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Ghost ileostomy as a selective diversion strategy after colorectal cancer surgery: A comparative cohort study

Ahmed Lamey[1]*, Tamer A. Abouelgreed[2], Mohammed Wahba Youssef[3], Ahmed Abdelmonem Gabr[4], Anwar Kamel Oraby[5], Sobhy Teama[6], Mohamed Abdelrahaman Mohamed[7], Mohamed Sherif Ali Ahmed[8], Osama Mohamed Abdelmoneim[9], Mohamed Abdel Aziz Ali Khalil[10]

[1]Department of General Surgery, Faculty of Medicine, Kafr Elsheikh University, Egypt & Burjeel Royal Hospital, Abu Dhabi, United Arab Emirates; Email: dr.ahmedlamey@gmail.com; ORCID: https://orcid.org/0000-0002-4284-5330

[2]Department of Urology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt; Email: dr_tamer_ali@yahoo.com; ORCID: https://orcid.org/0000-0003-2640-3425

[3]Department of General Surgery, Faculty of Medicine, Al-Azhar University, Cairo, Egypt;

Email: wahba.mohammed73@gmail.com; ORCID: https://orcid.org/0009-0006-9430-3599

[4]Department of General Surgery, Faculty of Medicine, Al-Azhar University, Damietta, Egypt;

Email: drahmedgabr@yahoo.com

[5]Department of Surgical Oncology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt;

Email: anwarkamel71@gmail.com

[6]Department of General Surgery, Faculty of Medicine, Al-Azhar University, Cairo, Egypt;

Email: sobhyteama2007@gmail.com; ORCID: https://orcid.org/0000-0003-0838-1082

[7]Department of General Surgery, Faculty of Medicine, Al-Azhar University, Assiut, Egypt;

Email: mohamedabdelrahaman363@gmail.com; ORCID: https://orcid.org/0009-0008-7962-6378

[8]General Practitioner, Faculty of Medicine, Mansoura University, Mansoura, Egypt;

Email: mohamedsherifaliahmed@gmail.com; ORCID: https://orcid.org/0009-0007-7258-039X

[9]General Practitioner, Faculty of Medicine, Mansoura University, Mansoura, Egypt;

Email: osama.md99@gmail.com; ORCID: https://orcid.org/0009-0005-7904-6910

[10]Department of General Surgery, Faculty of Medicine, Arish University, Egypt;

Email: mohamed76aziz@gmail.com; ORCID: https://orcid.org/0009-0005-0641-8525

Corresponding Author: Ahmed Lamey

Email: dr.ahmedlamey@gmail.com

ABSTRACT

Background: Conventional diverting loop ileostomy can mitigate the clinical consequences of anastomotic leakage after low rectal anastomosis, but it exposes many patients to stoma-related morbidity and a subsequent reversal procedure. Ghost ileostomy is a selective-diversion strategy in which an ileal loop is prepared for rapid exteriorization only if postoperative diversion becomes necessary. Methods: We conducted a retrospective comparative cohort study of 56 patients undergoing elective colorectal cancer surgery with a stapled colorectal anastomosis between January 2023 and December 2024. Thirty-three patients underwent ghost ileostomy (GI) and 23 underwent conventional loop ileostomy (LI). Baseline clinical, oncological, operative, and postoperative outcomes were compared. Between-group comparisons were performed using appropriate parametric and exact tests; exploratory multivariable analyses were undertaken where appropriate. Results: The GI and LI groups differed in age (67.00±0.83 vs 67.52±0.51 years; P=0.010), body mass index (27.95±0.34 vs 28.63±0.45 kg/m²; P<0.001), and tumor distance from the anal verge (7.05±0.15 vs 6.69±0.16 cm; P<0.001). An initially

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positive intraoperative leak test was identified in 8/56 patients (14.3%); all occurred in the LI group (8/23, 34.8%), whereas all GI patients had a negative initial leak test (P<0.001), reflecting the treatment-selection algorithm. Mean blood loss was lower with GI (200.0±13.9 vs 340.0±13.8 mL; P<0.001). Postoperative anastomotic leakage occurred in 3/33 GI patients (9.1%) and 1/23 LI patients (4.3%; P=0.636). Two GI leaks underwent conversion to a functioning ileostomy; consequently, 31/33 GI patients (93.9%) avoided conventional diversion. Overall postoperative complications (15.2% vs 69.6%), stoma-related complications (9.1% vs 56.5%), and Clavien-Dindo grade ≥III morbidity (15.2% vs 69.6%) were lower in GI (all P<0.001). Hospital-stay distribution also favored GI (P=0.004). Conclusions: Ghost ileostomy appears to be a feasible selective-diversion strategy that may reduce unnecessary conventional stoma formation while preserving a rescue option when postoperative anastomotic leakage occurs. Although postoperative leakage did not differ significantly between groups, GI was associated with lower reported morbidity, fewer stoma-related events, less blood loss, and a hospital-stay distribution favoring shorter admissions. These findings should be interpreted cautiously because of the retrospective, non-randomized design, baseline imbalance, treatment-selection bias, and a small number of leakage events. Larger prospective studies are required before GI can be recommended as a routine alternative to conventional loop ileostomy.

Keywords: *Ghost Ileostomy, Colorectal Cancer, Low Anterior Resection, Anastomotic Leakage, Selective Diversion.*

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1. INTRODUCTION

Anastomotic leakage remains one of the most consequential complications following low anterior resection for colorectal cancer. It is associated with postoperative sepsis, reintervention, prolonged hospitalization, impaired functional recovery, and potentially adverse oncological outcomes. The International Study Group of Rectal Cancer (ISREC) proposed a standardized definition and grading system to improve comparability across studies by classifying anastomotic leakage according to its impact on clinical management [1]. Temporary fecal diversion, most commonly with a diverting loop ileostomy (LI), is widely used to mitigate the clinical consequences of anastomotic leakage after low colorectal or rectal anastomosis. In a randomized multicenter trial, Matthiessen et al. demonstrated that a defunctioning stoma reduced symptomatic leakage after low anterior resection [2]. Nevertheless, conventional diversion introduces its own clinically important morbidity. Systematic reviews have demonstrated substantial risks of high-output stoma, dehydration, electrolyte disturbances, renal impairment, stoma-related readmission, and other stoma-related complications after ileostomy formation [3,4]. In a meta-analysis of 71 studies involving 82,451 patients, Vogel et al. reported an overall 30-day readmission rate of approximately 20% after ileostomy creation, with dehydration representing the leading cause of readmission [3]. Similarly, Borucki et al. demonstrated that a diverting ileostomy following colorectal cancer resection was associated with an increased risk of dehydration and renal impairment [4]. The burden of conventional diversion may also extend beyond early postoperative morbidity. Although diverting ileostomies are generally intended to be temporary, delayed or failed reversal may expose patients to prolonged stoma-related morbidity and impaired quality of life. A 2024 meta-analysis of 13 studies involving 3,026 patients undergoing sphincter-preserving rectal cancer surgery demonstrated that temporary ileostomy non-closure remains a clinically relevant problem and identified several patient- and disease-related factors associated with failed reversal [5]. Ghost ileostomy, also termed virtual ileostomy, was developed as an intermediate strategy between routine diversion and no stoma. The technique involves identification and temporary fixation of a distal ileal loop, permitting rapid postoperative exteriorization if clinically relevant anastomotic leakage develops, while avoiding the immediate construction of a functioning stoma in patients who recover uneventfully. Comparative studies, randomized investigations, and meta-analyses suggest that GI may reduce unnecessary conventional stoma formation without a clearly demonstrated increase in anastomotic leakage, although the certainty of evidence remains limited by relatively small sample sizes, heterogeneity, and predominantly observational designs [6-11]. Recent systematic reviews and randomized feasibility work have reinforced interest in selective-diversion approaches while emphasizing the need for prospective validation and standardized patient-selection criteria [6, 7, 9]. The principal clinical question is therefore not whether GI prevents anastomotic leakage, but whether it can safely support a selective-diversion strategy that reduces unnecessary exposure to a functioning ileostomy while preserving the ability to establish timely rescue diversion when clinically significant leakage occurs. Accordingly, the present study compared GI with conventional LI in patients undergoing elective colorectal cancer surgery. We evaluated baseline and operative characteristics, postoperative anastomotic leakage, conversion of GI to a functioning ileostomy, postoperative morbidity, stoma-related complications, length of hospital stay, and exploratory factors associated with diversion strategy and intraoperative leak-test positivity.

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2. MATERIALS AND METHODS

This retrospective comparative cohort study included patients undergoing elective colorectal cancer surgery at Burjeel Hospitals in the United Arab Emirates over a 24-month period from January 2023 to December 2024. The study was conducted in accordance with the Declaration of Helsinki and applicable institutional requirements. Eligible patients had primary left-sided colonic or rectal malignancy and underwent elective sphincter-preserving resection with a stapled colorectal anastomosis. Procedures recorded in the source dataset included low anterior resection (LAR) or ultra-low anterior resection (Ultra-LAR) with total mesorectal excision (TME). Exclusion criteria were emergency or complicated colorectal surgery (including obstruction, perforation, para-colic or para-rectal abscess, or major rectal bleeding), hand-sewn colorectal anastomosis, metastatic colorectal cancer, and previous anastomotic leakage.

Preoperative assessment

Preoperative evaluation included history and physical examination, routine laboratory investigations, tumor markers, metastatic staging, and computed tomography and/or magnetic resonance imaging of the abdomen and pelvis as clinically indicated. Neoadjuvant treatment was recorded as a binary variable.

Intraoperative management and diversion strategy

At the completion of colorectal resection and stapled colorectal anastomosis, an intraoperative anastomotic leak test was performed in all patients. An air leak test was performed by filling the pelvis with saline and insufflating the rectum transanally while the proximal bowel was occluded. Visible bubbling from the anastomosis was considered a positive finding. An initially positive leak test prompted anastomotic reinforcement, revision, or a repeat anastomosis, as appropriate, until a negative repeat test was obtained. A conventional diverting loop ileostomy was subsequently created. Although the present analysis was retrospective, the diversion strategy reflected the institutional clinical algorithm used during the study period. In patients with a negative initial leak test, the decision between GI and LI was based on the operating surgeon's overall assessment of anastomotic and patient-related risk. No formal numerical risk score was applied. Patients selected for GI had a negative initial leak test and were considered suitable for selective diversion based on intraoperative findings and the surgeon’s judgment.

Ghost ileostomy technique and postoperative surveillance

For GI, an ileal loop was prepared for potential postoperative exteriorization without creating an immediate functioning stoma. If postoperative anastomotic leakage was confirmed, the prepared loop was converted to a functioning ileostomy by exteriorization through the abdominal wall. In the absence of leakage, the prepared loop was released back into the peritoneal cavity on postoperative day 8. A segment of the terminal ileum approximately 50–70 cm proximal to the ileocecal valve was identified. A small mesenteric window was created adjacent to the selected ileal loop, taking care to avoid injury to the mesenteric vessels. A vascular loop or catheter was then passed through the mesenteric window to encircle and identify the bowel loop without compromising its vascular supply. The predetermined ileostomy site was located in the right lower abdominal quadrant, approximately midway between the umbilicus and the right anterior superior iliac spine, at the site marked preoperatively. The procedure could be performed through either an open or laparoscopic approach, according to the operative technique used for the colorectal resection. To ensure the correct orientation of the bowel, should delayed exteriorization become necessary, the oral (proximal) limb of the ileum was marked approximately 1–2 cm proximal to the silicone loop using a non-absorbable serosal suture. This marking allowed reliable identification of the proximal limb and minimized the risk of twisting or incorrect orientation during subsequent stoma maturation. At the preoperatively designated ileostomy site, the silicone loop was exteriorized through a small stab incision in the abdominal wall and secured externally to the skin using a stoma rod and non-absorbable sutures. The selected ileal loop itself remained intra-abdominal and below the abdominal fascia, without tension, torsion, or exteriorization. Thus, no functioning stoma was created at the initial operation. Postoperative surveillance included clinical assessment, complete blood count, serum albumin, serum C-reactive protein, serum procalcitonin, and drain biomarkers where available. Computed tomography with rectal/retrograde contrast was performed when anastomotic leakage was suspected. In the absence of leakage, the externalized silicone loop/catheter was removed after the planned observation period, allowing the selected ileal segment to remain freely within the peritoneal cavity. If postoperative anastomotic leakage was confirmed and fecal diversion was considered necessary, the patient was transferred to the operating room, where the previously prepared ileal loop was exteriorized through the predetermined stoma site under local anesthesia. The proximal serosal marking was used to confirm the correct bowel orientation, after which the loop was brought through the abdominal wall and matured as a functional loop ileostomy. The principal technical steps of ghost ileostomy construction and the postoperative appearance of the prepared stoma site are illustrated in Figure 1.

Outcomes

The primary clinical outcome was postoperative anastomotic leakage. The primary strategy-specific outcome was the avoidance of a functioning conventional ileostomy among patients initially managed with GI. Secondary outcomes

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included GI-to-functional ileostomy conversion, reoperation/re-exploration, readmission, overall postoperative complications, stoma-related complications, Clavien-Dindo grade ≥III morbidity, mortality, intraoperative blood loss, and length of hospital stay. Postoperative complications, readmission, reoperation, anastomotic leakage, and mortality were assessed through postoperative day 30. Postoperative anastomotic leakage was defined and graded according to the International Study Group of Rectal Cancer (ISREC) classification [1]. Anastomotic leakage was defined according to ISREC as a defect of the intestinal wall at the colorectal anastomotic site, leading to communication between the intra- and extraluminal compartments. Anastomotic leakage was classified according to the ISREC classification as Grade A when no active therapeutic intervention was required; Grade B when active treatment was required without relaparotomy; and Grade C when relaparotomy or abdominal re-exploration was required. Anastomotic leakage was suspected based on clinical deterioration, including tachycardia, fever, prolonged ileus, abdominal or peritoneal signs, and feculent drain output. Laboratory abnormalities such as leukocytosis and elevated inflammatory markers, particularly C-reactive protein and procalcitonin, supported the diagnosis. When leakage was clinically suspected, contrast-enhanced computed tomography with rectal/retrograde contrast was the principal imaging modality, with contrast extravasation, perianastomotic fluid collection, or air-fluid collections considered suggestive of leakage. In patients with GI, exteriorization of the previously prepared ileal loop under local anesthesia through the predetermined stoma site, without laparotomy, was considered a Grade B intervention. Overall postoperative complications were defined as all documented surgical and medical adverse events occurring within the predefined postoperative follow-up period. Postoperative complications were graded according to the Clavien–Dindo classification, with Grade III or higher considered major morbidity [12]. Stoma-related complications included complications directly related to a functioning ileostomy, such as high-output stoma, dehydration, electrolyte disturbances, peristomal skin complications, retraction, prolapse, or obstruction. In the GI group, local complications related to the externalized identifying loop or the predetermined stoma access site were recorded separately as stoma-site/access-site complications. Planned stoma reversal was not classified as a complication unless undertaken therapeutically for a postoperative adverse event.

Sample size

No a priori sample-size calculation was performed because this retrospective study included all eligible patients treated during the predefined study period. The available sample therefore determined the study size, and analyses involving sparse outcomes were considered exploratory.

Statistical Analysis

Statistical analyses were performed using SPSS version 26. Continuous variables were summarized as mean ± standard deviation when normally distributed and compared using Student's independent-samples t test. Categorical variables were summarized as number and percentage and compared using Pearson's chi-square test, Fisher's exact test, or Fisher-Freeman-Halton exact test as appropriate. There were no missing data for variables included in the primary analyses. Statistical significance was defined as two-sided $P<0.05$. Multiple linear regression was used to explore predictors of intraoperative blood loss. Because the logistic regression datasets demonstrated quasi-complete separation, Firth-penalized logistic regression was used for exploratory analyses of factors associated with LI selection and positive intraoperative leak testing. Effect estimates are presented with 95% confidence intervals. Owing to the small cohort and sparse events, these logistic models were considered exploratory rather than confirmatory.

3. RESULTS

Baseline characteristics

A total of 56 patients were included: 33 in the GI group and 23 in the LI group. Patients in the LI group were slightly older (67.52±0.51 vs 67.00±0.83 years; $P=0.010$) and had a higher BMI (28.63±0.45 vs 27.95±0.34 kg/m²; $P<0.001$). Sex distribution and the prevalence of hypertension, diabetes mellitus, COPD, and IBD were not significantly different between groups. Tumors were located closer to the anal verge in the LI group (6.69±0.16 vs 7.05±0.15 cm; $P<0.001$). Tumor-stage distribution, use of neoadjuvant treatment, operative procedures, and the laparoscopic versus open approach did not differ significantly between the groups (Table 1). The study flow and distribution of patients according to the diversion strategy are shown in Figure 2.

Intraoperative and postoperative outcomes

An initially positive intraoperative leak test occurred in 8 of 23 LI patients and in none of the 33 GI patients ($P<0.001$). This finding reflects the treatment-selection algorithm rather than an independent postoperative outcome. Mean intraoperative blood loss was significantly lower in the GI group (200.0±13.9 vs 340.0±13.8 mL; $P<0.001$). Postoperative anastomotic leakage occurred in 3 GI patients (9.1%) and 1 LI patient (4.3%), with no statistically significant difference ($P=0.636$). Among the three postoperative anastomotic leaks in the GI group, one was classified as ISREC Grade A and two as Grade B. The Grade B leaks were managed by converting the pre-positioned ghost ileostomy into a functioning loop ileostomy under local anesthesia through the predetermined stoma site, without laparotomy or abdominal re-exploration. Accordingly, these cases were classified as Grade B rather than Grade C. The single anastomotic leak in the

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LI group was classified as ISREC Grade C because it required operative re-exploration (4.3%) and occurred in no GI patients (P=0.411). No readmissions were recorded in either group. Overall postoperative complications occurred in 5 GI patients (15.2%) and in 16 LI patients (69.6%; P<0.001). Stoma-related complications occurred in 2 GI patients (6.1%) and in 13 LI patients (56.5%; P<0.001). Clavien-Dindo grade ≥III morbidity occurred in 5 GI patients (15.2%) and in 16 LI patients (69.6%; P<0.001). Mortality was 0% in the GI and 4.3% (1/23) in the LI group (P=0.411). The distribution of hospital stay differed significantly between groups (chi-square=13.33; P=0.004). A stay of 5-10 days occurred in 63.6% of GI patients compared with 17.4% of LI patients, whereas stays of 11-20 days and >20 days were more common in the LI group. Detailed intraoperative and postoperative outcomes are presented in (Table 2A).

Factors associated with positive intraoperative leak testing in the LI group

Within the LI group, positive initial intraoperative leak testing was significantly associated with receipt of neoadjuvant treatment (75.0% vs 13.3%; P=0.006) and laparoscopic rather than open surgery (100% vs 40.0%; P=0.007). Age, BMI, sex, hypertension, diabetes mellitus, tumor distance from the anal verge, tumor stage, operative procedure, and intraoperative blood loss were not significantly associated with leak-test positivity (Table 2B).

Regression analyses

In the multiple linear regression model, ileostomy strategy was the only variable independently associated with blood loss. Operative procedure was not associated with initial intraoperative leak-test positivity (Table 3A). In exploratory Firth-penalized logistic regression for LI selection, higher BMI and shorter tumor distance from the anal verge remained statistically associated with the diversion strategy; however, the effect estimates were extreme and imprecise, consistent with quasi-complete separation as presented in (Table 3B). Exploratory analysis of factors associated with initial intraoperative leak-test positivity is presented in (Table 3C).

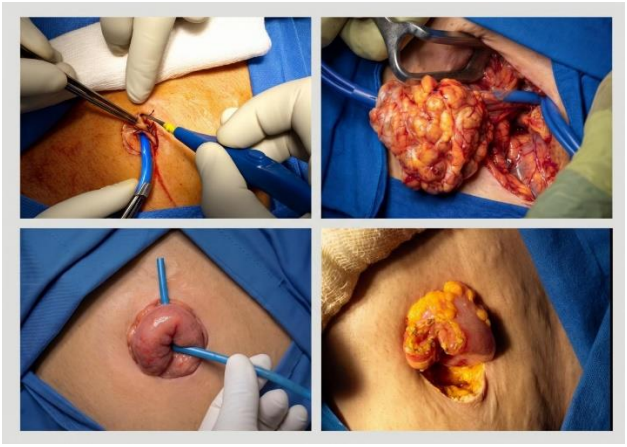


Figure 1. Ghost ileostomy technique and postoperative management.

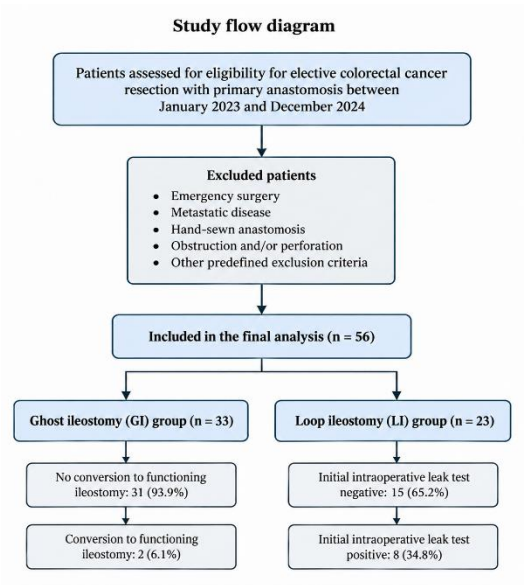


Figure 2. Study flow diagram.

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Table 1. Baseline demographic, oncological, and operative characteristics according to ileostomy strategy

Variable		GI, n=33	LI, n=23	Test	P value
Demographic and clinical characteristics	Age, years, mean ± SD	67.00 ± 0.83	67.52 ± 0.51	t=-2.680	0.010
	BMI, kg/m², mean ± SD	27.95 ± 0.34	28.63 ± 0.45	t=-6.491	<0.001
	Male sex, n (%)	16 (48.5)	12 (52.2)	χ^2=0.074	0.786
	Female sex, n (%)	17 (51.5)	11 (47.8)		
	Hypertension, n (%)	11 (33.3)	11 (47.8)	χ^2=1.194	0.275
	Diabetes mellitus, n (%)	8 (24.2)	7 (30.4)	χ^2=0.265	0.607
	COPD, n (%)	1 (3.0)	1 (4.3)	Fisher exact	1.000
	IBD, n (%)	2 (6.1)	2 (8.7)	Fisher exact	1.000
Tumor characteristics	Tumor distance from anal verge, cm	7.05 ± 0.15	6.69 ± 0.16	t=8.276	<0.001
	Stage I, n (%)	9 (27.3)	4 (17.4)	χ^2=0.753	0.686
	Stage II, n (%)	11 (33.3)	9 (39.1)		
	Stage III, n (%)	13 (39.4)	10 (43.5)		
	Neoadjuvant treatment, n (%)	10 (30.3)	10 (43.5)	χ^2=1.025	0.311
Operative characteristics	LAR+TME, n (%)	19 (57.6)	12 (52.2)	χ^2 = 0.160	0.689
	Ultra-LAR+TME, n (%)	14 (42.4)	11 (47.8)		
	Laparoscopic surgery, n (%)	26 (78.8)	14 (60.9)	χ^2=2.132	0.144
	Open surgery, n (%)	7 (21.2)	9 (39.1)		

Data are presented as mean ± SD or n (%). COPD, chronic obstructive pulmonary disease; IBD, inflammatory bowel disease; LAR, low anterior resection; Ultra-LAR, ultra-low anterior resection; TME, total mesorectal excision.

Table 2. Primary and secondary outcomes and factors associated with positive intraoperative leak testing

Panel A. Primary and secondary outcomes

Outcome	GI, n=33	LI, n=23	Statistical test	P value
Positive initial intraoperative leak test, n (%)	0 (0.0)	8 (34.8)	Fisher exact	<0.001*
Blood loss, mL, mean ± SD	200.00 ± 13.92	340.00 ± 13.82	t=-37.139	<0.001*
Postoperative anastomotic leakage, n (%)	3 (9.1)	1 (4.3)	Fisher exact	0.636
GI-to-functional ileostomy conversion, n (%)	2 (6.1)	N/A	Descriptive	—
Reoperation/re-exploration, n (%)	0 (0.0)	1 (4.3)	Fisher exact	0.411
Readmission, n (%)	0 (0.0)	0 (0.0)	Not applicable	—
Overall postoperative complications, n (%)	5 (15.2)	16 (69.6)	Fisher exact	<0.001
Stoma-related complications, n (%)	2 (6.1)	13 (56.5)	Fisher exact	<0.001
Clavien-Dindo ≥III morbidity, n (%)	5 (15.2)	16 (69.6)	Fisher exact	<0.001
Mortality, n (%)	0 (0.0)	1 (4.3)	Fisher exact	0.411
Hospital stay <5 days, n (%)	2 (6.1)	1 (4.3)	Overall χ^2=13.33	0.004
Hospital stay 5-10 days, n (%)	21 (63.6)	4 (17.4)		
Hospital stay 11-20 days, n (%)	8 (24.2)	12 (52.2)		
Hospital stay >20 days, n (%)	2 (6.1)	6 (26.1)		

Panel B. Factors associated with positive intraoperative leak testing within the loop ileostomy group

Variable	Negative test, n=15	Positive test, n=8	Test	P value
Age, years, mean ± SD	67.55 ± 0.52	67.50 ± 0.52	Student's t=0.220	0.828
BMI, kg/m², mean ± SD	28.65 ± 0.45	28.60 ± 0.47	Student's t=0.250	0.805
Male sex, n (%)	10 (66.7)	5 (62.5)	Fisher exact	1.000
Female sex, n (%)	5 (33.3)	3 (37.5)		
Hypertension, n (%)	5 (33.3)	6 (75.0)	Fisher exact	0.089

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Diabetes mellitus, n (%)	3 (20.0)	4 (50.0)	Fisher exact	0.182
Tumor distance from anal verge, cm	6.68 ± 0.17	6.70 ± 0.17	Student's t=−0.269	0.791
Stage I, n (%)	4 (26.7)	0 (0.0)	Fisher–Freeman–Halton exact	0.373
Stage II, n (%)	5 (33.3)	4 (50.0)		
Stage III, n (%)	6 (40.0)	4 (50.0)		
Neoadjuvant treatment, n (%)	2 (13.3)	6 (75.0)	Fisher exact	0.006
LAR+TME, n (%)	7 (46.7)	5 (62.5)	Fisher exact	0.667
Ultra-LAR+TME, n (%)	8 (53.3)	3 (37.5)		
Laparoscopic surgery, n (%)	6 (40.0)	8 (100)	Fisher exact	0.007
Open surgery, n (%)	9 (60.0)	0 (0.0)		
Blood loss, mL, mean ± SD	340.91 ± 14.46	339.17 ± 13.79	Student's t=0.279	0.783

Table 3. Regression Analyses

Panel A. Multiple Linear Regression for Predictors of intraoperative blood loss

Predictor	B	SE	95% CI for B	P value
Loop vs ghost ileostomy	141.95	13.69	114.33 to 169.57	<0.001*
Age, per year	-0.90	6.35	-13.73 to 11.92	0.888
Male sex	-0.17	6.22	-12.72 to 12.39	0.979
BMI, per kg/m²	0.09	5.88	-11.78 to 11.95	0.988
Hypertension	-0.06	10.23	-20.71 to 20.59	0.995
Diabetes mellitus	5.21	7.06	-9.04 to 19.45	0.465
Tumor distance from anal verge, per cm	-5.97	23.57	-53.54 to 41.59	0.801
Neoadjuvant treatment	-10.19	8.93	-28.21 to 7.83	0.260
Stage II vs Stage I	-10.16	7.59	-25.48 to 5.15	0.188
Stage III vs Stage I	-7.35	11.04	-29.62 to 14.93	0.509
Ultra-LAR+TME vs LAR+TME	-4.94	7.82	-20.73 to 10.85	0.531
Open vs. laparoscopic	-11.17	10.50	-32.36 to 10.02	0.293

Model R^2=0.965; adjusted R^2=0.955; overall model P<0.001.

Panel B. Exploratory Firth-penalized logistic regression for factors associated with loop rather than ghost ileostomy

Predictor	Univariable OR (95% CI)	P	Adjusted OR (95% CI)	P
Age, per year	2.66 (1.18-6.01)	0.019	2.27 (0.53-9.72)	0.268
Male sex	1.15 (0.40-3.34)	0.793	—	—
BMI, per kg/m²	54.58 (6.56-453.87)	<0.001	22.25 (1.14-433.71)	0.041
Hypertension	1.80 (0.60-5.36)	0.291	—	—
Diabetes mellitus	1.36 (0.41-4.49)	0.610	—	—
COPD	0.69	1.000	—	—
IBD	0.68	1.000	—	—
Tumor distance from anal verge, per cm	1.74×10^-8 (3.13×10^-14-0.0097)	0.008	9.19×10^-8 (9.93×10^-14-0.085)	0.021
Neoadjuvant treatment	1.74 (0.57-5.27)	0.327	—	—
Open vs laparoscopic surgery	2.31 (0.71-7.54)	0.163	1.62 (0.19-13.63)	0.657

Panel C. Exploratory Firth-penalized logistic regression for positive initial intraoperative leak testing

Predictor	Univariable OR (95% CI)	P	Adjusted OR (95% CI)	P
Age, per year	1.91 (0.75-4.85)	0.173	—	—
Male sex	1.00 (0.28-3.51)	1.000	—	—
BMI, per kg/m²	6.28 (1.55-25.47)	0.010	3.83 (0.28-51.98)	0.313
Hypertension	1.73 (0.49-6.14)	0.398	—	—
Diabetes mellitus	1.54 (0.40-6.00)	0.532	—	—
Tumor distance from anal verge, per cm	0.0059 (0.00019-0.190)	0.004	0.00043 (2.64×10^-7-0.691)	0.040
Neoadjuvant treatment	13.80 (2.87-66.27)	0.001	19.43 (0.59-641.70)	0.096
Stage II vs Stage I	4.91 (1.29-18.76)	0.020	8.03 (0.31-208.81)	0.210

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Stage III vs Stage I	0.037 (0.002-0.698)	0.028	0.127 (0.001-19.11)	0.420
Ultra-LAR+TME vs LAR+TME	0.61 (0.11-3.34)	0.571	—	—
Open vs laparoscopic surgery	0.069 (0.004-1.36)	0.079	—	—

4. DISCUSSION

The present study evaluated GI as a selective-diversion strategy rather than as a direct substitute for protective diversion in all patients. The most clinically relevant finding was that only 2 of 33 GI patients (6.1%) required conversion to a functioning ileostomy; thus, 93.9% avoided immediate conventional diversion. Postoperative anastomotic leakage occurred in 9.1% of GI patients and 4.3% of LI patients. No statistically significant difference in postoperative anastomotic leakage was detected; however, the small number of events precluded definitive assessment of comparative safety. These findings support the concept that GI may reduce unnecessary stoma exposure in carefully selected patients while preserving a rescue pathway when clinically relevant leakage develops. This interpretation is consistent with the available comparative evidence. McKechnie et al. analyzed 14 studies, including 946 patients, and found no statistically significant difference between GI and LI in anastomotic leakage, overall morbidity, or length of stay [6]. Zizzo et al. Similarly reported comparable short-term anastomotic outcomes between virtual/ghost and defunctioning ileostomy strategies [7]. Earlier randomized and observational studies also demonstrated the feasibility of GI and its potential to avoid routine diversion in selected patients [8,10,11,13]. Nevertheless, the current evidence remains limited by heterogeneity in patient selection, surgical technique, conversion criteria, and outcome reporting. The protective role of conventional diversion in high-risk low rectal anastomosis remains well established. In the randomized multicenter trial by Matthiessen et al., defunctioning stoma reduced symptomatic anastomotic leakage after low anterior resection [2]. Accordingly, the present findings should not be interpreted as evidence that GI should replace LI in patients with overtly compromised anastomoses. In the present cohort, an initially positive intraoperative leak test formed part of the treatment pathway leading to conventional LI, indicating that patients receiving LI constituted a clinically higher-risk population by design. This treatment-selection mechanism represents an important source of confounding by indication and should be considered when interpreting between-group differences. The 93.9% conventional stoma avoidance rate in the GI group is clinically attractive. Zenger et al. reported successful conversion of GI when postoperative leakage developed and described favorable morbidity and cost outcomes compared with conventional diversion [8]. Contemporary randomized pilot work has further demonstrated the feasibility of studying GI prospectively, although small sample sizes continue to limit firm conclusions [9]. Stoma-related morbidity was lower among patients managed with the GI strategy. This finding is clinically plausible because most GI patients never received a functioning ileostomy and therefore avoided many complications inherent to conventional diversion. Contemporary evidence confirms that ileostomy formation carries a substantial morbidity burden. Vogel et al. reported a pooled 30-day all-cause readmission rate of 20% following ileostomy creation, with dehydration occurring in approximately 6% of patients and representing the leading cause of readmission [3]. Borucki et al. similarly found that diverting ileostomy after colorectal cancer resection was associated with a more than threefold higher risk of dehydration compared with resection without diversion, with potential consequences including acute kidney injury and persistent renal dysfunction [4]. These data reinforce the potential clinical value of avoiding an unnecessary functioning ileostomy when a selective strategy can be used safely. The clinical burden of conventional diversion may also persist beyond the initial postoperative period. In a 2024 meta-analysis of 13 studies including 3,026 patients undergoing sphincter-preserving surgery for rectal cancer, He et al. reported a pooled incidence of temporary ileostomy non-closure of 16% (95% CI, 13–19%), indicating that approximately one in six temporary ileostomies ultimately remained unreversed and progressed to a permanent stoma [5]. The authors also identified older age, male sex, ASA score ≥3, comorbidity, and distant metastasis as significant preoperative risk factors for non-closure. These findings emphasize that a temporary diverting ileostomy does not invariably result in restoration of intestinal continuity. Therefore, avoiding an unnecessary initial ileostomy may have implications beyond early stoma-related morbidity, including avoidance of delayed reversal, additional surgery, prolonged stoma dependence, and the possibility of permanent diversion. Major postoperative morbidity was substantially more frequent in the LI group. Clavien–Dindo grade ≥III complications occurred in 16 of 23 LI patients (69.6%) compared with 5 of 33 GI patients (15.2%; $P<0.001$). A similar pattern was observed for overall postoperative complications, which occurred in 69.6% versus 15.2% of patients, respectively. These findings suggest a considerably greater postoperative morbidity burden among patients undergoing conventional diversion. However, interpretation should remain cautious because treatment allocation was non-randomized and patients selected for LI had features suggesting greater intraoperative risk. The morbidity associated with conventional ileostomy should also be considered in the context of subsequent reversal. Stoma closure represents an additional operative episode and is itself associated with postoperative complications. Recent evidence evaluating the timing of ileostomy closure after rectal cancer surgery confirms that reversal is not a clinically trivial procedure, with postoperative surgical morbidity remaining relevant regardless of the closure strategy [14]. Consequently, the ability of GI to avoid both initial stoma formation and a subsequent reversal procedure in patients who do not develop clinically significant leakage may represent an important potential advantage of the selective-diversion concept. The distribution of hospital stay was significantly shifted toward shorter admissions in the GI group. Most GI patients were discharged within 5–10 days (63.6%), whereas only 17.4% of LI patients were discharged within the same

interval. In contrast, prolonged hospitalization was considerably more frequent after LI: 52.2% of LI patients remained hospitalized for 11–20 days and 26.1% for more than 20 days, compared with 24.2% and 6.1%, respectively, in the GI group. The overall distribution of length of stay differed significantly between the two strategies (P=0.004). Because hospital stay was available as grouped categorical data rather than individual patient-level durations, mean or median differences could not be estimated reliably; nevertheless, the observed distribution indicates a clear shift toward longer hospitalization in the LI group. This difference may reflect the greater perioperative complexity, major morbidity, and stoma-related care requirements observed among LI patients. Intraoperative blood loss was greater in the LI group than in the GI group. In multiple linear regression, conventional LI remained associated with greater blood loss. This association should not, however, be interpreted as evidence that construction of a loop ileostomy itself caused the observed difference. Patients selected for LI had features indicating greater intraoperative risk, including positive initial leak testing, and the observed association is therefore likely influenced by confounding by indication and differences in operative complexity. Blood loss should consequently be interpreted primarily as a marker of the characteristics of patients selected for conventional diversion rather than as a direct effect of ileostomy construction. Exploratory penalized regression suggested that higher BMI and shorter tumor distance from the anal verge were associated with selection of conventional LI. The association between a lower anastomotic level and a greater perceived leakage risk is clinically plausible and consistent with contemporary evidence demonstrating that anastomotic leakage after rectal cancer surgery remains influenced by anatomical, patient-related, and treatment-related factors [13]. Harada et al., in a contemporary 2025 analysis of rectal cancer surgery, reinforced the multifactorial nature of anastomotic leakage risk in modern surgical practice [13]. Nevertheless, the very large odds ratio for BMI and the extremely small estimate associated with tumor distance in our cohort reflect marked separation and limited overlap between treatment groups rather than precise estimates of effect magnitude. These findings should therefore be regarded as exploratory and hypothesis-generating rather than as validated independent predictors. Similar caution is required when interpreting the exploratory analysis of initial intraoperative leak-test positivity. Only 8 positive tests were observed, resulting in sparse cells and wide confidence intervals for several predictors. Although shorter tumor distance from the anal verge retained statistical significance in the adjusted penalized model, the estimate remained imprecise. Importantly, the revised operative classification showed no significant association between procedure type and initial leak-test positivity: Ultra-LAR with TME was not significantly associated with a positive leak test compared with LAR with TME (OR 0.61, 95% CI 0.11–3.34; P=0.571). Thus, the present data do not support the operative procedure type itself as an independent determinant of initial leak-test positivity. Penalized regression is appropriate for reducing small-sample bias in the presence of separation, but it cannot overcome the limited amount of information contained in a small number of events. Four postoperative anastomotic leaks occurred in the entire cohort: three in the GI group and one in the LI group. Among the GI leaks, one was classified as ISREC Grade A and two as Grade B. In the latter two patients, rescue diversion was achieved by exteriorization of the previously prepared ileal loop under local anesthesia through the predetermined stoma site, without laparotomy or formal abdominal re-exploration. These two cases illustrate a potential practical advantage of the GI concept: when clinically significant leakage develops, the pre-positioned ileal loop may permit timely diversion without the need for a full relaparotomy. Similar feasibility of delayed exteriorization has been described in previous GI and delayed-stoma studies [8, 10, 11]. This study has several important limitations. First, its retrospective, non-randomized design introduces selection bias and confounding by indication, particularly because intraoperative findings contributed directly to selection of the diversion strategy. Second, significant baseline differences in age, BMI, and tumor distance from the anal verge demonstrate incomplete comparability between groups. Third, the relatively small sample size and the occurrence of only four postoperative anastomotic leaks substantially limit statistical power for safety comparisons and produced imprecise estimates in exploratory regression analyses. Fourth, postoperative outcomes could not be robustly adjusted for all clinically relevant confounders because of the small cohort and sparse event counts. Fifth, the study did not evaluate patient-reported quality of life or longer-term stoma-related outcomes. Finally, because the GI strategy depends on careful intraoperative selection and the ability to perform timely rescue exteriorization, the findings may not be generalizable to centers without comparable surgical expertise or postoperative surveillance protocols. Despite these limitations, the study addresses an important clinical question: whether selective preparation of a rescue ileostomy can reduce unnecessary conventional stoma formation without compromising the ability to intervene when leakage develops. The data support further prospective evaluation using standardized eligibility criteria, leak definitions, conversion protocols, and patient-centered stoma outcomes.

5. CONCLUSION

Ghost ileostomy appears to be a feasible selective-diversion strategy that may reduce unnecessary conventional stoma formation while preserving a rescue option when postoperative anastomotic leakage occurs. Although postoperative leakage did not differ significantly between groups, GI was associated with lower reported morbidity, fewer stoma-related events, less blood loss, and a hospital-stay distribution favoring shorter admissions. These findings should be interpreted cautiously because of the retrospective, non-randomized design, baseline imbalance, treatment-selection bias, and a small number of leakage events. Larger prospective studies are required before GI can be recommended as a routine alternative to conventional loop ileostomy.

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DECLARATIONS

Institutional Review Board Statement:

The study was conducted in accordance with the Declaration of Helsinki and applicable institutional and regulatory requirements. The study protocol was reviewed and approved by the Institutional Review Board of Burjeel Hospitals, UAE (approval no. BURJ/RERC/2022/012).

Informed Consent Statement:

Owing to the retrospective nature of the study and the use of previously collected clinical data, the requirement for individual informed consent was waived by the Institutional Review Board.

Data Availability Statement:

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable institutional, ethical, and patient-confidentiality requirements.

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Author Contributions:

AL, TA, MW: manuscript preparation, protocol, data collection and management, manuscript editing. AA, AK, ST: Data acquisition, data analysis and management, manuscript editing. MA, MS, OM, MA: Manuscript editing, project development, data analysis, and project development. All the authors have read and approved the manuscript.

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