

# The Feasibility and Safety of Barbed Running Suture in Total Laparoscopic Distal Gastrectomy (TLDG) for Gastric Cancer

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## Technical innovations

**Keywords:** gastric cancer, laparoscopic gastrectomy, intracorporeal anastomosis, barbed suture

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**Title:** The Feasibility and Safety of Barbed Running Suture in Total Laparoscopic Distal Gastrectomy (TLDG)for Gastric Cancer

**Running head:** Barbed suture method in TLDG

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## **Abstract**

**Background:** Totally laparoscopic distal gastrectomy (TLDG) is a minimally invasive method for gastric cancer. Intracorporeal reconstruction of the digestive tract with technically challenging is a critical step.

**Objective:** This study aimed to evaluate the feasibility and efficacy of a simplified method using a unidirectional barbed suture to create a continuous hand-sewn for gastrointestinal enterotomy closure and reinforcement of the duodenal stump (RDS) in our institutional experience.

**Methods:** From March 2019 to December 2019, 32 patients who underwent TLDG with a hand-sewn gastrojejunostomy (GJA), jejunojejunostomy (JJ) and reinforcement the duodenal stump (RDS) were enrolled in this study. After tumor resection, the technique with the knotless unidirectional barbed suture was used to close the common incision for the linear stapler during the intracorporeal reconstruction following the TLDG. Patient

characteristics, operative time, length of hospital stay, the time of the first flatus, and postoperative complications were evaluated.

**Results:** The reinforcement and closure method were successfully performed after TLGD in the 32 patients without re-exploration. No major adverse events occurred during or after the operation. The mean procedure time was  $(247.3 \pm 44.2)$  min, while the common incision closure procedure took a mean of  $9.5 \pm 1.6$  min, the Laparoscopic Reinforcement Suture (LRS) procedure took a mean of  $5.7 \pm 0.9$  min, the blood loss was  $(68.0 \pm 48.3)$  ml. The mean number of LNs dissected was  $(31.5 \pm 11.3)$ , the mean time of the first flatus was  $(3.7 \pm 1.2)$  days, the postoperative bed activity time  $(1.7 \pm 0.3)$  days, and the mean postoperative hospital stay was  $(9.5 \pm 2.7)$  days. The complications rate was 6.3%, including one emptying dysfunction, and one local abscess near duodenal stumps.

**Conclusions:** The use of the unidirectional absorbable barbed suture for gastrojejunal/jejunojejunal enterotomy closure and reinforcement of the duodenal stump is safe and effective in TLGD.

**Keywords:** gastric cancer, laparoscopic gastrectomy, intracorporeal anastomosis, barbed suture

## 1. Introduction

Gastric cancer (GC) is currently the most prevalent fatal cancer globally[1]. Laparoscopic-assisted gastrectomy has since become a universal method of treating gastric cancer due to its accelerated recovery. Since its discovery in 1994 by Kitano et al[2], laparoscopic-assisted gastrectomy has substantially evolved in the last decade. Improvements in laparoscopic techniques and instruments have permitted totally laparoscopic gastric resections with intracorporeal digestive reconstruction [3, 4]. TLGD (totally laparoscopic distal gastrectomy) is gradually becoming the treatment of choice for GC[3-7]. Compared with laparoscopic-assisted distal gastrectomy (LADG), TLGD is a less-invasive surgery

for tumor resection, which accelerates recovery. In addition, the laparoscopic reconstruction of the digestive tract has a better operating field of vision and space to avoid misoperation. This ensures the anastomosis is unobstructed while implementing TLDG during the operation. Unavoidably, anastomosis leakage is the major complication for TLDG and is associated with post-operation morbidity and mortality. Incomplete closure of the anastomosis defect occurs due to technical difficulties in intracorporeal digestive reconstruction. Furthermore, a knot can be a source of failure[8-10].

Various methods and devices for intracorporeal reconstruction have been studied in an attempt to improve surgical efficiency and invasiveness[11, 12]. The intracorporeal suturing and knot tying procedure for anastomoses requires high technical expertise, long procedure duration, and increases the cost of laparoscopic digestive surgery. Therefore, we endeavored to find a safer, reproducible, and easier way to close the defect and reinforce the duodenal stump after resection. The main purpose of the study was to characterize the safety and efficacy of the barbed suture for the intracorporeal reconstruction of the digestive tract following TLDG for gastric cancer.

## **2. Materials and Methods**

### ***2.1 Patients and equipment preparation***

From March 2019 to December 2019, patients with gastric cancer were included for analysis retrospectively from a single-center. Preoperative assessments included preoperative endoscopy, ultrasonography, and contrast-enhanced computed tomography (CT). The inclusion criteria included: (1) cancerous invasion within cT1-4a and located in distal of the stomach; (2) lack of a suspected positive LN in station No. 13.16 or distal

metastasis; (3) tumor no larger than 10 cm; (4) patients requiring salvage surgery after incomplete endoscopic resection; (5) a patient aged over 20 years, and with neither a critical organ dysfunction nor a contraindication for laparoscopic surgery; (6) an Eastern Cooperative Oncology Group performance status (ECOG PS) of either 0 or 1. Informed consent forms were signed by the participants before the procedures, including intraoperative or postoperative bleeding, secondary infection, postoperative gastrointestinal tract leakage, and possible secondary surgery. The study design was approved by the institutional research ethics committee. 3-0 polyglyconate (polyglycolide) barbed suture (V-LOC™ 180 Absorbable Wound Closure Device, Covidien, Mansfield, MA) was used to secure the suture.

## ***2.2 operative procedures***

The patient was placed in a reverse Trendelenburg position with the head slightly elevated. The surgeon stood on the left side of the patient, the first assistant on the right side, and the camera assistant between the legs of the patient. A 10 mm trocar was inserted for the camera below the navel, and a 12 mm trocar in the left upper quadrant and right lower quadrant abdomen, and a 5 mm trocar in the right upper quadrant and left lower quadrant abdomen, respectively. These were done while maintaining a relief pressure of 12 to 13 mmHg after establishing pneumoperitoneum (Figure.1). Ultrasonically activated shears were used for lymph node dissection. All the procedures were performed using a five-port system. After performing distal gastrectomy with D2 lymph node dissection, the duodenum was transected about 2 cm distal from the pylorus and the stomach 4–5 cm proximal to the tumor, using a 60mm laparoscopic linear anastomator (anastomotic) through the main operation port B. The specimen was inserted into a self-made plastic bag, tightened, and

temporarily moved from the left upper abdomen to right upper abdomen. It was then extracted through a small umbilicus incision after the completion of reconstruction. Alternatively, the specimen could be removed before the reconstruction to check the adequacy of the surgical margin. Before performing the anastomosis, we confirmed that the resection of the resected tissue was sufficient by visually examining a frozen section.

### ***2.3 Reconstruction procedures***

During reconstruction, the surgeon and the assistant stood on the right side of the patient and performed the following through the main working 12mm port. All patients in our center have undergone reconstruction using intracorporeal anastomosis since March 2019. A marking was made at the jejunum on the antimesenteric border 10-15 cm away from the Treitz ligament by suture. BII Braun reconstruction was performed with an antecolic (ante colic) route and an isoperistaltic manner. A small opening was made at the stapling line on the greater curvature side of the gastric stump (Figure 2.A). Another opening was made at the jejunum on the antimesenteric border 35-40 cm away from the Treitz ligament (Figure 2.B). Next, using a laparoscopic linear stapler 60mm in length with white cartilage, an antecolic side-to-side gastrojejunostomy with an afferent Loop on the greater curvature was performed (Figure 2.C). We carefully checked the anastomosis staple line which was created between the gastric and jejunum for any active bleeding (Figure 2.D). Then, the entry hole was sutured using a 30-cm 3-0 V-Loc suture on a V-20 needle for both layers. The full-thickness (Cornell-Lembert) closure was initiated by passing through a 5mm proximal to the corner of the intestinal wall to the opposite hole of the stomach with a continuous technique (Figure 3.A). Several running bites were taken, and the suture line was completed by taking 1-2 additional bites beyond the terminal extent of the enterotomy

(Figure 3.B-C). Once the full-thickness layer was complete, the second seromuscular layer was initiated, returning toward the initial corner using the same barbed suture. Each anastomosis found in the tissue was firmly drawn to permit a tight anastomosis (Figure 3.D-G). The barbs allowed for unidirectional movement of the suture material through the tissue during suturing and prevented backward slippage. No end knot was required if the suture line was extended by 1 - 2 bites beyond the termination of the incision (Figure 3.H). After the last stitch, the suture is simply cut, no clip is needed to ensure the distal end of the suture. Finally, the process of closure for the common entry hole is completed (Figure 3.I). Braun anastomosis was performed about 25 cm distal to the gastrojejunostomy at the marking point using a linear stapler 60 mm in length with white cartilage. The entry hole was closed using the same technique as gastrointestinal anastomosis described above. LRS commenced from the upper to the lower part on the staple line of the duodenal stump. Continuous suture with invagination of the duodenal stump was performed using a 3-0 15cm V-loc barbed suture. At the upper end of the duodenal stump, a knotless unidirectional suture was performed. A seromuscular suture was placed on the duodenum wall, 1.0-1.5cm away from the duodenal stump (Figure 4.A). A reinforcement suture with invagination of the staple line was initiated from the upper end of the duodenal stump and then the suture tightened using a laparoscopic needle holding or grasping forceps (Figure 4.B-C). At the lower end, the remnant suture with invagination was repeated once (Figure 4. D-E). After the continuous suture with invagination ends, the duodenal stump staple line is buried under the barbed suture. The continuous suture with invagination requires a total of 4 or 5 stitches to complete (Figure 4.F). Petersen's defect was routinely repaired by a continuous suture with V-Loc. Finally, the specimen was extracted through a single 3-cm

umbilical incision. Thereafter, the TLDG was finished two drainage tube was then placed behind the gastrointestinal anastomosis.

#### ***2.4 Post-operative care***

(1) The patient was put on a fluid diet 24 h after surgery, and no matter was recovered in anal exsufflation. (2) An upper gastrointestinal contrast was performed on day 4 post-operation to identify anastomosis leakage and obstruction. The patient was advanced to a semifluid diet after a liquid diet or gastrointestinal contrast. On the next two days of semifluid diet, the abdominal drainage was removed, unless the drainage character was abnormal. Patients were routinely discharged on postoperative day 6-7 when they showed no discomfort with a soft diet.

#### ***2.4 Outcomes evaluation***

Surgical outcomes and postoperative complications were recorded for patients who underwent TLDG. In addition, postoperative complications were defined with day 30 as a cut-off point. Complications before day 30 were considered early complications and depicted the safety of surgery, while the late ones depicted quality of life. The main early complications included intraperitoneal or digestive tract hemorrhage, leakage of anastomosis or duodenal stump, bowel or anastomosis obstruction, or abdominal infection. Pulmonary infection and other organ dysfunctions were defined as minor complications. Follow-up with a median period of 6 (range 3–12) months was conducted to evaluate the late complications, which included reflux esophagitis, anastomotic stenosis, and weight loss. Among the total 32 patients, 24 patients have been followed over 6 months and have undergone endoscopic examination postoperatively.

## ***2.5 Statistical analysis***

Simple descriptive statistics were generated using the SPSS software (version 23.0, SPSS Inc., Chicago, IL, USA) to report the proportions and characteristics of the study. Data are presented as mean  $\pm$  standard deviation for continuous variables and as numbers and percentages for categorical variables.

## **3.Results**

### ***3.1 Patients and tumor characteristics***

We recorded patient characteristics including age, gender, body mass index (BMI), history of abdominal surgery, and status of chronic disease. Data from 32 patients who underwent TLGD for clinical stage I and III gastric cancer were analyzed in this study. The patients comprised 20 males (62.5%) and 12 females (37.5%) with a mean age of 55.4 years. The mean body mass index (BMI) was 24.3kg/m<sup>2</sup>. Four patients scored above 9 for the patient-generated subjective global assessment (PG-SGA). Histologic types included 1 well-differentiated case, 12 moderately differentiated cases, and 19 poorly differentiated cases. With regard to the pathological TNM status, stage I, stage II, and stage III had 8, 8, and 16 cases respectively. The characteristics of patients and tumors are shown in Table 1.

### ***3.2 Surgical outcomes and pathological findings***

The average procedure time was (247.3  $\pm$  44.2) min, while the common incision closure procedure took a mean of 9.5  $\pm$  1.6 min (range 8.5-12.2 min). The RDS procedure took a mean of 5.7  $\pm$  0.9min (range 5.0-7.1 min). The averaged intraoperative blood loss was 68.0  $\pm$  48.3ml, therefore no transfusion was required. There were neither intraoperative

complications nor cases converted to open surgery. There were no open surgery cases or deaths resulting from the surgical procedure. After the surgical procedure, the first flatus time of the patients was  $3.7 \pm 1.2$  days, the mean duration before the first diet was  $2.3 \pm 1.0$  days, the postoperative bed activity time was  $1.7 \pm 0.3$  days, the average length of the incision below the navel was  $2.5 \pm 0.3$  cm, the length of hospital stay was  $9.5 \pm 2.7$  days, and the mean number of LNs dissected was  $31.5 \pm 11.3$ . The postoperative surgical outcomes are shown in Table 2.

### ***3.3 Morbidity of Complications and mortality***

Two patients experienced complications (6.3%), including one emptying dysfunction (on postoperative day 6) and one intraabdominal abscess (on postoperative day 21). These were managed through conservative methods, with no patient undergoing a second surgery. None of the 32 patients died, had anastomotic leakage, or experienced tumor recurrence during follow-ups. In addition, there were no complaints of dumping syndrome. The postoperative surgical complications and mortality are shown in Table 3. 32 patients underwent endoscopy follow-up at on the 6-month post-operation, and neither reflux esophagitis nor anastomotic stenosis and fibrotic stenosis due to ischemia was diagnosed (Figure.5).

## **Discussion**

The safety and efficacy of laparoscopic gastrectomy in the treatment of locally advanced gastric cancer have been demonstrated in several randomized clinical trials[13-15]. Traditionally, LADG is usually performed with a circular stapler or hand-sewing through

a mini-laparotomy. LADG is currently preferred to TLDG in laparoscopic gastrectomy[16]. Although TLDG is gradually being adopted, using it to perform a digestive tract reconstruction requires high technical expertise. The key challenge in the TLDG procedure is how to prevent fistula from the staple line of the duodenal stump and anastomotic leakages during laparoscopic gastrectomy to avoid surgery. Given that secure incision closure is of paramount importance, we evaluated the barbed suturing methods in intracorporeal gastrojejunostomy (GJ), jejunojejunostomy (JJ) and reinforcement duodenal stump during the TLDG. The preliminary outcomes of this study are satisfactory and show promising prospects.

Reports have shown B-II anastomosis is preferred for reconstruction. This is due to its relatively lower cost, irrespective of tumor location or remnant stomach size, and other physiological advantages, such as allowing food to pass through the jejunum, which to an extent reduces the postoperative incidence of cholecystitis and gallstones cholelithiasis[17-20]. Besides, recent studies have shown Billroth II with Braun enteroenterostomy anastomosis can reduce the incidence of reflux gastritis [21]. Compared with LADG in extracorporeal anastomosis, TLDG provides apparent superiorities as the anastomosis is not pulled out through the limited laparotomy incision. Pulling might increase the tension at the anastomosis site, and the risk of intestinal loop torsion. However, TLDG, a pure laparoscopic technique, consisting of both gastric resection and reconstruction, demands high technical expertise. In particular, relatively more anastomosis staplers are needed and most surgeons still doubt in the safety of TLDG. Therefore, a convenient, reliable, and time-saving procedure would provide an alternative.

Previous findings from our center demonstrated that common incision with closure using linear stapler without suture is an effective treatment. However, it has the following disadvantages. First, for gastrojejunostomy and jejunajejunostomy, closing an irregular common entry hole after iterative traction to appropriately position and fire the two forks of a linear stapler is time-consuming, and require high technical skill. Additionally, high-level tacit cooperation between the surgeon and assistant, which may be difficult to formalize in a short period of time, is required for the success of the procedure. Moreover, linear-stapled closure for a large common incision of enterotomy tends to cause a narrow anastomosis lumen. Further, local ischemia at the junction of the two staple lines may lead to fibrosis, which could contribute to the development of anastomotic stenosis[22]. Secondly, the length of the remnant stomach probably limits the application of the linear-stapler for gastrojejunostomy. Thirdly, given that enterotomy closure with a linear stapler is a single layer suture method, it does not protect the force-bearing point of the anastomosis. In addition, the risk of increasing adherence due to the linear stapler probably exists since it is non resorbable. It also does not provide for serosa-serosa healing of the anastomosis. However, studies with longer follow-up periods should be designed to investigate these components. Fourth, anastomotic bleeding is a major concern which follows intracorporeal anastomosis, and is often caused by the closure of common incision using linear staplers. Given that the cutting line is vertical to the jejunal muscle fibers during the common entry closure, the number of injured muscles is usually higher around the mesentery. This poses a challenge to the prevention of anastomosis bleeding. Unfortunately, hemostasis by either electrocoagulation or interrupted suture is required to manage anastomosis bleeding. In addition, some researchers have warned of a potential

risk of anastomosis leakage from only using stapler closure in patients with risk factors such as local edema on the gastrointestinal wall, tissue vulnerability, or a short length of the duodenal stump. So far, reports indicate that a knotless barbed suture may simplify the laparoscopic suturing procedure[[23-25](#)].

Sang-Woong Lee al.[[26](#)]found the use of the knotless barbed absorbable suture for gastrointestinal closure to be safe and effective in laparoscopic gastrectomy. Nevertheless, the feasibility and safety of barbed running sutures in totally laparoscopic distal gastrectomy such as the intracorporeal suture closure of the gastrojejunal enterotomy, jejunojejunal enterotomy and reinforcement of the duodenal stump, have not been confirmed. In this pilot study, we adopted a two-layered continuous technique using a 15cm/30cm V-Loc barbed suture to reduce the overlapping staple lines sites, thereby achieving low rates of stenosis. We did not encounter anastomotic stenosis, which could be attributed to the wide anastomotic lumen occasioned by adjusting the interval of the needle pitch. This was later corrected during suturing. The absorbable suture technique employed in the study appears to be ideal for intracorporeal laparoscopic suturing. First, performing an intracorporeal suturing using the barbed suture technique eliminates the need for laparoscopic knotting[[26](#), [27](#)]. This makes the suturing procedure easier and reduces the overall operative duration. Second, once pulled tightly, the suture should resist slippage hence precluding the constant traction requirement. Unlike the traditional suture which only has two points of fixation at the knots, a barbed suture allows for multiple points of fixation along with the closure of the incision. It also permits a greater distribution of tension strength along with the anastomosis and increases the surface area of adhesion between the tissues. Thirdly, the use of separation forceps to lift the incisal edges in this

barbed suture technique makes it easy to invert the gastric wall into the lumen of the remnant stomach in a clear view. This facilitates the completion of the suture procedure and minimizes the risk of anastomosis leakages. Fourth, the risk of increasing adherence due to the barbed suture probably is nonexistent because it is a resorbable suture which achieves serosa-to-serosa healing. Fifth, bleeding at the staple line may result from mismatching the staple height, and the double “over-line” of stapling and thickness of the tissue. However, too tight stapling might cause ischemia at the anastomosis site which could lead to leakage. Hemostasis can easily be achieved within a short period of time using barbed suture. We found that barbed suture prevents anastomosis bleeding without causing ischemia. The procedure therefore shortens operation duration and decreases morbidities such as postoperative bleeding or leakage. Consequently, this method is considered safe and feasible. Sixth, we found that the barbed suture is only satisfying and trustworthy when the direction and strength of suture performed are synchronous. Therefore, this maneuver should be performed by a single surgeon. Moreover, there is a short learning curve related to barbed suture without knotting suturing, that only requires basic laparoscopic skills. Finally, the barbed suturing technique ensures cost-effectiveness by closing the entry hole of the stapler instead of stapling or conventional knot-tying anastomosis.

A recent study reported that the laparoscopic approach increases the risk of developing duodenal stump leakage (DSF), unlike the open approach[28]. Similarly, Cozzaglio et al. [29] reported that the laparoscopic technique increases the risk of DSF about 5 times, and attributed it to the lack of reinforcement of the duodenal stump. Various methods have recently been applied to facilitate reinforcement of the duodenal stump during laparoscopic

gastrectomy. Such methods include an absorbable membrane or bovine pericardium, and suturing on the staple line. The least leakage rate was achieved after reinforcement on the staple line using an absorbable membrane or over-sewing the suture line[30]. In addition, DSF is associated with difficulties in emptying the afferent jejunal loop due to the stricture from gastrojejunostomy. Therefore, continuous suture with invagination of the duodenal stump on staple-line performed using a barbed suture reduces the complication. The V-Loc suture is useful in performing an intracorporeal laparoscopic suturing since it is knotless, absorbable, and fixed. Finally, it is a concern that the free tail of the barbed suture could result in intestinal obstruction[31, 32]. To overcome the drawbacks of adhesive obstructions, the suture ends should be cut as short as possible. Laparoscopic duodenal stump reinforcement is complicated even for the experienced surgeons due to the complexity of the restriction of sewing angles, the uncontrollability of knotting strength, and unskilled cooperation. Thus, we propose a barbed suture, which is an effective and easy maneuver to overcome the reinforcement problems. On the other hand, repeated grasping of the duodenal wall could easily arouse local inflammation, edema, and tissue injuries. However, Lambert's barbed sutures in TLDG receiving LRS could avoid tearing of the plasma muscle layer. Moreover, due to the simple inversion embedding suturing of the duodenal stump, LRS should be conducted by a single surgeon to reduce disturbed coordination, and avoid the unbalanced tension and inconsistent directions. We also recommend proper loosening of the Kocher incision to reduce the tension of the duodenal stump. Thus, it is convenient to place a seromuscular barbed suture on the duodenal wall 1.0-1.5cm away from the duodenal stump staple-line using barbed suture, and tighten the barbed suture after pushing the duodenal stump into the suture by a single operator. For

duodenal stump length less than 1 cm, the barbed suture is a better choice compared with the purse-string suture or interrupted suture of the duodenal stump. In our series, the success rate of common incision closure and LRS was 100% (32/32). In successful cases, the mean procedure duration of common incision closure was  $9.5 \pm 1.6$  min (range 8.5-12.2 min), while LDS procedure lasted for only  $5.7 \pm 0.9$  min (range 5.0-7.1 min), which is a quite acceptable duration. The LRS method and single purse-string sutures[33] spent approximately equal time on the reinforcement of the duodenal stump. Besides, it was approximately the average time of reinforcement of duodenal stump, including barbed suture[34], Lambert suture[35], and two half-purse-string sutures[36]. However, these methods require multiple stitches and knots, which is rather difficult for inexperienced surgeons. Therefore, the feasibility and safety of the simple LRS procedure, which can achieve the reinforcement of duodenal stump in a shorter duration, should be confirmed during the TLGD. In addition, no severe complications occurred including anastomosis bleeding, leaks, stenosis, bowel obstruction, and peritonitis. These results indicate that the barbed suture closure of the gastric common incision and LRS after laparoscopic gastrectomy is a safe and effective technique for the treatment of patients with gastric cancer.

The limitations of this study included the following. First, was a single-arm study without a control group, and selection bias may have influenced the results. Second, the sample size in this study was relatively small. However, the results obtained using this method were satisfactory and its advantages conformed to the previously published researches.

#### **4. Conclusion**

In conclusion, the laparoscopic suturing method using the barbed suture is technically safe, feasible, and reproducible among GC patients undergoing TLDG. Given that the technique decreased the anastomotic weak points and reinforced the duodenal stump, it holds promising prospects for GC patients. However, further clinical studies should be conducted to confirm these results.

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#### **Authors' contributions**

Study conception design: Lei Ge, Chun-Guang Guo. Data acquisition: Lei Ge, Tong-Bo Wang, Hong Zhou, Jian-Jian Wei. Data analysis and interpretation: Lei Ge, Chun-Guang Guo, Dong-Bing Zhao. Drafting the article: Lei Ge, Chun-Guang Guo. Critical revision for intellectual content: Chun-Guang Guo, Dong-Bing Zhao. Final approval of the manuscript: Lei Ge, Tong-Bo Wang, Hong Zhou, Jian-Jian Wei, Chun-Guang Guo, Dong-Bing Zhao. Agree to be accountable for all aspects of work to ensure that questions regarding accuracy & integrity investigated and resolved: Lei Ge, Tong-Bo Wang, Hong Zhou, Jian-Jian Wei, Chun-Guang Guo, Dong-Bing Zhao. The authors read and approved the final manuscript.

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#### **Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

#### **Ethics approval and consent to participate**

Ethics approval and individual patient consent is required before the operation in this study.

#### **Consent for publication**

Not applicable

## Competing interests

The author(s) declare no potential conflicts of interest.

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## Figure Legends

### Figure 1. Trocar placement

Placement of the trocars and the location of the incision A A 10-mm curved incision is made lower right to the umbilicus, followed by a 10-mm trocar putting in place. Two 12-mm trocar and two 5-mm trocars are used. B An arc incision extended from the 10-mm umbilical trocar site is made to remove the specimen

**Figure2:** Schematic illustration of the completed staple-conserving V-shaped gastrojejunostomy. (A-C) insertion of an anvil fork into jejunum on the antimesenteric border, insertion of a cartridge fork into gastrostomy along the greater curvature wall of the gastric stump, with each fork positioned to join the wall together. (D)V-shaped stapler entry hole between the stomach and the jejunum, check the anastomosis staple line for whether active bleeding existing.

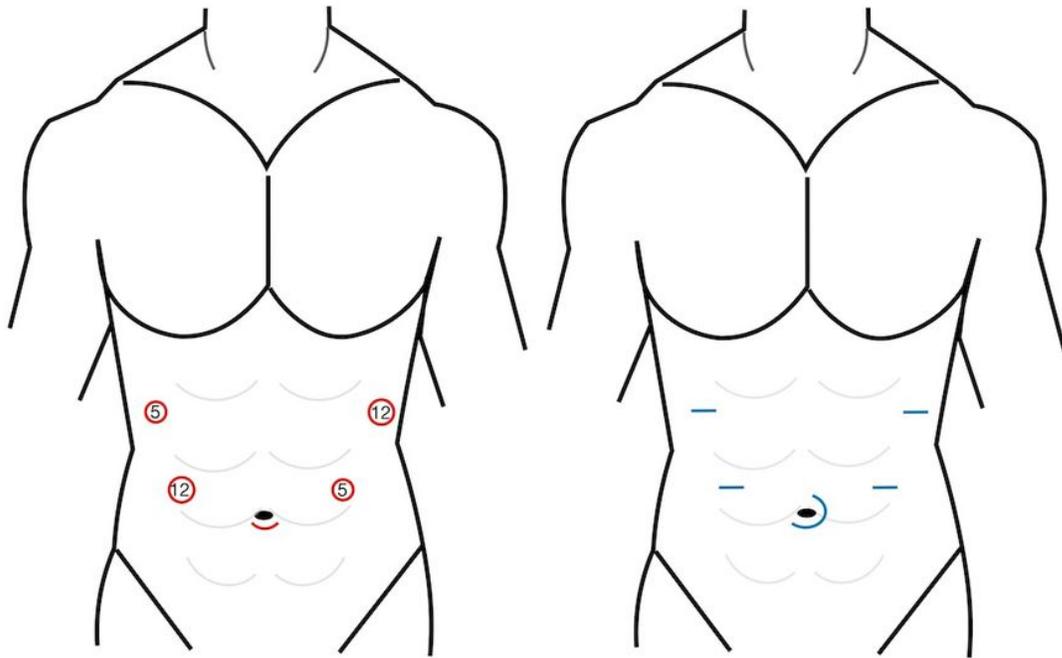
**Figure 3.** Schematic illustration of the common enterotomy hole for a linear stapler is closed with the Cornell-Lembert 2-layer continuous suture using a knot-less, unidirectional barbed suture. (A, J) Using a 30-cm 3-0 V-Loc suture on a V-20 needle for both layers, the full-thickness (serosa out to mucosa) inner layer closure is commenced from passing through 5mm proximal to the corner of the intestinal wall to the opposite hole of the stomach with a continuous technique. (B-C, K-L) Several running bites were taken, and the suture line was completed by taking 1-2 additional bites beyond the terminal extent of the enterotomy. (D-G, M-P) Once the full-thickness layer is complete, the second seromuscular layer is initiated, returning toward the started corner using the same barbed suture. The anastomosis each caught in the tissue has to be firmly drawn to permit a tight anastomosis. (H, Q) The barbs allow for unidirectional movement of the suture material through the tissue during suturing and prevent backward slippage. No end knot is required if the suture line is continued 1-2 bites beyond the termination of the incision. (I, R) After the last stitch, the suture is simply cut, no clip is needed to ensure the distal end of the suture. Finally, the process of closure for the common entry hole is completed.

**Figure 4.** Schematic illustration of the continuous LRS with the invagination technique. (A; G). At the upper end of the duodenal stump, a knotless unidirectional suture is performed. Place a seromuscular suture on the duodenum wall 1.0-1.5cm away from the duodenal stump. (B, C; H, I). A reinforcement suture with invagination of the staple line is started from the upper end of the duodenal stump and then tighten the suture using laparoscopic needle holding or grasping forceps. (D, E; J, K). At the lower end, the remnant

suture with invagination is performed once again. (F; L). After the continuous suture with invagination ends, the duodenal stump staple line is buried under the barbed suture. The continuous suture with invagination is totally required 4 or 5 stitches to complete.

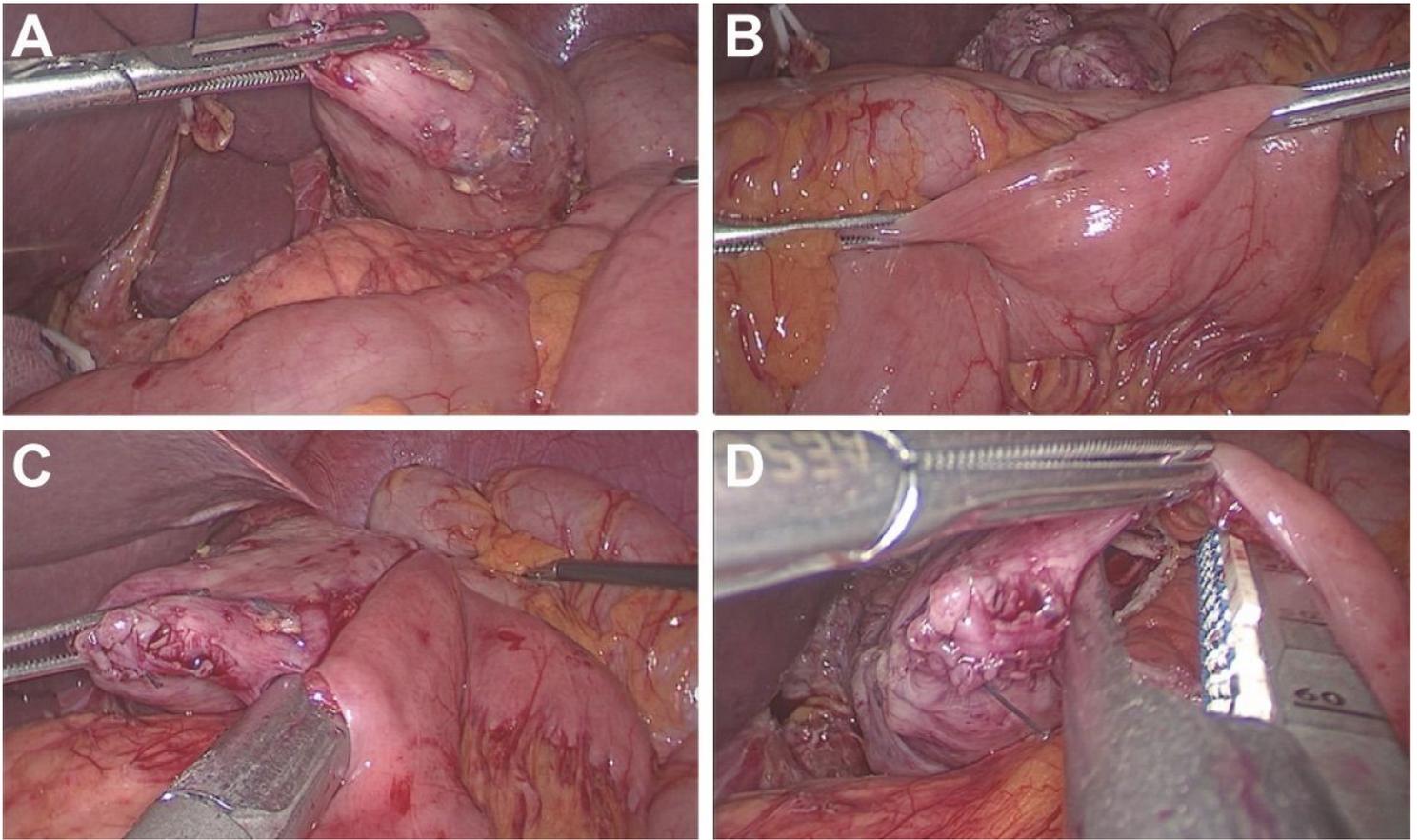
**Figure 5.** Endoscopic images at 6 months after the operation. anastomosis areas were enough without stenosis and ischemia.

# Figures



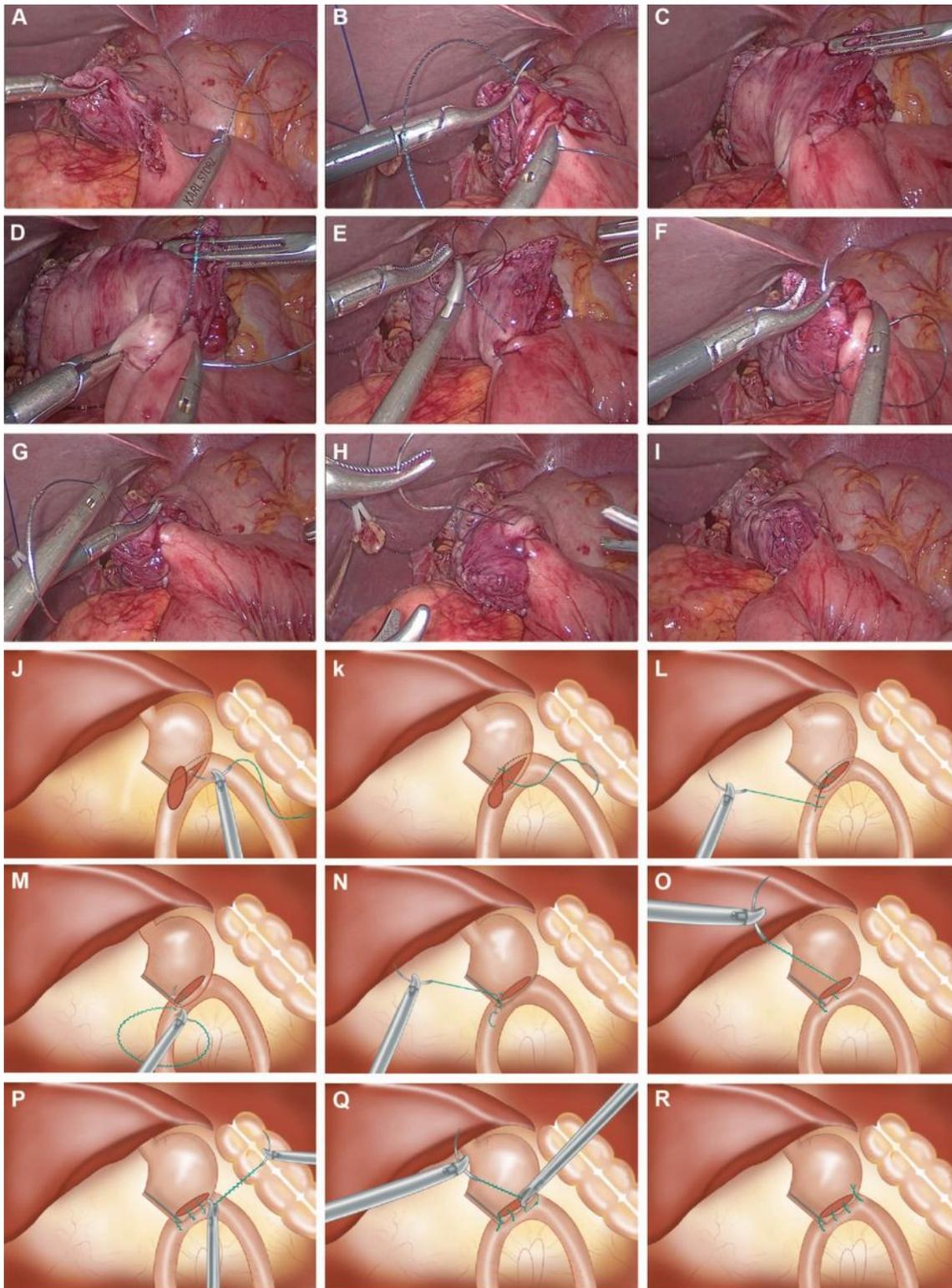
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**Figure 2**

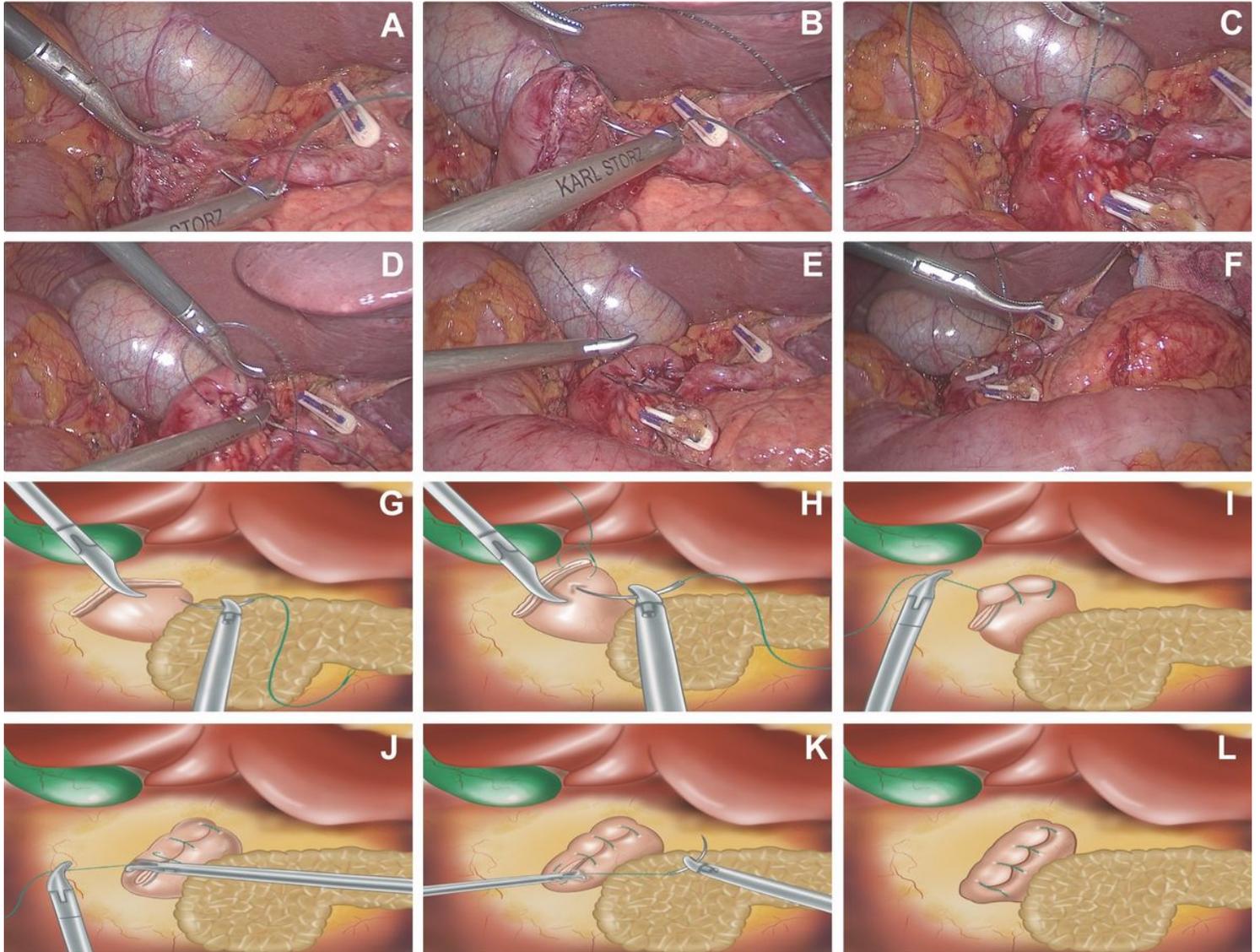
Schematic illustration of the completed staple-conserving V-shaped gastrojejunostomy. (A-C) insertion of an anvil fork into jejunum on the antimesenteric border, insertion of a cartridge fork into gastrostomy along the greater curvature wall of the gastric stump, with each fork positioned to join the wall together. (D) V-shaped stapler entry hole between the stomach and the jejunum, check the anastomosis staple line for whether active bleeding existing.



**Figure 3**

Schematic illustration of the common enterotomy hole for a linear stapler is closed with the Cornell-Lembert 2-layer continuous suture using a knot-less, unidirectional barbed suture. (A, J) Using a 30-cm 3-0 V-Loc suture on a V-20 needle for both layers, the full-thickness (serosa out to mucosa) inner layer closure is commenced from passing through 5mm proximal to the corner of the intestinal wall to the opposite hole of the stomach with a continuous technique. (B-C, K-L) Several running bites were taken,

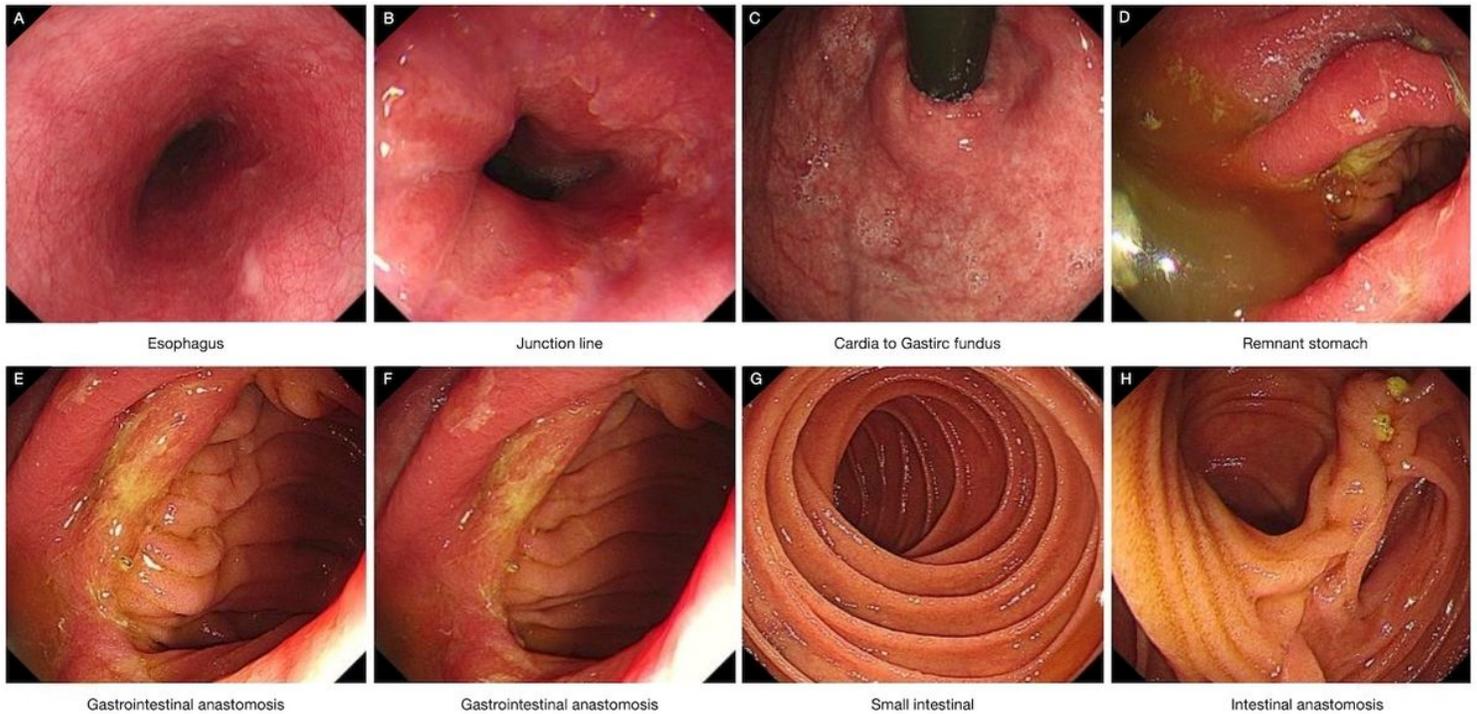
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**Figure 4**

Schematic illustration of the continuous LRS with the invagination technique. (A; G). At the upper end of the duodenal stump, a knotless unidirectional suture is performed. Place a seromuscular suture on the duodenum wall 1.0-1.5cm away from the duodenal stump. (B, C; H, I). A reinforcement suture with invagination of the staple line is started from the upper end of the duodenal stump and then tighten the suture using laparoscopic needle holding or grasping forceps. (D, E; J, K). At the lower end, the remnant

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**Figure 5**

Endoscopic images at 6 months after the operation. anastomosis areas were enough without stenosis and ischemia.

## Supplementary Files

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