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ORIGINAL ARTICLE

Preservation of physiological passage through the remnant stomach prevents postoperative malnutrition after proximal gastrectomy with double tract reconstruction

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Abstract

Purpose Double tract reconstruction (DT) after proximal gastrectomy (PG) is considered beneficial for postoperative nutrition status by preserving the physiological passage of food. We conducted this study to assess postoperative nutrition status based on food passage after this operation.

Methods The subjects of this retrospective study were 63 patients who underwent PG with DT. The patients were divided into two groups according to whether they had postoperative malnutrition (PM) 1 year postoperatively (PM group) or not (non-PM group). PM was defined by both weight loss > 10% and a low body mass index of < 20 or < 22 kg/m^2 for patients younger and older than 70 years, respectively. We then evaluated the predictors of PM.

Results There were 33 patients in the PM group. These patients were predominantly female ($p < 0.01$) and lacked physiological passage through the remnant stomach (PRS) on postoperative fluoroscopy (defined as non-PRS, $p = 0.03$). Multivariate logistic regression analysis revealed that female gender and non-PRS status were independent predictors of PM (odds ratio [95% CI]; 7.42 [1.33–41.4]; $p = 0.02$, 6.77 [1.01–45.4]; $p = 0.04$, respectively).

Conclusion Preservation of the physiological passage of food through the remnant stomach prevents PM after PG with DT.

Keywords Proximal gastrectomy · Double tract reconstruction · Postoperative malnutrition · Fluoroscopy

Introduction

Proximal gastrectomy (PG) with regional lymph node dissection is performed for early gastric cancer located in the upper stomach and for early esophagogastric junction (EGJ) cancer [1, 2]. Recent studies show that the oncological outcome of PG is equivalent to that of TG [3]. According to one study, PG was superior to TG for preventing postoperative disorders, such as diarrhea, dumping syndrome, and weight loss [4]. Therefore, PG seems to be performed more often as function-preserving surgery with oncological safety for early upper-third gastric cancer and EGJ cancer.

Considering proximal gastrectomy as function-preserving surgery, the reconstruction procedure plays an important role in compensating for the lost function. There are several possible reconstructive procedures after proximal gastrectomy: esophagogastrostomy (EG), jejunal interposition (JI), jejunal pouch interposition (JPI), and double tract (DT) reconstruction. The advantages of each procedure are documented; however, no consensus exists on the optimal reconstructive procedure after PG [5]. DT reconstruction after gastrectomy was first reported by Kajitani and Sato in 1965. In DT reconstruction, gastrojejunostomy is performed below the esophagojejunostomy to preserve physiological food passage to the duodenum through the remnant stomach, which should prevent postoperative malnutrition (PM). There are several reports on postoperative nutritional status after PG

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with DT [6, 7], but none focuses on food passage after this reconstruction procedure.

We assessed PM after proximal gastrectomy with double tract reconstruction, retrospectively, evaluating the passage of food by postoperative fluoroscopy. The purpose of this study was to elucidate the influence of the passage of food on postoperative nutritional status after PG with DT.

Materials and methods

Patients

Between 2009 and 2016, 77 patients underwent PG with DT in the Department of Gastroenterological Surgery of Graduate School of Medical Science at Kumamoto University (Kumamoto, Japan). The operative indications were clinically early gastric cancer and EGJ cancer, including additional resections after endoscopic resection, and when more than half of the distal stomach could be preserved. The following patients were excluded from the analysis: six who did not undergo postoperative fluoroscopy due to their poor condition, four whose medical records lacked complete clinical data, and four with preoperative malnutrition with a BMI less than 18.5. The remaining 63 patients enrolled in this retrospective study were divided into two groups according to whether they had PM (PM group) or not (non-PM group). Malnutrition was defined according to the diagnostic criteria for malnutrition option 2 in the ESPEN guideline as follows: weight loss > 10% and reduced body mass index (BMI) which is < 20 or < 22 kg/m^2 in patients younger and older than 70 years, respectively [8]. The study procedures were approved by the institutional review board (No. 1037), which waived the requirement for informed consent because of the retrospective nature of the study.

Surgical procedure and postoperative treatment

All patients underwent either open or laparoscopic PG with DT. The laparoscopic approach was generally performed for early gastric cancer in our institute. The surgical technique was described in detail previously [7]. Briefly, the upper part of the stomach, and in some cases the lower esophagus, was resected with adequate surgical margins for the tumor. Standard D1 + lymph node dissection, as defined by the Japanese gastric cancer treatment guidelines [1], was performed for all patients. After resection and lymph node dissection, DT reconstruction was performed. The jejunum was transected at a point 20 cm distal from the ligament of Treitz and the distal jejunal limb was brought up through the antecolic or retrocolic route. Esophagojejunostomy (EJ) was performed using a circular stapler and jejunojejunostomy (JJ) was performed using the hand-sewn technique. Gastrojejunostomy (GJ) was performed using a linear stapler or the hand-sewn technique. The distance of the anastomosis from EJ to GJ and to JJ was 15 cm and 40 cm, respectively (Fig. 1).

Evaluation of clinical parameters

The patient characteristics, surgical parameters, and postoperative outcomes were obtained from their medical records. The preoperative subcutaneous and visceral fat areas at the umbilicus level were measured by the Synapse Vincent system (FUJIFILM, Japan) using a previously reported procedure [9]. All preoperative clinical data were obtained within 1 month preoperatively, and postoperative data were obtained 1 year postoperatively. The pathological classification of the tumor was based on the Japanese Classification of Gastric Carcinoma [10] and postoperative complications were assessed by the Clavien–Dindo classification [11].

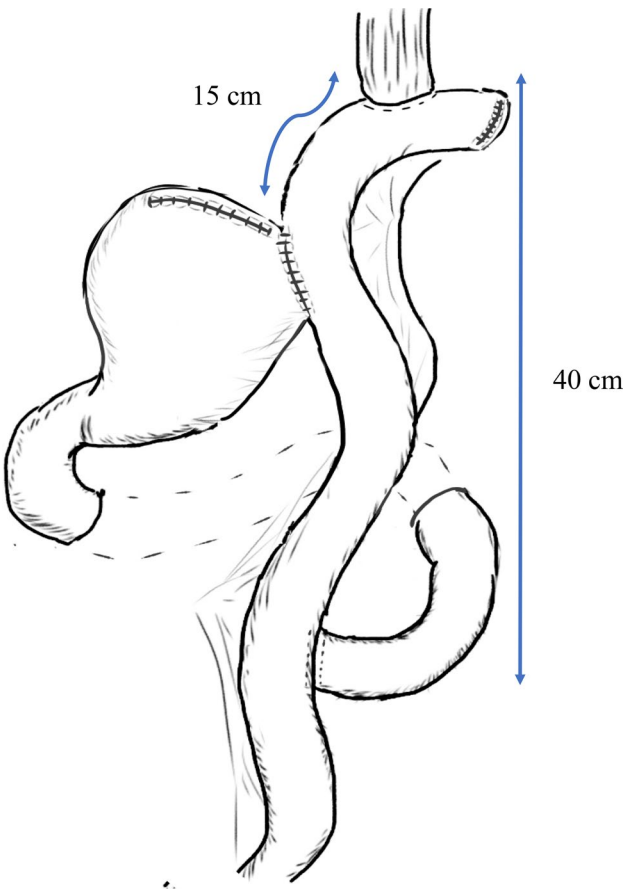

Fig. 1 Schema of double tract reconstruction. Esophagojejunostomy (EJ) was performed using a circular stapler and jejunojejunostomy (JJ) was performed using the hand-sewn technique. Gastrojejunostomy (GJ) was performed using a linear stapler or hand-sewn technique. The distance of the anastomosis from EJ to GJ and to JJ was 15 cm and 40 cm, respectively

Postoperative fluoroscopy

Postoperative fluoroscopy was performed routinely on postoperative day (POD) 4 to confirm the absence of anastomotic leakage or stenosis. The findings were classified into two types according to the passage route of the contrast agent: if the contrast agent passed through the remnant stomach, this was defined as "passed through the remnant stomach (PRS)", whereas if it did not pass through the remnant stomach, this was referred to as non-PRS (Fig. 2).

Statistical analysis

The clinicopathological factors and clinical outcomes of the two groups were compared using Wilcoxon tests for quantitative variables and Chi square tests for qualitative variables. Multivariate logistic regression analysis was performed to identify independent predictors of PM. All statistical analyses were performed by JMP® version 13.1 software (SAS Institute) and $p < 0.05$ was considered significant.

Results

Table 1 summarizes the patients' background and clinicopathological features. There were 33 patients in the PM group and 30 patients in the non-PM group. Women were more likely than to have PM (men, 18; women, 15; $p < 0.01$). No significant differences were observed between the groups in preoperative nutrition factors such as BMI, subcutaneous fat or visceral fat, and hematological nutritional indicators including serum albumin, total protein, and hemoglobin levels. Tumor factors such as location, size, histological type, T stage, N stage, and stage grouping did not differ significantly between the two groups.

Table 2 shows the operative procedure and postoperative short-term outcomes. The operative approach did not differ significantly and there were no significant differences in the operative time or intraoperative blood loss between the two groups. Regarding the short-term outcomes, postoperative complications, including anastomotic leakage and anastomotic stenosis, were equivalent in the two groups. Notably, PRS was significantly less likely to cause postoperative malnutrition ($p = 0.03$). There was no difference between the two groups even in the presence or absence of reflux symptoms 1 year postoperatively. Furthermore, early recurrence within 1 year was detected in six patients, which was not associated with PM. The nutritional parameters such as serum albumin, total protein, and hemoglobin level 1 year postoperatively in the PM group tended to be lower than that in the non-PM group. The total weight loss (TWL) and %TWL in the PM group were significantly higher than those in non-PM group ($p < 0.01$).

Logistic regression analyses were performed to identify the predictor of PM (Table 3). Univariate analysis showed that the following factors were significantly associated with PM: female gender and non-PRS. Finally, multivariate analysis revealed that the following factors were independent predictors of PM: female gender (odds ratio (OR) 7.42, 95% CI 1.33–41.4, $p = 0.02$) and non-PRS (OR 6.77, 95% CI 1.01–45.4, $p = 0.04$).

Discussion

The present study assessed postoperative nutrition status after PG with DT. In addition to gender, the passage of contrast agent through the remnant stomach in postoperative fluoroscopy was associated with PM, suggesting that physiological food passage to the duodenum through the remnant stomach does maintain postoperative nutrition status. Only a few reports on nutritional assessment after PG with DT have been published and, to our knowledge, this is the first report evaluating actual food passage by postoperative fluoroscopy.

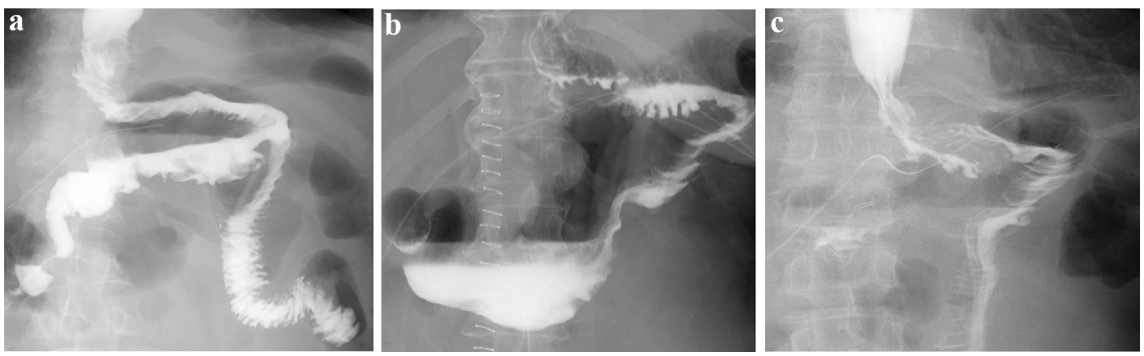

Fig. 2 Postoperative fluoroscopy images. The contrast agent passed through both the remnant stomach and the jejunum in **a**, only the remnant stomach in **b** and only the jejunum in **c**. The images in **a** and **b** were classified as "passing through the remnant stomach (PRS) and those in **c** were classified as non-PRS

Table 1 Clinicopathological features of the patients

	Total ($N=63$)	Postoperative malnutrition		p value
		Presence ($N=33$)	Absence ($N=30$)	
Age (years)	73 (36–87)	66 (36–87)	74 (36–87)	0.07
Sex				**< 0.01**
Male	44 (69.8%)	18 (54.5%)	26 (86.7%)	
Female	19 (30.2%)	15 (45.5%)	4 (13.3%)	
BMI (kg/m^2)[a]	22.5 (18.9–33.3)	23.5 (18.9–28.9)	23.5 (19.5–33.3)	0.19
Subcutaneous fat (cm^2)[a]	107.9 (12.8–362.4)	100.3 (12.8–362.4)	114.8 (24.5–232.1)	0.95
Visceral fat (cm^2)[a]	120.3 (13.4–242.5)	119.7 (38.2–236.1)	121.6 (13.4–242.5)	0.88
Albumin (mg/dl)	4.0 (2.8–5.2)	4.0 (2.8–4.7)	4.1 (3.6–5.2)	0.40
Total protein (mg/dl)	6.9 (5.6–7.8)	6.9 (5.6–7.7)	6.9 (5.6–7.8)	0.77
Hemoglobin (mg/dl)	13.3 (8.7–18.4)	13.2 (8.7–18.4)	13.8 (10.2–16.9)	0.17
Tumor location				0.96
EG/E = G/GE	33 (52.4%)	13 (39.4%)	12 (40.0%)	
U	30 (47.6%)	20 (60.6%)	18 (60.0%)	
Tumor size (mm)	(10.0–80.0)	26 (10–75)	31 (10–80)	0.40
Histological type				0.49
Differentiated	47 (74.6%)	26 (78.8%)	21 (70.0%)	
Undifferentiated	13 (20.6%)	5 (15.1%)	8 (26.7%)	
Others[b]	3 (4.8%)	2 (6.1%)	1 (3.3%)	
T stage				0.91
T1/T2	50 (79.4%)	26 (78.8%)	24 (80.0%)	
T3/T4	13 (20.6%)	7 (21.2%)	6 (20.0%)	
N stage				0.65
N0	51 (80.9%)	26 (78.8%)	25 (83.3%)	
N1/N2/N3	12 (19.1%)	7 (21.2%)	5 (16.7%)	
Stage				0.84
I	49 (77.8%)	26 (78.7%)	23 (76.7%)	
II	9 (14.3%)	5 (15.2%)	4 (13.3%)	
III	5 (7.9%)	2 (6.1%)	3 (10.0%)	

Data are represented by the number of cases (%) or mean number (range)

BMI body mass index

[a]BMI, subcutaneous fat, and visceral fat values are those within 1 month before the operation

[b]Others include neuroendocrine carcinoma, adenosquamous carcinoma, and basaloid carcinoma

PG is currently regarded as limited surgery with function preservation. Therefore, it is important that the quality of life (QOL) of patients who undergo PG is maintained, including postoperative nutritional status, which depends greatly on the reconstruction procedure. Although there are only limited studies with small sample sizes [6, 7], DT is a simpler reconstruction procedure with relatively few reflux symptoms. Moreover, DT seems to have an advantage in terms of digestion and absorption by preserving food passage through the remnant stomach and duodenum. In fact, Takase et al. found that food passage through the duodenum resulted in better absorption ability and physiological state in patients who underwent gastrectomy using stable isotope ^{13}C-labeled lipid compound [12]. Nevertheless, previous studies which compared DT with other reconstruction procedure did not consider whether food passes to the jejunum and the remnant stomach in DT, which may lead to underestimating the nutritional utility of DT [7, 13]. Thus, we examined the relationship between the passage route and PM and confirmed the importance of preserving physiological food passage to prevent PM. Furthermore, we evaluated the passage route by postoperative fluoroscopy performed routinely after the operation to confirm the absence of anastomotic leakage or stenosis. This simple and minimally invasive modality is a valuable indicator of nutritional status.

In the current study, we used the diagnostic criteria for malnutrition proposed in the ESPEN guideline, which is widely accepted all over the world [8]. There are two options in this guideline: option 1 is a BMI < 18.5; and option 2 is a combination of weight loss > 10% and a reduced BMI, to < 20 kg/m^2 for people < 70 years of age, or < 22 kg/m^2 for people ≥ 70 years of age, respectively. Although it is easy

Table 2 Operative procedure and short-term outcomes

	Total ($N=63$)	Postoperative malnutrition		p value
		Presence ($N=33$)	Absence ($N=30$)	
Approach				0.50
Open	28 (44.4%)	16 (48.5%)	12 (40.0%)	
Laparoscopic	35 (55.6%)	17 (51.5%)	18 (60.0%)	
Operative time (min)	388 (238–628)	372 (238–628)	402 (248–612)	0.43
Blood loss (g)	212 (5–1330)	200 (5–1330)	280 (11–803)	0.31
Postoperative fluoroscopy				**0.03**
PRS	52 (82.5%)	24 (72.7%)	28 (93.3%)	
Non-PRS	11 (17.5%)	9 (27.3%)	2 (6.7%)	
Complications				
Presence (≥CDc grade III)	16 (25.4%)	6 (18.2%)	10 (33.3%)	0.17
Anastomotic leakage	10 (15.9%)	3 (9.1%)	7 (23.3%)	0.12
Anastomotic stenosis	2 (3.0%)	2 (6.1%)	0 (0.0%)	0.10
Adjuvant chemotherapy	9 (14.3%)	4 (12.1%)	5 (16.7%)	0.61
Postoperative reflux syndrome	8 (12.7%)	5 (15.2%)	3 (10.0%)	0.54
Recurrence within 1 year	6 (9.5%)	3 (9.1%)	3 (10.0%	0.90
Postoperative nutritional status[a]				
TWL (kg)	8.6 (1.8–32)	10.8 (4.0–28.5)	5.75 (1.8–32.0)	**<0.01**
%TWL	14.7 (2.7–43.5)	19.8 (10.1–43.5)	9.4 (2.7–31.1)	**<0.01**
Albumin (mg/dl)	3.9 (2.7–4.5)	3.8 (2.9–4.5)	4.1 (2.7–4.5)	0.06
Total protein (mg/dl)	6.6 (4.4–7.8)	6.6 (4.4–7.6)	6.7 (5.8–7.8)	0.33
Hemoglobin (mg/dl)	12.3 (8.2–16.1)	11.7 (8.8–16.1)	12.7 (8.2–15.9)	0.09

Data are expressed as the number of cases (%) or mean value (range)

PRS passage through the remnant stomach, *TWL* total weight loss, *CDc* Clavien–Dindo classification

[a]The values were measured 1 year postoperatively

Table 3 Univariate and multivariate analyses for predicting postoperative malnutrition

Factors	Objective variables	Controls	Univariate analysis			Multivariate analysis		
			OR	95% CI	p value	OR	95% CI	p value
Age	≥65 years	<65 years	2.73	0.94–7.98	0.06			NS
Sex	Female	Male	5.42	1.54–19.0	**<0.01**	7.42	1.33–41.4	**0.02**
Preoperative BMI	<22	≥22	0.98	0.35–2.68	0.96			NS
Tumor location	EGJ	U	0.98	0.35–2.68	0.96			NS
Approach	Open	Laparoscopic	1.41	0.52–3.84	0.50			NS
Postoperative fluoroscopy	Non-PRS	PRS	5.25	1.03–26.7	**0.03**	6.77	1.01–45.4	**0.04**
Complications (>CDc grade III)	Presence	Absence	0.44	0.14–1.43	0.17			NS
Adjuvant chemotherapy	Presence	Absence	0.69	0.17–2.85	0.61			NS
T stage	T3, T4	T1, T2	1.08	0.32–3.66	0.91			NS
N stage	N1, N2, N3	N0	1.35	0.38–4.80	0.65			NS

OR odds ratio, *CI* confidence interval, *BMI* body mass index, *EGJ* esophagogastric junction, *PRS* passage through the remnant stomach, *CDc* Clavien–Dindo classification

to perform objective nutritional assessment by the BMI, the cutoff BMI of <18.5 in the clinical and care setting remains questioned [14]. Option 2 includes factors such as body weight loss, which is commonly used as the dynamic postoperative nutritional parameter, and BMI depending on age. Therefore, we selected the option 2 criteria, which combined %TWL and age-specific BMI. Further analysis is needed to confirm that this definition is the optimal diagnostic criteria for PM.

This study had several limitations. First, it used a single-center retrospective study design and the sample size was relatively small because only recently PG has been

performed as function-preserving surgery with oncological safety. However, to our knowledge, this study has the largest sample size of all published studies assessing the postoperative nutritional status of patients who underwent PG with DT. Second, the passage route was evaluated by fluoroscopy 1 week postoperatively and it is unknown whether this early evaluation reflects long-term status. Although the passage route several years after the operation usually remains the same as that seen in the postoperative assessment, further evaluation in a time series might be needed. Moreover, we used contrast agent for evaluating the passage and it is unclear how well this agent reflects solid matter such as food. As reported earlier, these findings could be confirmed by using another modality, such as magnetic resonance imaging (MRI) and scintigraphy [15, 16]. Finally, this study design did not include long-term prognosis because PG is often performed for a relatively early-stage cancer with a good prognosis. Several studies have shown that nutritional status was associated with prognosis after gastrectomy [17, 18] and postoperative nutritional management is considered important, except for the oncological aspect.

In conclusion, we found that the preservation of physiological passage through the remnant stomach prevents PM in patients who underwent PG with DT. It is desirable to establish a reconstructive procedure that allows food to pass through both the distal jejunum side and the residual stomach side to maintain nutritional status after PG with DT because the factors associated with PRS remains unclear (Supplementary Table 1). We have improved several surgical techniques, including anastomosis with remnant stomach behind jejunum rib and fixation of remnant stomach to keep the original position. Further analysis is required to confirm that these techniques can improve PM.

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Author contributions YK and IM were responsible for the study conception and design; YK, KY, TT, KY, and KD for the acquisition of data; YK and IM for the analysis and interpretation of data; YK for the drafting of the manuscript; SH, HY, BY, MY, YN, and BH for critical revision of the manuscript.

Compliance with ethical standards

Conflict of interest We have no conflicts of interest to declare.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Ethical approval was obtained in all participating centers.

Informed consent Informed consent was obtained from all individual participants included in the study prior to recruitment. This article does not contain any studies with animals performed by any of the authors.

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