Esophagojejunal Anastomosis After Totally Laparoscopic Total Gastrectomy: π-shaped Versus Reverse Puncture Device Anastomosis

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AIM: This study aimed to compare the advantages of π-shaped anastomosis with reverse puncture device (RPD) anastomosis following totally laparoscopic total gastrectomy (TLTG).

METHODS: Clinical data from 133 patients with gastric cancer who underwent TLTG between 1 January 2020 and 1 January 2024, in the Department of Gastrointestinal Surgery at the First Affiliated Hospital of Bengbu Medical University were retrospectively analyzed. Patients were categorized into a π-shaped group (67 patients) and an RPD group (66 patients) according to the esophagojejunal anastomosis method. The median follow-up duration was 6 months (95% CI: 5.2–6.8 months). Baseline characteristics, postoperative conditions, and postoperative complications were compared and analyzed between the two groups.

RESULTS: There were no significant differences between the groups in intraoperative bleeding volume, total lymph node dissection number, first flatus time, hospitalization time, or the incidence of postoperative non-anastomotic complications (all $p > 0.05$). Compared with the RPD group, the π-shaped group demonstrated shorter anastomosis time, smaller main incision length, and a lower incidence of anastomotic complications (all $p < 0.05$). Conversely, the RPD group has a significantly longer esophageal resection margin compared to the π-shaped anastomosis group ($p < 0.05$).

CONCLUSIONS: Both RPD and π-shaped anastomosis are safe and effective for esophagojejunal reconstruction after TLTG. The π-shaped anastomosis is recommended as the preferred anastomosis for totally laparoscopic total gastrectomy, and the RPD anastomosis can be applied to gastroesophageal junction cancer with a higher tumor location.

Keywords: gastric cancer; totally laparoscopic total gastrectomy; π-shaped anastomosis; reverse puncture device; Adenocarcinoma of the Esophagogastric Junction

Introduction

Laparoscopic surgery has developed rapidly in recent years due to its advantages of smaller surgical incisions, reduced postoperative pain, and rapid postoperative recovery [1,2]. Totally laparoscopic total gastrectomy (TLTG) maximizes these benefits of minimally invasive surgery [3]. Esophagojejunostomy is a crucial step in determining the success of the operation. An ideal anastomosis should be easy to perform, have a short anastomotic time, and reduce the occurrence of anastomotic complications [4]. Roux-en-Y anastomosis is the main method of digestive tract reconstruction after total gastrectomy [5,6]. Anastomosis methods using circular staplers include Orvil [7], hemi-double stapling technique (HDST), and reverse puncture device (RPD), while those using linear staplers include overlap anastomosis [8], functional end anastomosis and π-shaped anastomosis [9]. The RPD anastomosis resembles traditional open anastomosis and replaces the purse-string suture with a linear stapler to close the esophageal stump, simplifying the procedure. By contrast, π-shaped anastomosis is a representative anastomotic method using a linear stapler in TLTG. Compared with overlap anastomosis, the π-shaped approach does not transect the esophagus before anastomosis. The retraction of the esophagus can be avoided by pulling the esophagus, which simplifies the anastomosis process [10]. At present, there are relatively few comparative studies on these two anastomotic methods. Therefore, this study aimed to provide evidence for selecting an appropriate anastomotic esophagojejunal anastomotic method in TLTG by comparing early postoperative outcomes and complications between π-shaped and RPD anastomosis.

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Methods

Study Subjects

Clinical data of 133 patients with gastric cancer who received total laparoscopic total gastrectomy between 1 January 2020 and 1 January 2024, in the Department of Gas-

trointestinal Surgery at the First Affiliated Hospital of Bengbu Medical University, were retrospectively analyzed. Patients were categorized into the π-shaped group (67 patients) and the RPD group (66 patients) according to the esophagojejunal anastomosis method.

All patients were fully informed about the surgical procedure, associated risks, and potential postoperative complications. All surgeries were performed by gastric surgeons with more than 10 years of experience in laparoscopic gastric surgery.

Inclusion criteria: (1) pathologically verified gastric adenocarcinoma diagnosed by gastroscopy and contrast-enhanced computed tomography (CT); (2) tumor was located in the Adenocarcinoma of the Esophagogastric Junction (AEG) (type Siewert II) [11,12], AEG (type Siewert III), and non-AEG gastric cancer (the center of the tumor was more than 5 cm away from the esophagogastric junction, including the gastric fundus, gastric body, and gastric antrum) required total gastrectomy; (3) pathological Tumor-Node-Metastasis (pTNM) stages I–III disease, without distant metastasis (M0), according to the 8th edition of the American Joint Committee on Cancer (AJCC) TNM classification system [13]; (4) patients undergoing TLTG with esophagojejunostomy performed using either π-shaped or RPD anastomosis.

Exclusion criteria: (1) AEG Siewert type I; (2) history of undergoing surgery or intraperitoneal adhesions precluding laparoscopic; (3) distant metastasis detected preoperatively; (4) severe heart and lung system diseases, unable to tolerate surgery; (5) advanced gastric cancer requiring neoadjuvant chemotherapy or radiotherapy.

This study was conducted in accordance with the ethical guidelines of the 2013 version of the Declaration of Helsinki and was approved by the Ethics Committee of the First Affiliated Hospital of Bengbu Medical University (approval number: 2020AH011100). Written informed consent was obtained from all patients before enrollment in this study.

Surgical Methods

All Patients in both groups were placed in the reverse Trendelenburg position. The camera holder stood between the patient's legs, while the chief surgeon and assistant stood on the left and right sides of the patient, respectively. A camera port was placed below the umbilicus. The upper abdomen was inserted with four trocars, including two 12-mm trocars and two 5-mm trocars. Among these, the trocars at the upper left and lower right were 12 mm. The same surgical team completed D2 lymph node dissection under laparoscopy in accordance with the Japanese Gastric Cancer Treatment Guidelines 2018 (5th edition) [14].

RPD Group

Following completion of the D2 lymphadenectomy, duodenal transection was conducted using a 60-mm Ethicon linear stapler (EC60A+ECR60W, Ethicon Endo-Surgery, Cincinnati, OH, USA). Circular staplers (Ethicon CDH25A, Ethicon Endo-Surgery, Cincinnati, OH, USA) we used for esophagojejunostomy. The anvil of the circular staplers was tied with a 2-0 silk suture. The 12-mm trocar in the left upper abdomen was dilated to allow the introduction of the anvil of the stapler. An incision was made on the esophagus, 1–2 cm above the esophagogastric junction (EGJ) (Fig. 1A), and the anvil was inserted into the esophageal lumen (Fig. 1B). A purse-string suture was secured by applying traction to the sutures prefixed on the anvil, and the stump of the esophagus was closed with a 60-mm Ethicon linear stapler (Fig. 1C,D). The jejunum, approximately 15–25 cm distal to the ligament of Treitz, was selected to ensure that there was no tension after traction. After transection and division of the mesenteric vessels, the Roux limb (efferent) and biliopancreatic limb (afferent) were created. A small upper midline incision was made to remove the specimen. The circular stapler (Ethicon CDH25A, Ethicon Endo-Surgery, Cincinnati, OH, USA) was then introduced through the Roux limb. The anvil head and circular stapler (Ethicon CDH25A, Ethicon Endo-Surgery, Cincinnati, OH, USA) were connected (Fig. 1E). The Jejunum stump was closed with a 60-mm Ethicon linear stapler (EC60A+ECR60W, Ethicon Endo-Surgery, Cincinnati, OH, USA) after esophagojejunostomy (Fig. 1F). The Roux limb was anastomosed to the biliopancreatic limb about 45–50 cm below the esophagojejunostomy by using another two staplers (EC60A+ECR60W, Ethicon Endo-Surgery, Cincinnati, OH, USA) under laparoscopy. The mesenteric gap and the Peterson gap were all closed under laparoscopy. Frozen sections of the esophageal margins were examined in all patients, and all results were negative. Air leak testing was conducted in all cases, with uniformly negative results.

π-Shaped Anastomosis Group

Following completion of the D2 lymphadenectomy, duodenal transection was conducted using a 60-mm Ethicon linear stapler (EC60A+ECR60W, Ethicon Endo-Surgery, Cincinnati, OH, USA). The lower section of the esophagus was ligated with a sterilized hemp rope to facilitate traction of the esophagus (Fig. 2A). Mobilization of the abdominal esophagus was routinely performed. A full-thickness esophageal incision was then made 2–3 cm above the rope (Fig. 2B). The jejunum, approximately 15–25 cm distal to the ligament of Treitz, was selected after confirming adequate mesenteric mobility and ensuring a tension-free elevation. A small enterotomy was made on the antimesenteric border of the intestinal wall (Fig. 2C). A side-to-side anastomosis was then created between the right wall of the esophagus and the antimesenteric wall of the jejunum using a second Ethicon linear stapler (EC60A+ECR60B, Ethicon Endo-Surgery, Cincinnati, OH, USA) (Fig. 2D). The esophagojejunostomy anastomo-

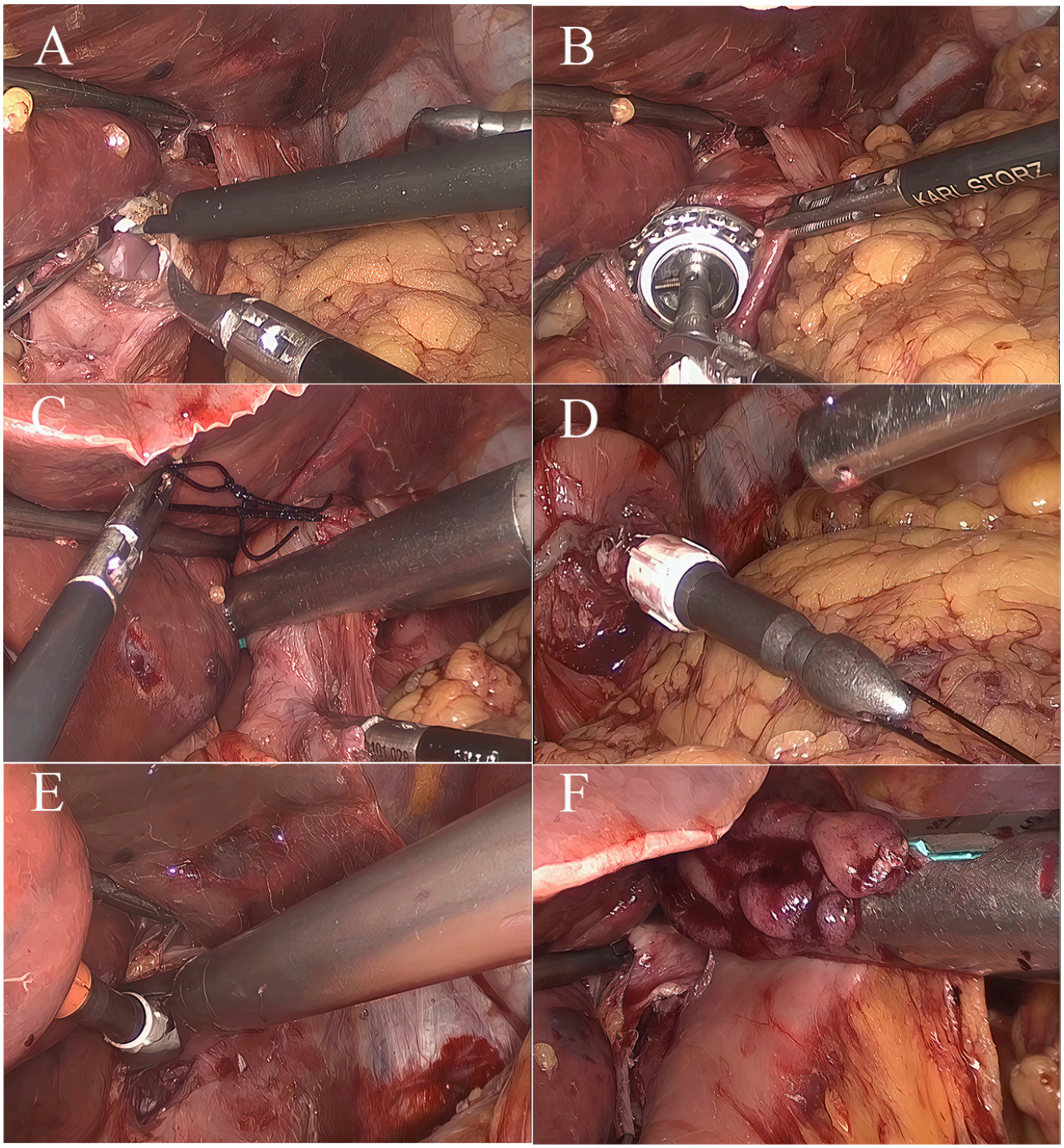

Fig. 1. Reverse puncture device technique. (A) An incision was made on the esophagus. (B) The anvil was inserted into the esophagus. (C,D) The stump of the esophagus was closed and the anvil was pulled out. (E) The anvil was engaged with the circular stapler. (F) The jejunum stump was closed with a 60-mm Ethicon linear stapler.

sis (E-J) was inspected through the entry hole (Fig. 2E), which was subsequently closed with a third linear stapler (EC60A+ECR60B, Ethicon Endo-Surgery, Cincinnati, OH, USA) (Fig. 2F). The Roux limb was anastomosed to the biliopancreatic limb about 45–50 cm below the esophagojejunostomy using another two staplers (EC60A+ECR60W, Ethicon Endo-Surgery, Cincinnati, OH, USA) under laparoscopy. The specimen was removed through the enlarged observation port. Both the mesenteric gap and Peterson's gap were closed under laparoscopy. Frozen sections of the esophageal margins were examined in all patients, with uniformly negative results. Air leak testing was conducted in all cases, and no leaks were detected.

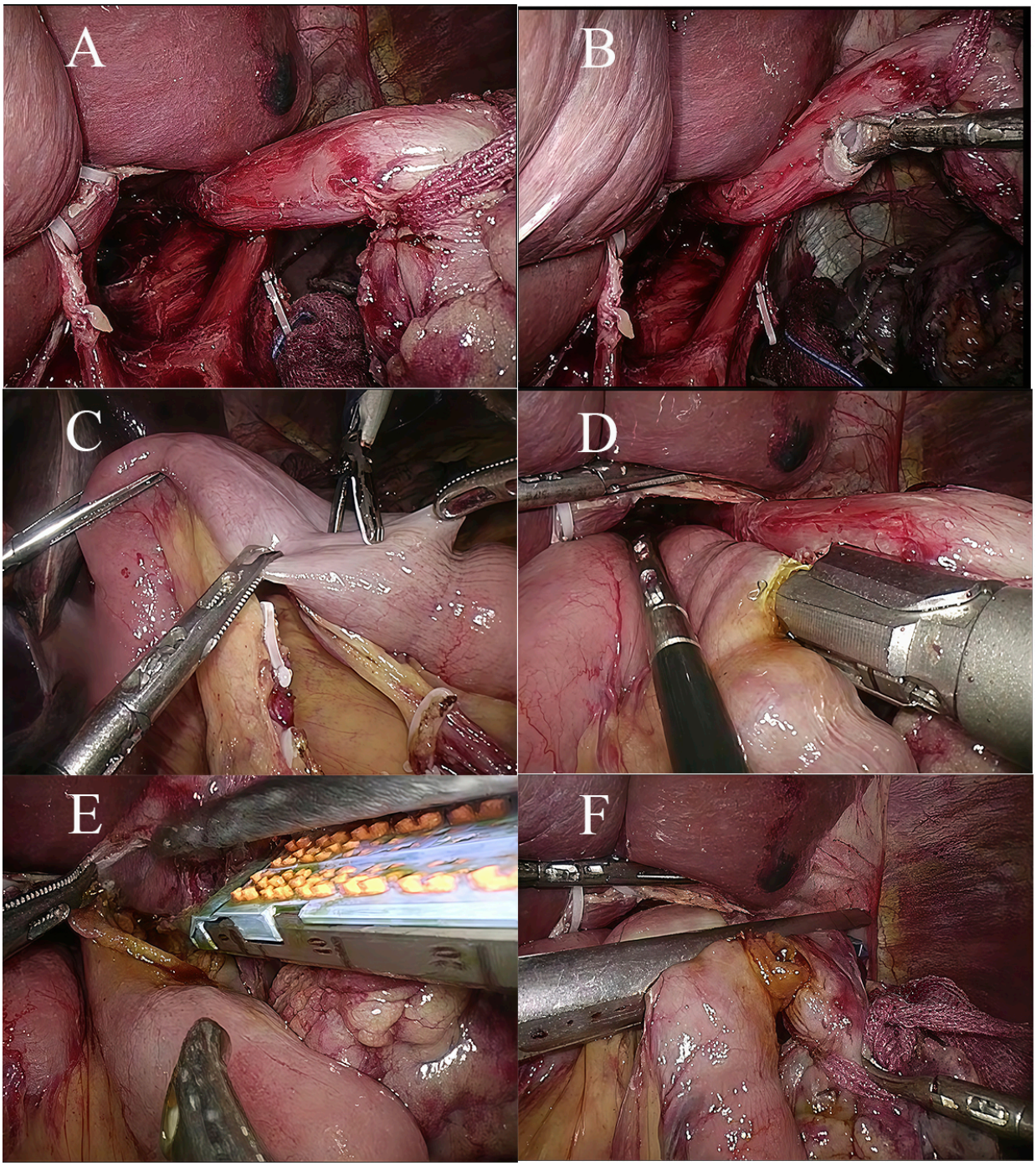

Fig. 2. π-shaped anastomosis method. (A) The esophagus was pulled with a sterilized hemp rope. (B) An incision was made on the esophagus. (C) An incision was made on the antimesenteric border of the jejunum. (D) A side-to-side anastomosis between the esophagus and the jejunum was conducted. (E) The condition of the anastomosis was checked. (F) The common opening was closed.

Observation Indicators

We collected the basic clinical data, intraoperative variables, and postoperative recovery indicators, including anastomotic time, operation time, volume of intraoperative bleeding, main incision length, number of intraoperative lymph node dissections, length of the esophageal margin, postoperative flatus time, and postoperative hospitalization time.

Postoperative complications were divided into anastomotic complications and non-anastomotic complications. All patients underwent scheduled monthly postoperative follow-up evaluations after surgery. The median follow-up duration was 6 months (95% CI: 5.2–6.8 months). Esophageal jejunal anastomotic complications, including bleeding, leakage, and stricture, often occurred within 3 months after surgery. The severity of all complications was

Table 1. Patients' clinical characteristics of the two groups.

Variables	π-shaped group (n = 67)	RPD group (n = 66)	t/χ^2	*p*
Age (years)	64.9 ± 8.9	66.3 ± 7.3	–0.99	0.37
Sex			0.07	0.79
Male	38 (57%)	39 (59%)		
Female	29 (43%)	27 (41%)		
BMI (kg/m^2)	22.4 ± 3.0	21.7 ± 3.5	1.23	0.23
Tumor location			0.58	0.96
AEG (Siewert II)	4 (6%)	5 (8%)		
AEG (Siewert III)	32 (48%)	28 (42%)		
gastric fundus	12 (18%)	11 (17%)		
gastric body	15 (22%)	17 (26%)		
gastric antrum	4 (6%)	5 (7%)		
Tumor maximum diameter (cm)	4.1 ± 0.5	4.0 ± 0.6	1.12	0.27
pT category			0.12	0.99
T1	14 (21%)	13 (20%)		
T2	28 (42%)	30 (45%)		
T3	16 (24%)	15 (23%)		
T4	9 (13%)	8 (12%)		
T4a	9 (13%)	8 (12%)		
T4b	0	0		
pN category			0.43	0.93
N0	4 (6%)	6 (9%)		
N1	32 (48%)	29 (44%)		
N2	25 (37%)	26 (39%)		
N3	6 (9%)	5 (8%)		
pTNM category			0.41	0.81
I	21 (31%)	18 (27%)		
II	37 (55%)	40 (61%)		
III	9 (14%)	8 (12%)		
Borrmann type			0.25	0.97
I	19 (28%)	17 (26%)		
II	36 (54%)	39 (59%)		
III	8 (12%)	7 (11%)		
IV	4 (6%)	3 (4%)		
ASA			0.35	0.84
1	7 (10%)	8 (12%)		
2	55 (82%)	54 (82%)		
3	5 (8%)	4 (6%)		

Abbreviations: BMI, body mass index; ASA, American Society of Anaesthesiologists; AEG, Adenocarcinoma of the Esophagogastric Junction; RPD, reverse puncture device; pTNM, pathological Tumor-Node-Metastasis.

evaluated using the Clavien-Dindo classification (CDC) [15]. To confirm the complications of the anastomosis, upper gastrointestinal radiography was done for patients 1 week after surgery. Routinely, endoscopic examinations were arranged for patients 2 months after the operation.
All anastomotic complications were confirmed by endoscopy. Non-anastomotic complications, including pulmonary infection, ileus, lymphatic leakage, duodenal stump leakage, and wound problems, were also recorded.

Data Analysis

All statistical analyses were performed using SPSS software (version 27.0, IBM Corp, Armonk, New York, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables are expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Between-group comparisons were conducted using the Student's *t*-test for normally distributed continuous variables, or the Mann–Whitney U test for non-normally distributed variables. The Pearson chi-square test or Fisher's exact test was

Table 2. Intraoperative and postoperative conditions of the two groups.

Variables	π-shaped group (n = 67)	RPD group (n = 66)	*t*	*p*
Total operation time (min)	219.8 ± 13.3	223.5 ± 13.1	1.62	0.106
Anastomosis time (min)	25.5 ± 5.0	34.6 ± 4.4	11.1	<0.001
Intraoperative bleeding volume (mL)	116.1 ± 9.8	118.2 ± 8.6	1.31	0.192
Total number of lymph node dissections (pieces)	30.9 ± 4.8	31.1 ± 3.9	0.26	0.793
The main incision length (cm)	4.9 ± 0.6	7.4 ± 0.8	19.32	<0.001
The length of the esophageal margin (mm)	26.3 ± 3.1	35.9 ± 4.2	14.8	<0.001
Time until first flatus (days)	3.7 ± 1.1	3.5 ± 1.1	1.05	0.296
Hospitalization time (days)	10.7 ± 1.7	11.2 ± 4.4	0.87	0.387

Table 3. Postoperative non-anastomotic complications of the two groups.

Variables	π-shaped group (n = 67)	RPD group (n = 66)	t/χ^2	*p*-value
Non-anastomotic complications	8	12	0.86	0.35
Pulmonary infection	2	3	0.13	0.72
Duodenal stump leakage	0	0	-	NA
Ileus	2	1	0.34	0.56
Wound problem	2	7	2.86	0.09
Lymphatic leakage	2	1	0.34	0.56

NA, not applicable.

applied for categorical variables, as appropriate. A two-tailed p-value < 0.05 was considered statistically significant.

Results

Comparison of Clinical Data Between Two Groups

All patients included in this study underwent successful surgery. Intraoperative frozen sections of the esophageal margins were examined to were negative. There were no significant differences in age, sex, body mass index (BMI), tumor location, tumor maximum diameter, Borrmann type, neoadjuvant chemotherapy, or pathological stage between the π-shaped anastomosis group (n = 67) and the RPD group (n = 66) (Table 1).

Comparison of Intraoperative and Postoperative Conditions

No significant differences were found between the two groups with respect to total operation time, intraoperative bleeding volume, total lymph node dissection number, first flatus time, or hospitalization time ($p > 0.05$). However, the π-shaped group had significantly shorter anastomotic time and smaller incision length compared with the RPD group ($p < 0.05$). In contrast, the esophageal margin length was significantly longer in the RPD group than in the π-shaped anastomosis group ($p < 0.05$) (Table 2).

Comparison of Postoperative Complications Between the Two Groups

There were no significant differences in the incidence of postoperative non-anastomotic complications between the π-shaped group and the RPD group (Table 3). However, the incidence of anastomotic complications was significantly higher in the RPD group compared with the π-shaped group ($p < 0.05$). Specifically, there were no significant differences in the rates of anastomotic leakage or bleeding ($p > 0.05$). Anastomotic stricture occurred only in the RPD group, affecting 2 patients with CDC grade II strictures and 4 patients with CDC grade IIIa strictures, which was statistically significant ($p < 0.05$) (Table 4).

Discussion

The methods for esophagojejunostomy in TLTG have been under continuous exploration, with each approach presenting distinct advantages and limitations [16,17]. In this study, we compared two commonly used anastomotic methods in total laparoscopic total gastrectomy: π-shaped anastomosis and the RPD anastomosis. By comparing the preoperative data, intraoperative conditions, and the occurrence of short-term postoperative complications, we aimed to identify the respective advantages and disadvantages of these methods, thereby providing a theoretical basis for surgeons in selecting anastomotic methods after TLTG. The results showed no statistically significant differences between the two groups in terms of patients' general data, total operative time, intraoperative blood loss, number of lymph nodes dissected, time until first flatus, hospitalization time, or postoperative non-anastomotic complications. These findings suggest that both anastomotic methods are safe and effective.

The RPD anastomosis was first reported by Japanese surgeons in 2009. Due to its similarity to the anastomotic method used in open surgery, it has since been widely applied. However, in patients with obesity or narrow costal arches, the abdominal surgical incision needs to be extended to ensure the safety of anastomosis, which increases

Table 4. Postoperative anastomotic complications of the two groups.

Variables	π-shaped group (n = 67)	RPD group (n = 66)	t/χ^2	*p*-value
Anastomotic complications	1 (1.5%)	12 (18.2%)	9.23	0.002
Leakage	0	4 (6.1%)	3.02	0.08
I	0	0		
II	0	0		
IIIa	0	3 (4.5%)	1.53	0.24
IIIb	0	1 (1.5%)	0.51	0.48
IV	0	0		
V	0	0		
Stricture	0	6 (9.1%)	6.14	0.02
I	0	0		
II	0	2 (3.0%)	2.03	0.28
IIIa	0	4 (6.1%)	4.06	0.06
IIIb	0	0		
IV	0	0		
V	0	0		
Bleeding	1 (1.5%)	2 (3.0%)	0.34	1.00
I	0	0		
II	0	0		
IIIa	1 (1.5%)	1 (1.5%)	0	1.00
IIIb	0	1 (1.5%)	0.51	1.00
IV	0	0		
V	0	0		

the probability of incisional pain in patients after surgery [18]. Consistent with the results of this study, the incision length in the RPD group was larger than that in the π-shaped group. For anastomosis with the linear stapler (e.g., overlap or π-shaped), a longer segment of the esophagus needed to be mobilized [19], whereas anastomosis with the circular stapler (e.g., RPD) did not require this. This may explain why the length of the esophageal margin in the RPD group was longer than that in the π-shaped group in this study. Therefore, in patients with high BMI or narrow costal arches, the choice of π-shaped anastomosis can result in a shorter abdominal incision; however, the length of the esophageal resection margin will also be shorter.

It has been reported that esophagojejunostomy using a linear stapler is associated with a lower rate of anastomotic leakage compared with the circular stapler after total gastrectomy [20,21]. To further reduce the rate of anastomotic fistula, the overlap anastomosis method was first conducted by Orringer after total gastrectomy [22]. The procedure involved a two-layer suture after a side-to-side esophagojejunostomy, which was shown to reduce the incidence of anastomotic leakage than other circular-stapler anastomoses [23]. In the present study, however, certain technical modifications were applied. In the RPD anastomosis group, closure of the jejunal stump after anastomosis with a circular stapler was completed using a linear stapler; in the π-shaped anastomosis group, the closure of the common opening was also performed using a linear stapler. No additional steps of suturing the anastomotic stoma were added in either group. Therefore, the incidence rates of anastomotic leakage and bleeding were similar between the two groups, with no statistically significant differences.

The π-shaped anastomosis was first proposed by Korean scholars in 2016 [9]. Its major advantage lies in the fact that anastomosis is performed before the transection of the esophagus and jejunum. Simultaneously, the esophagus and jejunum are transected and the entry hole is closed. Kwon referred to this as the “three-in-one technique”, suggesting that one linear stapler could complete three steps: transection of the esophagus, transection of the jejunum, and closure of the entry hole. Compared with the overlap anastomosis, the esophagus is not transected before anastomosis. With the aid of gentle traction, intraoperative esophageal retraction can be avoided during esophagojejunostomy, thereby simplifying the procedure and reducing operative time. This likely explains why anastomosis was completed more quickly in the π-shaped group than in the RPD group.

The reported incidence of anastomotic stenosis after total gastrectomy ranges from 3 to 13% [24]. In the RPD anastomotic method, due to limitations imposed by the inner diameter of the jejunum, a 21-mm stapler sometimes needs to be selected. Allen W *et al*. [24] reported that using 21 anastomotic devices, the double-staple technique anastomosis and female patients were all causes of anastomotic stenosis. However, in this study, all patients in the RPD group underwent anastomosis with a 25-mm circular stapler. The 2 patients with grade II strictures improved with conservative

management (including anti-inflammatory agents, edema-reducing drugs, and nutritional support). The 4 patients with grade IIIa strictures required balloon dilation combined with conservative treatment before discharge. As for the causes of stenosis, one possible reason is that the jejunum needed to be fixed to the central rod of the stapler with a rubber band before anastomosis and it was difficult to feel the tension of traction when connecting the anvil head with the circular stapler in laparoscopic surgery. As is well known, tension was a main risk factor for stenosis.

However, this study has several limitations. First, as a retrospective study, it may be subject to research design bias. Second, the small sample size, absence of hierarchical analysis, lack of assessment of the learning curve, and absence of blinding may limit the generalizability and reliability of the findings. Third, the relatively short-term follow-up restricts the ability to fully evaluate postoperative complications and long-term outcomes, particularly with regard to late-onset events such as anastomotic stricture and recurrence. Future research should include multicenter, randomized, and large-sample studies, as well as stratified subgroup analysis, such as BMI and AEG type II/III subtypes classification.

Conclusions

Both RPD and π-shaped anastomosis are safe and effective techniques. The π-shaped anastomosis is recommended as the preferred anastomosis for totally laparoscopic total gastrectomy, and the RPD anastomosis can be applied to gastroesophageal junction cancer with a higher tumor location.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

ZL and ML designed the research study. ZL and ZZ performed the research. ZL, ZZ and TZ analyzed the data. ZL drafted the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study obtained approval from the First Affiliated Hospital of Bengbu Medical University (approval number: 2020AH011100), and all patients were informed of all possible clinical outcomes of the different treatments and signed a written informed consent. The study conformed to the provisions of the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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