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Proximal Anterior-Antrum Posterior (PAAP) Overlapping Anastomosis in Minimally Invasive Pylorus-Preserving Gastrectomy for Early Gastric Cancer Located in the High Body and Posterior Wall of the Stomach

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ABSTRACT

Purpose: To evaluate the feasibility and safety of intracorporeal overlapping gastrogastrostomy between the proximal anterior wall and antrum posterior wall (PAAP; PAAP anastomosis) of the stomach in minimally invasive pylorus-preserving gastrectomy (PPG) for early gastric cancer (EGC).

Materials and Methods: From December 2016 to December 2019, 17 patients underwent minimally invasive PPG with PAAP anastomosis for EGC in the high body and posterior wall of the stomach. Intraoperative gastroscopy was performed with the rotation maneuver during proximal transection. A longer antral cuff (>4–5 cm) was created for PAAP than for conventional PPG (≤3 cm) at the point where a safe distal margin and good vascular perfusion were secured. Because the posterior wall of the proximal remnant stomach was insufficient for intracorporeal anastomosis, the anterior wall was used to create an overlapping anastomosis with the posterior wall of the remnant antrum. The surgical and oncological outcomes were analyzed, and the stomach volume was measured in patients who completed the 6-month follow-up. The results were compared to those after conventional PPG (n=11 each).

Results: PAAP anastomosis was successfully performed in 17 patients. The proximal and distal resection margins were 2.4±1.9 cm and 4.0±2.6 cm, respectively. No postoperative complications were observed during the 1-year follow-up esophagogastroduodenoscopy (n=10). The postoperative remnant stomach (n=11) was significantly larger with PAAP than with conventional PPG (225.6±118.3 vs. 99.1±63.2 mL; P=0.001). The stomach length from the anastomosis to the pylorus was 4.9±2.4 cm after PAAP.

Conclusions: PAAP anastomosis is a feasible alternative for intracorporeal anastomosis in minimally invasive PPG for highly posteriorly located EGC.

Keywords: Stomach neoplasms; Laparoscopy; Surgical anastomosis; Minimally invasive surgical procedures; Volumetric CT

Author Contributions
Conceptualization: K.S.H.; Data curation: P.J.H.; Formal analysis: P.J.H.; Funding acquisition: K.S.H.; Investigation: C.J.H., P.S.H.; Methodology: P.J.H., K.S.H.; Supervision: S.Y.S., P.D.J., L.H.J., Y.H.K.; Software: MEDIP group; Visualization: Medical Art Studio (K.S.J., C.S.Y.); Writing - original draft: P.J.H.; Writing - review & editing: P.J.H., K.S.H., C.J.H., P.S.H., S.Y.S., P.D.J., L.H.J., Y.H.K.

INTRODUCTION

Pylorus-preserving gastrectomy (PPG) is a representative function-preserving gastrectomy. Both the vagus nerve and pyloric ring are preserved in PPG, which reduces the incidence of postoperative dumping syndrome and bile reflux, thereby improving the nutritional status and quality of life of patients [1-3]. PPG can be performed for cT1N0M0 gastric cancer located in the middle one-third of the stomach, approximately 4–5 cm away from the pylorus [4,5]. However, our group recently reported that PPG is also an alternative treatment for early gastric cancer (EGC) involving the upper one-third of the stomach, because it is associated with lower postoperative morbidity, better functional outcomes, and the same oncological safety as distal gastrectomy or total gastrectomy [6].

Anastomosis in laparoscopic PPG has been safely performed by hand-sewn gastrogastrostomy [7-9]. Furthermore, several studies have reported the safety and feasibility of totally laparoscopic PPG (TLPPG) with the introduction of different methods of intracorporeal anastomoses, such as the delta-shaped, hybrid, and piercing methods. However, these anastomosis techniques are usually performed when EGC is located in the middle one-third of the stomach [10-13]. As reported in our previous study, EGC located in the upper one-third of the stomach can be safely treated with PPG, not only oncologically but also surgically using the rotation maneuver [6]. However, anastomosis using the posterior wall of the remnant stomach is not feasible when a substantial portion of the posterior wall is removed in cases of cancer located on the posterior side. Intracorporeal anastomosis is much more difficult to perform because the conventional delta-shaped anastomosis and its modified methods use only the posterior walls of the proximal and distal remnant stomach for anastomosis.

In the current study, we re-examined the oncologic safety of PPG for EGC located in the mid to high body of the stomach using a large-volume database of our institution. Specifically, we evaluated the safety and feasibility of overlapping intracorporeal gastrogastrostomy between the anterior wall of the proximal remnant stomach and the posterior wall of the remnant antrum; this procedure is termed proximal anterior wall-antrum posterior wall (PAAP) anastomosis, which is used to overcome the limitations of intracorporeal anastomosis in TLPPG.

MATERIALS AND METHODS

Ethical statements
This study was approved by the Institutional Review Board of Seoul National University Hospital (approval number: 1908-176-1059). The requirement for informed consent was waived due to the retrospective nature of the study design. All procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki of 1964 and later versions.

Rationale for PPG and segmental resection for EGC located in the high body and posterior wall of the stomach
Definite surgical treatment guidelines for EGC located in the high body and posterior wall of the stomach have not yet been determined. Therefore, to confirm the oncologic safety of PPG or segmental resection (SR) for EGC located in the high body and posterior wall of the

stomach, lymph node (LN) metastasis was investigated using a cohort separate from the PAAP cohort. A database of all patients who underwent surgery for gastric cancer from 2004 to 2017 in Seoul National University Hospital was retrospectively reviewed (n=9,638). Among these patients, the patterns of LN metastasis in 286 patients who underwent surgery for EGC (pT1a, T1b, T2) located in the mid to high body/high body and posterior wall of the stomach were analyzed.

Patients

We retrospectively reviewed the data of 17 patients who underwent minimally invasive PPG or SR between December 2016 and December 2019 for EGC located in the high body and posterior wall of the stomach without any clinical evidence of LN metastasis (cT1N0M0). The PAAP anastomosis technique was used for intracorporeal gastrogastrostomy in all patients. PAAP anastomosis was performed by a single surgeon with approximately 10 years of experience as a gastric cancer specialist and who performs 150–250 gastric cancer surgeries each year.

Preoperative preparation

In all patients, preoperative endoscopic clipping was performed to localize the cancerous lesion. The lesion was marked with an endoscopic metal clip approximately 1 cm above and below the lesion in most cases. The endoscopic cautery marking method introduced by Kamiya et al. [14] was modified and applied to 5 cases to obtain a safer resection margin. Two endoscopic metal clips instead of one were placed on the proximal side: one clip toward the esophagogastric junction, and the other along the direction of the rugae, which points to the top of the fundus (**Fig. 1A**). An intraoperative gastroscope (IOG) was inserted in all patients to confirm the exact location of the tumor since the clip cannot be detected through tactile sensing by palpating the stomach wall in intracorporeal anastomosis (**Fig. 1B and C**). To confirm the lymphatic flow at LN stations 4d and 6 in the greater curvature, an additional 0.5 mL of 0.1 mg/mL indocyanine green (ICG) was injected at four sites around the tumor during insertion of the IOG in 5 patients who underwent SR for ICG-guided LN navigation surgery.

Surgical technique

Decisions-making of SR according to ICG-guided navigation

ICG-guided navigation with LN dissection was performed in five patients who underwent SR. The fluorescent signals were only observed in the lesser curvature, and not in the great curvature. Partial omentectomy was performed at the bottom of the stomach to fully open the lesser sac. After confirming the absence of ICG fluorescent signals around LN station 6, SR, which omits the dissection of LN station 6 and ligation of the right gastroepiploic artery (RGEA), was performed. LN station 11p was further dissected in some patients (9 patients with PPG and 4 patients with SR), because the cancer was located higher than the usual location for which PPG is indicated.

Transection of the proximal stomach using the rotation maneuver, and transection of the distal stomach

The rotation maneuver, which is the traditional surgical approach used by our group, was applied when proximal transection was performed to ensure an appropriate proximal resection margin [6]. The laparoscopic linear stapler was placed in the direction from the lesser curvature to the great curvature, and the body of the stomach was rotated counterclockwise while simultaneously observing the two endoscopic metal clips through the IOG. Consequently, by rotating the stomach body, the lesion in the posterior wall was relocated to the new lesser curvature side and transection of the proximal stomach was performed (**Fig. 1B and C**). In conventional PPG,
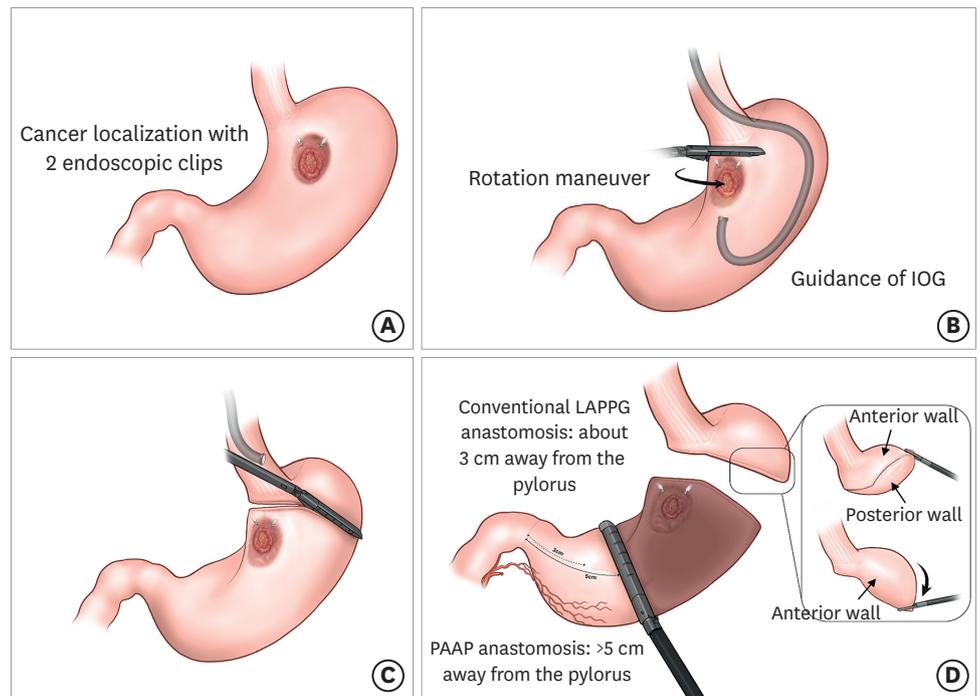
Fig. 1. Preoperative preparation and distal/proximal stomach transection.
(A) Preoperative preparation with the modified endoscopic cautery marking method. (B) The rotation maneuver with IOG guidance during the first proximal transection. (C) Second proximal transection. (D) Distal transection approximately 4–5 cm away from the pylorus in PAAP anastomosis. The posterior wall of the proximal remnant stomach is usually not sufficient to perform anastomosis.
IOG = intraoperative gastroscope; LAPPG = laparoscopic-assisted pylorus-preserving gastrectomy; PAAP = proximal anterior-antrum posterior.

distal transection is usually performed approximately 3 cm away from the pylorus. However, in the current study, distal transection was performed approximately 4–5 cm away from the pylorus, where the vascularity is secured, in order to obtain greater antrum (**Fig. 1D**). In SR, an even longer (>5 cm) distal antrum was obtained with good vascularity because the RGEA is saved by omitting the dissection of LN station 6. The sequence of the transection may be performed in the proximal part first, followed by the distal part, or vice versa, depending on the surgical situation, which can be affected by factors such as the preparation time required for the gastroscope and the order of LN dissection. Safe proximal resection with an adequate proximal margin was performed with the rotation maneuver. However, the posterior wall of the proximal remnant stomach was generally not sufficient for performing intracorporeal anastomosis (**Fig. 1D**). This situation is a good indication for PAAP anastomosis because a large area of the posterior wall of the stomach, usually used for intracorporeal anastomosis, is resected using the rotation maneuver.

PAAP anastomosis
After extracting the specimen from the abdominal cavity, PAAP anastomosis was simulated by pulling down the proximal remnant stomach and pulling up the remnant antrum (**Fig. 2A**). PAAP anastomosis was performed when both walls smoothly overlapped each other without any tension. A small gastrostomy was made at the edge of the greater curvature of each proximal or distal stomach. The cartridge side of the laparoscopic linear stapler was inserted into the gastrostomy in the proximal remnant stomach, whereas the anvil side was inserted into the gastrotomy of the antrum. The anterior wall of the proximal remnant stomach,

and the posterior wall of the antrum were adjusted to ensure that both walls overlapped each other evenly. Next, we aimed to create a space of at least 1 cm from the transection staple lines for good vascularity (**Fig. 2B**). Intracorporeal overlapping gastrogastrostomy was performed using a 60-mm green or black laparoscopic linear stapler (**Fig. 2C**). After ensuring adequate stapling and observing no evidence of bleeding from the anastomosis line, 2 laparoscopic tagging sutures were used at the edge of the gastrogastrostomy. Each tagging string was lifted to the same height, and the common entry was closed with the laparoscopic linear stapler (**Fig. 2D and E**).
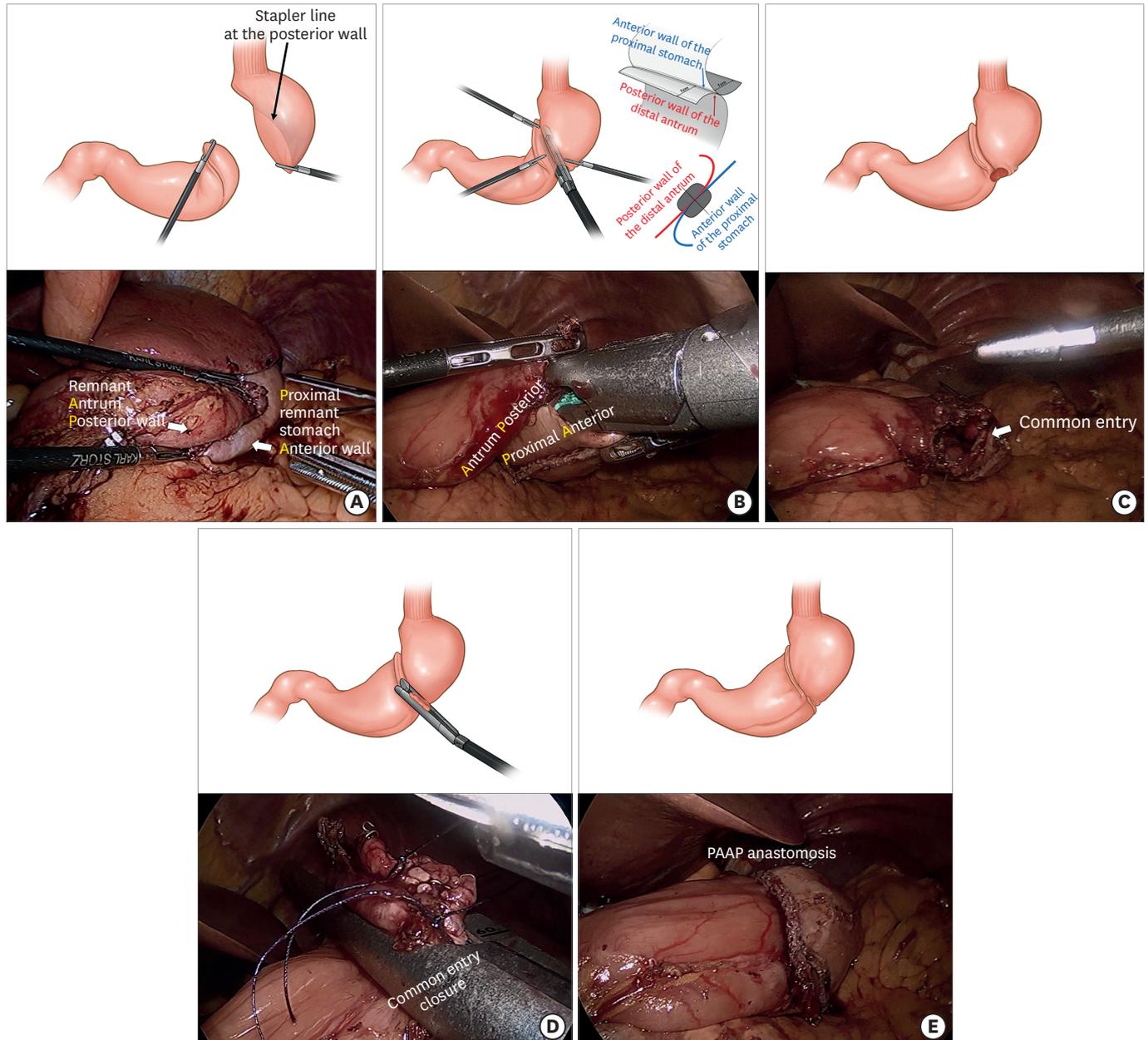

Fig. 2. Intracorporeal overlapping gastrogastrostomy between the proximal anterior wall and antrum posterior wall (PAAP anastomosis).
(A) Simulation of PAAP anastomosis by pulling down the proximal remnant stomach and pulling up the remnant antrum. (B) PAAP anastomosis using a laparoscopic linear stapler. (C) Intracorporeal gastrogastrostomy. (D) Common entry closure using a laparoscopic linear stapler. (E) TLPPG with PAAP anastomosis.
TLPPG = totally laparoscopic pylorus-preserving gastrectomy; PAAP = proximal anterior-antrum posterior.

Surgical and oncological outcomes

The surgical outcomes included the operative time, postoperative hospital stay (days), postoperative complications, length of the greater/lesser curvature in the extracted specimen, tumor size, proximal/distal resection margin, and T/N stage. Each LN station was routinely separated from the surgical specimen before pathological evaluation, and resected and metastatic LN data were obtained from postoperative pathological reports. Postoperative complications were classified according to the Clavien-Dindo classification system [15]. All patients underwent a follow-up examination that included upper gastrointestinal series (UGIS), stomach computed tomography (CT), and esophagogastroduodenoscopy (EGD) at 3, 6, and 12 months after surgery, respectively.

Stomach volume and nutritional outcomes

From January 2013 to December 2019, a total of 727 patients underwent laparoscopy-assisted PPG (LAPPG) or robot-assisted PPG (RAPPG). Among them, 48 patients underwent LAPPG as a result of EGC located in the mid to high/high body posterior wall. The stomach volume and nutritional outcomes of 11 patients who completed the 6-month follow-up after minimally invasive PPG with PAAP anastomosis were compared to those of 11 patients who have preoperative and postoperative follow-up stomach CT (not abdominal pelvic CT) after LAPPG. For both the PAAP and LAPPG groups, body weight, body mass index (BMI), and serological data (hemoglobin, total protein, and albumin levels) were collected preoperatively and at 6 months postoperatively to evaluate postoperative nutritional status. The stomach volume was measured preoperatively and postoperatively using commercially available software (Medical Imaging Processing [MEDIP] version 1.3.2.0; Medical IP, Seoul, Korea). Two-dimensional (2D) cross-sectional preoperative and postoperative stomach CT scans were used to construct 3-dimensional (3D) stomach models. The stomach volumetric and nutritional differences between the 2 groups were calculated and analyzed.

Statistical analysis

Continuous variables are expressed as mean±standard deviation. The Mann-Whitney U test was used to analyze differences between the PAAP and LAPPG groups, and the PAAP group was divided into the PPG and SR subgroups. The postoperative proximal and distal stomach volumes and the distal length from the anastomosis were additionally measured and compared between PPG and SR, because the anastomosis staple line was visible on postoperative stomach CT scans. SPSS version 25 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis.

RESULTS

The LN metastasis pattern for EGC located in the high body and posterior wall of the stomach was retrospectively analyzed. As shown in **Table 1**, only 1 case of LN metastasis was observed at LN station 4d in patients with T1a (1.2%). Although more LN metastases were detected at LN

Table 1. LN metastasis pattern for EGC located in the mid to high body or high body and posterior wall of the stomach

LN station	1	2	3	4sa	4sb	4d	5	6	7	8a	9	10	11p	11d	12a
T1a (%)	0/88 (0)	0/68 (0)	0/88 (0)	0/67 (0)	0/86 (0)	1/86 (1.2)	0/53 (0)	0/66 (0)	0/88 (0)	0/85 (0)	0/87 (0)	0/24 (0)	0/81 (0)	0/38 (0)	0/12 (0)
T1b (%)	2/135 (1.5)	0/114 (0)	5/136 (3.7)	0/119 (0)	0/135 (0)	0/130 (0)	0/79 (0)	1/100 (1.0)	3/135 (2.2)	0/133 (0)	0/131 (0)	0/42 (0)	2/128 (1.6)	2/72 (2.8)	0/28 (0)
T2 (%)	6/59 (10.2)	0/56 (0)	20/60 (33.3)	1/55 (1.8)	2/60 (3.3)	1/58 (1.7)	0/48 (0)	0/51 (0)	9/59 (15.3)	1/59 (1.7)	2/57 (0)	0/32 (0)	4/56 (7.1)	3/40 (7.5)	0/23 (0)

LN = lymph node; EGC = early gastric cancer.

stations 1, 3, 6, 7, 11p, and 11d in patients with T1b, the percentage of LN metastases was as low as <4%. In particular, there was no LN metastasis at LN stations 2 and 4sa in any case, except one with T2 (1/479, 0.2%), despite the high location of the cancer (**Table 1**).

Patient characteristics

From December 2016 to December 2019, all 17 patients (10 men and 7 women) successfully underwent minimally invasive PPG or SR with the PAAP anastomosis technique: 12 patients with LPPG or robotic PPG, and 5 patients with laparoscopic SR with ICG-guided LN navigation surgery. The mean age and BMI were 63.0±10.1 years and 25.6±3.5 kg/m^2, respectively (**Table 2**).

Surgical and oncological outcomes

The mean operative time was 219.7±42.0 minutes. All patients were discharged without immediate postoperative complications after 7.1±1.4 days of hospitalization. There were no intraoperative complications, conversions to open surgery, or acute postoperative complications. The tumor size was 2.2±1.4 cm, and the proximal and distal resection margins measured 2.4±1.9 cm and 4.0±2.6 cm, respectively. Fourteen patients had T1N0, 1 patient had T2N0, 1 patient had T1bN1, and 1 patient had T1bN2 (**Table 3**). Postoperative follow-up UGIS, CT, and EGD revealed intact anastomoses without any bile reflux, gastric stasis, or esophageal reflux (n=10), as shown in **Fig. 3**.

Table 2. Patient characteristics

Parameters	Values (n=17)
Age (yr)	63.0±10.1 [37–77]
Sex	
Male	10
Female	7
BMI (kg/m²)	25.6±3.5 [18.3–31.2]
Surgery (minimally invasive surgery)	
Pylorus-preserving gastrectomy (laparoscopy/robot)	12 (11/1)
IOG	11
IOG+ICG injection	1
Segmental resection (all laparoscopy)	5
IOG+ICG injection	5

Values are presented as number or mean±standard deviation [range].
BMI = body weight index; IOG = intraoperative gastroscope; ICG = indocyanine green.

Table 3. Surgical and oncological outcomes

Parameters	Values (n=17)
Operation time (min)	219.7±42.0 [160–300]
POD (day)	7.1±1.4 [5–10]
Postoperative complications, C–D grade	0
Length of the great curvature in the extracted specimen (cm)	14.3±3.8 [8.5–23.0]
Length of the lesser curvature in the extracted specimen (cm)	5.7±1.8 [2.7–8.5]
Cancer size (cm)	2.2±1.4 [0.0–6.0]
Proximal resection margin (cm)	2.4±1.9 [0.3–8.1]
Distal resection margin (cm)	4.0±2.6 [0.9–10.5]
T stage	
T1 (T1a/T1b)	16 (5/11)
T2	1
N stage	
N0/N1/N2	15/1/1

Values are presented as number or mean±standard deviation [range].
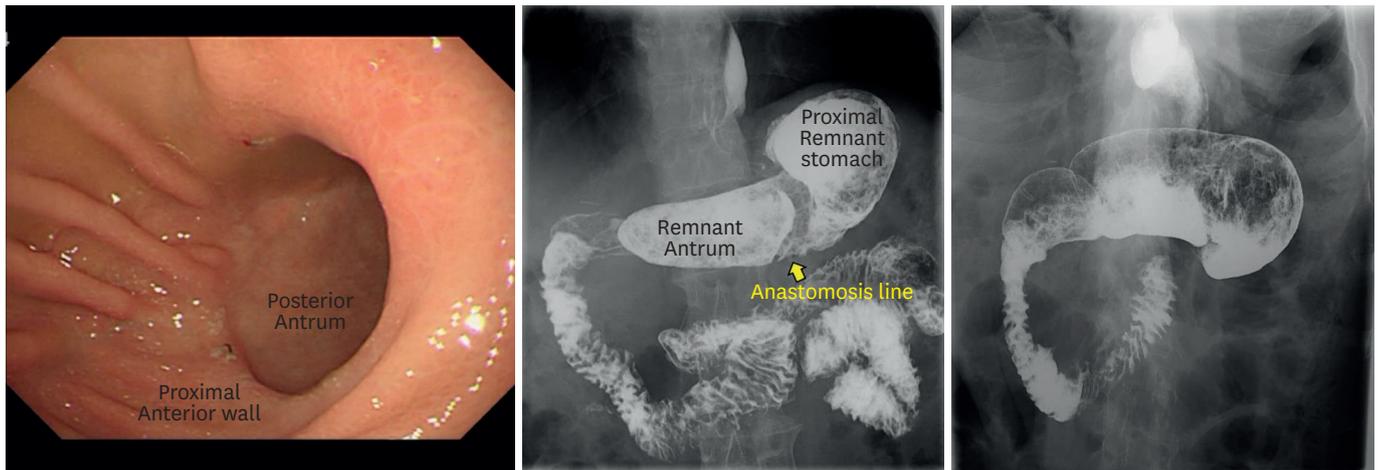POD = postoperative day.

Fig. 3. Postoperative esophagogastroduodenoscopy and upper gastrointestinal series.
Intact anastomoses without postoperative complications such as bile reflux or pylorus stenosis.

Stomach volume and nutritional outcomes

Differences in the stomach volume and nutritional parameters between the PAAP and LAPPG groups are presented in **Tables 4, 5**, and **Fig. 4**. Although the preoperative stomach volume was larger in the LAPPG group than in the PAAP group (579.9±226.0 mL vs. 501.8±69.5 mL), the size of the postoperative remnant stomach was smaller in the LAPPG group than in the PAAP group (99.1±63.2 mL vs. 225.6±118.3 mL; P=0.001). There was a significantly larger decrease in the stomach volume in the LAPPG group than in the PAAP group (84.0% vs. 55.4%; P=0.000).

Even though there was a tendency for better nutritional outcomes after PAAP compared to LAPPG, it was not statistically significant (**Table 5**). The postoperative proximal and distal stomach volumes in the PAAP group were 174.3±129.5 mL and 50.1±35.8 mL, respectively.

Table 4. Stomach volumetric

Stomach volume difference	PAAP (n=11)	Conventional LAPPG (leaving 3 cm of the distal antrum) (n=11)	P-value*	SR (n=3)	PPG (n=8)	P-value†
Preoperative stomach volume (mL)	501.8±69.5	579.9±226.0	0.740			
Postoperative remnant stomach volume (mL)	225.6±118.3	99.1±63.2	0.001			
Removed stomach volume (mL)	276.3±115.9	480.8±167.9	0.004			
Postoperative stomach volume decrease (%)	55.4±21.4	84.0±4.9	0.000			
Postoperative proximal stomach volume (mL)	174.3±129.5			138.1±159.2	187.9±126.2	0.497
Postoperative distal stomach volume (mL)	50.1±35.8			86.9±45.8	36.3±20.7	0.085
Postoperative stomach length from anastomosis to pylorus (cm)	4.9±2.4			7.7±2.9	3.9±1.2	0.048

PAAP = proximal anterior wall-antrum posterior wall; LAPPG = laparoscopy-assisted pylorus-preserving gastrectomy; SR = segmental resection; PPG = pylorus-preserving gastrectomy.
*P-value presented as PAAP vs. Conventional LAPPG; †P-value presented as SR vs. PPG.

Table 5. Nutritional outcomes

Nutritional outcome	PAAP (n=11)	Conventional LAPPG (leaving 3 cm of the distal antrum) (n=11)	P-value
Body weight differences 6 months after surgery (kg)	−5.8±4.4	−6.8±4.4	0.608
BMI differences 6 months after surgery (kg²/m)	−2.7±1.5	−2.7±1.8	0.833
Hemoglobin differences 6 months after surgery (g/dL)	−0.7±0.9	−0.3±0.9	0.169
Total protein differences 6 months after surgery (g/dL)	0.2±0.5	0.01±0.5	0.487
Albumin differences 6 months after surgery (g/dL)	0.1±0.4	−0.1±0.3	0.211

PAAP = proximal anterior wall-antrum posterior wall; LAPPG = laparoscopy-assisted pylorus-preserving gastrectomy; BMI = body mass index.
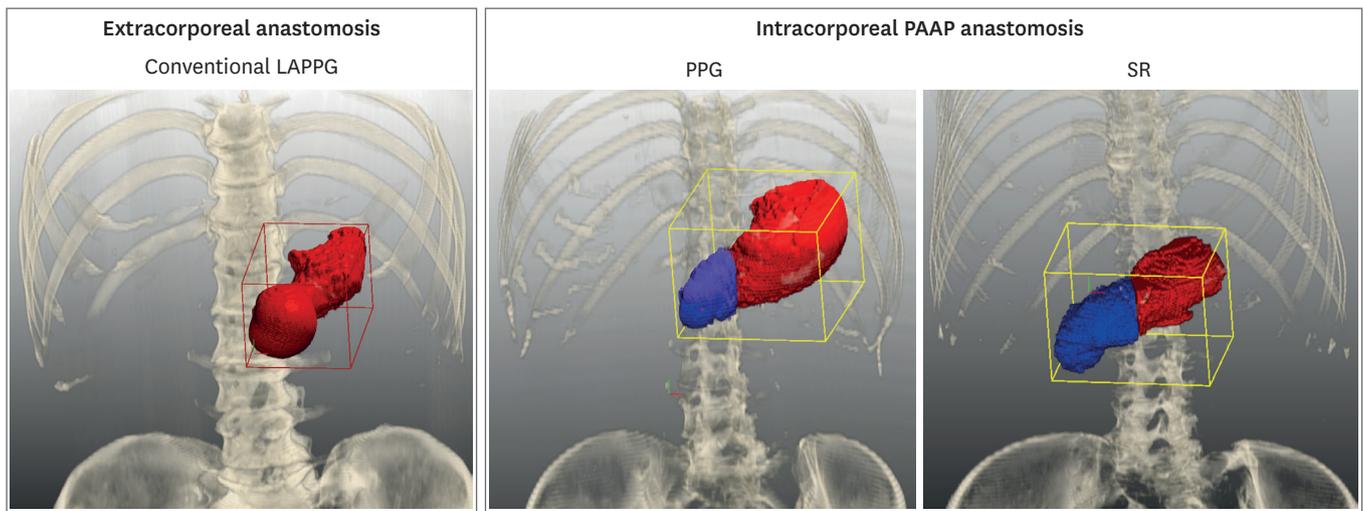
Fig. 4. Stomach volume measurement (MEDIP software program).
The size of the postoperative remnant stomach was larger in the PAAP group than in the LAPPG group. The antrum cuff length was longer in the SR group than in the PPG group.
LAPPG = laparoscopic-assisted pylorus-preserving gastrectomy; SR = segmental resection; PPG = pylorus-preserving gastrectomy; PAAP = proximal anterior-antrum posterior.

The postoperative stomach length from the anastomosis to the pylorus was 4.9±2.4 cm. The proximal remnant volume was smaller in the SR group than in the PPG group (138.1±159.2 and 187.9±126.2, respectively), whereas the volume of the remnant antrum (86.9±45.8 and 36.3±20.7, respectively) and the antrum length (7.7±2.9 and 3.9±1.2, respectively; P=0.048) were larger in the SR group than in the PPG group (**Table 4**).

DISCUSSION

PPG is a good surgical treatment for EGC located in the middle one-third of the stomach [4,5]. Indeed, several previous studies have shown that PPG improves postoperative quality of life by preserving stomach function [1,2]. However, if the cancer is located slightly higher than the middle one-third of the stomach and is biased toward the posterior wall of the stomach, then the surgical options will vary (e.g., proximal gastrectomy, distal gastrectomy, PPG, or SR). Although no definite surgical treatment guidelines for EGC in the high body and posterior wall have been established, recent studies have suggested that PPG or SR are good surgical treatments in terms of oncological and surgical safety [6].

According to our large-volume database, there was no LN metastasis in LN stations 2 and 4sa among patients with T1a and T1b. LN station 4sa is a high-level area on the side of the greater curvature. Therefore, EGC that is located in the high body of the stomach, which is approximately 3 cm away from the esophagogastric junction, and does not involve cardia may be an indication for PPG. However, dissection of LN station 6 and ligation of the RGEA in PPG causes ischemia at approximately 5–6 cm above the pylorus [16]. SR can save more of the antrum because the RGEA is preserved. Mizuno et al. [17] reported that lymphadenectomy along the infrapyloric artery is important for treating gastric cancer invading the antrum, but it may not be essential when performing pylorus preservation in early-stage gastric cancer of the middle one-third of the stomach. In our database, even though 1 case of LN metastasis was observed at station 4d in T1a and 1 case of LN metastasis was observed at station 6 in T1b,

these were extremely rare (1.2% and 1%, respectively). The results of the study by Mizuno et al. [17], as well as our own database analysis support our hypothesis that SR would be possible by omitting dissection of LN station 6 in some cases, especially for EGC located in the high body and posterior wall of the stomach. Additionally, the sensitivity of LN dissection in ICG-guided navigation surgery has been proven by a previous study [18]. Therefore, to confirm the oncological safety, ICG-guided LN navigation surgery was performed during LN dissection in patients who underwent SR. Dissection of LN station 11p was additionally performed, while station 6 was omitted according to ICG fluorescence navigation. If the EGC is located in the high body, then dissection of LN station 11p may be needed in some cases.

Of a total of 17 patients, stage discrepancy between the clinical stage and pathologic stage was observed in 3 patients: T2N0, T1bN1, and T1bN2 (**Table 3**). This discrepancy was not a problem encountered during this study alone, but instead, is a common problem that needs to be addressed when selecting the type of gastrectomy and the extent of LN dissection. In a previous study, a discrepancy rate of 8.6% was found when comparing the preoperative and postoperative diagnoses of gastric cancer patients [19]. In highly located tumors, whether to preserve the fundus without dissecting LN station 2 and 4sa is a common problem of pylorus-preserving gastrectomy and distal gastrectomy. According to our database (**Table 1**), the metastasis rate of LN station 2 was 0% in both T1 and T2, and in T2 tumors, there was only 1 patient with metastasis in LN station 4a. Moreover, whether to preserve the antrum without dissecting LN station 5 represents another important issue in pylorus-preserving gastrectomy [16]. In the current study, tumors that were located in the high body had a lower probability of LN metastasis in LN station 5 compared to tumors located in the true middle one-third or the lower part of the stomach. As shown by our database analysis, there was no LN metastasis in LN station 5; however, there was 1.6% of LN metastasis in LN station 11p in T1b tumors. Because of the higher possibility of LN metastasis in LN station 11p, it is considered to be safer to dissect LN station 11p in cases of highly located tumors. It is also expected that ICG lymphangiography, which was used to confirm that there was no LN metastasis in LN station 4d and 6 so that SR could be performed in this study, may help surgeons to decide the proper extent of LN dissection.

If the cancer is located in the high body and posterior wall of the stomach, then it is not easy to transect the proximal stomach with a secure margin. In this study, we successfully performed proximal resection of the stomach with an adequate margin, and confirmed no cancer involvement in the resection margin by using the frozen section during surgery, or the final histopathological result in all cases. Furthermore, we modified Kamiya's endoscopic cautery marking method to increase the remnant stomach, while also ensuring oncologically safe margins [14]. The cancer location was marked preoperatively with dual endoscopic metal clips instead of a single clip on the proximal side of the tumor, and transection was performed with IOG guidance [20]. Because our group has shown that the rotation maneuver is effective for maintaining a safe proximal margin when the cancer is located in the upper one-third of the stomach [6], we rotated the body of the stomach counterclockwise during proximal transection to maintain a safe margin. Although these methods provided advantages for securing the proximal resection margin, anastomosis becomes more difficult to perform because the remnant proximal stomach is usually small.

Conventional intracorporeal anastomosis methods are feasible without tension when the cancerous lesion is located in the middle one-third of the stomach [11-13]. However, those anastomosis methods are unsuitable when the cancer is located in the high body

and posterior wall of the stomach because the amount of the remnant proximal stomach is usually smaller than expected after resection to ensure a sufficient proximal margin. In particular, the Delta-shaped anastomosis method only used the posterior wall of the proximal and distal remnant stomach at the time of anastomosis by using a laparoscopic linear stapler. Therefore, when the cancer is located in the high body and posterior wall of the stomach, the posterior wall of the proximal remnant stomach is not usually large enough to mechanically pull down to create the anastomosis with the distal remnant antrum. The delta anastomosis technique has a great advantage in realizing minimally invasive surgery in PPG, but its use is limited by the location of the cancerous lesion.

LAPPG with extracorporeal anastomosis could be considered for treating EGC [7,9]. LAPPG is not only less invasive than open PPG but can also be performed as safely as open PPG because the location of the lesion is easily identified by touching the endoscopic metal clips [8]. Therefore, the proximal resection margin can be determined precisely without excessive resection of a large part of the proximal stomach. However, pulling the stomach through the mini-laparotomy and performing an extracorporeal hand-sewn anastomosis without tension remains technically difficult, especially when the lesion is located in the high portion of the stomach. In this study, we used the MEDIP software program to measure the stomach volume, in which the 2D CT images of the stomach can be used to construct 3D models of the stomach. Segmentation of the image or merging of the segmented data can be handled easily with this program, which makes it useful for measuring the volume of the desired area [21,22]. As our data has shown (**Tables 4**), the size of the remnant stomach was larger in PAAP anastomosis than in conventional extracorporeal anastomosis. However, the incidence of complications, such as delayed emptying, was not increased. According to our results, if distal gastrectomy with Billroth II anastomosis was performed because of technical problems with anastomosis, only 174.3 mL of the stomach would have remained. Thus, PPG could save approximately 50.1 mL more of the stomach because the distal antrum is left after transection. We performed PAAP anastomosis by using the anterior wall of the proximal remnant stomach and the posterior wall of the remnant antrum. We observed tendency for nutritional benefits with PAAP (**Table 5**), although it was not statistically significant; however, a previous study showed that the remaining stomach size was beneficial for nutrition [23]. The Japanese Gastric Cancer Association guidelines recommend leaving at least 50% of the distal stomach after proximal gastrectomy, which seems to reflect the empirical consensus that the volume of the distal stomach will be related to dietary intake. Whether obtaining a larger stomach will provide nutritional benefits is a good topic for future research, and the volumetric method used in this study is expected to be a good tool for studying PPG and SR.

In conclusion, we believe that PAAP anastomosis is a feasible and safe first choice technique in minimally invasive PPG when the EGC is located in the high body and the posterior wall of the stomach. To the best of our knowledge, this anastomosis technique has not been previously reported. Further studies of the long-term outcomes and nutritional benefits of this technique are needed.

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