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Risk factors for pulmonary complications following laparoscopic gastrectomy

A single-center study

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Abstract

The risk factors associated with postoperative pulmonary complications (PPCs) following laparoscopic gastrectomy have not been well studied. We sought to identify the risk factors for PPCs following gastric cancer surgery.

A retrospective analysis was performed on all gastric cancer patients in a prospective database who underwent a laparoscopic gastrectomy from 2004 to 2014. The potential risk factors for PPCs were evaluated.

PPCs occurred in 6.8% (83/1205) of patients and included pneumonia in 56 (67.5%) patients, pleural effusion in 26 (31.3%) patients, and pulmonary embolism in 1 (1.2%) patient. The multivariate analysis identified the following significant risk factors for PPCs: advanced age (odds ratio [OR] = 1.043, 95% confidence interval [CI] = 1.021%, 1.066%), chronic obstructive pulmonary disease (COPD) (OR = 17.788, 95% CI = 2.618%, 120.838%), total gastrectomy (OR = 2.781, 95% CI = 1.726%, 4.480%), time to first diet (OR = 1.175, 95% CI = 1.060%, 1.302%), and postoperative hospital stay (OR = 1.015, 95% CI = 1.002%, 1.028%). The risk factors for pneumonia included advanced age (OR = 1.036, 95% CI = 1.010%, 1.063%), total gastrectomy (OR = 3.420, 95% CI = 1.960%, 5.969%), and time to first diet (OR = 1.207, 95% CI = 1.703%, 1.358%). Only pancreatectomy was a risk factor for pleural effusion (OR = 9.082, 95% CI = 2.412%, 34.206%).

The frequency of PPCs in patients with gastric cancer who underwent laparoscopic surgery was relatively high. Patients with cardiac and pulmonary comorbidities and those who undergo total gastrectomy and combined resection should be considered at high risk.

Abbreviations: BMI = body mass index, CCI = Charlson Comorbidity Index, COPD = chronic obstructive pulmonary disease, ECOG = Easter Cooperative Oncology performance status, GC = gastric cancer, PPC = postoperative pulmonary complication, TNM = tumor node metastasis, UICC = Union for International Cancer Control.

Keywords: gastric cancer laparoscopic surgery, postoperative pulmonary complications

1. Introduction

Gastric cancer is one of the most frequent types of cancer and the most common cause of cancer-related deaths globally.[1,2] Within Asia, China has the highest incidence of advanced gastric cancer. Surgeons who perform minimally invasive laparoscopic techniques have been at the forefront of this area of medicine and have perfected the technique for gastric cancer resection. To date, radical gastrectomy with an effective D2 lymphadenectomy has remained the primary option for therapy.

Despite the advantages of minimally invasive surgery,[3] concerns have focused on improving postoperative outcomes. In gastric cancer patients undergoing laparoscopic gastrectomy surgery, postoperative pulmonary complications (PPCs) are a significant contributor to postoperative morbidity and mortality because healing of the affected wound is closely related to tissue hypoxia.[4–6] However, most studies have focused on general complications, which have their own criteria, and postoperative complications remain a clinically relevant issue.[7] PPCs are most common after upper abdominal surgery, including laparoscopic gastrectomy. Pulmonary function decreases because of reduced diaphragmatic activity and microatelectasis, which may lead to PPCs.

PPCs have become increasingly common adverse events; therefore, the identification and mitigation of perioperative risk factors in patients undergoing laparoscopic gastrectomy surgery for gastric cancer should enable further improvements in outcomes and decrease the length of hospital stay. To date, no studies have been published that have examined the incidence of PPCs in gastric cancer patients who have undergone laparoscopic surgery.

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The purpose of this study was to identify the risk factors for postoperative PCCs in patients with gastric cancer who undergo laparoscopic surgery.

2. Methods

2.1. Data collection

We identified all patients who underwent laparoscopic gastrectomy surgery for gastric cancer between January 2004 and December 2014, which included 1205 patients in the Department of General Surgery, Nanfang Hospital. The inclusion criteria consisted of analyzed PPC events that occurred following elective laparoscopic gastrectomy surgery. Data regarding patient demographics, clinicopathological characteristics, extent of lymph node (D1+ or D2) involvement, type of surgery, and intraoperative and postoperative outcomes were prospectively obtained from our departmental database and retrospectively analyzed with a focus on specific factors that might influence the risk of PCCs. We excluded patients who underwent laparoscopic exploration because of peritoneal dissemination and those who exhibited either unresectable disease or distant adjuvant organ invasion. We also excluded patients who underwent open laparotomy surgery and those younger than 18 years. All patients provided written informed consent. The study was approved by the ethics committee of Nanfang Hospital.

All laparoscopic gastrectomy resections and lymph node dissections were performed according to Japanese guidelines.[8] TNM staging was conducted according to the American Joint Committee on Cancer, 7th edition, which was in accordance with the UICC classification.[9] Patients with pathological stages II, III, and IV disease received postoperative chemotherapy.

Postoperative morbidity and mortality were based on any events, complications, or deaths that occurred during the first 30 days following surgery. All postoperative adverse events were recorded and classified according to the Clavien–Dindo classification of severity.[10]

2.2. Data analysis

Investigated data included age, sex, body mass index (BMI), Charlson Comorbidity Index (CCI), Easter Cooperative Oncology performance status (ECOG), comorbidities, TNM stage, pathological stage, surgical procedure, lymph node dissection, operative time, additional procedures, estimated blood loss, intraoperative complications, and postoperative outcomes.

2.3. Definition and evaluation of PPCs

PPCs and adverse events were recorded postoperatively in all patients and were defined as the development of pneumonia, pleural effusion, or pulmonary embolism within 30 days after laparoscopic gastrectomy surgery.

Pneumonia was defined based on the signs and symptoms of PPCs (shortness of breath, cough, chest pain, and fever); blood tests and x-ray or CT scans were used to confirm the diagnosis of pneumonia.[11,12] Blood tests or x-rays were used for clinical evaluation before discharge (postoperative day 7–9).

Pleural effusion was defined as evidence of excessive fluid in the pleural space in the absence of clinical symptoms associated with abnormal findings detected by a simple chest radiography examination that required percutaneous intervention.

Pulmonary embolism was defined as the presence of clinical chest pain or blood gas abnormalities detected by simple chest radiography or a CT scan.

2.4. Statistical analysis

Data are expressed as means ± standard deviations, medians (quartile ranges), or frequencies (percentages). The Pearson χ^2 test, Fishere exact test, Student t test, and the Mann-Whitney U test were used for statistical analyses. Both univariate and multivariate logistic regression models were used to generate odds ratios (ORs). A value of $P < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS software (SPSS version 20.0; IBM, Inc, Chicago, IL).

3. Results

3.1. Patient demographics

We identified all patients who underwent a laparoscopic gastrectomy for treatment of gastric cancer between January 2004 and December 2014, which included 1205 patients in the Department of General Surgery, Nanfang Hospital. Data regarding patient demographics, clinicopathological characteristics, and preoperative and intraoperative variables were prospectively collected and retrospectively analyzed. The subjects included 822 men (68.2%) and 383 women (31.8%), with a mean age of 55 ± 12 years. Nineteen (1.6%) patients had congestive heart failure (CHF), and 5 (0.4%) had preexisting chronic obstructive pulmonary disease (COPD) before surgery. No significant differences were observed among the 2 groups with respect to BMI, CCI, ECOG, lymph node dissection, estimated blood loss, and intraoperative transfusion. The distribution of PPCs is shown in Table 1.

3.2. PPCs and postoperative outcomes

Eighty-three (6.8%) patients exhibited PCCs, and the types of complications were significantly different. Several risk factors that were strongly associated with PPCs are shown in Table 2. The most common complication experienced by the majority of our patients was pneumonia (67.5%, 56/83 patients), followed by pleural effusion (31.3%, 26/83 patients) and pulmonary embolism (1.2%, 1/83 patients).

Table 3 summarizes the postoperative morbidity and mortality. Overall, 27.7% of patients experienced PPCs and 11.5% experienced non-PPCs ($P < 0.001$). Significant differences were found for renal complications (4.8% vs 0.9%, $P = 0.007$), hepatic complications (4.8% vs 1.2%, $P = 0.025$), intra-abdominal abscesses (8.4% vs 2.5%, $P = 0.006$), and abdominal bleeding (6.0% vs 0.9%, $P < 0.001$) in patients with and without PPCs. One death occurred (0.1%) during hospitalization in

Table 1

Frequency table for three PPC subtypes.

	Frequency	Percentage
PPCs	83	100.0
Pneumonia	56	67.5
Pleural effusion	26	31.3
Pulmonary embolism	1	1.2

PPCs = postoperative pulmonary complications.

Table 2

Univariate and multivariate analyses of the risk factors for PPCs.

Variables	Non-PPCs (n=1122)	PPCs (n=83)	Univariate		Multivariate	
			OR (95% CI)	*P*	OR (95% CI)	*P*
Sex, n (%)						
Male	759 (67.6)	63 (75.9)	Ref			
Female	363 (32.4)	20 (24.1)	0.664 (0.395, 1.115)	0.121		
Age, y*	55.51±11.80	60.84±10.97	1.042 (1.021, 1.064)	<0.001	1.043 (1.021, 1.066)	<0.001
BMI, kg/m^{2}*	21.77±3.09	22.37±3.25	1.062 (0.978, 1.154)	0.153		
CCI, n (%)						
0	848 (75.8)	56 (67.5)	Ref			
1	243 (21.7)	24 (28.9)	1.496 (0.908, 2.463)	0.114		
2	26 (2.3)	3 (3.6)	1.747 (0.513, 5.950)	0.372		
3	1 (0.1)	0 (0.0)	—	1.000		
ECOG, n (%)						
0	20 (1.8)	1 (1.2)	Ref			
1	776 (69.2)	55 (66.3)	1.418 (0.187, 10.760)	0.736		
2	232 (20.7)	18 (21.7)	1.552 (0.197, 12.234)	0.677		
3	62 (5.5)	6 (7.2)	1.935 (0.220, 17.057)	0.552		
4	32 (2.9)	3 (3.6)	1.875 (0.182, 19.293)	0.597		
Comorbidities n (%)						
Diabetes	43 (3.8)	5 (6.0)	1.609 (0.619, 4.177)	0.329		
Hypertension	132 (11.8)	14 (16.9)	1.522 (0.833, 2.780)	0.172		
CHF	15 (1.3)	4 (4.8)	3.737 (1.212, 11.525)	0.022		
Severe arrhythmia	2 (0.2)	0 (0.0)	—	0.999		
COPD	3 (0.3)	2 (2.4)	9.210 (1.517, 55.904)	0.016	17.788 (2.618, 120.838)	0.003
Asthma	3 (0.3)	0 (0.0)	—	0.999		
Other†	116 (10.3)	9 (10.8)	1.055 (0.514, 2.163)	0.884		
Lymph node dissection, n (%)‡						
D1 or D1+	26 (2.5)	1 (1.3)	Ref			
D2	1035 (97.5)	77 (98.7)	1.934 (0.259, 14.446)	0.520		
Tumor size, mm§	35.0 (25.0, 50.0)	40.0 (28.5,52.5)	1.007 (0.997, 1.017)	0.174		
Type of operation, n (%)						
Subtotal gastrectomy	820 (73.1)	42 (50.6)	Ref		ref	
Total gastrectomy	302 (26.9)	41 (49.4)	2.651 (1.690, 4.157)	<0.001	2.781 (1.726, 4.480)	<0.001
Operative time, min, n (%)						
<200	650 (58.0)	37 (44.6)	Ref			
≥200	471 (42.0)	46 (55.4)	1.716 (1.095, 2.688)	0.018		
Combined resection, n (%)						
Splenectomy	25 (2.2)	3 (3.6)	1.645 (0.486, 5.567)	0.423		
Pancreatectomy	16 (1.4)	4 (4.8)	3.500 (1.143, 10.718)	0.028		
Estimated blood loss, mL, n (%)						
<100	282 (25.5)	16 (19.3)	Ref			
≥100	826 (74.5)	67 (80.7)	1.430 (0.815, 2.508)	0.212		
T stage, n (%)						
T0	2 (0.2)	0 (0.0)	—	0.999		
T1	200 (18.8)	11 (13.6)	0.689 (0.353, 1.342)	0.273		
T2	113 (10.6)	9 (11.1)	0.997 (0.479, 2.076)	0.994		
T3	75 (7.0)	7 (8.6)	1.168 (0.513, 2.660)	0.711		
T4	676 (63.4)	54 (66.7)	Ref			
N stage, n (%)						
N0	437 (40.9)	33 (40.2)	Ref			
N1	195 (18.2)	7 (8.5)	0.475 (0.207, 1.093)	0.080		
N2	217 (20.3)	17 (20.7)	1.037 (0.565, 1.904)	0.906		
N3	220 (20.6)	25 (30.5)	1.505 (0.873, 2.594)	0.141		
M stage, n (%)						
M0	1063 (99.2)	82 (100.0)	Ref			
M1	9 (0.8)	0 (0.0)	—	0.999		
TNM stage, n (%)‖						
IA	151 (14.4)	11 (13.6)	Ref			
IB	82 (7.8)	2 (2.5)	0.335 (0.072, 1.547)	0.161		
IIA	60 (5.7)	7 (8.6)	1.602 (0.593, 4.326)	0.353		
IIB	207 (19.7)	15 (18.5)	0.995 (0.444, 2.227)	0.990		
IIIA	159 (15.1)	6 (7.4)	0.518 (0.187, 1.436)	0.206		
IIIB	174 (16.6)	14 (17.3)	1.104 (0.487, 2.506)	0.812		

Variables	Non-PPCs (n = 1122)	PPCs (n = 83)	Univariate		Multivariate	
			OR (95% CI)	P	OR (95% CI)	P
IIIC	189 (18.0)	24 (29.6)	1.743 (0.828, 3.672)	0.144		
IV	28 (2.7)	2 (2.5)	0.981 (0.206, 4.665)	0.980		
Time to first diet, d[§]	5.0 (4.0, 6.0)	5.0 (4.0, 7.0)	1.153 (1.047, 1.270)	0.004	1.175 (1.060, 1.302)	0.002
Postoperative hospital stay, d[§]	10.0 (8.0, 12.0)	12.0 (10.0, 17.0)	1.016 (1.000, 1.031)	0.045	1.015 (1.002, 1.028)	0.022

BMI = body mass index, CCI = Charlson Comorbidity Index, CHF = congestive heart failure, CI = confidence interval, COPD = chronic obstructive pulmonary disease, ECOG = Eastern Cooperative oncology group, OR = odds ratio, PPC = postoperative pulmonary complication.
[*] Values are shown as the mean (standard deviations).
[†] One patient had >1 complication.
[‡] According to the treatment guidelines issued by the Japanese Cancer Association.
[§] Values are shown as medians (interquartile ranges).
[||] American Joint Committee on Cancer classification system.

the non-PPC group, but no significant difference was observed between the 2 groups.

Table 4 shows the complications in patients with pneumonia (23.2%) compared to patients without pneumonia (12.1%) ($P = 0.014$). Abdominal bleeding was more common in the pneumonia group (5.4% vs 1.0%, $P = 0.026$). Postoperative outcomes for patients with pleural effusion are shown in Table 5, and the overall complication rate was significantly different between patients with and without pleural effusion (38.5% vs 12.0%, $P < 0.001$). Renal complications (7.7% vs 1.8%, $P = 0.035$), hepatic complications (7.7% vs 1.3%, $P = 0.050$), and abdominal bleeding (7.7% vs 1.1%, $P = 0.040$) exhibited significant differences between patients with and without pleural effusion.

3.3. Risk factors related to PPCs

The types of risk factors in our study were diverse. After both univariate and multivariate analyses were conducted, advanced age (>60 years), preexisting CHF, preexisting COPD, the operative method (laparoscopic total gastrectomy), prolonged surgery (≥200 min), additional procedures (pancreatectomy), time to first diet, and postoperative hospital stay were identified as risk factors for PPCs (Table 2). The multivariate logistic regression model determined 5 independent risk factors for PPCs, including advanced age (OR = 1.043, 95% confidence interval [CI] = 1.021%, 1.066%; $P < 0.001$), preexisting COPD (OR = 17.788, 95% CI = 2.618%, 120.838%; $P = 0.003$), operative method (total gastrectomy) (OR = 2.781, 95% CI = 1.726%, 4.480%; $P < 0.001$), time to first diet (OR = 1.175, 95% CI = 1.060%, 1.302%; $P = 0.002$), and postoperative hospital stay (OR = 1.015, 95% CI = 1.002%, 1.028%; $P = 0.022$).

Table 6 summarizes the results of both the univariate and multivariate analyses of the risk factors for pneumonia. Advanced age, operative method (laparoscopic total gastrectomy), and time to first diet were significant risk factors associated with pneumonia according to the univariate analysis. Three

Table 3

Postoperative complications of the PPC group.

	PPCs	Non-PPCs	χ^2	P
Postoperative morbidity[*]	23 (27.7)	129 (11.5)	18.431	<0.001
Postoperative complications				
Wound complication	3 (3.6)	20 (1.8)	0.580	0.446
Ileus	4 (4.8)	26 (2.3)	1.095	0.295
Renal complications	4 (4.8)	10 (0.9)	7.245	0.007
Gastroparesis	0 (0.0)	8 (0.7)	0.005	0.943
Cholecystitis[†]	0 (0.0)	2 (0.2)		1.000
Pancreatic fistula	2 (2.4)	4 (0.4)	3.084	0.079
Cardiac complications	2 (2.4)	4 (0.4)	3.084	0.079
Hepatic complications	4 (4.8)	13 (1.2)	5.046	0.025
Lymphatic leakage	2 (2.4)	18 (1.6)	0.012	0.913
Intra-abdominal abscess	7 (8.4)	28 (2.5)	7.672	0.006
Anastomotic leakage[†]	1 (1.2)	3 (0.3)		0.249
Abdominal bleeding	5 (6.0)	10 (0.9)	12.651	<0.001
Deep vein thrombosis[†]	0 (0.0)	2 (0.2)		1.000
Cerebrovascular complications[†]	0 (0.0)	1 (0.1)		1.000
Clavien–Dindo classification				
Grade I	11 (13.3)	55 (4.9)	8.860	0.003
Grade II	9 (10.8)	46 (4.1)	6.594	0.010
Grade IIIa	7 (8.4)	29 (2.6)	7.216	0.007
Grade IIIb	5 (6.0)	10 (0.9)	12.651	<0.001
Grade IV[†]	0 (0.0)	3 (0.3)		1.000
30-Day mortality[†]	0 (0.0)	1 (0.1)		1.000

PPC = postoperative pulmonary complication.
[*] One patient had >1 complication.
[†] Fisher exact test.

Table 4

Postoperative complications in the pneumonia group.

	Pneumonia	Non-pneumonia	χ^2	P
Postoperative morbidity*	13 (23.2)	139 (12.1)	5.987	0.014
Postoperative complications				
Wound complication	1 (1.8)	22 (1.9)	0.000	1.000
Ileus	2 (3.6)	28 (2.4)	0.009	0.926
Renal complications	2 (3.6)	12 (1.0)	1.177	0.278
Gastroparesis	0 (0.0)	8 (0.7)	0.000	1.000
Cholecystitis†	0 (0.0)	2 (0.2)		1.000
Pancreatic fistula	1 (1.8)	5 (0.4)	0.185	0.667
Cardiac complications	1 (1.8)	5 (0.4)	0.185	0.667
Hepatic complications	2 (3.6)	15 (1.3)	0.679	0.410
Lymphatic leakage	2 (3.6)	18 (1.6)	0.373	0.541
Intra-abdominal abscess	4 (7.1)	31 (2.7)	2.331	0.127
Anastomotic leakage†	0 (0.0)	4 (0.3)		1.000
Abdominal bleeding	3 (5.4)	12 (1.0)	4.952	0.026
Deep vein thrombosis†	0 (0.0)	2 (0.2)		1.000
Cerebrovascular complications†	0 (0.0)	1 (0.1)		1.000

* One patient had >1 complication.

† Fisher exact test; according to Clavien–Dindo classification.

predictive risk factors for pneumonia were identified in the multivariate logistic analysis, including advanced age (OR = 1.033, 95% CI = 1.008%, 1.059%; $P = 0.010$), total gastrectomy (OR = 3.420, 95% CI = 1.960%, 5.969%; $P < 0.001$), and time to first oral diet (OR = 1.207, 95% CI = 1.073%, 1.358%; $P = 0.002$).

Table 7 summarizes the results of the univariate and multivariate analyses of risk factors for pleural effusion, which identified advanced age, preexisting CHF, preexisting COPD, prolonged surgery (>200 min), and combined resection (splenectomy and pancreatectomy) as risk factors. The predictive risk factors for pleural effusion identified in the multivariate logistic analysis included advanced age (OR = 1.052, 95% CI = 1.013%, 1.091%; $P = 0.008$), pre-existing COPD (OR = 31.953, 95% CI = 4.842%, 210.862%; $P < 0.001$), and additional pancreatectomy (OR = 9.082, 95% CI = 2.412%, 34.206%; $P = 0.001$).

4. Discussion

In this study, we focused on PCCs in gastric cancer patients, and we identified several risk factors for PPCs following a laparoscopic gastrectomy, including advanced age, preexisting COPD, total gastrectomy, time to first oral diet, and length of hospital stay. Our study is important because we determined the incidence of PPCs (6.8%) and revealed the correlated risk factors for PPCs in gastric cancer patients following laparoscopic gastrectomy. Some of the risk factors that we identified are preventable. PPCs increase morbidity and mortality.[13] Multiple

Table 5

Postoperative complications of the pleural effusion group.

	Pleural effusion	Nonpleural effusion	χ^2	P
Postoperative morbidity*	10 (38.5)	142 (12.0)	13.798	<0.001
Postoperative complications				
Wound complications†	2 (7.7)	21 (1.8)		0.086
Ileus†	2 (7.7)	28 (2.4)		0.135
Renal complications†	2 (7.7)	12 (1.0)		0.035
Gastroparesis†	0 (0.0)	8 (0.7)		1.000
Cholecystitis†	0 (0.0)	2 (0.2)		1.000
Pancreatic fistula†	1 (3.8)	5 (0.4)		0.123
Cardiac complications†	1 (3.8)	5 (0.4)		0.123
Hepatic complications†	2 (7.7)	15 (1.3)		0.050
Lymphatic leakage†	0 (0.0)	20 (1.7)		1.000
Intra-abdominal abscess†	3 (11.5)	32 (2.7)		0.037
Anastomotic leakage†	1 (3.8)	3 (0.3)		0.084
Abdominal bleeding†	2 (7.7)	13 (1.1)		0.040
Deep vein thrombosis†	0 (0.0)	2 (0.2)		1.000
Cerebrovascular complications†	0 (0.0)	1 (0.1)		1.000

* One patient had >1 complication.

† Fisher exact test; according to Clavien–Dindo classification.

Table 6

Univariate and multivariate analyses of the risk factors for pneumonia.

Variables	Non-pneumonia (n = 1149)	Pneumonia (n = 56)	Univariate		Multivariate	
			OR (95% CI)	*P*	OR (95% CI)	*P*
Sex, n (%)						
Male	779 (67.8)	43 (76.8)	Ref			
Female	370 (32.2)	13 (23.2)	0.637 (0.338, 1.198)	0.162		
Age, y*	55.68 ± 11.78	59.93 ± 11.98	1.033 (1.008, 1.058)	0.009	1.033 (1.008, 1.059)	0.010
BMI, kg/m^{2}*	21.78 ± 3.09	22.36 ± 3.44	1.060 (0.957, 1.174)	0.267		
CCI, n (%)						
0	868 (75.8)	36 (64.3)	Ref			
1	249 (21.7)	18 (32.1)	1.743 (0.973, 3.123)	0.062		
2	27 (2.4)	2 (3.6)	1.786 (0.409, 7.803)	0.441		
3	1 (0.1)	0 (0.0)	—	1.000		
ECOG, n (%)						
0	20 (1.7)	1 (1.8)	Ref			
1	793 (69.0)	38 (67.9)	0.958 (0.125, 7.331)	0.967		
2	237 (20.6)	13 (23.2)	1.097 (0.136, 8.821)	0.931		
3	65 (5.7)	3 (5.4)	0.923 (0.091, 9.374)	0.946		
4	34 (3.0)	1 (1.8)	0.588 (0.035, 9.931)	0.713		
Comorbidities, n (%)						
Diabetes	44 (3.8)	4 (7.1)	1.932 (0.669, 5.580)	0.224		
Hypertension	135 (11.7)	11 (19.6)	1.836 (0.927, 3.636)	0.081		
CHF	17 (1.5)	2 (3.6)	2.466 (0.556, 10.947)	0.235		
Severe arrhythmia	2 (0.2)	0 (0.0)	—	0.999		
COPD	5 (0.4)	0 (0.0)	—	0.999		
Asthma	3 (0.3)	0 (0.0)	—	0.999		
Other†	118 (10.3)	7 (12.5)	1.248 (0.553, 2.819)	0.594		
Lymph node dissection, n (%)‡						
D1 or D1+	27 (2.5)	0 (0.0)	—	0.998		
D2	1060 (97.5)	52 (100.0)	Ref			
Tumor size (mm)§	35.0 (25.0, 50.0)	40.0 (26.5, 55.0)	1.006 (0.993, 1.018)	0.383		
Type of operation, n (%)						
Subtotal gastrectomy	837 (72.8)	25 (44.6)	Ref		ref	
Total gastrectomy	312 (27.2)	31 (55.4)	3.327 (1.933, 5.724)	<0.001	3.420 (1.960, 5.969)	<0.001
Operative time, min, n (%)						
<200	660 (57.5)	27 (48.2)	Ref			
≥200	488 (42.5)	29 (51.8)	1.453 (0.849, 2.485)	0.173		
Combined resection n (%)						
Splenectomy	28 (2.4)	0 (0.0)	—	0.998		
Pancreatectomy	19 (1.7)	1 (1.8)	1.081 (0.142, 8.225)	0.940		
Estimated blood loss, mL, n (%)						
<100	286 (25.2)	12 (21.4)	Ref			
≥100	849 (74.8)	44 (78.6)	1.235 (0.643, 2.371)	0.526		
T stage, n (%)						
T0	2 (0.2)	0 (0.0)	—	0.999		
T1	203 (18.6)	8 (14.8)	0.760 (0.348, 1.660)	0.491		
T2	117 (10.7)	5 (9.3)	0.824 (0.317, 2.142)	0.691		
T3	77 (7.0)	5 (9.3)	1.252 (0.477, 3.284)	0.648		
T4	694 (63.5)	36 (66.7)	Ref			
N stage, n (%)						
N0	447 (40.8)	23 (41.8)	Ref			
N1	196 (17.9)	6 (10.9)	0.595 (0.239, 1.484)	0.265		
N2	225 (20.5)	9 (16.4)	0.777 (0.354, 1.708)	0.531		
N3	228 (20.8)	17 (30.9)	1.449 (0.759, 2.767)	0.261		
M stage, n (%)						
M0	1090 (99.2)	55 (100.0)	Ref			
M1	9 (0.8)	0 (0.0)	—	0.999		
TNM stage, n (%)‖						
IA	154 (14.3)	8 (14.8)	Ref			
IB	84 (7.8)	0 (0.0)	—	0.997		
IIA	61 (5.7)	6 (11.1)	1.893 (0.631, 5.684)	0.255		
IIB	212 (19.7)	10 (18.5)	0.908 (0.350, 2.354)	0.843		
IIIA	160 (14.9)	5 (9.3)	0.602 (0.193, 1.879)	0.382		
IIIB	179 (16.6)	9 (16.7)	0.968 (0.365, 2.570)	0.948		
IIIC	199 (18.5)	14 (25.9)	1.354 (0.554, 3.310)	0.506		
IV	28 (2.6)	2 (3.7)	1.375 (0.277, 6.817)	0.697		

Variables	Non-pneumonia (n = 1149)	Pneumonia (n = 56)	Univariate OR (95% CI)	Univariate P	Multivariate OR (95% CI)	Multivariate P
Time to first diet, d[§]	5.0 (4.0, 6.0)	5.0 (4.0, 7.8)	1.190 (1.063, 1.333)	0.003	1.207 (1.073, 1.358)	0.002
Postoperative hospital stay, d[§]	10.0 (8.0, 12.0)	12.0 (10.0, 17.0)	1.012 (0.999, 1.026)	0.067		

MI = body mass index, CCI = Charlson Comorbidity Index, CHF = congestive heart failure, CI = confidence interval, COPD = chronic obstructive pulmonary disease, ECOG = Eastern Cooperative Oncology Group, OR = odds ratio.

[*] Values are shown as means (standard deviations)

[†] One patient had >1 complication.

[‡] According to the treatment guidelines issued by the Japanese Cancer Association.

[§] Values are shown as medians (interquartile ranges).

[||] American Joint Committee on Cancer classification system.

risk factors have been closely correlated with the development and incidence of PPCs.[14]

In our retrospective study, we emphasized the definition of each PCC in gastric cancer patients who underwent laparoscopic surgery and categorized the different complications to assess the risk factors. We also demonstrated that significant predictors vary among types of complications. Many types of PCCs have been correlated with a longer postoperative hospital stay. Therefore, the prevention of PPCs following laparoscopic gastrectomy for gastric cancer may decrease both the morbidity rate and healthcare costs.

Several studies in the literature have evaluated the incidence of morbidity and mortality or postoperative outcomes following gastric cancer surgery in general and have compared open and laparoscopic approaches, with all complications included in these analyses. Although these studies analyzed specific postoperative outcomes,[15–18] to our knowledge, no previous study has specifically examined the incidence of PCCs and the risk factors associated with laparoscopic gastrectomy surgery for gastric cancer. These critical gaps suggest the need for a specific analysis focused on laparoscopic gastrectomy with respect to PPCs because the risk factors cannot be determined based on other studies that have focused on other types of upper abdominal surgery.[6,19,20] Moreover, significant heterogeneity is present in the existing literature regarding the definition of PPCs. Therefore, our study identified the risk factors for PPCs, including infection (pneumonia), abnormal complications (pleural effusion), and thromboembolic complications (pulmonary embolism). We also investigated various preoperative, intraoperative, and postoperative risk factors that may lead to the development of PPCs.

Advanced age was identified as a risk factor for PPCs in previous studies.[21–23] The results of our study revealed advanced age as a predictive risk factor related to PCCs and morbidity following laparoscopic gastrectomy. This finding is similar to and corroborates previous studies that have found increased age to be a risk factor for the development of PCCs.[24,25] However, in our study, the probability of developing PCCs was high in older individuals (60 years) and in individuals with preexisting cardiopulmonary disease. The factors that might influence and lead to poorer outcomes in some older groups of individuals may be correlated with the presence and incidence of COPD comorbidity and significant postoperative complications in this group of patients.

Patients with COPD have a greater risk of developing atelectasis, pneumonia, bronchitis, and fever during the postoperative period.[26] Several studies have reported that comorbidities, such as COPD, increase the risk of perioperative PCCs.[20,27] In our study, the multivariate analysis identified preexisting COPD as a risk factor associated with an increased prevalence of PPCs. This finding is consistent with previous studies.[28,29] Sex, ECOG performance status, and the CCI measurements did not affect the development of PPCs. Among other patient characteristics, BMI was not a risk factor, which is inconsistent with the existing literature.[20,30] Mitigation strategies should focus on the refinement of patient selection and the improvement of outcomes in patients with a preexisting cardiopulmonary status in this group of high-risk patients.

The results of our study also indicate that a longer operative time and the type of operative procedure were predictive risk factors for the development of PCCs. Both factors might lead to patients developing significant morbidity and undergoing longer hospitalization. In addition, both factors might have a strong relationship with tumor stage or other complications, such as bleeding. We also analyzed the TNM stage of the tumor to determine whether these factors increase the risk of PCCs, and we found no correlations. We aimed to determine whether a prolonged operative time would increase the risk of PPC development. It is notable that surgeries lasting >3 hours are correlated with a likelihood of PPCs,[31,32] and the results of our study showed that this is a risk factor. These findings are consistent with the existing literature, which identifies prolonged surgery as a risk factor for PPCs.[31,32] We believe this might be because of the complexity of the surgical procedure, tumor size, and complex anatomy of the abdomen.

Our study found that patients with gastric cancer, particularly those who underwent laparoscopic total gastrectomy, had more risk factors for developing PPCs and a longer operative time than those who underwent a subtotal gastrectomy. This finding is similar to the results reported by Papenfuss et al,[33] who showed that a total gastrectomy carries significant morbidity and is related to a long operative time. In addition to the magnitude of the operation itself, resection around the esophagus might be a risk factor for PPCs. However, we did not identify a difference between laparoscopic and laparotomy procedures because that was not the intent of our study, and all patients in this study underwent laparoscopic surgery. Studies have not indicated a consensus regarding the advantages of laparoscopic approaches in terms of PPCs. Laparoscopic approaches have several advantages, including less operative pain, faster recovery, reduction in direct trauma to the respiratory muscles, and better short-term quality of life than open gastrectomy[34,35]; however, preoperative PCCs have been shown to be related to increased pneumoperitoneum, which significantly affects respiratory pressure and pulmonary resistance.[14,36–38] In our study, the univariate analysis indicated that patients who underwent a laparoscopic gastrectomy with an additional procedure had an increased risk of PPCs, and this finding is supported by previous studies.[39,40] Attention should be paid to the surgical technique and patients who require additional resections because it is known that these are significant risk factors that could negatively influence patient management, particularly for those who require

Table 7

Univariate and multivariate analyses of the risk factors for pleural effusion.

Variables	Non-pleural effusion (n = 1179)	Pleural effusion (n = 26)	Univariate		Multivariate	
			OR (95% CI)	*P*	OR (95% CI)	*P*
Sex, n (%)						
Male	803 (68.1)	19 (73.1)	Ref			
Female	376 (31.9)	7 (26.9)	0.787 (0.328, 1.888)	0.591		
Age, y*	55.74 ± 11.85	62.19 ± 8.04	1.053 (1.015, 1.092)	0.006	1.052 (1.013, 1.091)	0.008
BMI, kg/m^{2}*	21.80 ± 3.10	22.32 ± 3.03	1.054 (0.919, 1.210)	0.453		
CCI, n (%)						
0	884 (75.2)	20 (76.9)	Ref			
1	261 (22.2)	6 (23.1)	1.016 (0.404, 2.557)	0.973		
2	29 (2.5)	0 (0.0)	—	0.998		
3	1 (0.1)	0 (0.0)	—	1.000		
ECOG, n (%)						
0	21 (1.8)	0 (0.0)	—	0.998		
1	814 (69.0)	17 (65.4)	0.345 (0.076, 1.554)	0.166		
2	246 (20.9)	4 (15.4)	0.268 (0.047, 1.522)	0.137		
3	65 (5.5)	3 (11.5)	0.762 (0.121, 4.783)	0.771		
4	33 (2.8)	2 (7.7)	Ref			
Comorbidities, n (%)						
Diabetes	47 (4.0)	1 (3.8)	0.963 (0.128, 7.262)	0.971		
Hypertension	143 (12.1)	3 (11.5)	0.945 (0.280, 3.187)	0.927		
CHF	17 (1.4)	2 (7.7)	5.696 (1.246, 26.041)	0.025		
Severe arrhythmia	2 (0.2)	0 (0.0)	—	1.000		
COPD	3 (0.3)	2 (7.7)	32.667 (5.218, 204.512)	<0.001	31.953 (4.842, 210.862)	<0.001
Asthma	3 (0.3)	0 (0.0)	—	0.999		
Other†	124 (10.5)	1 (3.8)	0.340 (0.046, 2.533)	0.293		
Lymph node dissection, n (%)‡						
D1 or D1+	26 (2.3)	1 (4.0)	Ref			
D2	1088 (97.7)	24 (96.0)	0.574 (0.075, 4.401)	0.593		
Tumor size, mm§	35.0 (25.0, 50.0)	40.0 (30.0, 52.5)	1.010 (0.993, 1.027)	0.256		
Type of operation, n (%)						
Subtotal gastrectomy	333 (28.2)	10 (38.5)	Ref			
Total gastrectomy	846 (71.8)	16 (61.5)	1.588 (0.713, 3.534)	0.257		
Operative time, min, n (%)						
<200	678 (57.6)	9 (34.6)	Ref			
≥200	500 (42.4)	17 (65.4)	2.561 (1.132, 5.793)	0.024		
Combined resection, n (%)						
Splenectomy	25 (2.1)	3 (11.5)	6.021 (1.696, 21.368)	0.005		
Pancreatectomy	17 (1.4)	3 (11.5)	8.916 (2.442, 32.548)	0.001	9.082 (2.412, 34.206)	0.001
Estimated blood loss, mL, n (%)						
<100	295 (25.3)	3 (11.5)	Ref			
≥100	870 (74.7)	23 (88.5)	2.600 (0.775, 8.721)	0.122		
T stage, n (%)						
T0	2 (0.2)	0 (0.0)	—	1.000		
T1	209 (18.6)	2 (7.7)	0.379 (0.087, 1.645)	0.195		
T2	118 (10.5)	4 (15.4)	1.341 (0.446, 4.031)	0.601		
T3	80 (7.1)	2 (7.7)	0.989 (0.225, 4.340)	0.988		
T4	712 (63.5)	18 (69.2)	Ref			
N stage, n (%)						
N0	461 (41.0)	9 (34.6)	Ref			
N1	201 (17.9)	1 (3.8)	0.255 (0.032, 2.025)	0.196		
N2	226 (20.1)	8 (30.8)	1.813 (0.690, 4.762)	0.227		
N3	237 (21.1)	8 (30.8)	1.729 (0.659, 4.539)	0.266		
M stage, n (%)						
M0	1119 (99.2)	26 (100.0)	Ref			
M1	9 (0.8)	0 (0.0)	—	0.999		
TNM stage, n (%)‖						
IA	160 (14.5)	2 (7.7)	Ref			
IB	82 (7.4)	2 (7.7)	1.951 (0.270, 14.103)	0.508		
IIA	66 (6.0)	1 (3.8)	1.212 (0.108, 13.598)	0.876		
IIB	217 (19.6)	5 (19.2)	1.843 (0.353, 9.622)	0.468		
IIIA	164 (14.8)	1 (3.8)	0.488 (0.044, 5.433)	0.559		
IIIB	183 (16.6)	5 (19.2)	2.186 (0.418, 11.421)	0.354		
IIIC	203 (18.4)	10 (38.5)	3.941 (0.851, 18.241)	0.079		

Variables	Non-pleural effusion (n = 1179)	Pleural effusion (n = 26)	Univariate		Multivariate	
			OR (95% CI)	P	OR (95% CI)	P
IV	30 (2.7)	0 (0.0)	—	0.998		
Time to first diet, d[§]	5.0 (4.0, 6.0)	4.5 (3.0, 7.0)	1.011 (0.997, 1.026)	0.122		
Postoperative hospital stay, d[§]	10.0 (8.0, 12.0)	13.0 (9.5, 17.5)	1.062 (0.894, 1.261)	0.495		

BMI = body mass index, CCI = Charlson Comorbidity Index, CHF = congestive heart failure, CI = confidence interval, COPD = chronic obstructive pulmonary disease, ECOG = Eastern Cooperative Oncology Group, OR = odds ratio.

[*] Values are shown as means (standard deviations).

[†] One patient had >1 complication.

[‡] According to the treatment guidelines issued by the Japanese Cancer Association.

[§] Values are shown as medians (interquartile ranges).

[||] American Joint Committee on Cancer classification system.

chemotherapy. We should address these issues to minimize their potential negative impact on patients.

Importantly, we found that the time to first diet was a predictive risk factor for PPC development. It has been noted that patients who undergo laparoscopic gastrectomy surgery have nutritional difficulties. Therefore, attention should focus on optimizing the nutritional status of these patients both before and after surgery.

We examined the length of the hospital stay as an independent risk factor, and the multivariate analysis indicated that it was a risk factor for PPCs. In addition, in both groups, a prolonged length of hospital stay after surgery was a significant predictor of PPC development, which was consistent with our cohort study. A prolonged hospital stay may occur because of differences in the healthcare hospital culture or other influential factors.

Data suggest that the immobilization of patients following surgery has an influence on and may lead to PPC development and may contribute to thromboembolism, as was also reported by Brooks et al.[6] A pulmonary embolism occurred in 1 patient in our study; however, we did not analyze that patient because the number of patients in this study was small, and it was statistically impossible to compare 1 patient with the entire cohort.

This study has several limitations that must be acknowledged. First, it is a single-center study. Therefore, the results may be biased by a lack of data on important variables, such as the American Society of Anesthesiologist classification of physical health, nasogastric tube decompression related to PPCs, and nutritional status. Another important limitation is that we were unable to assess perioperative pulmonary function in COPD patients to investigate how this affected respiratory capacity; simple pulmonary spirometry analysis alone may be sufficient to avoid this complication. The impact of this factor is not measureable and could be controlled because of the retrospective nature of the study. Only randomized clinical trials may provide more definitive evidence.

When considering the laparoscopic gastrectomy procedure, patients with gastric cancer should carefully weigh the benefits and risks of the various treatment options. Papenfuss et al[33] reported that the incidence of morbidity was significantly increased in patients who underwent a total gastrectomy compared to patients who underwent a subtotal gastrectomy. We cannot report the relative advantages of different laparoscopic procedures. However, we will conduct a study that will provide information regarding the relative advantages of different surgical methods with regard to fewer complications, quality of life, and patient satisfaction.

Our study findings may not be generalizable outside of our institution. Regardless, the results reported in this study may serve as a useful benchmark for future studies.

In conclusion, we have identified the risk factors and the frequency of PPCs in patients with gastric cancer following laparoscopic gastrectomy surgery, which is a relatively common procedure. Advanced age, preexisting COPD, total gastric resection, time to first diet, and postoperative hospital stay are factors associated with a high risk of PPCs. Attention should be paid to these patients, and strategies should be developed to improve and reduce the incidence of PPCs.

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