REPORT

Safety of the stent-based diverting technique after low anterior resection in patients with rectal cancer

Yifan Tong,[1,8] Mingyu Chen,[1,8] Zhangfa Song,[2,*] Wenbin Chen,[3] Weiping Chen,[4] Xuefeng Huang,[2] Sheng Dai,[2] Da Wang,[2] Weifeng Lao,[2] Danyang Wang,[3] Tao Xiang,[3] Qiken Li,[4] Gang Wang,[4] Pengyang Zhou,[4] Bingjun Bai,[2] Zhongyu Wu,[5] Hui Liu,[6] Lingfei Li,[7] and Xiujun Cai[1,*]

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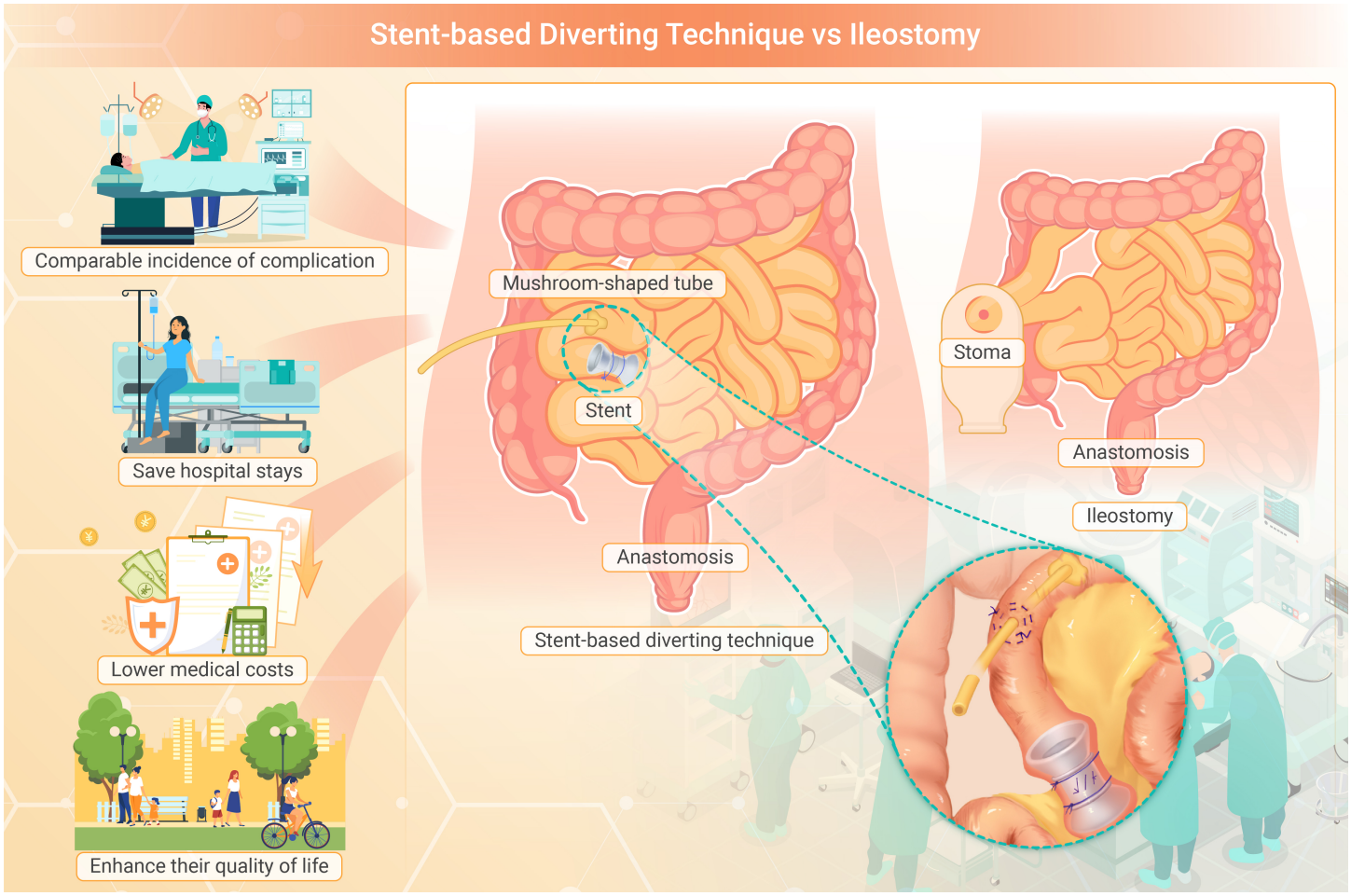
GRAPHICAL ABSTRACT



PUBLIC SUMMARY

- Stent-based diverting technique did not raise the incidence of complication.
- Stent-based diverting technique reduced postoperative hospital stays.
- Stent-based diverting technique lowered medical costs.
- Stent-based diverting technique improved quality-of-life.

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Safety of the stent-based diverting technique after low anterior resection in patients with rectal cancer

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Given that anastomotic leakage (AL) is a severe complication of low anterior resection (LAR) for rectal cancer, ileostomy is the most common method for reducing the severity of AL, which in turn has stoma-related side effects. A self-developed technique named the stent-based diverting technique (SDT) not only protects the anastomosis but also avoids the stoma. From December 2021 to March 2023, 80 patients were randomized into the ileostomy arm (n = 43) or the SDT arm (n = 37). Demographic characteristics, laboratory test results, surgical outcomes, and oncological features were compared between the groups. For the primary endpoint, the incidence of severe complications was 14.0% in the ileostomy arm and 8.1% in the SDT arm (relative risk=0.58, 95% confidence interval=0.156-2.163, p=0.494). For the second endpoint, the incidences of mild and total complications were comparable. The shorter the hospital stay, the lower the cost and quality of life, which could be improved by the SDT procedure. This prospective randomized clinical trial preliminarily evaluated the usefulness of SDT after LAR for patients with rectal cancer, suggesting that SDT might be an alternative operation for patients who need to receive ileostomy after rectal surgery.

INTRODUCTION

Low anterior resection (LAR) is regarded as the primary surgical management option for potentially curable low rectal cancer, where the restoration of bowel continuity is planned and anastomosis is safely feasible.[1,2] Nevertheless, colorectal anastomotic leakage (AL) after LAR in patients with rectal cancer remains common worldwide.[3] Accumulating evidence suggests that clinical AL following LAR invariably leads to greater mortality, more frequent surgeries, longer hospital stays, and a worse partial quality of life.[4]

In this context, a number of technologies have been developed to reduce the frequency of AL and the severity of consequences linked to AL.[5] Among these, ileostomy has proven to be a successful strategy for lowering the incidence of AL in patients with rectal cancer. Compared with no diversion after LAR, the findings of prior research suggest that ileostomy could successfully lower the clinical AL associated with rectal cancer.[6] However, ileostomy also increases stoma-associated morbidity and the risk of stoma-associated complications (e.g., stenosis, retraction, ischemia, reoperation, and failure to reverse ileostomy), longer hospital stays, and higher hospitalization costs.[3] Therefore, there has been a long interest in efficiently reducing the rate of AL without defunctioning stoma in the field of colorectal surgery.

To accomplish fecal diversion, a stent-based diverting technique (SDT) has been developed instead of ileostomy.[7] The SDT comprises two parts. One is a solid occluding intestinal stent (Sunstone, Co., Ltd., Hangzhou, China) synthesized from 1,3-propanediol, 1,2-propanediol, and sebacic acid, which is inserted 15-20 cm from the terminal ileum and degrades gradually to CO_2 and H_2O over three to four weeks.[7] The mushroom-shaped tube (from MKL, Co., Ltd., Suzhou, China) is another component that is positioned 5-10 cm in front of the previously mentioned occluding stent. With this SDT, the mushroom-shaped tube could be used to redirect intestinal contents, and the stent prevents feces from entering the colon. After stent degradation, the intestinal contents are able to freely access the colon when the mushroom-shaped tube is removed after three to four weeks. In these patients, stoma reversal was avoided.

In our previous study, the incidence of AL in the SDT group was 1 of 34 (2.9%), which was comparable to the documented incidence of AL in the ileostomy group.[7] However, there was no control group because this was a one-arm study with a limited sample size. Additionally, ileostomy, such as neoadjuvant radiotherapy, severe diabetes, severe malnutrition, obesity (body mass index greater than 30 kg/m^2), and middle-low rectal cancer, is only advised for individuals who are at high risk of AL.

This study aimed to preliminarily assess the safety of SDT following LAR in patients with rectal cancer, given the additional safety requirements of SDT resulting from the fact that intestinal obstruction linked to stents is a complication of concern. Patients with middle-low rectal cancer were included in this study to minimize the number of confounders. The primary objective of this study was to evaluate the incidence of severe complications associated with the use of SDT or ileostomy following LAR. Generally, the SDT could offer a novel therapeutic approach for patients who plan to receive ileostomy.

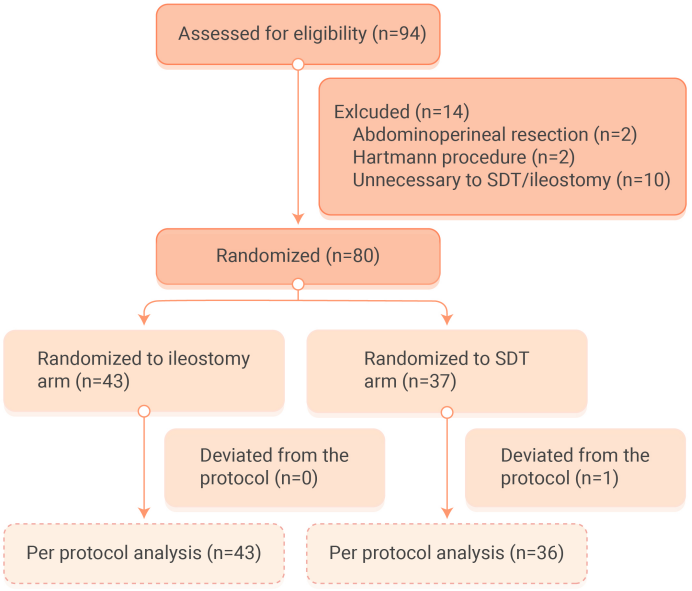

Figure 1. The flowchart of study SDT, stent-based diverting technique.

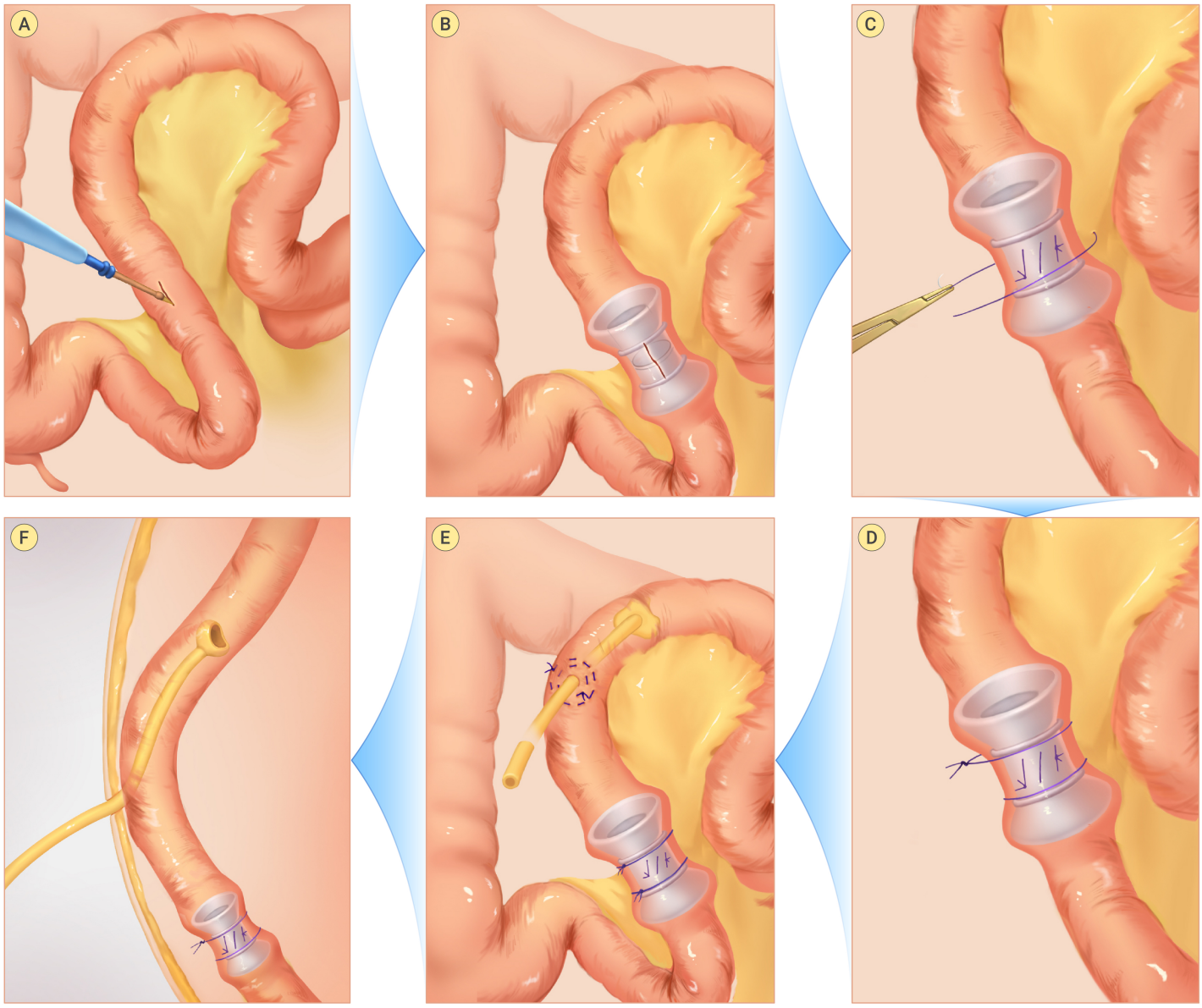

Figure 2. Schematic diagram of stent-based diverting technique (A) The ileocecal junction was pulled out through the median incision. (B) The degradable stent was implanted, and the intestine was sutured. (C) and (D) The stent was held in place using an external tie around the bowel, and picture of stent. (E) A mushroom-shaped tube (28 Fr) was placed into the intestine proximal to the aforementioned stent. (F) This part of the intestine was fixed on the abdominal wall with an absorbable line. The other side of the mushroom-shaped tube was inserted through the right lower abdominal wall, and picture of mushroom-shaped tube (28 Fr) .

MATERIALS AND METHODS

Ethics

Three hospitals in China participated in this randomized, multicenter, open-label trial from December 2021 to March 2023 in accordance with the Declaration of Helsinki. This study not only was approved by the ethics committee of the Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University (No. KY20210105-12) but also followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines. In addition, local institutional review board approval was obtained from each participating hospital, and written informed consent was obtained from all participants. The trial was registered with the Chinese Clinical Trial Registry (ChiCTR2100049953).

Study Design

Patients with rectal cancer who underwent surgery were considered eligible. All preoperative procedures complied with the guidelines for the diagnosis and treatment of colorectal cancer.[8] TNM stage was determined according to the American Joint Committee on Cancer (8th version). A multidisciplinary treatment strategy involving a colorectal surgeon, radiologist, oncologist, pathologist, nutritionist and anesthetist will be recommended for complicated cases. Details of the inclusion and exclusion criteria are given in Supplement File 1. In terms of the diagnosis and treatment of rectal cancer, as well as the technique of total mesorectal excision, all operative procedures were in compliance with the guidelines. Perioperative management, including nutritional screening, nutritional support, preoperative bowel preparation and preservation of the left colonic artery, was determined by the surgeon according to their own experiences and patients' conditions. Radiological AL assessments were also performed according to the surgeons' experiences.[9] All procedures were performed by experienced surgeons who met the qualifications of the participating surgeons.

Intervention

After low anterior resection, patients were randomly assigned to two groups (SDT and ileostomy groups). Simple randomization was obtained through computer-generated random number sequence allocation.

For the study group, SDT will be performed (Figure 2). In brief, the small intestine 20 cm from the ileocecal junction was removed through a median

Table 1. Demographic and pathological characteristics of the patients

Characteristics	Ileostomy Group (n=43)	SDT group (n=37)	P value
Age, years	57.0 (53.0, 66.0)	65.0 (60.0, 71.0)	**0.003**
Gender			0.260
Male	18 (41.9)	11 (29.7)	
Female	25 (58.1)	26 (70.3)	
BMI, kg/m^2	23.6 (21.6, 25.2)	24.2 (21.5, 27.2)	0.241
Concomitant disease			
Hypertension	30 (69.8)	22 (59.5)	0.335
Diabetes	33 (76.7)	28 (75.7)	0.911
Others	6 (14.0)	7 (18.9)	0.548
ASA grade			0.194
I	14 (32.6)	8 (21.6)	
II	29 (67.4)	27 (73.0)	
III	0 (0.0)	2 (5.4)	
Hemoglobin, g/L	138.0 (130.0, 144.0)	141.0 (132.0, 148.0)	0.341
Platelet, 10^9/L	226.0 (192.5, 253.5)	216.0 (191.0, 251.0)	0.521
INR	0.96 (0.92, 1.00)	0.98 (0.92, 1.00)	0.502
ALT, IU/L	18.0 (12.0, 25.0)	18.0 (14.0, 24.0)	0.787
AST, IU/L	22.0 (17.5, 27.5)	20.0 (17.0, 26.0)	0.364
Albumin, g/L	43.7 (40.7, 46.2)	43.9 (40.3, 46.1)	0.858
Total bilirubin, umol/L	10.3 (7.4, 13.2)	11.0 (8.6, 15.0)	0.226
Creatine, umol/L	62.2 (56.5, 78.5)	73.0 (55.0, 85.0)	0.463
CEA, ng/mL	3.6 (1.5, 8.8)	4.0 (2.2, 9.7)	0.569
CA199, IU/mL	11.9 (4.1, 18.5)	9.7 (5.0, 16.9)	0.923
Tumor size, cm	3.2 (2.3, 4.9)	4.0 (2.8, 4.7)	0.582
Neoadjuvant therapy			0.067
Absent	33 (76.7)	34 (91.9)	
Present	10 (23.3)	3 (8.1)	
Differentiation			0.305
High	3 (7.0)	3 (8.1)	
Middle	12 (27.9)	5 (13.5)	
Low	25 (58.1)	28 (75.7)	
Unreported	3 (7.0)	1 (2.7)	
Pathology			0.414
Adenocarcinoma	41 (95.3)	37 (100.0)	
Mucinous adenocarcinom	1 (2.3)	0 (0.0)	
Neuroendocrine tumor	1 (2.3)	0 (0.0)	
T stage			0.296
Tis	1 (2.3)	0 (0.0)	
1	4 (9.3)	9 (24.3)	
2	7 (16.3)	4 (10.8)	
3	25 (58.1)	17 (45.9)	
4	6 (14.0)	7 (18.9)	
N stage			0.893
0	22 (51.2)	17 (45.9)	
1	15 (34.9)	14 (37.8)	
2	6 (14.0)	6 (16.2)	
M stage			NA
0	43 (100.0)	37 (100.0)	
1	0 (0)	0 (0)	
TNM stage			0.785
0	1 (2.3)	0 (0)	
I	9 (20.9)	8 (21.6)	
II	12 (27.9)	9 (24.3)	
III	21 (48.8)	20 (54.1)	
IV	0 (0)	0 (0)	

Date were presented as median with interquartile range or number with percentage.

SDT, stent-based diverting technique; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ASA, American society of anesthesiologists; INR, international normalized ratio; ALT, alanine transaminase; AST, aspartate aminotransferase; CEA, carcinoembryonic antigen; CA 19-9, carbohydrate antigen 19-9; NA, not applicable.

TNM stage was according to the American Joint Committee on Cancer (8th version).

Bold P value indicated the significant difference.

incision in the lower abdomen. After a lengthwise incision was established in the mesenteric margin of the small intestine, the degradable stent was implanted, and the intestine was sutured. The stent was then held in place using an external tie around the bowel. Next, a mushroom-shaped tube (28 Fr) was placed into the intestine proximal (5-10 cm) to the aforementioned stent. After this incision of the intestine was closed, this part of the intestine was fixed on the abdominal wall with an absorbable line. The other side of the mushroom-shaped tube was inserted through the right lower abdominal wall and connected to a drainage bag. Before the abdominal cavity and incision were closed, an abdominal drainage tube or anal tube, if necessary, was placed at the appropriate site. Abdominal X-ray was routinely performed every week to detect stent degradation, and the mushroom-shaped tube (28 Fr) was removed two days after stent degradation.

For the control group, an ileostomy will be performed. An incision with a diameter of 2 cm was made in the right lower abdomen, and the layers were separated into the abdominal cavity. The intestine, 20 cm from the ileocecal junction under laparoscopic vision, was removed. The anterior sheath of the rectus abdominis and serous layer of the intestine was sutured with an absorbable line. The middle point of the mesangial margin of the intestine was then transected, and the intestine was fixed on the skin. No volvulus or angular formation of the intestine should be confirmed laparoscopically. For both groups, the abdominal drainage tube was placed in the appropriate place.

Endpoints

The primary endpoint was the incidence of severe complications within 90

Table 2. Surgical outcomes of the patients

Outcomes	Ileostomy Group (n=43)	SDT group (n=37)	P value
Blood loss, mL	50.0 (30.0, 50.0)	50.0 (35.0, 50.0)	0.603
Operation time, mins	185.0 (148.5, 218.5)	205.0 (161.0, 257.0)	0.124
Anastomosis to anus, cm	3.0 (2.0, 4.0)	3.0 (3.0, 5.0)	0.497
Surgical type			0.555
Laparoscopic LAR	30 (69.8)	28 (75.7)	
Robotic LAR	13 (30.2)	9 (24.3)	
Patients with complications	17 (39.5)	7 (18.9)	**0.045**
Patients with mild complications	11 (25.6)	6 (16.2)	0.307
Patients with severe complications	6 (14.0)	3 (8.1)	0.494[a]
Number and grade of complications	19	10	
I	8	5	
II	5	1	
III	6	3	
IV	0	1	
V	0	0	
Converse to ileostomy	NA	2 (5.4)	
Stoma ending			
Reversal on time	36 (83.7)	2 (100)	
Delayed reversal	6 (14.0)	NA	
Permanent stoma	1 (2.3)	NA	
PHS (stage I), days	7.0 (6.0, 9.0)	8.0 (7.0, 10.0)	0.151
PHS (stage II), days	6.0 (5.0, 7.0)	0 (0,0)	0.153
Total PHS, days	14.0 (12.0, 16.5)	8.0 (7.0, 10.0)	**<0.001**
Cost (stage I), Ten thousand Yuan	5.6 (4.9, 7.9)	5.9 (5.6, 8.4)	**0.037**
Cost (stage II), Ten thousand Yuan	3.0 (2.6, 3.5)	0 (0,0)	0.077
Total Cost, Ten thousand Yuan	8.7 (7.9, 9.9)	5.9 (5.6, 8.6)	**<0.001**

Date were presented as median with interquartile range or number with/without percentage.

SDT, stent-based diverting technique; LAR, low anterior resection; PHS, Postoperative hospital stay; NA, not applicable.

Mild complications, Clavien-Dindo ≤ II; Severe complications, Clavien-Dindo ≥ III. Two patients of ileostomy group presented two mild complications, while two patients of SDT group presented one mild and one severe complications, and one patient of SDT group presented two severe complications. The stage II represented the reversal of the ileostomy or any causes leading to the unplanned operations.

The "a" represented the Fisher' exact test.

Bold P value indicated the significant difference.

days (Clavien-Dindo score ≥III). The secondary endpoints were total complications, Clavien-Dindo grade, clinical coloanal anastomotic leakage, cost, postoperative hospital stay, quality of life 90 days after the first operation and changes in the gut microbiota before and after the operation.[10] Mild complications were defined as Clavien–Dindo ≤ II, while severe complications were defined as Clavien–Dindo ≥ III. For the quality-of-life assessment, the score ranged from 1 to 5 or 6 for each item. Primary score = highest score - actual score + 1; Standard score = (primary score − lowest score) × (highest score − lowest score). The higher the score is, the healthier the receiver is.

In terms of the time frame, 90 days was defined as the follow-up period for the patients in the SDT group. If the patient converted to ileostomy, the follow-up period was extended to 90 days after the second surgery (reversal of the stoma). For the ileostomy group, the follow-up period was defined as from the time of ileostomy to 90 days after stoma reversal. If the patient did not undergo stoma reversal, the follow-up period was defined as 90 days after ileostomy.

Statistical analysis

Based on information from multiple published articles showing that the incidence of major complications ranged from 15% to 20% in LAR patients who underwent ileostomy,[6,11,12] we assumed that the incidence of major complications in the ileostomy arm was 20%. Our previous study indicated that the incidence of major complications in patients who underwent SDT was 2.9%. With 0.7 power and a 0.05 significance level, each arm needed to recruit 40 patients overall.

The analysis of the primary endpoint will be conducted by comparing 95% confidence intervals. Baseline data and surgical outcomes will be obtained on an intent-to-treat (ITT) basis, and per-protocol analyses will be performed. Continuous variables will be presented as medians and interquartile ranges and compared using the Wilcoxon rank-sum test, while categorical data will

be presented as numbers and percentages and compared using the Pearson $\chi 2$ test or Fisher exact test, as appropriate.

Post hoc analysis was adopted to show the interactions between surgical type (ileostomy or SDT) and clinical parameters. For the primary endpoint (the incidence of major complications), stratified analysis was conducted using the Cochran–Mantel–Haenszel (CMH) test. For the secondary outcomes (hospital stay, cost, and quality of life assessment), the interaction effect was assessed using linear regression. A two-sided $P < 0.05$ indicated statistical significance. All data analyses will be performed using the SPSS statistical package (version 22.0, IBM).

RESULTS

In total, 94 consecutive patients were initially enrolled in this study, and 14 patients were excluded for various reasons (Figure 1). Finally, 80 patients were randomized into either the ileostomy group (n = 43) or the SDT group (n = 37). Postoperative pathology revealed that only one patient in the SDT group withdrew from the allocated intervention because of multiple tumors. According to the ITT analysis, the demographic and tumor features were comparable (Table 1).

The surgical endpoints are summarized in Table 2. For the primary endpoints, the incidences of severe complications were 6 (14.0%) in the ileostomy group and 3 (8.1%) in the SDT group [relative risk (95% confidence interval)=1.84 (0.43-7.93), p=0.494]. For the secondary endpoints, the incidences of mild and total complications were 11 (25.6%) and 17 (39.5%) in the ileostomy group and 6 (16.2%) and 7 (18.9%) in the SDT group (p=0.307 and p=0.045), respectively. In detail, ten severe complication events generally occurred. A total of 6 severe events (abdominal infection = 1, AL = 1, ileus = 1, bowel necrosis at the stoma = 1, and rectal anastomotic stricture = 2) occurred in the ileostomy group, while 4 events (pulmonary embolism = 1, AL = 1, incision infection = 1, and pleural effusion = 1) occurred in the SDT group (Table 3). Two patients in the ileostomy group presented two mild complications, two patients in the SDT group presented one mild complication and one severe complication, and one patient in the SDT group presented two severe complications. Generally, the clinical AL included 1 patient with grade B and 1 patient with grade C. The AL rates were 2.3% (n=1, grade B) in the ileostomy group and 2.7% (n = 1, grade C) in the SDT group, and no significant difference was detected between the groups (p = 0.620). The patient with AL (grade C) in the SDT received ileostomy as the salvage measure and recovered well. Another patient with chronic hepatic fibrosis experienced an unhealed incision and infection, and salvageable ileostomy was performed to prevent AL.

Additionally, 36 of 43 (83.7%) patients in the ileostomy group completed the stage II procedure (reversal of stoma) as planned. Six (14.0%) patients had to delay the stage II procedure for various reasons, and 1 (2.3%) patient received a permanent stoma due to tumor recurrence. With regard to the SDT group, 5 (13.5%) patients presented with incomplete intestinal obstruction, which improved after conservative treatment. No intestinal leakage, stent displacement or nondegradation occurred in this study. Other surgical parameters, namely, estimated blood loss, operation time, surgical type, and anastomosis position, were similar between the two groups.

The postoperative hospital stay (PHS) of the patients in the SDT group was 8.0 (7.0-10.0) days, and two patients who underwent conversion to ileostomy had a second hospital stay. The PHSs in the ileostomy group were 7.0 (6.0-9.0) and 6.0 (5.0-7.0) days in stage I (ileostomy, n=43) and stage II (reversal of stoma, n=36) patients, respectively. The total PHS was 14.0 (12.0-16.5) days, which was significantly longer than the 8.0 (7.0-10.0) days in the SDT group (p<0.001). However, the cost in stage I in the ileostomy group was 5.6 (4.9-7.9, ten thousand yuan), which was lower than 5.9 (5.6-8.4, ten thousand yuan) in the SDT group (p=0.037), while the total cost in the ileostomy group was 8.7 (7.9-9.9, ten thousand yuan), which was markedly higher than (7.6-8.6, ten thousand yuan) in the SDT group (p<0.001). Notably, as a novel surgical technique, the clinical management of SDT requires some experience. In early clinical practice, the first two patients recovered smoothly during the procedure. However, they were concerned about the safety of SDT and did not discontinue it until the mushroom-shaped tube was removed, which partially led to an increase in PHS and cost in the SDT arm.

The partial quality-of-life assessment form (Chinese version of the SF-8 questionnaire), consisting of eight parts, namely general health (GH), physical function (PF), role-physical (RP), body pain (BP), vitality (VT), social functioning (SF), mental health (MH), and role-emotional (RE), was adopted 90 days after the first operation to comprehensively assess the mental health status of patients in both arms. For each item, the higher the standard score is, the better the mental health is. The standard scores of the two arms are shown in Table 4. Through SDT, PF, RP, VT, SF, MH, and RE, but not GH or BP, could improve. Stated differently, patients felt better on the inside after undergoing SDT rather than ileostomy, could engage in more social activities, and ultimately enjoyed a higher partial quality of life, as they no longer needed stoma reversal in most cases. Although quality of life was a complicated and individualized outcome, at least a portion of it was improved in this study.

The results of the per-protocol analysis were very similar to those of the ITT analysis (Tables 4 & S1-S3).

The post hoc analyses revealed that, with confounding factor stratification (e.g., age, sex, and BMI), the incidence of significant complications was also comparable between the ileostomy and SDT arms (Figure S1). These results indicated that SDT did not increase complications. The interaction effects for the secondary outcomes (hospital stay, cost, and quality-of-life assessment) were limited to the cost of ASA (p=0.032) and the total quality-of-life assessment score of T stage (p=0.045). Through subgroup analysis, we found that patients who were older (aged ≥60 years), had obesity (BMI≥25.0 kg/m^2), had concomitant disease, and had a high ASA grade (II/III) were more likely to

Table 3. Details of complications

Complications	Ileostomy Group (n=43)	SDT group (n=37)
Total Complications	19	10
General Complications	15	5
Clinical anastomotic leakage	1	1
Radiological anastomotic leakage	2	0
Anastomotic stenosis	2	0
Abdominal infection	1	0
Pleural effusion	1	1
Ileus	3	0
Gastrointestinal dysmotility	1	0
Urinary tract infection	1	1
Thrombus of lower extremity veins	2	0
Pulmonary embolism	0	1
Incision infection	1	1
Stoma-related complications	4	0
Prolapse	1	0
Dermatitis	2	0
Necrosis	1	0
SDT-related complications	NA	5
SDT-related ileus	NA	5
Ileac leakage	NA	0
Displacement of stent	NA	0
Non-degradation of stent	NA	0

Date were presented as number.

Two patients of ileostomy group presented two complications, while one patient of SDT group presented two complications. SDT, stent-based diverting technique; NA, not applicable.

Table 4. Quality of life evaluation

	ITT analysis			Per-protocol analysis		
	Ileostomy (n=43)	SDT (n=37)	P value	Ileostomy (n=43)	SDT (n=36)	P value
GH	80 (60-80)	80 (60-80)	0.582	80 (60-80)	80 (60-80)	0.616
PF	75 (50-100)	75 (75-100)	**0.036**	75 (50-100)	75 (75-100)	**0.034**
RP	75 (50-100)	100 (75-100)	**0.007**	75 (50-100)	100 (75-100)	**0.004**
BP	80 (60-100)	100 (70-100)	0.364	80 (60-100)	100 (65-100)	0.425
VT	50 (50-75)	100 (75-100)	**0.005**	50 (50-75)	100 (75-100)	**0.008**
SF	50 (50-75)	100 (75-100)	**0.002**	50 (50-75)	100 (75-100)	**0.001**
MH	50 (50-75)	100 (75-100)	**0.007**	50 (50-75)	100 (75-100)	**0.004**
RE	75 (75-100)	100 (75-100)	**0.013**	75 (75-100)	100 (75-100)	**0.001**

Date were presented as median with interquartile range or number with percentage.

ITT, intention-to-treat; SDT, stent-based diverting technique; GH, General Health; PF, Physical Function, RP, Role-Physical, BP, Bodily Pain; VT, Vitality; SF, Social Functioning, MH, Mental Health; RE, Role-Emotional.

The score is from 1 to 5 or 6 for each item. Primary score = highest score - actual score + 1; Standard score = (primary score – lowest score) × (highest score – lowest score). The higher the score, the healthier the receiver is. Bold P value indicated the significant difference.

benefit from the SDT procedure. More research is necessary to determine whether the tumor size, T or N stage, or the presence of adjuvant therapy affects the benefit of SDT.

DISCUSSION

The present study evaluated the incidence and grade of complications and AL as well as secondary endpoints by comparing ileostomy and SDT after LAR for patients with rectal cancer. For the primary outcome, the severe complication rate was 14.0% in the ileostomy group and 8.1% in the SDT group, which was not a significant difference. Given the limited power due to the insufficient sample size, this study only suggested that the application of SDT may not increase the incidence of severe complications compared with ileostomy. Similarly, SDT could prevent severe AL, although one patient converted to ileostomy as salvage treatment. It is worth mentioning that most patients who underwent SDT had reduced postoperative hospital stays and medical costs and improved quality of life by avoiding stoma reversal. Additionally, the patients in the SDT group [65.0 (60.0, 71.0) years] seemed to be older than those in the ileostomy group [57.0 (53.0, 66.0) years]. Although randomization was performed, we suspected that the benefits of SDT might be more notable if age was parallel.

The actual rates of clinical AL in the ileostomy and SDT groups were 2.3% and 2.7%, respectively, which are relatively lower than those in previous studies.[6,13-15] Generally, for patients with low rectal cancer, ileostomy is usually needed; however, there is debate regarding the necessity of ileostomy for patients with middle rectal cancer. In our study, patients were defined as individuals with middle to low rectal cancer. In addition, 3 of 37 (8.1%) patients in the SDT group and 10 of 43 (23.3%) patients in the ileostomy group who received neoadjuvant radiotherapy were enrolled; tissue edema and friability are unfavorable for anastomosis healing.[16-19] Moreover, as radiological AL assessments were not mandatory, only two radiological ALs were detected in the ileostomy group. Another potential reason was the heterogeneity of the study populations. Malnutrition patients or those with a history of continuous systematic administration of corticosteroids within the past month were excluded from this study. Taken together, the relatively low incidence of AL could be explained by the abovementioned reasons. Due to the limitations of the small sample size and low rate of AL, the protection of AL by either ileostomy or SDT needs further investigation.

Ileostomy is still one of the most common methods used for AL prevention in clinical practice, even though diverting stomas can reduce the incidence of AL.[20-22] In turn, ileostomy increases postoperative stay, readmission and dehydration. Up to 20% of stomas eventually fail to reverse.[3,23-24] Therefore, it has long been of interest to create a new approach to simultaneously reduce the rate of anastomotic leakage and avoid stoma-related side effects. Given that the core goal is to achieve fecal diversion, several methods have been developed to prevent symptomatic AL. For instance, a transanal drainage tube (TDT) is beneficial for reducing both endoluminal pressure and fecal diversion, resulting in a protective effect on anastomotic healing.[25-27] Regrettably, Zhao et al. revealed no differences between the TDT and non-TDT arms in terms of AL protection.[28] In addition, Pinsk et al. reported a nonrandomized, one-arm study in which the CG-100 intraluminal bypass device may be an alternative method to prevent AL.[29] Another fecal diversion device, an alternative technique to conventional stoma procedures, was shown to be safe and effective in a randomized clinical trial with a small sample size.[30]

Our invention, SDT, achieved fecal diversion through a mushroom-shaped tube (28 Fr). In addition, biodegradable stents ensure that intestinal contents do not enter the colon. After 3-4 weeks, intestinal patency was restored with stent degradation, and the mushroom-shaped tube was removed in an outpatient setting. The incidence of severe complications in the ileostomy and SDT arms was 14.0% and 8.1%, respectively, which was not significantly different. This result indicated that, compared with ileostomy, SDT did not increase complications by efficiently reducing stoma-related complications. Moreover, the price for SDT is 0.6 ten thousand yuan, which is much lower than the cost of stoma reversal. Alternatively, SDT could be a new approach for reducing hospital stays and medical costs and improving the quality of life for patients who need ileostomy after rectal surgery. Additionally, avoiding stoma is expected to reduce gut microbiota disorders and related complications.[31]

However, several SDT-related issues have been mentioned. First, some experts have wondered whether an enterocutaneous fistula occurs after removal of a mushroom-shaped tube. Although the tip of the drain is relatively large, the material is sufficiently soft. Similar to the removal of the T-tube after common bile duct exploration, we speculated that the formation of the sinus tract alone with the mushroom-shaped tube avoided the incidence of enterocutaneous fistula, as it rarely occurs with biliary leakage after T-tube removal in patients with common bile duct exploration. Empirically, we used a double purse string to suture the intestine, which could lower the rate of enterocutaneous fistula. Most importantly, the mushroom-shaped tube was unobstructed, and the intestinal contents were allowed to flow out smoothly. Second, stent-associated ileus was the most common adverse event. In this study, 5 of 37 (13.5%) patients experienced incomplete ileus that resolved spontaneously and smoothly after the mushroom-shaped tube was irrigated with normal saline. Irrigation was empirically indicated when the intestinal contents were viscous, and liquid or semiliquid was recommended until the mushroom-shaped tube was removed. Moreover, the fixation of the mushroom-shaped tube on the abdominal wall should not be too tight, as mild

dermatitis with no serious impact is commonly present along with the mushroom-shaped tube.

The stents included three types: BIS22-HB (small), BIS24-HB (middle), and BIS26-HB (large). Clinically, the most commonly used stents were BIS22-HB or BIS24-HB, and BIS26-HB was prepared for patients whose small bowel lumen was extremely large. Overall, no cases of ileac leakage, stent displacement, or stent degradation occurred. Sometimes, ileostomy is required for an extended period because of delayed AL. Of note, ileostomy remains a salvageable measure for delayed AL after SDT, as the stent usually degrades within 3-4 weeks. Therefore, our team is currently embarking on optically mediated degradation stents. In brief, optical fibers were inserted into the stent through a mushroom-shaped tube, and the timing of degradation was precisely controlled, thereby solving the problem of delayed AL.

The present study had some limitations that should be acknowledged. First, a multicenter, randomized controlled, noninferiority study with a sufficient sample size is warranted to further investigate the efficacy and safety of SDT. As the follow-up period of 90 days is insufficient for thoroughly evaluating the long-term safety and effectiveness of the SDT, the overall results are still being monitored. Second, the application of SDT may not be extrapolated to the entire population of patients with rectal cancer, as only patients who underwent LAR were enrolled in this pilot study. At the same time, the indications for the SDT technique remain problematic. For patients with other high-risk factors, namely, preoperative radiotherapy, malnutrition, severe diabetes, and long-term steroid intake, the feasibility of SDT remains controversial. Currently, for patients with middle-low rectal cancer, SDT may be an option if the patient will undergo ileostomy. Therefore, real-world studies and the long-term efficacy of SDT are important.

CONCLUSION

This prospective randomized clinical trial preliminarily evaluated the usefulness of SDT after LAR for patients with rectal cancer, suggesting that SDT might be an alternative operation for patients who need to receive ileostomy. Although the SDT procedure appears to help patients avoid complications more frequently, save hospital stays, lower medical costs, and enhance their quality of life, more research is needed to determine whether the procedure is feasible in general patient populations with rectal cancer.

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AUTHOR CONTRIBUTIONS

Yifan Tong, Conceptualization, Data Curation, Writing-Original Draft. Zhangfa Song, Xuefeng Huang, Sheng Dai, Da Wang, Weifeng Lao, Bingjun Bai, Wenbin Chen, Danyang Wang, Tao Xiang, Pengyang Zhou, Qiken Li, Gang Wang, Weiping Chen, Lingfei Li, Resources, Data Curation. Mingyu Chen, Zhongyu Wu, Hui Liu, Methodology, Formal Analysis. Xiujun Cai, Conceptualization, Writing-Review & Editing, Supervision, Project Administration.

DECLARATION OF INTERESTS

The authors declare no competing interests.

ETHICAL STATEMENT AND PATIENT CONSENT

This study not only was approved by the ethics committee of the Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University (No. KY20210105-12) but also followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines. In addition, local institutional review board approval was obtained from each participating hospital, and written informed consent was obtained from all participants. The trial was registered with the Chinese Clinical Trial Registry (ChiCTR2100049953).

DATA AND MATERIALS AVAILABILITY

The data in this study are available from the lead contact upon reasonable request.

SUPPLEMENTAL INFORMATION

It can be found online at https://doi.org/10.59717/j.xinn-med.2024.100079

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