



Risk factors and prognosis of gastric stasis, a crucial problem after laparoscopic pylorus-preserving gastrectomy for early middle-third gastric cancer

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Abstract

Background Pylorus-preserving gastrectomy (PPG) is a function-preserving procedure for cT1N0 gastric cancer located in the middle-third of stomach, which is currently performed through a laparoscopic approach (LPPG). PPG is sometimes associated with a crucial problem during the early postoperative course, designated gastric stasis. However, information regarding gastric stasis remains to be fully elucidated.

Methods The study included 897 patients who underwent LPPG between 2005 and 2017. Early postoperative gastric stasis (E-stasis) was defined when the following conditions were fulfilled: upper abdominal distension, remnant stomach fullness on radiography image, and period of starvation exceeding 72 h within 1 month postoperatively. To evaluate long-term outcomes of E-stasis, late postoperative food residue (L-residue) was defined as grade 2 or higher food residue endoscopically according to the RGB (residue, gastritis, bile) classification at 1 year postoperatively. Risk factors and long-term outcomes of E-stasis were retrospectively analyzed.

Results E-stasis was the most common complication during the early postoperative course. E-stasis occurred in 68 (7.6%) patients. Multivariate analysis identified age (≥ 61 years), DM, and postoperative intraabdominal infection as risk factors. At 1 year postoperatively, relative body weight ratio and postoperative serum albumin in the patients who experienced E-stasis was significantly lower than those in the other patients ($P=0.042$ and 0.011 , respectively). Of the patients who suffered from E-stasis, 42.5% experienced L-residue.

Conclusions E-stasis after LPPG occurs in 7.6% of patients. Age, DM, and intraabdominal infection are significantly related to E-stasis. E-stasis is associated with poorer nutritional and functional outcomes even at 1 year postoperatively.

Keywords Laparoscopic pylorus-preserving gastrectomy · Gastric stasis · Early gastric cancer and remnant stomach

Ryo Takahashi and Manabu Ohashi contributed equally to this study.

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Introduction

Gastric cancer is the fifth most common cancer diagnosed worldwide, and affects approximately 1 million new individuals each year [1]. Because early gastric cancer is typically curable [2, 3], recent developments have tended to focus on function-preserving and less-invasive approaches to improve quality of life after surgery [4].

Pylorus-preserving gastrectomy (PPG) was initially applied to gastric ulcer in 1967 [5] and has been widely accepted as a function-preserving gastrectomy for gastric cancer [6]. In the current version of the Japanese Gastric Cancer Treatment Guidelines [7], PPG is described as a modified procedure for cT1N0 gastric cancer located in the middle-third of stomach. Currently, the procedure is

performed through a laparoscopic approach (LPPG) in many institutions [8–13]. Compared with conventional distal gastrectomy, PPG has several advantages for postoperative dumping syndrome, including postoperative nutritional status, bile reflux, and prognosis [14, 15].

However, PPG is sometimes associated with a crucial problem in the early postoperative course, designated gastric stasis or delayed gastric emptying. The problem remains to be fully clarified, even regarding its definition, although it is encountered by many surgeons who perform PPG. Patients with postoperative gastric stasis have excess food residue in the remnant stomach because of delayed discharge to the duodenum and experience postprandial nausea or upper abdominal distention. Such patients do not usually receive effective treatment and simply wait for recovery with starvation and infusion, inducing longer hospital stays. Based on these backgrounds, PPG is considered to confer benefits on limited patients. Some surgeons like to perform PPG because of its enhanced benefits, while others do not perform PPG because they dislike such unfavorable events. Thus, for performance of PPG that truly provides patient benefits, we should first understand why postoperative gastric stasis occurs and whether patients achieve benefits from PPG even if they experience gastric stasis. Although we previously reported that preservation of the infrapyloric vein was associated with prevention of gastric stasis [16], the results were based on data for only 56 consecutive patients. Because the incidence of gastric stasis was up to 23% in some reports [13–20], reliable investigations of gastric stasis based on information from large numbers of patients have not realized to date. Studies focusing on patients who experienced gastric stasis after PPG are indispensable to identify the risk factors and prognosis of such patients.

Herein we retrospectively analyzed a large number of patients with gastric cancer who underwent LPPG to identify the risk factors and long-term outcomes for gastric stasis after LPPG. To our knowledge, this is the first report to precisely focus on gastric stasis related to PPG. Information obtained from this large-size study will provide surgeons with useful foundations for indications, technical procedures, and postoperative follow-up of LPPG.

Methods

Patients

We selected patients from our prospective input database and reviewed their clinical records. All patients underwent LPPG for gastric cancer located in the middle-third of the stomach at Cancer Institute Hospital, Japanese Foundation for Cancer Research, Tokyo, Japan between March 2005 and December 2017. We excluded patients who underwent

conversion to open surgery or reoperation for additional resection, and those with synchronous malignancies or without gastric adenocarcinoma in histological subtypes.

Our indications for LPPG were early gastric cancer located in the middle-third of the stomach, intramucosal or submucosal carcinoma without lymph node metastasis (cT1N0), and patients without hiatal hernia or esophageal reflux. Although we considered that pyloric function was frequently insufficient in elderly patients, we considered that function-preserving and less-invasive approaches also bring benefits for these patients. Thus, we made a careful decision to perform LPPG for patients aged > 75 years.

Surgical procedure

The details of our operative techniques were described previously [16–18, 21–23]. A D1+ lymphadenectomy (Station No. 1, 3, 4sb, 4d, 6, 7, 8a, and 9 lymph nodes) was performed. The left side of the suprapancreatic lymph nodes (No. 11p) was also routinely dissected. During LPPG, the infrapyloric artery was routinely preserved [17], while the infrapyloric vein was only preserved in surgeries undertaken after August 2012 to retain venous drainage in the pyloric cuff [16]. The hepatic and pyloric branches of the vagal nerve were routinely preserved, and the celiac branch was often preserved by surgeon choice [21] in the former period of the study. Proximal gastric transecting line was Demel's line in principal. Oral remnant stomach was approximately preserved for one-third to one-second of whole stomach. The antrum was transected at 3–5 cm proximal to the pylorus at the anal side of the tumor to preserve the pyloric cuff. A gastrogastrostomy was performed extracorporeally by hand suture [22] in the former period. We introduced total LPPG with an intracorporeal delta-shaped gastrogastrostomy [18] from July 2010 and several surgeons began to use an intracorporeal end-to-end gastrogastrostomy by a piercing technique [23] from April 2014.

Analysis

In the present study, early postoperative gastric stasis (E-stasis) was defined when the following conditions were fulfilled: upper abdominal distension, remnant stomach fullness on radiography image, and period of starvation exceeding 72 h within 1 month postoperatively.

We assessed whether the following factors were associated with gastric stasis: sex, age (≥ 61 years vs. < 61 years), body mass index (BMI) (≥ 20.9 kg/m² vs. < 20.9 kg/m²), diabetes mellitus (DM), operation time (≥ 259 min vs. < 259 min), intraoperative blood loss (≥ 30 ml vs. < 30 ml), anastomotic procedure (extracorporeal vs. intracorporeal), preservation of infrapyloric vein, preservation of celiac branch of vagal nerve, and postoperative intraabdominal infection. Body weight was

regularly measured at hospital visits or recorded on self-reports by patients.

We analyzed the long-term outcomes of patients who experienced E-stasis (E-stasis group) by assessing their relative body weight ratios (postoperative/preoperative) at 1 year postoperatively compared with patients without E-stasis (non-E-stasis group). For evaluation of nutritional status, serum levels of total protein and albumin, and level of hemoglobin were compared between the two groups. The remnant stomach function was evaluated by endoscopic findings at 1 year postoperatively. During preparation for remnant stomach examination by gastroscopy, we recommended that patients ate a soft diet on day 2 before the procedure, liquid food on the day before, and fasted from 16:00 on the day before. The presence of residual food according to the RGB (residue, gastritis, bile) classification was recorded [24]. Residue classified as grade 2 (moderate amount of residual food, but possible to observe entire surface of remnant stomach with body rolling) or higher, which disturbed gastric cancer screening by endoscopy, at 1 year postoperatively was defined as late postoperative food residue (L-residue) on function evaluation of the remnant stomach after LPPG.

All descriptions of gastric cancer were based on the Japanese Classification of Gastric Carcinoma, 3rd English Edition [25]. The Institutional Review Board of the Cancer Institute Hospital approved this study.

Statistical analysis

Statistical calculations were carried out using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) [26]. Factors that may affect gastric stasis were evaluated by univariate analyses using Fisher's exact test or the Chi-square test. Optimal cut-off levels of age (≥ 61 years vs. < 61 years) (ESM 1), BMI (≥ 20.9 kg/m² vs. < 20.9 kg/m²) (ESM 2), operation time (≥ 259 min. vs. < 259 min.) (ESM 3), and blood loss (≥ 30 ml vs. < 30 ml) (ESM 4) were calculated by the receiver operating characteristic curve. The independent contributions of various factors were assessed by multivariable logistic regression analysis. Risk factors with univariate *P* values of < 0.05 were included in the multivariate analysis. The Mann–Whitney *U* test was used to compare relative body weights and nutritional statuses. *P* values of < 0.05 were considered to indicate statistical significance.

Results

Patient characteristics

Among the 919 patients who underwent LPPG, 897 patients were enrolled in the present study (Fig. 1). The characteristics of the patients are summarized in Table 1. Fifty-eight patients (6.4%) had pT2 or deeper gastric cancer, and 70 (7.8%) had lymph node-positive cancer. Only 3 patients (0.3%) experienced recurrence. Regarding postoperative complications, E-stasis was the most common one (7.6%). There was no patient who needed intervention under general anesthesia indicated for E-stasis. The other common complications with Clavien–Dindo classification grade II or higher were: intraabdominal abscess/infection (6.5%); pancreatic fistula (3.7%); anastomotic leakage/fistula (1.4%); bleeding (1.2%); wound infection (1.0%); and bowel obstruction (0.7%). Only 1 patient experienced anastomotic stenosis.

Incidence and risk factors for E-stasis

E-stasis was observed in 68 patients (7.6%). The risk factors related to gastric stasis were analyzed and incidences of E-stasis according to each factor are shown in Table 2. Univariate analyses showed that age ($P = 0.016$), DM ($P = 0.006$), and intraabdominal infection ($P < 0.001$) were significantly related to incidence of E-stasis (Table 3). Multivariate analysis further identified age (≥ 61 years), DM, and intraabdominal infection as risk factors for E-stasis (Table 3). The incidence of E-stasis according to age bracket is shown in Fig. 2. As age increased, patients were more likely to experience E-stasis. One-third of patients with E-stasis had intraabdominal infection, while one-fifth of patients with

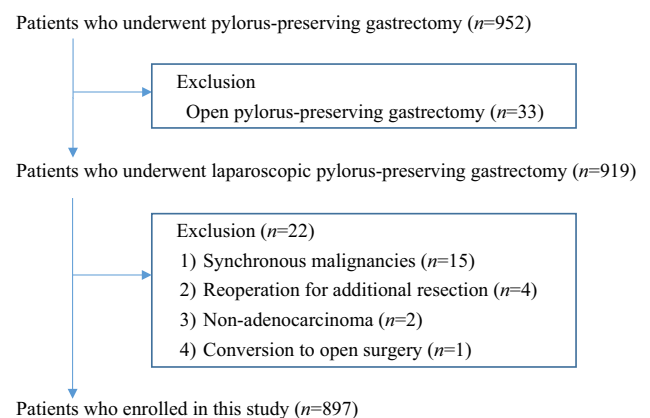


Fig. 1 Patient selection

Table 1 Characteristics of 897 patients undergoing laparoscopic pylorus-preserving gastrectomy (LPPG)

Variable	Number of patients (%)
Sex	
Male	471 (52.5)
Female	426 (47.5)
Age (years), median (IQR)	59 (50–65)
BMI (kg/m ²), median (IQR)	22.1 (19.9–24.3)
DM	31 (3.5)
Additional surgery after ER	150 (16.7)
Operation time (min), median (IQR)	255 (217–290)
Blood loss (ml), median (IQR)	20 (10–40)
Anastomotic procedure	
Extracorporeal	487 (54.3)
Intracorporeal	410 (45.7)
Preservation of infrapyloric vein	
+	405 (45.2)
–	492 (54.8)
Preservation of celiac branch of vagal nerve	
+	343 (38.2)
–	554 (61.8)
Histological type	
Differentiated	283 (31.5)
Undifferentiated	614 (68.5)
pT factor	
T1a	430 (47.9)
T1b	409 (45.6)
T2	36 (4.0)
T3	18 (2.0)
T4a	4 (0.4)
pN factor	
N0	827 (92.2)
N1	48 (5.4)
N2	19 (2.1)
N3a	3 (0.3)
pStage	
IA	787 (87.7)
IB	63 (7.0)
IIA	28 (3.1)
IIB	16 (1.8)
IIIA	3 (0.3)
Recurrence	3 (0.3)

IQR interquartile range, BMI body mass index, DM diabetes mellitus, ER endoscopic resection

intraabdominal infection experienced E-stasis. When the incidence of E-stasis was compared between delta-shaped method and piercing technique, there was no significant difference ($P = 0.86$).

Short-term and long-term outcomes of E-stasis

Patients who experienced E-stasis had longer postoperative hospital stay (median: E-stasis, 24 days vs. non-E-stasis, 10 days). Of the 68 patients who experienced E-stasis, 17 patients required invasive treatment such as insertion of a nasal feeding tube or a nasogastric tube, which is equivalent to Clavien-Dindo classification grade II, and 15 patients underwent dilation of the pylorus with a gastroendoscope, equivalent to grade IIIa. None of the patients suffered from aspiration pneumonia after vomiting during postoperative hospital stay.

Body weight data for 235 patients at 1 year postoperatively could not be obtained from the clinical records. The median relative body weight ratio of the remaining 662 patients was 93.4% (range 70.3–119.4%; interquartile range [IQR] 89.2–98.1%). Comparison between the E-stasis group and non-E-stasis group is shown in Table 4. The relative body weight ratio in the E-stasis group (median 91.0%; range 70.3–111.7%; IQR 86.9–97.2%) was significantly lower than that in the non-E-stasis group (median 93.5%; range 71.1–119.4%; IQR 89.5–98.2%) ($P = 0.042$).

Regarding the blood examinations for nutritional status, data for 876 patients were available. Postoperative serum albumin level was significantly lower in the E-stasis group ($P = 0.011$). There were no significant differences between the two groups in serum level of total protein and level of hemoglobin.

Among the 68 patients who experienced E-stasis, data for 62 patients regarding postoperative gastroscopy could be obtained from the clinical records. Of the 62 patients, 28 (45.2%) presented with L-residue. In the 807 patients who did not experience E-stasis and underwent postoperative gastroscopy, L-residue was observed in 198 (24.5%). Multivariate analysis identified sex, age, BMI, and E-stasis as risk factors for L-residue (Table 5).

Discussion

Three new findings on postoperative gastric stasis after LPPG for early middle-third gastric cancer were obtained from this large-scale retrospective study. First, the incidence of E-stasis was 7.6% according to our definition, and E-stasis was significantly related to age (≥ 61 years), DM, and postoperative intraabdominal infection. Second, patients who experienced E-stasis had poorer outcomes in postoperative body weight and serum albumin level at 1 year postoperatively. Third, over 40% of patients who suffered from E-stasis experienced L-residue, which was newly defined as a parameter for evaluation of E-stasis. L-residue was associated with sex, age, BMI, and E-stasis. These new findings regarding a crucial problem associated with LPPG may

Table 2 Analyses for incidence of early postoperative gastric stasis (E-stasis) according to each risk factor

Parameter	Total (n = 897)	E-stasis, n (%)		P value
		Positive	Negative	
Sex				
Male	471	34 (7.2)	437 (92.8)	0.76
Female	426	34 (8.0)	392 (92.0)	
Age (years), median (IQR)				
< 61	510	29 (5.7)	481 (94.3)	0.016
≥ 61	387	39 (10.1)	348 (89.9)	
BMI (kg/m ²), median (IQR)				
< 20.9	319	30 (9.4)	289 (90.6)	0.15
≥ 20.9	578	38 (6.6)	540 (93.4)	
DM				
+	31	7 (22.6)	24 (77.4)	0.006
-	866	61 (7.0)	805 (93.0)	
Operation time (min), median (IQR)				
< 259	473	30 (6.3)	443 (93.7)	0.16
≥ 259	424	38 (9.0)	386 (91.0)	
Intraoperative blood loss (ml), median (IQR)				
< 30	515	39 (7.6)	476 (92.4)	1.00
≥ 30	382	29 (7.6)	353 (92.4)	
Anastomotic procedure				
Extracorporeal	487	33 (6.8)	454 (93.2)	0.38
Intracorporeal	410	35 (8.5)	375 (91.5)	
Preservation of infrapyloric vein				
+	405	29 (7.2)	376 (92.8)	0.76
-	492	39 (7.9)	453 (92.1)	
Preservation of celiac branch of vagal nerve				
+	343	23 (6.7)	320 (93.3)	0.52
-	554	45 (8.1)	509 (91.9)	
Intraabdominal infection				
+	82	17 (20.7)	65 (79.3)	< 0.001
-	815	51 (6.3)	764 (93.7)	

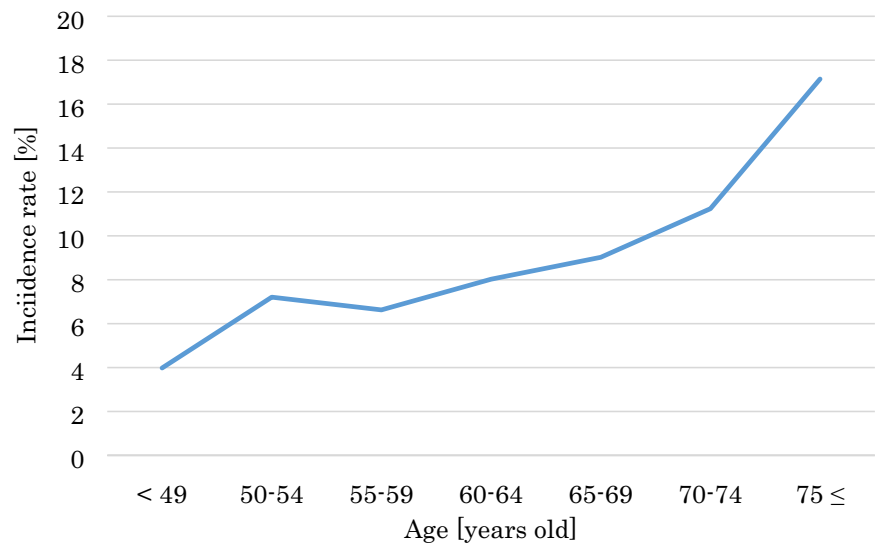
IQR interquartile range, BMI body mass index, DM diabetes mellitus

Table 3 Univariate and multivariate analyses of risk factors for early postoperative gastric stasis (E-stasis)

Parameter	Univariate analysis		Multivariate analysis	
	HR (95% CI)	P value	HR (95% CI)	P value
Sex (female vs. male)	1.0 vs. 0.84 (0.50–1.42)	0.53		
Age (years) (< 61 vs. ≥ 61)	1.0 vs. 1.86 (1.10–3.18)	0.015	1.0 vs. 1.70 (1.02–2.83)	0.042
BMI (kg/m ²) (< 20.9 vs. ≥ 20.9)	1.0 vs. 1.47 (0.86–2.50)	0.15		
DM (- vs. +)	1.0 vs. 3.84 (1.34–9.66)	0.006	1.0 vs. 2.84 (1.13–7.15)	0.026
Operation time (min) (< 259 vs. ≥ 259)	1.0 vs. 1.45 (0.86–2.48)	0.16		
Blood loss (ml) (< 30 vs. ≥ 30)	1.0 vs. 1.00 (0.59–1.70)	1.00		
Anastomotic procedure (extra vs. intracorporeal)	1.0 vs. 1.28 (0.76–2.18)	0.38		
Preservation of infrapyloric vein (- vs. +)	1.0 vs. 0.90 (0.52–1.52)	0.71		
Preservation of celiac branch of vagal nerve (- vs. +)	1.0 vs. 0.81 (0.46–1.40)	0.52		
Intraabdominal infection (- vs. +)	1.0 vs. 3.91 (2.00–7.36)	< 0.001	1.0 vs. 3.56 (1.92–6.60)	< 0.001

BMI body mass index, E-stasis early postoperative gastric stasis, HR hazard ratio, CI confidence interval, DM diabetes mellitus

Fig. 2 Incidence of early postoperative gastric stasis (E-stasis) according to age bracket. As aged increased, patients were more likely to experience E-stasis



Number of patients 201 111 166 162 133 89 35

Table 4 Preoperative and postoperative relative body weights and nutritional statuses after laparoscopic pylorus-preserving gastrectomy (LPPG)

Variable	Total (n)	Preoperative		P value	Postoperative 1 year		P value
		Median	IQR		Median	IQR	
Body weight ratio (%)	662						
Non-E-stasis group	604	100			93.5	89.5–98.2	0.042
E-stasis group	58	100			91.0	86.9–97.2	
Serum total protein (g/dL)	876						
Non-E-stasis group	812	7.0	6.7–7.2	0.15	7.2	6.9–7.4	0.38
E-stasis group	64	7.1	6.7–7.3		7.1	6.8–7.4	
Serum albumin (g/dL)	876						
Non-E-stasis group	812	4.2	4.0–4.4	0.89	4.3	4.1–4.5	0.011
E-stasis group	64	4.2	4.0–4.4		4.2	4.1–4.4	
Hemoglobin (g/dL)	876						
Non-E-stasis group	812	13.4	12.5–14.3	0.64	13.4	12.5–14.2	0.84
E-stasis group	64	13.4	12.7–14.2		13.4	12.5–14.4	

E-stasis early postoperative gastric stasis, IQR interquartile range

Table 5 Univariate and multivariate analyses of risk factors for late postoperative food residue (L-residue)

Parameter	Univariate analysis		Multivariate analysis	
	HR (95% CI)	P value	HR (95% CI)	P value
Sex (female vs. male)	1.0 vs. 1.82 (1.33–2.48)	<0.001	1.0 vs. 1.49 (1.06–2.09)	0.019
Age (years) (<61 vs. ≥61)	1.0 vs. 1.60 (1.18–2.17)	0.002	1.0 vs. 1.50 (1.10–2.05)	0.011
BMI (kg/m ²) (<20.9 vs. ≥20.9)	1.0 vs. 1.92 (1.36–2.70)	<0.001	1.0 vs. 1.82 (1.27–2.60)	0.001
DM (– vs. +)	1.0 vs. 2.76 (1.31–5.82)	0.007	1.0 vs. 1.97 (0.91–4.27)	0.085
Operation time (min) (<259 vs. ≥259)	1.0 vs. 0.90 (0.67–1.23)	0.52		
Blood loss (ml) (<30 vs. ≥30)	1.0 vs. 1.52 (1.12–2.06)	0.007	1.0 vs. 1.32 (0.96–1.81)	0.093
Anastomotic procedure (extra vs. intracorporeal)	1.0 vs. 0.76 (0.56–1.03)	0.074		
Preservation of infrapyloric vein (– vs. +)	1.0 vs. 0.93 (0.68–1.25)	0.61		
Preservation of celiac branch of vagal nerve (– vs. +)	1.0 vs. 0.93 (0.68–1.27)	0.65		
E-stasis (– vs. +)	1.0 vs. 2.53 (1.50–4.28)	<0.001	1.0 vs. 2.53 (1.47–4.37)	<0.001

BMI body mass index, E-stasis early postoperative gastric stasis, HR hazard ratio, CI confidence interval, DM diabetes mellitus

support the indications for this procedure and aid in clinical management of patients with postoperative gastric stasis.

Postoperative gastric stasis is not generally defined, even though many surgeons recognize it as a crucial problem after LPPG. In the extended Clavien-Dindo classification defined by Japan Clinical Oncology Group (JCOG) [27], postoperative gastric stasis is classified as follows: grade I, clinical observation or diagnostic evaluation only, intervention not indicated; grade II, medical management (e.g., peristalsis-stimulating drugs), nasogastric tube placement, enteral/intravenous nutrition indicated; grade IIIb, intervention under general anesthesia indicated. The endoscopic dilation of the pylorus which is not defined by JCOG would be equivalent to Clavien-Dindo classification grade IIIa. According to this classification, patients who receive small amounts of intravenous drip or peristalsis-stimulating drugs are classified as grade II, and are often encountered in clinical management for gastrectomy other than PPG. However, we do not know how to deal prophylactic medication. E-stasis was sometimes defined as a period of starvation exceeding 24 h with upper abdominal distension and remnant stomach fullness on radiography image in previous reports [17, 18, 20]. In the present study, we defined E-stasis as a period of starvation exceeding 72 h similar to the report by Kiyokawa et al. [16] and E-stasis was equivalent to Clavien-Dindo classification grade II. Because we considered that lengthening of hospital stay by only 1 or 2 days may not be meaningful for clinical management. In our data, 9.7% of patients required starvation for longer than 24 h (data not shown). Thus, 2.1% of patients recovered by starvation for only 1 or 2 days, and such short times of starvation may not be associated with E-stasis, which was the focus of the present study. Upper abdominal distension and fullness of the remnant stomach are common symptoms, even after other types of gastrectomy, and starvation for 1 or 2 days is sometimes needed for minor problems. Although the definition including starvation for longer than 72 h does not have powerful evidence, it meets our clinical expectations for a crucial problem.

We identified three risk factors for E-stasis in the present study. First, patients aged ≥ 61 years had a higher risk of E-stasis. Furthermore, the incidence of E-stasis increased as patient age increased. It seems reasonable that the function of the remnant stomach in older patients may be worse than that in younger patients. This means that aged patients should be selected carefully for LPPG. E-stasis in such patients may cause vomiting followed by aspiration pneumonia, similar to the case for patients with hiatal hernia or esophageal reflux. This assumption suggests that E-stasis is not only associated with dysfunction for dietary intake, but may also be a mortal complication. When LPPG is intended for patients with early gastric cancer in the middle-third stomach, we should be strongly concerned about patient age. Second, patients with DM also had a higher risk. DM can

induce diabetic gastroparesis involving neuropathy of vagal nerve, abnormal myenteric neurotransmission, impairment of the inhibitory nitric oxide-containing nerves, damage of the pacemaker interstitial cells of Cajal, and underlying smooth muscle dysfunction [28–32]. Thus, the potential function of the stomach in patients with DM may be worse than that in non-DM patients. We also should be concerned about DM as the patient comorbidity. The third risk factor for E-stasis was intraabdominal infection, suggesting that intraabdominal inflammation may paralyze the remnant stomach. Sophisticated surgery may prevent postoperative complications. Thus, a significant accumulation of surgical experience for laparoscopic gastrectomy is necessary for surgeons. Our previous study showed that preservation of the infrapyloric vein may prevent the incidence of postoperative gastric stasis after LPPG [16]. Although the present study was larger, the data did not show that preservation of the infrapyloric vein prevented E-stasis, similar to smaller studies by Nishizawa et al. and Kaji et al. [20, 33]. Unfortunately, the previous study might be misleading due to the small sample size. Even if the preservation of the infrapyloric vein does not reduce E-stasis, we consider that preservation of both the infrapyloric artery and vein is technically safe to keep the optimal layer for dissecting the station No. 6 lymph nodes and useful to reduce the incidence of postoperative complications other than E-stasis. Furthermore, we did not identify technical factors, such as preservation of the vagal nerve and anastomotic method (mechanical or hand sewing), that could reduce the incidence of E-stasis in the present study. Regarding mechanical anastomosis, we initially concerned that delta shaped method increased E-stasis, and expected that piercing technique did not increase E-stasis. However, both methods were completely equivalent in the incidence of E-stasis.

We found that patients who experienced E-stasis had poorer long-term outcomes for postoperative body weight and serum albumin level at 1 year postoperatively than patients without E-stasis. We considered that the difference of body weight ratio for 2.5% had a great meaning, while a difference of serum albumin level had little clinical impact. Furthermore, we found that the function of the remnant stomach after E-stasis may not fully recover quickly, because over 40% of patients who experienced E-stasis experienced L-residue, which was newly defined in the study. Patients with E-stasis would feel postprandial nausea or upper abdominal distention and reduce dietary intake even after discharge. Thus, E-stasis is not only an early postoperative problem, but also a crucial problem that lasts for a long time and continues to trouble patients even though LPPG is a function-preserving gastrectomy that must provide benefits after surgery. Surgeons need to make their best efforts to prevent E-stasis in terms of indications, techniques, and postoperative management.

There have been few reports regarding long-term remnant gastric function after PPG that included evaluations at more than 3 years postoperatively [19, 34]. The number of patients who complained of symptoms related to late postoperative gastric stasis was reported to increase at 1 year postoperatively and decrease thereafter [20]. Thus, we proposed a novel definition for L-residue at 1 year postoperatively according to endoscopic findings as an evaluation tool for long-term remnant gastric function in the present study. We identified male sex, advanced age, high BMI, and E-stasis as risk factors for L-residue, which were different from the risk factors for E-stasis. We supposed that the risk factors for L-residue included different natures. The function of the remnant stomach after E-stasis may not fully recover quickly or the stomach with E-stasis may essentially have a static nature. Thus, the risk factors for L-residue included advanced age and E-stasis. Meanwhile, male sex and high BMI were quite different factors. We assumed that these factors were strongly related to individual dietary intake. Patients with higher food intake may reserve more residual food. We suppose that L-residue may be related to both function of the remnant stomach and individual dietary intake. However, patients who presented with L-residue sometimes had no complaints during follow-up after surgery. Although L-residue brings clinical problems for endoscopic examination, it does not always trouble patients in daily life.

Our study had three apparent limitations. First, although the total size was relatively larger than previous studies, the findings were based on retrospective data from a single institution. It was essentially unclear how surgeons decided to stop giving food to patients with gastric stasis or to start providing food again, which are very important issues to define E-stasis, while L-residue was defined by endoscopic findings that were objective. Second, we did not perform LPPG for patients aged > 75 years in the former period of the study. Thus, we did not have reliable data regarding these elderly patients, although age was one of the risk factors for E-stasis. Thus, the present results may not be definitive. Third, we could not get long-term systematic evaluation for symptoms and quality of life (QOL) in patients after LPPG in this retrospective analysis. These data might be important for such function-preserving surgery. Besides, we identified high incidence of L-residue and concerned the relation between symptoms and L-residue. The Postgastrectomy Syndrome Assessment Study (PGSAS) revealed that an integrated questionnaire (PGSAS-45) consisting of 45 items was a useful scale for assessing postoperative symptoms and QOL [35, 36]. We should collect the data from now on. However, we believe that the new information obtained in the present study can provide a reasonably reliable reference for gastric stasis after LPPG, based on the little information available for this unique condition. Further

multi-institutional prospective studies are required to obtain confirmative information.

In conclusion, E-stasis after LPPG for gastric cancer occurs in 7.6% of patients. Age and postoperative intraabdominal infection are significantly related to E-stasis. Patients who experienced E-stasis have poorer nutritional and functional outcomes even at 1 year postoperatively. More strict indications and safer surgery are required to prevent postoperative gastric stasis introduced by LPPG and to ensure benefits for patients with curable gastric cancer.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Ethical standards All procedures were conducted in accordance with the ethical standards of institutional and national committees responsible for human experimentation and with the 1964 and later versions of the Declaration of Helsinki.

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