Annals of Surgical Oncology, **13**(9): 1182–1188
DOI: 10.1245/s10434-006-9005-0

Hospital Volume and Inpatient Mortality After Cancer-Related Gastrointestinal Resections: The Experience of an Asian Country

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Background: Using 4-year nationwide population-based data for Taiwan, this study compared in-hospital surgical mortality rates with hospital volume for five cancer-related gastrointestinal resections.

Methods: The study sample was drawn from the Taiwan National Health Insurance Research Database. A total of 34,715 patients, each of whom had undergone a cancer-related colectomy, gastrectomy, esophagectomy, pancreatic resection, or liver lobectomy between 2000 and 2003, were selected as the study sample. The outcome measure was in-hospital mortality. The study sample was categorized into five patient groups for each procedure, and logistic regression analyses were performed for each procedure after adjustment for hospital and patient characteristics to assess the independent association between hospital volume and in-hospital mortality.

Results: The adjusted odds ratios showed a steady decline in mortality rates for colectomy, gastrectomy, esophagectomy, and liver lobectomy with increasing hospital volume. The adjusted mortality odds for these four procedures in very-high-volume hospitals, relative to very-low-volume hospitals, ranged from .65 to .05. As regards pancreatic resection, after adjustment for patient, clinical, and hospital factors, no statistically significant association was discernible between hospital volume and the likelihood of mortality.

Conclusions: After adjustment for hospital and physician characteristics, in four of the five procedures, patients treated at higher-volume hospitals had lower in-hospital mortality rates than those treated at lower-volume hospitals. Our findings confirm, for the most part, the hypothesis that better outcomes are associated with higher-volume hospitals.

Key Words: In-hospital mortality—Hospital volume—Gastrointestinal oncology—Colectomy

The past three decades have witnessed growing debate in medical circles on the association between patient outcomes and the volume of surgical procedures performed by physicians and hospitals. A large body of research has consistently documented better health outcomes at hospitals with larger procedure volumes.[1–4] These studies also suggest that thousands of surgical deaths could be prevented if surgery were performed in hospitals or by physicians with adequate surgical experience in the respective surgical procedures.[5–9] On the basis of the documented volume-outcome relationship, researchers in

Received December 6, 2005; accepted February 13, 2006; published online August 5, 2006.

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the United States have proposed policies to reduce preventable mortality, such as regionalized or centralized approaches to cluster surgical procedures by hospital or physician and selective referral of patients to high-volume providers relative to the procedure.[7]

However, most of these studies have been located in the United States, with few or none available from other regions, particularly from the developing world. Does this relationship hold universally, regardless of health system factors? Answering this question through studies in other health systems is an essential prerequisite to designing policy initiatives directed at reducing preventable mortality from care provided in low-volume hospitals. This is because validation of the relationship in differently designed health systems and cultures lends credence to the hypothesis that practice indeed makes perfect even in medicine or, alternatively, that patient self-referral to quality-reputed institutions is a cycle that needs to be encouraged through appropriate policies. Regardless of the mechanism by which the volume-outcome relationship is fueled, it is useful to document whether the relationship itself is invariant to the particular design of the health system. Such documentation would provide an empirically robust ground for health care policy makers, regardless of health system characteristics, to initiate policies to reduce preventable iatrogenic deaths. The potential to save lives is too important to let matters take their course on this issue.

Taiwan's National Health Insurance database presents an opportunity to examine volume-outcome relationships in a developing country. All of Taiwan's ≥23 million citizens have been covered under National Health Insurance since March 1995. It has a unique combination of characteristics: universal coverage, comprehensive benefits, and a single-payer system with the government as the sole insurer. In addition, all patients in Taiwan have free access to any health care provider of their choice, unlike other health care delivery systems, which can often limit a patient's choice with regard to certain providers and which may confound the relationship between provider volumes and patient outcomes.

Using 4-year nationwide population-based data, from January 2000 to December 2003, this study examined in-hospital surgical mortality rates as a function of hospital volume for five gastrointestinal cancer-related resection procedures: colectomy, gastrectomy, esophagectomy, pancreatic resection, and liver lobectomy. To our knowledge, this is the first nationwide population-based study on volume-mortality relationships in high-risk cancer surgery outside of the United States.

METHODS

Database

Patients were drawn from Taiwan's National Health Insurance Research Database (NHIRD), which covers all inpatient claims for its population of > 23 million. The NHIRD database includes a registry of contracted medical facilities, a registry of board-certified surgeons, a monthly claims summary for inpatient claims, and details of inpatient orders and expenditures on prescriptions dispensed at contracted pharmacies. This database is possibly the largest and most comprehensive population-based data source currently available, providing International Classification of Diseases, 9th Revision, Clinical Modification codes of the primary diagnosis and up to four secondary diagnoses.

Study Sample

The data were accessed from the NHIRD. During January 2000 through December 2003, we selected all patients who underwent one of the five following major gastrointestinal resections with an accompanying cancer diagnosis code: colectomy, gastrectomy, esophagectomy, pancreatic resection, and liver lobectomy. These procedures were selected because they are generally associated with high mortality rates, are relatively large in number, and have been the focus of other studies on the volume-outcome relationship,[4,10,11] notably in the United States. Of the total approximately 10 million inpatient admissions during the study period, 13,055, 11,348, 6,674, 1,766, and 1,872 were for cancer-related colectomy, gastrectomy, esophagectomy, pancreatic resection, and liver lobectomy, respectively.

Hospital Volume Groups

Because unique hospital identifiers are available against each claim in the database, we were able to calculate hospital-wise volume for each cancer resection procedure (total number of operations conducted at the hospital) during the 4-year study period. This is consistent with the definition of hospital volume adopted in previous studies.[12,13] For each procedure, hospitals were sorted in ascending order of volume, and the cutoff points were determined by the volume that most closely sorted the sampled patients into five approximately equal groups. This method is also consistent with the methodology used in previous studies. The five quintiles for each procedure are very low volume, low volume, medium volume, high volume, and very high volume. Given Taiwan's population and the total number of cases of each procedure available, the quintile volume thresholds are lower than those used in US studies.

Statistical Analysis

The SAS statistical package (SAS System for Windows, version 8.2; SAS Institute, Cary, NC) was used. The outcome measure was in-hospital mortality, defined as "patient death any time after the operation and the patient did not leave the hospital alive." The patient was the unit of analysis. Hospital volume was measured at the hospital level.

Logistic regression analysis was performed separately for each procedure to assess the independent association between hospital volume and in-hospital mortality, adjusted for hospital and patient characteristics, including clinical comorbidity. Finally, the generalized estimated equation was used to account for clustering effects among sample patients treated at a given hospital.[14] *Clustering effects* refer to the likelihood of similarity of a given provider's patient outcomes, as opposed to between-hospital effects. Our dataset did not provide unique physician identifiers, which would have enabled us to examine the additional effect of physician volume in addition to the effect of hospital volume.

Hospital characteristics included hospital ownership (public, private not-for-profit, or private for-profit), hospital level (medical center with ≥500 beds, regional hospitals with 250–499 beds, and district hospitals with 20–249 beds), and geographical location (north, central, south, and east Taiwan). Hospital level serves as a proxy for hospital size and technological capabilities in clinical services. Hospital teaching status was not included because all medical centers and regional hospitals are teaching hospitals.

Patient characteristics that we controlled for included age (<45, 45–64, 65–74, 75–84, and >84 years), sex, and clinical comorbidities. For colectomy cases, an additional control variable used was the resection type: right hemicolectomy, left hemicolectomy, sigmoidectomy, transverse colon resection, other partial excision of the large intestine, and other procedures (for pancreatic resection, although it would be desirable to control for procedure type—Whipple's procedure [more complex and risky] vs. distal pancreatectomy—the dataset did not provide codes to distinguish between these procedures). To control for comorbidities, for all four diagnoses, we used the Charlson Comorbidity Index to adjust for clinical comorbidities.[15] The Charlson Comorbidity Index was developed in 1987 by Charlson et al.[15] to adjust for the higher mortality risks associated with comorbidities. It has been widely used for risk adjustment in administrative claims datasets.[16,17] Our dataset did not have information on the stage of cancer or the duration since cancer diagnosis. P values were two sided, and a significance level of $P \leq .05$ was used.

RESULTS

A total of 34,715 patients were admitted with 1 of 5 cancer-related gastrointestinal resections in Taiwan during January 2000 to December 2003. Table 1 lists the distribution of patients and hospitals according to hospital volume for the five procedures. During the study period, 178, 174, 111, 86, and 82 hospitals had performed 1 or more cancer-related colectomies, gastrectomies, esophagectomies, pancreatic resections, and liver lobectomies, respectively. The mean hospital volumes for the respective procedures in very-high-volume hospitals are approximately 45, 72, 30, 40, and 52 times the mean volumes at very-low-volume hospitals, thus reflecting wide variation in hospital volumes for all 5 procedures.

Table 2 lists the characteristics of sample patients, classified by hospital volume quintiles, under each procedure. Patients, particularly esophagectomy patients, were predominantly male. Age and comorbidity distributions show that very-low-volume hospitals, on average, had older patients and a lower comorbidity index. For colectomy, classification by procedure type (right hemicolectomy, left hemicolectomy, sigmoidectomy, transverse colon resection, other partial excision of the large intestine, and other procedure) is also shown. There were significant differences in the distribution by hospital volume quintile ($\chi^2 = 170.3$; $P < .001$): right hemicolectomy was disproportionately higher at very-high-volume hospitals, and other resection types were disproportionately higher at very-low-volume hospitals.

Table 3 lists the observed (unadjusted) in-hospital mortality rates among the hospital volume quintiles for the five procedures. For the most part, the unadjusted mortality rate decreased with increasing hospital volume for gastrectomy, esophagectomy, and liver lobectomy. For example, the unadjusted mortality likelihood of gastrectomy patients at very-

TABLE 1. *Distribution of patients and hospitals among quintiles of hospital volume for five gastrointestinal cancer resection procedures in Taiwan, 2000 to 2003*

Procedure	Hospital volume				
	Very low	Low	Medium	High	Very high
Colectomy					
Total No. patients (%)	2608 (20.0)	2538 (19.4)	2765 (21.2)	2574 (19.7)	2569 (19.7)
Right hemicolectomy[a]	936 (35.9)	1085 (42.8)	1181 (42.7)	1016 (39.5)	1190 (46.3)
Left hemicolectomy[a]	641 (24.6)	601 (23.7)	703 (25.4)	470 (18.3)	517 (20.1)
Sigmoidectomy[a]	501 (19.2)	395 (15.6)	449 (16.2)	517 (20.1)	433 (16.9)
Other partial excision of large intestine[a]	357 (13.7)	336 (13.2)	304 (11.0)	425 (16.5)	289 (11.3)
Transverse colon resection[a]	118 (4.5)	78 (3.1)	76 (2.8)	77 (3.0)	75 (2.9)
Others[a]	55 (2.1)	43 (1.7)	52 (1.9)	69 (2.7)	65 (2.5)
Volume threshold	< 82	82–193	194–338	339–668	> 668
Mean No. procedures (SD)	16 (19)	129 (33)	265 (42)	576 (65)	1152 (380)
Esophagectomy					
No. patients (%)	1354 (20.3)	1338 (20.1)	1382 (20.7)	1161 (17.4)	1439 (21.6)
No. hospitals	84	13	7	4	3
Volume threshold	< 78	78–135	136–235	236–346	> 346
Mean No. procedures (SD)	16 (21)	103 (19)	197 (21)	290 (42)	480 (165)
Pancreatic resection					
No. patients (%)	361 (20.4)	330 (18.7)	416 (23.6)	260 (14.7)	399 (22.6)
No. hospitals	66	11	5	2	2
Volume threshold	< 20	20–42	43–116	117–131	> 131
Mean No. procedures (SD)	5 (5)	30 (7)	83 (23)	130 (15)	200 (80)
Liver lobectomy					
No. patients (%)	362 (19.3)	386 (20.6)	379 (20.3)	430 (23.0)	315 (16.8)
No. hospitals	63	11	4	2	2
Volume threshold	< 25	25–51	52–186	197–231	> 231
Mean No. procedures (SD)	6 (6)	35 (9)	95 (61)	215 (31)	315 (28)

[a] Differences in distribution of colectomy type by volume quintiles is significant ($\chi^2 = 170.3$; $P < .001$).

low-volume hospitals was 1.61 times (reciprocal of .62) that of low-volume hospitals, 1.75 times (reciprocal of .57) that of medium-volume hospitals, 3.57 times that of high-volume hospitals, and 4.17 times that of very-high-volume hospitals. For colectomy and pancreatic resection, although very-low-volume hospitals still had the lowest unadjusted mortality rate, high-volume hospitals had somewhat higher mortality than those in the low-volume and medium-volume strata.

Table 3 also shows the adjusted odds ratio for in-hospital mortality, adjusted for clinical comorbidity, age, sex, and hospital characteristics, as well as procedure type for the colectomy group. For gastrectomy, esophagectomy, and liver lobectomy, the adjusted odds ratios showed a steady mortality rate decline with increasing hospital volume. The adjusted odds of mortality in very-high-volume hospitals for these three procedures ranged from .65 to .05 relative to very-low-volume hospitals.

In case of colectomy, the adjusted odds ratios declined going from very-low-volume hospitals to very-high-volume hospitals, although the middle categories of medium- and high-volume groups had similar mortality likelihoods, adjusted for hospital and patient characteristics. Pancreatic resection does not show statistically significant associations of mortality likelihood with hospital volumes when adjusted for patient, clinical, and hospital factors. When these results are adjusted for clustering effects by the generalized estimated equation, all the significant relationships remain, except for a widening of the confidence intervals.

DISCUSSION

This study was an uncommon opportunity to investigate hospital volume/outcome relationships for cancer resection operations by using population-based data outside of the United States. The findings of our study are based on 34,715 patients with 1 of the 5 leading gastrointestinal cancer resection procedures in Taiwan between 2000 and 2003. It showed that for four out of five procedures, patients treated at higher-volume hospitals had lower in-hospital mortality than their counterparts treated at lower-volume hospitals after adjustment for hospital level, ownership, and location, as well as patient age, sex, and comorbidities. Our findings, for the most part, confirm the hypothesis that higher-volume hospitals are associated with better outcomes.

The literature suggests two possible hypotheses to explain the inverse volume-outcome relationship:

TABLE 2. *Patient characteristics for five gastrointestinal cancer resection procedures in Taiwan by hospital volume, 2000 to 2003*

	Hospital volume				
Procedure	Very low	Low	Medium	High	Very high
Colectomy					
Mean age, y (SD)	68 (14)	67 (14)	65 (14)	66 (13)	65 (14)
Female (%)	42	47	48	44	44
Charlson score ≥3 (%)	35	47	50	48	53
Gastrectomy					
Mean age, y (SD)	68 (13)	66 (14)	64 (14)	64 (14)	65 (14)
Female (%)	29	32	36	28	31
Charlson score ≥3 (%)	36	50	50	54	51
Esophagectomy					
Mean age, y (SD)	59 (12)	60 (12)	59 (12)	59 (12)	60 (12)
Female (%)	16	19	20	14	15
Charlson score ≥3 (%)	75	80	79	78	76
Pancreatic resection					
Mean age, y (SD)	65 (12)	63 (12)	64 (13)	64 (13)	63 (13)
Female (%)	43	47	40	37	38
Charlson score ≥3 (%)	37	39	48	50	48
Liver lobectomy					
Mean age, y (SD)	59 (14)	58 (14)	56 (15)	52 (12)	57 (14)
Female (%)	31	25	23	26	28
Charlson score ≥3 (%)	36	29	30	20	22

TABLE 3. *Operative in-hospital mortality rates and the association with hospital volume for five gastrointestinal cancer resection procedures in Taiwan, 2000 to 2003*

	Hospital volume				
Procedure	Very low	Low	Medium	High	Very high
Colectomy					
Observed mortality rate (%)	3.03	1.81	1.88	2.10	2.06
Unadjusted odds ratio	1.00	.59 (.41–.85)	.61 (.43–.87)	.69 (.48–.97)	.67 (.47–.96)
Adjusted odds ratio	1.00	.61 (.39–.94)	.56 (.29–.97)	.54 (.31–.94)	.33 (.17–.66)
Gastrectomy					
Observed mortality rate (%)	5.35	3.36	3.13	1.56	1.35
Unadjusted odds ratio	1.00	.62 (.46–.82)	.57 (.42–.77)	.28 (.19–.41)	.24 (.16–.36)
Adjusted odds ratio	1.00	.87 (.61–1.25)	.58 (.33–1.00)	.45 (.25–.81)	.28 (.15–.53)
Esophagectomy					
Observed mortality rate (%)	6.79	7.60	5.31	4.22	5.49
Unadjusted odds ratio	1.00	1.13 (.84–1.51)	.77 (.56–1.06)	.60 (.42–.86)	.80 (.58–1.09)
Adjusted odds ratio	1.00	.97 (.68–1.39)	.87 (.62–1.23)	.72 (.47–.91)	.65 (.43–.97)
Pancreatic resection					
Observed mortality rate (%)	6.09	1.82	1.20	3.08	2.51
Unadjusted odds ratio	1.00	.29 (.11–.71)	.19 (.07–.50)	.49 (.21–1.12)	.40 (.19–.85)
Adjusted odds ratio	1.00	.56 (.19–1.68)	.37 (.09–1.47)	1.16 (.27–5.05)	.69 (.18–2.71)
Liver lobectomy					
Observed mortality rate (%)	4.42	2.33	1.58	0	.32
Unadjusted odds ratio	1.00	.52 (.23–1.18)	.35 (.14–.90)	—[a]	.07 (.01–.52)
Adjusted odds ratio	1.00	.64 (.19–2.14)	.30 (.07–.56)	—[a]	.05 (.04–.59)

Data in parentheses are the 95% confidence intervals.
[a] Statistically indeterminate.

practice makes perfect and selective referral.[18,19] To identify which of these mechanisms is instrumental, two research strategies may be useful. One is to concurrently control for physician-specific volume to examine whether it is a stronger predictor of outcomes than is hospital volume. If physicians operating at multiple hospitals and having larger patient volumes for the procedure show superior outcomes regardless of the volume at the hospital operated in, then the ''practice makes perfect'' hypothesis is sustained. Statistically, then, the hospital volume effect should disappear once physician volume is added into the regression. Our dataset did not provide physician-level unique identifiers to investigate this issue.

Another way to test the ''practice makes perfect'' hypothesis is to conduct longitudinal studies of the effect of physician-specific volume over time. If a given physician, moving from very low through medium and high volumes, shows a declining mortality rate on average, this would strongly favor the ''practice makes perfect'' hypothesis. If this does not happen, then increasing self-referral to reputed hospitals for better quality and having low mortality rates may be credited with causing the volume-outcome relationship.

In our study, pancreatic cancer resections were the only group that did not support the volume-outcome relationship. This finding is not consistent with documented US studies, which have consistently found significant mortality differences between high- and low-volume hospitals.[20,21] Birkmeyer et al.[22] found that the mortality likelihood for patients treated at very-low-volume hospitals was approximately six times as high as that in very-high-volume hospitals. Halm et al.[9] also documented that pancreatic resection shows consistent and striking differences in mortality rates between high- and low-volume hospitals, in a systematic review of 272 volume-outcome studies of a variety of surgical procedures (the mean difference in mortality rates of high- and low-volume providers was between 3.0 and 17.9).

One likely reason for our departure from the US findings on pancreatic resection is confounding by procedure type. Pancreatic cancer resections largely fall into two categories: Whipple's procedure and distal pancreatic resection. Whipple's procedure is widely documented to be a far more complex procedure with a significant potential for adverse outcomes as a result of the complexities involved in the method of gastrointestinal reconstruction,[23] whereas distal pancreatic resection is documented to have generally better outcomes.[24] If the higher-volume hospitals performed disproportionately more Whipple's procedures, then their higher mortality due to this factor could be overshadowing the inverse volume-outcome relationship. The Charlson index, which is our only clinical status control variable, is not designed to account for differences in clinical severity, including the stage of disease and tumor size, grade, and differentiation, which are not documented in an administrative claims database. Evidently, the stage of cancer and the extent of infiltration into surrounding tissues, including vital organs and blood vessels, would play a critical role in surgical resection outcomes. This factor is particularly likely to affect pancreatic resection outcomes, and this may account for our lack of significant findings with this procedure.

We also found that the total in-hospital mortality rates for colectomy, gastrectomy, esophagectomy, pancreatic resection, and liver lobectomy in Taiwan between 2000 and 2004 were 2.18%, 2.97%, 5.93%, 2.89%, and 1.71%, respectively (not shown in the Tables). These figures were much lower than those reported in the United States. For example, Halm et al.[9] observed that the average mortality rates for colectomy, gastrectomy, esophagectomy, and pancreatic resection were 6.0, 10.9, 13.9, and 9.7, respectively, on the basis of a literature review. Most of the US studies used operative mortality as their outcome measure, defined as mortality before hospital discharge or within 30 days after the index procedure. This may be one reason for the difference between our mortality rates and US rates: our data did not include postdischarge deaths in the month after the procedure.[22,25] A request for discharge of terminally ill patients who may prefer to die at home is not uncommon in Taiwan. Differences in mortality rates could be partly due to this reason. Our limitation of excluding postdischarge deaths also qualifies our findings, because operative mortality should ideally capture postdischarge deaths.

Another reason for differences in mortality rates between Taiwan and the United States could be differences in the study periods; many documented studies used older data, between 1984 and 1997. The mortality rates found with older data (when surgical procedures were not as advanced) may not be comparable to the rates with the current state of the art.

Despite these limitations, this study found that after adjustment for patient and hospital characteristics, an inverse volume-outcome relationship exists in Taiwan for four of five gastrointestinal cancer operations. For lack of validation through longitudinal studies, however, the evidence cannot be considered adequate to proactively initiate policies to minimize operative mortality. This study contributes to the literature on this issue by showing that the volume-outcome relationship holds in a very different national and health system context. It indicates the possibility that the volume-outcome relationship is driven by local contextual factors in the United States. It also highlights the need for systematic longitudinal studies to clarify the operative mechanism: whether practice makes perfect or whether more patients self-refer to reputed hospitals.

If it turns out that patients' self-referring to reputed hospitals causes lower mortality in high-volume hospitals, then research will be needed to identify differences in clinical and care approaches between high-volume hospitals with excellent outcomes and low-volume hospitals with poor outcomes. The results of such studies could be used to improve the quality of patient care at low-volume hospitals.

ACKNOWLEDGMENTS

This study is based in part on data from the National Health Insurance Research Database provided by the Bureau of National Health Insurance, Department of Health and managed by the National Health Research Institutes, Taiwan. The interpretations and conclusions contained herein do not represent those of the Bureau of National Health Insurance, Department of Health, or the National Health Research Institutes.

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