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Early unplanned reoperations after gastrectomy for gastric cancer are different between laparoscopic surgery and open surgery

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Abstract

Background To compare the differences in occurrence rates, time intervals, main causes, and management strategies of early unplanned reoperations (EUROs) after gastrectomy for gastric cancer (GC) between laparoscopic and open surgery.

Methods From Jan. 2005 to Dec. 2014, 2608 and 1516 patients underwent laparoscopic-assisted gastrectomy (LAG) and open gastrectomy (OG), respectively. Perioperative outcomes and risk factors for EURO were analyzed.

Results The overall EURO rate was 1.3%, and the rate in LAG and OG groups was 1.1% and 1.6%, respectively. The EURO rate after 24 h postoperatively was significantly lower in LAG group than in OG group ($p=0.019$). No significant correlation was identified between laparoscopic surgery and EURO rate ($p=0.157$); age > 70 ($p=0.028$), body mass index (BMI) > 25 kg/m^2 ($p=0.009$), and estimated blood loss > 100 ml ($p=0.029$) were independent risk factors for EURO. The main cause of EURO was intra-abdominal bleeding, anastomotic bleeding, and anastomotic leakage in LAG group; and intra-abdominal bleeding, anastomotic leakage, and intestinal obstruction in OG group. The proportion of patients with intra-abdominal bleeding requiring EURO was markedly higher in LAG group than in OG group ($p=0.043$). Transverse mesocolonic vessels and spleen were the most common bleeding sites necessitating EURO in LAG and OG groups, respectively. Six of 28 (21.4%) patients with EUROs in LAG group underwent laparoscopic procedure ($p=0.025$). Mortality in patients requiring EURO was 3.6% and 20.8% in LAG and OG groups, respectively ($p=0.084$).

Conclusions Compared to open surgery, laparoscopic surgery does not increase the incidence of EURO in patients undergoing gastrectomy for GC; however, laparoscopic surgery is associated with a lower EURO rate after 24 h postoperatively and a higher proportion of patients with intra-abdominal bleeding requiring EURO than open surgery. Effective and accurate intraoperative hemostasis for intra-abdominal vessels and anastomotic sites will help further reduce the incidence of EURO following LAG within 24 h postoperatively.

Keywords Gastric cancer · Gastrectomy · Minimally invasive surgery · Reoperation · Mortality

Surgical resection remains the most primary curative option for patients with gastric cancer (GC) [1]. Laparoscopic surgery for the treatment of GC is becoming an increasingly popular alternative for early-stage disease [2, 3] to advanced lesions [4, 5], and this approach not only has short-term advantages, such as fast recovery of bowel function, obvious reduction in postoperative pain, and considerable shortening of the length of hospital stay [6, 7], but also comparable long-term oncologic outcomes to open surgery [8, 9]. Improving the safety of laparoscopic procedures to the greatest extent remains a primary issue for surgeons. Perioperative early unplanned reoperation (EURO, within 30 days of hospitalization) is usually aimed at resolving severe or life-threatening postoperative complications. On the one hand,

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EURO seriously affects postoperative recovery, obviously adds an economic burden and can even lead to early death in some patients [10–12]. On the other hand, EURO greatly increases the medical workload of healthcare workers. In addition to postoperative morbidity and mortality, EURO has attracted the attention of more surgeons recently and has become widely accepted as an important indicator of the quality of medical care [13–15].

Understanding the main causes and time intervals of EURO among GC patients undergoing gastrectomy, and in particular, evaluating the risk factors for EURO before surgery, might help surgeons to reduce the incidence of EURO and improve the safety of surgery. Most previously published studies have primarily considered the presence of morbidity and mortality after gastrectomy for GC [6, 7, 16] without focusing on the severity and urgency of EURO, making the conclusions less objective. Data directly comparing differences in EUROs following initial laparoscopic-assisted gastrectomy (LAG) and open gastrectomy (OG) have been quite limited so far [6, 7, 10, 15]; in particular, detailed data regarding perioperative consequences, treatment strategies, and high-risk factors for EURO following LAG and OG are still not available. Therefore, we investigated the differences in the incidence, causes, intervals, and clinical outcomes of EUROs performed in patients who underwent LAG or OG. The results of the current study may contribute to providing valuable clues for the prevention and treatment of EURO by precisely identifying perioperative consequences and high-risk factors according to different surgical approaches.

Materials and methods

Patients and methods

Between January 2005 and December 2014, 4124 patients with primary GC underwent radical gastrectomy at the Department of Gastric Surgery, Fujian Medical University Union Hospital, Fuzhou, China. A retrospective analysis was performed using a prospectively maintained comprehensive GC database [17]. The indications for both OG and LAG in this study included a preoperative diagnosis of clinical T1–T4a (cT1–T4a)-stage primary gastric adenocarcinoma; patients with remnant GC, T4b-stage lesions or distant metastatic tumors and those requiring emergency surgery from bleeding or perforation were excluded. Patients were informed of the potential complications of the procedure and the advantages and disadvantages of a laparoscopic vs. an open approach, and written informed consent was obtained from all the patients prior to surgery. In this study, 2608 patients undergoing LAG and 1516 patients undergoing OG were eligible for enrollment. This study was approved by the Institutional Review Board of Fujian Medical University Union Hospital (Approval number: 20070428).

Lymphadenectomies were classified based on the 3rd English editions of the Japanese Classification of Gastric Carcinoma [18]. The data on the extent of lymphadenectomy were revised retrospectively according to a recently published version of those guidelines [18]. The tumors were staged according to the final pathological results based on the 7th Edition of the American Joint Committee on Cancer (AJCC) staging system [19].

Variables and definitions

The potential risk factors for EURO were extracted from the database, along with age, gender, comorbidity, American Society of Anesthesiologists (ASA) score, body mass index (BMI), preoperative malnourishment, neoadjuvant treatment, abdominal surgery history, tumor location, tumor size, pathological TNM stage, LAG or OG, gastrectomy type, reconstruction type, operative time, intraoperative blood loss, and number of resected lymph nodes (LNs). Postoperative morbidity was defined as any one or more of the following: abdominal bleeding, anastomotic bleeding, anastomotic leakage, abdominal infection, ileus or mechanical obstruction, pancreatic fistula, incisional infection, incision dehiscence, and pneumonia. Postoperative morbidity was graded based on the revised version of the Clavien–Dindo classification system suggested by Dindo et al. [20] For patients with more than one complication, the most severe complication was selected. In-hospital mortality was defined as any patient with postoperative death at the time of discharge within a 30-day hospital stay. Hospital stay was defined as the time from initial hospitalization postoperatively to discharge. In this study, EURO refers to reoperation inside the peritoneal cavity performed in a patient with GC under general anesthesia and tracheal intubation because severe postoperative complications were caused by the original LAG or OG procedure within a 30-day hospital stay. The EURO rate was defined as the number of patients requiring reoperation divided by all of the patients.

Statistical analysis

Statistical analyses were performed using SPSS version 18.0 (SPSS, Chicago, IL, USA). Categorical data are presented as percentages and were analyzed using the χ^2 test or Fisher's exact test, whereas continuous data are reported as the mean ± standard deviation (SD), and the differences in the means between the groups were analyzed using Student's *t*-test. Variables with a *p* value of less than 0.05 were considered statistically significant. Variables with $p < 0.05$ in the univariate analysis were subsequently selected for inclusion in a multivariate binary logistic regression model and were presented as hazard ratios (HRs) with 95% confidence intervals (CIs).

Results

Clinicopathological characteristics in all patients and EURO patients

The clinicopathologic characteristics of all patients ($n=4124$) are shown in the Supplementary Table. Statistical differences were observed in age ($p<0.001$), BMI ($p=0.019$), comorbidities ($p=0.014$), ASA score ($p<0.001$), malnourishment ($p<0.001$), tumor size ($p<0.001$), history of abdominal surgery ($p=0.007$), tumor location ($p<0.001$), reconstruction type ($p<0.001$), T stage ($p<0.001$), N stage ($p<0.001$), and TNM stage ($p<0.001$) between the LAG and OG groups. There was no statistically significant difference in gender ($p=0.655$) or the extent of gastrectomy ($p=0.254$) between the two groups.

The clinicopathological characteristics of the patients requiring EURO ($n=52$) are shown in Table 1. Among 52 patients requiring EURO, 44 (84.6%) were male, and 8 (15.4%) were female. The mean age was 63.44 ± 10.78 years, and the mean BMI was 22.97 ± 3.97 kg/m^2. There were no significant differences in gender, age, BMI, comorbidities, ASA score, malnourishment, tumor size, history of abdominal surgery, tumor location, reconstruction type, extent of gastrectomy, N stage, or TNM stage (all $p>0.05$) for patients requiring EURO between the LAG and OG groups, but there was a significant difference between the two groups in T stage ($p=0.007$).

Postoperative complications and EURO

Among 4124 patients, overall postoperative complications within the 30-day hospitalization period occurred in 374 cases (15.2%), and there was a significant difference in the overall postoperative complication rate between the LAG and OG groups (14.3% vs 16.7%, $p=0.043$). Severe postoperative complications within the 30-day hospitalization period were observed in 159 cases (3.9%), and there was no statistical significance in the rate of severe postoperative complications (3.8% vs 4.0%, $p=0.669$) between the two groups. Approximately 0.6% of patients (23/4,124) died postoperatively within the 30-day hospitalization period, and mortality was higher in the OG group than in the LAG group (0.2% vs 1.1%, $p<0.001$). EURO within the 30-day hospitalization was observed in 52 cases (1.3%), and no significant difference was observed in the EURO rate between the LAG and OG groups (1.1% vs 1.6%, $p=0.157$). The EURO rate within 24 h postoperatively was similar between the two groups (0.4% vs 0.2%, $p=0.279$); however, the EURO rate after 24 h postoperatively was statistically lower in the LAG group than in the OG group (0.7% vs 1.4%, $p=0.019$) (Table 2).

Univariate and multivariate analyses

As shown in Table 3, the univariate analysis of all 4124 cases demonstrated that no significant correlation was found between gender ($p=0.107$), comorbidities ($p=0.792$), ASA score ($p=0.318$), malnourishment ($p=0.424$), neoadjuvant treatment ($p=0.637$), abdominal surgery ($p=0.410$), reconstruction type ($p=0.345$), gastrectomy type ($p=0.122$), and laparoscopy or not ($p=0.157$) and EURO. However, age ($p=0.019$), BMI ($p=0.006$), and estimated blood loss ($p=0.034$) were closely related to the EURO rate. Multivariate logistic two-regression analysis revealed that age > 70 (HR 1.950, $p=0.028$), BMI > 25 g/m^2 (HR 2.288, $p=0.009$), and estimated blood loss > 100 ml (HR 1.867, $p=0.029$) were independent risk factors for EURO after gastrectomy for GC.

Interval time to EURO and causes of EURO

The mean interval time to EURO after the first operation was 6.9 ± 6.7 days, and there was no significant difference in the interval time to EURO between the LAG and OG groups (5.6 ± 5.5 days vs. 8.3 ± 7.8 days, $p=0.148$). The leading causes for EURO in the 52 patients requiring EURO were abdominal bleeding in 23 cases (44.2%), anastomotic bleeding in 7 (13.5%), anastomotic leakage in 6 (11.5%), abdominal infection in 5 (9.6%), intestinal obstruction in 5 (9.6%), incision dehiscence in 3 (5.8%), jejunal perforation in 2 (3.8%), and pancreatic fistula in 1 (1.9%). The main cause of EURO in the LAG group was intra-abdominal bleeding, followed by anastomotic bleeding and anastomotic leakage; however, the main cause of EURO in the OG group was intra-abdominal bleeding, followed by anastomotic leakage and intestinal obstruction.

The proportion of EURO patients with abdominal bleeding was significantly higher in the LAG group than in the OG group (57.1% vs. 29.2%, $p=0.043$), and there was no significant difference in the proportion of EURO patients with anastomotic bleeding (17.9% vs. 8.3%, $p=0.551$), anastomotic leakage (7.1% vs. 16.7%, $p=0.525$), abdominal infection (7.1% vs. 12.5%, $p=0.856$), intestinal obstruction (3.6% vs. 16.7%, $p=0.261$), incisional dehiscence (3.6% vs. 8.3%, $p=0.891$), jejunal perforation (3.6% vs. 4.2%, $p=1.000$), or pancreatic fistula (0 vs. 4.2%, $p=0.462$) between the two groups (Table 4). Among 23 patients requiring EURO

Table 1 Clinicopathological characteristics of EURO

Variables	No. ($n=52$)	LAG ($n=28$)	OG ($n=24$)	p
Gender				
Male	44 (84.6)	26 (92.9)	18 (75.0)	0.163
Female	8 (15.4)	2 (7.1)	6 (25.0)	
Age (year)	63.44 ± 10.78	64.07 ± 10.37	62.71 ± 11.42	0.654
BMI (kg/m^2)	22.97 ± 3.97	23.27 ± 3.84	22.62 ± 4.16	0.558
Comorbidities				
No	36 (67.3)	20 (71.4)	16 (66.7)	0.711
Yes	16 (32.7)	8 (28.6)	8 (33.3)	
ASA score				
≤ 2	48 (92.3)	26 (92.9)	22 (91.7)	1.000
> 2	4 (7.69)	2 (7.1)	2 (8.3)	
Malnourishment				0.261
No	47 (90.4)	27 (96.4)	20 (83.3)	
Yes	5 (9.6)	1 (3.6)	4 (16.7)	
Tumor size (cm)	5.40 ± 2.84	5.60 ± 3.38	5.17 ± 2.93	0.597
History of abdominal surgery				0.799
No	43 (82.7)	24 (85.7)	19 (79.2)	
Yes	9 (17.3)	4 (14.3)	5 (20.8)	
Tumor location				0.456
Upper	17 (32.7)	9 (32.4)	8 (33.3)	
Middle	9 (17.3)	7 (25.0)	2 (8.3)	
Lower	19 (36.5)	9 (32.4)	10 (41.7)	
≥ 2 areas	7 (10.7)	3 (10.7)	4 (16.7)	
Reconstruction type				
Roux-en-y	36 (69.2)	19(67.9)	17 (70.8)	0.807
B-I	11 (21.2)	7(25.0)	4 (16.7)	
B-II	4 (7.7)	2(7.1)	2 (8.3)	
Esophagogastrostomy	1 (1.9)	0(0)	1 (4.2)	
Gastrectomy extent				
Total	37 (71.2)	19 (67.9)	18 (75.0)	0.571
Subtotal	15 (28.8)	9 (32.1)	6 (32.1)	
T stage				
T1	10(19.2)	6(21.4)	4(16.7)	0.007
T2	3 (5.8)	2 (7.1)	1 (4.2)	
T3	14 (26.9)	12 (42.9)	2 (8.3)	
T4a	25 (48.1)	8 (28.6)	17 (70.8)	
N stage				0.426
N0	15 (28.8)	8 (28.5)	7 (29.2)	
N1	7 (13.5)	5 (17.9)	2 (8.3)	
N2	5 (9.6)	4 (14.3)	1 (4.2)	
N3	25 (48.1)	11 (39.3)	14 (58.3)	
TNM stage				0.368
I	11 (21.2)	7 (25.0)	4 (16.7)	
II	14 (26.9)	9 (31.1)	5 (20.8)	
III	27 (51.9)	12 (42.9)	15 (62.5)	

due to intra-abdominal bleeding, transverse mesocolon vascular bleeding and unexplained intra-abdominal bleeding were the leading bleeding sites, followed by pancreatic vascular bleeding and splenic lobar artery bleeding. Transverse mesocolon vascular bleeding and splenic bleeding were the most common bleeding sites among EURO patients in the LAG and OG groups, respectively (Table 5).

Table 2 Morbidity and mortality after LAG and OG

Items	Overall (*n* = 4124)	LAG (*n* = 2608)	OG (*n* = 1516)	*p*
Overall complications	627 (15.2)	374 (14.3)	253 (16.7)	0.043
Severe complications	159(3.9)	98(3.8)	61(4.0)	0.669
Complication grade				
Grade I	11 (0.3)	7 (0.3)	4 (0.3)	0.999
Grade II	457 (11.1)	269 (10.3)	188 (12.4)	0.040
Grade III	91 (2.2)	61 (2.3)	30 (2.0)	0.448
Grade IV	45 (1.1)	31 (1.2)	14 (0.9)	0.429
Grade V	23 (0.6)	6 (0.2)	17 (1.1)	< 0.001
Reoperation	52 (1.3)	2(1.1)	2(1.6)	0.157
≤ 24	14 (0.3)	1(0.4)	(0.2)	0.279
> 24	38 (0.9)	17 (0.7)	21 (1.4)	0.019
In-hospital mortality	23 (0.6)	6 (0.2)	17 (1.1)	< 0.001

Clinical courses of patients undergoing EURO

There were 6 of 28 (21.4%) EURO patients in the LAG group, but none of the 22 EURO patients in the OG group underwent a laparoscopic procedure ($p = 0.025$). There was no significant difference in the number of EUROs performed between the two groups ($p = 0.590$). The morbidity rate in EURO patients was 39.2% in the LAG group and 50.0% in the OG group ($p = 0.438$), and the mortality rate in EURO patients was 3.6% in the LAG group and 20.8% in the OG group ($p = 0.084$). However, there was no significant difference in the length of hospital stay among EURO patients between the two groups (26.9 ± 14.3 days vs. 29.5 ± 11.6 days, respectively, $p = 0.429$) (Table 6).

Treatment and recovery after EURO

Management methods in the 52 patients who underwent EURO included laparoscopic surgery in 6 of 28 patients in the LAG group due to intra-abdominal bleeding in 3 cases, anastomotic bleeding in 2 cases, and intestinal perforation in 1 case. The remaining 46 patients (22 in the LAG group and 24 in the OG group) underwent open surgery. Detailed management strategies performed during the 52 EUROs included exploratory surgery alone, suturing or ligation, and splenectomy for intra-abdominal bleeding, endoscopy-guided suturing and debridement and/or reconstruction for anastomotic bleeding, debridement and/or splenectomy for intra-abdominal infection, enterolysis, enterectomy and/or reconstruction for intestinal obstruction, return and relaxation sutures for incisional dehiscence, debridement and repair for intestinal perforation, and debridement and drainage for a pancreatic fistula. Forty-six of 52 patients who underwent EURO recovered smoothly after EURO, but 6 patients died after EURO. Among them, one patient in the LAG group and 2 patients in the OG group died from sepsis, and 2 patients and 1 patient in the OG group died from disseminated intravascular coagulation (DIC) and multiple organ failure, respectively (Table 7).

Discussion

Postoperative complications have always been a focal point of concern for surgeons. EURO is generally considered necessary for the emergency management of particular, severe postoperative complications. In the previously published literature, the EURO rate after LAG was reported to range from 1.2 to 2.1% [6, 7, 16], and the EURO rate after OG was reported to range from 1.5 to 2.2% [6, 7, 10]. Kim et al. [16] reported that the EURO rate was closely related to preoperative comorbidities, type of reconstruction, operative time, and surgeon's experience. In a study by Oh [21] of EURO after OG, the results revealed that there was an older mean age and more males in the EURO group than in the non-EURO group. Two large prospective studies that compared the short-term outcomes between laparoscopic and open surgery in gastrectomy patients reported the detailed results of morbidity and mortality but only limited information on EURO itself [6, 7]. However, in contrast to Kim's [6] and Hu's [7] studies, in the current study, we focused only on differences in perioperative consequences, treatment strategies and high-risk factors for EURO by comparing patients who underwent LAG or OG to provide surgeons with certain evidence for the prevention and treatment of EURO. The EURO rate was 1.1% in the LAG group and 1.6% in the OG group, which is consistent with the results of previous studies [6, 7, 10, 16]. The type of procedure (laparoscopic or open) was not identified as a risk factor for EURO after gastrectomy for GC; however, age > 70, BMI > 25 kg/m^2, and estimated blood loss > 100 ml were independent risk factors for EURO. Therefore, no significant correlation was

Table 3 Univariate and multivariate analysis of risk factors for EURO

Variables	Univariate			Multivariate	
	No. patients	No.URO	*p*	OR (95% CI)	*p*
Age (year)			0.019		0.028
≤ 70	3369	36		1 (reference)	
> 70	755	16		1.950 (1.074–3.538)	
Gender			0.107		
Male	3093	44			
Female	1031	8			
Comorbidities			0.792		
No	2923	36			
Yes	1201	16			
ASA score			0.318		
≤ 2	3924	48			
> 3	200	4			
BMI (kg/m^2)			0.006		0.009
≤ 25	3554	38		1 (reference)	
> 25	570	14		2.288 (1.230–4.257)	
Malnourishment			0.424		
Yes	299	5			
No	3825	47			
Neoadjuvant treatment			0.637		
Yes	99	0			
No	4025	52			
Abdominal surgery			0.410		
No	3570	43			
Yes	554	9			
Tumor location			0.787		
Upper	1106	17			
Middle	790	9			
Lower	1697	19			
≥ 2 areas	531	7			
Tumor size(cm)			0.137		
≤ 5.0	2627	28			
> 5.0	1497	24			
Reconstruction type			0.354		
Roux-en-y[a]	2259	36			
B-I	1323	11			
B-II	406	4			
Esophagogastrostomy	94	1			
Roux-en-y[b]	42	0			
T stage			0.559		
T1	883	10			
T2	468	3			
T3	959	14			
T4	1814	25			
N stage			0.219		
N0	1414	15			
N1	571	7			
N2	683	5			
N3	1456	25			
Laparoscopy or not			0.157		

Table 3 (continued)

Variables	Univariate			Multivariate	
	No. patients	No.URO	*p*	OR (95% CI)	*p*
No	1516	24			
Yes	2608	28			
Gastrectomy type			0.122		
Total	2259	34			
Subtotal	1865	18			
Operation time(min)			0.425		
≤180	1971	22			
>180	2153	30			
Blood loss(ml)			0.025		0.029
≤100	3023	31		1 (reference)	
>100	1101	21		1.867 (1.067–3.267)	
No. of resected LNs			0.496		
≤30	2027	28			
>30	2097	24			

Table 4 Interval to EURO and main causes of EURO after LAG and OG

Items	No. of URO (*n*=52)	LAG (*n*=28)	OG (*n*=24)	*p*
Mean interval (d)	6.9±6.7	5.6±5.5	8.3±7.8	0.148
Cause of URO				
Intra-abdominal bleeding	23 (44.2)	16 (57.1)	7 (29.2)	0.043
Anastomotic bleeding	7 (13.5)	5 (17.9)	2 (8.3)	0.551
Anastomotic leakage	6(11.5)	2(7.1)	4 (16.7)	0.525
Intra-abdominal infection	5(9.6)	2(7.1)	3 (12.5)	0.856
Intestinal obstruction	5 (9.6)	1 (3.6)	4 (16.7)	0.261
Incision dehiscence	3 (5.8)	1 (3.6)	2 (8.3)	0.891
Jejunal perforation	2 (3.8)	1 (3.6)	1 (4.2)	1.000
Pancreatic fistula	1 (1.9)	0 (0)	1 (4.2)	0.462

Table 5 Location of intra-abdominal bleeding in 23 patients requiring EURO

Location	No. (*n*=23)	LAG (*n*=16)	OG (*n*=7)
Transverse mesocolon vessel	4 (17.4)	3 (18.8)	1 (14.3)
Splenic artery	3 (13.0)	2 (12.5)	1 (14.3)
Wall of remnant stomach vessel	2 (8.7)	2 (12.5)	0
Left gastric artery	1 (4.3)	1 (6.3)	0
Right gastric artery	1 (4.3)	1 (6.3)	0
Posterior gastric artery	1 (4.3)	0	1 (14.3)
Wall of duodenum vessel	1 (4.3)	1 (6.3)	0
Pancreatic vascular	3 (13.0)	2 (12.5)	1 (14.3)
Spleen	2 (8.7)	0	2 (28.6)
Crura of diaphragm	1 (4.3)	1 (6.3)	0
Unexplained bleeding	4 (17.4)	3 (18.8)	1 (14.3)

found between laparoscopic surgery and the EURO rate after LAG. Surgeons should pay particular attention to GC patients with advanced age, high BMI, and a large volume of intraoperative blood loss and improve perioperative management to prevent or reduce the occurrence of EURO after gastrectomy. Interestingly, further stratified analyses showed that the EURO rate within 24 h postoperatively was similar between the two groups, yet the EURO rate after 24 h postoperatively was statistically lower in the LAG group than in the OG group.

The main reasons for EURO after gastrectomy were different in previously published studies. In Kim's LAG study [16], abdominal bleeding, duodenal stump, and intestinal obstruction were the primary causes of EURO. However, Sah et al. [10] revealed that the leading causes for EURO after OG were abdominal bleeding and anastomotic leakage. In addition, Yi et al. [22] showed that the splenic hilar vessels, transverse mesocolonic vessels, greater omental vessels, and the spleen itself were common bleeding sites leading to EURO after OG. In the current study, the main

Table 6 Clinical courses of patients with EURO

Items	No. ($n=52$)	LAG ($n=28$)	OG ($n=24$)	p
EURO procedure				
Lap	6 (11.5)	6 (21.4)	0 (0)	0.025
Open	46 (88.5)	22 (78.6)	24 (100)	
No. of EURO				0.590
1	49 (94.2)	27 (96.4)	22 (91.7)	
≥ 2	3 (5.8)	1 (3.6)	2 (8.3)	
Morbidity following EURO*	23 (44.2)	11 (39.3)	12 (50.0)	0.438
Mortality following EURO*	6 (11.5)	1 (3.6)	5 (20.8)	0.084
Hospital stay (d)	28.2 ± 13.0	26.9 ± 14.3	29.8 ± 11.5	0.429

*Refers to parameters after the second operation

Table 7 Treatment and Status of EURO

Cause	LAG (n = 28)			OG (n = 24)		
	N	Treatment	Outcome	N	Treatment	Outcome
Intra-abdominal bleeding	16	12 Suture 3 laparoscopy 3 Exploratory 1 Splenectomy	1 Dead 15 Alive	7	3 Suture 1 Ligature 1 Exploratory 2 Splenectomy	1 Dead 6 Alive
Anastomosis bleeding	5	5 Suture 2 laparoscopy	5 Alive	2	2 Suture	2 Alive
Anastomotic leakage	2	1 Debridement 1 Reanastomosis	2 Alive	4	2 Debridement 2 Reconstruction &Reanastomosis	2 Dead 2 Alive
Intra-abdominal infection	2	1 Splenectomy 1 Debridement	2 Alive	3	2 Debridement 1 Splenectomy	3 Alive
Intestinal obstruction	1	1 Enterolysis & Reconstruction	1 Alive	4	2 Enterectomy & Reconstruction 2 Enterolysis	1 Dead 3 Alive
Incisional dehiscence	1	1 Return & Relaxation suture	1 Alive	2	2 Return & Relaxation suture	2 Alive
Intestinal perforation	1	1 Laparoscopic Repair	1 Alive	1	1 Debridement and Repair	1 Alive
Pancreatic fistula	0			1	1 Debridement and Drainage	1 Dead

cause of EURO was intra-abdominal bleeding, followed by anastomotic bleeding, anastomotic leakage in the LAG group, and intra-abdominal bleeding, followed by anastomotic leakage and intestinal obstruction in the OG group. The transverse mesocolonic vessels and spleen were the most common bleeding sites requiring EURO in the LAG and OG groups, respectively.

In this study, interestingly, we also found that the EURO rate within 24 h postoperatively was similar between the two groups, yet the EURO rate after 24 h postoperatively was statistically lower in the LAG group than in the OG group. Moreover, the proportion of patients with abdominal bleeding requiring EURO was markedly higher in the LAG group than in the OG group. Both in the LAG and OG groups, the main causes for EURO within 24 h after the initial surgery were intra-abdominal bleeding and anastomotic bleeding. On the one hand, we believe that improper application of energy devices [23, 24] intraoperatively, including the insufficient or excessive coagulation of blood vessels during LAG, probably causes bleeding due to blood clots breaking off the cut end of the vessels within 24 h after LAG, which may partly result in a higher EURO rate in the LAG group than in the OG group because of postoperative intra-abdominal bleeding. On the other hand, we purport that surgeons fully believe in and rely too much on all types of anastomotic instruments during LAG, frequently ignoring to inspect the anastomosis after reconstruction of the digestive tract, which may in part lead to the occurrence of EURO because of postoperative anastomotic bleeding within 24 h after LAG. Therefore, surgeons should attach great importance to the correct use of energy devices and anastomotic instruments, and reliable hemostasis and careful inspection of divided vessels and reconstructed anastomoses during surgery. This can help to reduce the rate of intra-abdominal bleeding or anastomotic bleeding within 24 h after surgery, which will further decrease the rate of EURO after LAG.

Laparoscopic surgery is safe and feasible for the treatment of patients with a history of abdominal surgery [25–27]. However, there are no relevant reports on whether laparoscopic procedures can be performed to treat emergency patients who require EURO after LAG. In the current study, laparoscopic surgery was successfully performed in 21.4% of patients in the LAG group requiring EURO. The management process of reoperation was similar between the LAG and OG groups and included suturing or ligation for hemostasis to control bleeding, splenectomy for hemorrhage, debridement plus irrigation-drainage or reanastomosis plus irrigation-drainage for anastomotic leakage and so on. For experienced surgeons, therefore, laparoscopy procedures could still be applied as an alternative to treat some patients requiring EURO after the initial LAG procedure for GC. Previous studies [10] have reported that the mortality rate after EURO following OG for GC was as high as 11.1%. In the current study, the mortality rate after EURO in the LAG group was 3.6%, which was lower than the mortality rate of 20.8% in the OG group, with marginal significance. The lower postoperative mortality rate after EURO in the LAG group may be mainly related to the laparoscopic procedure itself used for the initial operation, and EURO is associated with minimal surgical trauma and reduced stress response among the patients [28, 29].

For the first time, this study provides some valuable insights that can aid surgeons when planning to perform LAG or OG for GC. However, certain limitations also exist in this study. First, as a single-center retrospective study, the small sample size of patients who underwent EURO after gastrectomy for GC is one of the limitations of this study. Second, the average BMI of the patients in this study was relatively low compared to patients in other Western studies. Third, there were some differences in the clinicopathologic characteristics of the patients who underwent open vs. laparoscopic surgery in this study, partly because laparoscopy is performed more commonly than the open procedure, which may have increased the selection bias of patients to some extent. Fourth, patients were eligible for inclusion in the OG group and the LAG group in this study from Jan. 2005 to Dec. 2014 and from Jul. 2007 to Dec. 2014, respectively; thus, there was an obvious time difference during which patients were included in the two groups. However, Jul. 2007 was the cut-off date, and the patients who underwent OG were included in the early group, in which there were 658 cases from Jan. 2005 to Jul. 2007, and the late group, in which there were 858 cases from Aug. 2007 to Dec. 2014. The EURO rates between the early and late groups were 1.1% and 2.0%, respectively, without a significant difference ($p = 0.156$). Thus, prospective, multicenter, large-sample studies should be performed in the future to help confirm all these observations.

In conclusion, no significant correlation between laparoscopic surgery and the EURO rate was found in patients undergoing gastrectomy for GC. Laparoscopic surgery was associated with a lower EURO rate after 24 h postoperatively and a higher proportion of patients undergoing EURO for intra-abdominal bleeding than open surgery. Effective and accurate intraoperative hemostasis for intra-abdominal vessels and anastomotic sites will help to further reduce the incidence of EURO following LAG within 24 h postoperatively.

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Compliance with ethical standards

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References

1. McCulloch P, Niita ME, Kazi H, Gama-Rodrigues JJ (2005) Gastrectomy with extended lymphadenectomy for primary treatment of GC. Br J Surg 92:5–13
2. Kitano S, Shiraishi N, Uyama I, Sugihara K, Tanigawa N, Japanese Laparoscopic Surgery Study Group (2007) A multicenter study on oncologic outcome of laparoscopic gastrectomy for early cancer in Japan. Ann Surg 245:68–72
3. Kelly KJ, Selby L, Chou JF, Dukleska K, Capanu M, Coit DG, Brennan MF, Strong VE (2015) Laparoscopic versus open gastrectomy for gastric adenocarcinoma in the West: a case-control study. Ann Surg Oncol 22:3590–3596
4. Shinohara T, Satoh S, Kanaya S, Ishida Y, Taniguchi K, Isogaki J, Inaba K, Yanaga K, Uyama I (2013) Laparoscopic versus open D2 gastrectomy for advanced GC: a retrospective cohort study. Surg Endosc 27:286–294
5. Lin JX, Huang CM, Zheng CH, Li P, Xie JW, Wang JB, Jun L, Chen QY, Cao LL, Lin M (2016) Is all advanced GC suitable for laparoscopy-assisted gastrectomy with extended lymphadenectomy? A case-control study using a propensity score method. Ann Surg Oncol 23:1252–1260
6. Kim W, Kim HH, Han SU, Kim MC, Hyung WJ, Ryu SW, Cho GS, Kim CY, Yang HK, Park DJ, Song KY, Lee SI, Ryu SY, Lee JH, Lee HJ; Korean Laparo-endoscopic Gastrointestinal Surgery Study (KLASS) Group (2016) Decreased morbidity of laparoscopic distal gastrectomy compared with open distal gastrectomy

for stage I gastric cancer: short-term outcomes from a multicenter randomized controlled trial (KLASS-01).Ann Surg 263:28–35
7. Hu Y, Huang C, Sun Y, Su X, Cao H, Hu J, Xue Y, Suo J, Tao K, He X, Wei H, Ying M, Hu W, Du X, Chen P, Liu H, Zheng C, Liu F, Yu J, Li Z, Zhao G, Chen X, Wang K, Li P, Xing J, Li G (2016) Morbidity and mortality of laparoscopic versus open D2 distal gastrectomy for advanced GC: a randomized controlled trial. J Clin Oncol 34:1350–1357
8. Lee JH, Lee CM, Son SY, Ahn SH, Park DJ, Kim HH (2014) Laparoscopic versus open gastrectomy for GC: long-term oncologic results. Surgery 155:154–164
9. Kim HH, Han SU, Kim MC, Hyung WJ, Kim W, Lee HJ, Ryu SW, Cho GS, Song KY, Ryu SY (2014) Long-term results of laparoscopic gastrectomy for GC: a large-scale case-control and case-matched Korean multicenter study. J Clin Oncol 32:627–633
10. Sah BK, Chen MM, Yan M, Zhu ZG (2010) Reoperation for early postoperative complications after GC surgery in a Chinese hospital. World J Gastroenterol 16:98–103
11. Khoury W, Lavery IC, Kiran RP (2012) Impact of early reoperation after resection for colorectal cancer on long-term oncological outcomes. Colorectal Dis 14:e117–e123
12. Yang Y, Gao W, Zhao H, Yang Y, Shi J, Sun Y, Hu D (2016) Risk factors and consequences of perioperative reoperation in patients undergoing pulmonary resection surgery. Surgery 159:591–601
13. Birkmeyer JD, Hamby LS, Birkmeyer CM, Decker MV, Karon NM, Dow RW (2001) Is unplanned return to the operating room a useful quality indicator in general surgery? Arch Surg 136:405–411
14. Kroon HM, Breslau PJ, Lardenoye JW (2007) Can the incidence of unplanned reoperations be used as an indicator of quality of care in surgery? Am J Med Qual 22:198–202
15. Li P, Huang CM, Tu RH, Lin JX, Lu J, Zheng CH, Xie JW, Wang JB, Chen QY, Cao LL, Lin M (2017) Risk factors affecting unplanned reoperation after laparoscopic gastrectomy for gastric cancer: experience from a high-volume center. Surg Endosc 31:3922–3931
16. Kim MC, Kim W, Kim HH, Ryu SW, Ryu SY, Song KY, Lee HJ, Cho GS, Han SU, Hyung WJ. Korean Laparoscopic Gastrointestinal Surgery Study (KLASS) Group (2008) Risk factors associated with complication following laparoscopy-assisted gastrectomy for GC: a large-scale Korean multicenter study. Ann Surg Oncol 15:2692–2700
17. Hu YF, Yu J, Zhang C, Wang YN, Cheng X, Huang F, Li GX (2010) Development and implementation of a clinical data mining system for gastric cancer surgery (in Chinese). Chin J Gastrointest Surg 13:510–515
18. Japanese GC Association (2011) Japanese GC treatment guidelines 2010 (ver. 3). Gastric Cancer 14: 113–123
19. Washington K (2010) 7th edition of the AJCC cancer staging manual: stomach. Ann Surg Oncol 17:3077–3079
20. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213
21. Oh SJ, Choi WB, Song J, Hyung WJ, Choi SH, Noh SH, Yonsei Gastric Cancer Clinic (2009) Complications requiring reoperation after gastrectomy for GC: 17 years experience in a single institute. J Gastrointest Surg 13:239–245
22. Yi HW, Kim SM, Kim SH, Shim JH, Choi MG, Lee JH, Noh JH, Sohn TS, Bae JM, Kim S (2013) Complications leading reoperation after gastrectomy in patients with gastric cancer: frequency, type, and potential causes. J Gastric Cancer 13:242–246
23. Gossot D, Buess G, Cuschieri A, Leporte E, Lirici M, Marvik R, Meijer D, Melzer A, Schurr MO (1999) Ultrasonic dissection for endoscopic surgery. The E.A.E.S. Technology Group. Surg Endosc 13:412–417
24. Foschi D, Cellerino P, Corsi F, Taidelli T, Morandi E, Rizzi A, Trabucchi E (2002) The mechanisms of blood vessel closure in humans by the application of ultrasonic energy. Surg Endosc 16:814–819
25. Nunobe S, Hiki N, Fukunaga T, Tokunaga M, Ohyama S, Seto Y, Yamaguchi T (2008) Previous laparotomy is not a contraindication to laparoscopy-assisted gastrectomy for early gastric cancer. World J Surg 32:1466–1472
26. Kawamura H, Yokota R, Homma S, Sato M (2009) Acceptability of laparoscopy- assisted gastrectomy for patients with previous intra-abdominal surgery. Surg Laparosc Endosc Percutan Tech 19:431–435
27. Jabir MA, Brady JT, Wen Y, Dosokey EMG, Choi D, Stein SL, Delaney CP, Steele SR (2018) Attempting a laparoscopic approach in patients undergoing left-sided colorectal surgery who have had a previous laparotomy: is it feasible? J Gastrointest Surg 22:316–320
28. Evans C, Galustian C, Kumar D, Hagger R, Melville DM, Bodman-Smith M, Jourdan I, Gudgeon AM, Dalgleish AG (2009) Impact of surgery on immunologic function: comparison between minimally invasive techniques and conventional laparotomy for surgical resection of colorectal tumors. Am J Surg 197:238–245
29. Veenhof AA, Vlug MS, van der Pas MH, Sietses C, van der Peet DL, de Lange-de Klerk ES, Bonjer HJ, Bemelman WA, Cuesta MA (2012) Surgical stress response and postoperative immune function after laparoscopy or open surgery with fast track or standard perioperative care: a randomized trial. Ann Surg 255:216–221