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Comparison of short-term and long-term efficacy of laparoscopic and open gastrectomy in high-risk patients with gastric cancer: a propensity score-matching analysis

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Abstract

Background To determine whether laparoscopic surgery can be used in high-risk patients with gastric cancer.

Methods The clinicopathological data of 3743 patients with primary gastric adenocarcinoma, collected from January 2007 to December 2014, were retrospectively analyzed. Patients who had ≥ 1 of the following conditions were defined as high-risk patients: (1) age ≥ 80 years; (2) BMI ≥ 30 kg/m^2; (3) ASA (American Society of Anesthesiologists) grade ≥ 3; or (4) clinical T stage 4 (cT4). Propensity score matching (PSM) was used to reduce confounding bias; then, we compared the short-term and long-term efficacy of laparoscopic gastrectomy (LG) with open gastrectomy (OG) in high-risk patients with gastric cancer.

Results A total of 1296 patients were included in PSM. After PSM, no significant difference in clinicopathological data was observed between the LG group ($n=341$) and the OG group ($n=341$). The operative time (181.70 vs. 266.71 min, $p<0.001$) and blood loss during the operation (68.11 vs. 225.54 ml, $p<0.001$) in the LG group were significantly lower than those in the OG group. In the LG and OG groups, postoperative complications occurred in 39 (11.4%) and 63 (18.5%) patients, respectively, $p=0.010$. Multivariate analysis showed that laparoscopic surgery was an independent protective factor against postoperative complications ($p=0.019$). The number of risk factors was an independent risk factor for postoperative complications ($p=0.021$). The 5-year overall survival rate in the LG group was comparable to that in the OG group (55.0 vs. 52.0%, $p=0.086$). Hierarchical analysis further confirmed that the LG and OG groups exhibited comparable survival rates among patients with stages cI, pI, cII, pII, cIII, and pIII (all $p>0.05$).

Conclusions For high-risk patients with gastric cancer, LG not only exhibits better short-term efficacy than OG but also has a comparable 5-year survival rate to OG.

Keywords Gastric cancer · High-risk patients · Propensity score matching · Laparoscopic gastrectomy · Complication · Prognosis

Gastric cancer is the fourth most common malignancy in humans, and it is the second most common malignancy associated with cancer mortality [1]. Radical gastrectomy is the dominant treatment for patients with resectable gastric cancer. Since the first case of laparoscopic-assisted gastrectomy was performed in 1994 [2], a growing number of studies have confirmed that laparoscopic gastrectomy (LG) has superior short-term efficacy with regard to factors such as intraoperative blood loss, postoperative complications, time to flatus, and length of hospital stay [3–5]; additionally, patients undergoing LG can achieve long-term survival comparable to those undergoing open gastrectomy (OG) [6–8]. However, it is unknown whether patients with a preoperative

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ASA (American Society of Anesthesiologists) grade ≥ 3, BMI ≥ 30 kg/m^2, age ≥ 80 years, or a clinical T stage of 4 (cT4) can benefit from LG.

Previous studies have shown that an ASA grade ≥ 3, BMI ≥ 30 kg/m^2, age ≥ 80 years, and cT4 classification are sensitive indicators of surgical risk assessment in patients with cancer, and patients with these indicators are often defined as high-risk patients [9–19]. With the aging of society and the increasing number of obese people [20, 21], surgeons will face an increasing number of high-risk patients with gastric cancer. Therefore, for the first time, this study compared the short-term and long-term effects of LG with OG in high-risk gastric cancer patients during the same period and explored whether these patients can benefit from LG.

Materials and methods

Patients

In this retrospective analysis, data were collected from 3743 patients diagnosed with primary gastric adenocarcinoma at Fujian Medical University Union Hospital (FMUUH) Department of Gastric Surgery from January 2007 to December 2014. According to previous studies, patients with ≥ 1 of the following conditions were defined as high-risk patients: (1) age ≥ 80 years; (2) BMI ≥ 30 kg/m^2; (3) ASA grade ≥ 3; and (4) cT4 stage [22]. A total of 1601 patients were included. The exclusion criteria were as follows: (1) gastric stump cancer (n = 53); (2) intraperitoneal or distant metastasis confirmed during or after the operation (n = 67); (3) neoadjuvant chemotherapy (n = 43); (4) conversion to open laparotomy (n = 2); or (5) incomplete pathological data (n = 140). A total of 305 patients were excluded. The remaining 1296 patients undergoing radical gastrectomy were entered into the statistical analysis, of whom 378 patients underwent OG, and 918 underwent LG (see flowchart in Fig. 1). Tracheal intubation was given, and combined intravenous anesthesia was performed [23]. Preoperative clinical tumor-node-metastasis (cTNM) staging and postoperative pathological tumor-node-metastasis (pTNM) staging were based on the 7th American Joint Committee on Cancer (AJCC) staging system [24]. Two attending physicians staged the tumor before the operation according to gastroscopy, abdominal CT, total abdominal ultrasonography, and other examination results [25]. All patients were informed of the advantages and disadvantages of LG and OG before surgery and the procedure was selected by the patients themselves; all surgeries were performed by the same experienced surgical team. All patients signed an informed consent form. This study was approved by the FMUUH Ethics Committee.

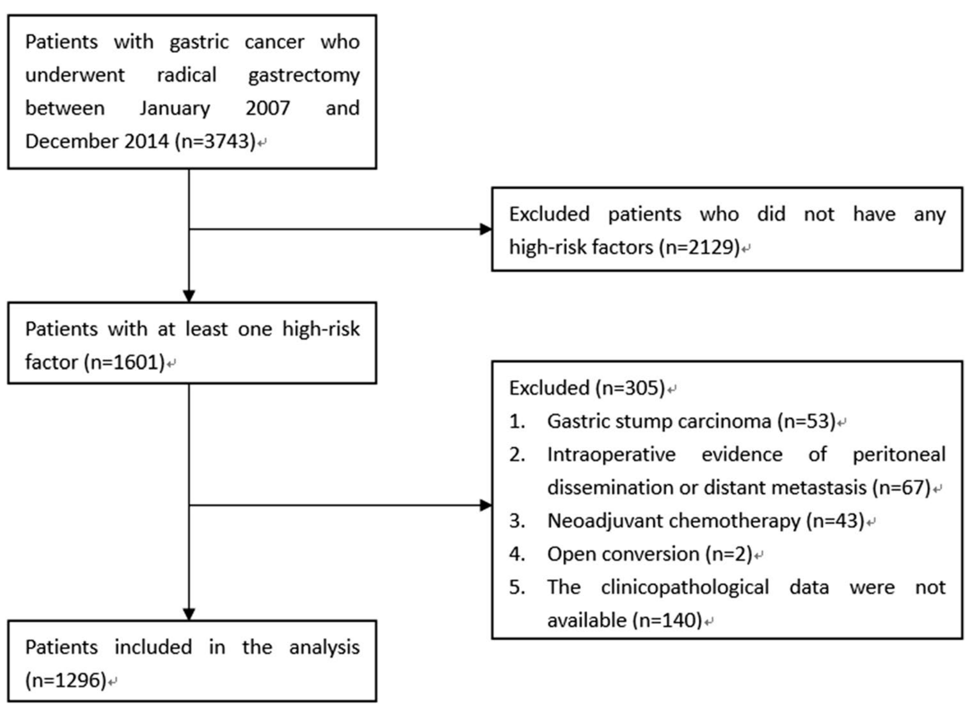

Fig. 1 Flowchart depicting the patient selection process

Definitions

High-risk patients: Patients with ≥ 1 of the following conditions: (1) age ≥ 80 years; (2) BMI ≥ 30 kg/m^2; (3) ASA grade ≥ 3; or (4) cT4 stage were considered high-risk patients [22].

Surgical complications

Complications developing within the scope of surgery, such as wounds or intra-abdominal cavity, and complications associated with surgery, such as wound infections and abdominal infections, were considered surgical complications. Non-surgical complications: Complications unrelated to the surgical field, such as pneumonia, were considered non-surgical complications [26]. Serious complications: Postoperative complications were graded according to the Clavien-Dindo classification system; complications greater than grade III were defined as serious complications [27].

Overall survival time

Survival time was defined as the period from the date of surgery to the date of death or final follow-up. All patients were monitored until death or September 2017, and the median follow-up time was 42 months (range 2–125 months).

Statistical analysis

A logistic regression model was chosen to calculate the propensity scores, and the following covariates were included: age, sex, ASA grade, BMI, tumor location, adjuvant chemotherapy, and nodal status. Continuous variables are reported as the means ± SD. Categorical and continuous variables were compared using a χ^2 test or Fisher's exact test and a *t* test, respectively. The cumulative survival rate was calculated using the Kaplan–Meier method and a log-rank test. Logistic regression analysis was used to identify independent risk factors associated with complications. A Cox proportional hazards regression model was used to determine independent prognostic factors associated with survival. All statistical analyses were performed using SPSS v. 18.0 for Windows (SPSS Inc., Chicago, IL, USA). Values of *p* lower than 0.05 were considered statistically significant.

Results

Clinicopathological characteristics of patients

Tables 1 and 2 show the demographic data of all the patients ($n = 1296$) and the propensity score-matched patients ($n = 682$). After propensity score matching (PSM), no significant differences between OG and LG patients were observed in clinicopathological characteristics, such as age, sex, BMI, ASA grade, clinical stage, and pTNM stage. The relationships between the number of risk factors and the pathological stage of patients after PSM are shown in Supplementary Tables 1 and 2.

Intraoperative outcomes

The operative time (181.70 vs. 266.71 min, $p < 0.001$) and blood loss during surgery (68.11 vs. 225.54 ml, $p < 0.001$) were significantly lower in the LG group than in the OG group. The number of harvested lymph nodes (35.00 vs. 31.24, $p < 0.001$) in the LG group was higher than that in the OG group. The difference between two groups in the digestive tract reconstruction and gastrectomy extent was not significant (all $p > 0.05$, Table 3).

Postoperative outcomes

In the LG and OG groups, postoperative complications occurred in 39 (11.4%) and 63 (18.5%) patients, respectively, $p = 0.010$. Twenty-one (6.2%) and 34 (10.0%) patients had surgical complications in the LG and OG groups, respectively, $p = 0.068$. The incidence of postoperative bleeding and wound infection was significantly lower in the LG group than in the OG group (1 vs. 8, $p = 0.038$; 1 vs. 8, $p = 0.038$). Twenty (5.9%) and 38 (11.1%) patients had non-surgical complications in the LG and OG groups, respectively, $p = 0.013$. The incidence of pneumonia in the LG group was significantly lower than that in the OG group [17 (5.0%) vs. 36 (10.6%), $p = 0.007$]. In addition, the incidence of serious complications in the LG group was significantly lower than that in the OG group [5 (1.5%) vs. 15 (4.4%), $p = 0.023$]. In the LG group, the postoperative hospital stay (12.63 vs. 18.03), time to flatus (3.79 vs. 4.13), and time to food intake (5.03 vs. 5.37) were significantly shorter than those in the OG group (all $p < 0.05$, Table 4).

Univariate and multivariate analyses of factors associated with complications

In the univariate analysis, age, BMI, the number of risk factors, Charlson Comorbidity Index (CCI), and surgical procedure were closely related to postoperative complications ($p < 0.05$).

Table 1 Clinicopathological characteristics of patients before matching

	All patients		
	OG (n = 378)	LAG (n = 918)	*p* value
Age (years)	62.06 ± 10.756	62.70 ± 11.519	0.350
Sex *n* (%)			0.169
Male	291 (77.0%)	673 (73.3%)	
Female	87 (23.0%)	245 (26.7%)	
BMI (kg/m^2)	22.11 ± 3.48	22.48 ± 3.63	0.100
ASA, *n* (%)			< 0.001
< 3	331 (87.6%)	860 (93.7%)	
≥ 3	47 (12.4%)	58 (6.3%)	
Number of high-risk factors, *n* (%)			0.002
1	327 (86.5%)	844 (91.9%)	
2	45 (11.9%)	71 (7.7%)	
3	6 (1.6%)	3 (0.3%)	
Previous abdominal surgery, *n* (%)			0.543
No	338 (89.4%)	810 (88.2%)	
Yes	40 (10.6%)	108 (11.8%)	
Charlson comorbidity index, *n* (%)			0.925
0	244 (64.6%)	603 (65.7%)	
1	92 (24.3%)	217 (23.6%)	
≥ 2	42 (11.1%)	98 (10.7%)	
Tumor diameter (mm)	55.00 ± 23.50	56.62 ± 24.07	0.268
Tumor location, *n* (%)			0.033
Upper	104 (27.5%)	228 (24.8%)	
Middle	68 (18.0%)	212 (23.1%)	
Lower	164 (43.4%)	344 (37.5%)	
Mixed	42 (11.1%)	134 (14.6%)	
Pathological type, *n* (%)			0.493
Differentiated	146 (38.6%)	336 (36.6%)	
Undifferentiated	232 (61.4%)	582 (63.4%)	
Adjuvant chemotherapy, *n* (%)			0.000
No	200 (52.9%)	650 (70.8%)	
Yes	178 (47.1%)	268 (29.2%)	
cT stage, *n* (%)			0.110
T1	15 (4.0%)	33 (3.6%)	
T2	28 (7.4%)	46 (5.0%)	
T3	66 (17.5%)	90 (9.8%)	
T4	269 (71.2%)	749 (81.6%)	
cN stage, *n* (%)			< 0.001
N0	127 (33.6%)	321 (35.0%)	
N1	149 (39.4%)	263 (28.6%)	
N2	81 (21.4%)	228 (24.8%)	
N3	21 (5.6%)	106 (11.5%)	
cTNM, *n* (%)			0.009
I	13 (3.4%)	22 (2.4%)	
II	97 (25.7%)	313 (34.1%)	
III	268 (70.9%)	583 (63.5%)	
pT stage, *n* (%)			< 0.001
T1	22 (5.8%)	76 (8.3%)	
T2	23 (6.1%)	64 (7.0%)	
T3	82 (21.7%)	294 (32.0%)	

Table 1 (continued)

	All patients		
	OG (n = 378)	LAG (n = 918)	*p* value
T4	251 (66.4%)	484 (52.7%)	
pN stage, *n* (%)			0.745
N0	71 (18.8%)	195 (21.2%)	
N1	60 (15.9%)	132 (14.4%)	
N2	71 (18.8%)	171 (18.6%)	
N3	176 (46.6%)	420 (45.8%)	
pTNM, *n* (%)			0.172
I	27 (7.1%)	93 (10.1%)	
II	79 (20.9%)	204 (22.2%)	
III	272 (72.0%)	621 (67.6%)	

Furthermore, the multivariate analysis showed that LG was an independent protective factor against postoperative complications, $p = 0.019$, and the number of risk factors was an independent risk factor for postoperative complications, $p = 0.021$ (Table 5).

Univariate and multivariate analyses of factors associated with overall survival

The univariate analysis showed that ASA grade, tumor diameter, tumor location, pathological type, pTNM stage, cTNM stage, operative time, gastrectomy extent, and gastrointestinal reconstruction were closely related to the 5-year overall survival rate after the operation ($p < 0.05$). In the multivariate analysis, tumor diameter and pTNM stage were independent predictors of long-term survival (all $p < 0.05$, Table 6).

Survival after surgery

Figure 2 shows that postoperative 5-year overall survival in the LG group was comparable to that in the OG group (55.0 vs. 52.0%, $p = 0.086$) for high-risk patients with gastric cancer. According to the 7th AJCC-TNM staging system, the two groups of patients were stratified into p stages I–III and c stages I–III, corresponding to A–F in Fig. 3. Hierarchical analysis showed that the overall survival rate of each subgroup of the LG group was comparable to that of the corresponding OG subgroup, all $p > 0.05$.

Discussion

In recent years, laparoscopic radical gastrectomy has been popular because it has the advantage of being minimally invasive. The Korean Laparoendoscopic Gastrointestinal Surgery Study (Klass-01) showed that the postoperative short-term efficacy of LG was superior to that of OG in early gastric cancer patients, especially regarding wound-related complications (LG vs. OG, 3.6 vs. 7.0%, $p = 0.005$) [28]. Seigo's findings suggest that the long-term survival after LG in early gastric cancer is comparable to that after OG [8]. In addition, a multicenter prospective study from China showed no significant difference in the incidence of postoperative complications between LG and OG in patients with advanced gastric cancer (LG vs. OG, 15.2 vs. 12.9%, $p = 0.285$), indicating that surgeons can safely perform D2 lymph node dissection on advanced gastric cancer patients [5]. LG has also been reported to achieve long-term effects for advanced gastric cancer similar to those of OG [29]. However, at present, the vast majority of studies focus on typical gastric cancer patients, while less attention is given to high-risk patients.

By 2050, approximately 23% of people will be over 65 years old; by 2030, 57.8% of people will meet obesity standards [20, 21]. The aging population and obesity have become increasingly prominent issues. Surgical exposure is difficult in obese patients. Older patients or those with poor basic conditions cannot tolerate surgery well. Advanced tumors and other factors largely affect the success of the surgery. All of the above have been identified as surgical risk factors [22]. Therefore, the question of whether this subset of high-risk patients (elderly, high BMI, high ASA grade, and cT4) can also benefit from laparoscopic surgery has attracted increasing attention from researchers.

Indeed, it is generally believed that in high-risk patients with colorectal cancer, traditional laparotomy, rather than laparoscopic surgery, is always recommended due to their preoperative high-risk status [30], and pneumoperitoneum, established by carbon dioxide, may cause a number of adverse pathophysiological reactions, including hypercapnia, reduced venous return, increased peak airway pressure, and decreased lung compliance [31]. However, many studies have recently shown that even in high-risk patients with colorectal cancer, laparoscopic surgery is still safe and feasible, and it also has satisfactory clinical efficacy compared to

Table 2 Clinicopathological characteristics of patients after matching

	Propensity-matched patients		
	OG (n = 341)	LAG (n = 341)	p value
Age (years)	62.96 ± 12.36	63.56 ± 11.36	0.507
Sex n (%)			0.133
Male	261 (76.5%)	277 (81.2%)	
Female	80 (23.5%)	64 (18.8%)	
BMI (kg/m^2)	22.14 ± 3.53	22.57 ± 3.61	0.118
ASA, n (%)			1.000
< 3	305 (89.4%)	304 (89.1%)	
≥ 3	36 (10.6%)	37 (10.9%)	
Number of high-risk factors, n (%)			0.468
1	310 (90.9%)	316 (90.7%)	
2	26 (7.6%)	23 (6.7%)	
3	5 (1.5%)	2 (0.6%)	
Previous abdominal surgery, n (%)			0.282
No	306 (89.7%)	297 (87.1%)	
Yes	35 (10.3%)	44 (12.9%)	
Charlson comorbidity index, n (%)			0.244
0	236 (69.2%)	233 (65.4%)	
1	77 (22.6%)	77 (22.6%)	
≥ 2	28 (8.2%)	41 (12.0%)	
Tumor diameter (mm)	54.60 ± 23.79	57.73 ± 23.17	0.083
Tumor location, n (%)			0.061
Upper	94 (27.6%)	81 (23.8%)	
Middle	59 (17.3%)	83 (24.3%)	
Lower	148 (43.4%)	128 (37.5%)	
Mixed	40 (11.7%)	49 (14.4%)	
Pathological type, n (%)			0.150
Differentiated	131 (38.4%)	113 (33.1%)	
Undifferentiated	210 (61.6%)	228 (66.9%)	
Adjuvant chemotherapy, n (%)			0.089
No	183 (53.7%)	205 (60.1%)	
Yes	158 (46.3%)	136 (39.9%)	
cT stage, n (%)			0.868
T1	11 (3.2%)	9 (2.6%)	
T2	25 (7.3%)	23 (6.7%)	
T3	55 (16.1%)	62 (18.2%)	
T4	250 (73.3%)	247 (72.4%)	
cN stage, n (%)			0.721
N0	110 (32.3%)	99 (29.0%)	
N1	133 (39.0%)	133 (39.0%)	
N2	77 (22.6%)	83 (24.3%)	
N3	21 (6.2%)	26 (7.6%)	
cTNM, n (%)			0.662
I	13 (3.8%)	9 (2.6%)	
II	95 (27.9%)	93 (27.3%)	
III	233 (68.3%)	239 (70.1%)	
pT stage, n (%)			0.536
T1	22 (6.5%)	18 (5.3%)	
T2	22 (6.5%)	21 (6.2%)	
T3	79 (23.2%)	95 (27.9%)	
T4	218 (63.9%)	207 (60.7%)	
pN stage, n (%)			0.366
N0	62 (18.2%)	47 (13.8%)	
N1	55 (16.1%)	65 (19.1%)	
N2	63 (18.5%)	69 (20.2%)	
N3	161 (47.2%)	160 (46.9%)	
pTNM, n (%)			0.757
I	27 (7.9%)	22 (6.5%)	
II	69 (20.2%)	71 (20.8%)	
III	245 (71.8%)	248 (72.7%)	

Table 3 Intraoperative outcomes

	OG (n = 341)	LAG (n = 341)	p value
Operative time (min)	266.71 ± 73.44	181.70 ± 50.70	< 0.001
Intraoperative blood loss (ml)	225.54 ± 294.50	68.11 ± 102.26	< 0.001
Lymph nodes harvested (n)	31.24 ± 13.50	35.00 ± 13.70	< 0.001
Gastrectomy extent, n (%)			0.276
Total	189 (55.4%)	208 (61.0%)	
Distal	147 (43.1%)	130 (38.1%)	
Other	5 (1.5%)	3 (0.9%)	
Reconstruction			0.490
B-I	89 (26.1%)	95 (27.9%)	
B-II	47 (13.8%)	37 (10.9%)	
Roux-en-Y	205 (60.1%)	209 (61.3%)	

Table 4 Postoperative outcomes

	OG (n = 341)	LAG (n = 341)	p value
Overall complications	63 (18.5%)	39 (11.4%)	0.010
Surgical complications	34 (10.0%)	21 (6.2%)	0.068
Bleeding	8 (2.3%)	1 (0.3%)	0.038
Digestive tract fistula	8 (2.3%)	6 (1.8%)	0.589
Ileus	5 (1.5%)	7 (2.1%)	0.560
Gastroplegia	4 (1.2%)	2 (0.6%)	0.122
Wound infection	8 (2.3%)	1 (0.3%)	0.038
Abdominal infection	8 (2.3%)	5 (1.5%)	0.401
Lymphatic fistula	2 (0.6%)	2 (0.6%)	1.000
Non-surgical complications	38 (11.1%)	20 (5.9%)	0.013
Pneumonia	36 (10.6%)	17 (5.0%)	0.007
Cardiovascular system	2 (0.6%)	2 (0.6%)	1.000
Liver system	1 (0.3%)	1 (0.3%)	1.000
Urinary system	2 (0.6%)	2 (0.6%)	1.000
Clavien-Dindo classification			0.023
< 3	326 (95.6%)	336 (98.5%)	
≥ 3	15 (4.4%)	5 (1.5%)	
Postoperative hospital stay	18.03 ± 8.23	12.63 ± 7.11	< 0.001
Time to flatus	4.13 ± 1.29	3.79 ± 1.54	0.002
Time to food intake	5.37 ± 1.87	5.03 ± 1.88	0.018

Table 5 Univariate and multivariate analyses of factors associated with overall complications

	Univariate analysis			Multivariate analysis		
	HR	95% CI	*p* value	HR	95% CI	*p* value
Age (years)						
< 80	1.000			1.000		
≥ 80	3.632	1.774–7.436	< 0.001	1.627	0.637–4.158	0.309
Sex						
Male	1.000					
Female	1.166	0.681–1.996	0.575			
BMI (kg/m^2)						
< 30	1.000			1.000		
≥ 30	4.305	1.599–11.592	0.004	1.933	0.561–6.660	0.296
ASA						
< 3	1.000					
≥ 3	1.709	0.867–3.369	0.121			
cT						
T1–3	1.000					
T4	0.952	0.413–2.193	0.907			
Number of high-risk factors						
1	1.000			1.000		
2	4.450	2.390–8.285		2.929	1.219–7.035	
3	17.564	3.350-92.088	< 0.001	8.349	1.236–56.385	0.021
Previous abdominal surgery						
No	1.000					
Yes	1.295	0.696–2.409	0.415			
Surgical procedure						
OG	1.000			1.000		
LAG	0.593	0.384–0.914	0.018	0.585	0.374–0.915	0.019
Charlson comorbidity index						
0	1.000			1.000		
1	1.850	1.147–2.984		1.463	0.876–2.441	
≥ 2	1.637	0.843–3.181	0.028	0.983	0.463–2.126	0.315
Tumor diameter (mm)						
< 50	1.000					
≥ 50	1.040	0.665–1.627	0.864			
Tumor location						
Upper	1.000					
Middle	1.345	0.697–2.594				
Lower	1.591	0.907–2.789				
Mixed	1.208	0.561–2.598	0.428			
Pathological type						
Differentiated	1.000					
Undifferentiated	1.096	0.701–1.713	0.688			
pTNM						
I	1.000					
II	0.904	0.372–2.199				
III	0.862	0.388–1.916	0.929			
Ctnm						
I	1.000					
II	1.299	0.363–4.652				
III	1.011	0.291–3.514	0.563			

Table 5 (continued)

	Univariate analysis			Multivariate analysis		
	HR	95% CI	*p* value	HR	95% CI	*p* value
Operative time (min)						
< 180	1.000					
≥ 180	1.561	0.917–2.658	0.101			
Intraoperative blood loss (ml)						
< 50	1.000					
≥ 50	1.313	0.545–3.164	0.544			
Gastrectomy extent						
Total	1.000					
Distal	1.422	0.927–2.182				
Other	0.969	0.117–8.041	0.268			
Reconstruction						
B-I	1.000					
B-II	1.457	0.908–2.338				
Roux-en-Y	1.221	0.633–2.354	0.291			

open surgery. Jensen et al. concluded that laparoscopic colorectal resections in high-risk patients resulted in fewer hospitalization days, less intraoperative blood loss, and fewer cardiovascular complications than open surgery, and long-term survival was comparable to that in patients who underwent open surgery [32]. Feroci et al. found that patients with high-risk factors who underwent laparoscopic colorectal resection had lower rates of systemic complications and 30-day postoperative mortality than patients undergoing open surgery [33]. However, studies on whether the minimally invasive advantages of LG can reduce the surgical stress in high-risk patients with gastric cancer and improve the short-term and long-term efficacy of surgery have not been reported.

The results of this study showed that among high-risk patients, the LG group had significantly better postoperative recovery than the OG group with regard to factors such as time to flatus and food intake. The numbers of overall complications, non-surgical complications, and serious complications were significantly lower than those in the OG group, especially for bleeding, wound infection, and pneumonia; these complications may benefit from reductions in the bleeding during the operation, surgical invasiveness, and inflammatory response of the body associated with the LG procedure [3, 16, 18]. Although age ≥ 80 years, BMI ≥ 30 kg/m^2, ASA grade ≥ 3, and cT4 stage were not independent risk factors for postoperative complications, the number of risk factors was an independent risk factor for postoperative complications. These results suggest that in high-risk patients, the body's tolerance to surgical stress is affected by the synergistic effect of these four factors rather than by a single factor. High-risk patients with ≥ 1 risk factors should be given more attention after surgery to reduce postoperative complications. Additionally, laparoscopic surgery is an independent protective factor against postoperative complications. Therefore, in the context of postoperative complications, high-risk patients are more likely to benefit from LG. Moreover, our long-term postoperative survival analysis found that the 5-year overall survival rate in the LG group was comparable to that in the OG group and in all subgroups in the stratified analysis. Several studies have shown that CCI was associated with both the short-term and long-term efficacy of cancer-related surgery [34, 35]. Considering the population of patients assessed, we also evaluated the impact of CCI on these patients and found that CCI was not associated with postoperative complications and overall survival. As mentioned above, the results of this study indicate that LG is safe and feasible in high-risk patients and has significantly better short-term efficacy and comparable long-term efficacy to OG.

It has been reported that patients with metastasis before or after surgery and those undergoing neoadjuvant chemotherapy have significant differences in their short-term and long-term postoperative outcomes compared with those without metastasis or neoadjuvant chemotherapy [36–38]. In addition, previous studies comparing the long-term and short-term efficacy of laparotomy and laparoscopic surgery have excluded the above types of patients [5, 39]. Therefore, to reduce the baseline bias of cases and objectively assess the long-term and short-term efficacy of laparoscopic surgery for high-risk patients, we also excluded the patients with metastasis or patients treated with neoadjuvant chemotherapy, in this study.

Recently, several studies have confirmed that the fast-track surgery (FTS) protocol was feasible for gastric cancer patients who underwent open or laparoscopic surgery

Table 6 Univariate and multivariate analyses of factors associated with overall survival

	Univariate analysis			Multivariate analysis		
	HR	95% CI	*p* value	HR	95% CI	*p* value
Age (years)						
< 80	1.000					
≥ 80	1.293	0.802–2.084	0.292			
Sex						
Male	1.000					
Female	0.935	0.707–1.236	0.935			
BMI (kg/m^2)						
< 30	1.000					
≥ 30	0.799	0.377–1.691	0.557			
ASA						
< 3	1.000			1.000		
≥ 3	0.572	0.346–0.948	0.030	0.752	0.432–1.309	0.313
Number of high-risk factors						
1	1.000					
2	0.979	0.643–1.536				
3	0.424	0.557–4.018	0.725			
Previous abdominal surgery						
No	1.000					
Yes	0.923	0.639–1.333	0.670			
Charlson comorbidity index						
0	1.000					
1	1.174	0.899–1.533				
≥ 2	1.082	0.751–1.558	0.493			
Tumor diameter (mm)						
< 50	1.000			1.000		
≥ 50	3.058	2.264–4.133	< 0.001	2.011	1.458–2.775	< 0.001
Tumor location						
Upper	1.000			1.000		
Middle	0.776	0.558–1.078		0.744	0.533–1.040	
Lower	0.592	0.443–0.793		0.599	0.353–1.018	
Mixed	1.089	0.763–1.555	0.001	0.985	0.687–1.411	0.135
Pathological type						
Differentiated	1.000			1.000		
Undifferentiated	1.549	1.201–1.999	0.001	1.240	0.955–1.609	0.106
Adjuvant chemotherapy, *n* (%)						
No	1.000					
Yes	1.195	0.947–1.509	0.133			
pTNM						
I	1.000			1.000		
II	1.922	0.740–4.991		1.822	0.646–5.139	
III	6.952	2.868–16.855	< 0.001	5.038	1.839–13.805	< 0.001
cTNM						
I	1.000			1.000		
II	1.277	0.552–2.953		0.358	0.133–1.060	
III	2.156	0.958–4.854	< 0.001	0.410	0.153–1.096	0.105
Operative time (min)						
< 180	1.000			1.000		
≥ 180	1.707	1.267–2.301	< 0.001	1.274	0.913–1.778	0.154

Table 6 (continued)

	Univariate analysis			Multivariate analysis		
	HR	95% CI	*p* value	HR	95% CI	*p* value
Intraoperative blood loss (ml)						
< 50	1.000					
≥ 50	1.697	0.928-3.100	0.086			
Gastrectomy extent						
Total	1.000			1.000		
Distal	0.626	0.488–0.803		0.583	0.154–2.204	
Other	0.674	0.216–2.110	0.001	0.670	0.195–2.307	0.667
Reconstruction						
B-I	1.000			1.000		
B-II	0.505	0.371–0.688		1.700	0.474–6.106	
Roux-en-Y	1.029	0.732–1.447	< 0.001	2.623	0.722–9.527	0.071

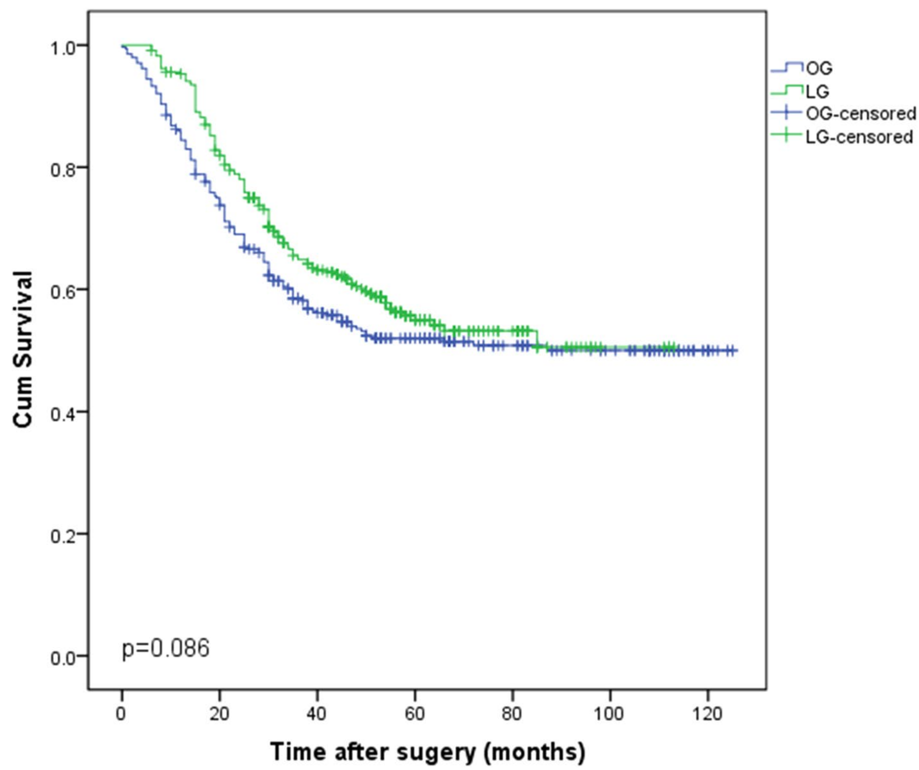

Fig. 2 Comparison of overall survival curves between the laparoscopic gastrectomy (LG) and open gastrectomy (OG) groups

[40–42]. However, research focused on the application of FTS for high-risk patients has not been reported. For the high-risk patients included in this study, we did not apply FTS. Therefore, we did not analyze whether these patients could benefit from FTS.

This study has the following limitations. First, this was a single-center study lacking external validation, and its results should, therefore, be confirmed by a multicenter prospective study. Second, this was a retrospective study that may have some bias. Third, this study did not analyze details about chemotherapy such as the number of chemotherapy program cycles and its impact on long-term survival. Nevertheless, this study used PSM to report a comparison of laparoscopic and open procedures in high-risk patients with gastric cancer for the first time and confirmed that the short-term efficacy of LG was better than that of OG and the long-term efficacy was comparable.

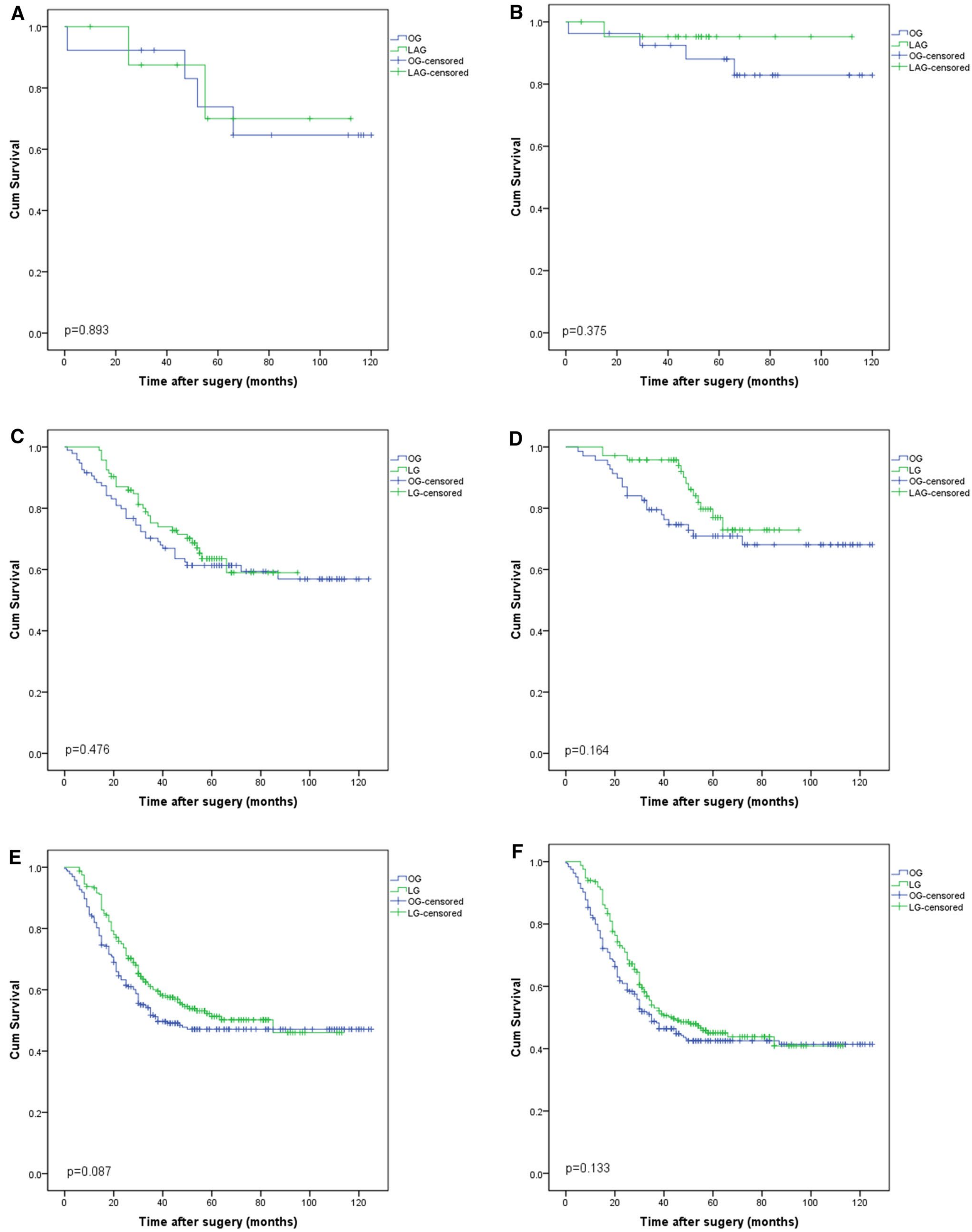

Fig. 3 Comparison of overall survival curves between the laparoscopic gastrectomy (LG) and open gastrectomy (OG) groups according to stage. **A** c stage I. **B** p stage (I). **C** c stage (II). **D** p stage II. **E** c stage (III). **F** p stage III

In conclusion, for high-risk patients with gastric cancer, LG not only has better short-term outcomes than OG but also results in comparable long-term survival. This study may help clinicians choose a reasonable surgical procedure for high-risk patients with gastric cancer.

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Compliance with ethical standards

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