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Billroth-I reconstruction using an overlap method in totally laparoscopic distal gastrectomy: propensity score matched cohort study of short- and long-term outcomes compared with Roux-en-Y reconstruction

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Abstract
Background Delta-shaped anastomosis is an established procedure for intracorporeal Billroth-I reconstruction (B-I). However, this procedure has several technical and economic problems. The aim of the current study was to present the technique of B-I using an overlap method (overlap B-I), which is a side-to-side intracorporeal gastroduodenostomy in laparoscopic distal gastrectomy (LDG), and to evaluate the short- and long-term outcomes of this overlap B-I procedure.
Methods We retrospectively reviewed the medical records of 533 patients who underwent LDG with overlap B-I (n = 247) or Roux-en-Y reconstruction (R-Y) (n = 286). Patients with overlap B-I were propensity score matched to patients with R-Y in a 1:1 ratio. Short- and long-term outcomes of the two procedures were compared after matching.
Results In the total cohort, anastomosis-related complications occurred in 2.4% of patients with overlap B-I, and 3.2% of those with R-Y ($P = 0.794$). Morbidity rate, including anastomosis-related complications, and postoperative course were comparable after overlap B-I performed by qualified versus general surgeons. Of 247 patients with overlap B-I, 169 could be matched. After matching, morbidity rate and postoperative course were comparable between the two procedures. Median operation time was significantly shorter for overlap B-I (205 min) than R-Y (252 min; $P < 0.001$). The incidence of readmission due to gastrointestinal complications was significantly lesser after overlap B-I (2.4%) compared with R-Y (21.9%; $P < 0.001$). The main causes of readmission after R-Y were bowel obstruction (7.3%) and gallstones (8.0%). Regarding the development of common bile duct (CBD) stones, 11 patients (3.8%) who underwent R-Y were readmitted due to CBD stones, whereas no patients who underwent B-I developed CBD stones.
Conclusions Overlap B-I is feasible and safe, even when performed by general surgeons. B-I was superior to R-Y concerning operation time and readmission due to gastrointestinal complications.

Keywords Gastric cancer · Laparoscopic distal gastrectomy · Billroth-I reconstruction · Roux-en-Y reconstruction

Laparoscopic distal gastrectomy (LDG) is now an established minimally invasive procedure for the treatment of gastric cancer [1, 2]. Compared with open distal gastrectomy, LDG is associated with several advantages that include less intraoperative blood loss, less postoperative pain, earlier postoperative recovery, and shorter hospital stay, with a similar overall survival rate [2–6]. The most common reconstruction methods performed after LDG are Billroth-I reconstruction (B-I) or Roux-en-Y reconstruction (R-Y) [2]. Although previous studies have compared the outcomes of B-I and R-Y after LDG, the reconstruction method of choice remains controversial [2, 7].

To remove the small laparotomy created by extracorporeal anastomosis in laparoscopy-assisted distal gastrectomy, intracorporeal anastomosis is currently being adopted and

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has given rise to totally LDG. Although intracorporeal anastomosis is complex and challenging, totally LDG reportedly has several advantages compared with laparoscopy-assisted distal gastrectomy [8–10]. When performing B-I in totally LDG, the delta-shaped anastomosis (DSA) (an intracorporeal anastomosis created using only endoscopic linear staplers) has been increasingly adopted since its introduction in 2002, especially in Korea and Japan [11–14]. Although the DSA is reportedly straightforward and has good long-term outcomes, this procedure has several complexities and pitfalls, such as the ventrodorsal direction of the duodenal transection, potential deterioration of the duodenal vascularity due to the creation of sufficient space around the duodenum, and difficulty in performing the common stub closure using endoscopic linear staples [11, 14–16]; moreover, this procedure needs three endoscopic liner stapler cartridges, which causes additional expense [11, 17]. Therefore, to overcome the difficulties and cost disadvantage of the DSA, we developed a distinct reconstructive procedure for B-I in totally LDG, namely B-I using an overlap method (overlap B-I). Our institution introduced this overlap B-I procedure in January 2008. The aim of the current study was to present the technique of overlap B-I in totally LDG, and to evaluate the short- and long-term outcomes of overlap B-I compared with R-Y using propensity score matching analysis.

Materials and methods

Patients and data collection

This retrospective study was approved by the Ethics Committee of our institution (approval number 201803067). We retrospectively reviewed the medical records of 655 consecutive patients who underwent LDG at our institution between 2008 and 2017. We excluded patients who underwent LDG for gastric ulcers ($n=2$), those who underwent LDG combined with other operations, including cholecystectomy ($n=70$), and those who underwent LDG with B-I using the DSA ($n=9$) or Billroth-II reconstruction (B-II) ($n=41$). As patients treated with B-II are reportedly at greater risk of remnant gastric carcinogenesis [18], B-II was performed only for older adult patients (≥ 80 years) at our institution. Data from the remaining 533 patients who underwent LDG with overlap B-I ($n=247$) or with R-Y ($n=286$) were analyzed. Short- and long-term outcomes of the two reconstructive methods were compared.

Demographic, clinical, perioperative, pathological, and survival data were analyzed. Demographic and clinical data included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) status, and history of abdominal surgery or endoscopic submucosal dissection. Tumor location and pathological tumor staging were classified in accordance with the Japanese Classification of Gastric Carcinoma, 3rd English Edition [19].

To minimize the impact of treatment allocation bias, we performed a propensity score matched analysis. Propensity scores were generated using perioperative characteristics including age, sex, BMI, ASA status, history of previous endoscopic submucosal dissection or previous abdominal surgery, tumor location, tumor size, pathological stage, and level of the operating surgeon (qualified versus general). Propensity scores were matched using a caliper width of 0.01 multiplied by the standard deviation of values calculated by a logistic regression model. Each patient who underwent overlap B-I was matched to a patient who underwent R-Y using a one-to-one nearest neighbor matching algorism without replacement. After matching, there were 169 patients in each of the B-I and R-Y groups.

Operating surgeons

As gastric cancer is common in Japan and our institution is a teaching hospital, LDG was performed by the general surgeons who were the attending physicians, as well as by qualified surgeons. Qualified surgeons were defined as surgeons qualified in accordance with the Japan Society of Endoscopic Surgery: Endoscopic Surgical Skill Qualification System [20]. In the present study, LDG was performed by five qualified and 29 general surgeons.

General surgical procedure

Under general anesthesia, the patient was placed in the reverse Trendelenburg position. Five trocars were placed in the upper abdomen, including the umbilicus, and a Nathanson liver retractor (Cook Medical Inc., Bloomington, IN, USA) was inserted from just below the xiphoid process to elevate the round ligament and the lateral segment of the liver. Lymphadenectomy was then performed under pneumoperitoneum as per the Japanese gastric cancer treatment guidelines [21]. During lymphadenectomy, the duodenum was transected from the greater curvature side to the lesser curvature side using an endoscopic linear stapler. After sufficient lymphadenectomy, the stomach was transected from the greater curvature side to the lesser curvature side, with adequate margins from the lesion. The specimen was removed through the extended umbilical wound using a plastic bag.

Reconstructive procedure

Our first choice of reconstructive procedure was overlap B-I (Fig. 1 and Video 1). R-Y was selected in cases with a small remnant stomach or short first portion of the duodenum, in which the anastomosis would be under tension, or in cases

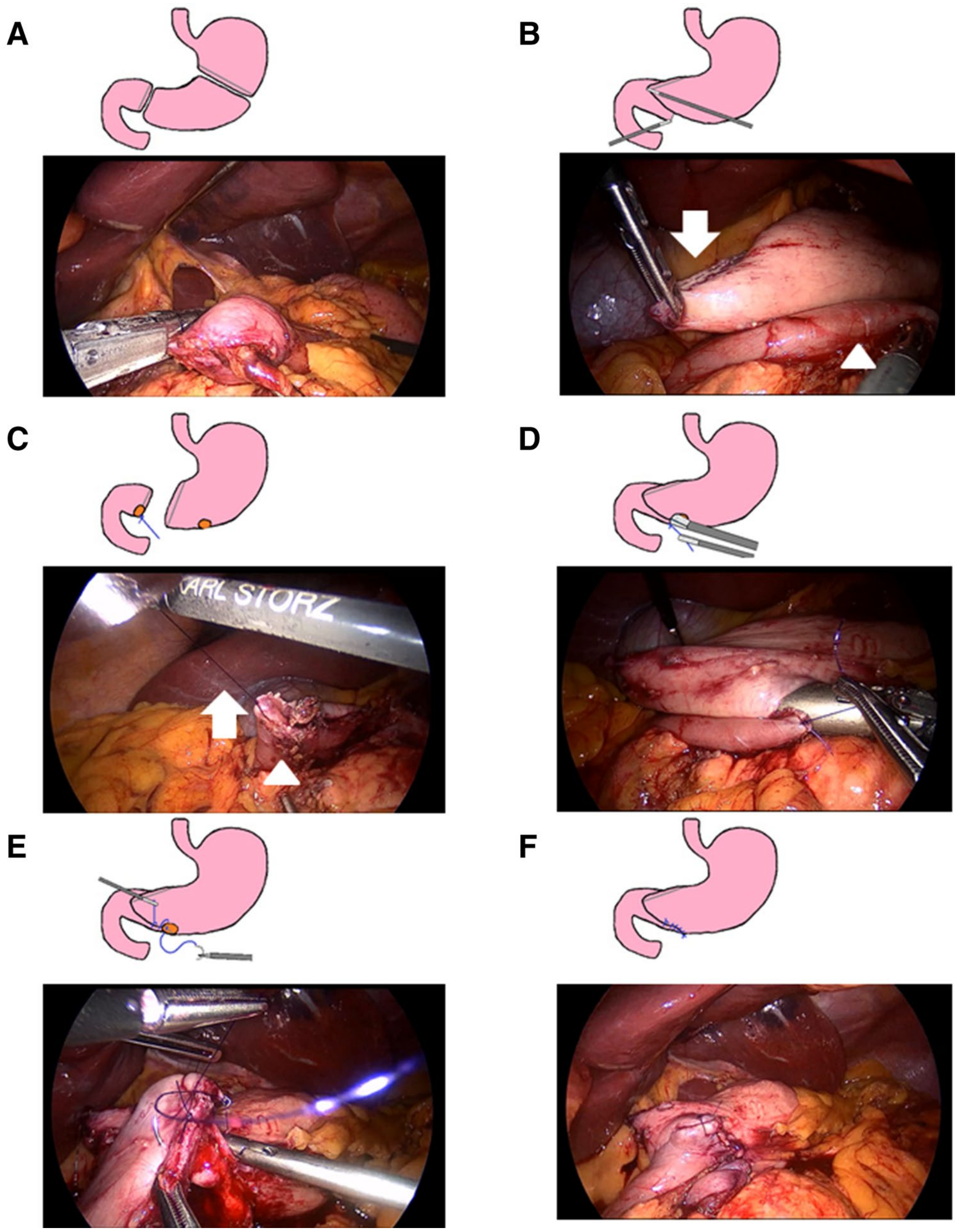

Fig. 1 Schemas and intraoperative photographs of Billroth-I reconstruction using the overlap method in totally laparoscopic distal gastrectomy. **(A)** Distal gastrectomy is performed. The duodenum is transected from the greater curvature side to the lesser curvature side using an endoscopic linear stapler. **(B)** To confirm the tension, the greater curvature side stumps of both the duodenum (arrow-head) and the remnant stomach (arrow) are grasped, and the posterior wall of the remnant stomach is overlapped on the anterior wall of the duodenum. If the remnant stomach can be overlapped about 5 cm without tension, Billroth-I reconstruction is performed. **(C)** A small incision is created on the greater curvature side of the duodenum stump (arrow-head). One suture is placed at the greater curvature side of a small incision in the duodenum (arrow). A small incision is also created on the greater curvature of the remnant stomach at 5 cm proximal to the stomach stump. **(D)** The greater curvature side of the posterior wall of the stomach and the anterior wall of the duodenum are approximated and joined with a 45 mm linear stapler. Grasping the suture placed in a small incision of the duodenum allows the easy and secure insertion and manipulation of a linear stapler. Then, a V-shaped side-to-side anastomosis is made between the remnant stomach and the duodenum. **(E)** The common stab incision is closed using 4-0 suture in a one-layer running pattern. **(F)** The intracorporeal Billroth-I reconstruction is accomplished

in which gastroesophageal reflux from a hiatal hernia was anticipated. To confirm the tension, the greater curvature side stumps of both the duodenum and the remnant stomach were grasped, and the posterior wall of the remnant stomach was overlapped on the anterior wall of the duodenum. Overlap B-I was selected when the remnant stomach could be overlapped about 5 cm without tension; otherwise R-Y was selected.

When overlap B-I was performed, a small incision was created on the greater curvature side of the duodenum stump. One 4-0 PDS-II suture (polydioxanone; Johnson and Johnson Co., New Brunswick, NJ) was placed at the greater curvature side of a small incision in the duodenum. A small incision was also created in the greater curvature of the remnant stomach at 5 cm proximal to the stomach stump. The posterior wall of the greater curvature side of the stomach and the anterior wall of the duodenum were approximated and joined with a 45 mm linear stapler. Then, a V-shaped side-to-side anastomosis was made between the remnant stomach and the duodenum. The common stab incision was closed with 4-0 PDS-II suture in a one-layer running pattern. Then, the intracorporeal overlap B-I was accomplished.

Our R-Y procedure was similar to that performed in other institutions [2, 7]. The jejunum was divided at 25 cm distal to the duodenojejunal flexure using a linear stapler. The Roux limb was brought up through the antecolic or retrocolic route. A small incision was created on the greater curvature side of the remnant stomach stump, and another was created on the antimesenteric side of the Roux limb 5 cm distal to the stump. Intracorporeally, a side-to-side isoperistaltic gastrojejunostomy was performed using a 45 mm linear stapler. The common stab incision was closed with 4-0 PDS-II suture in a one-layer running pattern. An extracorporeal end-to-side jejunojejunal anastomosis with 4-0 PDS-II suture in a one-layer running pattern via the extended umbilical wound or an intracorporeal side-to-side jejunojejunal anastomosis was created 30 cm distal from the gastrojejunostomy. Mesenteric defects, including Petersen's defect, were routinely closed using 3-0 nonabsorbable suture.

Postoperative data and follow-up

Postoperative data comprised postoperative complications, days until a regular oral diet was tolerated, hospital stay, and mortality. Postoperative complications were evaluated using the Clavien-Dindo classification system [22]; grades of III or higher were considered to indicate clinically relevant complications. Delayed gastric emptying (DGE) is one of the common adverse events after distal gastrectomy. DGE is not life-threatening, and can be treated conservatively; however, DGE after R-Y is referred to as Roux stasis syndrome [23]. Therefore, DGE was assessed separately. DGE was defined as (1) the presence of symptoms such as nausea, vomiting, or abdominal fullness without mechanical obstruction, and (2) more than 7 days of continuous fasting after LDG or refasting. Mortality was defined as 30 day or in-hospital death.

Follow-up examinations were performed using computed tomography and tumor marker measurement every 6–12 months. Endoscopy was performed annually in most patients. Endoscopic findings of the remnant stomach were evaluated in accordance with the residue, gastritis, bile classification, while gastroesophageal reflux was evaluated in accordance with the modified Los Angeles classification [24, 25]. The latest endoscopic findings from more than 1 year after LDG were used in analyses. Survival data included the occurrence and date of readmission caused by gastrointestinal complications and recurrence, the cause of readmission, and whether the patient was alive or dead. The last month of follow-up was March 2018.

Statistical analysis

Statistical analysis was performed using JMP statistical software (version 12; SAS Institute, Cary, NC, USA). Continuous data are presented as the median and range. The Mann–Whitney U test was used to assess continuous data. Fisher's exact test or the chi-squared test was used to evaluate differences in categorical data. Survival and readmission rates were calculated using the Kaplan–Meier method, and were compared between groups using the log-rank test. A P value of <0.05 was considered to indicate a statistically significant difference.

Results

Patients' background characteristics

The patients' characteristics are shown in Table 1. In the total cohort, the R-Y group had a significantly greater age, proportion of males, and BMI than the B-I group ($P=0.044$, $P<0.001$, and $P<0.001$, respectively). Furthermore, compared with the B-I group, the R-Y group had a significantly worse ASA status ($P=0.022$), lower prevalence of previous abdominal surgery ($P=0.019$), and larger tumor size ($P=0.007$). Tumor location did not differ between the two groups; however, the R-Y group included six (2.1%) lesions located in the upper third of the stomach. These intergroup differences were no longer present after propensity score matching.

Surgical outcomes and postoperative course

Surgical outcomes and postoperative course are shown in Table 2. Of the 286 patients who underwent R-Y, 73 underwent R-Y via the antecolic route, while 213 underwent R-Y via the retrocolic route. In the total cohort, the B-I group had a significantly shorter operation time, lesser blood loss, and shorter hospital stay than the R-Y group (all $P<0.001$). There were no significant differences between the B-I and R-Y group regarding the prevalence of complications ($P=1.000$), including anastomosis-related complications

Table 1 Patients' characteristics

Characteristics	Total cohort					Propensity score matched cohort				
	B-I group (n = 247)		R-Y group (n = 286)		*P* value	B-I group (n = 169)		R-Y group (n = 169)		*P* value
	Value	%	Value	%		Value	%	Value	%	
Age years	65 (30–86)		67 (28–90)		0.044	65 (33–86)		65 (28–87)		0.808
Sex					< 0.001					0.822
Male	125	50.6	190	66.4		104	61.5	107	63.3	
Female	122	49.4	96	33.6		65	38.5	62	36.7	
BMI kg/m^2	21.7 (15.4–38.2)		23.3 (14.5–34.1)		< 0.001	22.0 (15.4–38.2)		22.5 (14.5–34.1)		0.501
ASA status					0.022					0.519
1	71	28.7	56	19.6		46	27.2	37	21.9	
2	167	67.6	211	73.8		116	68.6	125	74.0	
3	9	3.6	19	6.6		7	4.1	7	4.1	
Previous treatment with ESD	22	8.9	30	10.5	0.562	18	10.7	17	10.1	1.000
Previous abdominal surgery	90	36.4	77	26.9	0.019	43	25.4	51	30.2	0.396
Tumor location[a]					0.073					0.828
Lower third	123	49.8	139	48.6		90	53.3	87	51.5	
Middle third	124	50.2	141	49.3		79	46.7	82	48.5	
Upper third	0	0	6	2.1						
Tumor size mm	30 (3–130)		30.5 (7–125)		0.007	30 (5–130)		30 (8–100)		0.618
Pathological stage[a]					0.445					0.905
IA	180	72.9	196	68.5		124	73.4	118	69.9	
IB	22	8.9	32	11.2		17	10.1	21	12.4	
IIA	14	5.7	25	8.7		13	7.7	12	7.1	
IIB	18	7.3	17	5.9		9	5.3	12	7.1	
IIIA	11	4.5	9	3.2		4	2.4	5	3.0	
IIIB	1	0.4	4	1.4		1	0.6	1	0.6	
IIIC	1	0.4	1	0.4		1	0.6	0	0	
IV	0	0	2	0.7		0	0	0	0	

Data are expressed as the median (range) or the number of patients

B-I Billroth-I reconstruction, *R-Y* Roux-en-Y reconstruction, *BMI* body mass index, *ASA* American Society of Anesthesiologists, *ESD* endoscopic submucosal dissection

[a]Classified in accordance with the Japanese Classification of Gastric Carcinoma, 3rd English edition

Table 2 Surgical outcomes and postoperative clinical course

Variable	Total cohort					Propensity score matched cohort				
	B-I group (n = 247)		R-Y group (n = 286)		*P* value	B-I group (n = 169)		R-Y group (n = 169)		*P* value
	Value	%	Value	%		Value	%	Value	%	
Operating surgeon[a]					0.792					0.825
Qualified surgeon	144	58.3	170	59.4		98	58.0	101	59.8	
General surgeon	103	41.7	116	40.6		71	42.0	68	40.2	
Operation time min	203 (107–418)		257 (134–495)		< 0.001	205 (107–418)		252 (134–410)		< 0.001
Blood loss ml	10 (0–380)		27.5 (1–915)		< 0.001	10 (0–380)		25 (5–830)		< 0.001
D2 lymph node dissection	56	22.7	54	18.8	0.286	36	21.3	32	18.9	0.684
Positive resection margin	2	0.8	1	0.4	0.599	1	0.6	0	0	1.000
Complications (CD ≥ 3)[b]	18	7.3	20	7.0	1.000	15	8.9	13	7.7	0.844
Anastomotic complication	6	2.4	9	3.2	0.794	6	3.6	7	4.1	1.000
Leakage	4	1.6	5	1.8	1.000	4	2.4	4	2.4	1.000
Stricture	0	0	3	1.1	0.253	0	0	3	1.8	0.248
Ulceration or bleeding	2	0.8	1	0.4	0.599	2	1.2	0	0	0.499
Pancreatic fistula	13	5.3	10	3.5	0.394	11	6.5	6	3.6	0.320
Intraabdominal abscess	7	2.8	4	1.4	0.361	5	3.0	2	1.2	0.448
Intraabdominal bleeding	3	1.2	2	0.7	0.667	3	1.8	1	0.6	0.623
Pneumonia	0	0	2	0.7	0.502	0	0	2	1.2	0.499
Perforation of the digestive tract	0	0	1	0.4	1.000	0	0	1	0.6	1.000
Pancreatitis	1	0.4	0	0	0.463	–	–	–	–	–
Empyema	0	0	1	0.4	1.000	0	0	1	0.6	1.000
Delayed gastric empting	3	1.2	11	3.9	0.100	2	1.2	9	5.3	0.061
Period until regular oral diet was tolerated days	3 (1–49)		3 (1–98)		0.459	3 (1–49)		3 (2–98)		0.808
Hospital stay days	11 (7–88)		12 (7-176)		< 0.001	11 (7–88)		12 (7–176)		0.029
Mortality	0	0	2	0.7	0.502	0	0	2	1.2	0.499

Data are expressed as the median (range) or the number of patients

B-I Billroth-I reconstruction, *R-Y* Roux-en-Y reconstruction, *CD* Clavien-Dindo classification

[a]Qualified surgeons were defined as surgeons qualified in accordance with the Japan Society of Endoscopic Surgery: Endoscopic Surgical Skill Qualification System

[b]Some patients had several complications

($P = 0.794$). These intergroup differences were still present after propensity score matching.

Comparison between qualified and general surgeons

The perioperative data for overlap B-I performed by qualified surgeons versus general surgeons is shown in Table 3. Operation time was significantly shorter in the qualified surgeons group than the general surgeons group ($P < 0.001$). However, there were no significant differences between qualified and general surgeons in other perioperative data. Regarding R-Y only, operation time was significantly shorter in the qualified surgeons group (median, 235 min; range 134–430 min) than the general surgeons group (median, 280 min; range, 186–495 min; $P < 0.001$); however, there were no significant differences between qualified and general surgeons in other perioperative data for R-Y only.

Endoscopic findings after laparoscopic distal gastrectomy

Endoscopic findings after LDG were available for 437 patients (82.0%) in the total cohort, and 270 (79.9%) in the propensity score matched cohort (Table 4). In the total cohort, the incidences of remnant gastritis and reflux esophagitis were significantly higher in the B-I group than the R-Y group ($P < 0.001$ and $P = 0.025$, respectively). Conversely, the prevalence of residual food was significantly higher in the R-Y group than the B-I group ($P = 0.007$). None of the patients with overlap B-I needed conversion from B-I to R-Y due to remnant gastritis or reflux esophagitis.

Table 3 Data from patients who underwent Billroth-I reconstruction using the overlap method performed by qualified surgeons versus general surgeons

Variable	Qualified surgeons[a] n = 144		General surgeons[a] n = 103		*P* value
	Value	%	Value	%	
Sex					0.123
Male	79	54.9	46	44.7	
Female	65	45.1	57	55.3	
BMI kg/m^2	21.8 (15.4–32.3)		21.5 (16.0–38.2)		0.663
ASA status					0.847
1	42	29.2	29	28.2	
2	96	66.7	71	68.9	
3	6	4.2	3	2.9	
Previous treatment with ESD	12	8.3	10	9.7	0.822
Previous abdominal surgery	46	31.9	44	42.7	0.107
Tumor location					0.797
Lower third	73	50.7	50	48.5	
Middle third	71	49.3	53	51.5	
Tumor size mm	30 (3–130)		27 (5–70)		0.181
Pathological stage[b]					0.319
IA	106	73.6	74	71.8	
IB	10	6.9	12	11.7	
IIA	11	7.6	3	2.9	
IIB	10	6.9	8	7.8	
IIIA	5	3.5	6	5.8	
IIIB	1	0.7	0	0	
IIIC	1	0.7	0	0	
Operation time min	188 (107–340)		228 (153–418)		< 0.001
Blood loss ml	10 (0–165)		15 (1–380)		0.101
Lymph node dissection					
D2	34	23.6	22	21.4	0.759
Complications (CD ≥ 3)[c]	11	7.6	7	6.8	1.000
Anastomotic complication	4	2.8	2	1.9	1.000
Period until regular oral diet was tolerated days	3 (2–49)		3 (1–35)		0.792
Hospital stay days	11 (7–88)		11 (7–47)		0.107

Data are expressed as the median (range) or the number of patients

BMI body mass index, *ASA* American Society of Anesthesiologists, *ESD* endoscopic submucosal dissection, *CD* Clavien-Dindo classification

[a]Qualified surgeons were defined as surgeons qualified in accordance with the Japan Society of Endoscopic Surgery: Endoscopic Surgical Skill Qualification System

[b]Classified in accordance with the Japanese Classification of Gastric Carcinoma, 3rd English edition

[c]Some patients had several complications

In the propensity score matched cohort, the incidence of remnant gastritis was significantly higher in the B-I group than the R-Y group ($P = 0.024$). Furthermore, compared with the B-I group, the R-Y group tended to have a higher prevalence of residual food, and a lower prevalence of reflux esophagitis; however, these differences were not significant ($P = 0.077$ and $P = 0.051$, respectively).

Long-term outcomes after laparoscopic distal gastrectomy

The median follow-up periods were 52 months (range, 0–122 months) in the total cohort, and 55 months (range, 1–120 months) in the matched cohort. In both cohorts, the recurrence-free and overall survival rates did not differ

Table 4 Endoscopic findings after laparoscopic distal gastrectomy

Variable	Total cohort					Propensity score matched cohort				
	B-I group (n = 214)		R-Y group (n = 211)		*P* value	B-I group (n = 148)		R-Y group (n = 122)		*P* value
	N	%	n	%		n	%	n	%	
Follow-up period months	49 (12–97)		49 (12–109)		0.471	49 (12–92)		59 (12–109)		0.176
Remnant gastritis (grade ≥ 1)[a]	46	20.9	18	8.3	< 0.001	28	18.9	11	9.0	0.024
Residual food (grade ≥ 1)[a]	14	6.4	31	14.3	0.007	8	5.4	14	11.5	0.077
Bile reflex (grade ≥ 1)[a]	2	0.9	0	0	0.499	2	1.4	0	0	0.503
Reflux esophagitis (LA ≥ A)[b]	19	8.6	7	3.2	0.025	14	9.5	4	3.3	0.051

Data are expressed as the median (range) or the number of patients

B-I Billroth-I reconstruction, *R-Y* Roux-en-Y reconstruction, *LA* Los Angeles classification

[a]Classified in accordance with the residue, gastritis, bile (RGB) classification

[b]Classified in accordance with the Los Angeles classification system with Japanese modifications

between the two groups (Fig. 2A–D). However, readmission probability was significantly higher in the R-Y group than the B-I group (Fig. 2E, F). Causes of readmission are shown in Table 5. Anastomotic complications tended to occur more frequently in the R-Y group than the B-I group in both cohorts; however, these differences were not significant. Bowel obstruction and gallstones with/without cholecystocholangitis were the main complications that occurred in the R-Y group. In the total cohort, seven (2.4%) patients in the R-Y group who underwent surgery for bowel obstruction at readmission were diagnosed with strangulated bowel obstruction caused by internal herniation after reoperation. Of these seven patients, one had undergone antecolic R-Y, while six had undergone retrocolic R-Y. The median interval from the initial LDG with R-Y to reoperation for internal herniation was 17 months (range, 1–54 months). The cause of internal herniation was reopening of the Petersen's defect in five patients, and of the defect of the transverse mesocolon in two patients who underwent retrocolic R-Y. All seven patients lost weight during the interval from the initial LDG to reoperation (median weight loss, − 5.0 kg; range, − 2.1–− 13.3 kg). The incidence of reoperation for strangulated bowel obstruction caused by internal herniation did not differ between the antecolic R-Y group (1.4%) and the retrocolic R-Y group (2.8%; $P = 0.68$). Regarding the development of common bile duct (CBD) stones, 11 patients (3.8%) who underwent R-Y were readmitted due to CBD stones, whereas no patients who underwent B-I developed CBD stones.

Discussion

The DSA is now an established procedure for B-I in totally LDG. Previous studies have shown that the DSA has an acceptable morbidity rate of 5.0–13.5%, including an anastomosis-related complications rate of 1.0–6.3% [14, 15, 26–28]. However, there are some difficulties and disadvantages associated with this procedure [11, 14–17]. To overcome the disadvantages of DSA, we developed an overlap B-I, and described this method in the present study. However, we could not directly compare the overlap B-I with the DSA. Thus, we compared overlap B-I with R-Y, which is the established reconstructive procedure after LDG.

The present study showed that overlap B-I had comparable surgical outcomes to the DSA, with a morbidity rate of 7.3% and an anastomosis-related complications rate of 2.4%. Moreover, these surgical outcomes were comparable to R-Y. Our overlap B-I procedure might solve the problems associated with the DSA. As the posterior wall of the stomach and the anterior wall of the duodenum are anastomosed, there is no need to create space around the posterior wall of the duodenum. Therefore, this reduces the possibility of damage to the surrounding structures and the duodenum relative to the creation of an anastomosis on the posterior wall of the duodenum in the DSA. Moreover, our reconstructive procedure approaches the anterior wall of the duodenum, which provides an easier angle of stapler insertion than that required when performing the DSA that approaches from the posterior wall. As the anastomosis alignment in overlap B-I is parallel with the direction of the stomach and duodenum, and the traction force from the stapler is in one direction, the operating surgeon can easily perform the anastomosis between the stomach and duodenum using an endoscopic linear stapler (without the help of the assistant surgeon). Grasping the suture placed in a small incision of the duodenum allows the easy and secure insertion and manipulation of a linear stapler. In the present study, the perioperative data for overlap B-I performed by qualified versus general surgeons were compared. It is reasonable to expect a significantly longer operation time in the general surgeons group than in the qualified surgeons group, and this result was

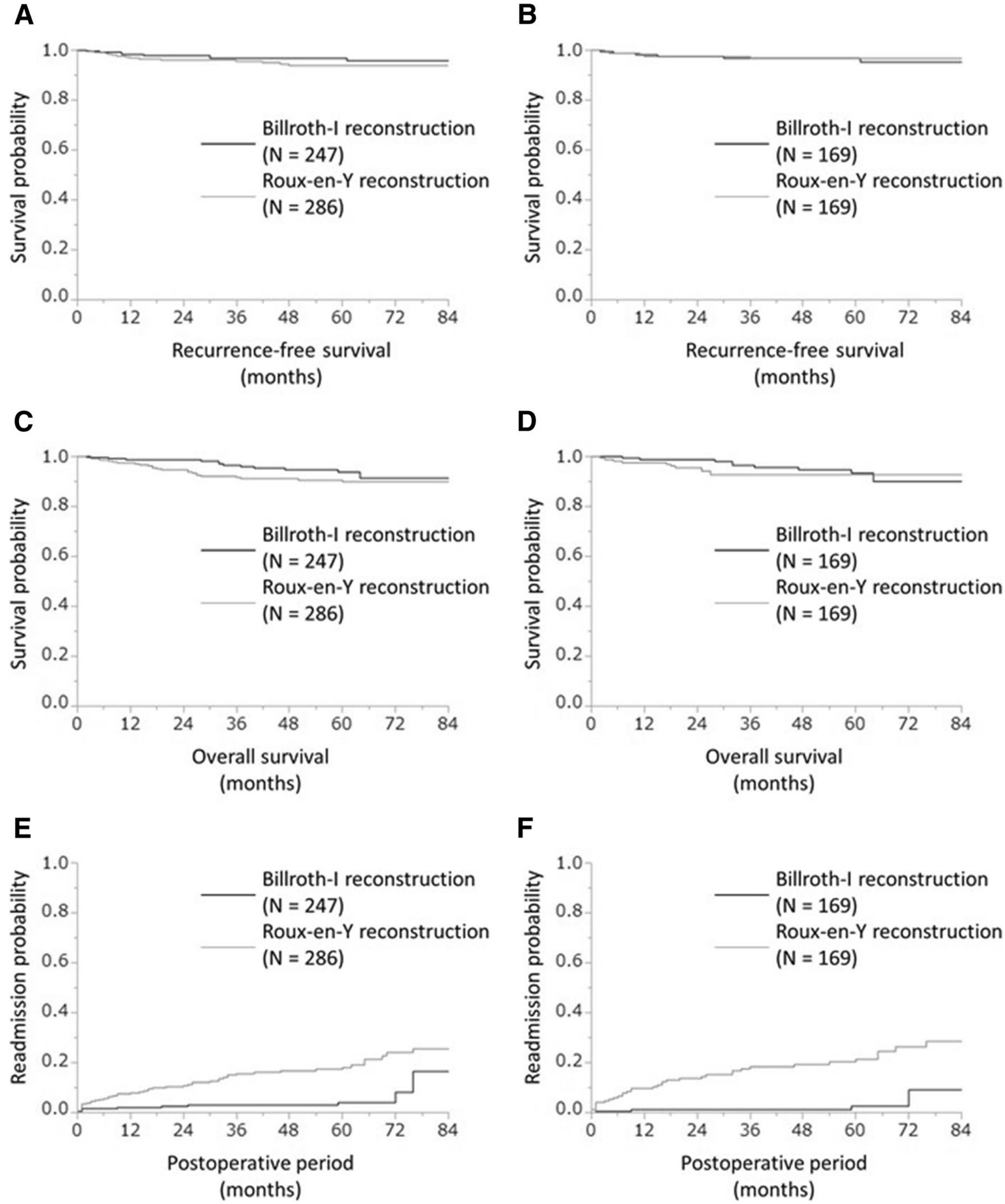

Fig. 2 Recurrence-free survival, overall survival, and readmission rates after laparoscopic distal gastrectomy. Recurrence-free survival of **(A)** the total cohort ($P = 0.240$), and **(B)** the propensity score matched cohort ($P = 0.777$). Overall survival of **(C)** the total cohort ($P = 0.124$), and **(D)** the propensity score matched cohort ($P = 0.722$). Readmission rate of **(E)** the total cohort ($P < 0.001$), and **(F)** the propensity score matched cohort ($P < 0.001$)

the same in both overlap B-I and R-Y. However, overlap B-I performed by general surgeons had a similar morbidity rate, anastomosis-related complications rate, and postoperative course as that performed by qualified surgeons. This indicates that overlap B-I is a safe and easy procedure, even when performed by general surgeons. Moreover, our procedure needs only one endoscopic linear stapler cartridge during reconstruction, which reduces medical costs compared with the DSA.

R-Y can be performed irrespective of the size of the remnant stomach or the degree of obesity of the patient, whereas B-I cannot be performed in patients with a small remnant

Table 5 Readmission after laparoscopic distal gastrectomy

Variable	Total cohort					Propensity score matched cohort				
	B-I group (n = 247)		R-Y group (n = 286)		*P* value	B-I group (n = 169)		R-Y group (n = 169)		*P* value
	n	%	n	%		n	%	n	%	
Readmission	10	4.1	51	17.8	< 0.001	4	2.4	37	21.9	< 0.001
Anastomotic complication	1	0.4	7	2.5	0.074	1	0.6	6	3.6	0.121
Leakage	0	0	2	0.7	0.502	0	0	2	1.2	0.499
Stricture	0	0	4	1.4	0.128	0	0	4	2.4	0.123
Anorexia	1	0.4	1	0.4	1.000	1	0.6	0	0	1.000
Bowel obstruction	3	1.2	21	7.3	< 0.001	1	0.6	16	9.5	< 0.001
Conservative therapy	1	0.4	14	4.9	< 0.001	0	0	11	6.5	< 0.001
Surgery	2	0.8	7	2.4	0.187	1	0.6	5	3.0	0.215
Gallstones	3	1.2	23	8.0	< 0.001	2	1.2	16	9.5	< 0.001
Intraabdominal abscess	2	0.8	5	1.8	0.459	0	0	5	3.0	0.061
Intraabdominal bleeding	1	0.4	2	0.7	1.000	0	0	1	0.6	1.000

B-I Billroth-I reconstruction, *R-Y* Roux-en-Y reconstruction

stomach or high body mass index. However, R-Y requires two anastomoses (gastrojejunostomy and jejunojejunal anastomosis), whereas B-I only requires gastroduodenostomy. Moreover, the use of small intestine for reconstruction in R-Y carries the risk of internal herniation during follow-up, and mesenteric defect closures are required after reconstruction [29, 30]. Therefore, operation time was significantly longer for R-Y than B-I. Although previous studies have compared the outcomes of B-I versus R-Y after LDG, the optimal reconstruction method remains controversial.

Previous studies of short-term outcomes have shown that R-Y is associated with lower incidences of gastroesophageal reflux and remnant gastritis on endoscopic examination compared with B-I [31–33]. Although our endoscopic examination after LDG was cross-sectional, the long-term endoscopic outcomes between R-Y and overlap B-I in the present study were similar to these previous studies. In other studies, clinical symptoms caused by these types of reflux occurred in 0–17% of patients after R-Y, compared with 12–63% of patients after B-I at 3–6 months postoperatively [31, 34]. Therefore, R-Y should be selected when gastroesophageal reflux from a hiatal hernia is anticipated preoperatively. Several studies of long-term outcomes have shown that the incidence of clinical reflux symptoms after B-I is successfully decreased during follow-up via the implementation of medical therapy or dietary improvements [2, 35]. None of the present patients with overlap B-I have so far needed conversion to R-Y due to reflux symptoms; this suggests that the reflux symptoms after overlap B-I might be controllable in most patients. However, further studies are needed to determine whether R-Y decreases long-term clinical reflux symptoms.

In the present study, the recurrence-free and overall survival rates after LDG for gastric cancer did not differ between the B-I and R-Y groups. Therefore, the survival outcomes of B-I and R-Y were similar. However, the R-Y group had a significantly greater rate of readmission for gastrointestinal complications than the B-I group. One of the main causes of readmission after R-Y was bowel obstruction due to internal herniation. Internal herniation after laparoscopic R-Y gastric bypass is a known complication in the field of bariatric surgery, with a reported incidence of 0.2 to 9.0% [29, 30]. Similarly, internal herniation also occurs after LDG with R-Y for gastric cancer, with a reported incidence of 0.2–6.9% [36–42]. Closure of the mesenteric defect is widely reported to reduce internal herniation after LDG as well as after laparoscopic R-Y gastric bypass [29, 30, 39–42]. Failure to close the mesenteric defects after LDG with R-Y is associated with a high rate of internal herniation (2.8–6.9%) [36–38]. However, careful closure of the defect after LDG with R-Y reduces the incidence of internal herniation to 0.2–4.0% [39–42]. The incidence of internal hernia after LDG with R-Y in the current study was 2.4%, which is similar to the incidences reported in the latter studies. Internal herniation after distal gastrectomy can occur due to insufficient closure of the defect [29, 39], but is also associated with body weight loss [36, 43]. Weight loss results in enlargement of the mesenteric defect over time, because of the loss of mesenteric fat. In the current study, all seven patients with bowel obstruction due to internal herniation lost weight during the interval from the initial LDG to reoperation. Therefore, this complication cannot be completely prevented after R-Y, despite routine closure of the mesenteric defect.

The other main cause of readmission after R-Y was gallstones. Nunobe et al. [35] reported that R-Y significantly increased gallstone formation compared with B-I during follow-up after open distal gastrectomy. Similarly, Inokuchi et al. [2] reported a relatively higher rate of gallstone formation after LDG with R-Y than B-I. Although a greater extent of lymph node dissection is reportedly associated with a higher incidence of gallstones [44, 45], the extent of lymph node dissection did not differ between the B-I and R-Y groups in the present study. When R-Y is performed, food does not transit through the duodenum, and this is reportedly an important risk factor for gallstone formation after distal gastrectomy [45]. The present findings indicate that B-I was superior to R-Y concerning readmission. This is a novel finding, as no previous report including a relatively large population has described long-term outcomes concerning readmission due to later gastrointestinal complications after LDG.

The present study has some limitations. (1) This was a retrospective study conducted at a single institution. Moreover, the study population included patients with relatively short-term follow-up. These patients will continue to be monitored. (2) The results of overlap B-I were compared with R-Y, rather than with B-I using the DSA, as only nine patients underwent B-I with DSA during the study period. Although propensity score matching analysis was performed, the comparison of the B-I group versus R-Y group was substantially inadequate. The results of overlap B-I should ideally be compared with the DSA in future studies. (3) Although nutritional indexes such as serum albumin level, serum total cholesterol level, and bodyweight are reportedly similar after R-Y and B-I in the short- and long-term [2, 7, 32], nutritional status was not assessed in the present study because of its retrospective nature. (4) The assessment of endoscopic findings after LDG was cross-sectional. This may be the cause of the comparatively low incidence of remnant gastritis or reflux esophagitis after overlap B-I despite the wide anastomosis. Moreover, the endoscopic reports were retrospectively reviewed. Previous studies report incidences of bile reflux during endoscopy after B-I ranging from 32 to 54% [2, 7]. However, the incidence of bile reflux in the present study was relatively low (0.9%). This discrepancy is difficult to explain, as the incidences of remnant gastritis or reflux esophagitis after LDG in the present study were comparable to the incidences reported in previous studies [31–33].We considered that the wide anastomosis obtained in overlap B-I may reduce the incidence of residual food, but would probably increase the incidence of bile reflux. It is possible that the incidence of bile reflux in the present study may have been artificially lowered, as the endoscopists might only have paid attention to the findings of remnant gastritis or reflux esophagitis, while overlooking the findings of bile reflux. (5) Postgastrectomy syndrome was not assessed, and oral administrations after LDG (including digestive agents or antacid drugs) were not evaluated. Further prospective multi-institutional studies with larger populations are required to assess the true efficacy of overlap B-I in totally LDG.

In conclusion, overlap B-I is a safe and easy procedure in totally LDG. Overlap B-I has several technical and economic merits compared with the DSA. The surgical outcomes of overlap B-I were comparable to those for R-Y, and to those previously reported for the DSA, and this overlap B-I procedure was even performed safely by general surgeons. Readmission probability was significantly higher in the R-Y group than the B-I group. The main causes of readmission after R-Y were bowel obstruction and gallstones. Although the optimal reconstruction method after LDG remains controversial, B-I was superior to R-Y concerning readmission due to gastrointestinal complications as well as operation time.

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