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Original Article

Complication After Gastrectomy for Gastric Cancer According to Hospital Volume: Based on Korean Gastric Cancer Association-Led Nationwide Survey Data

Sang-Ho Jeong [1,*], Moon-Won Yoo [2,*], Miyeong Park [3], Kyung Won Seo [4], Jae-Seok Min [5], Information Committee of the Korean Gastric Cancer Association

[1]Department of Surgery, Gyeongsang National University College of Medicine and Gyeongsang National University Changwon Hospital, Changwon, Korea
[2]Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea
[3]Department of Anesthesiology, Gyeongsang National University Changwon Hospital, Changwon, Korea
[4]Department of Surgery, Kosin University Gospel Hospital, Busan, Korea
[5]Department of Surgery, Dongnam Institute of Radiological and Medical Sciences, Cancer Center, Busan, Korea

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Correspondence to
Jae-Seok Min
Department of Surgery, Dongnam Institute of Radiological and Medical Sciences, Cancer Center, 40 Jwadong-gil, Jangan-eup, Gijang-gun, Busan 46033, Korea.
Email: mdoogy@naver.com

*Sang-Ho Jeong and Moon-Won Yoo contributed equally to this study.

ORCID iDs
Sang-Ho Jeong
https://orcid.org/0000-0001-9061-6236
Moon-Won Yoo
https://orcid.org/0000-0003-0346-9042
Jae-Seok Min
https://orcid.org/0000-0002-5798-4595

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ABSTRACT

Purpose: This study aimed to analyze the incidence and risk factors of complications following gastric cancer surgery in Korea and to compare the correlation between hospital complications based on the annual number of gastrectomies performed.
Materials and Methods: A retrospective analysis was conducted using data from 12,244 patients from 64 Korean institutions. Complications were classified using the Clavien-Dindo classification (CDC). Univariate and multivariate analyses were performed to identify the risk factors for severe complications.
Results: Postoperative complications occurred in 14% of the patients, severe complications (CDC IIIa or higher) in 4.9%, and postoperative death in 0.2%. The study found that age, stage, American Society of Anesthesiologists (ASA) score, Eastern Cooperative Oncology Group (ECOG) score, hospital stay, approach methods, and extent of gastric resection showed statistically significant differences depending on hospital volumes (P<0.05). In the univariate analysis, patient age, comorbidity, ASA score, ECOG score, approach methods, extent of gastric resection, tumor-node-metastasis (TNM) stage, and hospital volume were significant risk factors for severe complications. However, only age, sex, ASA score, ECOG score, extent of gastric resection, and TNM stage were statistically significant in the multivariate analysis (P<0.05). Hospital volume was not a significant risk factor in the multivariate analysis (P=0.152).
Conclusions: Hospital volume was not a significant risk factor for complications after gastric cancer surgery. The differences in the frequencies of complications based on hospital volumes may be attributed to larger hospitals treating patients with younger age, lower ASA scores, better general conditions, and earlier TNM stages.

Keywords: Gastric neoplasms; Postoperative complications; Health facility size; High-volume hospitals; Low-volume hospitals

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

Author Contributions
Conceptualization: J.S.H., Y.M.W., S.K.W., M.J.S.; Investigation: J.S.H., Y.M.W., P.M., S.K.W., M.J.S.; Methodology: J.S.H., Y.M.W., M.J.S.; Project administration: J.S.H., Y.M.W., S.K.W., M.J.S.; Resources: Information Committee of the Korean Gastric Cancer Association; Writing - original draft: J.S.H., M.J.S.; Writing - review & editing: J.S.H., Y.M.W., P.M., S.K.W., M.J.S.

INTRODUCTION

Gastric cancer is one of the most common and fatal cancers globally [1]. South Korea shows a similar trend [2]. Between 1999 and 2019, 577,502 new patients were diagnosed with gastric cancer in South Korea. Among them, 33.2% were over 70 years of age and 66.8% were male [3]. Localized or regional gastric cancer accounted for more than 80% of the cases, making surgical resection the first treatment of choice for over 70% of patients with gastric cancer [3]. As South Korea's population ages, the proportion of elderly patients newly diagnosed gastric cancer cases is increasing. The incidence and crude rates vary slightly but not significantly by region. Consequently, gastric cancer is one of the most attention-worthy cancers in Korea.

A notable characteristic of gastric cancer treatment in Korea is the concentration of patients in several large tertiary hospitals. According to a 2019 report by the Information Committee of the Korean Gastric Cancer Association (KGCA), surgeons at 6 institutions performed approximately 45% of the gastrectomies in Korea [4]. Gastrectomy operations numbered over 1,000 cases per year at 3 institutions and between 500 and 999 cases per year at the other 3 institutions [4]. This centralization trend is accelerating owing to improved transportation, with approximately 38% of non-business, high-speed train usage attributed to hospital visits [5]. Consequently, tertiary general hospitals in the central regions are establishing additional cancer hospitals or centers, increasing bed capacity, and attracting more medical staff. This could indicate that fierce competition among hospitals is necessary to attract new patients with cancer. However, no study has empirically investigated the postoperative complications and mortality rates based on the number of surgeries performed at each institution using nationwide Korean data.

Previous international studies have suggested that the experience and skill levels of gastrectomy operators can affect treatment outcomes (volume-outcome relationship); thus, institutions with a higher number of operations have better results [6-13]. However, these studies often have relatively small sample sizes or only present mortality and long-term survival rates. There has been limited research on the number of gastrectomies and complications in patients with gastric cancer internationally. Furthermore, information on postoperative complications by hospital volume based on large-scale data remains scarce. In Korea, gastrectomy techniques for gastric cancer are standardized and commonly implemented nationwide [14]. Reports indicate that postoperative complications, mortality, and long-term survival rates are not poor in low-volume hospitals in Korea [15-17]. Therefore, it is essential to collect empirical data on domestic patients and understand the current situation in Korea. This study aimed to analyze the incidence and risk factors of complications following gastric cancer surgery and compare the correlation between complications by hospital according to the annual number of gastrectomies performed in Korea.

MATERIALS AND METHODS

Data collection

The Information Committee of the KGCA developed a case report form for the 2019 nationwide survey, drawing on data from previous Korean surveys [4,18]. The Information Committee of the KGCA was responsible for reviewing the collected data and filtering incorrect or missing data. Representatives of each institution were queried regarding any

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incorrect or missing data. A case report form consisting of 54 questions was sent to each institution, and data on patient demographics, medical history, pathological findings, operative methods, and surgical outcomes were collected via email from March to December 2020 [4]. The age classification was divided into equal thirds based on the distribution of patient ages. This approach was used to capture a balanced representation of the different age groups in the study population. The histological data were classified according to the 2010 World Health Organization classification [19]. Pathological staging was based on the eighth edition of the American Joint Committee on Cancer tumor-node-metastasis (TNM) classification [20].

The data of 14,076 patients who underwent surgery for gastric adenocarcinoma in 2019 were collected from 68 institutions. We obtained this survey data (n=14,076) and excluded patients (n=988) with distant metastasis, those who underwent bypass surgery or palliative gastrectomy, and those with missing stage values. We included patients (n=13,088) who underwent curative radical (R0) gastrectomy. For the analysis of complication data, we excluded cases (n=844) with missing complication values. Ultimately, we enrolled patients (n=12,244) who underwent radical gastrectomy with complication records (**Fig. 1**). This study was approved by the Institutional Review Board (IRB) at Gyeongsang National University Hospital in Changwon (IRB No. GNUCH-202303035). Because this study had a multicenter, retrospective, observational design, the requirement for informed consent was waived.

Postoperative complications were defined as events occurring within 30 days after gastrectomy, including leakage or stricture of the anastomotic site, leakage at the duodenal stump, intra-abdominal or intraluminal hemorrhage, intra-abdominal fluid retention or abscess, pancreatic fistula, mechanical ileus, wound complications, pneumonia, cerebrovascular events, heart disease, etc. [4]. Postoperative complications were categorized using the Clavien-Dindo classification (CDC). Postoperative death was defined as death within 30 days after gastrectomy or during hospitalization.

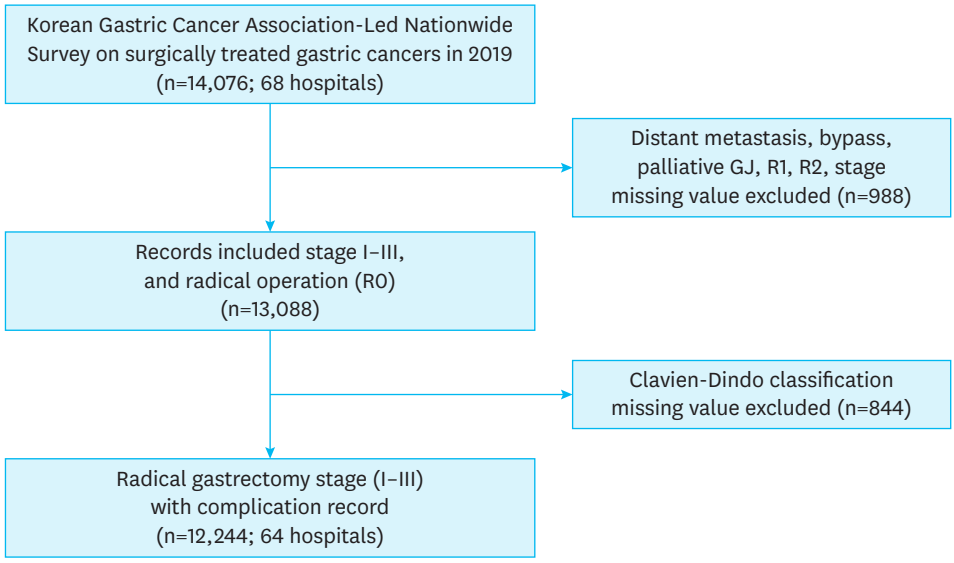

Fig. 1. Flow chart of study selection.
GJ = gastrojejunostomy.

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Statistical analysis

Continuous variables were expressed as means and standardized, and the difference between their means was determined using analysis of variance and post hoc analysis. The results of the post hoc analyses were indicated as "P<0.05" or "P>0.05" in the table. Categorical variables were expressed as numbers and proportions, and the difference in their frequencies was analyzed using the χ^2 test. The univariate and multivariate analyses were performed using a binary regression analysis model [21]. Statistical analyses were performed using IBM SPSS Statistics version 26.0 for Windows (IBM Corporation, Armonk, NY, USA). We used the binary logistic regression model with the Enter method for the univariate and multivariate analyses. Statistical significance was defined as P<0.05. The statistical methods used in the table are described in the footnotes.

RESULTS

Patients demographics

The demographic characteristics of the enrolled patients are shown in **Table 1**. In total, 12,244 patients with a mean age of 62.8 years were enrolled. The number of males and females was 7,993 and 4,251, respectively, with a ratio of 1.8:1. The mean body mass index (BMI) of the patients was 24.0±3.3 kg/m^2, and the mean tumor size was 3.7±2.7 cm. Regarding the TNM stage, stage I (n=8,527) was the most common, accounting for 69.6% of cases, followed by stages II (n=1,888, 15.4%) and III (n=1,829, 14.9%). In the histological classification of gastric cancer, moderately differentiated tubular adenocarcinoma was the most common at 32.7%, followed by poorly differentiated adenocarcinoma at 26.6%, and poorly cohesive carcinoma at 18.5%. Preoperative chemotherapy was performed in 3.7% of the enrolled patients, and

Table 1. Patients demographics

Factor	Value
Age (yr)	62.8±11.8
Sex	
Male	7,993 (65.3%)
Female	4,251 (34.7%)
BMI (kg/m^2)	24.0±3.3
Tumor size (cm)	3.7±2.7
TNM stage	
I	8,527 (69.6%)
II	1,888 (15.4%)
III	1,829 (14.9%)
Tumor histology	
Papillary carcinoma	77 (0.6%)
Well differentiated tubular adenocarcinoma	1,286 (10.5%)
Moderately differentiated tubular adenocarcinoma	3,996 (32.7%)
Poorly differentiated tubular adenocarcinoma	3,252 (26.6%)
Poorly cohesive carcinoma and/or Signet ring cell carcinoma	2,266 (18.5%)
Mucinous carcinoma	162 (1.3%)
Mixed type of tubular adenocarcinoma and signet ring cell carcinoma	864 (7.1%)
Gastric carcinoma with lymphoid stroma	163 (1.3%)
Others	153 (1.3%)
Preoperative chemotherapy	
No	11,783 (96.2%)
Yes	459 (3.7%)
Existence of comorbidity	
No	4,033 (35.7%)
Yes	7,272 (64.3%)

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Table 1. (Continued) Patients demographics

Factor	Value
ASA score	
1	2,824 (23.1%)
2	7,280 (59.5%)
3	1,838 (15.0%)
4	46 (0.4%)
5	10 (0.1%)
ECOG	
0	4,269 (64.7%)
1	1,943 (29.5%)
2	332 (5.0%)
3	43 (0.7%)
4	8 (0.1%)
Hospital stay (days)	9.1±7.9
Approach methods	
Totally laparoscopic gastrectomy	7,218 (59.0%)
Laparoscopy-assisted gastrectomy	1,077 (8.8%)
Open gastrectomy	3,170 (25.9%)
Robot-assisted gastrectomy	777 (6.3%)
Gastric resection extent	
Distal gastrectomy	9,183 (75.1%)
Total gastrectomy	2,445 (20.0%)
Proximal gastrectomy	332 (2.7%)
Pylorus Preserving gastrectomy	241 (2.0%)
Wedge resection of stomach	32 (0.3%)
No. of harvested lymph nodes	40.0±17.2
Morbidity	
Yes	1,717 (14.0%)
No	10,527 (86.0%)
Clavien-Dindo classification	
0	10,527 (86.0%)
I	261 (2.1%)
II	863 (7.0%)
IIIa	330 (2.7%)
IIIb	143 (1.2%)
IVa	90 (0.7%)
IVb	3 (0.02%)
V (mortality)	27 (0.2%)
Group by hospital volume (gastrectomy cases per year)/No. of hospital	
A group (≤99 cases)	33
B group (100–199 cases)	16
C group (200–499 cases)	9
D group (≥500 cases)	6
Group by hospital volume (gastrectomy cases per year)/No. of patients underwent gastrectomy	
A group (≤99 cases)	1,446 (11.8%)
B group (100–199 cases)	1,991 (16.3%)
C group (200–499 cases)	2,895 (23.6%)
D group (≥500 cases)	5,912 (48.3%)

Values are represented as mean ± standard deviation or number of patients (percentages). Values and percentages were analyzed after excluding missing values.
BMI = body mass index; TNM = tumor-node-metastasis; ASA = American Society for Anesthesiology; ECOG = Eastern Cooperative Oncology Group.

comorbidities coexisted in 64.3% of the patients before gastrectomy. In the American Society of Anesthesiologists (ASA) score distribution, ASA score 2 was the most common at 59.5%, ASA score 1 was 23.1%, ASA score 3 was 15%, and ASA scores 4 and 5 were 0.4% and 0.1%, respectively. In the Eastern Cooperative Oncology Group (ECOG) analysis, ECOG 0 was the most common at 64.7%, followed by ECOG 1 at 29.5%, and ECOG 2, 3, and 4 at 5%, 0.7%, and 0.1%, respectively. The mean hospital stay was 9.1±7.9 days. Regarding approach

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methods, intra-corporeal anastomosis (totally laparoscopic gastrectomy) was performed in 59.0% of patients, extracorporeal anastomosis (laparoscopy-assisted gastrectomy) in 8.8%, robotic gastrectomy in 6.3%, and open gastrectomy in 25.9%. Regarding the extent of gastric resection, distal gastrectomy was the most common procedure (75.1%), followed by total gastrectomy (20%). Complications occurred in 14% of the enrolled patients; severe complications of CDC IIIa or higher occurred in 4.9%, and death occurred in 0.2%. The hospitals were divided according to the number of patients undergoing gastrectomy per year: group A had 99 or fewer gastrectomy cases per year, group B had 100–199 cases, group C had 200–499 cases, and group D had 500 or more cases. The numbers of hospitals in groups A, B, C, and D were 33, 16, 9, and 6, respectively. The number of patients who underwent gastrectomy was 1,446 patients (11.8%) in group A, 1,991 patients (16.3%) in group B, 2,895 patients (23.6%) in group C, and 5,912 patients (48.3%) in group D. Although group D had the fewest hospitals, it had the highest number of patients who underwent gastrectomy.

Comparison of patients' features according to hospital volume

The data comparing the features according to hospital volume are shown in **Table 2**. Patients in group A were the oldest with a mean age of 66.2 years, while the mean ages for groups B, C, and D were 64.4 years, 62.7 years, and 61.4 years, respectively, with statistically significant differences (group A vs. group B $P<0.05$, group B vs. group C $P<0.05$, group C vs. group D $P<0.05$). There were no significant differences between the groups in terms of BMI and tumor size. The difference in TNM stages was statistically significant ($P<0.0001$). Stage I was lower in groups A (65.3%) and B (68.7%) than in groups C (70.2%) and D (70.9%), and groups A and B had a higher percentage of patients with stages II and III than groups C and D (stage II: group A 17.2%, group B 14.9%, group C 14.7%, group D 15.5%; stage III: group A 17.6%, group B 16.7%, group C 15.1%, group D 13.6%). There was a significant difference between the groups regarding the presence of comorbidities; patients in groups A (69.2%) and B (69.7%) had a higher number of comorbidities than those in groups C (66.3%) and D (59.9%) ($P<0.0001$). There was a significant difference in ASA scores between the groups; patients in groups A and B had higher ASA scores than those in groups C and D ($P<0.0001$). In addition, comparison of ECOG scores also showed statistically significant differences, with patients in groups A and B scoring higher than those in groups C and D ($P<0.0001$).

Regarding hospital stay, groups A (11.6 days) and B (10.3 days) had longer stays than groups C (8.6 days) and D (8.4 days), and this difference was statistically significant (group A vs. group B, $P<0.05$; group B vs. group C, $P<0.05$; group C vs. group D, $P>0.05$). Approach methods, extent of gastric resection, and number of harvested lymph nodes were also significantly different according to hospital volume ($P<0.0001$). Robotic gastrectomy was more commonly performed in group D (9.6%) than in groups A (2.8%), B (1.7%), and C (4.6%).

In cases of total complications, there was a significant difference in the incidence of complications according to hospital volume ($P<0.0001$). In cases of severe morbidity with CDC scores of IIIa or higher, the incidence decreased as the hospital volume increased ($P=0.044$). When comparing only minimally invasive surgeries in each group, the incidence of complications above CDC IIIa in groups A, B, C, and D was significantly reduced to 5.6%, 5.1%, 3.9%, and 3.1%, respectively ($P<0.0001$). However, there were no statistically significant differences in the open surgery group ($P=0.564$).

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Table 2. Comparison of patients' features according to hospital volume

Factors (total n=12,244)	Group A (≤99 cases) (n=1,446)	Group B (100–199 cases) (n=1,991)	Group C (200–499 cases) (n=2,895)	Group D (≥500 cases) (n=5,912)	P-value
No. of hospitals	33	16	9	6	
Age (yr, n=11,765)	66.2	64.4	62.7	61.4	A vs. B P<0.05* B vs. C P<0.05* C vs. D P<0.05*
BMI (kg/m^2, n=12,234)	24	24	24.1	24	P>0.05*
Tumor size (cm, n=12,191)	3.7	3.7	3.7	3.6	P>0.05*
TNM stage (n=12,244)					P<0.0001
I	944 (65.3%)	1,361 (68.7%)	2,032 (70.2%)	4,190 (70.9%)	
II	248 (17.2%)	297 (14.9%)	425 (14.7%)	918 (15.5%)	
III	254 (17.6%)	333 (16.7%)	438 (15.1%)	804 (13.6%)	
Existence of comorbidity (n=11,305)	994 (69.2%)	1,332 (69.7%)	1,838 (66.3%)	3,108 (59.9%)	P<0.0001
ASA score (n=11,998)					P<0.0001
1	377 (26.1%)	387 (22.2%)	760 (26.3%)	1,300 (22.0%)	
2	792 (54.8%)	1,055 (60.5%)	1,678 (59.5%)	3,755 (63.5%)	
3	262 (18.1%)	291 (16.7%)	453 (15.0%)	832 (14.1%)	
4	14 (1.0%)	10 (0.6%)	46 (0.4%)	18 (0.3%)	
5	1 (0.1%)	2 (0.1%)	10 (0.1%)	7 (0.1%)	
ECOG (n=6,595)					P<0.0001
0	757 (61.0%)	1,144 (65.8%)	1875 (78.6%)	493 (40.1%)	
1	388 (31.3%)	462 (26.2%)	471 (19.7%)	622 (50.6%)	
2	74 (6.0%)	117 (6.7%)	34 (1.4%)	107 (8.7%)	
3	19 (1.5%)	14 (0.8%)	4 (0.2%)	6 (0.5%)	
4	3 (0.2%)	2 (0.1%)	2 (0.1%)	1 (0.1%)	
Hospital stay (days, n=12,215))	11.6	10.3	8.6*	8.4*	A vs. B P<0.05* B vs. C P<0.05* C vs. D P>0.05*
Approach methods (n=12,242)					P<0.0001
Totally laparoscopic gastrectomy	862 (59.6%)	1,420 (71.3%)	1,761 (60.9%)	3,175 (53.7%)	
Laparoscopy-assisted gastrectomy	128 (8.9%)	104 (5.2%)	141 (4.9%)	704 (11.9%)	
Open gastrectomy	416 (28.8%)	433 (21.7%)	858 (29.6%)	1,463 (24.8%)	
Robotic gastrectomy	40 (2.8%)	34 (1.7%)	134 (4.6%)	569 (9.6%)	
Gastric resection extent (n=12,233)					P<0.0001
Distal gastrectomy	1,123 (77.8%)	1,574 (79.2%)	2,172 (75.1%)	4,314 (73.0%)	
Total gastrectomy	294 (20.4%)	349 (17.6%)	596 (20.6%)	1,206 (20.4%)	
Proximal gastrectomy	17 (1.2%)	56 (2.8%)	69 (2.4%)	190 (3.2%)	
Pylorus preserving gastrectomy	8 (0.6%)	6 (0.3%)	29 (1.0%)	198 (3.4%)	
Wedge resection of stomach	2 (0.1%)	3 (0.2%)	26 (0.9%)	1 (0.01%)	
No. of harvested lymph nodes (n=11,925)	39.1	38.3	41.3	40.1	A vs. B P<0.05* B vs. C P<0.05* C vs. D P<0.05*
Clavien-Dindo classification (n=12,244)					P<0.0001
0	1,237 (85.5%)	1,725 (86.6%)	2,402 (83.0%)	5,163 (87.3%)	
I	37 (2.6%)	29 (1.5%)	71 (2.5%)	124 (2.1%)	
II	89 (6.2%)	128 (6.4%)	276 (9.5%)	370 (6.3%)	
IIIa	38 (2.6%)	57 (2.9%)	87 (3.0%)	148 (2.5%)	
IIIb	28 (1.9%)	28 (1.4%)	44 (1.5%)	43 (0.7%)	
IVa	6 (0.4%)	16 (0.8%)	12 (0.4%)	56 (0.9%)	
IVb	0 (0.0%)	3 (0.2%)	0 (0.0%)	0 (0.0%)	
V	11 (0.8%)	5 (0.3%)	3 (0.1%)	8 (0.1%)	
Severe morbidity rate (Clavien-Dindo ≥IIIa)	83/1,446 (5.7%)	109/1,991 (5.5%)	146/2,895 (5.0%)	255/5,912 (4.3%)	P=0.044
Severe morbidity rate in minimal invasive surgery group	58/1,030 (5.6%)	80/1,558 (5.1%)	80/2,036 (3.9%)	140/4,448 (3.1%)	P<0.0001
Severe morbidity rate in open surgery group	25/416 (6.0%)	29/433 (6.7%)	66/858 (7.7%)	115/1,463 (7.9%)	P=0.564
Mortality (Clavien-Dindo V)	11/1,446 (0.8%)	5/1,991 (0.3%)	3/2,895 (0.1%)	8/5,912 (0.1%)	P<0.0001

Severe morbidity means Clavien-Dindo classification IIIa or higher.
BMI = body mass index; TNM = tumor-node-metastasis; ASA = American Society for Anesthesiology; ECOG = Eastern Cooperative Oncology Group.
*The difference between continuous variables their means was performed using analysis of variance test and post hoc analysis, The difference of categorical variables in their frequency was implemented using χ^2 analysis.

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Comparison of postoperative severe complication (CDC IIIa) according to hospital volume

The occurrence of severe postoperative complications was compared based on hospital volume (**Table 3**). The analysis revealed no statistically significant differences in the incidence of complications such as anastomotic leakage, stricture, duodenal stump leakage, intraluminal bleeding, pancreatic fistula, mechanical ileus, pneumonia, and cerebrovascular accident (CVA) (P>0.05). However, significant differences were observed in the occurrence of intra-abdominal bleeding, intra-abdominal abscesses, fluid collection, wound problems, and heart problems, among others.

Regarding major complications, intra-abdominal bleeding showed a statistically significant difference, with group A having the highest incidence at 0.5%, followed by groups B, C, and D (P=0.043). No statistical differences were observed in nonsurgical complications, such as pneumonia and CVA. However, Group A had the highest incidence of heart problems, followed by groups C, B, and D; this difference was statistically significant (P=0.001).

Univariate and multivariate analysis of risk factors for severe complications (CDC ≥ IIIa)

To analyze the risk factors for morbidity, a univariate analysis was performed on the risk factors that were statistically significant for severe complications (**Table 4**). Patients' age, sex, comorbidity, ASA score, ECOG score, approach methods, extent of gastric resection, TNM stage, tumor histology, and hospital volume were statistically significant (P<0.05). However, patient BMI and preoperative chemotherapy were not statistically significant in the univariate analysis (P≥0.05).

In the multivariate analysis, patients' age, sex, ASA score, ECOG, extent of gastric resection, and TNM stage were statistically significant (P<0.05). However, patients' comorbidities, approach methods, tumor histology, and hospital volume were not statistically significant (P≥0.05). Hospital volume was not a significant risk factor for severe morbidity in the multivariate analysis (P=0.152).

Table 3. Comparison of postoperative severe complication (Clavien-Dindo classification > IIIa) according to hospital volume

Complication (total n=12,244)	Group A (≤99 cases) (n=1,446)	Group B (100–199 cases) (n=1,991)	Group C (200–499 cases) (n=2,895)	Group D (≥500 cases) (n=5,912)	P-value
Anastomosis leakage	13 (0.9%)	21 (1.1%)	20 (0.7%)	36 (0.6%)	0.196
Anastomosis stricture	5 (0.3%)	6 (0.3%)	5 (0.2%)	31 (0.5%)	0.077
Duodenal stump leakage	5 (0.3%)	5 (0.3%)	8 (0.3%)	24 (0.4%)	0.670
Intra-abdominal bleeding	7 (0.5%)	8 (0.4%)	9 (0.3%)	8 (0.1%)	0.043
Intra-luminal bleeding	3 (0.2%)	0 (0%)	9 (0.3%)	11 (0.2%)	0.106
Pancreatic fistula	0 (0%)	2 (0.1%)	1 (0.01%)	2 (0.01%)	0.489
Intra-abdominal abscess	13 (0.9%)	10 (0.5%)	14 (0.5%)	13 (0.2%)	0.002
Fluid collection	1 (0.1%)	16 (0.8%)	16 (0.6%)	36 (0.6%)	0.035
Wound problem	5 (0.3%)	8 (0.4%)	9 (0.3%)	42 (0.7%)	0.047
Mechanical ileus	7 (0.5%)	4 (0.2%)	15 (0.5%)	18 (0.3%)	0.207
Pneumonia	7 (0.5%)	7 (0.4%)	18 (0.6%)	16 (0.3%)	0.088
CVA	1 (0.1%)	2 (0.1%)	0 (0%)	3 (0.1%)	0.454
Heart problem	7 (0.5%)	4 (0.2%)	8 (0.3%)	2 (0.01%)	0.001
Others	9 (0.6%)	16 (0.8%)	14 (0.5%)	13 (0.2%)	0.003

Difference of categorical variables in their frequency was implemented using χ^2 analysis.
CVA = cerebrovascular accident.

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Table 4. Univariate and multivariate analysis of risk factors for severe complication (Clavien-Dindo classification ≥ IIIa)

Risk factor	All cases	Severe complication	Univariate			Multivariate		
			OR	95% CI	P-value	OR	95% CI	P-value
Age (yr)					<0.0001			0.022
19–62	4,098	157 (3.8%)	1.00			1.00		
63–73	3,964	167 (4.2%)	1.10	0.88–1.37		0.87	0.63–1.22	
74–99	3,703	247 (6.7%)	1.79	1.46–2.20		1.29	0.93–1.78	
Sex					<0.0001			0.001
Male	7,993	461 (5.8%)	1.91	1.56–2.32		1.66	1.24–2.17	
Female	4,251	132 (3.1%)	1.00			1.00		
BMI (kg/m^2)					0.339			
>22.4	3,930	193 (4.9%)						
22.5–25.2	4,175	186 (4.5%)						
25.3–49.1	4,129	212 (4.1%)						
Comorbidity					<0.0001			0.512
No	4,033	142 (3.5%)	1.00					
Yes	7,272	371 (5.1%)	1.47	1.20–1.79				
Preoperative chemotherapy					0.14			
No	11,783	564 (4.8%)						
yes	459	29 (6.3%)						
ASA score					<0.0001			0.039
1	2,824	119 (4.2%)	1.00			1.00		
2	7,280	325 (4.5%)	1.06	0.85–1.31		0.94	0.66–1.32	
3	1,838	133 (7.2%)	1.77	1.37–2.28		1.47	0.97–2.21	
4	46	2 (4.3%)	1.03	0.24–4.31		0.43	0.05–3.48	
5	10	3 (30.0%)	9.74	2.48–38.14		0.00	0.0001–	
ECOG					<0.0001			0.027
0	4,269	189 (4.4%)	1.00			1.00		
1	1,943	123 (6.3%)	1.45	1.15–1.84		1.38	1.06–1.79	
2	332	29 (8.7%)	2.06	1.37–3.01		1.69	1.06–2.68	
3	43	5 (11.6%)	2.84	1.10–7.29		2.93	1.06–8.08	
4	8	1 (12.5%)	3.08	0.37–25.19		1.83	0.21–15.45	
Approach methods					<0.0001			0.916
Totally laparoscopic gastrectomy	7,218	294 (4.1%)	1.00					
Laparoscopy-assisted gastrectomy	1,077	45 (4.2%)	1.02	0.74–1.41				
Open gastrectomy	3,170	235 (7.4%)	1.88	1.58–2.25				
Robotic gastrectomy	777	19 (2.4%)	0.59	0.36–0.94				
Gastric resection extent					<0.0001			<0.0001
Distal gastrectomy	9,183	346 (3.8%)	1.00			1.00		
Total gastrectomy	2,445	209 (8.5%)	2.38	1.99–2.85		2.11	1.62–2.76	
Proximal gastrectomy	332	20 (6.0%)	1.63	1.02–2.60		2.25	1.29–3.90	
Pylorus preserving gastrectomy	241	16 (6.6%)	1.81	1.08–3.05		1.91	0.79–4.61	
Wedge resection of stomach	32	1 (3.1%)	0.82	0.11–6.05		0.94	0.12–7.15	
TNM stage					<0.0001			0.001
I	8,527	314 (3.7%)	1.00			1.00		
II	1,888	122 (6.5%)	1.80	1.45–2.24		1.40	1.02–1.92	
III	1,829	157 (8.6%)	2.45	2.01–2.99		1.74	1.28–2.38	
Tumor histology					<0.0001			0.213
Papillary carcinoma	77	10 (13.0%)	1.00					
Well differentiated tubular adenocarcinoma	1,286	64 (5.0%)	0.35	0.17–0.71				
Moderately differentiated tubular adenocarcinoma	3,996	235 (5.9%)	0.41	0.21–0.82				
Poorly differentiated tubular adenocarcinoma	3,252	145 (4.5%)	0.31	0.15–0.62				
Poorly cohesive carcinoma and/or signet ring cell carcinoma	2,266	78 (3.4%)	0.23	0.15–0.62				
Mucinous carcinoma	162	8 (4.9%)	0.34	0.11–0.48				
Mixed type of tubular adenocarcinoma and signet ring cell carcinoma	864	39 (4.5%)	0.31	0.13–0.92				
Gastric carcinoma with lymphoid stroma	163	8 (4.9%)	0.34	0.13–0.91				
Others	153	6 (3.9%)	0.27	0.09–0.78				
Hospital volume (gastrectomy cases per year)					0.044			0.152
≤99	1,446	83 (5.7%)	1.35	1.04–1.74				
100–199	1,991	109 (5.5%)	1.28	1.02–1.61				
200–499	2,895	146 (5.0%)	1.17	0.95–1.45				
≥500	5,912	255 (4.8%)	1.00					

Values are presented as number (%). Values and percentages were analyzed after excluding missing values. We used the binary logistic regression model by Enter method.

OR = odd ratio; CI = confidence interval; ASA = American Society for Anesthesiology; ECOG = Eastern Cooperative Oncology Group; TNM = tumor-node-metastasis.

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DISCUSSION

This study aimed to analyze the incidence and risk factors of complications following gastric cancer surgery in Korea and compare the correlation between hospital complications based on the annual number of gastrectomies performed. In the results of the univariate analysis, the incidence of severe complications decreased as the hospital volume increased. However, hospital volume was not a significant risk factor in the multivariate analysis. This difference could be due to the fact that larger hospitals treated patients who were younger, had better general conditions, fewer comorbidities, and earlier TNM stage.

For various reasons, each hospital has different characteristics. We analyzed the features of patients who underwent curative (R0) gastrectomy for gastric cancers according to hospital volume (**Table 2**). Patients who underwent gastrectomy in high-volume hospitals were significantly younger, had fewer comorbidities before gastrectomy, had better ASA and ECOG scores, and had earlier TNM stages than those in small-volume hospitals. This result was expected because of the prejudiced composition of patients in Korea. Although group D had the lowest proportion of comorbidities, it is interesting to note that ASA 1 and ECOG 0 were also the lowest in this group. This suggests that large-volume hospitals tend to evaluate patients more strictly within the subjective scope of ASA and ECOG assessments. Additionally, the high-volume hospital group D (≥500 cases/year) had the lowest number of hospitals (n=6) and the highest number of patients who underwent gastrectomy (n=5,912, 48.3%). According to previous reports, the incidence of gastric cancer varies slightly by region in Korea [3]. In this study, most high-volume hospitals (group D, ≥500 cases/year) were in Gyeonggi-do or Seoul, the capital of South Korea. In Korea, which is relatively small in area and has developed transportation, it is not difficult for patients to receive treatment at hospitals in other regions. Elderly patients or those with prominent symptoms of advanced gastric cancer who are unable to move far often receive treatment in hospitals near their homes. In contrast, relatively young patients who are diagnosed with early gastric cancer and those who have no or mild symptoms often visit large-volume hospitals in Seoul.

Regarding the approach methods during gastrectomy, robotic gastrectomy was more commonly performed in group D than in the other groups. When comparing the extents of gastric resection, the rates of distal and total gastrectomies were not significantly different. By contrast, proximal and pylorus-preserving gastrectomies were performed slightly more often in high-volume hospitals. This is because proximal and pylorus-preserving gastrectomies are cumbersome and complicated compared with distal and total gastrectomies. Therefore, it was inferred that hospitals with a relatively small number of surgeries might not be willing to perform them for reasons such as a learning curve. Group C performed wedge resection of the stomach most commonly, presumably because patients who were enrolled in the SENORITA trial that was conducted at several institutions were mostly included in group C [22-24].

Postoperative complications can impede recovery, delay the initiation of postoperative chemotherapy, reduce quality of life, and correlate with cancer prognosis. Therefore, minimizing the incidence of postoperative complications is crucial. Older age, poor performance status, advanced tumor stage, and comorbid diseases are independent risk factors for complications after gastrectomy [25-32]. The authors speculate that there could be differences in the incidence of complications or mortality by hospital depending on the characteristics of the patients in each hospital, regardless of hospital volume. In this

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study, the age of the patients was divided into approximately one-third of the groups. In the multivariate analysis of patient age, only the highest age group (74 years or older) showed an approximately 1.3 times risk of complications. Previous studies have reported that patients' BMI or body composition can affect the occurrence of postoperative complications [33-36]. However, in the present study, BMI did not affect complications.

In the univariate analysis of approach methods, severe complications occurred more frequently after open gastrectomy than after minimally invasive operations. However, there was no statistically significant difference in the multivariate analysis. The reason for this is thought to be that open surgery was performed more frequently in patients with an advanced-stage disease. Additionally, previous studies have reported that open gastrectomy has a higher complication rate than laparoscopic surgery [37,38]. In the analysis of the extents of gastric resection, the risk of complications was higher in total gastrectomy than in distal gastrectomy in both univariate and multivariate analyses. These results were similar to those reported in previous papers [39-41].

Our study had some limitations. First, this was a retrospective study, and the characteristics of the groups according to hospital volume were different; therefore, there could be bias in the incidence of complications and mortality by groups. Second, this was a multicenter, retrospective study using a nationwide survey, and some data were missing. For example, regarding ECOG, group D's response rate is about 20%, which is very low compared to 82% in group C. As a result, it is less representative, and there is a high likelihood of selection bias. Third, the variation in standards across hospitals is a limitation of this retrospective study. Nevertheless, to the best of our knowledge, this is the first study to compare the relationship between hospital volume and complications using large-scale data in Korea.

In conclusion, hospital volume was not a significant risk factor for complications after gastric cancer surgery. The differences in the frequency of complications between hospital volumes might be attributed to larger hospitals treating patients who were younger, had lower ASA scores, better general conditions, and earlier TNM stages. Future research that removes bias through propensity score matching is needed.

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