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The efficacy of open transanal drainage tube against anastomotic leakage in left-sided colorectal cancer surgery: a propensity score matching study

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Abstract

Background/Aim The effectiveness of a transanal drainage tube (TAT) for the prevention of anastomotic leakage after double stapling technique (DST) anastomosis in colorectal cancer has been reported. Previously, TATs had been placed and connected to drainage bags. It was considered that a higher decompression effect could be expected by inserting an open-type TAT, without connection to a drainage bag. In this study, the relation between anastomotic leakage and the application of this type of TAT in left-sided colorectal cancer surgery was investigated, using propensity score matching (PSM).

Materials and methods From January 2016 to July 2023, 233 consecutive patients underwent radical surgery for sigmoid colon and rectal cancers and reconstruction using DST at Osaka Metropolitan University Hospital. Patients were divided into two groups: those who had a closed TAT inserted (CLOSED group), and those who had an open TAT inserted (OPEN group).

Results Overall, open TATs were inserted in 43 patients, and closed TATs were inserted in 190 patients. PSM was performed between the OPEN and CLOSED groups on the basis of the following 13 factors: age, sex, BMI, diabetes mellitus (DM), smoking history, modified Glasgow prognostic score (mGPS), ASA-PS, location of distal tumor edge, operative procedure, surgical approach, operative time, intraoperative blood loss, and pathological stage. The multivariate analysis of significant factors identified a BMI of 25 or more, a location of distal edge on middle to lower rectum, and a closed TAT, as independent risk factors for anastomotic leakage (HR: 8.72; $p=0.038$, HR: 10.06; $p=0.034$ and HR: 17.43; $p=0.033$).

Conclusion An open TAT may be effective in preventing anastomotic leakage in left-sided colorectal cancer surgery.

Keywords Colorectal cancer, Transanal drainage tube, Anastomotic leakage

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Background

Colorectal cancer is the third most common malignancy worldwide and the second leading cause of cancer-related deaths [1]. Surgical resection remains the mainstay of curative treatment for colorectal cancer, but it may be associated with anastomotic leakage, a severe complication, which decreases the postoperative quality of life and survival rates of patients and increases recurrence and re-operation rates [2–4]. The elevation of endoluminal pressure is reported to be a risk factor for anastomotic leakage [5]. The effectiveness of a transanal drainage tube (TAT) for the prevention of anastomotic leakage after double-stapling technique (DST) anastomosis in colorectal cancer has been reported [6–8]. TAT may be effective in reducing anastomotic leakage by reducing endoluminal pressure and draining gas and watery stools [7]. Even if anastomotic leakage does occur, the TAT may reduce severity and reoperation rates [7, 9].

For these reasons, TATs were placed to prevent anastomotic leakage. Previously, TATs had been placed and connected to drainage bags, but occasional cases of insufficient decompression due to constriction caused by fecal impaction were observed. Generally, closed drain is less likely to be associated with retrograde infection, but more likely to lead to an obstruction [10–13].On the other hand, compared to closed drain, open drains have been reported to have a longer duration of drainage effect and more drainage [14, 15]. It was considered that a higher decompression effect might be expected if an open-type TAT, without connection to a drainage bag, was to be inserted. Since September 2022, therefore, the MIT drain® (Create Medic, Kanagawa, Japan), a specialized TAT, has been used as an open TAT.

In this study, the relation between anastomotic leakage and this type of TAT has been investigated in left-sided colorectal cancer surgery using propensity score matching (PSM).

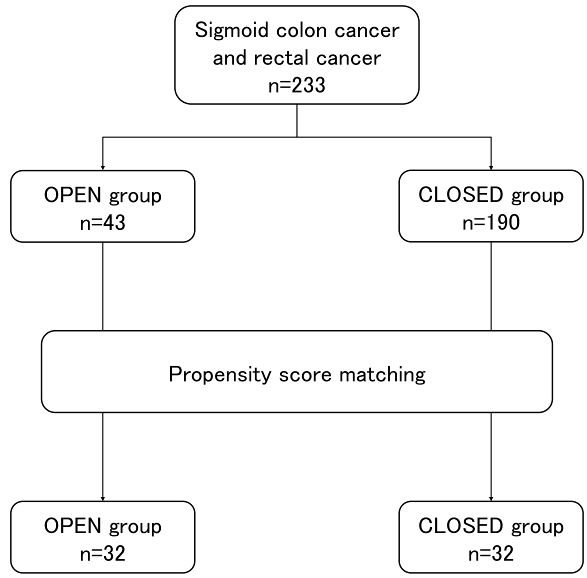

Fig. 1 Flowchart of patient inclusion in the present study. Patients with a constructed diverting ileostomy, pathological Stage IV disease, non-curative (R1 or R2) resection, and synchronous surgeries for other cancers were excluded

Materials and methods

Patients and study design

A retrospective analysis was conducted on 233 consecutive patients who underwent radical surgery under general anesthesia for sigmoid colon and rectal cancers and reconstruction using the DST at Osaka Metropolitan University Hospital, between January 2016 and July 2023. Patients in which a diverting ileostomy had been constructed; who were at Stage IV disease; who had experienced non-curative (R1 or R2) resections; or who had undergone synchronous surgeries for other cancers, were excluded. A flowchart of the study is shown in Fig. 1.

The following clinical and surgical data were collected from electronic medical records: age, sex, body mass index (BMI), patient history, and blood test results. The Brinkman index was calculated as (Number of cigarettes smoked per day) × (Number of years smoked), and smoking history was defined as 400 ≥ Brinkman index. Rectum was divided into 3 parts, as follows: lower rectum, < 5 cm; middle rectum, 5–10 cm; and upper rectum, 10–15 cm from the anal verge [16]. The clinicopathological characteristics of the patients are summarized in Table 1. Histological diagnosis was based on the World Health Organization criteria. Pathological staging was performed according to the 3rd English Edition of the Japanese Classification of Colorectal, Appendiceal, and Anal Carcinoma [17].

Patients were divided into two groups: those in whom a closed TAT had been placed (CLOSED group), and those in whom an open TAT had been placed (OPEN group). The study protocol was reviewed and approved by the Ethical Committee of Osaka Metropolitan University Graduate School of Medicine (Approval Number: 4182). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical procedures

All patients underwent fasting and ingested preoperative bowel preparation with MOVIPREP® (Sodium chloride, Potassium chloride, Anhydrous sodium sulfate, Macrogol 4000, Ascorbic acid, and Sodium L-ascorbate) 2 days before surgery. A glycerin enema was also administered on the morning of the surgery, which were performed by surgeons certified by the Japanese Society of Gastrointestinal Surgery or the Japanese Society of Endoscopic Surgery. This study focuses on oncological procedures in all cases and the surgical procedures were performed according to the guidelines of the Japanese Society for Cancer of the Colon and Rectum [18]. The basic procedure involved a total mesorectal excision or

Table 1 The relationship between the type of transanal drainage tube and the clinicopathological factors before propensity score matching

		Total		OPEN group		CLOSED group		*P*-value
		n **= 233**		***n*** **= 43**	**18.5%**	***n*** **= 190**	**81.5%**	
Sex	female	98	42.1%	23	53.5%	75	39.5%	0.093
	male	135	57.9%	20	46.5%	115	60.5%	
Average age (SD)		68.4(10.5)		68.8(11.2)		68.4(10.3)		0.820
Average BMI (SD)		23.0(3.6)	kg/m^2	22.2(3.7)	kg/m^2	23.2(3.8)	kg/m^2	0.112
DM	+	44	18.9%	11	25.6%	33	17.4%	0.241
	-	189	81.1%	32	74.4%	157	82.6%	
Brinkman index	≥ 400	82	35.2%	11	25.6%	71	37.4%	0.144
	< 400	151	64.8%	32	74.4%	119	62.6%	
mGPS	0	181	77.7%	34	79.1%	147	77.4%	0.765
	1	33	14.2%	5	11.6%	28	14.7%	
	2	17	7.3%	4	9.3%	13	6.8%	
ASA-PS	1	9	3.9%	1	2.3%	8	4.2%	0.843
	2	175	75.1%	33	76.7%	142	74.7%	
	3	49	21.0%	9	20.9%	40	21.1%	
Distal tumor edge	Sigmoid colon	104	44.6%	11	25.6%	93	48.9%	< 0.001
	upper rectum	66	28.3%	15	34.9%	51	26.8%	
	millde rectum	49	21.0%	9	20.9%	40	21.1%	
	lower rectum	14	6.0%	8	18.6%	6	3.2%	
Operative procedure	S	94	40.3%	14	32.6%	80	42.1%	0.134
	HAR	56	24.0%	8	18.6%	48	25.3%	
	LAR	83	35.6%	21	48.8%	62	32.6%	
Surgical approach	Lap	188	80.7%	22	51.2%	166	87.4%	< 0.001
	Ro	45	19.3%	21	48.8%	24	12.6%	
Average operative time (SD)		238(79.6)	min	263(77.2)	min	233(79.3)	min	0.012
Average blood loss (SD)		37.4(77.3)	ml	45.1(96.4)	mL	35.7(72.5)	mL	0.471
T	is, 1, 2	111	47.6%	21	48.8%	90	47.4%	0.862
	3. 4	122	52.4%	22	51.2%	100	52.6%	
N	(+)	58	24.9%	15	34.9%	43	22.6%	0.093
	(-)	175	75.1%	28	65.1%	147	77.4%	
Stage	0/1	97	41.6%	17	39.5%	80	42.1%	0.207
	2	78	33.5%	11	25.6%	67	35.3%	
	3	58	24.9%	15	34.9%	43	22.6%	
Postoperative complication								
All complications	(+)	76	32.6%	8	18.6%	68	35.8%	0.030
	(-)	157	67.4%	35	81.4%	122	64.2%	
All complications over C-DIIIA	(+)	25	10.7%	1	2.3%	24	12.6%	0.033
	(-)	208	89.3%	42	97.7%	166	87.4%	
Anastomotic leakage	(+)	23	9.9%	1	2.3%	22	11.6%	0.048
	(-)	210	90.1%	42	97.7%	168	88.4%	
Reoperation due to anastomotic leakage	(+)	8	3.4%	0	0.0%	8	4.2%	0.357
	(-)	225	96.6%	43	100.0%	182	95.8%	

tumor-specific mesorectal excision, with a distal resection margin of > 10 cm (Sigmoid colon), > 3 cm (upper to middle rectum) or > 2 cm (lower rectum). The rectum was subsequently irrigated with sodium to clear any tumor cells and transected with a linear stapler. Anastomosis of the descending or sigmoid colon with the stump of the rectum was performed using the DST technique with a circular stapler. After anastomosis, an air leak test was performed. The anastomotic site was repaired by suturing according to the surgeon's choice. An intra-abdominal drain was placed posterior to the anastomosis through a port hole in the right lower abdomen and was scheduled for removal a few days postoperatively. In the CLOSED group, a 10 mm pleats drain tube® (Sumitomo Bakelite, Tokyo) was inserted through the anus, and the tip of the TAT was placed approximately 5 cm from the oral side of the anastomosis. The TAT was fixed to the buttocks and connected to the drainage bag as a passive gravity drain. In the OPEN group, a 24-Fr 170 mm MIT drain® (Create Medic, Kanagawa, Japan) was inserted through the anus, and the tip of the TAT was placed approximately 5 cm from the oral side of the anastomosis. The TAT was fixed to both sides of the buttocks with the wing plate of the tube, and the tube near the wing plate was cut. In both groups, the TAT was scheduled for removal a few days postoperatively.

Definition of postoperative complications including anastomotic leakage

Postoperative complications were diagnosed by the surgeons and categorized according to the Clavien-Dindo classification system. Anastomotic leakage was defined as a communication between the intra- and extraluminal compartments owing to a defect of the integrity of the intestinal wall at the anastomosis between the colon and rectum or the colon and anus, within 30 days of the rectal resection [19]. With symptoms, such as abdominal pain, abdominal distension, fever, increased inflammatory reaction and emission of feces from the abdominal drains, computed tomography (CT) should be performed. If anastomotic leakage is suspected on CT scan, anastomotic leakage was diagnosed by simple contrast enema radiography with a water-soluble contrast agent, or repeat surgery to confirm the leakage.

Statistical analysis

Data are expressed as the mean ± standard error, and significant differences were analyzed using the unpaired Student's t-test. Comparative analyses of the clinicopathologic features between the two groups were performed using the chi-squared test or Fisher's exact test. PSM was performed to minimize bias in the baseline information. The matched baseline information included age, sex, BMI, diabetes mellitus (DM), smoking history, modified Glasgow prognostic score (mGPS), ASA-PS, location of distal tumor edge, operative procedure, surgical approach, operative time, intraoperative blood loss, and pathological stage. Patients were matched 1:1 by means of the neighbor-matching method, using a caliper width with a standard deviation of 0.2. Univariate analyses were performed using the chi-square test for categorical variables and the Mann–Whitney U test for continuous variables. Univariate and multivariate analyses using a Cox proportional hazards model were performed to calculate hazard ratios (HRs) and 95% confidence intervals, and to identify the risk factors for anastomotic leakage. JMP 13 software (SAS Institute Japan, Tokyo, Japan) was used for all the analyses.

Results

Patient characteristics

A total of 233 patients who underwent curative resection for sigmoid colon or rectal cancer were included in this study. The average age of patients was 68.4 (10.5) years. The average BMI of the patients was 23.0 (3.6) kg/m2. 44 (18.9%) patients developed diabetes mellitus and 82 (35.2%) patients have smoking history. ASA-PS was 1 in nine (3.9%), 2 in 175 (75.1%), and 3 in 49 (6.0%) patients. The mGPS was 0 in 181 (77.7%), 1 in 33 (14.2%), and 2 in 17 (7.3%) patients. Distal tumor edge was located on sigmoid colon in 104 (44.6%), upper rectum in 66 (28.3%), middle rectum in 49 (21.0%) and lower rectum in 14 (6.0%) patients. A sigmoidectomy was performed in 94 (40.3%) patients; rectal high anterior resection was performed in 56 (24.0%) patients; and a rectal low anterior resection was performed in 83 (35.6%) patients. Laparoscopic surgery was performed in 188 (80.7%) patients, and robot-assisted surgery was performed in 45 (19.3%) patients. The average operative time and blood loss were 238 min (79.6 min) and 37.4 mL (77.3 mL), respectively. Incision anastomotic leakage occurred in 23 (9.9%) patients, and eight (3.4%) patients required reoperation.

Relationship between TAT and clinicopathological characteristics and operative outcome before PSM

The relationships between the TAT and clinicopathological factors are examined in Table 1. Overall, 190 patients had closed TATs, and 43 patients had open TATs. There were no significant differences in sex, age, BMI, DM, smoking history, preoperative modified GPS, ASA-PS, operative procedure, blood loss, and pathological T and N factor and stage ($p = 0.093$–0.862). The OPEN group had more cases with lower tumor localization ($p < 0.001$). In the OPEN group, laparoscopic surgery was performed for 22 (51.2%) patients, and robot-assisted surgery was performed in 21 (48.8%) patients. The CLOSED group contained 166 (87.4%) patients on whom laparoscopic surgery was performed; and 24 (12.6%) patients who underwent robot-assisted surgery ($p < 0.001$). The average operative time was significantly longer in the OPEN group ($p = 0.012$). Regarding postoperative complications, the rates of complications and anastomotic leakage were significantly lower in the OPEN group ($p = 0.030$

and 0.048, respectively). No cases required reoperation due to anastomotic leakage in the OPEN group.

PSM between the OPEN and CLOSED groups

PSM was performed between the OPEN and CLOSED groups based on the following 13 factors: age, sex, BMI, DM, smoking history, mGPS, ASA-PS, location of distal tumor edge, operative procedure, surgical approach, operative time, intraoperative blood loss, and pathological stage. The relationship between the type of TAT and clinicopathological factors in the matched cases is presented in Table 2. There were no significant differences between the OPEN and CLOSED groups in terms of sex, age, BMI, DM, smoking history, mGPS, ASA-PS, location of distal tumor edge, operative procedure, surgical approach, operative time, intraoperative blood loss, and pathological T and N factor and stage ($p = 0.418–0.949$). The rate of anastomotic leakage was significantly lower in the OPEN group ($p = 0.027$).

Efficacy of open TAT against anastomotic leakage

Univariate and multivariate analyses of the relationship between anastomotic leakage and clinicopathological factors are shown in Table 3. No significant differences were observed in age, sex, DM, mGPS, ASA-PS, operative procedure, surgical approach, operative time, intraoperative blood loss, and pathological stage. BMI, smoking history and the type of TAT were correlated with anastomotic leakage rate ($p = 0.042$, 0.032 and 0.05, respectively). Location of distal tumor edge was relatively correlated with anastomotic leakage rate ($p = 0.055$). The multivariate analysis of significant factors identified a BMI of 25 or more, a location of distal edge on middle to lower rectum, and a closed TAT, as independent risk factors for anastomotic leakage (HR: 8.72; $p = 0.038$, HR: 10.06; $p = 0.034$ and HR: 17.43; $p = 0.033$).

Discussion

In this study, the efficacy of an open TAT compared with a closed TAT was evaluated against anastomotic leakage in colorectal cancer surgery. This was based on an analysis of the efficacy of an open TAT without PSM, where the rate of anastomotic leakage was significantly lower than that of a closed TAT. After PSM, multivariate analyses revealed that among those with a BMI ≥ 25, low anterior resection was an independent risk factor for anastomotic leakage in a closed TAT.

Due to the historical background of a growing number of robot-assisted surgeries, the rate of robot-assisted surgery was significantly higher in the OPEN group in terms of surgical approach. The operative time has been reported to be potentially longer for robot-assisted surgery than for laparoscopic surgery [20, 21]. Therefore, operative times in the OPEN group were hypothesized to be significantly longer than that in the CLOSED group, because of the higher proportion of robot-assisted surgeries. PSM was performed to homogenize these differences. After PSM, there were no significant differences between the two groups in terms of operative time, surgical procedure, and patient background.

The multivariate analysis of significant factors identified not only a closed TAT but also a BMI of 25 or more and a location of distal edge on middle to lower rectum as independent risk factors for anastomotic leakage. Obesity is known to be a risk factor for the development of postoperative complications in abdominal surgery [22, 23]. In accordance with this, obesity was found to be an independent risk factor for anastomotic leakage in this study [6, 24, 25]. Several hypotheses have been suggested to explain the association between obesity and anastomotic leakage. Obesity may induce a healing defect; increased abdominal pressure may impair anastomosis and microcirculation; and lead to increased mesocolon thickness. However, there is no fixed opinion [25]. The height of the anastomosis above the anal verge has also been reported to be a predictor of anastomotic leakage [6, 7, 24, 26, 27]. Lower anastomosis corresponds to more difficult operations and higher risks of leakage [7]. With regard to all these factors, the results of this study were consistent with those of previous reports.

Several studies have recently addressed the efficacy of TAT for the prevention of anastomotic leakage after DST anastomosis in colorectal cancer [6–8]. In contrast, to our knowledge, no clinical studies have investigated the differences between open and closed TATs for anastomotic leakage. Xiao et al. reported anastomotic leakage in 4% of patients randomized to receive a TAT in their prospective study, whereas in our study the anastomotic leakage was exhibited in 2.3% of OPEN TAT group, showing good outcome [7]. Closed drain is less likely to be associated with retrograde infection, but open drain has a longer duration of drainage effect and more drainage [10–15]. Among closed drains, particularly passive gravity drains, obstruction may be a problem due to viscous stools. Moreover, if a TAT is placed as a closed drain, patients have to manage two drainage tubes, the TAT tube and an intra-abdominal drain tube. Thus, the management of drains becomes complicated and may easily cause drain flexion. The disadvantage of an open TAT is that the majority of feces is collected in a nappy, which can lead to a foul smell, discomfort, and perianal dermatitis. However, even with a closed TAT, side leakage occurs, and a certain amount of feces must be collected in a nappy. Furthermore, since the TAT is inserted into the intestinal tract, there is no need to care about retrograde infection.

Table 2 The relationship between the type of transanal drainage tube and clinicopathological factors after propensity score matching

		OPEN group		CLOSED group		*P*-value
		n **= 32**	**%**	***n*** **= 32**	**%**	
Sex	female	16	50.0%	14	43.8%	0.616
	male	16	50.0%	18	56.3%	
Average age (SD)		67.0(11.2)		67.3(10.3)		0.803
Average BMI (SD)		22.4(4.1)	kg/m^2	22.4(3.6)	kg/m^2	0.756
DM	+	7	21.9%	6	18.8%	0.756
	-	25	78.1%	26	81.3%	
Brinkman index	≥ 400	8	25.0%	10	31.3%	0.578
	< 400	24	75.0%	22	68.8%	
mGPS	0	24	75.0%	23	71.9%	0.754
	1	4	12.5%	6	18.8%	
	2	4	12.5%	3	9.4%	
ASA-PS	1	1	3.1%	0	0.0%	0.600
	2	24	75.0%	25	78.1%	
	3	7	21.9%	7	21.9%	
Distal tumor edge	Sigmoid colon	10	31.3%	11	34.4%	0.949
	upper rectum	12	37.5%	11	34.4%	
	millde rectum	7	21.9%	8	25.0%	
	lower rectum	3	9.4%	2	6.3%	
Operative procedure	S	11	34.4%	13	40.6%	0.852
	HAR	7	21.9%	7	21.9%	
	LAR	14	43.8%	12	37.5%	
Surgical approach	Lap	20	62.5%	18	56.3%	0.611
	Ro	12	37.5%	14	43.8%	
Average operative time (SD)		256(77.8)	min	261(105.8)	min	0.418
Average blood loss (SD)		49.6(110.3)	ml	41.1(93.0)	ml	0.771
T	is, 1, 2	14	43.8%	15	46.9%	0.802
	3. 4	18	56.3%	17	53.1%	
N	(+)	13	40.6%	10	31.3%	0.435
	(-)	19	59.4%	22	68.8%	
Stage	0/1	10	31.3%	12	37.5%	0.731
	2	9	28.1%	10	31.3%	
	3	13	40.6%	10	31.3%	
Postoperative complication						
All complications	(+)	6	18.8%	11	34.4%	0.157
	(-)	26	81.3%	21	65.6%	
All complications over C-DIIIA	(+)	1	3.1%	8	25.0%	0.013
	(-)	31	96.9%	24	75.0%	
Anastomotic leakage	(+)	1	3.1%	7	21.9%	0.027
	(-)	31	96.9%	25	78.1%	
Reoperation due to anastomotic leakage	(+)	0	0.0%	1	3.1%	1.00
	(-)	32	100.0%	31	96.9%	

In the CLOSED group, a 10mm pleats drain tube was inserted as TAT, in the OPEN group, a 24-Fr 170mm MIT drain® was inserted as TAT. The rate of anastomotic leakage decreased in OPEN group despite the insertion of a TAT with a smaller diameter than in CLOSED group. This result confirms the higher decompression effect of the OPEN drain. Even if anastomotic leakage occurs, TATs have been reported to reduce reoperation rates [7, 9]. In this study, although there was no significant difference between the

Table 3 Univariate and multivariate analyses for detecting risk factors of anastomotic leakage

		Univariate analysis					Multivariate analysis		
		Anastomotic leakage +		Anastomotic leakage -		*P* value	Hazard	95% CI	*P* value
Variables		*n* = 7	14.1%	*n* = 56	92.2%				
Age	≥ 75	1	6.3%	15	93.8%	0.397			
	< 75	7	14.6%	41	85.4%				
Sex	male	3	10.0%	27	90.0%	0.572			
	female	5	14.7%	29	85.3%				
BMI	≥ 25	5	26.3%	14	73.7%	0.042	8.72	1.13–67.30	0.038
	< 25	3	6.7%	42	93.3%				
DM	+	2	15.4%	11	84.6%	0.725			
	-	6	11.8%	45	88.2%				
Brinkman index	≥ 400	5	27.8%	13	72.2%	0.032	7.32	0.95–56.60	0.057
	< 400	3	6.5%	43	93.5%				
mGPS	≥ 1	2	11.8%	15	88.2%	0.915			
	0	6	12.8%	41	87.2%				
ASA-PS	≥ 3	1	20.0%	4	80.0%	0.602			
	≤ 2	7	11.9%	52	88.1%				
Distal tumor edge	Middle/lower rectum	5	25.0%	15	75.0%	0.055	10.06	1.19–84.89	0.034
	Sigmoid colon/upper rectum	3	6.8%	41	93.2%				
Operative procedure	LAR	5	19.2%	21	80.8%	0.191			
	S/HAR	3	7.9%	35	92.1%				
Surgical approach	Ro	3	11.5%	23	88.5%	0.848			
	Lap	5	13.2%	33	86.8%				
TAT	close	7	21.9%	25	78.1%	0.050	17.43	1.26–240.28	0.033
	open	1	3.1%	31	96.9%				
Operative time min	≥ 240 min	2	14.3%	12	85.7%	0.624			
	< 240 min	3	21.4%	11	78.6%				
Blood loss ml	≥ 30 ml	3	27.3%	8	72.7%	0.120			
	< 30 ml	5	9.4%	48	90.6%				
Stage	III	3	13.0%	20	87.0%	0.922			
	I II	5	12.2%	36	87.8%				

CLOSED and OPEN groups, no cases required reoperation due to anastomotic leakage in the OPEN group. This suggests that TATs, especially open TATs, may be useful, not only in preventing anastomotic leakage, but also in reducing reoperation rates, as previously reported.

This work has some limitations. This study was retrospective in nature with a small sample size and long accrual period and was conducted in a single department. Although PSM was used to limit the selection bias, there may have been some residual confounding factors. Only patients of Japanese origin were enrolled in this study. Prospective multi-center studies including diverse ethnic populations are necessary for additional validation.

Conclusion

To our knowledge, this is the first study to examine the relationship between anastomotic leakage and the type of TAT used in left-sided colorectal cancer surgery. The PSM study revealed that open TATs may be effective in preventing anastomotic leakage in left-sided colorectal cancer surgery, compared with closed TATs. Therefore, open TATs need to be adopted in colorectal cancer surgery.

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Authors' contributions
GT and TF designed and performed the experiments and co-wrote the manuscript. GT and TF contributed equally. KM suggested and co-designed the study. All authors read and approved the final manuscript.

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Data availability
The data supporting the study's findings are not publicly available because they contain potentially sensitive information. However, the data can be obtained from the corresponding author or the Ethics Committee (gr-a-knky-ethics@omu.ac.jp) on reasonable request.

Declarations

Ethics approval and concept to participate
The protocol for this research project has been approved by the Ethical Committee of Osaka Metropolitan University Graduate School of Medicine (Approval Number: 4182). Patients provided written informed consent, and ethical approval was obtained from the institutional review boards of Osaka Metropolitan University (reference no. 4182). This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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