.01	62.36 ± 6.68	2.428	0.016	63.87 ± 6.09	63.62 ± 6.88	0.174	0.862
Sex, n (%)			0.003	0.955			0.000	1.000
Male	18(24.66)	16(24.24)			9(23.08)	9(23.08)		
Female	55(75.34)	50(75.76)			30(76.92)	30(76.92)		
BMI(kg/m ²)	24.66 ± 2.46	24.98 ± 2.85	0.727	0.469	24.92 ± 2.67	24.67 ± 2.61	0.429	0.669
Abdominal Surgery History(%)			0.903	0.342			0.831	0.362
No	63(86.30)	53(80.30)			31(79.49)	34(87.18)		
Yes	10(13.70)	13(19.70)			8(20.51)	5(12.82)		
Cardiopulmonary Diseases History(%)			0.046	0.830			0.059	0.808
No	51(69.86)	45(68.18)			26(66.67)	27(69.23)		
Yes	22(30.14)	21(31.82)			13(33.33)	12(30.77)		
Diabetes History(%)			0.003	0.954			0.083	0.774
No	60(82.19)	54(81.82)			31(79.49)	32(82.05)		
Yes	13(17.81)	12(18.18)			8(20.51)	7(17.95)		
Preoperative pyloric obstruction(%)			0.074	0.786			0.831	0.362
No	61(83.56)	54(81.82)			34(87.18)	31(79.49)		
Yes	12(16.44)	12(18.18)			5(12.82)	8(20.51)		
Preoperative smoking(%)			0.177	0.674			0.831	0.362
No	60(82.19)	56(84.85)			31(79.49)	34(87.18)		
Yes	13(17.81)	10(15.15)			8(20.51)	5(12.82)		
Preoperative malnutrition(%)			0.009	0.923			0.626	0.429
No	58(79.45)	52(78.79)			28(71.79)	31(79.49)		
Yes	15(20.55)	14(21.21)			11(28.21)	8(20.51)		
Preoperative neoadjuvant chemotherapy(%)			0.296	0.586			0.000	1.000
No	71(97.26)	62(93.94)			37(94.87)	38(97.44)		
Yes	2(2.74)	4(6.06)			2(5.13)	1(2.56)		
ASA classification, n (%)			2.547	0.280			0.266	0.875
I	36(49.32)	30(45.45)			20(51.28)	19(48.72)		
II	16(21.92)	22(33.33)			10(25.64)	12(30.77)		
III	21(28.77)	14(21.21)			9(23.08)	8(20.51)		
Tumor TNM staging			4.411	0.220			3.752	0.289
I	15(20.55)	22(33.33)			10(25.64)	13(33.33)		
II	17(23.29)	18(27.27)			9(23.08)	8(20.51)		
III	29(39.73)	19(28.79)			18(46.15)	12(30.77)		
IV	12(16.44)	7(10.61)			2(5.13)	6(15.38)		
Tumor size (cm)	3.4 ± 0.96	3.36 ± 1.11	0.199	0.843	3.39 ± 0.91	3.31 ± 1.17	0.330	0.742
Distance between tumor and anus (cm)	8.34 ± 2.51	8.6 ± 2.64	0.602	0.548	8.60 ± 2.68	8.29 ± 2.78	0.505	0.615
Tumor location(%)			7.084	0.029			0.511	0.774
Lower (≤ 5 cm)	21(28.77)	8(12.12)			8(20.51)	7(17.95)		
Middle (5.1–10 cm)	28(38.36)	25(37.88)			19(48.72)	17(43.59)		
Upper (10.1–15 cm)	24(32.88)	33(50.00)			12(30.77)	15(38.46)		
Degree of tumor differentiation(%)			2.136	0.344			0.524	0.769
low	17(23.29)	9(13.64)			9(23.08)	7(17.95)		
middle	33(45.21)	33(50.00)			18(46.15)	21(53.85)		
high	23(31.51)	24(36.36)			12(30.77)	11(28.21)		

Table 2. Comparison of general information before and after matching between RAL and LCS subgroup of LL group.

time to flatus (2.11 ± 0.60 days vs. 2.28 ± 0.62 days, $p = 0.177$), time to regular diet (4.15 ± 1.60 days vs. 4.13 ± 1.44 days, $p = 0.946$), or postoperative hospital stay (7.85 ± 3.86 days vs. 8.34 ± 3.55 days, $p = 0.524$).

Operative morbidity

Table 7 details operative morbidity. The LL group had a significantly lower incidence of anastomotic leakage compared to the HL group (1.44% vs. 7.91%, $p = 0.011$), as well as a lower rate of ileus (2.16% vs. 7.91%, $p = 0.028$).

	Entire cohort		X ² /t	P	PSM cohort		X ² /t	P
	HL-LCS	HL-RAL			HL-LCS	HL-RAL		
Age, years	63.61 ± 6.64	64.44 ± 7.13	-0.705	0.482	64.91 ± 6.78	63.34 ± 6.11	1.184	0.240
Sex, n (%)			0.017	0.897			0.048	0.826
Male	25(33.33)	22(34.38)			16(34.04)	15(31.91)		
Female	50(66.67)	42(65.63)			31(65.96)	32(68.09)		
BMI(kg/m ²)	25.67 ± 2.97	25.17 ± 3.46	0.906	0.366	25.74 ± 3.35	25.21 ± 3.41	0.763	0.447
Abdominal Surgery History(%)			0.852	0.356			0.336	0.562
No	60(80.00)	55(85.94)			39(82.98)	41(87.23)		
Yes	15(20.00)	9(14.06)			8(17.02)	6(12.77)		
Cardiopulmonary Diseases History(%)			0.309	0.578			0.737	0.391
No	47(62.67)	43(67.19)			32(68.09)	28(59.57)		
Yes	28(37.33)	21(32.81)			15(31.91)	19(40.43)		
Diabetes History(%)			0.530	0.467			0.301	0.583
No	61(81.33)	55(85.94)			40(85.11)	38(80.85)		
Yes	14(18.67)	9(14.06)			7(14.89)	9(19.15)		
Preoperative pyloric obstruction(%)			0.343	0.558			0.079	0.778
No	63(84)	56(87.5)			39(82.98)	40(85.11)		
Yes	12(16)	8(12.5)			8(17.02)	7(14.89)		
Preoperative smoking(%)			1.216	0.270			0.072	0.789
No	64(85.33)	50(78.13)			39(82.98)	38(80.85)		
Yes	11(14.67)	14(21.88)			8(17.02)	9(19.15)		
Preoperative malnutrition(%)			12.081	0.001			0.000	1.000
No	55(73.33)	61(95.31)			43(91.49)	44(93.62)		
Yes	20(26.67)	3(4.69)			4(8.51)	3(6.38)		
Preoperative neoadjuvant chemotherapy(%)			0.046	0.829			0.000	1.000
No	72(96.00)	60(93.75)			46(97.87)	45(95.74)		
Yes	3(4.00)	4(6.25)			1(2.13)	2(4.26)		
ASA classification, n (%)			1.277	0.528			0.591	0.744
I	37(49.33)	33(51.56)			21(44.68)	24(51.06)		
II	21(28.00)	13(20.31)			13(27.66)	10(21.28)		
III	17(22.67)	18(28.13)			13(27.66)	13(27.66)		
Tumor TNM staging			1.285	0.733			1.255	0.740
I	20(26.67)	17(26.56)			11(23.40)	13(27.66)		
II	20(26.67)	13(20.31)			10(21.28)	11(23.40)		
III	28(37.33)	25(39.06)			22(46.81)	17(36.17)		
IV	7(9.33)	9(14.06)			4(8.51)	6(12.77)		
Tumor size (cm)	3.33 ± 1.19	3.38 ± 1.20	-0.259	0.796	3.17 ± 1.06	3.35 ± 1.25	-0.725	0.470
Distance between tumor and anus (cm)	8.33 ± 2.30	8.24 ± 2.37	0.221	0.825	8.49 ± 2.34	8.25 ± 2.59	0.477	0.634
Tumor location(%)			1.516	0.468			0.531	0.767
Lower (≤ 5 cm)	18(24.00)	10(15.63)			8(17.02)	6(12.77)		
Middle (5.1–10 cm)	29(38.67)	28(43.75)			19(40.43)	22(46.81)		
Upper (10.1–15 cm)	28(37.33)	26(40.63)			20(42.55)	19(40.43)		
Degree of tumor differentiation(%)			0.737	0.692			2.421	0.298
low	14(18.67)	10(15.63)			5(10.64)	10(21.28)		
middle	39(52.00)	31(48.44)			28(59.57)	22(46.81)		
high	22(29.33)	23(35.94)			14(29.79)	15(31.91)		

Table 3. Comparison of general information before and after matching between RAL and LCS subgroup of HL group.

No significant differences were observed in superficial surgical site infection (1.44% vs. 2.16%, $p=1.0$), deep surgical site infection (1.44% vs. 2.88%, $p=0.68$), anastomotic bleeding (5.76% vs. 4.32%, $p=0.583$), anastomotic stenosis (1.44% vs. 2.16%, $p=1.0$), bowel perforation (0% vs. 0.72%, $p=1.0$), or reoperation rates (2.16% vs. 2.88%, $p=1.0$).

For the LL group, Table 8 shows that the RAL subgroup had lower anastomotic leakage rates than the LCS subgroup (0% vs. 0.51%, $p=0.474$), though this was not statistically significant. There were no significant differences in rates of superficial surgical site infection (2.56% vs. 0%, $p=1.0$), deep surgical site infection (0%

	Entire cohort		t	P	PSM cohort		t	P
	HL	LL			HL	LL		
Operation time(min)	130.65±8.53	127.00±24.88	1.764	0.078	130.86±8.64	128.67±26.03	0.943	0.346
Blood loss(mL)	65.60±7.48	54.01±12.68	10.607	0.000	65.71±7.37	54.42±12.99	8.908	0.000
Number of harvested LNs	19.51±4.78	19.19±2.92	0.963	0.336	19.54±4.85	18.81±2.89	1.533	0.126
Number of positive LNs	5.40±1.67	5.84±1.06	-3.758	0.000	5.50±1.64	5.71±1.10	-1.242	0.215
Time to flatus (day)	2.15±0.57	2.30±0.73	-2.308	0.021	2.17±0.57	2.03±0.79	1.654	0.099
Urinary catheter withdrawal time (day)	6.02±2.38	4.37±1.70	9.294	0.000	6.06±2.43	4.87±2.04	4.414	0.000
Postoperative hospital stay (day)	7.98±3.36	6.66±2.41	5.260	0.000	7.96±3.44	7.35±2.24	1.776	0.077
Time to regular diet (day)	4.02±1.52	3.54±0.94	4.570	0.000	4.01±1.52	3.76±1.01	1.628	0.105

Table 4. Operative findings before and after matching between HL and LL group.

	Entire cohort		t	P	PSM cohort		t	P
	LL-LSC	LL-RAL			LL-LSC	LL-RAL		
Operation time(min)	127.88±26.85	129.55±25.26	-0.376	0.707	117.41±24.55	132.69±25.94	-2.672	0.009
Blood loss(mL)	56.47±12.62	52.15±13.12	1.975	0.050	58.1±10.73	50.13±12.3	3.052	0.003
Number of harvested LNs	17.96±2.61	19.74±2.91	-3.812	0.000	17.69±2.61	19.67±3.13	-3.026	0.003
Number of positive LNs	5.66±1.18	5.77±1.02	-0.612	0.541	5.46±1.29	5.54±1.07	-0.286	0.776
Time to flatus (day)	2.15±0.76	1.89±0.81	1.935	0.055	2.21±0.73	1.95±0.79	1.484	0.142
Urinary catheter withdrawal time (day)	5.21±2.33	4.5±1.61	2.057	0.042	5.18±2.45	4.69±1.58	1.045	0.299
Postoperative hospital stay (day)	7.86±2.26	6.77±2.1	2.937	0.004	7.74±2.30	6.95±2.01	1.623	0.109
Time to regular diet (day)	4.03±1.03	3.45±0.91	3.458	0.001	3.79±0.92	3.59±0.88	1.005	0.318

Table 5. Operative findings before and after second time matching between LSC and RAL subgroups of LL group.

	Entire cohort		t	P	PSM cohort		t	P
	HL-LSC	HL-RAL			HL-LSC	HL-RAL		
Operation time(min)	129.68±9.00	132.25±8.05	-1.761	0.081	128.00±9.07	132.28±7.61	-2.476	0.015
Blood loss(mL)	67.15±7.06	64.02±7.42	2.545	0.012	66.68±6.59	63.40±6.85	2.362	0.020
Number of harvested LNs	18.80±4.40	20.41±5.23	-1.966	0.051	18.53±4.33	20.98±4.99	-2.540	0.013
Number of positive LNs	5.35±1.74	5.69±1.51	-1.221	0.224	5.30±1.88	5.77±1.52	-1.329	0.187
Time to flatus (day)	2.25±0.59	2.06±0.53	1.98	0.050	2.28±0.62	2.11±0.60	1.360	0.177
Urinary catheter withdrawal time (day)	6.13±2.36	5.97±2.52	0.398	0.692	6.30±2.41	5.74±2.36	1.123	0.264
Postoperative hospital stay (day)	8.33±3.33	7.53±3.55	1.375	0.171	8.34±3.55	7.85±3.86	0.640	0.524
Time to regular diet (day)	3.96±1.51	4.06±1.53	-0.396	0.693	4.13±1.44	4.15±1.60	-0.068	0.946

Table 6. Operative findings before and after second time matching between LSC and RAL subgroups of HL group.

vs. 5.13%, $p=0.474$), anastomotic bleeding (0% vs. 12.82%, $p=0.064$), anastomotic stenosis (2.56% vs. 2.56%, $p=1.0$), ileus (0% vs. 2.56%, $p=1.0$), or reoperation (0% vs. 2.56%, $p=1.0$).

In the HL group, as indicated in Table 9, the RAL subgroup had significantly lower anastomotic leakage rates than the LSC subgroup (0% vs. 14.89%, $p=0.018$). No significant differences were observed in rates of superficial surgical site infection (2.13% vs. 4.26%, $p=1.0$), deep surgical site infection (0% vs. 2.13%, $p=1.0$), anastomotic bleeding (2.13% vs. 4.26%, $p=1.0$), anastomotic stenosis (2.13% vs. 2.13%, $p=1.0$), ileus (2.13% vs. 4.26%, $p=1.0$), or reoperation (2.13% vs. 4.26%, $p=1.0$).

Postoperative genitourinary function was assessed in 81 male patients (34 in the LL group and 47 in the HL group) with normal preoperative function, 6 to 12 months post-surgery. As shown in Table 10, in the LL group, 94.12% maintained normal urinary function (grade I), and 5.88% experienced grade II dysfunction, with no cases of grade III or IV dysfunction. In the HL group, 51.06% maintained normal function, with 19.15%, 21.28%, and 8.51% experiencing grade II, III, and IV dysfunction, respectively, showing a significant difference in total urinary dysfunction rates between the groups. No significant differences were observed between the LSC and RAL subgroups within both the LL and HL groups, as shown in Tables 11 and 12. No urinary dysfunction was reported in the LL-RAL subgroup.

	Entire cohort		X ²	P	PSM cohort		X ²	P
	HL	LL			HL	LL		
Anastomotic leakage, n (%)			17.076	0.000			6.536	0.011
No	136(90.67)	453(98.05)			128(92.09)	137(98.56)		
Yes	14(9.33)	9(1.95)			11(7.91)	2(1.44)		
Surgical site infection superficial, n (%)			1.622	0.203			0.000	1.000
No	146(97.33)	458(99.13)			136(97.84)	137(98.56)		
Yes	4(2.67)	4(0.87)			3(2.16)	2(1.44)		
Bowel perforation, n (%)			-	1.000			-	1.000
No	149(99.33)	459(99.35)			138(99.28)	139(100)		
Yes	1(0.67)	3(0.65)			1(0.72)	0(0)		
Surgical site infection deep(%)			2.487	0.115			0.170	0.680
No	146(97.33)	459(99.35)			135(97.12)	137(98.56)		
Yes	4(2.67)	3(0.65)			4(2.88)	2(1.44)		
Anastomotic bleeding, n (%)			0.003	0.955			0.301	0.583
No	144(96.00)	444(96.10)			133(95.68)	131(94.24)		
Yes	6(4.00)	18(3.90)			6(4.32)	8(5.76)		
Anastomotic stenosis, n (%)			0.143	0.705			0.000	1.000
No	146(97.33)	454(98.27)			136(97.84)	137(98.56)		
Yes	4(2.67)	8(1.73)			3(2.16)	2(1.44)		
Cardiovascular, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Ileus, n (%)			11.127	0.001			4.814	0.028
No	138(92.00)	452(97.84)			128(92.09)	136(97.84)		
Yes	12(8.00)	10(2.16)			11(7.91)	3(2.16)		
Trocar site hernia, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Pneumonia, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Presence of foreign body, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Intraabdominal hematoma, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Reoperation, n (%)			0.605	0.437			0.000	1.000
No	146(97.33)	456(98.70)			135(97.12)	136(97.84)		
Yes	4(2.67)	6(1.30)			4(2.88)	3(2.16)		
Death, n (%)			-	-			-	-
No	150(100)	462(100)			139(100)	139(100)		
Yes	0(0)	0(0)			0(0)	0(0)		

Table 7. Operative morbidity before and after second time matching between LL and HL group. Note: “-” indicates no exact value;

For sexual function, all patients had normal preoperative sexual activity. Postoperative erectile and ejaculatory functions were significantly better in the LL group compared to the HL group ($p < 0.05$). In the LL group, 94.12% retained complete erectile and ejaculative capacities. In the HL group, 57.45% retained erectile capacity, and 61.7% retained ejaculative capacity. No significant differences were observed between the LSC and RAL subgroups within both the LL and HL groups. In the LL-LSC subgroup, 77.78% maintained erectile capacity, and 88.89% maintained ejaculatory capacity, while in the LL-RAL subgroup, all patients retained both capacities. In the HL-LSC subgroup, 56.25% maintained both capacities, and in the HL-RAL subgroup, 66.67% maintained both capacities.

	Entire cohort		X ²	P	PSM cohort		X ²	P
	LL-LSC	LL-RAL			LL-LSC	LL-RAL		
Anastomotic leakage, n (%)			-	0.498			0.513	0.474
No	71(97.26)	66(100)			37(94.87)	39(100)		
Yes	2(2.74)	0(0)			2(5.13)	0(0)		
Surgical site infection superficial, n (%)			-	0.224			-	1.000
No	73(100)	64(96.97)			39(100)	38(97.44)		
Yes	0(0)	2(3.03)			0(0)	1(2.56)		
Bowel perforation, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Surgical site infection deep(%)			-	0.498			0.513	0.474
No	71(97.26)	66(100)			37(94.87)	39(100)		
Yes	2(2.74)	0(0)			2(5.13)	0(0)		
Anastomotic bleeding, n (%)			0.047	0.828			3.419	0.064
No	68(93.15)	63(95.45)			34(87.18)	39(100)		
Yes	5(6.85)	3(4.55)			5(12.82)	0(0)		
Anastomotic stenosis, n (%)			-	1.000			0.000	1.000
No	72(98.63)	65(98.48)			38(97.44)	38(97.44)		
Yes	1(1.37)	1(1.52)			1(2.56)	1(2.56)		
Cardiovascular, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Ileus, n (%)			0.008	0.93			-	1.000
No	72(98.63)	64(96.97)			38(97.44)	39(100)		
Yes	1(1.37)	2(3.03)			1(2.56)	0(0)		
Trocar site hernia, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Pneumonia, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Presence of foreign body, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Intraabdominal hematoma, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Reoperation, n (%)			0.000	1.000			-	1.000
No	71(97.26)	65(98.48)			38(97.44)	39(100)		
Yes	2(2.74)	1(1.52)			1(2.56)	0(0)		
Death, n (%)			-	-			-	-
No	73(100)	66(100)			39(100)	39(100)		
Yes	0(0)	0(0)			0(0)	0(0)		

Table 8. Operative morbidity before and after second time matching between LSC and RAL subgroups of LL group. Note: “-” indicates no exact value;

Discussion

This study assessed perioperative outcomes of rectal cancer resections with and without preservation of the left colic artery (LCA), comparing low ligation (LL) and high ligation (HL) techniques. Our results indicate that LL provides operational efficiency and safety similar to HL, with advantages such as reduced blood loss, lower rates of anastomotic leakage and ileus, shorter urinary catheterization times, and improved genitourinary function. Additionally, LL procedures showed less blood loss and more lymph nodes harvested, particularly in robotic-assisted laparoscopic (RAL) surgeries compared to laparoscopic (LSC) ones.

The operating time for LL was not significantly longer than for HL. Sekimoto et al⁵ reported similar findings, noting no increase in operating time or intraoperative bleeding with LL compared to HL. Wei et al¹¹ suggest that, for colorectal cancer surgery, RAL procedures have comparable safety and efficacy to traditional laparoscopic surgery. However, RAL subgroups showed longer operating times than LSC subgroups in both LL

	Entire cohort		X ²	P	PSM cohort		X ²	P
	HL-LSC	HL-RAL			HL-LSC	HL-RAL		
Anastomotic leakage, n (%)			1.694	0.193			5.557	0.018
No	67(89.33)	61(95.31)			40(85.11)	47(100)		
Yes	8(10.67)	3(4.69)			7(14.89)	0(0)		
Surgical site infection superficial, n (%)			0.000	1.000			0.000	1.000
No	73(97.33)	63(98.44)			45(95.74)	46(97.87)		
Yes	2(2.67)	1(1.56)			2(4.26)	1(2.13)		
Bowel perforation, n (%)			-	1.000			-	-
No	74(98.67)	64(100)			47(100)	47(100)		
Yes	1(1.33)	0(0)			0(0)	0(0)		
Surgical site infection deep(%)			0.449	0.503			-	1.000
No	74(98.67)	61(95.31)			46(97.87)	47(100)		
Yes	1(1.33)	3(4.69)			1(2.13)	0(0)		
Anastomotic bleeding, n (%)			0.381	0.537			0.000	1.000
No	73(97.33)	60(93.75)			45(95.74)	46(97.87)		
Yes	2(2.67)	4(6.25)			2(4.26)	1(2.13)		
Anastomotic stenosis, n (%)			0.000	1.000			0.000	1.000
No	73(97.33)	63(98.44)			46(97.87)	46(97.87)		
Yes	2(2.67)	1(1.56)			1(2.13)	1(2.13)		
Cardiovascular, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Ileus, n (%)			0.348	0.555			0.000	1.000
No	70(93.33)	58(90.63)			45(95.74)	46(97.87)		
Yes	5(6.67)	6(9.38)			2(4.26)	1(2.13)		
Trocar site hernia, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Pneumonia, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Presence of foreign body, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Intraabdominal hematoma, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		
Reoperation, n (%)			0.121	0.728			0.000	1.000
No	72(96)	63(98.44)			45(95.74)	46(97.87)		
Yes	3(4)	1(1.56)			2(4.26)	1(2.13)		
Death, n (%)			-	-			-	-
No	75(100)	64(100)			47(100)	47(100)		
Yes	0(0)	0(0)			0(0)	0(0)		

Table 9. Operative morbidity before and after second time matching between LSC and RAL subgroups of HL group. Note: “-” indicates no exact value; Postoperative Genitourinary Function.

and HL groups ($P < 0.01$), consistent with Ferrara et al¹², who found comparable operative times across various colorectal surgeries. This discrepancy is likely due to the additional setup time required for robotic arms and the intraoperative instrument changes¹³.

Lymph node metastasis is critical in rectal cancer prognosis¹⁴. Cirocchi et al¹⁵ demonstrated that thorough lymph node dissection at the IMA root, while preserving the LCA, does not compromise oncological outcomes, aligning with our findings. The robotic system, with its precise dissection capabilities and stable visual field, enhances lymph node retrieval¹⁶, explaining the higher lymph node counts in RAL subgroups. Furthermore, Sun et al¹⁷ reported that the use of indocyanine green (ICG) fluorescence imaging during laparoscopic colorectal surgery enhances lymph node harvest, which could be combined with our findings to achieve more thorough lymphadenectomy. Similarly, as suggested by Mukai et al¹⁸, using ICG fluorescence to assess anastomotic blood supply may help reduce postoperative morbidity and alleviate the financial burden on patients. Anastomotic

	Entire cohort		z/X ²	P	PSM cohort		z/X ²	P
	HL	LL			HL	LL		
Postoperative urinary function(%)			-4.036	0.000			-4.201	0.000
I	25(51.02)	151(77.04)			24(51.06)	32(94.12)		
II	10(20.41)	30(15.31)			9(19.15)	2(5.88)		
III	10(20.41)	15(7.65)			10(21.28)	0(0)		
IV	4(8.16)	0(0)			4(8.51)	0(0)		
Total urinary dysfunction	24(48.98)	45(22.96)	13.119	0.000	23(48.94)	2(5.88)	17.138	0.000
Postoperative erectile function(%)			-3.895	0.000			-3.582	0.000
I	29(59.18)	163(83.16)			27(57.45)	32(94.12)		
II	11(22.45)	27(13.78)			11(23.40)	1(2.94)		
III	9(18.37)	6(3.06)			9(19.15)	1(2.94)		
Total erectile dysfunction	20(40.82)	33(16.84)	13.296	0.000	20(42.55)	2(5.88)	13.410	0.000
Postoperative ejaculation function(%)			-4.894	0.000			-3.412	0.001
I	30(61.22)	175(89.29)			29(61.70)	32(94.12)		
II	9(18.37)	15(7.65)			8(17.02)	2(5.88)		
III	10(20.41)	6(3.06)			10(21.28)	0(0)		
Total ejaculatory dysfunction	19(38.78)	21(10.71)	22.595	0.000	18(38.30)	2(5.88)	11.148	0.001

Table 10. Genitourinary function before and after second time matching between LL groups and HL group. Note: “-” indicates no exact value.

	Entire cohort		z/X ²	P	PSM cohort		z/X ²	P
	LL-LSC	LL-RAL			LL-LSC	LL-RAL		
Postoperative urinary function(%)			-0.085	0.933			-1.000	0.317
I	17(94.44)	15(93.75)			8(88.89)	9(100)		
II	1(5.56)	1(6.25)			1(11.11)	0(0)		
III	0(0)	0(0)			0(0)	0(0)		
IV	0(0)	0(0)			0(0)	0(0)		
Total urinary dysfunction	1(5.56)	1(6.25)	-	1.000	1(11.11)	0(0)	-	1.000
Postoperative erectile function(%)			-1.353	0.176			-1.455	0.146
I	16(88.89)	16(100)			7(77.78)	9(100)		
II	1(5.56)	0(0)			1(11.11)	0(0)		
III	1(5.56)	0(0)			1(11.11)	0(0)		
Total erectile dysfunction	2(11.11)	0(0)	-	0.487	2(22.22)	0(0)	-	0.471
Postoperative ejaculation function(%)			-0.085	0.933			-1.000	0.317
I	17(94.44)	15(93.75)			8(88.89)	9(100)		
II	1(5.56)	1(6.25)			1(11.11)	0(0)		
III	0(0)	0(0)			0(0)	0(0)		
Total ejaculatory dysfunction	1(5.56)	1(6.25)	-	1.000	1(11.11)	0(0)	-	1.000

Table 11. Genitourinary function before and after second time matching between RAL and LSC subgroup of LL group. Note: “-” indicates no exact value.

leakage is a significant complication in rectal cancer surgery. Factors such as blood flow and anastomotic tension are crucial in its prevention¹⁹. Liu et al^{20,21}. reported that in HL surgeries, blood flow in the marginal arch decreases significantly over distance, leading to low blood supply efficiency. Dworkin et al²². noted that not preserving the LCA reduces intestinal blood flow by approximately 40%, particularly affecting elderly patients with atherosclerosis. Our study found a lower incidence of anastomotic leakage in the LL group, likely due to better blood perfusion. Additionally, RAL subgroup in the HL group exhibited a higher rate of anastomotic leakage compared to the LSC subgroup ($P<0.05$). Surgical procedures can damage the abdominal wall and peritoneum, triggering immune responses that may lead to complications such as anastomotic leakage and ileus²³. The robotic system’s precision reduces trauma to tissues, aiding faster bowel recovery²⁴, and preserving the LCA enhances blood supply, potentially lowering complications²⁵.

Voiding and sexual dysfunction are common postoperative issues after extensive rectal cancer surgeries, with reported urinary dysfunction rates between 7% and 70% and sexual dysfunction between 40% and 100%²⁶. High ligation of the IMA can injure the hypogastric nerve, leading to urinary and ejaculatory dysfunction^{27–29}. Our study found superior postoperative genitourinary function in the LL group compared to the HL group.

	Entire cohort		z/X ²	P	PSM cohort		z/X ²	P
	HL-LSC	HL-RAL			HL-LSC	HL-RAL		
Postoperative urinary function(%)			-0.775	0.439			-1.549	0.121
I	12(48.00)	12(54.55)			7(43.75)	10(66.67)		
II	4(16.00)	5(22.73)			3(18.75)	3(20.00)		
III	6(24.00)	4(18.18)			4(25.00)	2(13.33)		
IV	3(12.00)	1(4.55)			2(12.5)	0(0)		
Total urinary dysfunction	13(52.00)	10(45.45)	0.201	0.654	9(56.25)	5(33.33)	1.642	0.200
Postoperative erectile function(%)			-1.630	0.103			-0.753	0.452
I	17(68.00)	10(45.45)			9(56.25)	10(66.67)		
II	5(20.00)	6(27.27)			4(25.00)	4(26.67)		
III	3(12.00)	6(27.27)			3(18.75)	1(6.67)		
Total erectile dysfunction	8(32.00)	12(54.55)	2.433	0.119	7(43.75)	5(33.33)	0.354	0.552
Postoperative ejaculation function(%)			-0.787	0.431			-0.705	0.481
I	17(68.00)	12(54.55)			9(56.25)	10(66.67)		
II	3(12.00)	5(22.73)			3(18.75)	3(20.00)		
III	5(20.00)	5(22.73)			4(25.00)	2(13.33)		
Total ejaculatory dysfunction	8(32.00)	10(45.45)	0.896	0.344	7(43.75)	5(33.33)	0.354	0.552

Table 12. Genitourinary function before and after second time matching between RAL and LSC subgroup of HL group.

This study has several limitations. The sample size may have affected the robustness of the results. It was a nonrandomized controlled trial based on propensity score-matched data³⁰, and variations in surgical techniques between surgeons could influence outcomes. Additionally, different propensity matching models for secondary outcomes were not constructed. Future multicenter, large-sample, randomized controlled trials are necessary to address these limitations.

Conclusions

In summary, the results of this PSM analyzed single-center retrospective study suggest that the blood loss, urinary catheter withdrawal time, the rate of anastomotic leakage and ileus, and postoperative genitourinary function outcomes associated with LCA preservation in resection of rectal cancer are better than those associated with ligation of the artery at the origin of the IMA. Concurrent with this, the surgical approach with RAL can reduce the probability of blood loss and improve harvest LNs in patients with rectal cancer. Moreover, RAL surgery shows obvious advantages in prevent anastomotic leakage in high ligation. However, further multicenter randomized controlled trials are required to confirm the validity of these results in a broader context.

Data availability

The data of the study are available from the corresponding authors with reasonable request.

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Author contributions

(I) Conception and design: DWang, MJ, QZ; (II) Administrative support: Department of Gastrointestinal surgery of Northern Jiangsu people's Hospital; (III) Provision of study materials or patients: MJ, QZ, LS, BL, WW; (IV) Collection and assembly of data: MJ, JJ, LS, YJ, J W, MA; (V) Data analysis and interpretation: MJ, QZ, JJ, QS, YW, BL, JR, LW, WW, DT; (VI) Manuscript writing: MJ; (VII) Final approval of manuscript: All authors.

Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

We identified that the Ethics Committee of Northern Jiangsu Province People's Hospital approved this research (2020KY-137), including any relevant details. Informed consent was obtained from each patient preoperatively. The study was also registered on ClinicalTrials (NCT06376227).

Additional information

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