RESEARCH

Study of Short-Term and Long-Term Outcomes Between Esophagogastrostomy and Double-Tract Reconstruction After Proximal Gastrectomy

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Abstract

Background As the opportunities for proximal gastrectomy (PG) for early gastric cancer in the upper third stomach have been increasing, the safety and feasibility of PG have been a great concern in recent years. This study aimed to compare the short-term and long-term outcomes between patients who underwent esophagogastrostomy (EG) and those who underwent double-tract reconstruction (DTR) after PG.

Methods We retrospectively reviewed the medical records of 34 patients who underwent EG and 39 who underwent DTR at our hospital between 2011 and 2022. We compared the procedure data and postoperative complications including anastomotic complications within 1 year after surgery as short-term outcomes and the rates of change in nutritional status, skeletal muscle mass, and 3-year survival as long-term outcomes.

Results Although operation time of the DTR group was significantly longer than that of the EG group, there were no significant differences in postoperative complications between 2 groups. Regarding the endoscopic findings, the incidence of anastomotic stenosis and reflux esophagitis was significantly higher in the EG group than in the DTR group (26.5% vs 0%, $p < 0.001$; 15.2% vs 0%, $p = 0.020$). In long-term outcomes, there were no significant differences in body weight, BMI, laboratory data, and skeletal muscle mass index between 2 groups for 3 years. The 3-year overall survival rates of 2 groups were similar.

Conclusion DTR after PG could prevent the occurrence of anastomotic complications in comparison to EG. The long-term outcomes were similar between these 2 types of reconstruction.

Keywords Proximal gastrectomy · Esophagogastrostomy · Double-tract reconstruction · Long-term outcomes

Introduction

The prevalence of gastric cancer is diminishing due to the decreased incidence of *Helicobacter pylori* infection and Westernization of diet and lifestyle in Japan. However, the rate of proximal gastric cancer, including esophagogastric junction cancer, has steadily increased in recent years [1–3].

With advancements in diagnostic techniques and the spread of nationwide mass screening programs, an increasing number of patients are being diagnosed with early-stage gastric cancer [1, 4].

Proximal gastrectomy (PG) and total gastrectomy (TG) are surgical procedures performed for gastric cancer of the upper third of the stomach. Although TG or PG can be performed for early proximal gastric cancer, there were more opportunities to administer TG than PG some decades ago. However, surgeons were distressed as to whether TG might be excessively invasive for small-sized early proximal gastric cancer. As early gastric cancer has an excellent prognosis, long-term outcomes should be considered. As a function-preserving procedure, PG is more valuable than TG for proximal gastric cancer [5]. Theoretically, PG has advantages in terms of nutritional and functional aspects because the partial function of the stomach is preserved.

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Actually, some studies have shown either the superiority or equivalence of PG relative to TG for proximal gastric cancer [6, 7]. PG was associated with better nutritional status than TG in some reports [6, 8, 9]. Based on the Japanese Gastric Cancer Treatment Guidelines (ver. 6), PG is weakly recommended for clinical T1N0 tumors in the upper third of the stomach [10]. As the number of patients requiring PG has increased, perioperative safety and the long-term outcomes after PG have gained increasing attention [11]. At present, a major problem with PG is the high incidence of anastomotic complications such as reflux esophagitis (RE) and anastomotic stenosis (AS).

Several reconstruction methods can be applied after PG including esophagogastrostomy (EG), jejunal interposition (JIP), and double-tract reconstruction (DTR) [12]. Although EG is a traditional and most widely performed reconstruction method, conventional EG is associated with a high risk of anastomotic complications [13]. To overcome these problems, several new techniques, using two approaches, have been developed [8, 14]. One approach is the addition of an anti-reflux procedure to the anastomotic site in EG, such as fundoplication, SOFY, or double-flap technique. Another approach is the esophagojejunostomy, which includes JIP and DTR. In this reconstruction, the esophagus is connected to the jejunum, which prevents the reflux of gastric acid directly into the esophagus [15, 16]. Some studies have reported that DTR may reduce the incidence of anastomotic complications after PG [17]. As there are advantages and disadvantages of each method, there is no consensus regarding the optimal reconstruction method after PG. Although there have been some reports on the short-term surgical safety and nutritional outcomes between reconstruction methods after PG [18, 19], the long-term outcomes in nutrition and muscle mass have rarely been investigated. Thus, we aimed to compare the short-term and long-term outcomes between patients who received EG and those who received DTR after PG and evaluate an appropriate reconstruction method after PG.

Material and Methods

We reviewed the medical records to collect data between 2011 and 2022. A total of 78 patients have undergone PG for gastric cancer at the Department of Gastroenterological Surgery of Osaka City General Hospital (Osaka, Japan). The inclusion criteria for this retrospective study were as follows: preoperative diagnosis of clinical T1N0 adenocarcinoma located in the upper third of the stomach and esophagogastric junction without distant metastasis. We excluded five patients: one who received neoadjuvant chemotherapy and four who received gastric tube reconstruction ($n = 1$) and double-flap technique ($n = 3$) after resection. Finally, 73 patients were included in this retrospective study.

Surgical Procedure

The surgical procedure in our hospital was performed in accordance with the Japanese Gastric Cancer Treatment Guidelines [10]. Almost all PG procedures of laparoscopic and robot-assisted laparoscopic PG (68/71) were performed by one of the six surgeons who were certificated as "qualified surgeons" by the Japan Society for Endoscopic Surgery. Although 3 of 71 cases of laparoscopic PG were performed by a non-certificated surgeon, they were supervised by a certificated surgeon. Radical PG included resection of the proximal stomach and part of the abdominal esophagus and preservation of the distal side of the stomach. Systemic lymph node dissection was performed according to the Japanese Gastric Cancer Guidelines. We discussed about the reconstruction method after PG on preoperative conference with our surgical team. The reconstruction methods were finally determined by the surgeons before surgery. Basically, the selection criteria to choose reconstruction method are the size of the remnant stomach and surgeon's preference.

In the EG group, the gastroesophageal reconstruction methods included conventional anastomosis with fundoplication (convEG) and side overlap with fundoplication by Yamashita (SOFY) [20]. convEG was performed by end-to-side anastomosis with a circular stapler between the esophagus and the anterior wall of remnant stomach added fundoplication. In SOFY, the esophageal stump and the anterior wall of the remnant stomach were anastomosed using a linear stapler by side-to-side anastomosis and both sides of the esophagus, remnant stomach, and diaphragmatic crus were suture-fixed due to making pseudo-fornix.

In DTR with a circular stapler, the jejunum was cut at 20 cm from the ligament of Treitz using a linear stapler. Esophagojejunostomy was performed through end-to-side anastomosis, using a circular stapler. After esophagojejunostomy, the jejunum was anastomosed to the posterior wall of the stump of the remnant distal stomach, caudal to the esophagojejunostomy. In the overlap method, the jejunum was lifted up and esophagojejunostomy was performed with side-to-side anastomosis using a linear stapler. After esophagojejunostomy, anastomosis was performed between the jejunum and remnant stomach. After cutting the jejunum at 20 cm from the ligament of Treitz, jejunojejunostomy was performed. The marginal vessels of the lifted-up jejunum were not cut during this reconstruction [21] (Supplemental Fig. 1).

Clinical and Pathological Characteristics

The clinical and pathological characteristics of the patients collected from the medical records included sex, age, body weight (BW), BMI, comorbidities, preoperative laboratory data, American Society of Anesthesiologists physical status

(ASA-PS), tumor location and station, tumor size, degree of differentiation, lymphatic invasion, vascular invasion, and pathological stage (pStage) category.

Procedure Data and Postoperative Outcomes

Procedure data included the approach, conversion to open surgery, range of lymph node dissection (LND), number of harvested lymph nodes, operation time, blood loss volume, and intraoperative transfusion. The postoperative outcomes included pathological stage, postoperative complications, postoperative hospital stay, and adjuvant chemotherapy. Complications were defined according to the Clavien-Dindo (CD) classification system. Furthermore, all complications that occurred during the course were comprehensively evaluated by comprehensive complication index (CCI) based on the CD classification [22]. Endoscopy was recommended once a year after surgery. RE was evaluated by endoscopy at approximately 1 year after the operation, and the severity was classified according to the Los Angeles (LA) classification [23]. All patients with reflux symptoms were prescribed proton pump inhibitor (PPI). We defined cases requiring balloon dilation as anastomotic stenosis. As AS usually occurs within several months after surgery, endoscopy is performed for subjective symptoms. In this study, balloon dilation was performed in all cases with stenosis found on endoscopic findings.

Imaging Analyses

The skeletal muscle mass index (SMI), psoas muscle mass index (PMI), and intramuscular adipose tissue content (IMAC) were used to estimate the skeletal muscle quantity and quality. Measurements were performed using CT images at the superior aspect of the fourth lumbar vertebra [24]. The SMI and PMI were calculated by dividing the cross-sectional muscle mass area (bilateral erector spinae and psoas muscles, respectively) by the square of the height in meters. Due to IMAC, we also measured the CT values of the region of interest (ROI) in the subcutaneous fat by placing four circles on areas of subcutaneous fat away from the major vessels at the same level. As previously reported by Kitajima et al. [25, 26], IMAC was calculated using the ratio of CT values as follows: IMAC = mean CT value of the ROI of the multifidus muscle (HU)/mean CT value of the subcutaneous fat (HU). Low IMAC was considered a proxy for low muscle quality.

Follow-Up

Patients underwent follow-up examinations every 3 or 6 months after surgery. Each follow-up visit included measurement of BW and laboratory tests. Postoperative surveillance was performed a CT every 6 months, and an endoscopy was performed once annually. Based on the long-term outcomes, we evaluated the nutritional status and 3-year overall survival (OS) in patients who were followed for ≥ 3 years. The nutritional status included the rates of change of BW and BMI in comparison to the preoperative values at every 6 months and the laboratory data and results of imaging analyses (SMI, PMI, and IMAC) at every 1 year.

Statistical Analysis

In the statistical analyses, relationships between categorical and numerical variables were assessed using the chi-square (and Fisher's exact test where applicable) and Mann–Whitney U test, respectively. The durations of OS were calculated using the Kaplan–Meier method and analyzed using the log-rank test to compare the cumulative survival durations. In all tests, a p value of < 0.05 was defined as being statistically significant. All statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan) [27].

Results

Clinical and Pathological Characteristics

A total of 73 patients who underwent PG at our hospital were in this study. Thirty-four patients received EG and thirty-nine patients received DTR. In the EG group, there were two types of anti-reflux procedures: conventional EG with fundoplication (convEG; 11 cases), SOFY (SOFY; 23 cases) at our hospital. In the DTR group, we used a circular stapler (13 cases) with end-to-side anastomosis or a linear stapler with the overlap method (25 cases) for esophagojejunostomy. In one case in the DTR group, the stapler type was not found in the medical records.

The patient characteristics and tumor characteristics of the EG and DTR groups are summarized in Table 1. Age, sex, BW, BMI, comorbidities, ASA-PS score, and preoperative laboratory data including total lymphocyte count (TLC), hemoglobin (Hb), total protein (TP), albumin (Alb), and prognostic nutritional index (PNI) were comparable between two groups. Regarding tumor characteristics, there were no significant differences in the parameters that were compared.

Procedural Data and Surgical Outcomes

The surgical outcomes of the patients undergoing EG and DTR are detailed in Table 2. According to this approach, almost all procedures were performed with a laparoscopic or robot-assisted approach; only two cases in the EG group were performed with laparotomy. The operation time in DTR group was significantly

longer than that in EG group. There were no significant differences in blood loss volume, transfusion during the procedure, range of LND, the number of harvested lymph nodes, or length of postoperative hospital stay between two groups. Postoperative complications, including anastomotic leakage, pancreatic fistula, pneumonia, abdominal abscess, and superficial surgical site infection, were comparable between 2 groups (Table 3). The rates of postoperative complications classified as CD classification grade ≥ III in two groups did not differ to a statistically significant extent (5.9% vs 15.4%; $p = 0.271$). There were no significant differences in CCI between 2 groups.

Anastomotic Complications

The anastomotic complications in the endoscopic findings at 1 year after the procedure are shown in Table 3. The incidence of AS on endoscopic findings within 1 year was significantly higher in the EG groups (26.5% vs 0%, $p < 0.001$). All patients with AS underwent EG using a circular stapler with an anti-reflux procedure, such as the Toupet method. As all these patients had severe AS, one or more balloon dilatations were performed. The presence of esophageal reflux was evaluated based on endoscopic findings performed approximately 1 year after the procedure. RE occurred in five patients in the EG group (LA classification: grade A, 2; B, 2; C, 1; D, 0). The incidence of RE was significantly higher in the EG group than in the DTR group (15.2% vs 0%, $p = 0.02$). Although all patients with RE were reconstructed with SOFY, their symptoms were well controlled with medication of PPI.

Long-Term Outcomes in Nutrition, Muscle Mass, and Survival

Sixty patients followed for ≥ 3 years were selected for this study; their long-term outcomes included nutritional status, muscle mass, and survival. The rates of change of nutritional parameters were evaluated using BW, BMI, TLC, Hb, Alb, TP, and PNI in both groups (Fig. 1). There were no significant differences in any category between two groups at 3 years after surgery. For muscle mass, skeletal muscle changes were evaluated based on the SMI, PMI, and IMAC calculated using CT. There were no significant differences in the change rates of the SMI and PMI or values of IMAC between two groups at 3 years after surgery (Fig. 2). The 3-year OS rates in the EG and DTR groups were 90.3% and 92.3%, respectively ($p = 0.818$) (Fig. 3).

Discussion

In the present study, we compared the short-term clinical outcomes and the long-term nutritional outcomes of two reconstruction methods. Although the operation time in

DTR group was significantly longer than that in the EG group, there were no significant differences in postoperative complications between 2 groups. The incidence of RE tended to be higher in the EG group than in the DTR group, but the difference was not statistically significant. The incidence of AS was significantly higher in the EG group. Regarding the long-term nutritional outcomes, there was no significant difference in the rates of change of nutritional factors or muscle mass index between two groups at 3 years after surgery. The 3-year OS rates were comparable between the reconstruction methods.

The reconstruction methods after PG can be divided into two groups according to the organs connected to the esophagus: the remnant stomach or the jejunum. However, the reconstruction methods have been controversial because of postoperative anastomotic complications. EG is a simple and common reconstruction method after PG. Since EG is associated with a high incidence of postoperative anastomotic complications, several new techniques have been developed by adding anti-reflux procedures and performing advanced procedures, such as SOFY and double-flap method. In other approaches, using esophagojejunostomy, including jejunal interposition and DTR, the esophagus is connected to the jejunum, which prevents the reflux of gastric acid directly into the esophagus [15, 16]. In this study, RE and AS were not detected in the DTR group. In contrast, 9 cases of anastomotic stenosis occurred, and these only occurred among the convEG cases in the EG group. This result seems to be due to the strong tightening to prevent reflux of gastric juice. Fundoplication such as Toupet or Nissen is difficult to adjust. In the EG group, 5 cases of RE occurred among patients who received SOFY. All 5 cases of RE showed endoscopic findings at approximately 1 year after surgery, but their symptoms were well controlled by PPIs, irrespective of the LA classification, and a good intake was maintained at 1 year after the procedure. In many previous studies, the endoscopic findings of RE were not consistent with the patient symptoms [28]. Ji et al. reported that the reconstruction method was the only independent risk factor for RE [11]. These results suggested that DTR may reduce anastomotic complications after PG, which were similar to previous reports.

Previous studies have reported that DTR is more complex than EG. It is reasonable that the operation time of DTR was longer than that of EG. On the other hand, whether DTR causes a high rate of complications because of the technical complexity and increased number of anastomoses has been questioned [13, 29]. Our results showed the same outcome according to operation time. However, there were no significant differences in blood loss volume, length of postoperative hospital stay, and postoperative complications between the EG and DTR groups. In SOFY, anastomosis was only performed at one site (the esophagus
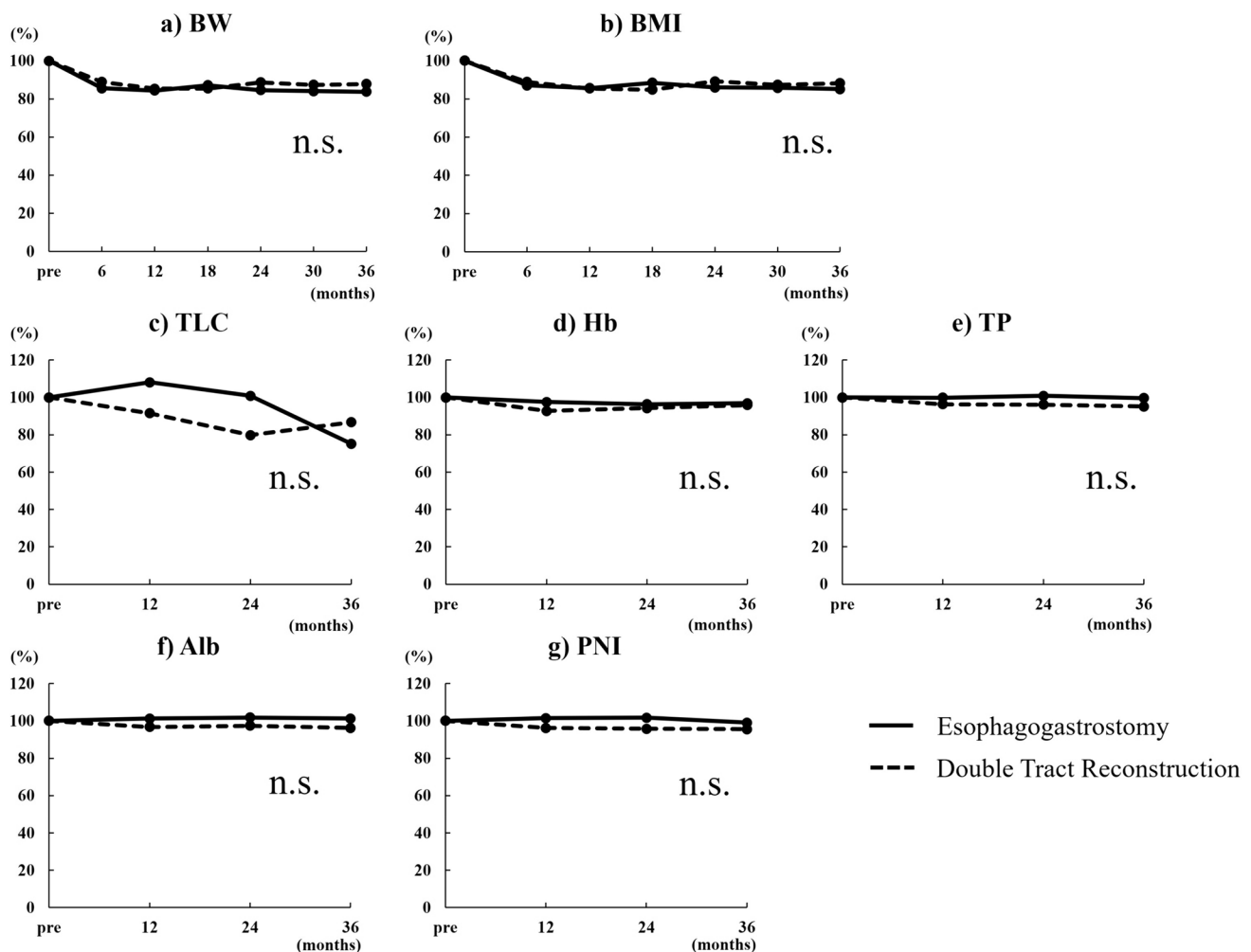
Fig. 1 Comparison of the change rates of nutritional parameters, **a** BW, **b** BMI, **c** TLC, **d** Hb, **e** TP, **f** Alb, and **g** PNI, between esophagogastrostomy and double-tract reconstruction after proximal gastrectomy during 3 years of follow-up. There were no significant differences in these factors 3 years after procedure. BW: body weight, BMI: body mass index, TLC: total lymphocyte count, Hb: hemoglobin, TP: total protein, Alb: albumin, PNI: prognostic nutritional index

and the anterior of remnant stomach), but many lines of suture section were required in these methods [14, 20]. As these advanced procedures were performed laparoscopically recently, they took a long time to complete. On the other hand, anastomosis is performed at more sites in DTR; the linear stapler made it possible to reduce the operation time. However, the development of a robot-assisted system is expected to shorten the operation time, despite the many suture sections in SOFY and double-flap methods. Furthermore, the rates of anastomotic leakage did not differ between two groups in this study. It has been reported that the number of anastomoses does not affect the incidence of anastomotic leakage or stenosis [12]. Although esophagojejunostomy has been difficult in laparoscopy, the popularization of the overlap method in laparoscopic TG might lead to a decrease in the number of complications in esophagojejunostomy.

Many studies have reported the nutritional status after PG [12, 15]. BW and BMI are typically used to measure the nutritional status. Other nutritional indicators were observed in our study. Theoretically, PG is suggested to have some nutritional advantages over TG because the distal part of the stomach remains. In previous studies, DTR had better in-laboratory outcomes than TG [6, 30]. Some studies have reported that the nutritional outcomes of the DTR group were similar to those of the EG group at 1 year after the procedure. Miyauchi et al. reported that ChE levels at 6 months were significantly higher in their DTR group than in their EG group, but the difference disappeared at 1 year [18]. There were no significant differences in the TP, Alb, and Hb levels between two groups. However, the difference in nutritional status between reconstruction methods after PG has not been clarified in the long term. We evaluated the nutritional outcomes such as the change rates of BW,

Table 1 Clinical and pathological characteristics of the patients

	EG (n = 34)	DTR(n = 39)	p value
<Patient characteristics>			
Gender M/F	27/7	27/12	0.425
Age	69.4 ± 9.9	66.6 ± 14.0	0.576
BMI	23.0 ± 3.6	22.3 ± 3.0	0.642
Comorbidities			
HT	13 (38.2%)	19 (48.7%)	0.479
DM	6 (17.6%)	5 (12.8%)	0.745
Lung disorder	2 (5.9%)	6 (15.4%)	0.270
Cardiovascular disease	6 (17.6%)	2 (5.1%)	0.135
Cerebrovascular disease	2 (5.9%)	3 (7.7%)	1.000
Anti-thrombotic drug	8 (23.5%)	6 (15.4%)	0.552
ASA-PS ≥ 3	4 (11.8%)	3 (7.7%)	0.698
TLC (/μL)	1874 ± 673	1788 ± 646	0.648
Hb (g/dL)	13.1 ± 1.9	13.5 ± 1.8	0.419
TP (g/dL)	7.1 ± 0.6	7.2 ± 0.6	0.899
Alb (g/dL)	4.0 ± 0.4	4.1 ± 0.4	0.117
PNI	49.5 ± 6.2	50.3 ± 5.5	0.601
<Tumor characteristics>			
Tumor location (E/U/M)	2/31/1	8/30/1	0.133
Tumor station (less/gre/post/ante/circ)	15/3/8/7/0	25/4/7/2/1	0.173
Tumor size	27.1 ± 12.2	31.9 ± 15.0	0.156
Pathology (tub/por/other)	22/8/4	23/13/3	0.641
ly +	6 (17.6%)	7 (17.9%)	1.000
v +	6 (17.6%)	4 (10.3%)	0.499
pN +	4 (11.8%)	6 (15.4%)	0.742
pStage (I/II/III)	29/4/1	30/6/3	0.665

BMI, and laboratory data over 3 years. No significant differences were observed between these factors in this study. As EG has a physiological structure in which all food passes through the stomach and duodenum, EG might be expected to achieve better nutritional outcomes than other reconstruction methods after PG. However, our results showed

Table 2 Operative data

	EG	DTR	p value
Approach (lap/robot/open)	21/11/2	24/15/0	0.373
Conversion to open	0	3 (7.7%)	0.247
Rage of LND D1 +	30 (88.2%)	35 (89.7%)	1.000
Number of harvested LN	23.9 ± 13.9	23.6 ± 12.5	0.938
Combined resection	1 (2.9%)	4 (10.3%)	0.364
(Gallbladder/lower esophagus)	(1/0)	(1/3)	
Operative time (min)	365.1 ± 99.5	404.5 ± 88.8	0.029*
Blood loss volume (mL)	122.3 ± 195.5	114.8 ± 143.9	0.723
Transfusion	3 (8.8%)	0	0.096
Post-op hospital stay (days)	15.8 ± 12.6	16.1 ± 10.9	0.644
Adjuvant chemotherapy	1 (2.9%)	6 (15.4%)	0.113

no significant differences in the rates of change in nutritional factors between the EG and DTR groups. These results are similar to those reported in previous studies [19]. This could be the reason why postoperative complications such as AS and RE in the early phase might lead to a decrease in nutritional status in the EG group. EG is associated with many postoperative anastomotic complications, but these are recognized early, and stenosis improves with balloon dilation. In addition, although RE can also be detected endoscopically and is often controlled with PPIs, it was thought that there would be no difference between two groups in terms of the long-term nutritional status.

The other postoperative evaluation factor was the skeletal muscle mass. It has been shown that skeletal muscle mass decreases after gastrectomy due to malnutrition, impaired absorption, and decreased postoperative activities of daily living [31, 32]. Miyauchi et al. showed that SMI did not exhibit differences in the first year after surgery [18]. However, many of these reports had short observation periods, and the long-term changes were not reported. Therefore, SMI, PMI, and IMAC were measured using regular postoperative CT scans and compared retrospectively in the present study. We followed the patients for 3 years, but there were

Table 3 Postoperative and anastomotic complications

	EG	DTR	*p*value
Postoperative complication	13 (38.2%)	13 (33.3%)	0.807
Leakage	5 (14.7%)	4 (10.3%)	0.725
Pancreatic fistula	0	2 (5.1%)	0.495
Ileus	0	0	
Pneumonia	0	2 (5.1%)	0.495
Abdominal abscess	2 (5.9%)	4 (10.3%)	0.679
Superficial SSI	3 (8.8%)	2 (5.1%)	0.659
Clavien-Dindo classification			
0/I/II/III/IV/V	22/3/7/1/0/1	27/0/6/5/1/0	0.125
Grade ≥ III	2 (5.9%)	6 (15.4%)	0.271
Comprehensive complication index	9.65 ± 18.8	8.80 ± 13.9	0.928
Endoscopic findings 1 y after procedure			
Anastomotic stenosis	9 (26.5%)	0	< 0.001*
Reflux esophagitis	5 (15.2%)	0	0.020*
LA classification (grade A/B/C/D)	2/2/1/0	0	

no significant differences between two groups in terms of the quality or quantity of the skeletal muscle mass. Considering that there was no difference in nutritional status, as mentioned above, these results were acceptable.

The previous study reported esophagogastrostomy includes several methods and the short-term outcomes are quite different [33]. Therefore, we compared the long-term outcomes of DTR vs convEG and DTR vs SOFY. There were no significant differences in BW, BMI, and skeletal muscle index in both comparisons. According to postoperative laboratory data about nutritional status, the change rates of these factors were comparable in convEG and DTR. In comparing SOFY and DTR, the change rates of TLC and PNI at 1 year were significantly higher in SOFY than in

DTR, but the difference disappeared after the second year (supplementary Fig. 2, 3). There was no significant difference in 3-year OS between two groups in this study. PG was originally indicated for early gastric cancer and had a good prognosis. There were also no intergroup differences in the incidence of postoperative complications. This result is similar to the results of previous reports [11]. Based on these results, our institute basically performs SOFY method when a larger residual stomach remains and performs DTR method when the residual stomach is a little smaller. We also believe that DTR can be adapted in a wide range of situations.

The present study was associated with some limitations. Firstly, the analysis was based on retrospective data collected at a single institution. Esophagogastrostomy
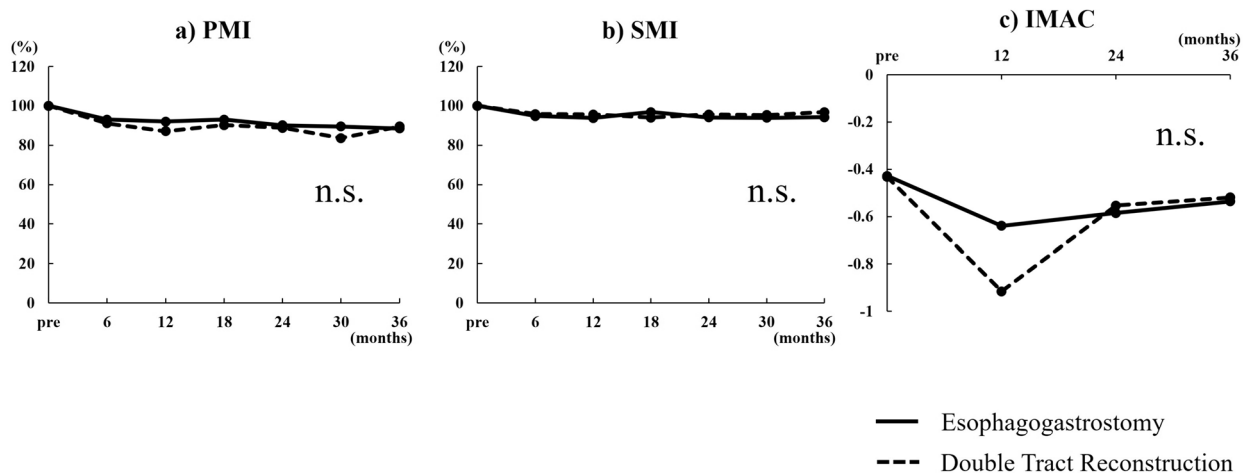
Fig. 2 Comparison of the change rates of muscular mass parameter, **a** PMI, **b** SMI, and **c** IMAC, between the 2 groups during 3 years of follow-up. No significant differences of these parameters in 2 groups were found between 2 groups for 3 years. PMI: psoas muscular mass index, SMI: skeletal muscular mass index, IMAC: intramuscular adipose tissue content
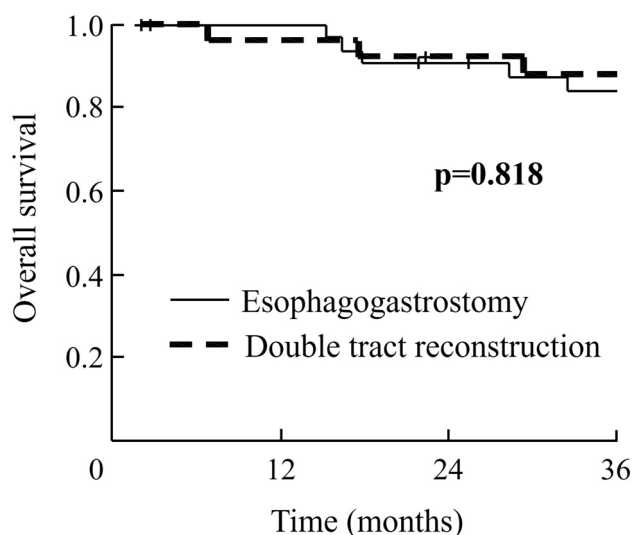
Fig. 3 Three-year overall survival curves of patients in the esophagogastrostomy and double-tract reconstruction groups. The 3-year overall survival rates of the 2 groups did not differ to a statistically significant extent

includes several methods (conventional EG, SOFY, and double-flap technique). Originally, the double-flap technique should have been included in this study, but it was excluded because the number of cases was too small (only 3 cases). Therefore, this study may have included a selection bias. Secondly, the sample size of the present study was not sufficiently large, which might make the results of this study less convincing. Multicenter studies were necessary to enhance the sample size. However, this study is a single-center retrospective. Propensity score matching would provide more reliable results to reduce biases, but it was difficult because the number of cases was limited. Further large-scale, prospective, randomized controlled trials are required to confirm the results of our study. Third, we did not compare the QOL between the two groups in this study. QOL is an important factor in the postoperative evaluation. Postoperative complications can induce physical and mental discomfort and impair QOL [34]. In particular, the evaluation of long-term QOL is important when considering reconstruction methods because patients treated with PG have early-stage gastric cancer and can be expected to have a good prognosis. In this study, we could not compare postoperative QOL, because we did not conduct a questionnaire survey, and the descriptions in the medical records were not sufficient to collect this information retrospectively. In the future, it will be necessary to evaluate QOL using questionaries, such as the EORTC QLQ STO-22 or PGSAS-45 [35, 36]. Finally, the actual motor function and activities of daily living were not evaluated. Instead, we used the SMI, PMI, and IMAC to evaluate the skeletal muscle mass.

In conclusion, DTR after PG was comparable to EG in terms of perioperative safety. DTR can better prevent postoperative anastomotic complications after PG. More RE was observed in SOFY methods, but it was well controlled with PPI in long term. No differences in long-term outcomes such as nutrition status, skeletal muscle mass, and 3-year OS were observed between reconstruction methods after PG.

Declarations

Ethics Approval The protocol for this study was approved by the Ethic Committee of the study center (Osaka City General Hospital, Approval No. 1806031) and complies with the Declaration of Helsinki and its later amendments.

Consent to Participate Informed consent was obtained from all the participants.

Competing Interests The authors declare no competing interests.

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