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Remnant Stomach Influx Reduces Esophageal Reflux and Malnutrition After Proximal Gastrectomy With Double Tract Reconstruction

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Abstract. *Background/Aim: Remnant stomach influx (RSI) from the anastomotic jejunal-remnant stomach, a physiological food passage, develops after proximal gastrectomy with double-tract reconstruction (PGDT). Sometimes, food passes into the jejunal-loop (JL). We investigated the association of the food passage route in PGDT (RSI/JL) with postoperative esophageal reflux and malnutrition. Patients and Methods: We retrospectively collected data for 50 patients with upper-third gastric cancer and esophagogastric junction cancer with PGDT. Using one-year postoperative fluoroscopy findings, 40 propensity score-matched patients were classified into RSI and JL groups (n=20/group), respectively. The groups were comparatively evaluated for: clinicopathological characteristics [age, sex, body mass index (BMI), visceral fat index (VFI), subcutaneous fat index (SFI), skeletal muscle index, pathological stage]; perioperative factors [approach, postoperative complications ≥ Clavien-Dindo Grade 2, postoperative food passage); and esophageal reflux (reflux esophagitis frequency ≥ Grade A, degree of reflux based on fluoroscopy findings). Univariate and multivariate analysis identified predictive factors for post-operative malnutrition in all 50 patients. Results: After propensity score matching, grade of reflux esophagitis and degree of reflux was significantly lower (p=0.014, p<0.001) in the RSI versus JL group. The RSI group showed significantly attenuated percent decrease in BMI, VFI, and SFI (p=0.049, p=0.002, p=0.006). Multivariate analysis identified food passage route (JL) and pathological stage as predictive factors for postoperative malnutrition. Conclusion: Postoperative esophageal reflux and malnutrition were attenuated by food passage mainly via the RSI after PGDT. Improved jejunal-remnant stomach is requisite to ensure satisfactory remnant stomach influx.*

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Proximal gastrectomy (PG) is an alternative procedure to total gastrectomy (TG) for patients with proximal gastric cancer (cT1N0), allowing for the preservation of more than half of the distal stomach (1). This function-preserving procedure may be indicated in patients with cancer of the esophagogastric junction and those with locally advanced gastric cancer in the proximal stomach. This is because several nationwide studies have reported the extremely low incidence of lymph node metastasis around the right gastric and right gastroepiploic area in these cases (2-4). Compared to PG, TG more frequently causes postoperative malnutrition and post-gastrectomy syndrome (5). PG is therefore recommended in view of maintaining postoperative quality of life by preserving the pylorus and hence remnant stomach volume. Nevertheless, conventional esophago-gastrostomy reconstruction after PG may result in postoperative esophageal reflux *via* bile reflux from the remaining pylorus (6).

The double tract (DT) reconstruction technique prevents esophageal reflux by interposition of the jejunal loop (JL) between the esophagus and the remnant stomach. A jejunal-remnant stomach (JRS) anastomosis is also created to maintain remnant stomach influx (RSI), a physiological route of food passage to the duodenum. Food sometimes passes into the jejunal loop, however, the nutritional implications of this are unclear.

On this background, we hypothesized that food passage into the jejunal loop may cause postoperative complications and malnutrition in PGDT. We thus sought to clarify the association of the food passage route in PGDT with postoperative esophageal reflux and malnutrition as a means to resolve these issues.

Patients and Methods

Study design. The primary endpoint of this retrospective study was clarifying whether food passage route in PGDT is associated with esophageal reflux and postoperative malnutrition before and after propensity score matching. The secondary endpoint was identifying independent predictors associated with postoperative malnutrition by using multivariate analysis.

Patient selection. In total, 53 patients with fStage I-III gastric cancer (U area) or esophagogastric junction cancer underwent PGDT at our institution during the period from July 2014 through January 2023. We excluded three patients, two who developed exacerbation of other disorders during the admission period and one with insufficient clinical data. Thus, clinical data from 50 patients were included in the analysis. Patient characteristics, surgical outcomes, and postoperative outcomes were collected from their medical records. All preoperative clinical data were collected within one month preoperatively, and postoperative data were collected one year thereafter. Pathological classification was as per the TNM classification (eighth edition) (7) and postoperative complications were evaluated using the Clavien-Dindo (CD) classification (8). The study was performed in accordance with the ethical principles of the Declaration of Helsinki. The study protocol was approved by the institutional review board of Tokyo Women's Medical University (Approval No. 2021-0112). All experimental procedures were conducted according to the Japanese Gastric Cancer Treatment guidelines (1). The requirement for informed consent was waived by the institution's Ethics Committee and opt-out consent was approved instead. This was obtained *via* the institutional websites where permission was requested for the use of participants' personal information in this study.

Double-tract reconstruction procedure. Either open or laparoscopic PGDT was performed in all patients. The laparoscopic approach was generally opted for in patients with early gastric cancer. The upper part of the stomach, specifically the cardia and fundus, and the abdominal esophagus in some patients, was resected from the tumor with adequate surgical margins. Standard D1+ or D2 lymph node dissection was performed. DT reconstruction was then performed after gastric resection. The jejunum was transected approximately 20 cm distal from the ligament of Treitz and the jejunal loop was raised up through the antecolic route. Esophagojejunostomy (EJ) was performed using a circular stapling technique in patients for whom the open approach was used. Either circular or linear stapling with the hand-sewn technique was applied in patients for whom the laparoscopic approach was used. Jejunal-remnant stomach (JRS) anastomosis was performed using a linear stapling and hand-sewn technique. Jejunojejunostomy (JJ) was performed using the hand-sewn technique. The anastomotic distance from the EJ to the JRS and to the JJ was in the range of 10-15 cm and 40-45 cm, respectively (Figure 1A).

Patient classification and propensity score matching methodology. Postoperative fluoroscopy was performed one year after surgery. We classified the patients into two groups based on anastomotic integrity evaluated according to the route of low-density barium sulfate suspension (210 w/v%) administered for this purpose. Smooth passage of the suspension through the remnant stomach *via* the JRS anastomosis was designated remnant stomach influx (RSI; Figure 1B). Passage of the suspension mainly through the jejunal loop, and not through the remnant stomach was defined as the jejunal loop passage (JL; Figure 1C). When the suspension passed through both the remnant stomach and the jejunal loop, this was defined as RSI. Taken together, we classified the patients into an RSI group (n=28) and a JL group (n=22). Next, we investigated the presence or absence of postoperative malnutrition after PGDT by propensity score matching using JMP® Pro Software ver. 15 (SAS Institute, Cary, NC, USA). Postoperative malnutrition was defined per the relevant ESPEN guideline on diagnostic criteria for malnutrition as follows: postoperative weight loss one-year after surgery >10% and decreased body mass index (BMI) of <20 or <22 kg/m^2 in patients younger and older than 70 years, respectively (9). Patients in the RSI and JL groups were compared using the background factors of age, sex, tumor location, pathological stage, and postoperative adjuvant chemotherapy. Overall, 40 patients were extracted (RSI group, n=20; JL group, n=20) after propensity score matching.

Evaluations. The degree and grade of esophageal reflux was evaluated by using fluoroscopy and upper gastrointestinal endoscopy one year after surgery. Degree of esophageal reflux was evaluated based on fluoroscopy findings using low-density barium sulfate suspension. During the measurements, each patient was asked to ingest a small amount (5-10 ml) of the suspension while in a standing position. Next, with the fluoroscopy table inclined and the patient lying supine, the degree of esophageal reflux was measured using the height of the suspension that flowed back and was graded as follows. Severe: Upper thoracic area (above the tracheal bifurcation); Moderate: Mid-thoracic area (upper half of the tracheal bifurcation and the esophagogastric junction); and Mild: Lower thoracic area (lower half of the tracheal bifurcation and the esophagogastric junction). Upper gastrointestinal endoscopy was performed to evaluate the grade of reflux esophagitis based on the Los Angeles classification of esophagitis (10). Visceral fat index (VFI), subcutaneous fat index (SFI), and skeletal muscle index (SMI) was measured from CT scans at the third lumber vertebra (L3) level, using the ImageJ software ver. 1.52i (National Institute of Health, Bethesda, MD, USA) and quantified using the methods previously described (11).

Statistical analysis. Continuous data are presented as the median. Continuous variables were analyzed nonparametrically with the Mann–Whitney *U*-test. Categorical variables were compared by using the χ^2 test when appropriate. Correlations between continuous variables were assessed by using Spearman correlation coefficients. Univariate and multivariate logistic regression analysis were applied to identify predictive factors relative to postoperative malnutrition defined by the ESPEN guideline described above. Univariate analysis selected variables with a p-value less than 0.05 as candidates for multivariate analysis. Propensity score was calculated by using logistic regression, and one-to-one and nearest neighbor or within-caliper matching was performed. The narrow caliper value was set as 0.05 to obtain an exact match. A p-value less than 0.05

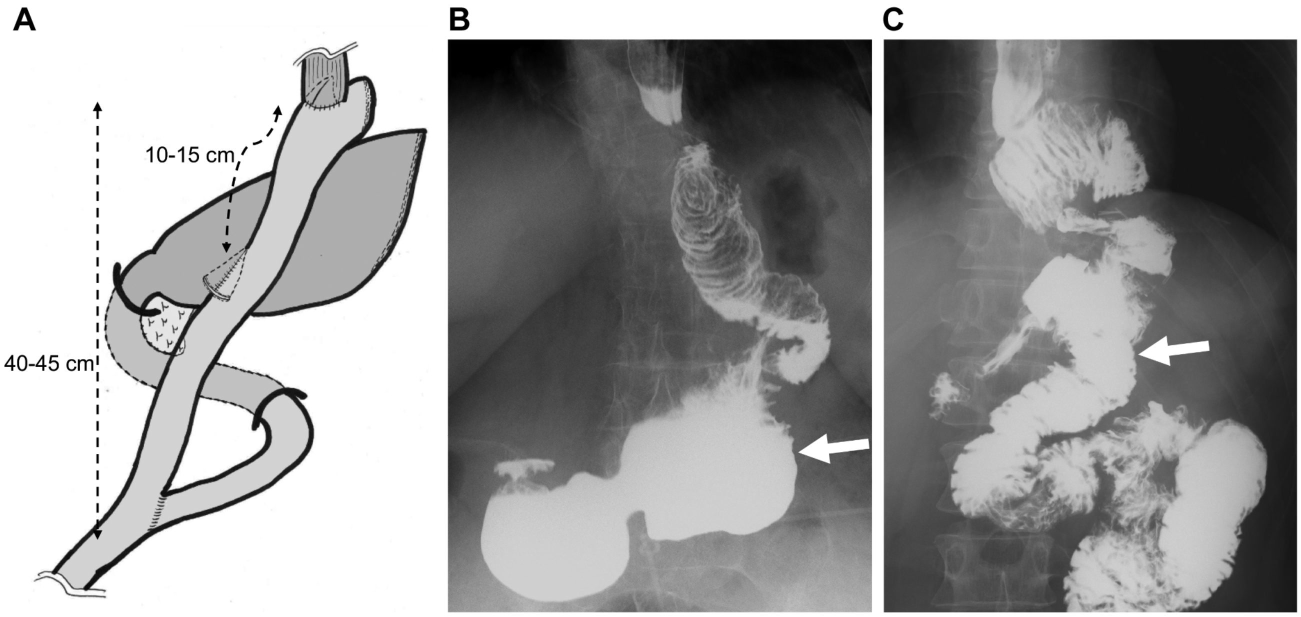

Figure 1. *Schema of the double-tract reconstruction procedure and representative postoperative fluoroscopy images showing low-density barium sulfate suspension. A) Esophagojejunostomy (EJ) using a circular stapling technique in patients operated on using the open approach; circular or linear stapling with the hand-sewn technique in those operated on with the laparoscopic approach. Jejunal-remnant stomach anastomosis (JRS) created using linear stapling and the hand-sewn technique. Jejunojejunostomy (JJ) was performed using the hand-sewn technique. Anastomotic distance from EJ to JRS and to JJ was 10-15 cm, and 40-45 cm, respectively. B) Postoperative fluoroscopy images showing low-density barium sulfate suspension passing through the remnant stomach, and C) jejunal loop.*

was considered to indicate statistical significance. All statistical data were analyzed with JMP® Pro 15 software (SAS Institute, Cary, NC, USA).

Results

Clinicopathological characteristics. The clinicopathological characteristics of patients in both the RSI and JL groups before and after propensity score matching are shown in Table I. Although not significant, patients in the RSI group tended to have higher VFI (p=0.065), lower depth of invasion (p=0.131), and lower postoperative adjuvant chemotherapy (p=0.115) than those in the JL group. After propensity score matching, all demographic and pathological characteristics were comparable between the two groups.

Preoperative BMI was significantly correlated with preoperative SMI (R=0.424; p=0.002; Figure 2A), VFI (R=0.622; p<0.001; Figure 2B), and SFI (R=0.642; p<0.001; Figure 2C). In addition, preoperative serum albumin level was significantly correlated with preoperative SMI (R=0.425; p=0.002; Figure 2D), VFI (R=0.353, p=0.012; Figure 2E), and SFI (R=0.340, p=0.016; Figure 2F).

Short term outcomes. Short term outcomes in both the RSI and JL groups after propensity score matching are shown in Table II. No significant difference was noted in surgical factors (operative time, blood loss, approach), postoperative complications of CD classification ≥ Grade 2, and postoperative duration of hospitalization.

Postoperative esophageal reflux findings. After propensity score matching (Table III), postoperative fluoroscopy findings showed a significantly higher degree of esophageal reflux in the JL group compared to the RSI group (p<0.001). Moreover, postoperative endoscopic findings showed a significantly higher grade of reflux esophagitis in the JL group compared to the RSI group (p=0.014).

Postoperative changes in nutritional factors. The postoperative changes in nutritional factors after propensity score matching are shown in Table IV. The percent decreases in BMI (p=0.049), VFI (p=0.002), and SFI (p=0.006) were significantly attenuated in the RSI group compared to the JL group. Also, postoperative controlling nutritional status score was significantly attenuated in the RSI group compared to the JL group (p=0.042).

Independent predictors associated with postoperative malnutrition. Univariate analysis using the logistic regression model showed that pathological stage, postoperative complications of CD classification ≥ Grade 2, and

Table I. *Clinicopathological characteristics.*

	All patients			After matching		
	RSI (n=28)	JL (n=22)	*p*-Value	RSI (n=20)	JL (n=20)	*p*-Value
Age, years	73 (44-85)	70 (38-83)	0.518	72.5 (52-85)	70 (40-83)	0.616
Sex						
Male	21 (75.0)	14 (63.6)	0.384	14 (70.0)	12 (60.0)	0.507
Female	7 (25.0)	8 (36.4)		6 (30.0)	8 (40.0)	
Body weight, kg	63 (44-85)	59.8 (41-76)	0.314	67.7 (44-80)	61 (41-76)	0.256
BMI, kg/m^2	23.7 (16.4-33.4)	23.1 (18-29.2)	0.253	24.2 (16.4-33.4)	23.1 (18-29.2)	0.304
Albumin, g/dl	4.0 (3.1-4.9)	3.8 (2.8-4.9)	0.336	4.0 (3.1-4.7)	3.8 (2.8-4.9)	0.296
C-reactive protein, mg/dl	0.13 (0.02-0.54)	0.14 (0.03-0.98)	0.487	0.13 (0.02-0.54)	0.08 (0.03-0.98)	0.776
Total cholesterol, mg/dl	182 (124-248)	183 (106-321)	0.815	180 (124-248)	183 (106-279)	0.655
Total lymphocyte count, 10^3 µl	1698 (754-2678)	1708 (869-3224)	0.525	1698 (754-2678)	1628 (869-3219)	0.655
SMI, cm^2/m^2	49.3 (31.7-75.9)	47.3 (36.4-66.7)	0.369	50.2 (31.7-75.9)	46.7 (36.4-66.7)	0.317
VFI, cm^2/m^2	57.1 (22.5-101.3)	46.6 (17.6-77.3)	0.065	58.1 (22.5-101.3)	44.1 (17.6-77.3)	0.126
SFI, cm^2/m^2	51.8 (17.5-210.1)	51.1 (10.8-108.3)	0.930	51.3 (17.5-210.1)	50.3 (10.8-108.3)	1.000
ASA-PS (1/2/3)	7 (25.0)/16 (57.1)/ 5 (17.9)	4 (18.2)/16 (72.7)/ 2 (9.1)	0.496	5 (25.0)/11 (55.0)/ 4 (20.0)	4 (20.0)/14 (70.0)/ 2 (10.0)	0.566
Tumor location						
Upper third	22 (78.6)	17 (77.3)	0.912	16 (80.0)	16 (80.0)	1.000
Esophagogastric junction	6 (21.4)	5 (22.7)		4 (20.0)	4 (20.0)	
Depth of invasion						
T1	19 (67.9)	9 (40.9)	0.131	12 (60.0)	9 (45.0)	0.490
T2	6 (21.4)	5 (22.7)		5 (25.0)	5 (25.0)	
T3	3 (10.7)	7 (31.8)		3 (15.0)	6 (30.0)	
T4	0 (0.0)	1 (4.6)		0 (0.0)	0 (0.0)	
Lymph node metastasis						
N0	23 (82.1)	15 (68.1)	0.507	15 (75.0)	15 (75.0)	1.000
N1	4 (14.3)	4 (18.2)		4 (20.0)	4 (20.0)	
N2	1 (3.6)	2 (9.1)		1 (5.0)	1 (5.0)	
N3	0 (0.0)	1 (4.6)		0 (0.0)	0 (0.0)	
Pathological stage[a]						
I	19 (67.8)	11 (50.0)	0.294	11 (55.0)	11 (55.0)	1.000
II	8 (28.6)	8 (36.4)		8 (40.0)	8 (40.0)	
III	1 (3.6)	3 (13.6)		1 (5.0)	1 (5.0)	
Postoperative adjuvant chemotherapy	2 (7.1)	5 (22.7)	0.115	2 (10.0)	3 (15.0)	0.633

Data shown as median (range) or number of cases (%). BMI: Body mass index; SMI: skeletal muscle mass index; VFI: visceral fat index; SFI: subcutaneous fat index; ASA-PS: American Society of Anesthesiologists-Physical Status; RSI: remnant stomach influx; JL: jejunal-loop. [a]TNM classification 8th edition.

postoperative food passage were significantly associated with postoperative malnutrition (Table V). Multivariate analysis extracted postoperative food passage (odds ratio=5.74; p=0.018) and pathological stage (odds ratio=6.30; p=0.015) as independent predictors of postoperative malnutrition.

Discussion

PG is a function-preserving gastrectomy procedure allowing for more than half of the remnant stomach volume and the pylorus to be retained. However, since the cardia prevents esophageal reflux in cooperation with the adjacent diaphragmatic crus, loss of the cardia results in esophageal reflux. Therefore, reconstruction procedures such as the double-flap technique (DFT), and the side overlap with fundoplication by Yamashita (SOFY) method have been developed for anti-reflux purposes other than DT (12-14). Previous studies have severally reported the rate of reflux esophagitis ≥ Grade B as 6.7-25% in DT (15-18), 0-10.5% in DFT (19-22), and 10% in the SOFY method (12). In this study, reflux esophagitis ≥ Grade B was comparable to that of these previous studies at 14% in all patients. After propensity score matching, rate of reflux esophagitis ≥ Grade B was 0% in the RSI group and 25% in the JL group, suggesting the importance of RSI in preventing esophageal reflux after PGDT. Consequently, we surmise that the reduced esophageal reflux in the RSI group was due to influx into the remnant stomach. In contrast, reflux easily reaches the esophagus due to the loss of RSI in the JL group in our opinion. While numerous studies have reported on the

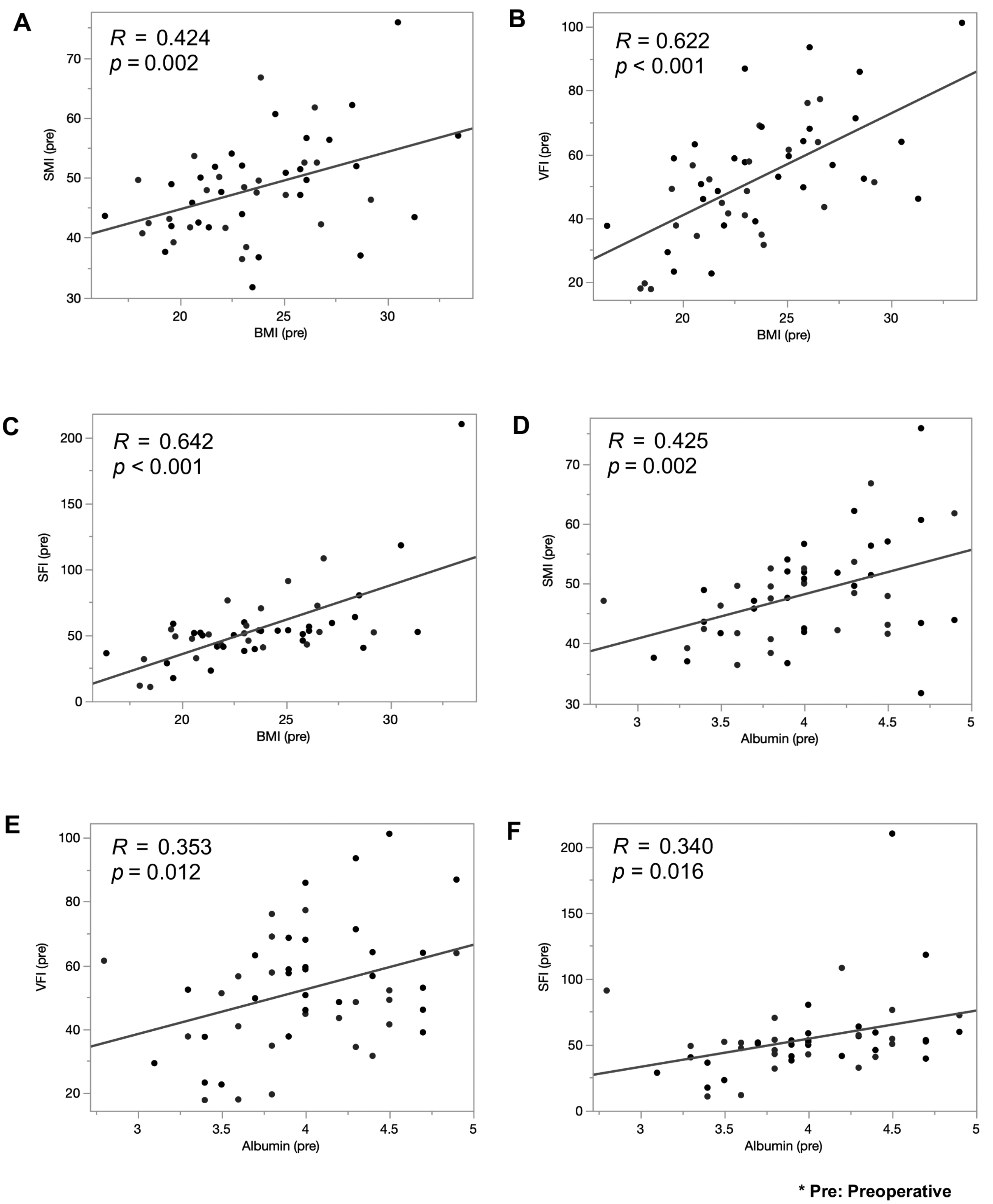

Figure 2. *Correlation between preoperative body mass index (BMI)/serum albumin levels and body composition values. BMI was significantly correlated with preoperative A) Skeletal muscle mass index (SMI) (R=0.424; p=0.002), B) Visceral fat index (VFI) (R=0.622; p<0.001), and C) Subcutaneous fat index (SFI) (R=0.642; p<0.001). Serum albumin level was significantly correlated with D) SMI (R=0.425; p=0.002), E) VFI (R=0.353, p=0.012), and F) SFI (R=0.340, p=0.016).*

Table II. *Short-term outcomes after propensity score matching.*

	RSI (n=20)	JL (n=20)	*p*-Value
Operative time, min	285.5 (207-483)	334.5 (206-549)	0.148
Blood loss, ml	163 (10-813)	182.5 (5-1142)	0.655
Approach			
Open	11 (55.0)	9 (45.0)	0.527
Laparoscopic	9 (45.0)	11 (55.0)	
Postoperative complications[a]			
Pulmonary	3 (15.0)	2 (10.0)	0.633
Bowel obstruction	2 (10.0)	2 (10.0)	1.000
Delayed gastric emptying	2 (10.0)	0 (0.0)	0.147
Anastomotic stricture	2 (10.0)	1 (5.0)	0.548
Anastomotic leakage	1 (5.0)	2 (10.0)	0.548
Biliary fistula	1 (5.0)	0 (0.0)	0.311
Postoperative hospitalization duration, days	15 (9-34)	13 (7-51)	0.254

Data shown as median (range) or number of cases (%). [a]Clavien-Dindo Classification ≥ Grade 2. RSI: Remnant stomach influx; JL: jejunal-loop.

Table III. *Postoperative esophageal reflux findings and pseudo-fornix formation after propensity score matching.*

	RSI (n=20)	JL (n=20)	*p*-Value
Postoperative fluoroscopy findings			
Degree of esophageal reflux			<0.001
None	1 (5.0)	0 (0.0)	
Mild	17 (85.0)	5 (25.0)	
Moderate	2 (10.0)	10 (50.0)	
Severe	0 (0.0)	5 (25.0)	
Postoperative endoscopic findings			
Grade of reflux esophagitis[a]			0.014
M	18 (90.0)	10 (50.0)	
A	2 (10.0)	5 (25.0)	
B	0 (0.0)	5 (25.0)	

Data shown as number of cases (%), [a]Los Angeles Classification System. RSI: Remnant stomach influx; JL: jejunal-loop.

association of malnutrition and food passage after PGDT (23, 24), to our knowledge, no study has yet evaluated the association of food passage route with esophageal reflux.

In this study, we defined postoperative malnutrition according to the ESPEN guideline, which focuses on postoperative weight loss and decreased BMI (9). Studies have shown that weight loss one year after surgery in PGDT was 5.9-12.4% (17, 18, 25, 26). Comparatively, postoperative weight loss in this study, was 13.1% in the RSI group and 18.1% in the JL group, which is slightly higher than in the previous studies. This is attributable to the older age in this study compared with those studies (72 years *vs*. 59.8-71 years, respectively). Moreover, this study had a higher percentage of fStage II, III cases compared to previous studies (40% *vs*. 0-47%, respectively); this may affect postoperative weight loss. Yamashita *et al*. evaluated the food passage route after PGDT, and reported that weight loss one year after surgery was 14.7% in all the patients. However, comparative weight loss between the RSI and JL groups was indeterminate (24). In addition to postoperative weight loss, we evaluated the percent decrease in body composition, showing that skeletal muscle was relatively maintained, while visceral fat and subcutaneous fat rapidly decreased in the JL group compared to the RSI group. Because preoperative VFI and SFI were correlated with preoperative serum albumin levels, we consider percent decrease in visceral fat and subcutaneous fat as important indicators of postoperative malnutrition, along with weight loss. In conclusion, the physiological food passage route through the remnant stomach and duodenum seems advantageous in terms of digestion and absorption, resulting in relatively maintained body weight, visceral fat, and subcutaneous fat in the RSI group.

In gastric cancer patients, PG along with TG is a risk factor for postoperative malnutrition compared to distal gastrectomy (27). In previous retrospective cohort studies, food passage route, sex, and postoperative weight loss were reported as risk

Table IV. *Postoperative changes in nutritional factors after propensity score matching*.

	RSI (n=20)	JL (n=20)	*p*-Value
Postoperative malnutrition[a]	11 (55.0)	15 (75.0)	0.185
BMI, kg/m^2			
Preoperative	24.2 (16.4-33.4)	23.1 (18-29.2)	0.304
Postoperative	20.7 (14.4-30.2)	18.3 (13.9-26)	0.022
Percent Change	–13.1%	–18.1%	0.049
Albumin, g/dl			
Preoperative	4.0 (3.1-4.7)	3.8 (2.8-4.9)	0.296
Postoperative	4.0 (2.9-4.7)	3.8 (1.7-4.4)	0.370
Percent change	–0.01%	–0.04%	0.946
CONUT score, normal/light/moderate/severe			
Preoperative	11 (55.0)/9 (45.0)/0 (0.0)/0 (0.0)	11 (55.0)/7 (35.0)/2 (10.0)/0 (0.0)	0.325
Postoperative	14 (70.0)/4 (20.0)/2 (10.0)/0 (0.0)	8 (40.0)/10 (50.0)/0 (0.0)/2 (10.0)	0.042
Modified GPS, score 0/1/2			
Preoperative	16 (80.0)/4 (20.0)/0 (0.0)	15 (75.0)/4 (20.0)/1 (5.0)	0.597
Postoperative	17 (85.0)/3 (15.0)/0 (0.0)	15 (75.0)/3 (15.0)/2 (10.0)	0.346
SMI, cm^2/m^2			
Preoperative	50.2 (31.7-75.9)	46.7 (36.4-66.7)	0.317
Postoperative	47.6 (23.3-73.4)	44.4 (24.9-60.5)	0.140
Percent change	–5.3%	–8.3%	0.409
VFI, cm^2/m^2			
Preoperative	58.1 (22.5-101.3)	44.1 (17.6-77.3)	0.126
Postoperative	35.1 (10.7-96.5)	15.1 (5.7-45.6)	0.002
Percent change	–30.9%	–56.3%	0.002
SFI, cm^2/m^2			
Preoperative	51.3 (17.5-210.1)	50.3 (10.8-108.3)	1.000
Postoperative	32.9 (11.5-182.2)	23.9 (3.7-58.1)	0.037
Percent change	–22.9%	–49.2%	0.006

Data shown as median (range) or number of cases (%), [a]ESPEN guideline. BMI: Body mass index; CONUT: controlling nutritional status; GPS: Glasgow prognostic score; SMI: skeletal muscle mass index; VFI: visceral fat index; SFI: subcutaneous fat index. RSI: remnant stomach influx; JL: jejunal-loop.

Table V. *Univariate and multivariate analysis of postoperative malnutrition in all patients*.

			Univariate		Multivariate	
Variables	Cut-off value	n	Odds ratio (95%CI)	*p*-Value	Odds ratio (95%CI)	*p*-Value
Age, years	<70	20	1.00	0.401		
	≥70	30	1.94 (0.41-9.14)			
Sex	Male	35	1.00	0.297		
	Female	15	2.44 (0.46-13.09)			
BMI, kg/m^2	<22.0	18	1.71 (0.36-8.06)	0.500		
	≥22.0	32	1.00			
Pathological stage	I	30	1.00	0.020	1.00	0.015
	II, III	20	6.15 (1.33-28.48)		6.30 (1.44-27.65)	
Approach	Open	24	1.57 (0.31-8.05)	0.587		
	Laparoscopic	26	1.00			
Operative time, min	<320	25	1.70 (0.34-8.44)	0.519		
	≥320	25	1.00			
Postoperative complications (CD ≥ Grade 2)	Yes	12	7.88 (1.04-59.63)	0.046	4.17 (0.79-21.90)	0.092
	No	38	1.00		1.00	
Postoperative food passage route	Remnant stomach	28	1.00	0.013	1.00	0.018
	Jejunal loop	22	7.70 (1.54-38.61)		5.74 (1.36-24.28)	

BMI: Body mass index; CD: Clavien-Dindo classification.

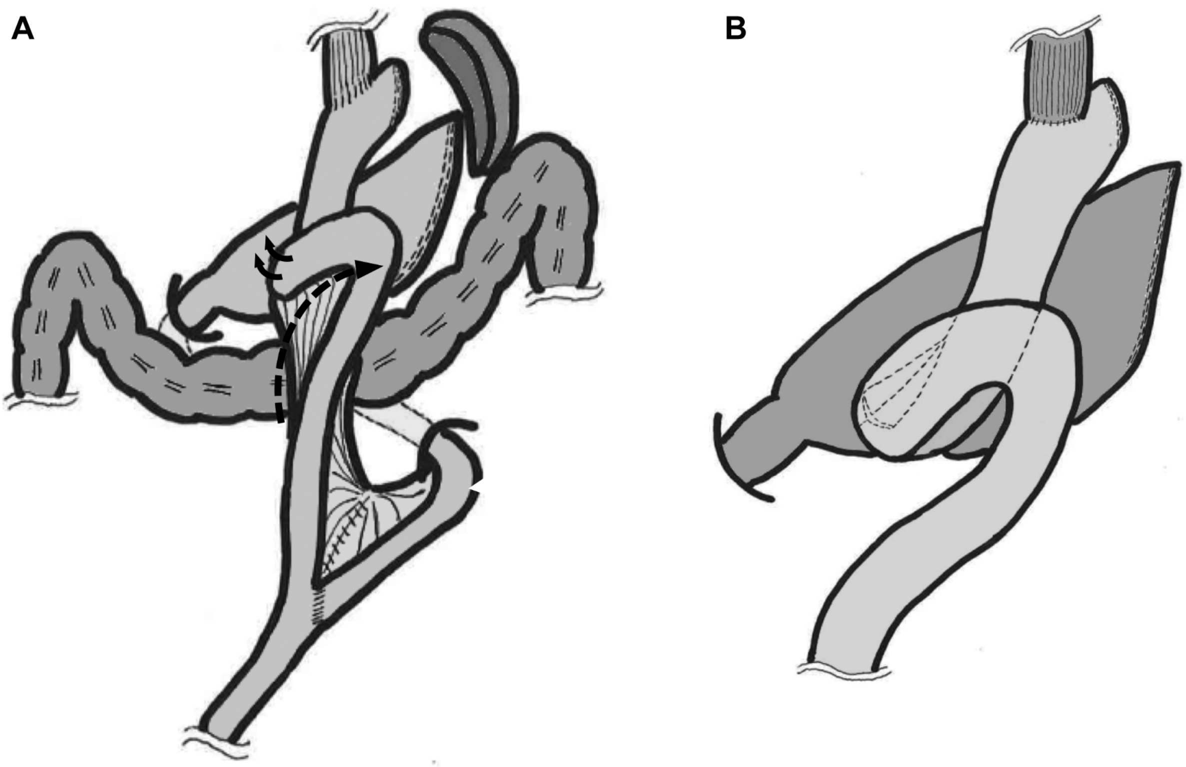

Figure 3. *Surgical techniques to prevent influx into the jejunal loop. A) After the double-tract reconstruction procedure, the jejunal loop distal from the JRS anastomosis was turned-over and lifted-up (dotted arrow), and fixed to the remnant stomach with 1-2 sutures (solid arrow). B) Food passage was more likely to influx into the remnant stomach by preventing influx into the distal jejunal loop.*

factors associated with postoperative malnutrition after PGDT (23, 24). In this study, postoperative complications of CD classification ≥ Grade 2 were selected as a predictor of postoperative malnutrition in the univariate analysis, but not in the multivariate analysis. Both the RSI and JL groups showed no difference in postoperative complications including delayed gastric emptying, anastomotic stricture, and anastomotic leakage. Therefore, postoperative malnutrition may be attenable to the postoperative food passage route, rather than the presence or absence of postoperative complications after PGDT. This yet again highlights the nutritional importance of food passage through the remnant stomach. Since influx into the jejunal loop was indicated as a risk factor for postoperative nutritional decline, we improved surgical techniques to prevent influx into the jejunal loop as shown in Figure 3. After the double-tract reconstruction procedure, we turned-over and lifted-up the jejunal loop distal from the JRS anastomosis, followed by fixation of the distal jejunal loop and remnant stomach (Figure 3A). With this improved method, we believe that food passage is more likely to influx into the remnant stomach while preventing its influx into the distal jejunal loop. Further studies are needed to evaluate esophageal reflux and nutritional status using this improved method after PGDT.

Study limitations. First, this was a single-center retrospective study where the follow-up duration was limited to one year. Observation was limited to short-term outcomes that developed during the one-year follow-up period, and this may limit the ability to observe findings that emerge over the long term. Second, the study included a limited number of patients, and so our findings may not be generalizable to a wider population. Third, contrast agents were typically used in liquid suspension to evaluate food passage; thus, solid food passage was not evaluated. Solid food containing contrast agents may be required for similar future studies. These limitations notwithstanding, to our knowledge, no studies have clarified the association of esophageal reflux, food passage route, and postoperative malnutrition in patients with gastric cancer after PGDT. Thus, we think our study constitutes valuable clinical research, quantifying food passage after PGDT along with other conventional predictive factors.

Conclusion

Our results suggest that food passage through the remnant stomach reduces postoperative esophageal reflux and postoperative malnutrition in patients with gastric cancer after PGDT. In addition, the postoperative food passage route is an independent predictor associated with postoperative malnutrition. Therefore, improvement of the jejunal-remnant stomach anastomosis is essential to ensure satisfactory remnant stomach influx.

Conflicts of Interest

The Authors declare no conflicts of interest in relation to this article.

Authors' Contributions

Conception and design: RN, TS, and SA. Analysis and interpretation of data: RN, TS, SA, MO, KY, MM, MS, KK, TU, and HY. Drafting of the article: RN. Critical revision for important intellectual content: TS, SA, and SS. Final approval of the article: All Authors.

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