



# Surgical outcomes and risk assessment for anastomotic complications after laparoscopic proximal gastrectomy with double-flap technique for upper-third gastric cancer

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## Abstract

**Background** Double-flap technique (DFT) has received increased attention as an anastomotic procedure preventing reflux esophagitis after laparoscopic proximal gastrectomy (LPG) for upper-third gastric cancer. However, incidence of anastomotic stricture still remains high. This study was a retrospective review aimed to demonstrate details of surgical outcomes and to assess risk factors for anastomotic complications using pre-operative CT image after LPG with DFT (LPG–DFT).

**Methods** Patient background data, surgical outcomes, post-operative courses, and complications for patients who underwent LPG–DFT from January 2013 to June 2017 were collected. In addition to the details of short-term outcomes, risk factors for anastomotic stricture and gastroesophageal reflux were analyzed.

**Results** The study sample was 147 patients, including 139 patients with upper-third gastric cancer and 8 patients with submucosal tumor of the upper-third stomach. The overall morbidity rate was 12.2% (18/147), and 97.3% (143/147) of the patients achieved R0 resection. Twelve (8.3%) patients required endoscopic balloon dilatation for anastomotic stenosis, and six (4.2%) suffered regurgitation grade  $\geq$  B in the Los Angeles classification. Multivariate analysis revealed that diameter of the esophagus  $<$  18 mm on pre-operative CT image and the presence of short-term complications were found to be independent risk factors for post-operative anastomotic stenosis. No specific risk for gastroesophageal reflux was identified.

**Conclusions** The incidence rate of anastomotic complications after LPG–DFT was far lower than that reported after conventional esophagogastrectomy. Alternative anastomotic method may be considered for patients with diameter of the esophagus  $<$  18 mm on pre-operative CT image. Prevention of short-term complications may lessen post-operative stricture.

**Keywords** Laparoscopy · Gastrectomy · Anastomosis · Stricture · Reflux esophagitis

## Introduction

Recent studies have reported an increased incidence rate of upper-third gastric cancer [1–3]. Total gastrectomy is the standard operative procedure; however, proximal gastrectomy (PG) is considered for early stage cancer as a function-preserving procedure [4]. Recently, laparoscopic proximal gastrectomy (LPG) has been increasingly introduced for upper-third gastric cancer to make the procedure less invasive [5, 6]. However, because reconstruction after PG has

been related to high risks of anastomotic complications such as anastomotic leakage, reflux esophagitis, and anastomotic stenosis [7–9], the functional superiority of PG versus total gastrectomy has been called into question.

To prevent gastroesophageal reflux after esophagogastrectomy, a novel esophagogastrectomy using a new technique, called double-flap technique (DFT), was developed in 2001 (described in Japanese literature). DFT is a hand-sewn esophago-gastric anastomosis designed to be soft and flexible with a double-flap valve to prevent regurgitation. Recently, DFT has reportedly been introduced to LPG (LPG–DFT) in Japan [10–12]. Previous reports have demonstrated the preventive effect of DFT against reflux esophagitis and anastomotic leakage due to the double seromuscular flap to reinforce the anastomosis; however, reported incidence of post-operative stenosis after LPG–DFT was still

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as high as 15–29% [10, 11, 13]; thus, risk analysis for post-operative stenosis has been needed.

The aim of this study was to demonstrate details of surgical outcomes and incidence rate of post-operative anastomotic complications, and to identify risk factors for post-operative anastomotic stenosis and reflux esophagitis after LPG–DFT. To the best of our knowledge, this is the first study to describe details of surgical outcomes after LPG–DFT, including the findings from post-operative endoscopic examination, in a large number of cases.

## Methods

### Patients

Patients with tumors of the upper-third stomach who underwent LPG–DFT from January 2013 to June 2017 in the Department of Gastroenterological Surgery at the Cancer Institute Hospital, Japanese Foundation for Cancer Research, Tokyo, Japan, were included in the study. Patients who underwent combined resection of other organs except for cholecystectomy were excluded. Additionally, patients with tumor with esophageal invasion which reached 3 cm above the esophago-gastric junction were also excluded from the study because they required resection of the abdominal esophagus. For each patient, surgery was either performed or supervised by five experts in laparoscopic surgery. All five surgeons introduced LPG–DFT at the same period. The extent of tumor depth (cT) and nodal involvement (cN) was determined by pre-operative evaluations, including barium radiography, upper gastrointestinal tract endoscopy, CT, and endoscopic ultrasonography, and were evaluated using the Japanese Classification of Gastric Carcinoma: 3rd edition [14]. According to the Japanese Gastric Cancer Treatment Guidelines 2014 (ver.4) [4], clinical Stage I gastric cancer located in the upper third of the stomach was the indication for LPG. Patients who were indicated for endoscopic resection underwent endoscopic submucosal dissection; however, patients with non-curative factors underwent additional surgical resection and were also included. Additionally, LPG was adapted for patients with symptomatic submucosal tumors and neuroendocrine neoplasms of the upper-third stomach, which required gastrectomy; these patients were also included.

Patients for whom LPG was indicated by pre-operative examinations underwent additional endoscopic examination to mark the distal margins by clips approximately 2 cm from the tumor, confirmed by biopsy to be negative for cancer. The proximal margins were also marked by clips in cases where the lesions had esophageal invasion. After marking, fluoroscopy of the stomach was performed to reveal the length of esophageal invasion, and to confirm that the size

of the remnant stomach was large enough for a tension-free reconstruction.

### Surgical procedure of LPG

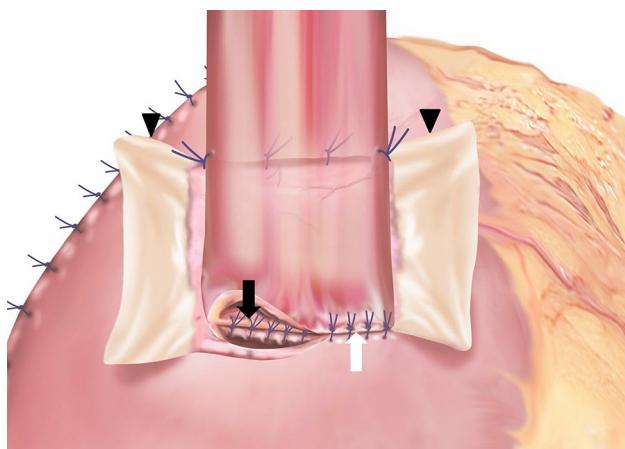
Laparoscopic proximal gastrectomy was performed under a pneumoperitoneum that was created by the injection of carbon dioxide (10–12 mmHg). A total of five ports (each 5–12 mm) were inserted, and modified D1+ (node numbers 1, 2, 3a, 4sa, 4sb, 7, 8a, 9, and 11p) lymph node dissection was performed except for patients with submucosal tumors according to the Japanese Gastric Cancer Treatment Guidelines 2014 (ver. 4) [4], as previously described [13]. The hepatic branch of the anterior branch of the vagal nerve was preserved. Additionally, the celiac branch of the posterior vagal trunk was preserved when possible. The right gastric artery and the right gastroepiploic artery were also preserved. After lymph node dissection, intraoperative gastroscopy was performed for all patients to confirm the location of the tumor and the marking clips, and a safe gastric transection line was determined and marked with blue dye or by suturing in the outer gastric wall. The stomach was transected with endoscopic linear staplers. Intraoperative pathological examination of the proximal and/or distal margin by frozen section was performed for all patients except for patients after endoscopic treatment, to confirm negative margins. After reconstruction, an indwelling drain was placed along the upper edge of the pancreas.

### Reconstruction by double-flap technique

Esophagogastromy with valvuloplasty by DFT was performed as previously reported [10–12, 15]. Briefly, double seromuscular flaps (2.5 cm wide and 3.5 cm high) were created at the anterior wall of the remnant stomach using an electric cautery. After creating the double flap, an incision was made at the inferior end of the mucosal window, and the superior end of the mucosal window of the stomach was fixed to the posterior wall of the esophagus 5 cm above the cut end. Then, the esophagus and the opened mucosa of the remnant stomach were anastomosed (Fig. 1). Seromuscular suture to reinforce the anastomosis was optional. Finally, the anastomotic site was fully covered with seromuscular flaps. Intraoperative gastroscopy was performed to confirm the appropriate tightness of the anastomosis.

### Post-operative management

Fluoroscopy was performed on post-operative day (POD) 3 as a screening test for anastomotic complications and neocardiac function. The indwelling drain was usually removed on POD 3 or 4. Patients who recovered well were usually discharged after POD 9. Patients underwent endoscopic

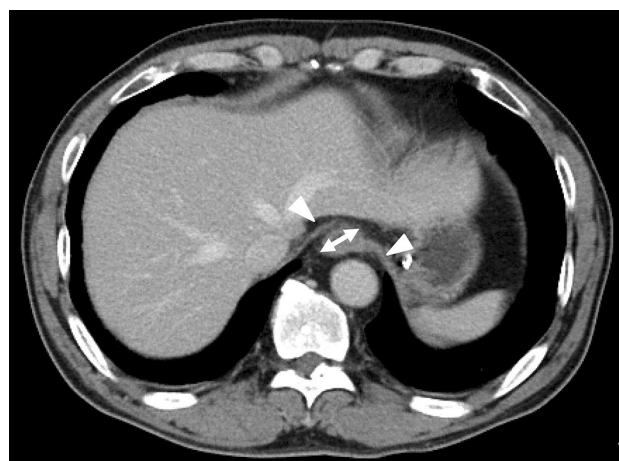


**Fig. 1** Esophagogastrostomy during LPG–DFT. Posterior wall of the anastomosis (black arrow) is performed between the whole layer of the esophagus, and mucosal and submucosal layers of the remnant stomach, whereas the anterior wall of the anastomosis is composed of the whole layer of the esophagus and the remnant stomach (white arrow). Arrowheads indicate the seromuscular flaps

examination approximately 12 months after surgery to screen for anastomotic complications and recurrence. For the patients who developed symptoms of anastomotic stricture and reflux esophagitis, endoscopy was performed at an earlier date. Reflux esophagitis was classified according to the Los Angeles classification, whereas grade  $\geq$  B cases were included. Post-operative anastomotic stricture was defined as the need for balloon dilatation, and details of balloon dilatation were also collected. Patients who were diagnosed as having pathological Stage II or III gastric cancer (except for patients with pT1 and pT3N0 tumors) underwent adjuvant chemotherapy on the basis of ACTS-GC trial [16, 17].

### Statistical analysis

The data collected included patient background data, such as age; sex; height; weight; body mass index; history of abdominal surgery; history of pre-operative endoscopic treatment; presence or absence and the length of esophageal invasion; cT; cN; clinical Stage; surgical outcomes, such as operation time and intraoperative blood loss; presence or absence of simultaneous cholecystectomy; post-operative courses, such as post-operative complications and hospital stays; and results from pathological examinations. The long-diameter of the esophagus on pre-operative CT imaging was measured at the level of the crura of the diaphragm and was also collected (Fig. 2). In patients with complications, details of the complications and Clavien–Dindo (CD) classification grade were determined. All patients were followed up at the outpatient clinic for  $>$  1 year, and late complications, including findings from the upper gastrointestinal endoscopy, were also reviewed.



**Fig. 2** Diameter of the esophagus (double-headed arrow) on pre-operative CT image at the level of the crura of the diaphragm (arrowheads)

Statistical analyses between the groups were performed using the Mann–Whitney *U* test and chi-squared test. In addition, multivariate binary logistic regression analysis, with the corresponding odds ratios (OR) and 95% confidence intervals (CI), was performed to identify independent risk factors for anastomotic stricture. All the statistical analyses were performed using Statistical Package for the Social Sciences, version 23.0 (SPSS, Chicago, IL, USA). A *P* value of  $<$  0.05 was considered as indicative of statistical significance. Unless otherwise indicated, data were presented as the median and range. This study was a retrospective study conducted in accordance with the International Conference on Harmonization of Guidelines for Good Clinical Practice and approved by the Ethics Committee of the Cancer Institute Hospital of JFCR (approval number: 2017-1168). Treatment was performed after obtaining informed consent and patient approval. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Results

### Patient demographics

Patient demographics after LPG–DFT are shown in Table 1. LPG–DFT was indicated for 139 patients with upper-third gastric cancer and 8 patients with submucosal tumor of the upper-third stomach. Among the eight patients with gastric submucosal tumor, three patients were planned for laparoscopy and endoscopy cooperative surgery [18], however, the procedure was converted to LPG–DFT intraoperatively due to potential risk for stricture of the suture site. No patients were converted to other procedure such as open surgery or

**Table 1** Patient background data

Variables	
Patients	147
Age (years)	67 (30–90)
Male	113 (76.9%)
Height (cm)	163.4 (140.0–185.0)
Weight (kg)	61.3 (43.0–100.0)
BMI (kg/m <sup>2</sup> )	23.0 (15.0–35.1)
ASA-PS ½	64/83
Patients after endoscopic treatment	57 (38.8%)
History of abdominal surgery	36 (24.5%)
Pre-operative diagnosis carcinoma/SMT	139/8
Tumors with esophageal invasion	24 (16.3%)
Diameter of the esophagus <sup>a</sup> (mm)	21 (11–27)

ASA-PS American Society of Anaesthesiologists-physical status, SMT submucosal tumor

<sup>a</sup>Diameter of the esophagus on pre-operative CT image at the level of the crura of the diaphragm

total gastrectomy. Fifty-seven (38.8%) patients received endoscopic treatment prior to surgery. The median diameter of the esophagus on pre-operative CT image at the level of the crura of the diaphragm was 21 (11–27) mm.

### Surgical results of LPG–DFT

Among the 147 patients, 144 (97.3%) patients achieved R0 resection. Two patients who underwent non-curative resection underwent completion gastrectomy at a later date for the residual cancer. The residual cancer of the other two patients could not be treated due to other diseases. Recurrence was observed for one patient after non-curative resection who was diagnosed as having pathological T3N3 tumor post-operatively. No recurrence was observed for the remaining 146 patients. Ten patients diagnosed as having pathological Stage II or III gastric cancer (except for patients with pT1 and pT3N0 tumors) underwent adjuvant chemotherapy. Median observation period for the 147 patients was 36 (13.9–67.1) months (Table 2).

### Post-operative courses after LPG–DFT

The overall morbidity rate was 12.2% (18/147), and no post-operative deaths were observed. Severe post-operative complications classified as grade  $\geq$  IIIa in the CD classification occurred in ten (6.8%) patients. Leakage occurred in five (3.4%) patients, including three cases (2.0%) of esophago-gastric anastomotic leakage and two cases (1.4%) of gastric stump leakage. One patient (0.7%) required rehospitalization by anastomotic bleeding (Table 2).

**Table 2** Operative results and post-operative courses of LPG–DFT

Variables	
Operation time (min)	420 (244–641)
Intraoperative blood loss (ml)	70 (10–670)
Dissected lymph nodes	33 (0–66)
R0 resection	143 (97.3%)
Hospital stay, days	10 (7–45)
Rehospitalization <sup>a</sup>	1 (0.7%)
pStage <sup>b</sup> I/pStage <sup>b</sup> II/pStage <sup>b</sup> III	124/13/2
Observation period (months)	36 (14–67)
Short-term complications	
CD <sup>c</sup> grade II	8 (5.4%)
Intraabdominal fluid collection	5 (3.4%)
Small bowel obstruction	1 (0.7%)
Pneumonia	1 (0.7%)
Anastomotic ulcer	1 (0.7%)
CD <sup>c</sup> grade IIIa	8 (5.4%)
Leakage	4 (2.7%)
Intraabdominal fluid collection	2 (1.4%)
Pancreatic fistula	1 (0.7%)
Anastomotic bleeding	1 (0.7%)
CD <sup>c</sup> grade IIIb	2 (1.4%)
Leakage	1 (0.7%)
Small bowel perforation	1 (0.7%)
Long-term complications	
Anastomotic stenosis <sup>d</sup>	12 (8.3%)
Gastroesophageal reflux <sup>e</sup>	6 (4.2%)

<sup>a</sup>Rehospitalization for the treatment of post-operative complications

<sup>b</sup>Pathological stage

<sup>c</sup>Clavien–Dindo classification

<sup>d</sup>Anastomotic stenosis which required balloon dilatation

<sup>e</sup>Reflux esophagitis grade  $\geq$  B in Los Angeles classification

### Risk factors for anastomotic complications after LPG–DFT

Within the 147 patients, 144 patients underwent post-operative endoscopic examination approximately 1 year after surgery. Endoscopic examination found anastomotic stenosis and gastroesophageal reflux in 12 (8.3%) and 6 (4.2%) patients, respectively (Table 2). Balloon dilatation was performed for the patients with anastomotic stenosis one to five times (median 2.5 times), and all patients were able to take regular diet after the treatment. Three patients each developed grade B and C reflux esophagitis in the Los Angeles classification during the observation period; however, they were well controlled by internal medicine.

Risk factors for post-operative anastomotic stenosis and reflux esophagitis are analyzed and presented in Tables 3, 4 and 5. By univariate analysis, the proportion of patients with pre-operative endoscopic treatment, patients with diameter

**Table 3** Risk factors for post-operative anastomotic stenosis after LPG–DFT

Variables	Without stenosis (N=132)	With stenosis (N=12)	P value
Age (years)	68 (30–90)	71 (47–80)	0.742
Male	102 (77.3%)	9 (75.0%)	0.858
BMI (kg/m <sup>2</sup> )	22.9 (15.0–35.1)	22.6 (20.1–29.4)	0.718
Pre-operative endoscopic treatment	49 (37.1%)	8 (66.7%)	0.045*
History of abdominal surgery	33 (25.0%)	2 (16.7%)	0.519
Esophageal invasion	21 (15.9%)	3 (25.0%)	0.418
Diameter of the esophagus <sup>a</sup> (mm)	22 (12–27)	17 (11–18)	<0.001*
Operation time (min)	425 (244–613)	410 (267–641)	0.742
Intraoperative blood loss (ml)	70 (10–670)	78 (10–150)	0.874
Short-term complication <sup>b</sup>	13 (9.8%)	5 (41.7%)	0.001*
Experience of conducting LPG–DFT <sup>c</sup> as an operator	22 (1–78)	10 (3–61)	0.018*

\*Statistically significant

<sup>a</sup>Diameter of the esophagus on pre-operative CT image at the level of the crura of the diaphragm<sup>b</sup>Grade II or above in Clavien–Dindo classification<sup>c</sup>Laparoscopic proximal gastrectomy with double-flap technique

of the esophagus < 18 mm on pre-operative CT imaging, patients who suffered short-term complications, and number of surgeons with 10 or lesser experience of conducting LPG–DFT as an operator were significantly higher in the patients with stenosis (Tables 3, 4). Multivariate analysis revealed that diameter of the esophagus < 18 mm on pre-operative CT imaging and presence of short-term complications were independent risk factors for post-operative anastomotic stenosis (Table 4). During this study, no specific pre-operative and intraoperative risk factor for post-operative gastroesophageal reflux was detected; however, a proportion of patients with tumor invading the esophagus was relatively higher in the patients with gastroesophageal reflux (Table 5).

## Discussion

To date, reconstruction procedures mainly performed after PG were esophagogastronomy [7–9, 19], jejunal interposition [6, 9], and double-tract reconstruction [5, 6]. Esophagogastronomy is the simplest and most biological reconstruction method but is associated with high risks of anastomotic leakage, reflux esophagitis, and anastomotic stenosis. Jejunal interposition is also related to intraoperative and post-operative problems, such as the technically complicated nature of the procedure; functional disorders, such as delayed emptying and anastomotic stricture; and difficulty in endoscopic surveillance [9]. Double-tract reconstruction is a technically complicated procedure, and the functional advantages over other procedures remain unclear [5].

To prevent gastroesophageal reflux after esophagogastronomy, DFT was developed and have been introduced to

LPG [10–12]. In 2017, Hayami et al. reported the superiority of LPG–DFT versus laparoscopic total gastrectomy for early upper-third gastric cancer in terms of morbidity, post-operative hospital stay, and post-operative nutritional status [13]. However, detailed information of post-operative outcomes, especially post-operative anastomotic complications in a longer observation period, has not been clarified.

In this series, severe post-operative complications classified as CD grade  $\geq$  IIIa were observed in only 6.8% of the patients, and 97.3% of the patients achieved R0 resection. The safety of LPG–DFT for tumors of the upper-third stomach has been demonstrated. Additionally, the rate of post-operative esophago-gastric anastomotic leakage, gastroesophageal reflux, and anastomotic stenosis was 2.0%, 4.2% and 8.3%, respectively, which was far lower than that of conventional esophagogastronomy [7–9, 19]. The results of this study may support the preventive effect of LPG–DFT against anastomotic stenosis by the hand-sewn esophago-gastric anastomosis designed to be soft and flexible, and against anastomotic leakage and reflux esophagitis by the seromuscular double-flap valve that reinforces the anastomosis, as previously reported [10–13].

Multivariate analysis detected diameter of the esophagus < 18 mm on pre-operative CT as an independent risk factor for post-operative stenosis. Because the anastomotic diameter is defined by the size of the esophageal lumen during LPG–DFT and the size of the lumen of the esophagus may prescribe the difficulty level of anastomosis, this result seems reasonable. Esophagogastronomy should be carefully performed to enlarge the anastomosis, especially in cases in which the diameter of the esophagus on pre-operative CT imaging is < 18 mm. For patients whom frequent post-operative endoscopic follow-up and balloon dilatation is

**Table 4** Univariate and multivariate analyses for the risk of post-operative stenosis

	Without stenosis <i>N</i> = 132	With stenosis <i>N</i> = 12	OR (95% CI)	<i>P</i> value
Univariate analysis for the risk of post-operative stenosis				
Age (years)				
< 70	75 (56.8%)	6 (50.0%)	Reference	0.649
≥ 70	57 (43.2%)	6 (50.0%)	1.316 (0.403–4.294)	
Gender				
Male	102 (77.3%)	9 (75.0%)	Reference	0.858
Female	30 (22.7%)	3 (25.0%)	1.133 (0.288–4.454)	
BMI (kg/m <sup>2</sup> )				
< 23	66 (50.0%)	6 (50.0%)	Reference	1.000
≥ 23	66 (50.0%)	6 (50.0%)	1.000 (0.307–3.261)	
Pre-operative endoscopic treatment				
Absent	83 (62.9%)	4 (33.3%)	Reference	0.045*
Present	49 (37.1%)	8 (66.7%)	3.388 (0.970–11.837)	
History of abdominal surgery				
Absent	99 (75.0%)	10 (83.3%)	Reference	0.519
Present	33 (25.%)	2 (16.7%)	0.600 (0.125–2.880)	
Esophageal invasion				
Absent	111 (84.1%)	9 (75.0%)	Reference	0.418
Present	21 (15.9%)	3 (25.0%)	1.762 (0.440–7.055)	
Diameter of the esophagus <sup>a</sup> (mm)				
≥ 18	119 (90.2%)	5 (41.7%)	Reference	< 0.001*
< 18	13 (9.8%)	7 (58.3%)	12.815 (3.554–46.208)	
Short-term complication <sup>b</sup>				
Absent	119 (90.2%)	7 (58.3%)	Reference	0.001*
Present	13 (9.8%)	5 (41.7%)	6.538 (1.813–23.576)	
Experience of conducting LPG–DFT <sup>c</sup> as an operator				
> 10	94 (71.2%)	5 (41.7%)	Reference	0.035*
≤ 10	38 (28.8%)	7 (58.3%)	3.463 (1.035–11.589)	
	OR	95% CI	<i>P</i> value	
Multivariate analysis for the risk of post-operative stenosis				
Pre-operative endoscopic treatment	2.575	0.605–10.959	0.200	
Pre-operative endoscopic treatment	2.575	0.605–10.959	0.200	
Diameter of the esophagus <sup>a</sup> < 18 mm	11.508	2.659–49.816	0.001*	
Short-term complication <sup>b</sup>	5.956	1.262–28.116	0.024*	
Experience of conducting LPG–DFT <sup>c</sup> as an operator ≤ 10	1.78	0.415–7.637	0.438	

OR odds ratio, 95% CI confidence interval

\*Statistically significant

<sup>a</sup>Diameter of the esophagus on pre-operative CT image at the level of the crura of the diaphragm

<sup>b</sup>Grade II or above in Clavien–Dindo classification

<sup>c</sup>Laparoscopic proximal gastrectomy with double-flap technique

difficult (e.g.: advanced age and poor performance status), other reconstruction methods using linear staplers [20] or double-tract reconstruction [5, 6] may be selected.

Development of post-operative short-term complications was also correlated with anastomotic stricture. Within the 12 patients with anastomotic stenosis, 3 patients suffered

short-term complications probably due to anastomotic insufficiency (one case of leakage and two cases of intra-abdominal fluid collection). Previous reports for esophago-gastrostomy after esophagectomy support this result that anastomotic insufficiency may be the risk factor for benign anastomotic stenosis [21, 22]. Reducing the incidence of

**Table 5** Risk factors for post-operative gastroesophageal reflux after LPG–DFT

Variables	Without reflux ( <i>N</i> = 138)	With reflux ( <i>N</i> = 6)	<i>P</i> value
Age (years)	68 (30–90)	56 (47–79)	0.093
Male	106 (76.8%)	5 (83.3%)	0.710
BMI (kg/m <sup>2</sup> )	22.8 (15.0–35.1)	24.7 (17.4–26.3)	0.757
Pre-operative endoscopic treatment	55 (39.9%)	2 (33.3%)	0.749
History of abdominal surgery	35 (25.4%)	0	0.156
Esophageal invasion	22 (15.9%)	2 (33.3%)	0.263
Diameter of the esophagus <sup>a</sup> (mm)	21 (11–27)	20 (17–24)	0.360
Diameter of the esophagus <sup>a</sup> < 18 mm	19 (13.8%)	1 (16.7%)	0.841
Operation time, min	425 (244–641)	406 (370–639)	0.719
Intraoperative blood loss (ml)	70 (10–670)	55 (35–270)	0.924
Short-term complication <sup>b</sup>	17 (12.3%)	1 (16.7%)	0.753
Experience of conducting LPG–DFT <sup>c</sup> as an operator	20 (1–78)	16 (2–31)	0.404
Experience of conducting LPG–DFT <sup>c</sup> as an operator ≤ 10	43 (31.2%)	2 (33.3%)	0.910

<sup>a</sup>Diameter of the esophagus on pre-operative CT image at the level of the crura of the diaphragm

<sup>b</sup>Grade II or above in Clavien–Dindo classification

<sup>c</sup>Laparoscopic proximal gastrectomy with double-flap technique

leaks may result in a reduced rate of stricture formation, and additionally, close endoscopic follow-up is recommended for patients after short-term complications for the early detection of anastomotic stenosis.

During this study, no specific risk factor for post-operative gastroesophageal reflux after LPG–DFT was detected, probably because of the small sample size. However, proportion of patients with tumor invading the esophagus was relatively higher in the patients with gastroesophageal reflux. Although incidence rate of reflux including the patients with tumor invading the esophagus was far lower than that reported after conventional esophagogastrectomy, and reflux symptoms were well controlled by internal medicine, further improvement of the anastomotic method may be needed for patients with tumors with esophageal invasion.

There were some limitations in this study, in particular, the retrospective nature of the analysis. Although this study included a large number of patients who underwent LPG–DFT, a relatively small number of patients developed anastomotic stenosis and gastroesophageal reflux, which may have affected the accuracy of the analysis, especially the results of the multivariate analysis. Further accumulation of cases is awaited. In addition, 15 patients with pathological stage II/III gastric cancer were pre-operatively under-diagnosed as clinical stage I in this study. Accuracy of the pre-operative diagnosis was 89.2% (124/135), equivalent to that of previous reports [23, 24]. Although no recurrence was observed for the patients except for one patient who was diagnosed as pathological T3N3 during this study, clinical under-diagnosis may carry the potential risk of incomplete treatments; thus, potential risk of clinical underestimations needs to be considered during LPG.

## Conclusions

The safety of LPG–DFT for tumors of the upper-third stomach was demonstrated. Introduction of LPG–DFT markedly decreased the risk of anastomotic complications after LPG relative to that after conventional esophagogastrectomy. Alternative anastomotic method may be considered for patients with diameter of the esophagus < 18 mm on pre-operative CT image. Prevention of short-term complications may lessen post-operative stricture.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Informed consent to be included in the study, or the equivalent, was obtained from all patients.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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