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ORIGINAL SCIENTIFIC REPORT

Correlation Between the Increased Hospital Volume and Decreased Overall Perioperative Mortality in One Universal Health Care System

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Abstract

Background Volume–outcome relationship has been demonstrated extensively for short-term outcomes for oncological surgery. However, its effect on long-term surgical outcomes or in one universal health care (UHC) system is unknown. This retrospective population-based study aims to validate the correlation between the increased hospital volume and better short- and long-term outcomes in patients who underwent total gastrectomy (TG) for gastric cancer.

Methods From the Taiwan National Health Insurance Research Database, we examined 7905 patients who underwent TG between 2000 and 2010. The surgical outcomes of this study were defined as death within 30, 60, and 180 days after TG.

Results A total of 7905 subjects were included for analysis. The mean age was 65.8 years, and 68.8% were males. The 30-, 60-, and 180-day mortality rates after TG for gastric cancer were 2.7%, 6.2%, and 18.2%, respectively. On the multivariate analysis, TG at high-volume hospitals significantly contributed to lower 30-day (odds ratio 0.64; 95% confidence interval 0.48–0.85; $P < 0.001$), 60-day (odds ratio 0.68; 95% confidence interval 0.56–0.82; $P < 0.001$), and 180-day mortality rates (odds ratio 0.80; 95% confidence interval 0.70–0.90; $P < 0.001$).

Conclusions Although TG is a complex operation with high mortality rates (~180-day), high hospital volume correlates with better perioperative outcomes even in UHC system. Hence, the strategy to advocate the centralization of TG is reasonable, especially for the elderly.

Abbreviations

TG	Total gastrectomy
CI	Confidence interval
DM	Diabetes mellitus
NHIRD	National Health Insurance Research Database
ICD-9-CM	International Classification of Disease, Ninth Revision, Clinical Modification

Introduction

Total gastrectomy (TG) is the mainstay surgical treatment for adenocarcinoma of the gastric cardia or the upper-third body, which is one of the most malignant types of cancer,

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the prevalence of which has increased by approximately sevenfold in the last three decades [1–4]. Notably, TG poses a relatively high surgical risk because of its complexity compared with distal gastrectomy, besides the fact that patients with gastric cancer typically experience malnutrition, cancer cachexia, or gastrointestinal discomfort [5, 6]. In TG patients who develop major complications, such as anastomotic/duodenal stump leakage, intra-abdominal abscess, internal bleeding, or pancreatic injury, the outcomes might be disastrous [7].

The correlation between volume and outcome has been extensively demonstrated for short-term outcomes for oncological surgery in private health care (PHC) system [6, 8], suggesting the centralization of major cancer operation; however, its long-term surgical outcome in one universal health care (UHC) system remains unclear. Current studies from PHC system found that universal health coverage could eliminate some disparity [9, 10]. It is unclear whether surgical outcome disparity by hospital volume may also be eliminated by universal health coverage.

Traditionally, the 30-day mortality rate has been widely accepted as the gold standard for assessing the quality of surgery [11]. However, modern advancements in critical care and interventional radiology support might attenuate the insults of major surgical complications; thus, surgery-related deaths might occur 30 days after surgery [12, 13]. Recently, some studies supported the use of the 90-day mortality to measure the quality of major abdominal operations [14, 15], and one study suggested an extension of the monitoring duration to as long as 180 days [16].

Extending the follow-up period after TG is imperative because some early complications can result in later major sequelae, such as intra-abdominal abscess, pancreatic fistula, or internal bleeding, which could contribute to late deaths. We hypothesized that the high hospital volume could account for lower long-term mortality rates because of better surgical skills and perioperative cares. This study aims to evaluate the correlation between hospital volumes and surgical outcomes (defined as 30-, 60-, and 180-day mortality rates) after TG in patients with gastric cancer in one UHC system.

Methods

Database

Since 1995, the healthcare and medical treatment of every Taiwanese citizen are covered under the National Health Insurance program of Taiwan. In this study, we selected patients from Taiwan's National Health Insurance Research Database (NHIRD), which covers all inpatients and outpatient claims of >23 million residents [17, 18]. The NHIRD used the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes to categorize diseases and surgical procedures. We selected patients with gastric cancer, the diagnosis of which was validated on the Registry of Catastrophic Illness Database, a subgroup of the NHIRD containing records of confirmed cases of catastrophic illnesses and cancer. Patients with catastrophic illness, such as gastric cancer, are required to submit a pathology report and related laboratory or imaging data to receive such certification [19].

Ethics statement

This retrospective study protocol was approved by the Institutional Review Board of the National Taiwan University Hospital (201606084W). Of note, the requirement to obtain informed consent was waived because of the retrospective nature of this study, and all sensitive information, including the identification of patients, medical institutions, and medical practitioners, was made anonymous.

Study cohort

We identified all patients who underwent TG (ICD-9-CM procedure code: 43.9) between 2000 and 2010 and excluded the patients as follows: (a) no gastric cancer; (b) aged <20 years, and (c) loss to follow-up within 180 days.

Surgical outcome and exposure variable

We defined the surgical outcomes (30-day, 60-day and 180-day overall mortality) of this study as death within 30, 60, and 180 days after index date of TG. In addition, the survival status and date of death of patients were ascertained by linking the study cohort with the National Register of Deaths Database of Taiwan. Of note, the accuracy of information on mortality was ensured because all death certificates in Taiwan must be issued by doctors and sent to the Ministry of Health and Welfare in Taiwan.

We assessed the following sociodemographic data from the NHIRD: sex, age (≤ 49, 50–64, and ≥65 years), and monthly income [New Taiwan dollar (NT$) ≤ 15,000, 15,000–22,799, and ≥22,800]. In addition, we collected the following data on the comorbidity of patients before TG using the ICD-9-CM codes: anemia (ICD-9-CM: 285.x), myocardial infarction (410.x and 412.x), mild liver disease (571.2 and 571.4–571.6), hyperlipidemia (272.0–272.2), diabetes mellitus (250.0–250.3, 250.7), chronic obstructive pulmonary disease (COPD; 490.x–496.x), renal failure (584.x–586.x), and hypertension (401.x–405.x).

In addition, major complications were defined as those requiring specific procedures, including transarterial embolization for intra-abdominal bleeding, pigtail drainages for intra-abdominal abscesses, endoscopic intervention for gastrointestinal bleeding, wound debridement, and relaparotomy during the index hospitalization or within 30 days of discharge.

We defined splenectomy during the same index hospitalization for TG using the ICD-9-CM procedure code of 41.5. In addition, we divided the dates on which TG was performed into two periods (2000–2005 and 2006–2010) to more systematically examine the potential impact of surgical advancements on the patient outcome. As the encryption code of each hospital constitutes a unique identification number in the NHIRD, we calculated the actual annual volume of TG procedures performed at each hospital during the study period and defined the average value as the reference. Furthermore, the hospital volume was stratified into two groups, high-volume (≥10 TGs per year) and low-volume hospitals (<10 TGs per year), to investigate the correlation between the hospital volume and outcomes.

Statistical analysis

In this study, all variables were calculated as percentages, and continuous variables were summarized as mean ± standard deviation. We used the Student's *t* test to compare the means of two continuous variables. In addition, the Chi-square test and the Fisher's exact test were used to test a correlation among categorical variables. Then, the independent effects of the study variables on the 30-, 60-, and 180-day mortality rates were determined using the logistic regression analysis. The results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). Next, the optimal candidate covariates ($P < 0.05$) were entered into multivariate models if they were statistically significant in the univariate analysis (i.e., $P < 0.05$ by two-sided tests). All data on cleaning and processing were conducted using SQL Server 2008 (Microsoft, Seattle, WA). Furthermore, statistical analyses were performed using IBM SPSS Statistics version 23 (IBM, Armonk, NY).

Results

Cohort characteristics

We identified 9424 patients who underwent TG between 2000 and 2010 and excluded 1519 cases as follows: (a) no gastric cancer ($n = 1432$); (b) aged < 20 years ($n = 7$), and (c) loss to follow-up within 180 days ($n = 80$). Thus, the final cohort comprised 7905 patients undergoing TG. Figure 1 provides a flow diagram outlining patients' inclusion and exclusion in this study. Patients with gastric cancer in the Taiwan NHIRD who underwent TG during the study period ($n = 7905$) had a mean age of 65.8 ± 13.3 years, and 68.8% were males.

Overall perioperative mortality

Table 1 summarizes the characteristics of the study population, including other recent nationwide data. The 30-, 60-, and 180-day mortality rates after TG were 2.7%, 6.2%, and 18.2%, respectively. As to the surgical outcomes, the comparisons between high-volume and low-volume hospitals are given in Table 2. High-volume hospitals had statistically significantly shorter length of hospital stays, lower rates of blood transfusion, and lower rates of major complications and mortality than low-volume hospitals. In the univariate analysis to compare between survivals and non-survivals, old age, low monthly income, anemia, hypertension, myocardial infarction, COPD, renal failure, operation date before 2005, blood transfusion of packed red blood cells (PRBCs), combined splenectomy, TG at a low-volume hospital, and major complications significantly correlated with higher 30-, 60-, and 180-day mortality rates. In addition, males had higher 60- and 180-day mortality rates than females (Table 3). In the multivariate analysis (Table 4), TG at high-volume hospitals significantly contributed to lower 30- (odds ratio 0.64; 95% confidence interval 0.48–0.85; $P < 0.001$), 60- (odds ratio 0.68; 95% confidence interval 0.56–0.82; $P < 0.001$), and

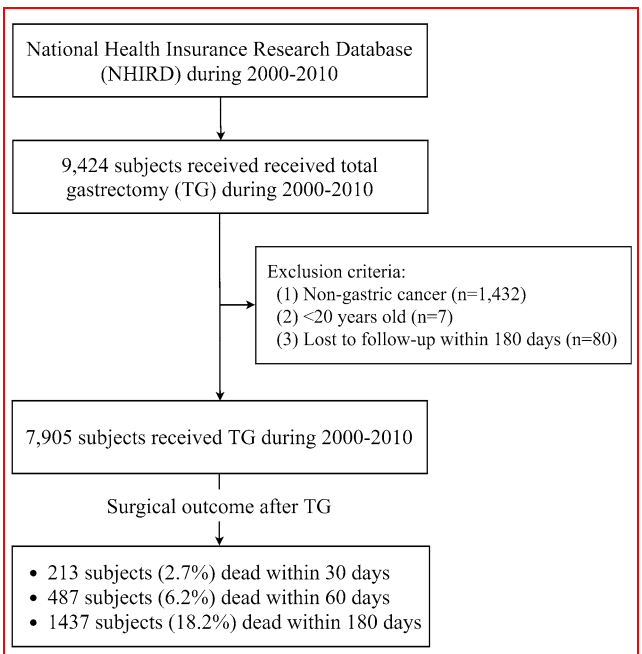

Fig. 1 The study flow diagram

Table 1 Characteristics of this study compared with other recent nationwide reports on mortality after total gastrectomy

Variable	Current study	Bartlett [29]	Watanabe [27]
No. of TGs	7905	1165	20011
Year of TG	2000–2010	2005–2011	2011
Sex			
Male	69%	60%	74%
Female	31%	40%	26%
Age (mean, years)	65.8	66.0[a]	68.9
≤49	1146 (14%)		
50–64	2095 (27%)		
≥65	4664 (59%)		
Monthly income (NT$)			
<15,000	1937 (25%)		
15,000–22,799	4399 (56%)		
≥22,800	1569 (20%)		
CCI scores	6.9 ± 3.3		
<2	1856 (24%)		
≥2	6049 (77%)		
ICU admission	3399 (43%)		
Length of hospital stay (days)	26.7 ± 25.5	10	
Survival outcome			
Died in ≤30 days	213 (2.7%)	4.7%	0.9%
Died in ≤60 days	487 (6.2%)		
Died in ≤180 days	1437 (18.2%)		
Median follow-up, months	23.2		

CCI Charlson comorbidity index

[a]Median

Table 2 Comparisons of patient number, hospital number, and clinical outcomes between low-volume and high-volume hospitals

Variable	Low-volume hospitals	High-volume hospitals	*P* value
Total patient number	2761	5144	
Total hospital number	166	19	
Outcomes			
Intensive care unit admission	1201 (43.4%)	2198 (42.7%)	0.062
Length of hospital stay (days)	29.1 ± 24.1	27.6 ± 20.1	<0.001
Blood transfusion	2024 (73.3%)	3008 (58.5%)	<0.001
Major complication	231 (8.4%)	334 (6.5%)	0.002
≤30 days mortality	114 (4.1%)	99 (1.9%)	<0.001
≤60 days mortality	248 (9.0%)	239 (4.6%)	<0.001
≤180 days mortality	634 (23.0%)	803 (15.6%)	<0.001

180-day mortality rates (odds ratio 0.80; 95% confidence interval 0.70–0.90; $P < 0.001$). In addition, not only patients aged ≥65 years but also blood transfusion was associated with poor outcomes. Both undergoing TG in the early period (2000–2005) and aged 50–64 years markedly correlated with the higher early (30- and 60-day) mortality. Furthermore, major complications (60- and 180-day) and splenectomy (180-day) contributed to late mortality.

Table 3 The factors associated with 30-, 60-, and 180-day mortality rates on univariate analysis

Variable	≤30 days			≤60 days			≤180 days		
	Alive $n = 7692$	Dead $n = 213$	P value	Alive $n = 7418$	Dead $n = 487$	P value	Alive $n = 6468$	Dead $n = 1437$	P value
Sex			0.368			0.001			0.022
Male	5284 (69%)	153 (72%)		5069 (68%)	368 (76%)		4412 (68%)	1025 (71%)	
Female	2408 (31%)	60 (28%)		2349 (32%)	119 (24%)		2056 (32%)	412 (29%)	
Age (years)			<0.001			<0.001			<0.001
≤49	1143 (15%)	3 (1%)		1124 (15%)	22 (5%)		998 (15%)	148 (10%)	
50–64	2062 (27%)	33 (15%)		2016 (27%)	79 (16%)		1815 (28%)	280 (19%)	
≥65	4487 (58%)	177 (84%)		4278 (58%)	386 (79%)		3655 (57%)	1009 (71%)	
Monthly income (NT$)			<0.001			<0.001			<0.001
<15,000	1877 (25%)	60 (28%)		1785 (24%)	152 (31%)		1536 (23%)	401 (28%)	
15,000–22,799	4264 (55%)	135 (64%)		4106 (55%)	293 (60%)		3540 (55%)	859 (60%)	
≥22,800	1551 (20%)	18 (8%)		1527 (21%)	42 (9%)		1392 (22%)	177 (12%)	
Diabetes	1541 (20%)	46 (22%)	0.603	1478 (20%)	109 (22%)	0.199	1283 (20%)	304 (21%)	0.259
Anemia	2037 (26%)	73 (34%)	0.015	1955 (26%)	155 (32%)	0.010	1666 (26%)	444 (31%)	0.001
Hypertension	3381 (44%)	112 (53%)	0.014	3241 (44%)	252 (52%)	0.001	2790 (43%)	703 (49%)	<0.001
Myocardial infarction	211 (3%)	13 (6%)	0.009	196 (3%)	28 (6%)	<0.001	164 (3%)	60 (4%)	0.001
Chronic obstructive pulmonary disease	2126 (28%)	77 (36%)	0.008	2022 (27%)	181 (37%)	<0.001	1733 (27%)	470 (33%)	<0.001
Renal failure	352 (5%)	38 (18%)	<0.001	306 (4%)	84 (17%)	<0.001	241 (4%)	149 (10%)	<0.001
Hyperlipidemia	657 (9%)	15 (7%)	0.533	635 (9%)	37 (8%)	0.503	563 (9%)	109 (8%)	0.174
Mild liver disease	1263 (16%)	36 (17%)	0.851	1219 (16%)	80 (16%)	1.000	1066 (16%)	233 (16%)	0.844
Neoadjuvant radiotherapy	112 (1%)	2 (1%)	0.772	104 (1%)	10 (2%)	0.237	76 (1%)	38 (3%)	0.061
Neoadjuvant chemotherapy	163 (2%)	1 (0%)	0.136	159 (2%)	5 (1%)	0.101	117 (2%)	47 (3%)	0.154
Year of index operation			0.004			<0.001			0.011
2000–2005	4773 (62%)	153 (72%)		4586 (62%)	340 (70%)		3988 (62%)	938 (65%)	
2006–2010	2919 (38%)	60 (28%)		2832 (38%)	147 (30%)		2480 (38%)	499 (35%)	
Blood transfusion (unit; U)			<0.001			<0.001			<0.001
No transfusion	2855 (37%)	18 (9%)		2841 (38%)	32 (6%)		2675 (41%)	198 (14%)	
1–2 U	1711 (22%)	24 (11%)		1676 (23%)	59 (12%)		1466 (23%)	269 (19%)	
3–4 U	1074 (14%)	19 (9%)		1041 (14%)	52 (11%)		890 (14%)	203 (14%)	
5–6 U	746 (10%)	26 (12%)		715 (10%)	57 (12%)		586 (9%)	186 (13%)	
>6 U	1306 (17%)	126 (59%)		1145 (15%)	287 (59%)		851 (13%)	581 (40%)	
Splenectomy	1915 (25%)	68 (32%)	0.025	1826 (25%)	157 (32%)	<0.001	1538 (24%)	445 (31%)	<0.001
ICU admission	3222 (42%)	177 (83%)	<0.001	3010 (41%)	389 (80%)	<0.001	2483 (38%)	916 (64%)	<0.001
Length of hospital stay (days)	26.9 ± 25.8	19.2 ± 7.1	<0.001	26.5 ± 26.1	29.6 ± 13.8	<0.001	32.1 ± 26.1	33.6 ± 21.1	<0.001
Hospital volume for TG			<0.001			<0.001			<0.001
Low-volume (<10/per year)	2647 (34%)	114 (54%)		2513 (34%)	248 (51%)		2127 (33%)	634 (44%)	
High-volume (≥10/per year)	5045 (66%)	99 (46%)		4905 (66%)	239 (49%)		4341 (67%)	803 (56%)	
Any major complication	542 (7%)	23 (11%)	0.042	480 (6%)	85 (17%)	<0.001	379 (6%)	186 (13%)	<0.001
Transarterial embolization	17 (0%)	0 (0%)	1.000	13 (0%)	4 (1%)	0.018	12 (0%)	5 (0%)	0.216
Intra-abdominal abscess drainage	62 (1%)	2 (1%)	0.691	54 (1%)	10 (2%)	0.005	37 (1%)	27 (2%)	<0.001

Table 3 continued

Variable	≤30 days			≤60 days			≤180 days		
	Alive $n = 7692$	Dead $n = 213$	*P* value	Alive $n = 7418$	Dead $n = 487$	*P* value	Alive $n = 6468$	Dead $n = 1437$	*P* value
Endoscopic intervention for GI bleeding	164 (2%)	6 (3%)	0.467	145 (2%)	25 (5%)	<0.001	124 (2%)	46 (3%)	0.003
Wound debridement	166 (2%)	2 (1%)	0.093	150 (2%)	18 (4%)	0.021	117 (2%)	51 (4%)	<0.001
Relaparotomy	177 (2%)	15 (7%)	<0.001	154 (2%)	38 (8%)	<0.001	92 (1%)	100 (7%)	<0.001

TG total gastrectomy, *ICU* intensive care unit, *GI* gastrointestinal

Table 4 The factors associated with 30-, 60-, and 180-day mortality rates in the multivariate analysis

Risk factor	≤30 days OR (95% CI)	≤60 days OR (95% CI)	≤180 days OR (95% CI)
Splenectomy	1.12 [0.83–1.53]	1.10 [0.89–1.36]	1.14 [1.01–1.31]*
Age (reference: ≤49) (years)			
50–64	5.68 [1.72–18.69]***	1.79 [1.09–2.93]*	0.93 [0.74–1.16]
≥65	11.31 [3.50–36.58]***	3.03 [1.88–4.87]***	1.28 [1.02–1.60]*
Female	1.16 [0.83–1.60]	0.94 [0.75–1.19]	1.03 [0.89–1.18]
Monthly income (reference: < 15,000)			
15,000–22,799	1.20 [0.86–1.66]	1.06 [0.85–1.32]	1.07 [0.93–1.24]
≥22,800	1.15 [0.63–2.09]	0.84 [0.56–1.26]	0.82 [0.66–1.03]
Anemia	0.95 [0.70–1.29]	0.84 [0.68–1.04]	0.90 [0.79–1.04]
Myocardial infarction	1.86 [0.98–3.41]	1.78 [1.14–2.78]*	1.40 [0.99–1.92]
Chronic obstructive pulmonary disease	1.12 [0.82–1.51]	1.22 [0.98–1.51]	1.14 [0.99–1.31]
Hypertension	0.93 [0.69–1.25]	0.92 [0.74–1.13]	0.98 [0.86–1.12]
Operation in 2006–2010 (reference: 2000–2005)	0.71 [0.52–0.98]*	0.80 [0.64–0.99]*	0.95 [0.84–1.08]
High-volume hospital	0.64 [0.48–0.85]***	0.68 [0.56–0.82]***	0.80 [0.70–0.90]***
Blood transfusion (reference: no)			
1–2 U	1.90 [1.02–3.52]*	2.73 [1.76–4.23]***	2.28 [1.88–2.78]***
3–4 U	2.24 [1.16–4.32]*	3.66 [2.33–5.75]***	2.76 [2.23–3.42]***
5–6 U	4.17 [2.24–7.75]***	5.56 [3.54–8.72]***	3.70 [2.95–4.64]***
>6 U	11.87 [7.06–19.95]***	16.70 [11.36–24.57]***	7.72 [6.38–9.34]***
Any complication	0.75 [0.48–1.19]	1.45 [1.10–1.90]**	1.32 [1.08–1.61]**

OR odds ratio, *CI* confidence interval

*P = 0.01–0.05; **P = 0.001–0.01; ***$P \leq 0.001$

Discussion

In this study of 7905 TGs for patients with gastric cancer, the overall postoperative mortality rate elevated dramatically over time and was almost seven times higher at 180 days than that at 30 days. TG patients at high-volume hospitals had markedly lower 30-, 60-, and 180-day mortality rates than those at low-volume hospitals after adjustment for age, sex, comorbidities, and year of the index operation. To the best of our knowledge, this is the first nationwide study with a large population and prolonged (up to 180 days) longitudinal period to establish the impact of the volume of TG procedures on the surgical outcomes in one UHC system.

To improve patients' outcomes, there is a growing recognition that patient outcome is not reducible to treatment alone since it is a complex interaction between three main factors (treatment + patient + system) [20]. Status of insurance, one key element of healthcare system, affects the surgical and medical outcomes [21–23]. Taiwan had adopted one UHC system since 1995 as a high-performing single-payer national health insurance system that is well known for good accessibility, comprehensive population coverage, and low co-payment [24]. After the

Affordable Care Act in America, state and local governments are trying to improve access to care and move toward one UHC system [25]. Our finding may present and reflect some information for the countries switching from PHC to UHC system to develop new policy or strategy.

Traditionally, mortality before hospital discharge or within 30 days after the index procedure has been considered as the standard outcome measure [15, 26]. Although most surgery-related deaths occurred in the early postoperative period, late deaths were also frequent [14], especially in patients with surgical complications. Short-term "surgical" outcome (30- or 60-day mortality) may not reflect the entire picture of the longitudinal "clinical" outcomes in patients undergoing complex oncological surgeries because intensive care and rescue interventions in the modern era could support patient survival for more than 1 month even when the patients develop postoperative complications. Our findings showed that the rate of 180-day mortality was approximately seven times higher than the 30-day mortality rate. This result implied that a more precise selection of TG for patients with cancer should be done to provide relatively long-term survival/benefits. Consequently, a longer duration of follow-up for TG-related deaths is essential to reflect the surgical quality. Unlike the short-term mortality rate of 0.9% in the Japan nationwide database (TG in 2011) [27], our 30-day mortality rates corroborated other nationwide studies [28, 29], and these findings still represented an average quality of surgical skills.

The favorable volume–outcome correlation in this study is consistent with the US Nationwide Inpatient Sample report focusing on complicated cancer surgery (e.g., pancreatic, esophageal, and rectal cancer) [30]. Although we did not investigate the mechanisms underlying the correlation between the hospital volume and mortality outcomes, high-volume hospitals might have had more surgeons specializing in TG and protocols in place focusing on the perioperative optimization, such as timely recognition of complications, better-staffed intensive care units, and multidisciplinary teams for dealing postoperative complications [6, 12, 31].

Increasing age, especially ≥65 years, was the leading factor contributing to the 30-day mortality, whereas its effect on the mortality became less significant after 180 days; this finding could be attributed to the decreased physiological reserve in the elderly, especially in those with postoperative complications. However, the elderly might be protected from complications by appropriate critical care. The life expectancy has been increasing worldwide, and it is anticipated that >16% of the world's population will be aged >65 years by the year 2050 [32]. This study suggests that offering TG to the elderly requires careful preoperative assessment and referral to high-volume hospitals.

The administration of >6 units of PRBCs is the most crucial variable associated with the increased short- and long-term mortality rates. The multivariable model revealed a dose–effect correlation even while adjusting for the preoperative diagnosis of anemia and hemorrhages needing intervention. In addition, risk factors for the blood transfusion included preoperative anemia, coagulopathy, complicated surgical procedures, and perioperative bleeding events after general surgical procedures. Some studies have suggested restricting the blood transfusion during oncological surgery because the blood transfusion might aggravate immunosuppression and adversely impact oncological outcomes after colorectal and hepatobiliary procedures [33–35]. A study using the database of the American College of Surgeons National Surgical Quality Improvement Program reported that patients who received intraoperative blood transfusions exhibited relatively high rates of mortality and severe morbidities [36]. However, the effects of the blood transfusion might extend beyond the early perioperative period because the postoperative blood transfusion could also affect outcomes beyond the first few postoperative days [37]. Thus, strategies to attain the goal of restrictive blood transfusion should be developed for patients undergoing TG. However, the retrospective nature of this study cannot exclude the likelihood of confounders that were more likely than transfusion per se to be directly associated with the mortality; these confounders include the inevitable transfusion because of the major intraoperative bleeding. Unfortunately, the transfusion for intraoperative and postoperative hemorrhages could not be differentiated in this study, and the blood transfusion should be defined and tracked separately to investigate the effect of its timing on the outcomes [38]. Transfusion remains a lifesaving practice in surgical patients who suffer substantial blood loss; however, increased blood transfusion during the TG index hospitalization contributed to worse outcomes.

Recent time period was associated with better surgical outcomes in this study. This finding may be attributed to progressive advancements in perioperative care, more experienced surgical skills, and development of new surgical instruments. During the study period, we found that a new series of staplers has been introduced since 2000 [39], which accelerate the procedures of enteral resection and anastomosis. Furthermore, new-generation hemostatic devices contributed to shorter operation times and less blood loss compared with conventional hemostatic techniques in patients with gastric cancer undergoing curative gastrectomy [40]. The aforementioned devices may partially decrease the workloads during complex TG procedures.

The findings of this study should be evaluated in the context of some limitations. First, the inherent retrospective cohort study design leads to the possibility of errors related to miscoding and omission, which might have affected the accuracy and quality of data. Hence, given the quality control provided by trained surgical clinical reviewers, the Taiwan NHIRD might be preferable than other large administrative datasets. Second, this study was limited by the unavailability of some critical confounding factors or information, such as body weight, blood loss, and cancer staging. To offset the shortcoming of lack of cancer staging, we performed another adjusted analysis (in the supplementary table) incorporating all total gastrectomy patients with benign and cancer diseases to predict surgical mortality, which indicated that high-volume hospitals were still significantly associated with lower surgical mortality rates compared with low-volume hospitals. Finally, the study was limited to an Asian population with relatively higher incidence of gastric cancer compared to western countries and the definition of annual number of hospital volumes may be adjusted. Hence, further studies are warranted to validate these findings in western countries.

Conclusions

This study reveals that although TG is a complex operation with high mortality rates (up to 180-day), high hospital volume correlates with perioperative outcomes. Hence, the strategy to advocate the centralization of TG is reasonable in one UHC system, especially for the elderly.

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