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ORIGINAL ARTICLE

Influence of hospital volume on outcomes of laparoscopic gastrectomy for gastric cancer in patients with comorbidity in Japan

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Summary *Objective:* Little information is available on the relationship between hospital volume and the outcomes of laparoscopic gastrectomy for gastric cancer in patients with comorbidity. This study aimed to investigate the influence of hospital volume on patient outcomes of laparoscopic gastrectomy for gastric cancer in patients with comorbidity using a national administrative database.
Methods: A total of 5941 comorbid patients treated with laparoscopic gastrectomy for gastric cancer were referred to 741 hospitals in Japan. We collected patients' data from the administrative database to compare laparoscopy-related complications, in-hospital mortality, length of stay (LOS), and medical costs during hospitalization in relation to hospital volume. Hospital volume was categorized into two groups: low (<40 cases in 3 years; $n = 4111$) and high (≥40 cases; $n = 1830$).
Results: There were no significant differences between the groups in laparoscopy-related complications and in-hospital mortality ($p = 0.684$ and $p = 0.200$, respectively). However, significant variations in mean LOS and medical costs were observed between hospital volume categories (26.1 days vs. 20.2 days and 16,163.9 US dollars vs. 14,345.9 US dollars, respectively; $p < 0.001$). Multiple linear regressions revealed that higher hospital volume was significantly associated with shorter LOS and lower medical costs during hospitalization. The unstandardized coefficient for LOS was −4.62 days (95% confidence interval = −5.63–−3.60, $p < 0.001$), whereas that for medical costs was −1424.1 US dollars (95% confidence interval = −1962.5–−885.6, $p < 0.001$).

Conflicts of interest: All authors have no conflicts of interest to declare.

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Conclusion: Hospital volume was significantly associated with a decrease of LOS and medical costs of comorbid patients undergoing laparoscopic gastrectomy for gastric cancer.

1. Introduction

Gastric cancer is one of the leading causes of cancer death in the world.[1,2] According to the vital statistics released by the Ministry of Health, Welfare, and Labour in Japan, approximately 50,000 Japanese people die from gastric cancer annually, representing approximately 15% of annual cancer-related deaths over the past 4 decades.[3] Recently, endoscopic resection, such as endoscopic mucosal resection or endoscopic submucosal dissection, has been frequently performed because of the early detection or diagnosis of gastric cancer.[4] However, the number of surgical resections for gastric cancer remains high in Japan.[5]

Recent advances in surgical techniques have enabled more effective and safe operations for gastric cancer. Laparoscopic gastrectomy is a less-invasive operation for gastric cancer compared with open gastrectomy, and some previous reports suggest that laparoscopic gastrectomy can be performed safely with lower morbidity and mortality.[6–8] In addition, this procedure has a favorable effect with regard to the length of hospitalization and the medical costs of patients.[9,10] Currently, laparoscopic gastrectomy is a widely accepted procedure for treating gastric cancer, and the number of patients undergoing laparoscopic gastrectomy has been increasing in Japan.[11]

Since Luft et al[12] reported a correlation between hospital volume and patient outcomes, health policy measures advocating high hospital volume have been predicated on the overwhelming empirical evidence of the hospital volume—outcome relationship. Many studies, especially over the past decade, have shown significant associations between the volume of hospital services provided and patient outcomes, particularly for a wide variety of surgical procedures.[13,14] Although the reasons for such relationships have not been fully explained, these results suggest that hospital volume is a significant independent indicator of patient outcome.

However, little information is available on the relationship between hospital volume and patient outcomes of laparoscopic gastrectomy for gastric cancer. In addition, there have been no reports that have focused on the volume effect for outcomes of patients with comorbidity. Clarification of the relationship between hospital volume and the outcomes of laparoscopic gastrectomy in patients with comorbidity could contribute to studies of the quality of patient medical care, which could in turn have significant implications for health care policy decision making.

In this study, we investigated the influence of hospital volume on outcomes of laparoscopic gastrectomy for gastric cancer in patients with comorbidity. This was achieved using the national administrative database developed in the Japanese case-mix system project named the Diagnosis Procedure Combination (DPC) system, which is a unique insurance reimbursement scheme for incentive payments.

2. Materials and methods

2.1. DPC system and database

The health care system of Japan has severe financial problems because of the expense of new medical technology, a rapidly aging society, and extended patient hospitalizations.[15,16] To address these issues, the Ministry of Health, Labour, and Welfare and its affiliated research institute have begun investigating whether the Japanese case-mix classification system can be used to standardize medical profiling and payment.[13–16] As a result, Japanese case-mix projects based on the DPC system were introduced to 82 academic hospitals (National Cancer Center, National Cardiovascular Center, and 80 university hospitals) in 2003.[13–16] Reimbursement from health insurance using the DPC system is common practice in Japan. According to the administrative database of the DPC system, the number of acute care hospitals has increased. Enormous amounts of inpatient data have been collected annually, covering approximately 90% of the total acute care inpatient hospitalizations.[13–16]

Each patient's financial data, claim information, and discharge summary, which includes principal diagnosis, comorbidity at the time of admission, and complications during hospitalization, are recorded in the administrative database of the DPC system. These data are coded using the International Classification of Diseases and Injuries,10th Revision (ICD-10) code. Additionally, this administrative database also contains comprehensive medical information, including all interventional or surgical procedures, medications, and devices that have been indexed in the original Japanese code. The Ministry of Health, Labour, and Welfare of Japan assigns these codes.[13–16] The date and amount of care delivered each day are also recorded in the DPC administrative database.[13–16]

2.2. Study setting

We selected 12,522 patients treated with laparoscopic gastrectomy for gastric cancer at 741 DPC participation hospitals (83 academic and 658 community hospitals) between 2009 and 2011 in Japan. The hospitals involved are dispersed throughout Japan and play leading roles in providing acute care medicine, advancing medical research, and educating students and medical residents.

We calculated the number of laparoscopic gastrectomies performed for gastric cancer in each hospital, and hospital volume was expressed as the number of cases during the

study period, and was initially evaluated as a continuous variable. However, categorical variables defining two categories of hospital volume were created to simplify the presentation of the results in this study: low-volume hospitals (LVHs) had $<$ 40 cases (n = 8561) and high-volume hospitals (HVHs) had $\geq$40 cases during the study period (n = 3961). These categories were based on cutoff values that yielded roughly equivalent numbers of patients in each volume category. This method has frequently been used in previous studies of hospital volume.[13,14,16]

In addition, we analyzed the Charlson Comorbidity Index (CCI) score for each patient using the data of the ICD-10 codes in the administrative database. The CCI score was expressed as the score of all comorbid conditions, and it was initially evaluated as a continuous variable.[15,16] We excluded 6581 patients whose CCI scores were zero (4450 patients at LVHs and 2131 patients at HVHs). This left 5941 comorbid patients treated with laparoscopic gastrectomy for gastric cancer allocated for analysis (4111 patients at LVHs and 1830 patients at HVHs; Fig. 1).

The use of DPC data was permitted by all institutions and hospitals that provided detailed data. The research protocol of the study was approved by the Ethics Committee of Medical Care and Research of the University of Occupational and Environmental Health, Kitakyushu, Japan.

2.3. Study variables

We collected data in the administrative database with regard to the characteristics of patients and hospitals as follows: levels of comorbidity, age, sex, location of gastric cancer, kinds of gastrectomy, hospital type, size, and region, laparoscopy-related complications, in-hospital mortality, length of stay (LOS), and medical costs during hospitalization.

Levels of comorbidity (by CCI score) defining three categories of severity were created to simplify the presentation of the results: 1, mild; 2, moderate; and $\geq$3, severe.[16] Furthermore, chronic comorbid conditions were classified according to each representative organ system: hypertension (I10—I15), diabetes mellitus (E10—E14), pulmonary diseases (J00—J99), ischemic heart diseases (I20—I25), cerebrovascular diseases (I60—I69), liver cirrhosis (K70—K74), and renal failure (N17—N19).[17] Age categories were stratified as follows: $<$ 60 years, 60—69 years, 70—79 years, and $\geq$80 years. Location of cancer was defined by the ICD-10 codes: C16.0 (cardia); C16.1 (fundus); C16.2 (body); C16.3 (antrum); C16.4 (pylorus); and C16.5, C16.6, C16.8, and C16.9 (unknown category). The Japanese Classification of Gastric Cancer describes tumor locations anatomically in three divisions, namely, upper, middle, or lower third.[18] Therefore, the locations of gastric cancer were divided into three anatomical positions: upper (cardia and fundus), middle (body), and lower third (antrum and pylorus) as described in the previously published medical literature.[18,19] Hospital type was classified as academic or community. Hospital size was categorized into three groups according to the number of hospital beds: small ($<$ 200 beds), medium (200—600 beds), and large ($>$600 beds). Hospital region was also divided into two categories: urban and rural. We defined an urban region as a prefecture that has a degree of population concentration of $\geq$50%, and a rural region as a prefecture that has a degree of population concentration $<$ 50%, as reported previously.[20] Laparoscopy-related complications included wound complications such as infection or dehiscence, anastomosis leakage, intra-abdominal hematoma, or others (T80—87), bowel obstruction (K56.5—56.7, K65.0, K65.8—9, K66.0, and K91.3), peritonitis (K56.0, K56.2), and acute pancreatitis (K85). These laparoscopy-related complications were defined according to published criteria.[9,10] For the analysis of medical costs during hospitalization, we assumed the yen to dollar exchange rate to be approximately 100 yen to the US dollar (June 2013).

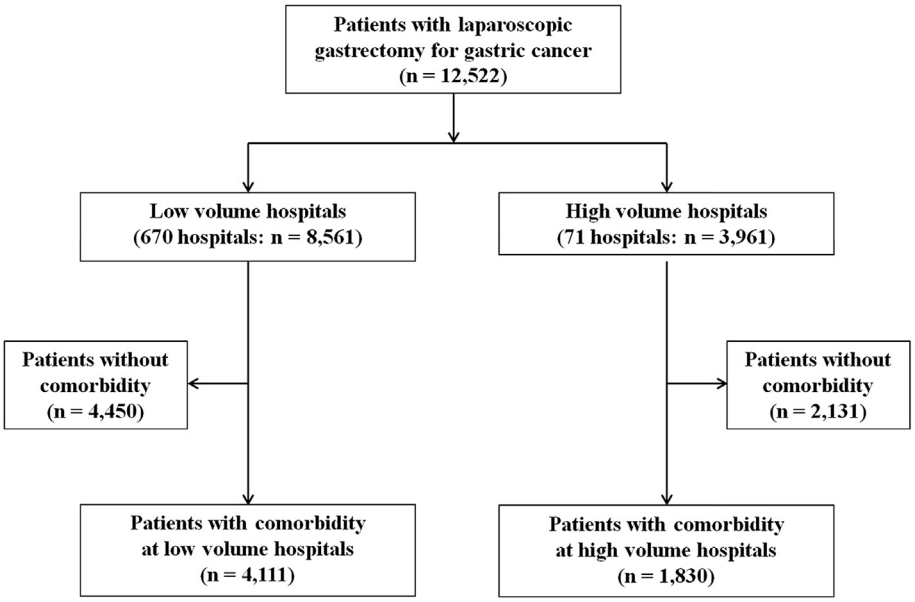

Figure 1 Patient selection and classification from the administrative database.

2.4. Statistical analysis

For tests of statistical significance, we used the χ^2 test for categorical data, and the Mann–Whitney U test for continuous variables. We used logistic regression models to estimate the odds ratios (ORs) and their 95% confidence intervals (CIs) for laparoscopy-related complications and in-hospital mortality, with the LVH group as the reference group. Linear regression models were also used to identify the influence of hospital volume on LOS and medical costs during hospitalization. To control for selection bias with regard to baseline characteristics of patients between groups, we performed generalized propensity score analysis to estimate the dose–response function for patient groups. The propensity score method has been widely used in observational studies to deal with possible biases that influence the effect of hospital volume.[21,22] We used a multinomial logistic regression model with logit as the link function to obtain generalized propensity scores using the data of patient characteristics such as levels of comorbidity, age, sex, location of gastric cancer, and type of gastrectomy. Multiple logistic and linear regression models were used to identify the influence of hospital volume, considering propensity scores and hospital characteristics.

All statistical analyses were performed using STATA version 11.0 statistical software (Stata Corporation, College Station, TX, USA). A value of $p < 0.05$ was considered significant.

3. Results

Characteristics of patients and hospitals are shown in Table 1. Although the ratio of severity of comorbid conditions was similar between hospital volumes, that of patients with diabetes mellitus or pulmonary diseases was significantly higher in LVHs. HVHs performed more total gastrectomies for gastric cancer than did LVHs (11.6% vs. 5.5%; $p < 0.001$). The rate of gastrectomy performed in urban regions was significantly higher in HVHs ($p < 0.001$). No significant difference was seen in the laparoscopy-related complications and in-hospital mortality between groups (9.3% vs. 9.0% and 0.3% vs. 0.5%; $p = 0.684$ and $p = 0.200$, respectively). However, significant variations in mean LOS and medical costs during hospitalization were observed between hospital volume categories ($p < 0.001$). Additionally, large hospitals had shorter LOS compared with small or medium-sized hospitals (21.6 days vs. 25.8 days vs. 24.6 days; $p < 0.001$ and data not shown, respectively).

The logistic regression analyses for laparoscopy-related complications and in-hospital mortality are shown in Table 2. Simple logistic regression revealed that hospital volume was not significantly associated with decreased relative risk of laparoscopy-related complications. The OR of HVHs was 0.96 ($p = 0.684$). After adjustment for patient characteristics as well as hospital characteristics, no significant association was seen between the occurrence of laparoscopy-related complications and hospital volume (OR: 1.03, $p = 0.728$). In addition, hospital volume was not significantly associated with a decreased relative risk of in-hospital mortality in comorbid patients with laparoscopic gastrectomy (OR: 0.66, $p = 0.447$).

Table 1 Characteristics of patients and hospitals according to hospital volume.

	LVHs (n = 4111)	HVHs (n = 1830)	p
Patient characteristics			
Comorbidity (%)			
Mild (CCI = 1)	56.3	58.9	0.087
Moderate (CCI = 2)	22.6	22.4	
Severe (CCI ≥ 3)	21.1	18.7	
Organ system (%)			
Hypertension	29.7	27.6	0.096
Diabetes mellitus	28.2	25.0	0.011
Pulmonary diseases	15.6	12.9	0.006
Ischemic heart diseases	12.3	11.1	0.194
Cerebrovascular diseases	8.4	8.2	0.832
Liver cirrhosis	3.2	2.7	0.310
Renal failure	2.0	2.3	0.414
Age categories (%)			
<60 y	15.5	16.4	<0.001
60–69 y	26.7	29.2	
70–79 y	35.8	37.1	
≥80 y	22.0	17.3	
Sex (%)			
Male	72.8	72.3	0.713
Female	27.2	27.7	
Location of cancer (%)			
Upper	4.3	5.4	<0.001
Middle	39.6	46.5	
Lower	39.4	37.3	
Unknown	16.7	10.8	
Type of gastrectomy (%)			
Total	5.5	11.6	<0.001
Partial	94.5	88.4	
Hospital characteristics			
Hospital type (%)			
Academic	7.7	21.2	<0.001
Community	92.3	78.8	
Hospital size (%)			
Small	32.9	17.9	<0.001
Medium	53.8	36.7	
Large	13.3	45.4	
Hospital region (%)			
Urban	45.5	60.8	<0.001
Rural	54.5	39.2	
Patient outcomes			
Laparoscopy complications (%)	9.3	9.0	0.684
In-hospital mortality (%)	0.5	0.3	0.200
Mean length of stay (d)	26.1	20.2	<0.001
Mean medical costs (US dollars)	16,163.9	14,345.9	<0.001

CCI = Charlson Comorbidity Index; HVH = high-volume hospital; LVH = low-volume hospital.

Table 2 Logistic regression analysis for laparoscopy-related complications and in-hospital mortality.

	OR	95% CI	*p*
Laparoscopy-related complications			
Simple logistic regression			
LVHs	1.00		
HVHs	0.96	(0.79–1.16)	0.684
Multiple logistic regression[a]			
LVHs	1.00		
HVHs	1.03	(0.84–1.27)	0.728
In-hospital mortality			
Simple logistic regression			
LVHs	1.00		
HVHs	0.53	(0.20–1.41)	0.208
Multiple logistic regression[a]			
LVHs	1.00		
HVHs	0.66	(0.23–1.89)	0.447

CI = confidence interval; HVH = high-volume hospital; LVH = low-volume hospital; OR = odds ratio.

[a] OR adjusted for propensity score (level of comorbidity, age, sex, location of gastric cancer, and type of gastrectomy) and hospital characteristics (hospital type, size, and region).

There was a consistently significant association between hospital volume and LOS. Multivariate regression analysis showed that hospital volume was significantly associated with decreasing LOS in comorbid patients with laparoscopic gastrectomy. The unstandardized coefficient of HVHs was −4.62 days ($p < 0.001$). Also, regarding the medical costs during hospitalization, hospital volume significantly influenced medical costs during hospitalization of comorbid patients undergoing laparoscopic gastrectomy. The unstandardized coefficient of HVHs was −1424.1 US dollars ($p < 0.001$; Table 3).

Table 3 Linear regression analysis for LOS and medical costs.

	Coefficient	95% CI	*p*
LOS (d)			
Simple linear regression			
LVHs	Reference		
HVHs	−5.84	(−6.78–−4.89)	<0.001
Multiple linear regression[a]			
LVHs	Reference		
HVHs	−4.62	(−5.63–−3.60)	<0.001
Medical costs (US dollars)			
Simple linear regression			
LVHs	Reference		
HVHs	−1817.9	(−2318.0–−1317.9)	<0.001
Multiple linear regression[a]			
LVHs	Reference		
HVHs	−1424.1	(−1962.5–−885.6)	<0.001

CI = confidence interval; HVH = high-volume hospital; LOS = length of stay; LVH = low-volume hospital.

[a] Coefficient adjusted for propensity score (level of comorbidity, age, sex, location of gastric cancer, and type of gastrectomy) and hospital characteristics (hospital type, size, and region).

4. Discussion

Using a national administrative database, we investigated the influence of hospital volume on outcomes of laparoscopic gastrectomy for gastric cancer in patients with comorbidity. The current study revealed that hospital volume was significantly associated with a decrease of LOS and medical costs of laparoscopic gastrectomy for gastric cancer in patients with comorbidity, whereas no association was observed in laparoscopy-related complications and in-hospital mortality of patients in Japan.

Although many reports have focused on the efficacy or safety of laparoscopic gastrectomy for gastric cancer, studies on the relationship between hospital volume and outcomes of patients with laparoscopic gastrectomy are rare. To the best of our knowledge, only one report describing the relationship between hospital volume and outcomes of laparoscopic gastrectomy for gastric cancer has been published. Kuwabara et al[23] investigated the relationship between hospital volume and outcomes of laparoscopic gastrectomy for gastric cancer, and concluded that hospital volume was not associated with the occurrence of complications, although operation time was significantly associated with complications of laparoscopic gastrectomy in patients with gastric cancer. However, their report did not focus on the outcomes of comorbid patients with laparoscopic gastrectomy for gastric cancer. The World Health Report has highlighted the acceleration of population aging worldwide, with dramatic increases in the numbers of elderly people in many countries.[24] Increasing life expectancy and an aging population will inevitably lead to a growing number of elderly patients with cancer. At the same time, the number of patients with comorbidity is rapidly increasing in some developed countries as the elderly population expands.[25,26] Therefore, evaluation of outcomes in comorbid patients with laparoscopic gastrectomy for gastric cancer is increasingly important because such information will be essential for targeting future quality improvement efforts for laparoscopic gastrectomy for gastric cancer.

This study identified significant associations between hospital volume and both LOS and medical costs during hospitalization of comorbid patients with laparoscopic gastrectomy. Several factors may be associated with shorter LOS or lower medical costs during hospitalization at HVHs. Some previous studies have suggested that higher volume hospitals have many experienced doctors in various fields of medicine and that specialized teams generally are present at hospitals with large case volumes and can provide multidisciplinary care that significantly contributes to improved clinical outcomes.[13–15,27] In addition, many previous reports have shown that hospitals with larger case volumes have greater available resources or treatment facilities for patients.[14,28] Also in this study, HVHs contained more large hospitals, and large hospitals had a shorter LOS compared with small or medium-sized hospitals. Furthermore, it is reasonable to suppose that medical costs will decrease with decreasing LOS.[29] It is therefore plausible that hospitals with larger case volumes have shorter LOS and lower medical costs during hospitalization compared with lower volume hospitals.

However, the in-hospital mortality and laparoscopy-related complications were similar between lower and higher volume hospitals in our study. Some recent studies have reported that comorbidity is a predictive risk factor for laparoscopic complications, and that this surgery for comorbid patients with gastric cancer should be limited to healthier patients.[30,31] However, several other studies have suggested that many Japanese surgeons have taken up the challenge of laparoscopic gastrectomy for gastric cancer, and that the greater experience of Japanese surgeons and ongoing technical innovations have resulted in successful surgical management of laparoscopic gastrectomy.[11,32] In particular, Kodera et al[11] have reported that the number of laparoscopic gastrectomies significantly increased between the early 1990s and late 2000s in Japan. Therefore, the widespread application of laparoscopic gastrectomy for gastric cancer enables the safe treatment of patients with comorbidity, and may obscure any effect of hospital volume on the in-hospital mortality and laparoscopy-related complications in comorbid patients in Japan. However, our results are not necessarily applicable to the USA or some European countries, where laparoscopic gastrectomy for gastric cancer has not been frequently performed. To clarify the effect of hospital volume on outcomes of laparoscopic gastrectomy for gastric cancer in comorbid patients, further studies from other countries except Japan may be needed.

The data used represent a major strength of the current study. One of the benefits of the national database was that it enabled evaluation of a large number of hospitals in an unbiased manner, because our investigation involved a nationally representative sample of patients in a community setting.[13–16] In 2008, records of 2,120,170 hospitalizations were gathered in the administrative database of the DPC system.[33] Therefore, this administrative database also enables interested parties to evaluate outcomes of individual detailed medical treatments, with the validity and reliability of the data from the DPC database having been reasonably assured.

The present study had some potential limitations. First, the data were obtained only from DPC-participating hospitals, so that this administrative database does not include the data from all hospitals in Japan.[10] Therefore, data from hospitals that do not participate in the DPC should be analyzed to confirm our findings. Second, because this administrative database does not include clinical data, such as staging or histological type of gastric cancer, as well as operation time or the extent of lymph node dissection, we could not evaluate the clinical characteristics of the included patients. Third, we could not investigate the number or kinds of stapling devices used for laparoscopic procedures because they were not recorded in the Japanese administrative database. These factors may affect the outcomes of patients who undergo laparoscopic procedures, particularly medical costs during hospitalization.[9] Fourth, we do not have the data about the number of surgeons (including experienced surgeons) in participating hospitals, so we could not investigate the influence of the ability of the surgeons on outcomes of patients with gastric cancer. Further clinical studies, including clinical data about the gastric cancer and devices used for laparoscopic procedures, as well as the ability of Japanese surgeons, are therefore needed to evaluate the effects of hospital volume on outcomes of laparoscopic gastrectomy in patients with comorbidity.

Despite these limitations, the current study has implications for health care policy decision making and quality of patient care. The current study confirmed that hospital volume significantly influenced LOS and medical costs during hospitalization of comorbid patients undergoing laparoscopic gastrectomy for gastric cancer. Therefore, the centralization of comorbid patients who require laparoscopic gastrectomy for gastric cancer could be a quality improvement initiative in Japan. The current findings provide good evidence supporting the attempt to steer comorbid patients with gastric cancer toward hospitals that have shorter LOS or lower medical costs during hospitalization. If these health implementations can be performed in the future, quality of care for gastric cancer will be maintained while LOS or medical costs during hospitalization are lowered in Japan. Further research examining the association between hospital volume and LOS or medical costs during hospitalization of comorbid patients might contribute to changing patient referral policies in Japan. In addition, consecutive monitoring of outcomes in higher volume hospitals should also be conducted in the future.

In conclusion, this study demonstrated that hospital volume was significantly associated with a decrease of LOS and medical costs of laparoscopic gastrectomy for gastric cancer in patients with comorbidity in Japan. The current findings could contribute useful information for future studies on the quality of patient care in comorbid patients undergoing laparoscopic gastrectomy for gastric cancer, as well as for health care policy decision making such as centralization of patients to higher volume hospitals. However, no association was observed in the laparoscopy-related complications and in-hospital mortality of patients with comorbidity. Further studies may be needed to clarify the effect of hospital volume for laparoscopy-related complications and in-hospital mortality of comorbid patients undergoing laparoscopic gastrectomy for gastric cancer.

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