Closure of Petersen's defect in gastrectomy for gastric cancer: an interrupted time-series analysis from a high-volume institution in China

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Research

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Abstract

Background

Internal hernia (IH) and small bowel obstruction (SBO) are serious complications after gastrectomy for gastric cancer. Whether closure of Petersen's defect (PD) might reduce the rates is unknown.

Methods

Patients underwent gastrectomy with PD were enrolled. From January 2014 to January 2017, we performed gastrectomy without closure of PD (non-closure group). From February 2017 to June 2018, we closed PD (closure group). The rates of IH, suspected internal hernia (SIH), and SBO were compared between the two groups.

Results

Among a total of 1213 patients, 151 patients (12.4%) developed SBO after gastrectomy, 10 patients (0.8%) developed IH and 20 patients (1.6%) developed SIH. The rate of SBO and SIH were 15.0% (124/828) and 2.3% (19/828) respectively in the non-closure group, compared with 7.0% (27/385) and 0.3% (1/385) in the closure group ($p = 0.017$ and $p = 0.015$ respectively). The rate of IH in the closure group (1/385, 0.3%) was lower than the non-closure group (9/828, 1.1%). Non-closure of PD was a risk factor for IH and SIH [odds ratio (OR) 6.58, 95%CI 1.56–27.85, $p = 0.011$].

Conclusions

Closure of PD is recommended after gastrectomy, as we noticed a significantly lower rate of SBO and SIH, and a tendency for lower rate of IH.

Introduction

Internal hernia (IH) can lead to small bowel obstruction (SBO) and life-threatening conditions, such as bowel ischemia or perforation[1, 2]. IH is a recognized and well-described complication after laparoscopic Roux-Y gastric bypass[3–6]. However, there have been few studies about IH after gastrectomy for gastric cancer[1, 7].

Distal gastrectomy with Billroth-2 (B-2) anastomosis can create a Petersen's defect (PD) between the transverse colon and the jejunal loop. Total gastrectomy with ante-colic approach Roux-en-Y (R-Y) anastomosis creates two potential defects. One is a PD between the transverse colon and the Roux limb, and the other is a jejunojejunostomy mesenteric defect (JMD) around the jejunojejunostomy. IH may occur through the two potential defects after gastrectomy for gastric cancer. It rarely occurs during other reconstruction procedures, such as esophagogastrostomy following proximal gastrectomy and Billroth-1 reconstruction[8].

The rare incidence and nonspecific manifestations make it difficult to diagnose IH preoperatively[7, 9, 10]. Some non-operatively managed patients were highly suspicious for IH according to the manifestations and computed tomography (CT) results[11, 12]; however, some of these patients might be misdiagnosed with adhesive SBO and managed non-operatively [13, 14]. Therefore, some patients suspicious for IH (SIH) are not confirmed by surgical

exploration. Patients with SIH may have non-specific and recurrent abdominal pain; they are also at risk for incarcerated internal hernia and bowel necrosis, so we should also pay great attention to these patients.

Closure of PDs and JMDs is now recommended for laparoscopic Roux-Y gastric bypass [2, 5]. However, IH can occur despite the closure of all mesenteric defects[8]. There is also concern that closure by itself may increase the risk of bleeding, mesenteric hematoma and anastomotic leakage due to vascular injury[3]. Similar mesenteric defects are created after gastrectomy for gastric cancer. However, to date, there has been no consensus on management of mesenteric defects after gastrectomy for gastric cancer.

Therefore, the purpose of our study was to investigate whether closure of PD during gastrectomy can decrease the rates of IH, SIH, and SBO. To our knowledge, this was the first study including SIH and SBO as endpoints concerning the effect of closure of mesenteric defects following gastrectomy for gastric cancer.

Materials And Methods

Ethical Statement

The study was based on information collected from the Surgical Gastric Cancer Patient Registry of West China Hospital (WCH-SGCPR-2019-10). The establishment of the database was approved by the Research Ethics Committee of West China Hospital. Besides, since this was an interrupted time-series study, patients did not provide written inform consent, but before statistical analysis, personal information was anonymous.

Patients

A total of 1213 consecutive patients with gastric cancer treated from January 2014 to June 2018 in West China Hospital were eligible for the study. The diagnosis of gastric cancer for all the patients was confirmed by upper gastrointestinal endoscopy and biopsy. The inclusion criteria were as follows: 1) patients with histologically proven gastric adenocarcinomas; 2) patients underwent curative distal gastrectomy with B-2 reconstruction and total gastrectomy with ante-colic R-Y reconstruction. The exclusion criteria were as follows: 1) other types of malignancies in stomach; 2) palliative surgery; 3) with an earlier history of gastrectomy 4) lost to follow-up. The flowchart of patients enrolled in the study is summarized in Supplementary Fig. 1.

Clinicopathological materials

Clinicopathological data including sex, age, body mass index (BMI), previous abdominal surgery history, tumor diameter (cm), tumor location, macroscopic type, tumor differentiation, pathologic TNM stage, reconstruction type (distal gastrectomy with B-2 anastomosis or total gastrectomy with ante-colic R-Y anastomosis), surgical approach (open or laparoscopy-assisted), and postoperative chemotherapy were evaluated. All the definitions, including macroscopic type, tumor differentiation, and TNM stage, were determined according to the 7th staging manual of American Joint Committee on Cancer[15].

Follow-up

Postoperative follow-up was performed either at the postoperative outpatient clinic or by telephone. It was recommended that all patients be followed every three months in the first two years, every six months in the third year and at least once a year in the following years. During follow-up, CT examination was required for each patient. Follow-up information was also collected from the database and updated to 1 July 2019. The duration of follow-up

was recorded as the time from gastrectomy until death or last registered patient at the postoperative outpatient clinic or by telephone, whichever came first.

Surgical technique

The surgical treatment principles were based on the Japanese Gastric Cancer Treatment Guidelines[16, 17]. For reconstruction, B-2 reconstruction was adopted for distal gastrectomy and ante-colic R-Y reconstruction was adopted for total gastrectomy. JMDs were all closed for patients who underwent R-Y reconstruction in both groups. From January 2014 to January 2017, we performed R-Y and B-2 reconstruction without closure of PD (non-closure group). From February 2017 to June 2018, we closed PDs in both R-Y and B-2 reconstruction (closure group). We closed all the defects using an interrupted 3-0 non-absorbable suture (Fig. 1A,1B).

Endpoints

The primary endpoints were 1) IH, 2) SIH, and 3) SBO. The secondary endpoints were postoperative complications within 30 days of gastrectomy.

IH was defined as a mesenteric defect hernia and was confirmed by surgical exploration.

SIH was defined as nonoperatively treated SBO patients who showed a whirling appearance of the mesentery and mesenteric vessels on CT scans (“whirl sign”, Supplementary Fig. 2). The “whirl sign” on CT examination was confirmed by two radiologists and was described in previous studies[11, 12, 18-20].

SBO was defined as an episode of intestinal obstruction found during surgery that was caused by IH or adhesions, or no other causes of mechanical intestinal obstruction (obstructive tumor, incisional hernia, inguinal hernia, intussusception, etc.) could be identified on CT scans following nonoperative management. Therefore, SBO can be caused by IH, SIH and adhesions in the present study.

Early postoperative complications were classified according to the Clavien-Dindo surgical complication grading system[21]. When a patient had two or more postoperative complications, the higher grade was adopted[22].

Statistical analysis

Categorical variables are presented as numbers with percentages, and continuous data are presented as mean with standard deviation (s.d.). Categorical data were compared with Pearson χ^2 test or Fisher’s exact test, and continuous data were compared with independent sample t test or Wilcoxon rank sum as appropriate. The cumulative rate of SBO after gastrectomy was calculated with the Kaplan-Meier method. The rates of IH, SIH, SBO and adhesions between the two groups were compared by log-rank test. A logistic regression analysis was performed to test the univariate and multivariate associations between variables to identify risk factors for IH and SIH. Two-sided $p<0.050$ was considered significant. Data were analyzed using statistical software SPSS 20.0 (SPSS®, Chicago, IL, USA).

Results

Baseline Data

A total of 1213 patients were enrolled in our study. The non-closure group included 828 patients, and the closure group included 385 patients. The demographic data of the entire patient population is presented in Table 1. There were no statistical differences between the two groups with respect to sex, age, BMI, previous abdominal surgery

history, tumor diameter, tumor location, macroscopic type, tumor differentiation, TNM stage, reconstruction type, surgical approach or postoperative chemotherapy. The non-closure group had a significantly longer median follow-up interval at 39 (i.q.r. 30-51) months vs. the closure group with 20 (i.q.r. 16-24) months (p=0.001).

Early Postoperative Complications

Table 2 shows the early postoperative complications. A total of 132 patients (15.9%) in the non-closure group and 55 patients (14.1%) in the closure group had early postoperative complications. There was no significant difference between the two groups respect to postoperative complications, non-surgical complications or surgical complications (p=0.457, 0.571 and 0.106 respectively).

Rate of IH, SIH and SBO

Among a total of 1213 patients, 151 patients (12.4%) developed SBO after gastrectomy, 10 patients (0.8%) developed IH and 20 patients (1.6%) developed SIH. In the non-closure group, which included 828 patients, 124 patients (15.0%) developed SBO, 9 patients (1.1%) developed IH and 19 patients (2.3%) developed SIH. The mean time intervals of SBO, IH and SIH were 14.0, 10.7 and 9·5 months respectively. After routine PD closure in 385 patients in the closure group, 27 patients (7.0%) developed SBO, 1 patient (0.3%) developed IH after 22 months, and 1 patient (0.3%) developed SIH after 19 months, the mean time interval to SBO was 10.6 months in the closure group.

Table 3 shows the causes and treatment of SBO. The rates of SBO and SIH were significantly decreased after PD closure (p=0.017 and p=0.015 respectively, log-rank test). The rates of IH and adhesions were not significantly different between the two groups (p=0.274 and p=0.212 respectively, log-rank test). Fig. 2 shows the cumulative incidence of SBO.

Characteristics of patients with IH

Table 4 shows the characteristics of patients with IH. 9 patients in the non-closure group and 1 patient in the closure group developed IH. All IHs were located in the PD (Fig. 1C), no IH was found in the JMD. We closed all the PDs after reduction of the herniated bowels, and no IH recurrence was observed until the end of the study. All 10 patients showed “whirl signs” on CT scans. 8 patients underwent emergency surgery, and 2 patients underwent elective surgery. The two patients in the elective surgery group experienced recurrent SBO and showed a “whirl sign” on the CT scan before surgery. Both of them were managed non-operatively and discharged from the hospital for every episode. Therefore, we advised surgery, and finally, they were confirmed to be IHs upon surgical exploration.

Risk Factors for IH and SIH

Table 5 shows the results of univariate and multivariate analyses to identify the independent risk factors for IH and SIH. In the multivariate analysis, non-closure of PD was the only risk factor for IH and SIH [odds ratio (OR) 6.58, 95% CI 1.56–27.85, p=0.011]. Sex, age, BMI, previous abdominal surgery history, reconstruction type, and surgical approach were not associated with IH and SIH occurrence.

Discussion

Gastric cancer is a major health problem, as it is the second leading cause of cancer death and the fourth most common cancer worldwide[23]. Surgery is a major curative strategy for gastric cancer[23]. A PD is created after

gastrectomy with B-2 or R-Y reconstruction. However, there has been no consensus yet on how to deal with it.

The study showed that the rates of SBO and SIH were significantly decreased after closure of PD. The rate of IH was not significantly decreased after closure of PD, probably reflecting the very low number of IHs. In the descriptive analysis, the rate of IH was much lower in the closure group (1/385, 0.3%) than the non-closure group (9/828, 1.1%). The analysis of the risk factors for IH and SIH additionally validated these findings. Our results were consistent with those of previous studies[9, 20, 24].

Theoretically, if mesenteric defects are completely closed, no IH can occur through mesenteric defects. However, similar to a previous study[8], after we closed the PDs, one case of IH occurred. We found that the IH patient underwent gastrectomy in the first week when we started to close the PD, and there have been no IH patients in closure group since then. Both surgeons participating in the study were very well experienced with gastrectomy and far beyond their learning curve for this operation, but this was not necessarily the case for PD closure. Therefore, the reason for this may be incomplete closure of the PD during primary surgery[25].Another explanation is that defects may open out after the loss of mesenteric fat, leading to the formation of IH[26]. Therefore, although closure of all mesenteric defects cannot completely prevent IH, current studies have shown that it may decrease the rate.

The overall rate of IH was 0.8% in our study, and it ranged from 0.19–5% in previous studies[1, 7, 8, 20]. The rate of IH varied greatly among different literatures. These differences may be caused by different inclusion groups, diagnostic criteria, follow-up periods, laparoscopy proportions, and mesenteric defect closures[1]. The rate of IH in the study was lower than that in most studies. The possible reason is that we routinely closed the JMD in all patients, and no IH was found in the JMD in this study; however, most authors left it open before they changed their technique to close all mesenteric defects. In a study conducted by Miyagaki et al[8], all gastrectomies, regardless of reconstruction method or gastrectomy type, were invested, including patients with little possibility of IH such as those who underwent esophagogastrostomy and Billroth-1 reconstruction. The 3-year incidence rate of IH in their study was 0.19%, which was the lowest in literature.

Laparoscopic surgery was considered a risk factor for IH in most previous studies[1, 7, 8, 20, 27]. The possible reason was fewer adhesions[1, 8]. However, similar to a previous study[9], it was not a risk factor in the present study. The possible explanation was that we adopted laparoscopy-assisted surgery in most cases. However, most authors mainly adopted total laparoscopic surgery in previous studies. Laparoscopy-assisted surgery may result in more adhesions than total laparoscopic surgery.

In previous studies on the effect of closure of mesenteric defects in gastrectomy for gastric cancer, IH was defined as the only endpoint, but if SBO and SIH were not included, the effect of mesenteric defects closure may be overlooked. Due to its rare incidence and nonspecific symptoms, it is difficult to diagnose IH preoperatively. CT scans have become the main work-up to diagnose IH before surgery[11] and some authors held the idea that “whirl sign” on CT scans was the most predictive sign of IH (sensitivity 78-100%, specificity 80-90%)[3, 12, 18, 19] . Kang et al[20] even used the “whirl sign” as a diagnostic criterion for IH in their study. In the present study, 2 patients were considered to have SIH according to our criteria before surgery, and they were finally confirmed to have IH by surgical exploration. Another 20 non-operatively treated SBO patients also showed a “whirl sign” on CT examinations. The reason why they were managed nonoperatively was that they had no signs of bowel necrosis, and they were reluctant to receive surgery, or surgery was not physically allowed. There is a high possibility that in some of these patients with SBO, it was caused by IH, although this was not confirmed by surgical exploration. Therefore, we defined these patients as having SIH in this study. Additionally, the work-up for IH was mainly

performed with CT scan, and it is possible that these false negative CT patients were not diagnosed with IH; however, SBO is not easily missed with CT scans[28]. It is also possible that some patients who underwent operation for SBO actually suffered from IH, and they were not identified during the procedure[29]. Therefore, considering the above factors, we included both SIH and SBO as endpoints in this study.

SBO is a well-described complication after abdominal surgery and adhesion is considered as the cause of almost 75% SBO, other etiologies including IH, inguinal hernia, incisional hernia, and obstructive tumor etc[30]. The rate of SBO after gastrectomy for gastric cancer ranged from 11.7 to 38.5% in previous studies[31, 32].The rate of SBO reported in this study was 12.4%, which was similar to previous studies. The rate of SBO may be influenced by different diagnostic criteria, follow-up periods, and proportions of laparoscopy. In our study, SBO was defined as an episode of intestinal obstruction caused by IH, SIH and adhesions. And we found that there was no significant difference in the rate of adhesive SBO between the two groups.

There is concern that closure of the mesenteric defects may be associated with a higher rate of postoperative complications such as mesenteric hematomas and bleeding. However, in our study, there was no difference in the rate of complications within 30 days between non-closure and closure groups. It showed that closure of PD did not increase early postoperative complications.

The strengths of the study were that it followed a standardized surgical protocol and two distinct groups for comparison. Both surgeons participating in the study were well and equally experienced in gastrectomy for gastric cancer. The limitations of the study include that it was a retrospective study conducted in a single center. The number of IHs in our study was too small for analysis, and we included SIH to investigated the risk factors. Another potential limitation of the study was that the follow-up duration was different between the two groups. However, the rate of IH seems to be highest within 1-2 years after operation[33-35],corresponding to the time of the largest weight loss[3]. And in the non-closure group, 7 out of 9 IH cases (78%) presented within the first 16 months after gastrectomy. Considering that 85% of patients in the closure group were followed for more than 16 months, we would not expect a large number of additional IHs in this group. A multicenter prospective study is required to evaluate patients with closure of all mesenteric defects during gastrectomy, including postoperative complications and quality of life.

In conclusion, closure of PD is recommended after gastrectomy for gastric cancer, as we noticed a significantly lower rate of SIH and SBO and a tendency for lower rate of IH, while the procedure did not significantly increase postoperative complications.

Abbreviations

IH: internal hernia

SBO: small bowel obstruction

LRYGB: laparoscopic Roux-Y gastric bypass

B-2: Billroth-2

R-Y: Roux-en-Y

PD: Petersen’s defect

JMD: jejunojejunostomy mesenteric defect

PDH: Petersen's defect hernia

CT: computed tomography

BMI: body mass index

Declarations

Ethics approval and consent to participate:

This study was based on the information gathered from the database of the Surgical Gastric Cancer Patient Registry of West China Hospital (WCH-SGCPR) under registration number: WCH-SGCPR-2019-10. The establishment of this database was approved by the Research Ethics Committee of West China Hospital. Informed consent individual patients were waived because of the retrospective nature of the analysis.

Consent for publication:

Not applicable.

Availability of data and materials:

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

Competing interests:

The authors declare that they have no competing interests.

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Authors' contribution:

1. Jian-kun Hu, Tao Pan, Hui Wang and Xin-zu Chen made substantial contributions to conception and design for this study.
2. Tao Pan, Hui Wang, Kai-Liu Xiao-long Chen and Wei-han Zhang acquired and analyzed data and Tao Pan drafted the article.
3. Since this was a large sample research in our institution, 1213 cases were included in our study, Kun Yang, Bo Zhang, Jian-Kun Hu and Zong-guang Zhou provided a large number of cases and gave many important suggestions for this study. They also participated in writing the paper.

4. Tao Pan, Hui Wang, Kai Liu, Xin-zu Chen, Wei-han Zhang, Xiao-long Chen, and Kun Yang also participated in revising it critically for important intellectual content;
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6. Tao Pan and Hui Wang contributed equally to this work.
7. Jian-kun Hu gave final approval of the version to be published.

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Tables

Table 1 Demographic data at the time of gastrectomy

	Non-closure group (First period, N=828)	Closure group (Second period, N=385)	p†
			0.077
	592 (71)	256 (66)	
.e	236 (29)	129 (34)	
ge at operation (years) *	58.0 (11.4)	59.0 (11.1)	0.077‡
ass index (kg/m^2) *	22.6 (2.9)	22.9 (3.2)	0.089‡
is abdominal surgery history			0.092
	137 (17)	79 (21)	
	691 (83)	306 (79)	
diameter (cm) *	4.6 (2.5)	4.4 (2.5)	0.208‡
location			0.813
	180 (22)	87 (23)	
.e	118 (14)	59 (15)	
r	516 (62)	231 (60)	
e	14 (2)	8 (2)	
scopic type			
nann 0–II	455 (55)	197 (51)	0.219
nann III–IV	373 (45)	188 (49)	
differentiation			0.307
moderately	226 (27)	116 (30)	
y/undifferentiated	602 (73)	269 (70)	
age			0.568
	217 (26)	102 (26)	
	213 (26)	109 (28)	
	398 (48)	174 (46)	
truction type			
Distal gastrectomy)	551 (67)	257 (67)	0.943
Total gastrectomy)	277 (33)	128 (33)	
al approach			0.516
a	721 (87)	330 (86)	
roscopy-assisted	107 (13)	55 (14)	
erative chemotherapy			0.649
	507 (61)	241 (63)	
	321 (39)	144 (37)	

Values in parentheses are percentages unless indicated otherwise; *values are mean(s.d.).

R-Y Roux-en-Y reconstruction, B-2 Billroth-2 reconstruction.

†χ^2 test, except‡ Paired t test

Table 2 Complications within 30 days of gastrectomy

	Non-closure group (First period)	Closure group (Second period)	p
stoperative complications (total)	132 (15.9)	55 (14.3)	0.457
n-surgical complications	96 (11.6)	49 (12.7)	0.571
Pulmonary disease	88 (10.6)	43 (11.2)	
Urinary disease	5 (0.6)	3 (0.8)	
Cardiac disease	0	1 (0.3)	
Delirium	2 (0.2)	1 (0.3)	
Venous thromboembolism	0	1 (0.3)	
Liver disfunction	1 (0.1)	0	
rgical Complications †	43 (5.2)	12 (3.1)	0.106
Anastomotic/stump leakage	5 (0.6)∝	1 (0.3) #	
Surgical site infection	10 (1.4)	3 (0.8)	
Pancreatic fistula	3 (0.4)	1 (0.3)	
Lymphatic leakage	1 (0.1)	0	
Post-operative bleeding	4 (0.5) ¶	3 (0.8)	
Delayed gastric emptying	19 (2.3)	4 (1.0)	
Other major complications	1 (0.1)§	0	
avien-Dindo classification			0.245
-II	125 (15.1)	52 (13.5)	
III-V	6 (0.8)	3 (0.8)	

Values in parentheses are percentages unless indicated otherwise;

7 patients in non-closure group and 6 patients in closure group had both surgical and general complications.

† Surgical complications other than small bowel obstruction.

∝Site of leakage was gastrojejunostomy for 1 patient, and duodenal stump for 4 patients.

Site of leakage was duodenal stump for 1 patient.

¶ Site of bleeding was abdominal cavity for 3 patients, and gastrointestinal tract for 1 patient.

Site of bleeding was abdominal cavity for 2 patient, and gastrointestinal tract for 1 patient.

- Small bowel perforation due to gallstone.

1 patient died of pulmonary infection and respiratory failure.

χ^2 test.

Table 3 The causes and treatment of SBO

	Non-closure group (First period, N=828)	Closure group (Second period, N=385)	p†
SBO	124 (15.0)	27 (7.0)	0.017
Causes			
IH	9 (1.1)	1 (0.3)	0.274
SIH	19 (2.3)	1 (0.3)	0.015
Adhesions	96 (11.6)	25 (6.5)	0.212
Treatment			-
Conservative	99 (12.0)	22 (5.7)	-
Surgical	25 (3.0)	5 (1.3)	-
Bowel resection			-
Yes	4 (0.5)	1 (0.3)	-
No	21 (2.5)	4 (1.0)	-

Values in parentheses are percentages.

SBO small bowel obstruction, IH internal hernia, SIH suspicious for internal hernia.

† Log-rank test

Table 4 Characteristics of patients with IH

Case	Age	Sex	Interval period (months)	Whirl sign	Closure of PD	Procedure of gastrectomy	Bowel resection	Type of surgery	Mortality
1	58	Male	22	Yes	Yes	Laparoscopy-assisted distal gastrectomy	No	Emergency	No
2	65	Male	24	Yes	No	Open distal gastrectomy	No	Emergency	No
3	64	Male	7	Yes	No	Open distal gastrectomy	No	Emergency	Yes*
4	47	Female	1	Yes	No	Laparoscopy-assisted distal gastrectomy	No	Elective	No
5	44	Female	7	Yes	No	Open total gastrectomy	Yes	Emergency	No
6	79	Male	27	Yes	No	Open total gastrectomy	No	Emergency	No
7	67	Male	16	Yes	No	Open distal gastrectomy	No	Emergency	No
8	78	Male	6	Yes	No	Open distal gastrectomy	No	Emergency	No
9	66	Male	1	Yes	No	Open distal gastrectomy	Yes	Emergency	No
10	60	Female	7	Yes	No	Open distal gastrectomy	No	Elective	No

* Died of sepsis caused by bowel necrosis

IH internal hernia, BMI body mass index, PD Petersen's defect

Table 5 Results of univariate and multivariate analyses to identify the independent risk factors for IH and SIH

	IH or SIH		Univariate analysis		Multivariate analysis	
	(No, n=1183)	(Yes, n=30)	OR (95% CI)	p	OR (95% CI)	p
Sex						
Female	358	7	1.00 (reference)			
Male	825	23	1.43 (0.61-3.35)	0.416		
Age (years)						
≥ 65	367	12	1.00 (reference)			
<65	816	18	0.68 (0.32-1.42)	0.298		
BMI (kg/m^2)						
≥ 25	928	24	1.00 (reference)			
<25	255	6	1.10 (0.45-2.72)	0.838		
Previous abdominal surgery history						
Yes	214	2	1.00 (reference)			
No	969	28	3.09 (0.73-13.08)	0.125		
Type of reconstruction						
R-Y (Total gastrectomy)	400	5	1.00 (reference)		1·00 (reference)	
B-2 (Distal gastrectomy)	783	25	2.55 (0.97-6.72)	0.058	2.49 (0.99-6.96)	0.062
Surgical approach						
Laparoscopy-assisted/Robot	160	2	1.00 (reference)			
Open	1023	28	2.19 (0.52-9.28)	0.287		
Closure of PD						
Yes (Second period)	383	2	1.00 (reference)		1.00 (reference)	
No (First period)	800	28	6.70 (1.59-28.28)	0.010*	6.58 (1.56-27.85)	0.011*

Values in parentheses are 95% confidence intervals.

OR odds ratio, CI confidence interval, IH internal hernia, SIH suspicious for internal hernia, BMI body mass index, R-Y Roux-en-Y reconstruction, B-2 Billroth-2 reconstruction, PD Petersen's defect

* Statistically significant difference ($p < 0.05$)

Supplementary Figure Legends

Supplementary Fig. 1 The flowchart of patients enrolled in the study;

Supplementary Fig. 2 Whirling appearance of the mesentery and mesenteric vessels on CT scans (“whirl sign”, red arrows).

Figures

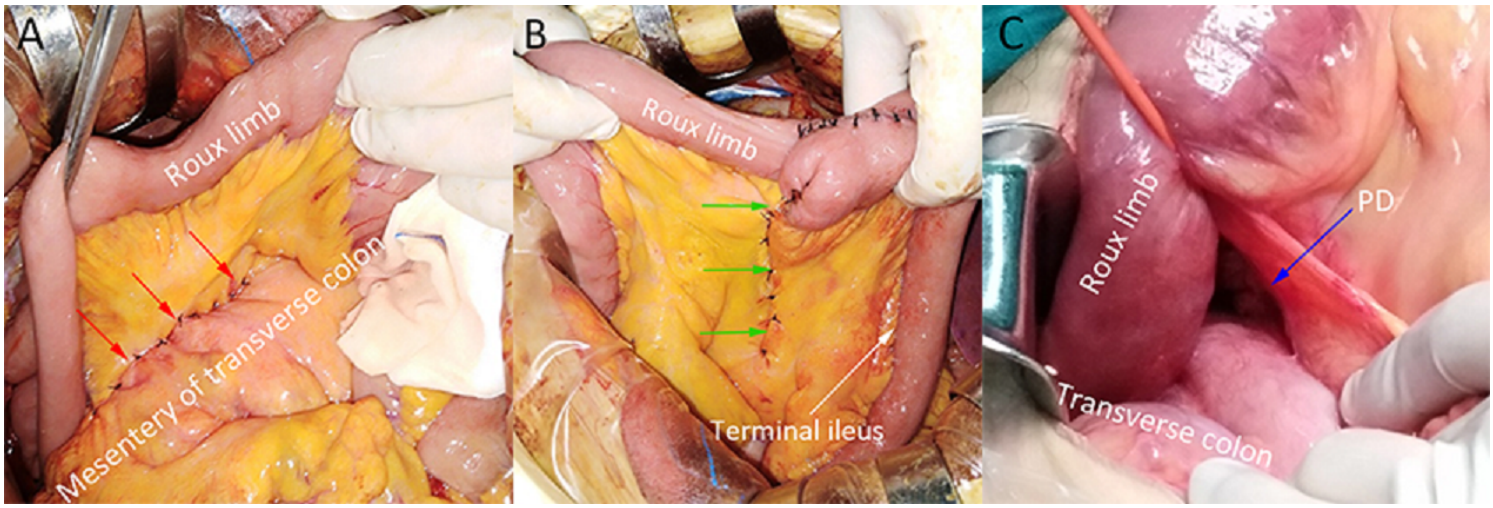

Figure 1

Operative pictures: A Closure of Petersen's defect (PD, red arrows). B Closure of jejunojejunostomy mesenteric defect (JMD, green arrows). C Petersen's defect (PD, blue arrow) was found open after reduction of the internal hernia (IH);

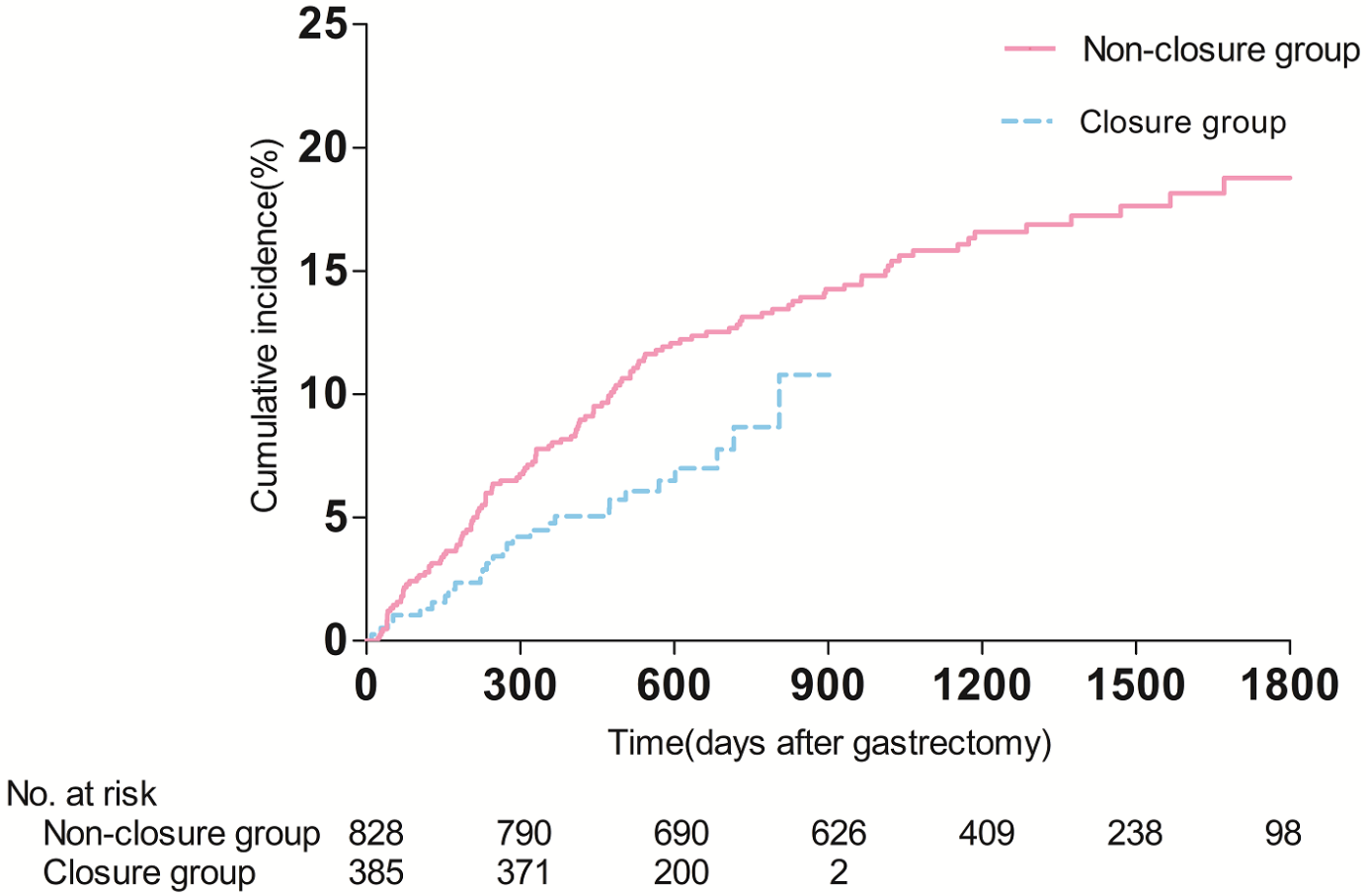

Figure 2

Cumulative incidence of small bowel obstruction (SBO);

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFig.2.tif
- SupplementaryFig.1.tif