Original Article

Comparison of Various Anastomosis Techniques in Anterior Resection and Lower Anterior Resection

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Key Words
Colorectal surgery;
Lower anterior resection;
End-to-end, end-to-side and side-to-side anastomosis;
Double stapling procedure

Purpose. Since the development of the double stapling technique for anterior resection (AR) and lower anterior resection (LAR), there has been ongoing debate about which anastomosis technique — end-to-end, end-to-side, or side-to-side — yields optimal outcomes. In 2015, a colorectal surgeon modified their approach, favoring alternative end-to-side and side-to-side anastomosis techniques over conventional end-to-end anastomosis. This change provided an opportunity to analyze surgical data before and after the shift.
Methods. The medical data of patients with colorectal cancer who underwent AR/LAR and anastomosis by the same attending surgeon were collected from July 1, 2013, to June 30, 2018. We gathered patient information, including demographics, surgical details and anastomosis technique, length of hospital stay and postoperative complications, and then categorized patients into two groups on the basis of the anastomosis technique used: conventional end-to-end and alternative end-to-side or side-to-side. These data were analyzed to examine the incidence of complications associated with different anastomosis techniques.
Results. Among 103 patients, 51 were in the E-E group and 52 in the S-E + S-S group. The anastomotic leakage rate was lower in the S-E + S-S group (3.8% vs. 13.2%, $p = 0.081$). The S-E + S-S group also showed significantly lower postoperative morbidity (24.5% vs. 49.1%, $p = 0.009$), bowel obstructions (3.8% vs. 15.1%, $p = 0.046$), and wound complications (1.9% vs. 11.3%, $p = 0.051$). Results remained consistent after excluding patients with concurrent chemoradiotherapy (CCRT) and stomas.
Conclusions. Alternative side-to-end and side-to-side anastomosis techniques result in lower morbidity and fewer complications compared to conventional end-to-end anastomosis, supporting their safety and efficacy as alternative approaches.

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Coloretcal cancer is the third most common cancer worldwide, underscoring the need for effective management strategies to optimize patient outcomes. Surgical resection remains a main treatment method for colorectal cancer, for example, anterior resection (AR) for sigmoid and rectosigmoid colon cancer, and lower anterior resection (LAR) for rectal cancer.[1-3] However, this procedure is associated with sig-

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nificant risks, most notably anastomotic leakage, which is recognized as the most critical surgical complication following colorectal resection with anastomosis.[4-6] Symptomatic anastomotic leakage not only increases the risk of morbidity but also profoundly affects mortality rates and long-term quality of life. Reported leakage rates after AR and LAR range from 1% to 19%, with associated mortality rates ranging from 6-39%.[7] Additionally, patients with anastomotic leakage have a 10-100% risk of requiring a permanent stoma. The risk is further increased in the context of distal anastomoses, where the rate of anastomotic dehiscence can reach up to 33%.[1,2,7-9]

The technique used for anastomosis in AR and LAR is a critical factor influencing outcomes, with three primary methods commonly employed: end-to-end double stapling method (E-E), side-to-end double stapling method (S-E), and side-to-side circular stapling method (S-S).[10] Despite extensive studies, no technique has been deemed superior, and the technique is often selected on the basis of the surgeon's experience and preference.

This study was inspired by the pivotal experience of a surgeon who, after observing innovative practices at Kyushu University Hospital in Japan, transitioned from traditional E-E anastomosis to S-E and S-S anastomosis techniques. Actually, Ikeda from Kyushu University Hospital presented their result with better outcome of the method by side-to-side with a circular stapler.[10] Azita Shishegar (2024) also confirmed through animal experiments that side-to-end anastomosis is superior to end-to-end anastomosis in terms of a lower incidence of anastomotic leakage.[11] Is it really or still controversial? To evaluate the impact of these anastomotic techniques on surgical complications and recovery, we conducted a retrospective analysis comparing E-E, S-E, and S-S anastomoses. By examining postoperative outcomes, such as anastomotic leakage and overall morbidity, the aim of this study is to provide evidence-based insights that could guide decision-making for anastomosis of AR and LAR.

Materials and Methods

This retrospective study analyzed the clinical data of colorectal cancer patients who underwent AR and LAR at a single institution between July 2013 and June 2018. Following the surgeon's observation of surgical techniques commonly performed at Kyushu University Hospital in Japan in 2015, a decision was made to transition from end-to-end (E-E) anastomosis to alternative approaches, including side-to-end (S-E) or side-to-side (S-S) anastomosis. The aim of this study was to assess whether, compared with conventional E-E anastomosis, these alternative techniques were associated with lower anastomotic leakage rates. Ethical approval was obtained from the Institutional Review Board (IRB), and all patient data were anonymized to protect confidentiality.

Patients were identified through a comprehensive review of the hospital's electronic medical records system, including surgical reports. A total of 139 patients with colorectal cancer who underwent AR/LAR during the study period were initially included. Patients were subsequently excluded on the basis of the following criteria: previous colectomy, hand-sewn anastomosis, no record of anastomosis, a combination of AR/LAR and other major surgeries or conversion to other surgeries. After applying these criteria, the medical data of the remaining patients were eligible for statistical analysis. These patients were divided into two groups on the basis of the anastomosis technique used: the conventional E-E group and the alternative S-E + S-S group.

A three-phase analytical approach was used in this study to account for potential confounders. In the first phase, all the patients included were analyzed. In the second phase, the patients who had undergone neoadjuvant concurrent chemoradiotherapy (CCRT) were excluded. In the third phase, the patients who underwent ostomy creation were excluded, resulting in a cohort for final analysis.

All surgeries were performed by a single experienced colorectal surgeon, ensuring consistency in technique. Both laparotomy and laparoscopic AR/LAR procedures were included. For conventional E-E anastomosis, we use the linear stapler to transect the rectum, and purse strings suture closure for the proximal colon stump after anvil insertion, and circular stapler is used for double stapling anastomosis. For S-E anastomosis, the anvil is extracted from the sidewall of the sigmoid colon approximately 4-5 cm proximal to the stump opening according to the anvil size, ensuring that the remaining bowel can be closed with a linear stapler without mechanical interference from the anvil base (Fig. 1-1). Double stapling anastomosis is also performed with circular stapler via rectum. For S-S anastomosis, the anvil is also extracted from the sidewall of the colon in the same way, and the circular stapler must avoid the linear staple line of the rectum stump during anastomosis, thus resulting in a single stapling rather than a double stapling technique (Fig. 1-2).

Demographic, preoperative, intraoperative, and postoperative data were meticulously collected for analysis. The demographic variables included age and sex. The preoperative variables included the American Society of Anesthesiologists (ASA) classification, tumor size, tumor location (the distance from the anal verge), cancer stage (pathologic stage), ECOG and pre-op and post-op albumin level. Intraoperative data included operative time and estimated blood loss, whereas postoperative outcomes were further categorized into postoperative outcomes and complications, including mortality, acute renal failure (post-op renal function deterioration as creatinine level increasing 1.0 mg/dL from the baseline), bowel obstruction (the patient could not keep oral intake due to adhesion ileus, paralytic ileus and anastomosis stricture, thus he/she should keep NPO and receive intravenous fluid supply), postoperative bleeding (including intraabdominal bleeding, upper gastrointestinal bleeding and anastomosis bleeding), wound complications (including wound dehiscence, infection and incisional hernia), overall morbidity, and length of hospital stay. Anastomotic leakage was diagnosed on the basis of imaging findings (free air out from bowel or pelvic abscess), clinical symptoms (digital examination or colonoscopy/proctoscopy showed anastomosis dehiscence), or changes in drainage characteristics (stool or pus found in the drainage).

Statistical analysis was conducted using SPSS software (version 29). Continuous variables were analyzed using either the t test or the Mann-Whitney U test, depending on the data distribution, whereas categorical variables were compared using the Chi-square test. Statistical significance was defined as a p value less than 0.05.

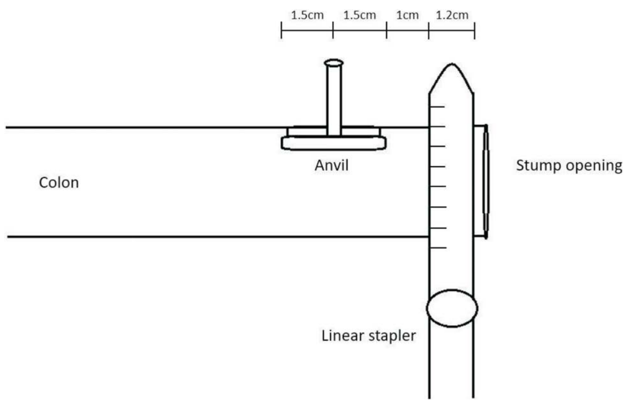

Fig. 1-1. Placement of the anvil in the proximal colon and closure of the stump opening for side-to-side and side-to-end anastomosis. The anvil is inserted into the proximal colon approximately 4-5 cm from the stump opening. A linear stapler is then used to close the stump opening, preparing for the subsequent anastomosis with a circular stapler.

Results

From July 2013 to June 2018, a total of 137 patients with colorectal cancer underwent anterior resection (AR) or lower anterior resection (LAR) by a single surgeon. After applying the exclusion criteria, in-

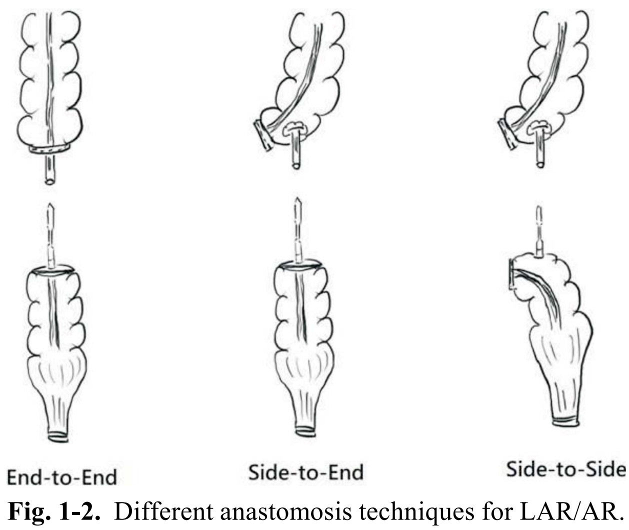

Fig. 1-2. Different anastomosis techniques for LAR/AR.

cluding previous colectomy (n = 4), missing record of anastomosis (n = 5), hand-sewn anastomosis (n = 4), conversion from TAMIS to LAR (n = 1), and LAR combined with other major surgeries (n = 20), a total of 103 patients were included in the analysis. The cohort was divided into three groups based on the anastomosis type: end-to-end anastomosis (E-E group) (n = 51), side-to-end anastomosis (S-E group) (n = 14) and side-to-side anastomosis (S-E group) (n = 38). For data analysis, two main experimental designs were adopted.

Experiment A compared the combined S-E + S-S group versus the E-E group across three phases (Phase A1, A2, and A3), each phase reflecting progressive exclusion of specific patient subgroups.

Experiment B involved comparisons among the three original groups (E-E, S-E, and S-S) in parallel fashion (Phase B1, B2, and B3).

The method of patient allocation, the number of patients, and the experimental procedures are all illustrated in Fig. 2.

During Experiment A, the baseline demographics and preoperative characteristics of phase A1 are summarized in Table A-1-1. No significant differences were observed between the two groups in terms of sex distribution (*p* = 0.442), age (*p* = 0.49), ASA classification (*p* = 0.517), ECOG (*p* = 0.675), tumor size (both 3.8 cm, *p* = 0.85), tumor location (*p* = 0.217), cancer stage (*p* = 0.713) and pre-op/post-op serum albumin level (*p* = 0.86/0.37). However, the E-E group had a higher proportion of laparotomy surgeries compared to the S-E and S-S groups (*p* = 0.049).

The postoperative parameters and complications in the 103 patients were summarized in Table A-1-2. The overall anastomotic leakage rate was 13.7% in the E-E group and 3.8% in the S-E + S-S group (*p* = 0.076). No significant difference was observed in mortality rate (5.9% vs. 1.9%, *p* = 0.298), and bleeding (5.9% vs. 0%, *p* = 0.076) and acute renal failure (*p* = 0.989). However, the incidence of bowel obstruction was significantly higher in the E-E group (13.7% vs. 1.9%, *p* = 0.025). Wound complication rates were higher in the E-E group (11.8% vs. 1.9%, *p* = 0.025). The overall morbidity rate was significantly higher in the E-E group than in the S-E + S-S group (49.0% vs. 23.1%, *p* = 0.009). The operative time was similar between the two groups (195 minutes vs. 165 minutes, *p* = 0.217), as was the blood loss (100 mL vs. 50 mL, *p* = 0.504). The median length of hospital stay tended to be longer in the E-E group than in the S-E + S-S group

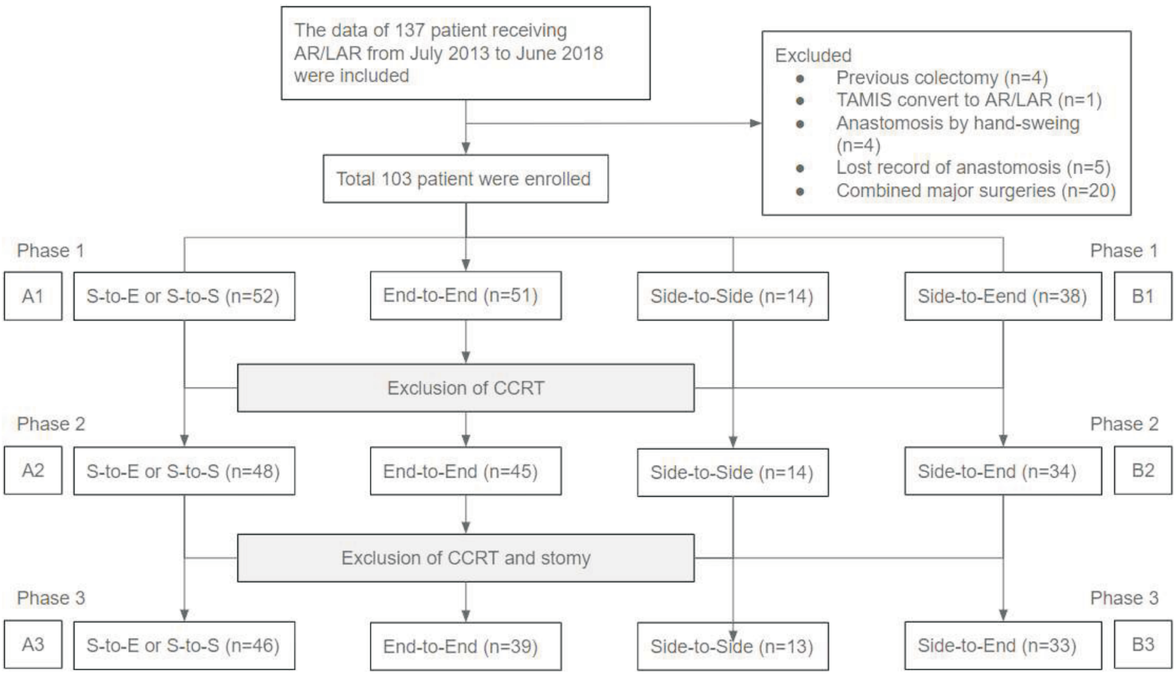

Fig. 2. A flowchart of the inclusion and exclusion of patients in the study.

Table A-1-1. Demographic and preoperative data of the studied groups
Sheet including E-E vs. S-E + S-S

Sheet including	N = 103		*p*-value
	E-E (%) (n = 51)	S-E + S-S (%) (n = 52)	
Sex			0.442
Men	36 (71)	33 (64)	
Women	15 (29)	19 (36)	
Age in years, mean ± SD	66.9 ± 10.4	64.6 ± 11.5	0.49
ASA			0.517
I	0	1 (2)	
II	29 (57)	31 (60)	
III	22 (43)	19 (36)	
IV	0	1 (2)	
ECOG			0.675
0	15 (29)	16 (31)	
1	19 (37)	22 (42)	
2	9 (18)	9 (17)	
3	6 (12)	5 (10)	
4	2 (4)	0	
Operation method			0.049
Laparotomy	21 (41)	12 (23)	
Laparoscopy	30 (59)	40 (77)	
Tumor size, mean ± SD	3.8 ± 1.9	3.8 ± 1.7	0.85
Tumor location AAV, median (range)	15 (5-40)	17 (5-28)	0.217
Location of anastomosis			0.269
D-S junction	1 (2)	0	
Sigmoid	15 (30)	10 (19)	
R-S junction and rectum	35 (68)	42 (81)	
Cancer stage			0.713
I	0	0	
IIA	10	10	
IIB	3	1	
IIIA	1	4	
IIIB	16	19	
IIIC	3	1	
IVA	2	1	
IVB	4	3	
Pre-operation albumin, mean ± SD	4 ± 0.6	4.0 ± 0.5	0.86
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.3 ± 0.4	0.37

Table A-1-2. Postoperative parameters and complications
Sheet including E-E vs. S-E + S-S

Sheet including	n = 103		*p*-value
Varieble	E-E (%) (n = 51)	S-E + S-S (%) (n = 52)	
Anastomosis leak			0.076
Yes	7 (14)	2 (4)	
No	44 (86)	50 (96)	
Mortality			0.298
Yes	3 (6)	1 (2)	
No	48 (94)	51 (98)	
Acute renal failure			0.989
Yes	1 (2)	1 (2)	
No	50 (98)	51 (98)	
Bowel obstruction			0.025
Yes	7 (14)	1 (2)	
No	44 (86)	51 (98)	
Bleeding			0.076
Yes	3 (6)	0	
No	48 (94)	52 (1)	
Wound complication			0.047
Yes	6 (12)	1 (2)	
No	45 (88)	51 (98)	
Morbidity			0.006
Yes	25 (49)	12 (23)	
No	26 (51)	40 (77)	
Operative time in minutes, median (range)	195 (118-400)	165 (100-295)	0.217
Blood loss in mL, median (range)	100 (2-1600)	50 (11-1200)	0.504
Length of stay in days, median (range)	10 (5-62)	9 (5-48)	0.039

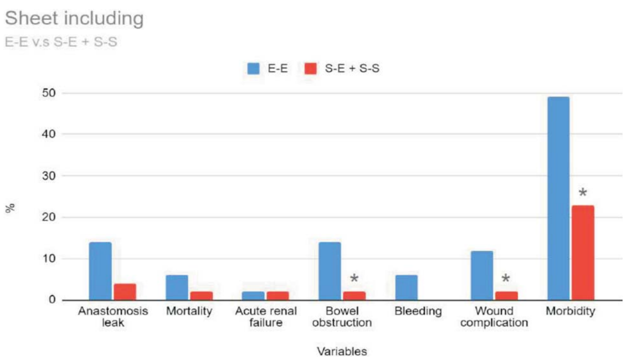

Fig. A-1. Comparison of postoperative complications between E-E and S-E/S-S anastomosis groups in total including patients (* $p < 0.05$).

(10 days vs. 9 days, $p = 0.039$). The results described above are presented as a bar chart in Fig. A-1 and Fig. A-2.

After 10 patients who underwent CCRT were excluded (six in E-E group and four in S-E + S-S group), 93 patients remained for further analysis of phase A2. The baseline characteristics was presented at the Ta-

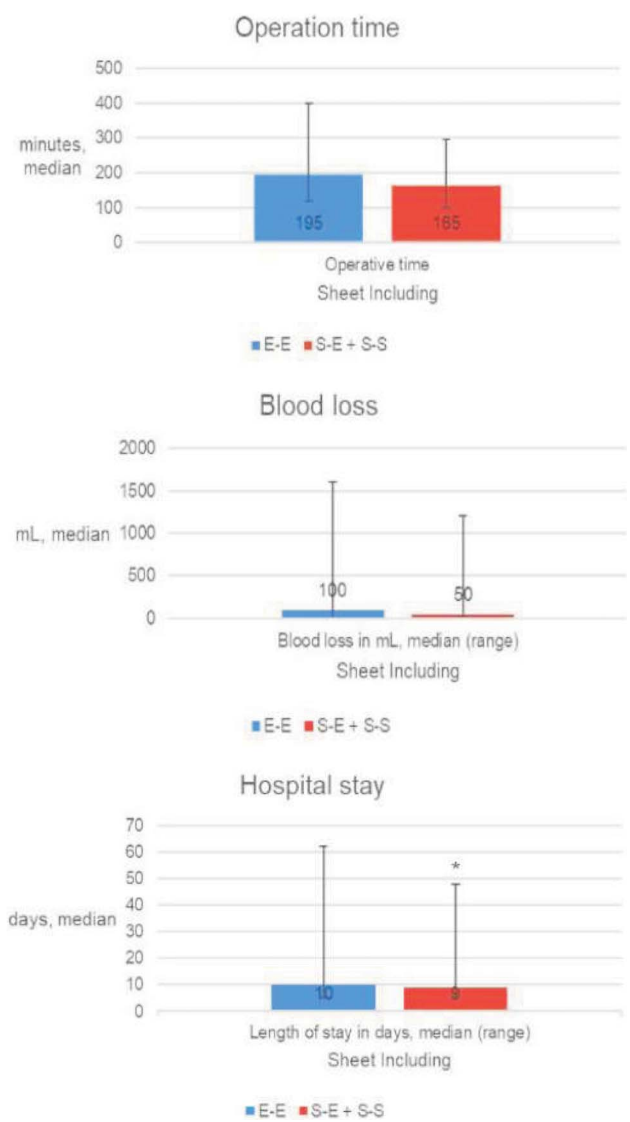

Fig. A-2. Comparison of operation time, blood loss, and hospital stay between E-E and S-E/S-S anastomosis groups in total including patients (* $p < 0.05$).

ble A-2-1, which revealed no significant differences in sex ($p = 0.675$), age ($p = 0.575$), ASA classification ($p = 0.85$), ECOG ($p = 0.661$), tumor size ($p = 0.789$), tumor location ($p = 0.614$), cancer stage ($p = 0.376$) and pre-op/post-op serum albumin level ($p = 0.925$/0.48). The E-E group still had a higher proportion of laparotomy than others ($p = 0.014$). The postoperative morbidity rate was significantly higher in the E-E group than in the S-E + S-S group (46.7% vs. 20.8%, $p = 0.008$), and wound complications were more common in the E-E group (11.1% vs. 0%, $p = 0.018$); these results are presented in Table A-2-2 and Fig. A-3, Fig. A-4.

In phase A3 analysis, 85 patients remained after those with a stoma were excluded (six in E-E group and two in S-E + S-S group). The results were consis-

Table A-2-1. Demographic and preoperative data of the studied groups

Ex-CCRT E-E vs. S-E + S-S

Ex-CCRT	N = 93		*p*-value
	E-E (%) (n = 45)	S-E + S-S (%) (n = 48)	
Sex			0.675
Men	30 (67)	30 (63)	
Women	15 (33)	18 (37)	
Age in years, mean ± SD	67 ± 9.5	65 ± 11.7	0.575
ASA			0.485
I	0	1 (2)	
II	25 (56)	29 (60)	
III	20 (44)	17 (36)	
IV	0	1 (2)	
ECOG			0.661
0	15 (33)	16 (33)	
1	15 (33)	19 (39)	
2	8 (18)	8 (17)	
3	5 (11)	5 (1)	
4	2 (4)	0	
Operation method			0.014
Laparotomy	19 (42)	9 (19)	
Laparoscopy	26 (58)	39 (81)	
Tumor size, mean ± SD	4.0 ± 1.9	3.8 ± 1.7	0.789
Tumor location AAV, median (range)	15 (8-40)	17 (5-28)	0.614
Location of anastomosis			0.21
D-S junction	1 (2)	0	
Sigmoid	15 (33)	10 (20)	
R-S junction and rectum	29 (65)	38 (80)	
Cancer stage			0.376
I	0	0	
IIA	9	10	
IIB	3	0	
IIIA	1	4	
IIIB	11	17	
IIIC	3	1	
IVA	2	1	
IVB	4	3	
Pre-operation albumin, mean ± SD	4.0 ± 0.6	4.0 ± 0.5	0.925
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.3 ± 0.4	0.48

Table A-2-2. Postoperative parameters and complications Ex-CCRT E-E vs. S-E + S-S

Ex-CCRT	n = 93		
Varieble	E-E (%) (n = 45)	S-E + S-S(%) (n = 48)	*p*-value
Anastomosis leak			0.115
Yes	6 (13)	2 (4)	
No	39 (87)	46 (96)	
Mortality			0.276
Yes	3 (7)	1 (2)	
No	42 (93)	47 (98)	
Acute renal failure			0.963
Yes	1 (2)	1 (2)	
No	44 (98)	47 (98)	
Bowel obstruction			0.077
Yes	5 (11)	1 (2)	
No	40 (89)	47 (98)	
Bleeding			0.069
Yes	3 (7)	0	
No	42 (93)	48 (1)	
Wound complication			0.018
Yes	5 (11)	0	
No	40 (89)	48 (1)	
Morbidity			0.008
Yes	21 (47)	10 (21)	
No	24 (53)	38 (79)	
Operative time in minutes, median (range)	180 (118-400)	160 (100-295)	0.467
Blood loss in mL, median (range)	85 (2-1600)	36 (11-1200)	0.633
Length of stay in days, median (range)	10 (5-35)	9 (5-48)	0.03

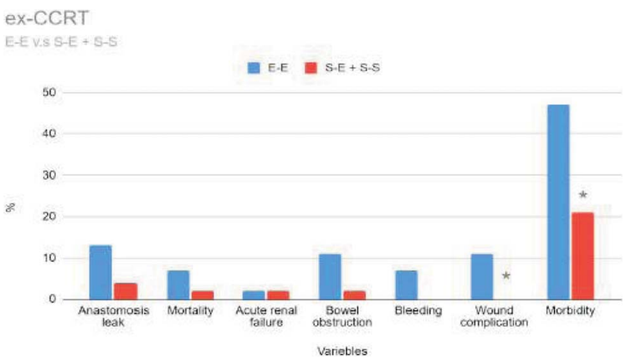

Fig. A-3. Comparison of postoperative complications between E-E and S-E/S-S anastomosis groups in including patients excluded CCRT (* $p < 0.05$).

tent with phase A1 and A2 analyses, and the proportion of laparotomy was still higher in the E-E group (p = 0.05) (Table A-3-1). The overall morbidity rate re-

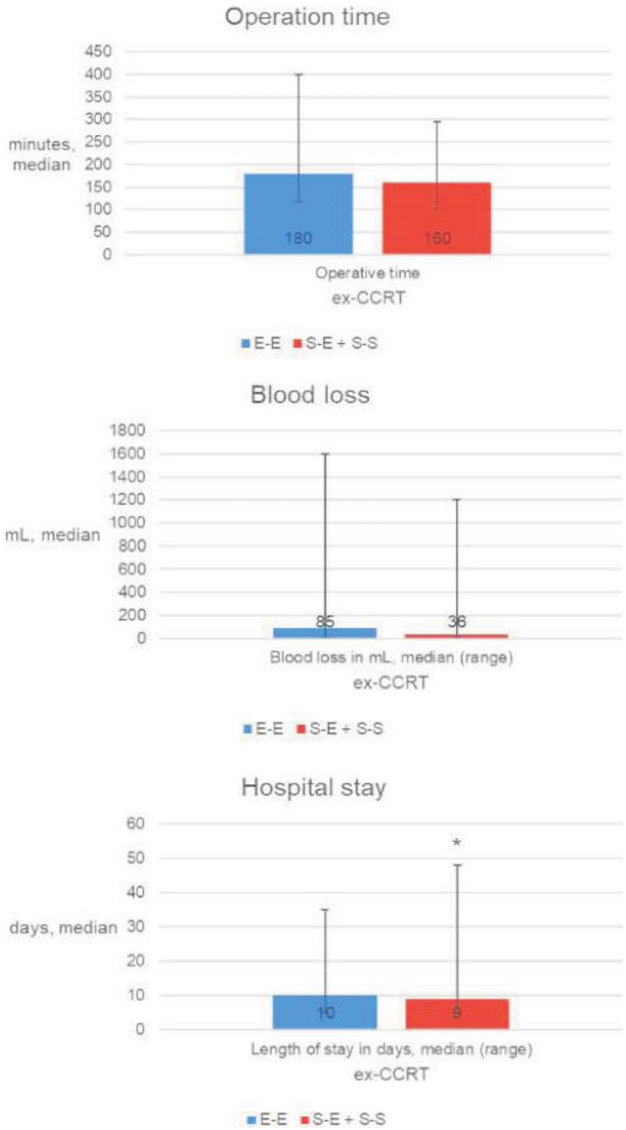

Fig. A-4. Comparison of operation time, blood loss, and hospital stay between E-E and S-E/S-S anastomosis groups in including patients excluded CCRT (* $p < 0.05$).

mained significantly higher in the E-E group than in the S-E + S-S group (41.0% vs. 19.6%, p = 0.03); anastomotic leakage rates were lower in the S-E + S-S group (10.3% vs. 2.2%, p = 0.115), although the difference was not statistically significant; these results are presented in Table A-3-2 and Fig. A-5, Fig. A-6.

Then we performed comparisons among the E-E, S-S, and S-E groups (Experiment B). The baseline demographics and preoperative characteristics of phase B1 are presented in Table B-1-1. No significant differ-

Table A-3-1. Demographic and preoperative data of the studied groups
Ex-CCRT/stomy E-E vs. S-E + S-S

Ex-CCRT/stomy	N = 85		
	E-E (%) (n = 39)	S-E + S-S (%) (n = 46)	*p*-value
Sex			0.759
Men	25 (64)	28 (61)	
Women	14 (36)	18 (39)	
Age in years, mean ± SD	66 ± 9.1	64.6 ± 11.7	0.75
ASA			0.592
I	0	1 (2)	
II	24 (62)	29 (63)	
III	15 (38)	15 (33)	
IV	0	1 (2)	
ECOG			0.689
0	15 (39)	16 (35)	
1	14 (36)	18 (39)	
2	7 (18)	7 (15)	
3	2 (5)	5 (11)	
4	1 (2)	0	
Operation method			0.05
Laparotomy	13 (33)	7 (15)	
Laparoscopy	26 (67)	39 (85)	
Tumor size, mean ± SD	3.8 ± 2.0	3.7 ± 1.7	0.97
Tumor location AAV, median (range)	15 (8-40)	17 (5-28)	0.83
Location of anastomosis			0.327
D-S junction	1 (3)	0	
Sigmoid	12 (31)	10 (22)	
R-S junction and rectum	26 (66)	36 (78)	
Cancer stage			0.48
I	0	0	
IIA	9	10	
IIB	1	0	
IIIA	1	4	
IIIB	8	16	
IIIC	3	1	
IVA	2	1	
IVB	3	2	
Pre-operation albumin, mean ± SD	4.2 ± 0.6	4.0 ± 0.5	0.58
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.3 ± 0.4	0.59

ences were observed between the three groups in terms of age ($p = 0.31$), ASA classification ($p = 0.684$), ECOG ($p = 0.408$), tumor size ($p = 0.38$), cancer stage ($p = 0.903$) and pre-op/post-op serum albumin level ($p = 0.49/0.66$). There was no statistically significant difference in the proportion of laparotomy surgeries among the E-E, S-E, and S-S groups ($p = 0.103$). How-

Table A-3-2. Postoperative parameters and complications
Ex-CCRT/stomy E-E vs. S-E + S-S

Ex-CCRT/stomy	n = 85		
Varieble	E-E (%) (n = 39)	S-E + S-S (%) (n = 46)	*p*-value
Anastomosis leak			0.115
Yes	4 (10)	1 (2)	
No	35 (90)	45 (98)	
Mortality			0.231
Yes	3 (8)	1 (2)	
No	36 (92)	45 (98)	
Acute renal failure			0.906
Yes	1 (3)	1 (2)	
No	38 (97)	45 (98)	
Bowel obstruction			0.115
Yes	4 (10)	1 (2)	
No	35 (90)	45 (98)	
Bleeding			0.055
Yes	3 (8)	0	
No	36 (92)	46 (1)	
Wound complication			0.055
Yes	3 (8)	0	
No	36 (92)	46 (1)	
Morbidity			0.03
Yes	16 (41)	9 (20)	
No	23 (59)	37 (80)	
Operative time in minutes, median (range)	180 (118-400)	160 (100-295)	0.717
Blood loss in mL, median (range)	50 (2-1600)	50 (11-1200)	0.9
Length of stay in days, median (range)	9 (5-35)	9 (5-48)	0.1

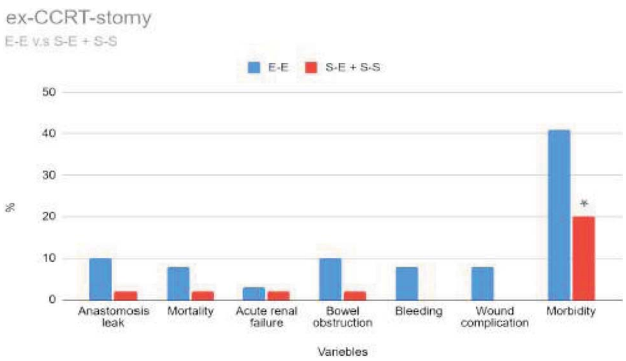

Fig. A-5. Comparison of postoperative complications between E-E and S-E/S-S anastomosis groups in including patients excluded CCRT and stomy (* $p < 0.05$).

ference in the proportion of laparotomy surgeries among the E-E, S-E, and S-S groups ($p = 0.103$). How-

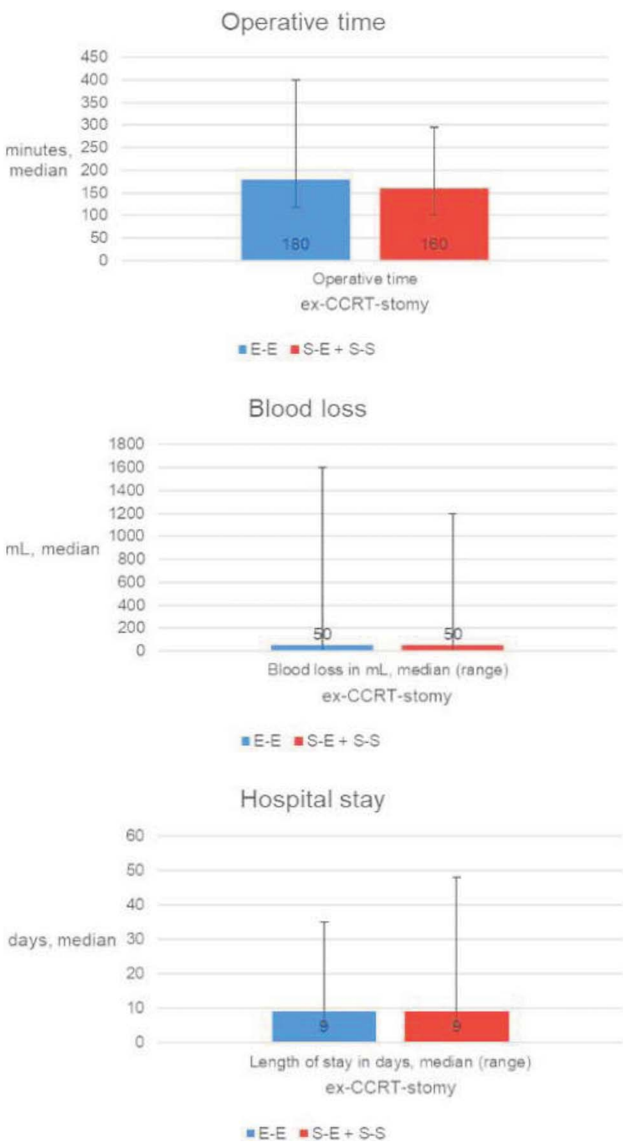

Fig. A-6. Comparison of operation time, blood loss, and hospital stay between E-E and S-E/S-S anastomosis groups in including patients excluded CCRT and stomy (* $p < 0.05$).

Table B-1-1. Demographic and preoperative data of the studied groups Sheet including E-E vs. S-S vs S-E

Sheet including	N = 103			*p*-value
	E-E (%) (n = 51)	S-S (%) (n = 14)	S-E (%) (n = 38)	
Sex				0.004
Men	36 (71)	4 (29)	29 (76)	
Women	15 (29)	10 (71)	9 (24)	
Age in years, mean ± SD	66.9 ± 10.4	68.6 ± 10.4	63 ± 12.1	0.31
ASA				0.684
I	0	0	1 (3)	
II	29 (57)	8 (57)	23 (60)	
III	22 (43)	6 (43)	13 (34)	
IV	0	0	1 (3)	
ECOG				0.408
0	15 (29)	3 (21)	13 (34)	
1	19 (37)	6 (42)	16 (42)	
2	9 (18)	5 (37)	4 (11)	
3	6 (12)	0	5 (13)	
4	2 (4)	0	0	
Operation method				0.103
Laparotomy	21 (41)	2 (14)	10 (26)	
Laparoscopy	30 (59)	12 (86)	28 (74)	
Tumor size, mean ± SD	3.8 ± 1.9	3.1 ± 1.4	4.1 ± 1.7	0.38
Tumor location AAV, median (range)	15 (5-40)	18 (13-28)	15 (5-20)	0.009
Location of anastomosis				0.472
D-S junction	1 (2)	0	0	
Sigmoid	15 (30)	4 (29)	6 (16)	
R-S junction and rectum	35 (68)	10 (71)	32 (84)	
Cancer stage				0.903
I	0	0	0	
IIA	10	3	7	
IIB	3	0	1	
IIIA	1	1	3	
IIIB	16	4	15	
IIIC	3	0	1	
IVA	2	0	1	
IVB	4	2	1	
Pre-operation albumin, mean ± SD	4 ± 0.6	4.1 ± 0.5	4.0 ± 0.5	0.49
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.2 ± 0.4	3.3 ± 0.4	0.66

ever, there was female dominant in the S-S group (p = 0.004) and tumor location was more distal in the S-S group (18 cm, p = 0.009) than the E-E group and S-E group.

The postoperative parameters and complications were presented in Table B-1-2. There was no significant difference in anastomosis leak (p = 0.182), mortality rate (p = 0.53), acute renal failure (p = 0.83), bowel obstruction (p = 0.078), bleeding (p = 0.207) and wound complication (p = 0.132). However, the overall morbidity rate was significantly higher in the E-E group than others (49.0% vs. 28.6% vs. 21.1%, p = 0.02). There were also no significant differences in the operative time (p = 0.088), blood loss (p = 0.442) and length of hospital stay (p = 0.083). The results described above are presented as a bar chart in Fig. B-1

Table B-1-2. Postoperative parameters and complications Sheet including E-E vs. S-S vs. S-E

Sheet including	n = 103			
Varieble	E-E (%) (n = 51)	S-S (%) (n = 14)	S-E (%) (n = 38)	*p*-value
Anastomosis leak				0.182
Yes	7 (14)	1 (7)	1 (3)	
No	44 (86)	13 (93)	37 (97)	
Mortality				0.53
Yes	3 (6)	0	1 (3)	
No	48 (94)	14 (1)	37 (97)	
Acute renal failure				0.83
Yes	1 (2)	0	1 (3)	
No	50 (98)	14 (1)	37 (97)	
Bowel obstruction				0.078
Yes	7 (14)	0	1 (3)	
No	44 (86)	14 (1)	37 (97)	
Bleeding				0.207
Yes	3 (6)	0	0	
No	48 (94)	14 (1)	38 (1)	
Wound complication				0.132
Yes	6 (12)	0	1 (3)	
No	45 (88)	14 (1)	37 (97)	
Morbidity				0.02
Yes	25 (49)	4 (29)	8 (21)	
No	26 (51)	10 (71)	30 (79)	
Operative time in minutes, median (range)	195 (118-400)	137 (100-270)	175 (120-295)	0.088
Blood loss in mL, median (range)	100 (2-1600)	24 (15-600)	100 (11-1200)	0.442
Length of stay in days, median (range)	10 (5-62)	8 (5-18)	9 (5-48)	0.083

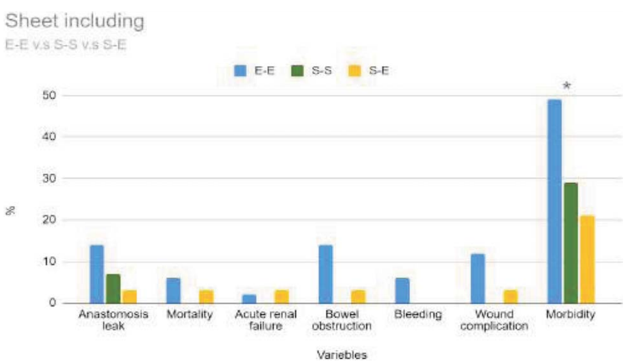

Fig. B-1. Comparison of postoperative complications between E-E, S-E, and S-S anastomosis groups in total including patients (* $p < 0.05$).

and Fig. B-2.

After 10 patients who underwent CCRT were excluded, the baseline characteristics of phase B2 study was presented at the Table B-2-1. There were no significant differences in age ($p = 0.35$), ASA classification ($p = 0.629$), ECOG ($p = 0.304$), tumor size ($p = 0.3$), tumor location ($p = 0.008$), cancer stage ($p = 0.751$) and pre-op/post-op serum albumin level ($p = 0.52/0.8$). Among these three groups, the E-E group had a higher proportion of laparotomy surgeries ($p = 0.044$), and the S-S group had a higher proportion of female ($p = 0.006$). The postoperative morbidity rate was significantly higher in the E-E group than others ($p = 0.023$), and wound complications were more

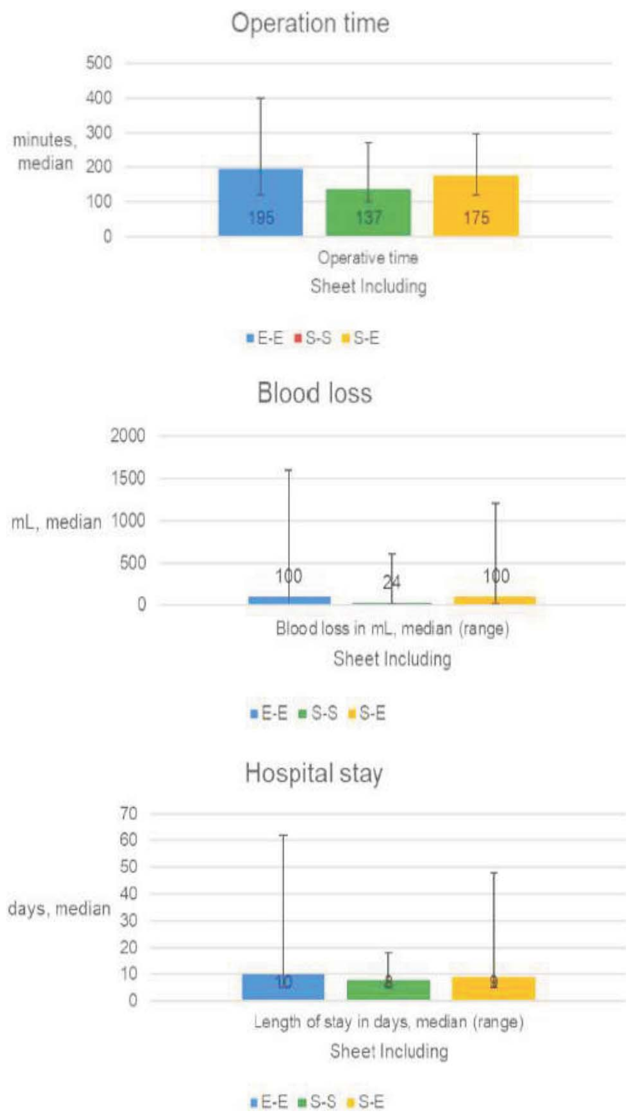

Fig. B-2. Comparison of operation time, blood loss, and hospital stay between E-E, S-E, and S-S anastomosis groups in total including patients (* $p < 0.05$).

Table B-2-1. Demographic and preoperative data of the studied groups Ex-CCRT E-E vs. S-S vs. S-E

Ex-CCRT	N = 93			*p*-value
	E-E (%) (n = 45)	S-S (%) (n = 14)	S-E (%) (n = 34)	
Sex				0.006
Men	30 (67)	4 (29)	26 (77)	
Women	15 (33)	10 (71)	8 (23)	
Age in years, mean ± SD	67 ± 9.5	68.5 ± 10.3	63 ± 12.0	0.35
ASA				0.629
I	0	0	1 (3)	
II	25 (56)	8 (57)	21 (62)	
III	20 (44)	6 (43)	11 (32)	
IV	0	0	1 (3)	
ECOG				0.304
0	15 (33)	3 (21)	13 (38)	
1	15 (33)	6 (42)	13 (38)	
2	8 (18)	5 (37)	3 (9)	
3	5 (11)	0	5 (15)	
4	2 (4)	0	0	
Operation method				0.044
Laparotomy	19 (42)	2 (14)	7 (21)	
Laparoscopy	26 (58)	12 (86)	27 (79)	
Tumor size, mean ± SD	4.0 ± 1.9	3.1 ± 1.4	4.1 ± 1.8	0.3
Tumor location AAV, median (range)	15 (8-40)	18 (13-28)	15 (5-20)	0.08
Location of anastomosis				0.445
D-S junction	1 (2)	0	0	
Sigmoid	15 (33)	4 (29)	6 (18)	
R-S junction and rectum	29 (65)	10 (71)	28 (82)	
Cancer stage				0.751
I	0	0	0	
IIA	9	3	7	
IIB	3	0	0	
IIIA	1	1	3	
IIIB	11	4	13	
IIIC	3	0	1	
IVA	2	0	1	
IVB	4	2	1	
Pre-operation albumin, mean ± SD	4.0 ± 0.6	4.1 ± 0.5	4.0 ± 0.5	0.52
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.2 ± 0.4	3.3 ± 0.4	0.8

Table B-2-2. Postoperative parameters and complications Ex-CCRT E-E vs. S-S vs. S-E

Ex-CCRT	n = 93			*p*-value
Varieble	E-E (%) (n = 45)	S-S (%) (n = 14)	S-E (%) (n = 34)	
Anastomosis leak				0.259
Yes	6 (13)	1 (7)	1 (3)	
No	39 (87)	13 (93)	33 (97)	
Mortality				0.498
Yes	3 (7)	0	1 (3)	
No	42 (93)	14 (1)	33 (97)	
Acute renal failure				0.815
Yes	1 (2)	0	1 (3)	
No	44 (98)	14 (1)	33 (97)	
Bowel obstruction				0.194
Yes	5 (11)	0	1 (3)	
No	40 (89)	14 (1)	33 (97)	
Bleeding				0.191
Yes	3 (7)	0	0	
No	42 (93)	14 (1)	34 (1)	
Wound complication				0.06
Yes	5 (11)	0	0	
No	40 (89)	14 (1)	34 (1)	
Morbidity				0.023
Yes	21 (47)	4 (29)	6 (18)	
No	24 (53)	10 (71)	28 (82)	
Operative time in minutes, median (range)	180 (118-400)	137 (100-270)	175 (120-295)	0.141
Blood loss in mL, median (range)	85 (2-1600)	24 (15-600)	55 (11-1200)	0.622
Length of stay in days, median (range)	10 (5-35)	8 (5-18)	9 (5-48)	0.079

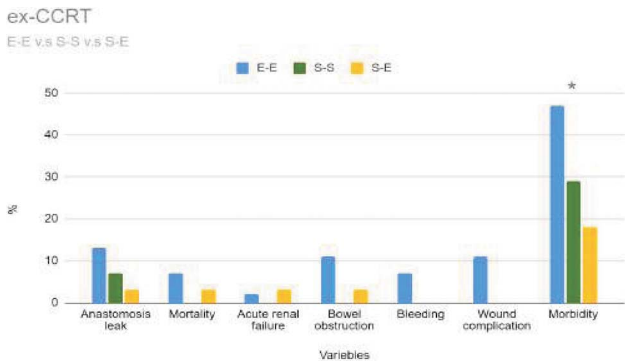

Fig. B-3. Comparison of postoperative complications between E-E, S-E, and S-S anastomosis groups in including patients excluded CCRT (* $p < 0.05$).

common in the E-E group which was close to reaching statistical significance ($p = 0.06$); these results are presented in Table B-2-2 and Fig. B-3, Fig. B-4.

In the phase B3 analysis, 85 patients remained after those with a stoma were excluded. The results were consistent with prior analyses, with no statistically significant difference in the proportion of laparotomy surgeries among the three groups ($p = 0.110$)

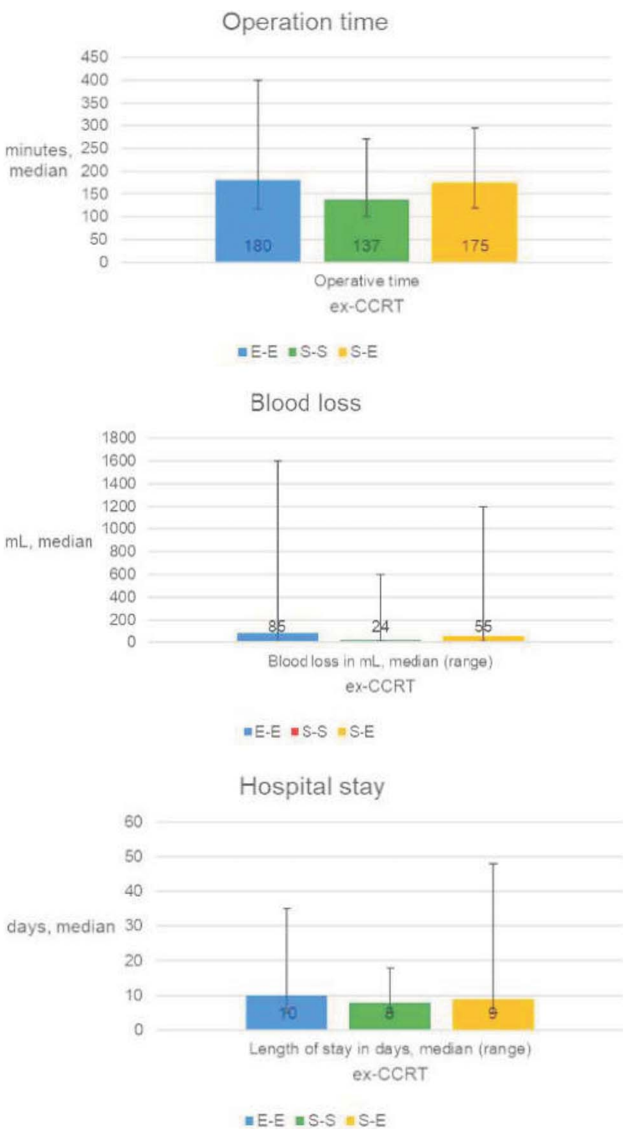

Fig. B-4. Comparison of operation time, blood loss, and hospital stay between E-E, S-E, and S-S anastomosis groups in including patients excluded CCRT (* $p < 0.05$).

Table B-3-1. Demographic and preoperative data of the studied groups Ex-CCRT/stomy E-E vs. S-S vs. S-E

Ex-CCRT/stomy	N = 85			*p*-value
	E-E (n = 39)	S-S (n = 13)	S-E (n = 33)	
Sex				0.004
Men	25 (64)	3 (23)	25 (76)	
Women	14 (36)	10 (77)	8 (24)	
Age in years, mean ± SD	66 ± 9.1	68 ± 10	63 ± 12	0.551
ASA				0.738
I	0	0	1 (3)	
II	24 (62)	8 (62)	21 (64)	
III	15 (38)	5 (38)	10 (3)	
IV	0	0	1 (3)	
ECOG				0.392
0	15 (39)	3 (23)	13 (39)	
1	14 (36)	6 (46)	12 (36)	
2	7 (18)	4 (31)	3 (9)	
3	2 (5)	0	5 (16)	
4	1 (2)	0	0	
Operation method				0.110
Laparotomy	13 (33)	1 (8)	6 (18)	
Laparoscopy	26 (67)	12 (92)	27 (82)	
Tumor size, mean ± SD	3.8 ± 2.0	2.9 ± 1.3	4.0 ± 1.8	0.24
Tumor location AAV, median (range)	15 (8-40)	18 (13-28)	15 (5-20)	0.097
Location of anastomosis				0.557
D-S junction	1 (3)	0	0	
Sigmoid	12 (31)	4 (31)	6 (18)	
R-S junction and rectum	26 (66)	9 (69)	27 (82)	
Cancer stage				0.91
I	0	0	0	
IIA	9	3	7	
IIB	1	0	0	
IIIA	1	1	3	
IIIB	8	4	12	
IIIC	3	0	1	
IVA	2	0	1	
IVB	3	1	1	
Pre-operation albumin, mean ± SD	4.2 ± 0.6	4.2 ± 0.4	4.0 ± 0.5	0.323
Post-operation albumin, mean ± SD	3.4 ± 0.4	3.3 ± 0.3	3.2 ± 0.4	0.83

(Table B-3-1). The postoperative result revealed no statistical significance in the anastomotic leakage rates ($p = 0.266$), wound complication rate ($p = 0.16$) and morbidity rate ($p = 0.091$); these results are presented in Table B-3-2 and Fig. B-5, Fig. B-6.

Discussion

Our Experiment A revealed that side-to-end (S-E) plus side-to-side (S-S) anastomosis provides better clinical outcomes than end-to-end (E-E) anastomosis does in patients who undergo AR and LAR. We observed a definite lower incidence of postoperative morbidity rates, and slightly shorter hospital stay in the S-E + S-S group than in the E-E group, supporting the notion that these techniques may be superior.

Table B-3-2. Postoperative parameters and complications Ex-CCRT/stomy E-E vs. S-S vs. S-E

Ex-CCRT/stomy	n = 85			
Varieble	E-E (%) (n = 39)	S-S (%) (n = 13)	S-E (%) (n = 33)	*p*-value
Anastomosis leak				0.266
Yes	4 (10)	0	1 (3)	
No	35 (90)	13 (1)	32 (97)	
Mortality				0.444
Yes	3 (8)	0	1 (3)	
No	36 (92)	13 (1)	32 (97)	
Acute renal failure				0.824
Yes	1 (3)	0	1 (3)	
No	38 (97)	13 (1)	32 (97)	
Bowel obstruction				0.266
Yes	4 (1)	0	1 (3)	
No	35 (9)	13 (1)	32 (97)	
Bleeding				0.16
Yes	3 (8)	0	0	
No	36 (92)	13 (1)	33 (1)	
Wound complication				0.16
Yes	3 (8)	0	0	
No	36 (92)	13 (1)	33 (1)	
Morbidity				0.091
Yes	16 (41)	3 (23)	6 (18)	
No	23 (59)	10 (77)	27 (82)	
Operative time in minutes, median (range)	180 (118-400)	140 (100-270)	172 (120-295)	0.319
Blood loss in mL, median (range)	50 (2-1600)	20 (15-600)	77 (11-1200)	0.651
Length of stay in days, median (range)	9 (5-35)	8 (5-18)	9 (5-48)	0.198

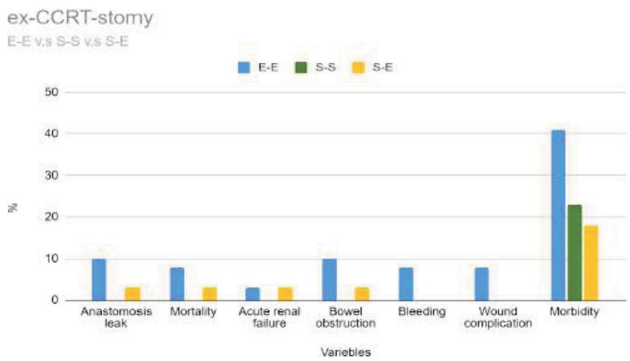

Fig. B-5. Comparison of postoperative complications between E-E, S-E, and S-S anastomosis groups in including patients excluded CCRT and stomy (* $p < 0.05$).

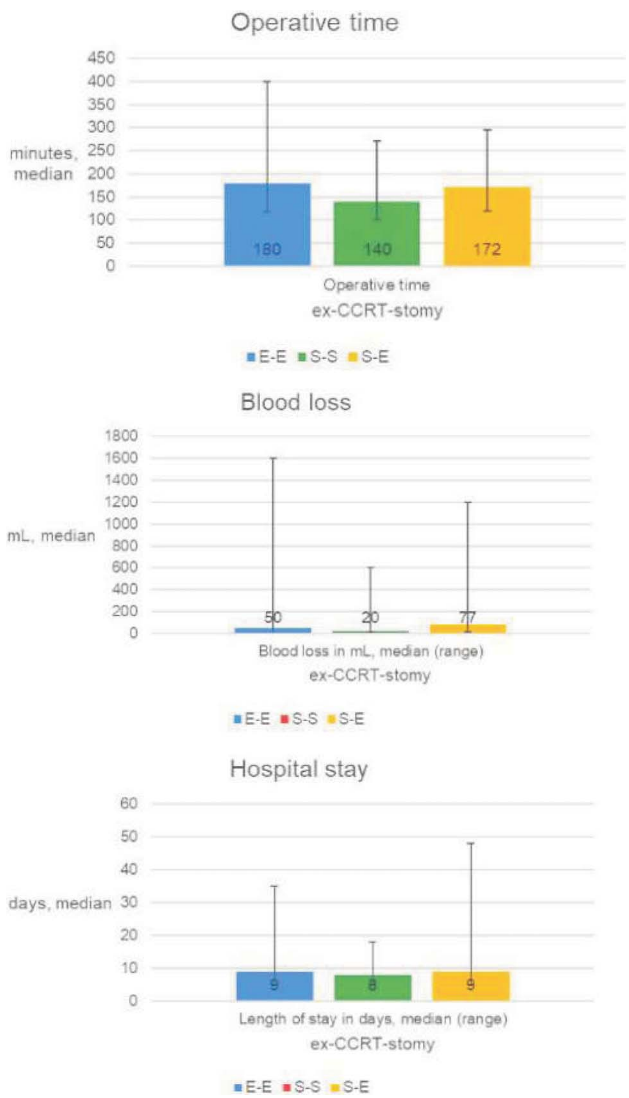

Fig. B-6. Comparison of operation time, blood loss, and hospital stay between E-E, S-E, and S-S anastomosis groups in including patients excluded CCRT and stomy (* $p < 0.05$).

Although the difference in anastomotic leakage rates was not statistically significant, the consistent trend favoring S-E + S-S anastomosis aligns with findings reported in prior studies. Ikeda et al. (2014) described their study result from Kyushu University that side-to-side colorectal anastomosis with a circular stapler may be better than end-to-end double stapling technique.[10] Brisinda et al. (2009) also reported a significantly lower leakage rate in the side-to-end group than in the end-to-end group (5% vs. 29.2%).[12] These results suggest that S-E or S-S anastomosis may be clinically beneficial, especially in cases in which reducing the risk of anastomotic leakage is critical. In Experiment A, laparotomy procedures were significantly more frequent in the E-E group; however, since the *p*-values in both phase 1 and phase 3 were around 0.05, and given that the difference between laparotomy and laparoscopic surgery does not substantially affect the anastomosis technique, we believe that the type of surgery has a limited impact on anastomotic outcomes.

During Experiment B, we compared the demographic characteristics among the S-E, S-S, and E-E groups. Although the sex distribution in the S-S group differed from that in the other two groups, we believed this had limited impact on the experimental results. In addition, in phase B1, the tumor location in the S-S group was slightly farther from the anus compared to the other groups. However, this statistical difference disappeared in phases B2 and B3; therefore, we consider its influence on the study results to be limited as well. Based on the same reasoning, the proportion of laparotomies in the E-E group reached statistical significance only in phase B2, but not in phases B1 or B3. Therefore, we believe that this factor has a limited impact on the results of our study. In phases B1 and B2, there were differences in morbidity rates among the three groups, with the E-E group clearly experiencing more complications. However, no statistically significant difference was observed in phase B3. As for anastomotic leakage, no significant differences were found among the three groups in any phase. Overall, the results of experiment B suggest that E-E anastomosis may be slightly inferior to the other two anastomotic techniques, but the differences among the three methods are not substantial.

Different predictive factors for leakage have been identified: inappropriate surgical technique, adequate anastomotic blood flow, contamination, anastomotic technique, pelvic drain placement, tension at the anastomotic site, absence of active disease or distal obstruction, and distance from the anal verge.[6,7,13,14] Ikeda et al. (2014) described the result from Kyushu University that side-to-side colorectal anastomosis with a circular stapler may induce a better burst pressure than double stapling technique; besides, the anastomosis line of side-to-side anastomosis with a circular stapler is a nearly perfect circle without overlap, and no lifted or dislocated staples, better than double stapling technique.[10] Kato et al. (2021) also demonstrated that side-to-end anastomosis is superior to end-to-end anastomosis due to its lower leakage rate. This advantage may be attributed to better blood flow at the anastomotic site in side-to-end configurations compared to end-to-end ones.[15]

The incidence of anastomotic leakage in this study was 8.4% (9 patients), with 4 patients requiring diverting colostomy due to generalized peritonitis, pelvic or perineal pain, fever and fecal contamination detected via pelvic drains. Previous research by Law and Chu[13] and Law et al.[16] similarly highlighted anastomotic leakage as a significant postoperative concern in anterior resection for colorectal cancer. Those studies revealed a higher leakage rate (8.1%) in patients who underwent total mesorectal excision than in those who underwent partial mesorectal excision (1.3%), emphasizing the impact of the surgical technique on postoperative outcomes. Furthermore, they identified male sex, the absence of a protective stoma, and increased intraoperative blood loss as critical risk factors for anastomotic leakage. In support of these findings, Matthiessen et al.[17] reported comparable results but did not find a definitive advantage of creating a temporary stoma. While creating a diverting stoma may not reduce the risk of anastomotic dehiscence itself, it can mitigate septic complications associated with a leak.

In recent years, there has been a growing emphasis on the quality of surgical care, with surgical outcomes increasingly recognized as key indicators of care quality. Dimick et al.[18] reported that patients who underwent colorectal cancer surgery had lower mortality rates when treated at high-volume centers. However, Urbach et al.[19] reported no significant improvement in outcomes when colorectal procedures were performed at such centers, suggesting that volume alone may not guarantee better results. Furthermore, a large study examining patients with stage I-III rectal cancer between 1994 and 1997 revealed that hospital volume influenced several critical outcomes, including colostomy rates, postoperative mortality, and overall survival.[20] Specifically, hospitals performing more than 20 procedures annually (highest quartile) had significantly lower colostomy rates (29.5% vs. 36.6%), lower 30-day postoperative mortality rates (1.6% vs. 4.8%), and higher 2-year overall survival rates (83.7% vs. 76.6%) than hospitals performing fewer than seven procedures annually (lowest quartile) did.[20] These findings underscore the potential impact of hospital surgical volume on patient outcomes. Our hospital, is a tertiary medical center that provides high-level care owing to its extensive resources and multidisciplinary support. All surgeries were performed by experienced colorectal surgeons, ensuring consistency and expertise in the surgical approach.

In our experiment, patients who received neoadjuvant CCRT or had a diverting stoma were excluded from Phase 2 and Phase 3 to avoid potential bias arising from unequal proportions of "CCRT-treated" and "stoma-present" patients between the two groups. In our experiment, both Phase 2 and Phase 3 yielded results similar to those of Phase 1, showing that the S-E and S-S groups had fewer complications compared to the E-E group. This suggests that even after excluding potential confounding factors, the S-E and S-S groups still demonstrated better outcomes, indicating that the results were not merely due to study design or group allocation.

In our study, we conducted both a comparison between the E-E group and the combined S-E and S-S groups (Experiment A), as well as a three-group comparison among the E-E, S-E, and S-S groups (Experiment B). The rationale for this approach includes the following: (1) The number of cases in the S-S group was relatively small, and its tumor location and gender distribution a little differed from that of the others; (2) The combined number of cases in the S-E and S-S groups was approximately equal to that in the E-E group. Since it is difficult to determine which grouping strategy is more appropriate, we presented both types of comparisons for reference. Ultimately, both grouping strategies yielded consistent results: the S-E and S-S groups demonstrated lower morbidity rates compared to the E-E group. This finding led to the final conclusion of our study.

Despite these promising results, several limitations of our study should be acknowledged. As a retrospective cohort study, our analysis is inherently prone to selection bias, which limits the ability to establish a clear cause-effect relationship between the anastomotic technique and surgical outcomes. Additionally, the study was conducted at a single institution by a single surgeon, which may limit the generalizability of its results to other settings or surgical teams with different experience levels. The lack of randomization and blinding further reduces the strength of our conclusions.

Moreover, intraoperative bowel perfusion monitoring via indocyanine green (ICG) fluorescence angiography was not employed during the study period. This limited our ability to assess real-time blood flow to the anastomotic site, which is a critical determinant of anastomotic healing and leakage risk. The incorporation of ICG monitoring in future studies could provide valuable insight into the vascular dynamics of different anastomotic techniques.

Our research has several limitations that warrant further review. First, owing to the limited S-E and S-S anastomoses differ, and with sufficient cases, they could be analyzed separately. If we conduct follow-up studies in the future, we should be able to regroup and explore these distinctions in greater detail. Additionally, we did not evaluate long-term functional outcomes, such as low anterior resection syndrome (LARS), which could offer a more comprehensive understanding of postoperative recovery and quality of life.

In conclusion, our study suggests that side-to-end or side-to-side anastomosis may be associated with superior outcomes compared with end-to-end anastomosis in patients undergoing lower anterior resection. The trends observed included a lower anastomotic leakage rate, shorter operative time, and lower morbidity rates, highlighting the need for routine consideration of these techniques in clinical practice. Future prospective, randomized controlled trials with larger patient cohorts, real-time vascular monitoring, and long-term functional assessments are warranted to validate these findings and refine surgical decision-making.

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原　著

各式吻合法應用於低位前方切除手術之比較

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目的　自從雙重縫合技術被應用來進行前方切除及低位前方切除手術以來，關於哪種吻合技術 — 端對端、端對側或側對側 — 能達到最佳效果的爭論一直持續不斷。2015 年，一位大腸直腸外科醫師改變了術式，優先選用端對側和側對側吻合技術來取代傳統的端對端技術。這一改變提供了一個分析術式改變前後手術數據的機會。

方法　我們收集了自 2013 年 7 月 1 日起至 2018 年 6 月 30 日間，由同一位主治醫師執行的前方切除及低位前方切除手術之結腸直腸癌患者的醫療數據。我們收集了病患之基本資料、手術內容及吻合的方式、住院天數及術後併發症，並將病患分為傳統的端對端 (E-E) 以及選擇性的側對端或側對側 (S-E + S-S) 兩組。我們對這些數據進行分析並探討各吻合方式及其併發症發生的機率。

結果　共有 103 名患者被納入研究，其中 51 名患者為傳統端對端吻合 (E-E) 組，另外 52 名患者為側對端或側對側 (S-E + S-S) 組。吻合滲漏發生率在 S-E + S-S 組較低 (3.8% vs. 13.2%, p = 0.081)。S-E + S-S 組的術後總併發症率顯著較低 (24.5% vs. 49.1%, p = 0.009)、腸梗阻發生率較低 (3.8% vs. 15.1%, p = 0.046)，傷口併發症也較少 (1.9% vs. 11.3%, p = 0.051)。排除接受術前化學放射治療 (CCRT) 與造口術的患者後的次群分析顯示一致的結果。

結論　側對端和側對側吻合技術比傳統的端對端技術在術後併發症率和發病率上更低，支持其作為安全有效的替代術式。

關鍵詞　大腸直腸手術、低位前方切除手術、端對端、側對端及側對側吻合術、雙重釘合技術。