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SCIENTIFIC REVIEW

Revisiting Laparoscopic Reconstruction for Billroth 1 Versus Billroth 2 Versus Roux-en-Y After Distal Gastrectomy: A Systematic Review and Meta-Analysis in the Modern Era

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Abstract

Background In this modern era, laparoscopic distal gastrectomy (LDG) has largely replaced open distal gastrectomy for the treatment of gastric cancer; however, a quantitative review of reconstruction methods applied exclusively using LDG has not yet been published. Thereafter, we compared three reconstruction methods (Billroth I, Billroth II, and Roux-en Y) using the data derived solely from LDG patients.

Methods A systematic search was conducted using electronic bibliographic databases (Google Scholar, PubMed, and Embase), for articles that compared reconstruction methods in LDG, published within the last decade. A systematic review comparing 12 outcome parameters and sensitivity analyses were performed to increase the statistical power and minimize the inconsistency and heterogeneity of results.

Results Twenty-three clinical trials involving 5797 patients were included in the meta-analysis. There were no significant differences in the postoperative recovery and intraoperative parameters, except for operation time. B1 demonstrated a significantly shorter operation time when compared with B2 and RY by 21.6 min ($P < 0.0001$) and 44.69 min ($P < 0.0001$), respectively. In terms of postoperative endoscopic symptoms, RY was significantly superior to B1 and B2 for bile reflux ($P < 0.001$) and remnant gastritis ($P < 0.001$). For postoperative complications, B1 showed a significantly lower rate of postoperative morbidity than did RY and B2 ($P = 0.0006$ and $P = 0.0005$, respectively).

Conclusions Our study is the first meta-analysis comparing anastomoses in LDG and introduces novel criteria for consideration when selecting reconstructions in LDG. Considering the significant differences in postoperative complications and endoscopic symptoms, these two parameters lay reasonable groundwork for guiding the surgeon's choice of reconstruction.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00268-019-04943-x) contains supplementary material, which is available to authorized users.

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Abbreviations

LDG	Laparoscopic distal gastrectomy
ODG	Open distal gastrectomy
B1	Billroth 1

B2 Billroth 2
RY Roux-en-Y

Introduction

Since the introduction of laparoscopic distal gastrectomy (LDG) in the 1990s, numerous studies have evaluated the effectiveness of laparoscopic surgery for treating gastric cancer. The results suggest that LDG is superior to open distal gastrectomy (ODG) in terms of postoperative complications, operation time, blood loss, and postoperative hospital stay [1]. As the benefits of LDG have been elucidated by cumulative studies and clinical experience, it has become more popular and has largely replaced conventional ODG in the past decade.

Since ODG and LDG have different technical approaches, it is difficult to postulate whether the knowledge acquired from ODG can be equally applied to LDG. Hence, in this era of laparoscopic surgery, it has become necessary to re-evaluate reconstruction under purely laparoscopic circumstances. Although there have been several clinical trial studies [2–24] comparing laparoscopic reconstructions, these have been primarily center-based and contradictory results have hindered the clarification of both clinical benefits and drawbacks of each laparoscopic anastomosis. Moreover, a quantitative review of reconstructions in LDG has not yet been conducted. Some studies have reviewed reconstructions in distal gastrectomy [25, 26]; however, limiting factors including lack of prospectively collected data, small sample sizes, and mixed data from both ODG and LDG made it challenging to precisely evaluate the reconstruction methods used in a laparoscopic approach.

The aim of this study was to revisit major reconstructions (Billroth I, Billroth II, and Roux-en Y) of distal gastrectomy. This study is the first large-scale quantitative meta-analysis comparing three major laparoscopic reconstructions exclusively in LDG patients. Subgroup and sensitivity analyses were also performed to increase the statistical power and minimize inconsistencies.

Materials and methods

Study selection

A systematic review was performed using the PubMed, Google Scholar, Medline, Embase, and Cochrane databases to identify articles published up to 2017 that compared reconstruction methods in LDG. The search terms used were: “laparoscopy,” “Billroth,” “Roux-en-Y,” “anastomosis,” “reconstruction,” “distal gastrectomy,” “gastroduodenostomy,” “gastroenterostomy,” “gastrojejunostomy,” “minimally invasive surgery,” “laparoscopic assisted,” and “gastric cancer.” Free-text and Mesh search terms were used as keywords. Identified articles’ citations were also reviewed, to search for additional articles that may not have been indexed. A Korean paper with suitable data presented in English was also included.

Study selection criteria

Studies that met the following criteria were included: (1) studies comparing perioperative outcomes of different reconstruction methods with LDG; (2) studies including at least one objective assessment of the outcomes mentioned; and (3) in cases where two studies were by the same author using identical cohorts, the study with the larger sample size was selected. Studies were excluded based on the following criteria: (1) studies that did not include outcomes of interest; (2) studies lacking the necessary statistical data for meta-analysis; (3) studies with mixed groups of LDG and ODG; (4) studies that did not identify the surgical approach (open vs. laparoscopic) or reconstruction type; and (5) posters, review papers, comments, and abstract-only papers.

Data extraction and quality assessment

Three reconstruction methods were compared based on 12 perioperative outcomes, consisting primarily of postoperative complications. Two independent reviewers evaluated the original studies and extracted the data including the first author, year of publication, hospital location, number of patients operated under each method, characteristics of the study population, study design, data needed for quality assessment, indication for surgery, and several perioperative outcome measures. 21 Non-randomized studies were qualitatively assessed on the basis of the Newcastle–Ottawa Scale (NOS) [27] (supplementary Table 1). Non-randomized studies were evaluated with respect to three major factors: (1) the selection of study groups, (2) comparability of the groups, and (3) ascertainment of outcomes. A NOS score of 0 to 9 was allocated to each study, and studies with a score of 6 or higher were considered as eligible, while a score of 7 or higher was classified as high quality. Two randomized controlled trials were assessed with Jadad scale (supplementary Table 2). Randomized studies were evaluated in respect of five factors: (1) described as randomization, (2) randomization method described and appropriate, (3) description of withdrawals (4) described as double-blinded, and (5) double-blinding method described and appropriate. Both RCTs exceeded score 3 out of 5.

Statistical analysis

This meta-analysis was performed in accordance with the recommendations of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement [28]. Statistical heterogeneity was estimated using Higgins I^2 statistics [27] and Cochran Q test. I^2 values were graded as follows: <25% as low, 25–50% as moderate, and >50% as high heterogeneity [26]. If the heterogeneity was high ($I^2 > 50\%$ or $P < 0.100$), a random-effects model was used for analysis. In a random-effects model, it is assumed that there is variation between the studies [29]. Patients operated on by different groups of surgeons may have diverse risk profiles and histories. Moreover, there are various criteria taken into consideration before deciding each surgical procedure. The random-effects model was selected to consider this heterogeneity. Where the heterogeneity level was low, a fixed effects model was selected. Analysis was conducted using the statistical software Review Manager (RevMan Version 5.3; The Nordic Cochrane Centre, Copenhagen, Denmark). Dichotomous variables were analyzed using risk ratio (RR), and continuous variables were analyzed using weighted mean difference (WMD). RRs and WMDs were presented with 95% confidence intervals (CIs).

Heterogeneity was evaluated using sensitivity analysis in studies that met the following requirements: (1) all studies; (2) studies published between 2010 and 2017; (3) studies of high quality (quality score (NOS) $\geq$ 7); (4) studies with a large sample size (>50 patients); (5) matched lymph node dissection; and (6) matched patient characteristics (age and body mass index (BMI)). A graphical funnel plot was generated to evaluate publication bias.

Results

Selected studies

Of the 737 articles screened, 112 papers were identified for peer review after excluding duplicates and irrelevant articles (Fig. 1). After considerable discussion and evaluation, 25 papers were finally selected for potential inclusion in this study. Two of these 23 articles were published by the same author on an identical cohort; thus, two were excluded to prevent bias. Finally, 23 articles with a total of 5797 patients were concluded to be eligible for inclusion and use in our meta-analysis. The authors of the studies were not contacted, as no additional information was required. All 5797 gastric cancer patients included in the studies were treated with LDG, and ODG cases were strictly excluded. There were no disagreements between the two reviewers during the study selection process, and all articles were included by discussion and mutual agreement.

Background information of included studies

The background information of all included studies is summarized in Table 1. Of the 23 included papers, 21 were retrospective observational studies and 2 were randomized controlled trials. Most of the data were collected in Korea and Japan, with one article originating from China. The publication period of articles ranged from 2007 to 2017, and operation types were exclusively laparoscopic. Detailed information about each cohort was provided in 17 studies (age, sex ratio, BMI, extent of lymph node dissection, and TNM Classification of Malignant Tumors [TNM] stage). In the remaining six studies, the subjects' information was presented more comprehensively. Matched patient factors (controlled factors) of the groups in the included studies are presented in the upper right portion of Table 1 and are listed as follows: (1) age, (2) sex ratio, (3) BMI, (4) extent of lymph node dissection, (5) American Society of Anesthesiologists physical status (ASA-PS), and (6) TNM stage. Wherever the data were missing from certain articles, the values have been indicated as blank (−).

Comparison of variables

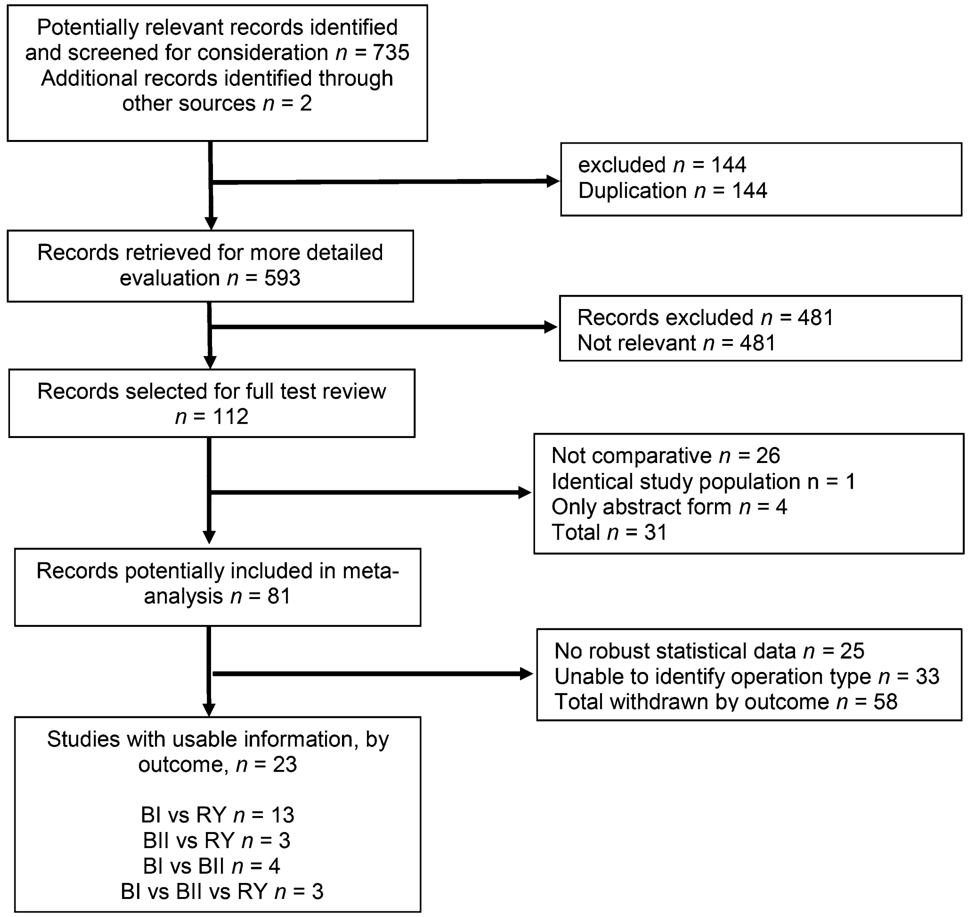
The three reconstruction methods with 12 different variables were compared with respect to four outcome parameters. The four parameters were postoperative complications (overall complications and reconstruction-related complications), operative parameters (operation time, blood loss, and number of retrieved lymph nodes), postoperative recovery (postoperative hospital stay, time to first flatus, and time to first solid diet), and postoperative endoscopic findings and symptoms (residual food, remnant gastritis, bile reflux, and reflux esophagitis).

Postoperative complications

Data regarding postoperative complications are presented in Fig. 2 and Table 2. The B1 group had a lower rate of postoperative complications compared to group RY, with respect to both overall complications (P = 0.0006, I^2 = 26%) and reconstruction-related complications (P = 0.02, I^2 = 17%), and there was no significant difference between B2 and RY. Subgroup analysis was also performed to see whether the differences of laparoscopic-assisted distal gastrectomy (LADG) and totally laparoscopic distal gastrectomy (TLDG) affect the result (Fig. 2d), and the subgroup analysis indicated that both LDG and TLDG have similar results.

Reconstruction-related complications included anastomotic leakage, anastomotic bleeding, anastomotic stenosis, delayed gastric emptying, roux stasis, ileus, fistula, luminal

Fig. 1 PRISMA diagram showing selection of articles for analysis. B1 = Billroth 1, B2 = Billroth 2, RY = Roux-en-Y



stenosis, stricture, duodenal stump leakage, ulceration, intraluminal bleeding. Overall complications additionally included intra-abdominal abscess, intra-abdominal bleeding, intra-abdominal fluid collection, pneumonia, pancreatic fistula, wound problem, cystitis, arthritis, peritonitis, cholecystitis, liver infarction, and ascites.

Operative parameters

The B1 group had a significantly shorter operative time compared to both, group RY ($P < 0.0001$, $I^2 = 85\%$) and group B2 ($P < 0.001$, $I^2 = 0\%$) (supplementary Fig. 1). There was no significant difference in blood loss between the three reconstruction methods, and no significant difference in the number of retrieved lymph nodes was observed between the three groups with matched patients of LN dissection.

Postoperative recovery

Duration of postoperative hospital stay was similar in all three reconstruction types. Time to first flatus, except for B1 versus RY ($P = 0.03$, $I^2 = 31\%$), and time to first solid diet presented no significant difference among the three reconstruction methods. Comparative results are presented in Table 2.

Postoperative endoscopic findings and symptoms

Occurrence of remnant gastritis was significantly lower in group RY than in group B1 ($P < 0.0001$, $I^2 = 61\%$) and B2 ($P = 0.003$, $I^2 = 94\%$) (supplementary Fig. 2). RY group also had a significantly lower bile reflux rate than group B1 ($P < 0.0001$, $I^2 = 47\%$) and B2 ($P = 0.01$, $I^2 = 96\%$), whereas group B1 had a significantly lower rate than group B2 ($P < 0.001$, $I^2 = 43\%$) (supplementary Fig. 3). RY was found to be a significantly better option for preventing reflux esophagitis compared to B1 ($P = 0.0002$, $I^2 = 50\%$) (supplementary Fig. 4), and all reported a similar frequency of residual food at some postoperative period.

Sensitivity analysis

Sensitivity analysis evaluates the robustness of the meta-analysis results. The results were compared to see whether there is a change in statistical significance with diverse

Table 1 Background information of included studies

References	Study design	Hospital location	Operation period	No. of patients (M/F)	Lymph node dissection	BMI (kg/m^2)	TNM stage I/II/III	Type of operation	Matched factor[a]
Kim et al. [2]	Retro	Korea	1998–2005	B1 861 B2 376 (775:462)	D1 + 545/D2 692	–	–	LADG	–
Lee et al. [3]	Retro	Korea	2011	B1 26(16:10) B2 21(16:5)	D1 + β 11/D2 15 D1 + β 13/D2 8	23.1 ± 2.7 23.7 ± 3.1	26/0/0 17/3/1.	LDG	1,2,3,4,5,6
Kang et al. [4]	Retro	Korea	1998–2005	B1 875(540:335) B2 384(252:132)	≤ D1 2/D1 + α 57/ D1 + β 346/D2 470 ≤ D1 6/D1 + α 34/ D1 + β 114/D2 230	–	818/41/16 337/28/19	LADG	1,2,4
Chen et al. [5]	Retro	china	2010–2013	B1 2(2:0) B2 7(4:3)	–	–	–	LDG	–
Shim et al. [6]	Retro	Korea	2011	B2 43(34:9) RY 38(25:13)	D1 + 31/D2 12 D1 + 28/D2 10	24.0 ± 3.93 26.0 ± 2.77	36/3/4. 33/3/2.	TLDG	1,2,4,6
Choi et al. [7]	Retro	Korea	2010–2012	B2 26(18:8) RY 40(28:12)	D2 26 D2 40	23.4 ± 2.0 23.7 ± 2.4	22/3/1. 37/3/0.	LDG	1,2,3,4,6
Kim et al. [8]	Retro	Korea	2004–2006	B1 11(5:6) RY 19(11:8)	D1 + β 3/D2 7 D1 + β 4/D2 14	23.7 ± 2.6 23.3 ± 2.6	9/1/0. 17/1/0.	TLDG	1,2,3,4,6
Kim et al. [9]	Retro	Korea	2008–2009	B1 34 RY 4	–	–	–	MIS	–
Nomura et al. [10]	Retro	Japan	2000–2008	B1 35(21:14) RY 43(31:13)	D1 + β 35 D1 + β 43	–	35/0/0 41/3/0	LDG	1,2,4,6
Oki et al. [11]	Retro	Japan	2005–2009	B1 114(62:52) RY 24(13:11)	D1 + α, β 86/D2 28 D1 + α, β 13/D2 11	22.3 ± 3.1 21.9 ± 3.2	106/5/3. 22/2/0.	TLDG	1,2,3,4,5,6
Kumagai et al. [12]	Retro	Japan	2005–2009	B1 329(197:132) RY 95(74:21)	D1 + α 1/D1 + β 266/D2 62 D1 + α 1/D1 + β 82/D2 12	23.2 ± 3.5 24 ± 3.3	–	LADG	1,3,4,5
Lee et al. [13]	Retro	Korea	2000–2011	B1 248(147:101) RY 128(90:38)	–	22 ± 3.1 22.6 ± 3	–	LDG	1,2,3
An et al. [14]	Retro	Korea	2011–2012	B1 50(28:22) RY 50(30:20)	D1 + β 33/D2 17 D1 + β 26/D2 24	23.3 ± 2.9 25.2 ± 3	–	TLDG	1,2,4,5
Inokuchi et al. [15]	Retro	Japan	1999–2006	B1 89(62:27) RY 83(51:32)	D1 + α 18/D1 + β 56/D2 15 D1 + α 4/D1 + β 63/D2 16	22 ± 2.5 23.1 ± 3.2	84/3/2. 77/5/1.	LDG	1,2,6
Okabe et al. [16]	Retro	Japan	2005–2012	B1 184 RY 56 (227:118)	D1 + 106/D2 135	22.3	259/51/35	LDG	–

Table 1 continued

References	Study design	Hospital location	Operation period	No. of patients (M/F)	Lymph node dissection	BMI (kg/m^2)	TNM stage I/II/III	Type of operation	Matched factor[a]
Kitagami et al. [17]	Retro	Japan	2008–2011	B1 68(39:29)	D1 + β 57/D2 11	23.7	68/0/0	LDG	1,2,3,4,6
				RY 60(45:15)	D1 + β 44/D2 16	22.5	60/0/0		
Suh et al. [18]	Retro	Japan	2014–2015	B1 11(6:5)	D1 + 11	23.2 ± 3.5	13/1/2.	LDG	1,2,3
				RY 5(4:1)	D1 + 5	24.5 ± 3.5			
Komatsu et al. [19]	Retro	Japan	2007–2010	B1 74(37:37)	≤D1 13/D1 + 51/D2 10	22	69/3/2.	LADG	2,3,4,6
				RY 43(27:16)	≤D1 10/D1 + 28/D2 5	22.2	39/3/1.		
Park et al. [20]	Retro	Korea	2005–2013	B1 39	D1 + 181/D2 11	24.4 ± 3.5	199/11/1/	LDG	–
				B2 76					
				RY 55					
Kim et al. [21]	Retro	Korea	2009–2013	B1 165(105:60)	D1 + 77/D2 88	23.9 ± 3.2	152/10/3.	LDG	2,3,6
				B2 371(239:132)	D1 + 273/D2 98	23.9 ± 3.2	332/29/10		
				RY 161(105:56)	D1 + 67/D2 94	23.9 ± 3.1	135/20/6.		
Lee et al. [22]	Retro	Japan	2012–2015	B1 96	–	22.5 ± 3.1	172/24/22	LDG	–
				B2 6					
				RY 67					
				(162:80)					
Yang et al. [23]	RCT	China	2015–2016	B2 79	–	–	2/27/50	LDG	1,2,3,4,5,6
				RY 79			3/31/45		
Choi [24]	RCT	Korea	2011–2014	B1 22	D1 + 9/D2 11	24.7 ± 3.6	17/2/1	LDG	1,2,4,5,6
				RY 22	D1 + 8/D2 12	26.6 ± 4.3	18/1/1		

[a]Matched patient factors: 1, age; 2, sex ratio; 3, BMI; 4, LN dissection; 5, ASA-PS; 6, TNM stage. Blank with (–) indicates no information presented by study. Retro, retrospective observational study; B1, Billroth I; B2, Billroth II; RY, Roux-en Y; LDG, laparoscopic distal gastrectomy; LADG, laparoscopic-assisted distal gastrectomy; TLDG, totally laparoscopic distal gastrectomy; MIS, minimally invasive surgery

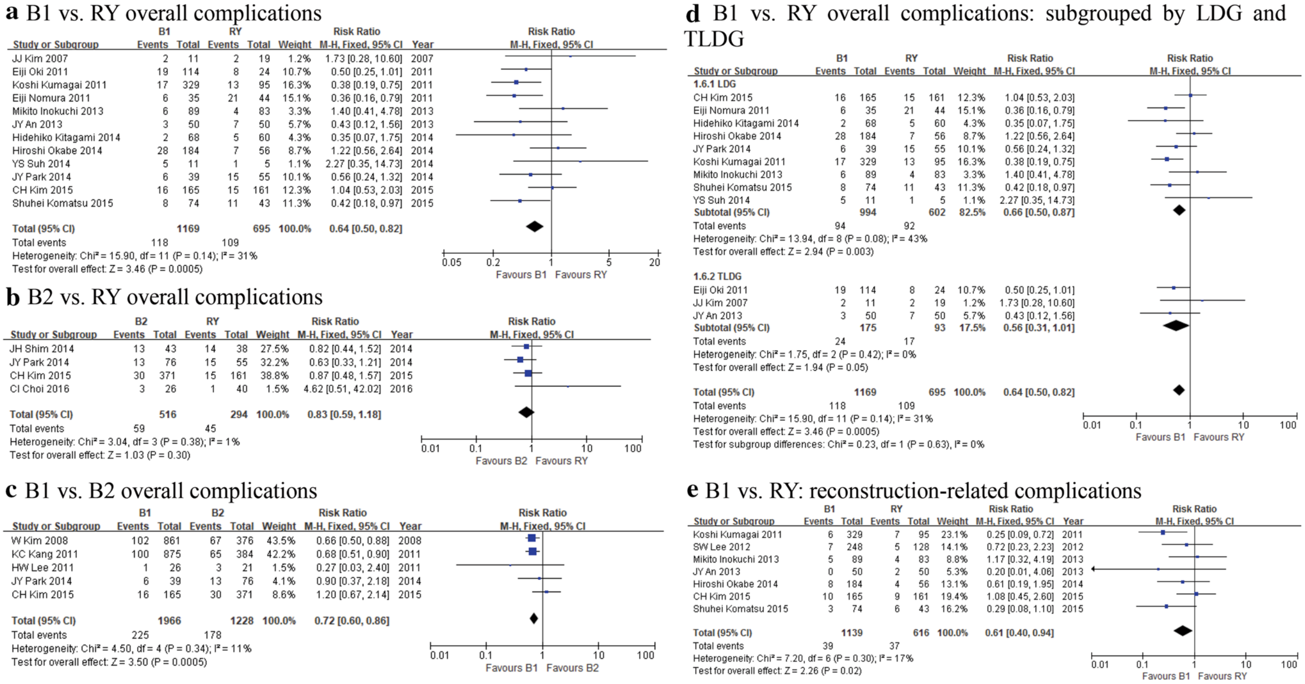


Fig. 2 Forest plot comparing postoperative complications of after laparoscopic distal gastrectomy: **a** Billroth I versus Roux-en Y. **b** Billroth II versus Roux-en Y. **c** Billroth I versus Billroth II. **d** Subgroup analysis of overall postoperative complications comparing B1 and RY (subgrouped by LDG and TLDG) and **e**. Reconstruction-related complications comparing B1 and RY. A Mantel–Haenszel fixed-effect model was used for all meta-analyses

assumptions (Table 2). This analysis included the following: (1) studies published after 2010 with relatively recent and updated data, (2) studies earning a high score in quality assessment (NOS $\geq$ 7), (3) studies with sample sizes large enough to minimize the small-study bias in the meta-analysis, (4) studies with patients matched by extent of lymph node dissection, and (5) studies with patients matched by age and BMI. Outcomes with insufficient data ($\leq$ 2) were excluded from the analysis. This sensitivity analysis was planned a priori.

Publication bias

Publication bias was evaluated using the funnel plot in RevMan, and no potential risk was observed (supplementary Fig. 5).

Discussion

This study involved an up-to-date meta-analysis using data from 5797 patients and is the first review to assume a purely laparoscopic stance. All comparative results are summarized in Table 3. Postoperative endoscopic findings, such as remnant gastritis, bile reflux, and reflux esophagitis, were significantly lower in group RY than in group B1, which was consistent with the results of previous studies [30, 31]. No significant differences were observed in residual food across all reconstructions. All results regarding endoscopic symptoms showed consistency across the sensitivity analyses (Table 2) and could therefore be considered statistically significant. In terms of recovery, the mean time to first flatus was significantly longer in group RY compared to that in group B1, and this can be explained by bowel movement alterations due to the manipulation of the jejunum during the RY procedure. The length of the hospital stay and time to first solid diet were comparable in all three reconstructions.

With respect to postoperative complications, our study suggests a significant difference in postoperative morbidity across the reconstruction types with robust and consistent results across sensitivity analyses. This contradicts the results of several previous studies [16, 17, 19, 30, 32] that found no such differences. This discrepancy may be attributable to the following: one, previous studies extracted data from patients of both LDG and ODG. Since ODG is known to carry higher postoperative risk than LDG [33], a group comprised of a greater number of ODG patients is likely to have a higher rate of postoperative complications. This could have affected the results, making it difficult to estimate postoperative complications with high precision. Second, the definition and measurement for postoperative

Table 2 Results of sensitivity analysis

Outcome/subgroup	B1 versus RY				B2 versus RY				B1 versus B2			
	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))
Total postoperative complications												
Overall	13	0.65	**0.0006**	**26**	5	0.88	0.460	**0**	5	0.72	**0.0005**	**11**
Publication year ≥ 2010	11	0.63	**0.0004**	**32**	4	0.83	0.300	**1**	4	0.76	**0.030**	**26**
Quality score (NOS) ≥ 7	10	0.63	**0.0009**	**38**	3	0.93	0.730	**10**	4	0.71	**0.0004**	**29**
Sample size > 30	9	0.62	**0.0008**	**36**	4	0.83	0.300	**1**	5	0.72	**0.0005**	**11**
Matched LN dissection	7	0.43	**0.00001**	**0**			–				–	
Matched age, BMI	5	0.52	**0.003**	**22**			–				–	
Reconstruction-related postoperative complications												
Overall	7	0.61	**0.02**	**17**	3	1.07	0.83	**0**			–	
Publication year ≥ 2010	7	0.61	**0.02**	**17**	3	1.07	0.83	**0**			–	
Quality score (NOS) ≥ 7	7	0.61	**0.02**	**17**	3	1.07	0.83	**0**			–	
Sample size > 30	7	0.61	**0.02**	**17**			–				–	
Matched LN dissection	3	0.26	**0.001**	**0**			–				–	
Matched age, BMI			**–**				–				–	
Operation time												
Overall	11	−44.69	**<0.0001**	85	6	−11.43	0.100	83	6	−21.60	**<0.001**	**0**
Publication year ≥ 2010	10	−43.80	**<0.0001**	86	5	−14.08	0.190	85	6	−21.60	**<0.001**	**0**
Quality score (NOS) ≥ 7	8	−43.43	**<0.0001**	89	4	−10.46	0.380	87	4	−22.15	**<0.001**	**0**
Sample size > 30	7	−41.27	**<0.0001**	90	5	−14.08	0.190	85	5	−21.38	**<0.001**	**0**
Matched LN dissection	6	−45.59	**<0.0001**	83			–				–	
Matched age, BMI	5	−53.27	**<0.0001**	73			–				–	
Blood loss												
Overall	9	−11.24	0.22	82	4	−14.0	0.800	91	4	26.02	0.680	92
Publication year ≥ 2010	8	−8.59	0.380	83	4	−14.0	0.800	91	4	26.02	0.680	92
Quality score (NOS) ≥ 7	7	−11.42	0.240	85	3	19.97	0.710	87	3	35.13	0.340	68
Sample size > 30	7	−7.50	0.460	86	4	−14.0	0.800	91	4	26.02	0.680	92
Matched LN dissection	5	−20.10	**0.0002**	**0**			–				–	
Matched age, BMI	4	−28.22	**<0.0001**	**0**			–				–	
Number of retrieved lymph node												
Overall	5	−3.80	**0.0003**	**33**	4	−4.08	**<0.001**	**0**	4	1.86	**0.004**	**31**
Matched LN dissection	2	−3.27	0.08	**37**	2	−2.03	0.310	**0**	2	1.86	**0.001**	**0**
Postoperative hospital stay												
Overall	7	0.05	0.920	62	4	−0.51	0.160	**24**	4	−0.49	0.240	54
Publication year ≥ 2010	6	−0.13	0.790	63	4	−0.51	0.160	**24**	4	−0.49	0.240	54

Table 2 continued

Outcome/subgroup	B1 versus RY				B2 versus RY				B1 versus B2			
	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))	Data set	Effect size*	*P*	Heterogeneity (I^2 (%))
Quality score (NOS) ≥ 7	5	−0.38	0.450	63	3	−0.66	0.100	**36**	3	−0.71	**0.040**	**33**
Sample size > 30	4	−0.36	0.510	69	4	−0.51	0.160	**24**	4	−0.49	0.240	54
Matched LN dissection	4	−0.07	0.950	**41**			–				–	
Matched age, BMI	4	0.3	0.740	53			–				–	
Time to first flatus												
Overall	4	−0.19	**0.003**	**31**	2	−0.23	0.510	87	3	0.09	0.750	95
Publication year ≥ 2010	4	−0.19	**0.003**	**31**			–		3	0.09	0.750	95
Quality score (NOS) ≥ 7	4	−0.19	**0.003**	**31**			–		3	0.09	0.750	95
Sample size > 30	3	−0.16	0.09	52			–		3	0.09	0.750	95
Matched LN dissection			–				–				–	
Matched age, BMI			**–**				–				–	
Time to first solid diet												
Overall	4	−0.05	0.620	57	2	0.0	1.000	84	2	−0.55	0.110	89
Publication year ≥ 2010	4	−0.05	0.620	57			–				–	
Quality score (NOS) ≥ 7	4	−0.05	0.620	57			–				–	
Sample size > 30	4	−0.05	0.620	57			–				–	
Matched LN dissection			–				–				–	
Matched age, BMI			**–**				–				–	
Residual food												
Overall	6	1.19	0.430	74	4	1.08	0.860	92	2	1.32	0.500	86
Publication year ≥ 2010	5	1.25	0.350	78	4	1.08	0.860	92			–	
Quality score (NOS) ≥ 7	4	1.25	0.460	83	3	1.34	0.600	92			–	
Sample size > 30	5	1.25	0.350	78	4	1.08	0.860	92			–	
Matched LN dissection			–				–				–	
Matched age, BMI			–				–				–	
Remnant gastritis												
Overall	7	2.51	**<0.0001**	61	5	2.67	**0.003**	94	2	0.91	0.670	92
Publication year ≥ 2010	6	2.45	**<0.0001**	62	4	3.26	**0.006**	94			–	
Quality score(NOS) ≥ 7	5	2.35	**<0.0001**	69	3	3.69	**0.040**	96			–	
Sample size > 30	7	2.49	**<0.0001**	55	4	3.26	**0.006**	94			–	
Matched LN dissection	3	1.68	**0.008**	**44**			–				–	
Matched age, BMI			**–**				–				–	
Bile reflux												
Overall	5	5.42	**<0.0001**	**47**	5	5.75	**0.01**	96	2	0.57	**<0.001**	**43**

Table 2 continued

Outcome/subgroup	B1 versus RY				B2 versus RY				B1 versus B2			
	Data set	Effect size*	P	Heterogeneity (I^2 (%))	Data set	Effect size*	P	Heterogeneity (I^2 (%))	Data set	Effect size*	P	Heterogeneity (I^2 (%))
Publication year ≥ 2010	4	4.85	**<0.0001**	57	4	8.12	**0.003**	90			–	
Quality score (NOS) ≥ 7	3	5.28	**<0.0001**	70	3	11.8	**0.030**	94			–	
Sample size > 30	4	4.85	**<0.0001**	57	4	8.12	**0.003**	90			–	
Matched LN dissection			**–**				–				–	
Matched age, BMI			**–**				–				–	
Reflux esophagitis												
Overall	4	2.05	**0.0002**	**50**	2	2.38	0.110	55			–	
Publication year ≥ 2010	4	2.05	**0.0002**	**50**			–				–	
Quality score (NOS) ≥ 7	4	2.05	**0.0002**	**50**			–				–	
Sample size > 30	5	1.95	**0.0002**	**37**			–					
Matched LN dissection	–						–				–	
Matched age, BMI			–				–				–	

*Effect size is presented either by weighted mean difference (WMD) for continuous variables and risk ratio (RR) for dichotomous variables, all with 95 percent confidence interval; in terms of B1 versus RY, negative WMD or RR below 1 favors B1 (left label) except for number of retrieved lymph nodes (in opposition). P value for effect size below 0.05 and heterogeneity I^2 value below 50 are designated in bold font. Blank with (−) indicates lack of data set (≤2); B1, Billroth I; B2, Billroth II; RY, Roux-en Y reconstruction

Table 3 Overall summary of three-arm comparisons of reconstruction methods for laparoscopic distal gastrectomy

Outcomes	Favors B1 versus RY		Favors B2 versus RY		Favors B1 versus B2		Overall comparison
	B1	RY	B2	RY	B1	B2	
Postoperative complications							
Overall complications	●		○		●		B1 > B2, RY
Reconstruction-related complications	●		NA		NA		B1 > RY
Operative parameters							
Operation time	●		○		●		B1 > B2, RY
Blood loss	○		○			○	No significant difference
Number of retrieved LN		○*		○*	○*		No significant difference
Postoperative recovery							
Postoperative hospital stay		○	○		○		No significant difference
Time to first flatus	●		○			○	No significant difference
Time to first solid diet	○		○		○		No significant difference
Postoperative endoscopic symptom							
Residual food		○	○			○	No significant difference
Remnant gastritis		●		●	○		RY > B1, B2
Bile reflux		●		●	●		RY > B1 > B2
Reflux esophagitis		●		○	NA		RY > B1

○ indicates no statistical significance ($P > 0.05$); ● indicates statistical significance ($P < 0.05$); ○*indicates no statistical significance ($P > 0.05$) with lymph node dissection matched patients or not enough data to be estimated; NA indicates not applicable (not enough data). Location of circle represents favor (estimated better option)

complications varies between institutions and surgeons, making it difficult to estimate complication rates. A large-scale quantitative approach would be helpful in dealing with such unequivocal variables, and this study compared postoperative complications of groups B1 and RY using 13 studies for meta-analysis, which has not previously been evaluated on this scale. RCTs [34, 35] comparing Billroth 1 and Roux-en Y in open surgery also reported no significant differences in postoperative complications, yet both studies commonly favored Billroth 1 because it resulted in lower complication rates. This trend was more apparent in the present study, possibly due to quantitative synthesis.

It should be noted that the choice of reconstruction method is often subject to the surgeon's personal preference and rule of thumb based on their clinical experience. RY is an increasingly popular choice, as there have been few reported differences across methods for parameters such as postoperative complications and postoperative recovery, but clear superiority with regard to bile reflux and remnant gastritis has been shown [36–38]. However, as our analysis found a significantly lower rate of postoperative complications in B1 compared to that in other reconstruction methods, this novel factor should be taken into account when choosing the method of reconstruction. The value placed on postoperative complications or endoscopic findings when selecting a method of reconstruction will depend on the individual surgeon's judgment and clinical context.

There are pros and cons of each reconstruction method. B1 had the lowest rate of postoperative complications in the present analysis and can be considered as a good choice with respect to both the surgeon and patient due to the low rate of complications. However, its drawback is that it is not applicable to severe gastric cancer cases requiring large dissection of the stomach as the method induces undue tension [39]. RY can be considered the best option for reducing the incidence of bile reflux, remnant gastritis, and reflux esophagitis. However, a previous study noted that reduction of bile reflux with RY does not necessarily correlate with postoperative quality of life of patients and implied that this method showed no significant difference in terms of the gastrointestinal quality of life index when compared with that of other reconstructions [40]. B2 was not superior to any other reconstruction methods with respect to the 12 variables studied in this study. It is therefore recommended as a second option where B1 is not applicable, as it is always possible to perform B2[_ENREF_4139]. However, this might be a rash conclusion for B2 since the introduction of Braun's anastomosis can resolve the complications associated with B2, as Braun is known to reduce bile reflux, ileus, and postoperative GI symptoms [41, 42].

This study had several limitations. First, we included studies with pure reconstruction methods. Therefore, any modifications or additional procedures including Billroth 2 with Braun's anastomosis or uncut Roux-en Y were not considered. Second, since only 2 RCTs regarding reconstruction in LDG have been published, mostly non-randomized studies were included. Retrospective observational studies have an inherent selection bias and were not excluded from this study. Finally, all LDG procedures were conducted in East Asia and results should be extrapolated to Western patient populations with caution.

Conclusion

B1 is the best option in terms of postoperative complications and operation time, while RY is the most effective anastomosis for reducing the incidence of bile reflux, gastritis, and reflux esophagitis. B2 did not show any particular strength over B1 and RY in LDG. There were no significant differences in postoperative hospital stay, time to first flatus, time to first diet, blood loss, and number of retrieved lymph nodes among the reconstructions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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