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Linear-shaped gastroduodenostomy (LSGD): safe and feasible technique of intracorporeal Billroth I anastomosis

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Abstract

Background Although delta-shaped gastroduodenostomy (DSGD) is used increasingly as an intracorporeal Billroth I anastomosis after distal gastrectomy, worries about anatomical distortion always exist in twisting stomach and making an oblique incision on duodenum. We developed a new method of intracorporeal gastroduodenostomy, the linear-shaped gastroduodenostomy (LSGD), in which anastomosis is done using endoscopic linear staplers only without any complicated rotation. In this report, we introduced LSGD and compared its short-term and long-term outcomes with DSGD.

Methods We analyzed 261 consecutive gastric cancer patients who underwent the intracorporeal gastroduodenostomy between January 2009 and May 2014 (LSGD: 190, DSGD: 71), retrospectively. All of them underwent a laparoscopic or robotic distal gastrectomy with regional lymph node dissection. Early surgical outcomes such as operation time, postoperative complications, days until soft diet began, length of hospital stay, and endoscopic findings in postoperative 6 and 12 months were evaluated.

Results Although the proportion of robotic approach and D2 lymphadenectomy were significantly higher in LSGD group, the rates for overall complications (13.2 % [LSGD] vs. 9.9 % [DSGD], $p = 0.470$) and major complications (5.8 vs. 5.6 %, $p = 1.0$) were similar between two groups. There were no differences in anastomotic bleeding (1.1 vs. 1.4 %, $p = 1.0$), stenosis (3.2 vs. 2.8 %, $p = 1.0$), and leakage (0.5 vs. 0.0 %, $p = 1.0$). Endoscopy performed 6 months postoperatively showed that residual food ($p = 0.022$), gastritis ($p = 0.018$), and bile reflux (42.0 vs. 63.2 %, $p = 0.003$) were significantly decreased in LSGD and there were no significant differences in postoperative 12 months.

Conclusion LSGD is an innovative reconstruction technique with comparable short-term outcomes to DSGD. In addition, reduced residual food, gastritis, and bile reflux were seen in LSGD.

Keywords Gastric cancer · Minimally invasive surgery · Intracorporeal reconstruction · Intracorporeal gastroduodenostomy · Linear-shaped gastroduodenostomy · Delta-shaped gastroduodenostomy

Since the first report of laparoscopy-assisted distal gastrectomy (LADG) in 1994 by Kitano et al. [1], in Korea [2] and Japan [3] where the gastric cancer incidence is very high, laparoscopic gastrectomy was widely accepted as a good alternative to open surgery because of comparable or even better surgical outcomes [4] and improved quality of life [5].

In LADG, reconstruction is performed extracorporeally through epigastric mini-laparotomy, and an extracorporeal reconstruction has an advantage that surgeons can perform an anastomosis similarly as in an open surgery. However, performing the anastomosis in the narrow and restricted space is often difficult, leading to possible subsequent complications especially in obese patients or in patients with a small remnant stomach.

In contrast, in totally laparoscopic distal gastrectomy (TLDG), reconstruction can be performed intracorporeally, and this maximizes the benefit of minimally invasive surgery. Recently, several techniques of intracorporeal anastomosis have been developed for TLDG [6]. Among the

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commonly used reconstruction methods after distal gastrectomy (Billroth I, Billroth II, Roux-en-Y), Billroth I (B-I) procedure is advantageous in that it requires only one anastomosis, retains physiologic food passage, and poses no risk of internal hernia. Until now, various intracorporeal B-I methods were reported [7–9].

The delta-shaped gastroduodenostomy (DSGD) was first introduced by Kanaya et al. [10], and DSGD has been a general trend among the various intracorporeal Billroth I anastomoses because it could be performed by only linear stapler. In spite of its simplicity, DSGD has some limitations in the aspect of complicated technique, relatively high anastomosis-related complication rate [11–14], and high rate of bile reflux [15].

We have developed a new, simple, and secure method of intracorporeal gastroduodenostomy, using endoscopic linear staplers only, which we named linear-shaped gastroduodenostomy (LSGD) [16] in 2009. Since then, we made some modification of LSGD in the procedure of stapler entry slit closure from 2013. In this paper, we introduced LSGD and compared its short-term and long-term outcomes with those of DSGD.

Materials and methods

Materials

A single-surgeon retrospective cohort study was performed between June 2009 and May 2014 at Ajou University Hospital, South Korea. During this study period, the single surgeon conducted 1298 cases of radical gastrectomy: open gastrectomy ($n = 341$), laparoscopic gastrectomy ($n = 745$), and robotic gastrectomy ($n = 212$). Before July 2010, the eligibility criterion for laparoscopic or robotic gastrectomy was cT1N0–cT2N0-stage gastric cancer, and from July 2010 onward, more advanced cancers were treated using minimally invasive techniques in accordance with our increased familiarity and experience with the procedure. Billroth I procedure was performed when the location of tumor was below half of stomach. Among 956 cases of minimally invasive radical gastrectomy, 741 cases were performed by distal gastrectomy. We reviewed the prospectively collected data of 271 patients who underwent laparoscopic or robotic distal gastrectomy with intracorporeal gastroduodenostomy. Except 10 patients with hand-sewn gastroduodenostomy, 261 patients were classified into two groups according to the reconstruction methods (LSGD group: $n = 190$; DSGD group: $n = 71$). All 261 operations were performed by an experienced laparoscopic and robotic surgeon, who had performed 1055 laparoscopic gastrectomies and 110 robotic gastrectomies before this study.

Surgical procedure

LSGD in laparoscopic or robotic distal gastrectomy

The patients were placed in the reverse Trendelenburg position to approximately 30°. The operator stood on the right side of the patient, the first assistant stood on the left, and the camera assistant stood between the operator's right hand and scrub nurse. After 11–13 mmHg of pneumoperitoneum was established through 10-mm infra-umbilical camera port, additional four working ports were introduced into the right upper quadrant (5 mm), right middle quadrant (12 mm), left middle quadrant (12 mm), and left upper quadrant (5 mm) regions of the abdomen (Fig. 1). A rigid 30° laparoscope was used to maintain the optimal surgical field. To secure the laparoscopic operating field, V-shape liver retraction was done as we had already reported [17].

It was routine to assume the imaginary resection line according to the tumor site. In the case of middle-body-located cancer [18], we used the metal clipping [19] or the intraoperative gastroscopy [20] to confirm the location of the tumor. Lymph node dissection and omentectomy were done according to the Japanese guideline [21]. After appropriate LN dissection (LN station 4sb, 4d, 6, and 5) and full mobilization of the gastroduodenum, a 60-mm endoscopic linear stapler (ECHELON FLEX^{TM} ENDOPATH$^{®}$

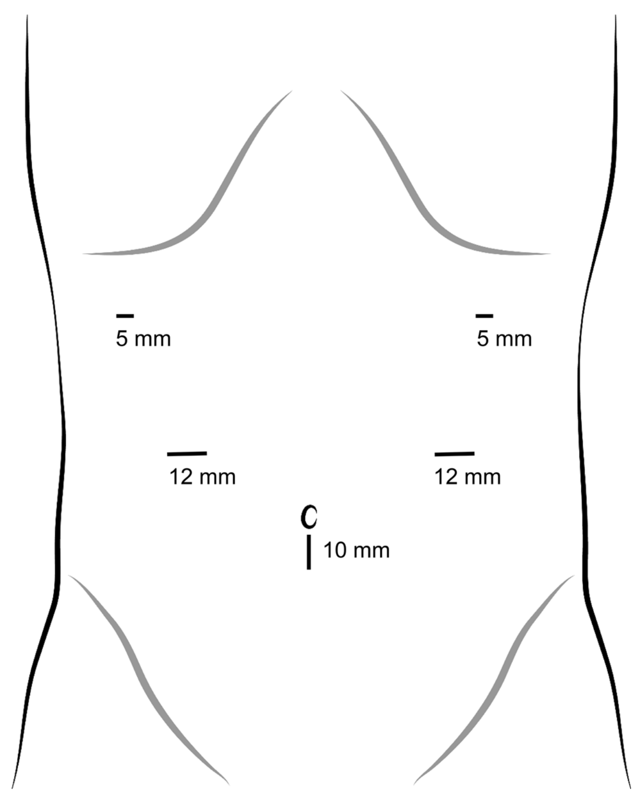

Fig. 1 Trocar placement and the size of the trocars

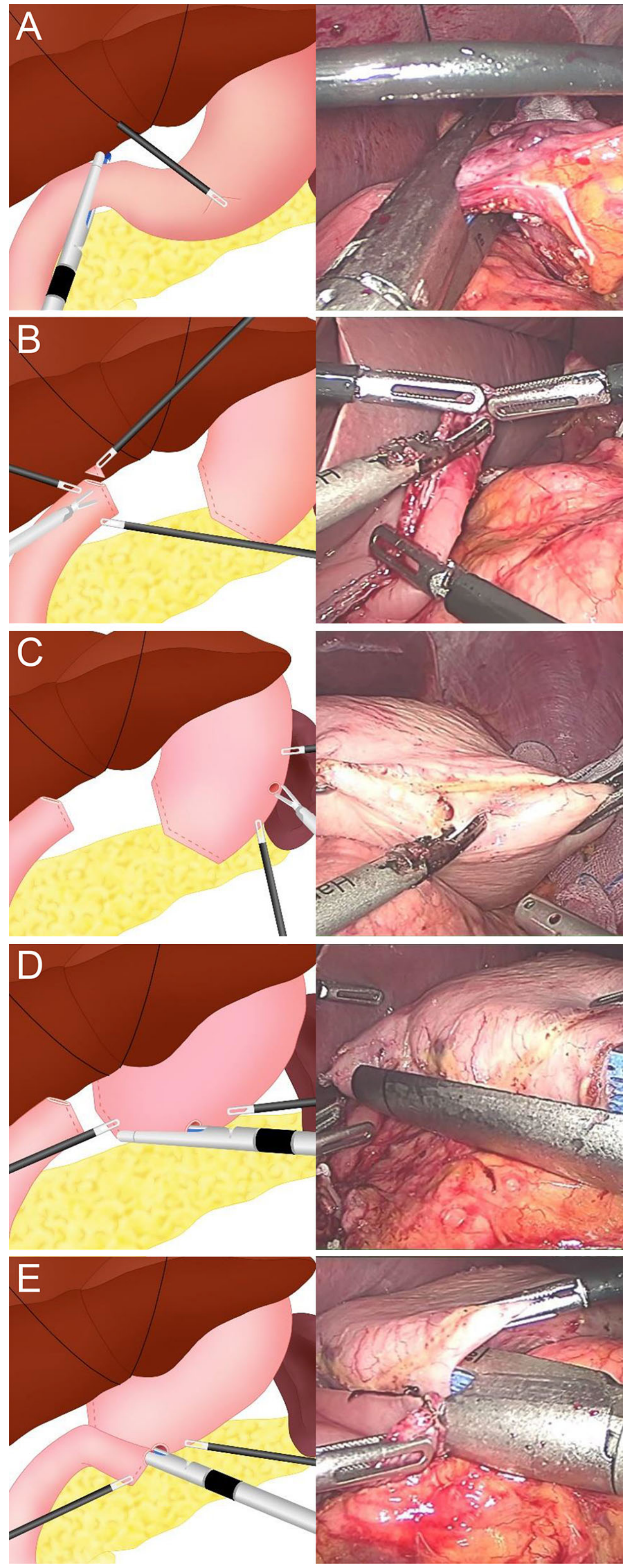

Fig. 2 Diagram and intraoperative photography of linear-shaped ▶ gastroduodenostomy before closing the common stab incision. **A** Duodenum transection through left upper assistant port in a craniocaudal direction without 90° rotation. **B** A small incision on the superior edge of the duodenal transection line. **C** A small incision on the greater curvature of remnant stomach at the point 60 mm apart from the resection line. **D** The cartridge jaw of 60-mm endoscopic linear stapler was inserted into remnant stomach. **E** The greater curvature of the remnant stomach and antero-superior side of the duodenum were put together, and the stapler was closed and fired

Staplers; Ethicon Endo-Surgery, Cincinnati, OH, USA) was introduced through right middle quadrant (12-mm) port. The duodenum was transected in a craniocaudal direction without 90° rotation which was crucial in DSGD. After additional lymphadenectomy, the stomach was transected. The resected specimen was inserted into a retrieval bag and retracted through extended infra-umbilical port site. Gross and pathological (proximal and distal) resection margins were checked.

A small incision on the superior edge of the duodenal transection line was created, and another small incision was created on the greater curvature of the remnant stomach 60 mm apart from the resection line. The 60-mm endoscopic linear stapler was introduced into the abdominal cavity through the left middle quadrant's 12-mm port, and the cartridge jaw was inserted into the remnant stomach. The linear stapler was moved to the duodenum, and the anvil jaw was inserted to the duodenum through the slit. The greater curvature side of the remnant stomach and antero-superior side of the duodenum were put together, and the stapler was closed and fired (Fig. 2).

After identifying the stapler line for bleeding, three stay sutures were added to each end of the common stab incision and the cutting edges of the stomach and duodenum. Another 60-mm endoscopic linear stapler was introduced through the left middle quadrant port, and 30° articulation was made. While the three sutures were pulled, the articulated stapler was introduced in tangential direction to the duodenal transection line, and the common stab incision was closed (Fig. 3).

In robotic distal gastrectomy, we used five trocars: an 11-mm infra-umbilical port for camera, three 8-mm working ports for robotic arm (right upper quadrant, right middle quadrant, and left upper quadrant), and a left lower quadrant (12-mm) port for assistance. Dissection and reconstruction was done in similar pattern with laparoscopic distal gastrectomy.

DSGD in laparoscopic or robotic distal gastrectomy

As Huang et al. [22] reported, we did similar modification of delta-shaped gastroduodenostomy [10]. Duodenal transection was in antero-dorsal direction by rotating 90°. After extraction of specimen, small incisions were made on the edge of greater curvature of the remnant stomach and

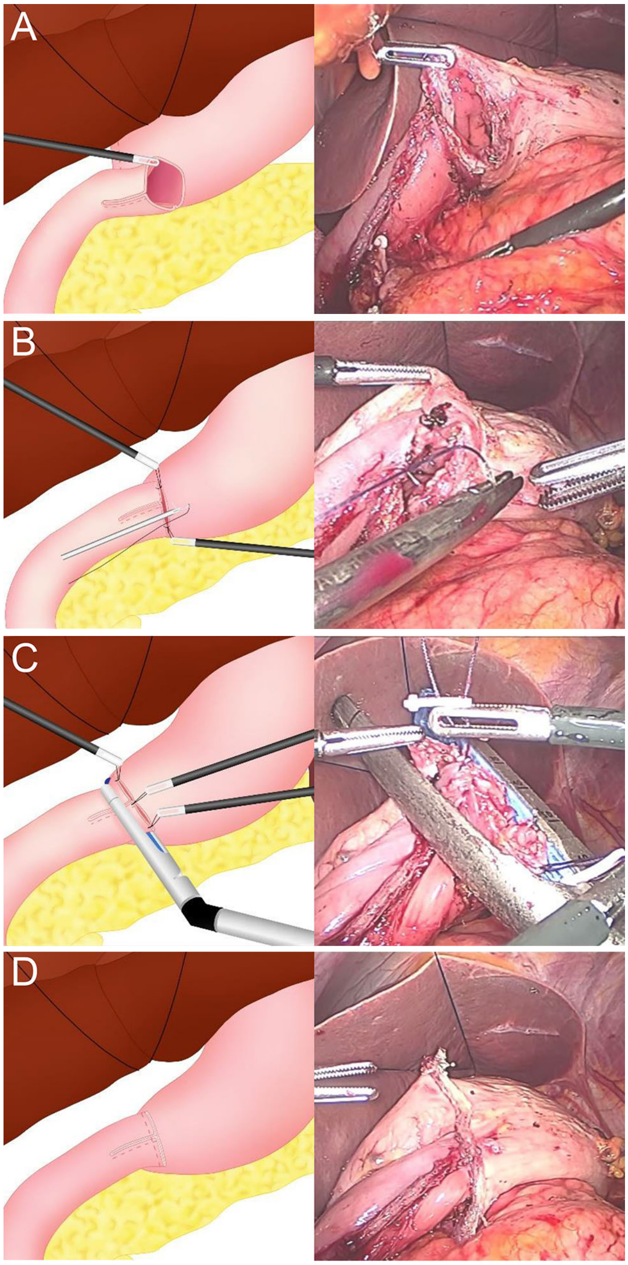

Fig. 3 Diagram and intraoperative photography of linear-shaped gastroduodenostomy in closing the common stab incision. **A** Identifying V-shape anastomosis. **B** Three stay sutures were added to each end of the common stab incision. **C** The articulated linear stapler was introduced in tangential direction to the duodenal transection line, and the common stab incision was closed. **D** The completed inverted T-shaped appearance of anastomosis in the LSGD

on the posterior side of the duodenum. After approximation of the posterior walls of the remnant stomach and duodenum with 90° counterclockwise rotation, the forks of the 45-mm endoscopic linear stapler were closed and fired, creating a V-shaped anastomosis on the posterior wall. The blind angle of the duodenum was completely resected at the same time when the common stab incision was closed with the stapler.

Endoscopic surveillance and classification of endoscopic findings

Regular follow-up programs were conducted according to the standard protocol (every 3, 6, 9, and 12 months for the first year) and included the endoscopic examination on the first 6 and 12 months. Three endoscopists were highly specialized in gastric cancer and were belonged to the Gastric Cancer Center. The endoscopy procedures were institutionally standardized. The patients received written instructions about diet preparation before the examinations. Diet preparation for the endoscopic examinations included a soft meal diet at 6 p.m. and fasting from 8:00 p.m. in the evening on the day before the endoscopy until the endoscopic examination. All endoscopic examinations were performed between 9:00 a.m. and 12:00 p.m. Endoscopic findings were annually evaluated using the RGB (residual food, gastritis, bile reflux) classification [23].

Ethics statement

Written consents were provided by the patients for their information to be stored in the hospital database and used for research. This study was approved by the Institutional Review Board of Ajou University Hospital (AJIRB- MED-MDB-14-433).

Statistics

All of the statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 22.0 for Windows (SPSS Inc, Chicago, USA). Data are expressed as the means ± standard deviations. Categorical variables were analyzed by the Chi-square test or Fisher's exact test, while continuous variables were analyzed by Student's t test. The level of significance was set at $P < 0.05$.

Results

Clinicopathological characteristics

Clinicopathological characteristics of two anastomosis groups are summarized in Table 1. Intracorporeal gastroduodenostomy after distal gastrectomy was performed in 261 patients; 190 (72.7 %) underwent LSGD; and 71

Table 1 Baseline clinicopathological characteristics of the patients

Characteristics	LSGD ($n = 190$)	DSGD ($n = 71$)	*P* value
Age (years, mean ± SD)	57.2 ± 12.5	56.5 ± 13.2	0.675
Gender (no. %)			0.031
Male	129 (67.9)	38 (53.5)	
Female	61 (32.1)	33 (46.5)	
Male sex (no. %)	129 (67.9)	38 (53.5)	0.031
Height (cm, mean ± SD)	164.4 ± 8.4	163.3 ± 9.5	0.432
Weight (kg, mean ± SD)	64.4 ± 11.9	63.2 ± 9.3	0.463
Body mass index[a] (mean ± SD)	23.7 ± 3.4	23.7 ± 2.9	0.976
Number of comorbidity (no. %)			0.069
0	94 (49.5)	47 (66.2)	
1	59 (31.1)	17 (23.9)	
≥2	32 (16.8)	5 (7.0)	
ASA[b] score (no. %)			0.256
1	95 (51.4)	40 (58.8)	
2	79 (42.7)	27 (39.7)	
3	11 (5.9)	1 (1.5)	
Previous abdominal surgery (no. %)	17 (9.0)	1 (1.4)	0.049
Tumor location[c] 1 (no. %)			0.349
Mid-body	65 (34.6)	29 (40.8)	
Lower body	123 (65.4)	42 (59.2)	
Tumor location[c] 2 (no. %)			0.312
Lesser curvature	67 (35.6)	24 (34.3)	
Greater curvature	31 (16.5)	14 (20.0)	
Anterior wall	36 (19.1)	12 (17.1)	
Posterior wall	44 (23.4)	20 (28.6)	
Circumferential	10 (5.3)	0 (0.0)	
Tumor size (cm, mean ± SD)	2.5 ± 1.4	2.5 ± 1.4	0.960
Histology by WHO (no. %)			0.921
Differentiated	84 (47.2)	34 (47.9)	
Undifferentiated	94 (52.8)	37 (52.1)	
T classification[d] (no. %)			0.974
T1	166 (87.4)	64 (90.1)	
T2	12 (6.3)	3 (4.2)	
T3	9 (4.7)	3 (4.2)	
T4a	3 (1.6)	1 (1.4)	
N classification[d] (no. %)			0.370
N0	166 (87.4)	57 (80.3)	
N1	14 (7.4)	8 (11.3)	
N2	9 (4.7)	6 (8.5)	
N3	1 (0.5)	0 (0.0)	
Stage[d] (no. %)			0.051
IA	156 (82.1)	52 (73.2)	
IB	12 (6.3)	10 (14.1)	
IIA	7 (3.7)	7 (9.9)	
IIB	9 (4.7)	1 (1.4)	
IIIA	4 (2.1)	0 (0.0)	
IIIB	2 (1.1)	1 (1.4)	

[a] Body mass index was measured as weight in kilogram divided by the square of height in meters

[b] American Society of Anesthesiologists score

[c] According to the 3rd English edition of Japanese classification of gastric carcinoma

[d] According to the American Joint Committee on Cancer

(27.3 %) underwent DSGD. Besides proportions of male patients (67.9 % [LSGD] vs. 53.5 % [DSGD], $p = 0.031$), there were no significant differences in age, height, weight, BMI, history of abdominal operation, medical comorbidity, ASA score, tumor size, tumor location, and TNM stage between LSGD group and DSGD group.

Operative characteristics

Table 2 shows the operative characteristics of the two groups. LSGD and DSGD were successfully completed in all patients, with none of these patients requiring conversion to open surgery. Compared to DSGD group, the proportion of robotic approach (31.1 % [LSGD] vs. 16.9 % [DSGD], $p = 0.022$) and D2 lymphadenectomy (34.2 % [LSGD] vs. 19.7 % [DSGD], $p = 0.031$) were significantly higher in LSGD group. Although operation time was significantly longer for patients in the LSGD group (147.9 min) than for in the DSGD group (128.8 min; $p = 0.001$), estimated blood loss was similar in both groups [97.3 mL (LSGD) vs 82.1 mL (DSGD); $p = 0.161$]. There was no difference in retrieved lymph nodes.

In LSGD group, the resected stomach size was 10.7 ± 2.2 cm (lesser curvature) and 16.0 ± 3.7 cm (greater curvature), and there were no significant differences compared to 11.1 ± 2.3 cm and 16.6 ± 4.4 cm of the DSGD group, respectively ($p = 0.207$; $p = 0.209$). There were no differences in the proximal margin length and distal margin length.

Early surgical outcomes

Early surgical outcomes including the hospital courses and postoperative complications are listed in Table 3. There were significant short diet buildup time and length of hospital stay between two groups.

The rates for overall complications (13.2 % [LSGD] vs. 9.9 % [DSGD], $p = 0.470$) and major complications (5.8 % [LSGD] vs. 5.6 % [DSGD], $p = 1.0$) were similar between the two groups. Types of complications were also comparable. Six patients (3.2 %) in the LSGD and 2 patients (2.8 %) in the DSGD group developed anastomotic stenosis. One patient who had binge eating disorder in LSGD developed anastomotic leakage on postoperative day 14. After normal discharge on postoperative day 6, the patient ate a large amount of food in a short period and visited emergency unit for abdominal pain. On the operation field, the gastroduodenostomy was seen 30 % disruption. Anastomosis-related intraluminal bleeding was seen in 2 patients (1.1 %) in the LSGD and 1 patient (1.4 %) in the DSGD group. In LSGD group, the bleeding was successfully controlled by endoscopic intervention. In DSGD group, a 69-year-old male patient, who had an end-stage renal disease on hemodialysis, underwent laparoscopic distal gastrectomy with cholecystectomy and was discharged on postoperative day 8. On postoperative day 23, the patient visited emergency unit for severe hematemesis and was identified with a massive anastomotic bleeding. Despite the endoscopic and radiologic intervention and re-operation, the patient died on the

Table 2 Operative characteristics of patients

Characteristics	LSGD ($n = 190$)	DSGD ($n = 71$)	P value
Approach (no. %)			0.022
Robot	59 (31.1)	12 (16.9)	
Laparoscopy	131 (68.9)	59 (83.1)	
Open conversion	0	0	N/A
Combined resection (no. %)	8 (4.2)	3 (4.2)	1.000
D2 lymph node dissection[a] (no. %)			0.023
<D2	125 (65.8)	57 (80.3)	
≥D2	65 (34.2)	14 (19.7)	
Retrieved lymph nodes (n, mean ± SD)	36.3 ± 13.0	37.6 ± 12.3	0.465
Operation time (min, mean ± SD)	147.9 ± 49.4	128.8 ± 35.8	0.001
Estimated blood loss (cc, mean ± SD)	97.3 ± 95.7	82.1 ± 68.3	0.161
Resected stomach size (cm, mean ± SD)			
Lesser curvature	10.7 ± 2.2	11.1 ± 2.3	0.207
Greater curvature	16.0 ± 3.7	16.6 ± 4.4	0.209
Resection margin (cm, mean ± SD)			
Proximal margin	4.8 ± 2.5	5.0 ± 2.1	0.523
Distal margin	4.6 ± 2.3	5.3 ± 3.0	0.118

[a] According to the Japanese gastric cancer treatment guideline 2010

Table 3 Early surgical outcomes

Characteristics	LSGD ($n = 190$)	DSGD ($n = 71$)	P value
Postoperative diet buildup			
Sips of water (days, mean ± SD)	1.8 ± 0.8	1.5 ± 0.6	0.004
Liquid diet (days, mean ± SD)	3.0 ± 1.2	2.5 ± 0.6	0.007
Soft diet (days, mean ± SD)	5.0 ± 1.9	4.4 ± 1.5	0.024
Length of stay (days, mean ± SD)	6.8 ± 3.1	5.8 ± 2.1	0.009
Any complication (no. %)	25 (13.2)	7 (9.9)	0.470
Wound infection	6 (3.2)	2 (2.8)	1.000
Fluid collection	1 (0.5)	1 (1.4)	0.471
Intra-abdominal bleeding	1 (0.5)	0 (0.0)	1.000
Intraluminal bleeding	2 (1.1)	1 (1.4)	1.000
Intestinal obstruction	2 (1.1)	0 (0.0)	1.000
Ileus	6 (3.2)	0 (0.0)	0.194
Stenosis	6 (3.2)	2 (2.8)	1.000
Leakage	1 (0.5)	0 (0.0)	1.000
Fistula	1 (0.5)	0 (0.0)	1.000
Pancreatitis	0 (0.0)	2 (2.8)	0.073
Pulmonary	0	0	N/A
Urinary	1 (0.5)	0 (0.0)	1.000
Renal	0	0	N/A
Hepatic	0 (0.0)	1 (1.4)	0.272
Cardiac	0	0	N/A
Endocrine	0	0	N/A
Other	2 (1.1)	0 (0.0)	1.000
Major complications[a] (no. %)	11 (5.8)	4 (5.6)	1.000
Operative mortality[b] (no. %)	0 (0.0)	1 (1.4)	0.272

[a] Clavien–Dindo classification ≥3

[b] In-hospital or 30-day mortality

postoperative day 25 after re-operation. Without these, no hospital mortality was noted in both groups.

Endoscopic findings on postoperative 6 months

Table 4 shows the endoscopic findings 6 and 12 months postoperatively. On postoperative 6 months, 176 (92.6 %) patients in the LSGD group and 68 (95.7 %) patients in the DSGD underwent endoscopy. The residual food grade and gastritis degree in the LSGD group were significantly low compared to DSGD group, respectively ($p = 0.022$, $p = 0.018$). Bile reflux in the remnant stomach was seen in 42.0 % in the LSGD and in 63.2 % in the DSGD group ($p = 0.003$). On postoperative 12 months, 160 (84.2 %) patients in the LSGD group and 57 (80.2 %) patients in the DSGD underwent endoscopy. There were no significant differences in residual food grade, gastritis degree, and bile reflux 12 months postoperatively.

Discussion

With advances in surgical technique and instruments, many gastric surgeons are currently attempting to perform totally laparoscopic gastrectomy, in which all the procedures, including gastric resection and anastomosis, are performed intracorporeally without making an additional abdominal incision.

Several techniques of intracorporeal anastomosis have been developed, and the delta-shaped gastroduodenostomy (DSGD) has been utilized as an intracorporeal Billroth I procedure due to its relative simplicity. However, this method has not been carried out extensively so far because higher technical demand is needed while most surgeons still doubt for its feasibility and safety.

We have developed a new, feasible method of intracorporeal gastroduodenostomy, using only endoscopic linear staplers, which we named the linear-shaped gastroduodenostomy (LSGD) [16]. In the current study, there

Table 4 Endoscopic findings in postoperative 6 and 12 months

Characteristics	6 months			12 months		
	LSGD ($n = 176$)	DSGD ($n = 68$)	P value	LSGD ($n = 160$)	DSGD ($n = 57$)	P value
Residual food (no. %)			0.022			0.662
Grade 0	143 (80.8)	43 (63.2)		132 (82.0)	44 (77.2)	
Grade 1	8 (4.5)	10 (14.7)		18 (11.2)	7 (12.3)	
Grade 2	6 (3.4)	4 (5.9)		4 (2.5)	1 (1.8)	
Grade 3	8 (4.5)	3 (4.4)		2 (1.2)	2 (3.5)	
Grade 4	12 (6.8)	8 (11.8)		5 (3.1)	3 (5.3)	
Gastritis (no. %)			0.018			0.316
Grade 0	12 (6.8)	2 (2.9)		11 (6.9)	3 (5.3)	
Grade 1	121 (68.8)	37 (54.4)		107 (66.9)	35 (61.4)	
Grade 2	38 (21.6)	28 (41.2)		33 (20.6)	18 (31.6)	
Grade 3	5 (2.8)	1 (1.5)		9 (5.6)	1 (1.8)	
Bile reflux (no. %)			0.003			0.069
Grade 0	102 (58.0)	25 (36.8)		98 (61.3)	27 (47.4)	
Grade 1	74 (42.0)	43 (63.2)		62 (38.8)	30 (52.6)	

were no significant differences between LSGD and DSGD for early surgical outcomes. Furthermore, endoscopy performed 6 months postoperatively showed that residual food grade, gastritis degree, and bile reflux were significantly decreased in LSGD compared to DSGD.

When selecting a proper anastomosis technique, technical feasibility and safety would be the most essential reference because of the severe nature of anastomosis-related complications. And considering that most patients undergoing minimally invasive gastrectomy are expected to have a high long-term survival rate, functional outcomes are also important.

We consider the LSGD to have better technical and functional benefits compared to the DSGD. Seen from the technical aspect, the complicated rotation of duodenum stomach was a mandatory procedure in DSGD to avoid the duodenal stump ischemia. But, in LSGD, the rotation was not needed because of the antero-superior border of duodenum and greater curvature of stomach which were perpendicular to the transection stapler line and it had little risk of poor vascular supply. Although Kanaya et al. [15] reported that the rate of anastomosis-related complication was only 1 % (one minor leak) in their initial 100 DSGD, some author in other institutes reported 1.0–12.7 % of anastomotic complication [11–14]. Noshiro et al. [14] reinforced with additional suture to the inferior edge of stapler line in original DSGD, and Huang et al. [22] completely resected the duodenal cut-edge to avoid the poor blood supply. In the present study, there was no anastomotic leakage in LSGD and duodenal cut-edge was completely resected in all DSGD.

In the aspect of function, the residual food grade, the incidence of gastritis in remnant stomach over grade 2 (24.4 % [LSGD] vs. 42.7 % [DSGD], $p = 0.022$), and bile reflux (42.0 % [LSGD] vs. 63.2 % [DSGD], $p = 0.003$) were significantly low in LSGD in the postoperative 6 months. And these differences disappeared in the postoperative 12 months. We assumed that this difference in postoperative 6 months was due to no twisting of anastomosis and larger anastomotic lumen. LSGD is a morphological 'up and down' side-to-side reconstruction between the greater curvature of the remnant stomach body and the superior border of the duodenum, and it could help gastric and bile content passage downward with gravity. Furthermore, larger anastomosis lumen could be obtained in LSGD because we use the 60-mm length linear stapler instead of 45-mm length linear stapler which was used in DSGD. We speculate that larger anastomosis lumen and these downward-straightforward structural alignments between the remnant stomach and the duodenum may facilitate the gastric food passage into duodenum and reduce the incidence of gastritis in remnant stomach and bile reflux. But in the postoperative 12 months, the difference in the RGB score disappeared. But in the DSGD, RGB score improved from 6 to 12 months. As Lee et al. [24] reported, after DSGD, gastric food passage and gastritis improved. And we speculated the similar endoscopic findings in the postoperative 12 months in spite of difference in the postoperative 6 months were due to the recovered gastric motility in the DSGD and this decreased the difference.

In LSGD procedure, at least 60 mm length of greater curvature side of remnant stomach is used for anastomosis and this may hinder the application of LSGD to intracorporeal Billroth I anastomosis in patients with cancer located at the middle or greater curvature. However, in the present study, the location of tumor for middle (27.6 % [LSGD] vs. 32.2 % [DSGD]) and greater curvature (19.0 % [LSGD] vs. 19.4 % [DSGD]) was similar between the two groups. Furthermore, size of the resected stomach measured along the greater curvature was longer in LSGD than in DSGD (13.7 ± 1.7 vs. 11.9 ± 1.9 cm). Thus, we concluded that while greater curvature of remnant stomach is used, it did not appear to be a clinical obstacle for application of LSGD to intracorporeal Billroth I anastomosis.

We had already reported the linear-shaped gastroduodenostomy (LSGD) [16] in 2009. In the original LSGD, the common stab incision was closed in parallel direction to duodenum with linear stapler which was inserted through the right middle quadrant port. But, with the experience in three cases of consecutive early anastomotic stenosis, we found that two stapler lines of the V-shape gastroduodenostomy were closed during the process of common stab incision closure in parallel direction to the duodenum. Then, we made a modification from parallel direction to tangential direction which was more efficient in maintaining of V-shape gastroduodenostomy (Fig. 3).

The present study had some limitations. First, this study was a retrospective cohort study biased in comparative analysis setup. There were some differences in the patient proportion, D2 lymphadenectomy, and sex ratio between groups. Although we designed this LSGD in May 2009 for the reason of technical complexity of DSGD, we conducted these two procedures randomly until January 2014 because DSGD was a general trend of intracorporeal Billroth I anastomosis. Since then, all intracorporeal Billroth I reconstruction has been performed by LSGD. And as the eligibility criteria expanded to more advanced cancer, numbers of D2 dissection were significantly greater in LSGD group. However, the surgeon had performed 1155 minimally invasive gastrectomy before 2009, and the effect of surgical experience of bowel reconstruction and D2 lymphadenectomy would not have affected the postoperative surgical outcome. And male sex was known to be irrelevant in the short-term surgical outcome in the laparoscopic gastrectomy. Second, a limitation existed in that internationally validated questionnaires were not used for evaluation of post-gastrectomy symptom. Third, although it was a study on gastric cancer patients and oncologic long-term data were important, most of the patients enrolled in this study had early gastric cancer and received gastrectomy from January 2009 and May 2014, and the comparison of long-term survival was impossible. Further investigation with a randomized clinical trial setting is needed to validate its feasibility and long-term outcomes.

In conclusion, linear-shaped gastroduodenostomy is an innovative reconstruction technique with good short-term outcomes comparable to DSGD. It decreased the concerns of ischemia and technical complexity of using the antero-superior border of duodenum and greater curvature in overlap fashion. The comparison of the postoperative course, including morbidity, revealed that modified LSGD and DSGD had similarly good outcomes. In addition, reduced incidence of residual food, gastritis, and bile reflux was seen in LSGD. LSGD is a recommendable reconstruction method, especially in the intracorporeal Billroth I procedure.

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Compliance with ethical standards

Disclosure Cheulsu Byun, Long Hai Cui, Sang-Yong Son, Hoon Hur, Young Kwan Cho, and Sang-Uk Han have no conflicts of interest or financial ties to disclose.

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