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Association Between Surgeon and Hospital Volume and In-Hospital Fatalities After Lung Cancer Resections: The Experience of an Asian Country

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Background. **We used 4-year nationwide population-based data to explore the volume-outcome relationships for lung cancer resections in Taiwan and to determine whether there is any association between high-volume hospitals or high-volume surgeons and lower in-hospital mortality rates.**

Methods. **We use pooled data for the years 2001 through 2004 obtained from the National Health Insurance Research Database in Taiwan. A total of 4,841 patients, identified as having undergone pulmonary resections for lung or bronchial tumors during the period of this study, were treated by 377 surgeons in 79 hospitals. Multivariate logistic regression analyses were then employed to assess the crude and adjusted odds ratio of in-patient fatalities between surgeon and hospital lung cancer resection volume groups.**

Results. **Patients treated by low-volume surgeons had significantly higher in-hospital fatality rates than those treated by either medium-volume surgeons (2.3% versus 1.0%; $p < 0.001$) or high-volume surgeons (2.3% versus 0.6%; $p < 0.001$). However, hospital case volume alone is not a significant predictor of hospital in-patient fatalities for lung cancer resections. With increasing surgeon volume, there was a decline in the adjusted odds ratio of hospital in-patient deaths. The odds of hospital in-patient deaths for those patients treated by low-volume surgeons were 2.04 times those of medium-volume surgeons, and 2.63 times those of high-volume surgeons.**

Conclusions. **We conclude that after adjusting for patient, surgeon, and hospital characteristics, an inverse volume-outcome relationship does exist for surgeons, but not for hospitals, in Taiwan.**

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It has been demonstrated over the past 3 decades that a clear association exists between the number of operations for cancer performed at particular hospitals (hospital volume) and the operative mortality rates for esophagectomy and gastrectomy operations [1, 2], as well as for pancreatic, breast, and colon cancer operations [3–5]; however, the evidence thus far provided on similar associations in the case of lung cancer resections remains both inconsistent and incomplete.

Some studies have reported no significant trend toward lower operative mortality rates for hospitals with a high volume of lung cancer resections [6–8], while others have reported significantly lower in-hospital mortality rates for high-volume providers undertaking similar resections [9, 10]. Most of these studies were, however, conducted on hospital-level volume alone whereas we have examined the simultaneous contribution to patient outcomes from both hospital and surgeon volume. Furthermore, we have found no examples of similar lung cancer volume-outcome studies having been conducted in Asia.

In this study, we use 4-year population-based data on Taiwan to examine the association between the volume of lung cancer resections (by both surgeons and hospitals) and the subsequent in-hospital mortality rates. We hypothesize that high-volume providers will be associated with superior treatment outcomes for patients undergoing lung cancer resections.

Material and Methods

Database

This study uses pooled data for the years 2001 to 2004, obtained from the National Health Insurance Research Database (NHIRD) published in Taiwan by the National Health Research Institute. The NHIRD database covers all in-patient medical benefit claims for the Taiwanese population of more than 20 million. It also provides principal operational procedures for each patient, along with one principal diagnosis code and as many as four secondary diagnosis codes obtained from the *International Classification of Disease, Ninth Revision, Clinical Mod-*

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ification (ICD-9-CM). Since these were de-identified secondary data, released for public access for research purposes, the study was exempt from full review by the Internal Review Board after consulting with the Director of the Internal Review Board of our university.

Study Sample

The study sample was identified from the pooled database by the diagnostic code 162.XX. We identified a total of 157,683 hospitalizations (45,610 patients) for malignant bronchus and lung neoplasms covering the period from January 2001 to December 2004. Of these, a total of 4,841 patients, treated by 377 surgeons in 79 hospitals, were identified as having undergone pulmonary resections for lung or bronchial tumors during the period under examination.

Surgeon and Hospital Lung Cancer Resection Volume Groups

As unique physician and hospital identifiers are available within the NHIRD for each medical claim submitted, that enabled us to identify the same physician, or the same hospital, carrying out one or more lung cancer resections between January 2001 and December 2004.

Surgeons and hospitals were sorted, in ascending order of their total volume of lung cancer resections, with the cutoff points (high, medium, and low) being determined by the volume that most closely sorted the sample patients into three groups that were roughly equal in size. This method is consistent with the methodologies adopted in many of the prior studies.

The sample of 4,841 patients was subsequently divided into three surgeon volume groups: 46 cases or fewer (hereafter referred to as low volume), 47 to 131 cases (medium volume), and 132 cases or more (high volume); whereas the three hospital volume groups were 135 cases or fewer (hereafter referred to as low volume), 136 to 467 cases (medium volume), and 468 cases or more (high volume).

Key Variables of Interest

Adjustments were made for surgeon, hospital, and patient characteristics in the overall assessment of the relationship between in-hospital deaths and volume groups. The primary study outcome was in-hospital mortality, with patient as the unit of analysis, and the key independent variables were the lung cancer resection volume groups for both surgeons and hospitals. We

Table 1. Surgeon and Patient Characteristics, by Surgeon Lung Cancer Resection Volume Groups, 2001–2004

	Surgeon Lung Cancer Resection Volume Groups											
	Low (1–46)				Medium (47–131)				High (≥132)			
Variable	No.	%	Mean	SD	No.	%	Mean	SD	No.	%	Mean	SD
Surgeon characteristics (n = 377)												
Total number of surgeons	347	92.0			22	5.8			8	2.2		
Lung cancer resection volume	—	—	4.7	8.5	—	—	73.3	27.3	—	—	208.4	73.7
Surgeon age (years)	—	—	41.4	7.3	—	—	41.4	6.6	—	—	48.0	9.2
Surgeon sex												
Male	335	96.5	—	—	22	100			8	100		
Female	12	3.5			—	—			—	—		
Patient characteristics (n = 4,841)												
Total number of patients	1,605	33.1			1,597	33.0			1,639	33.9		
Patient age (years)			64.8	12.2			64.1	11.5			63.8	11.6
<65	666	41.5			704	44.1			773	47.2		
65–74	571	35.6			586	36.7			563	34.4		
>74	368	22.9			307	19.2			303	18.5		
Patient sex												
Male	1,104	68.8			1,052	65.9			1,036	63.2		
Female	501	31.2			545	34.1			603	36.8		
Type of operation												
Segmental resection	182	11.3			190	11.9			99	6.0		
Wedge resection	595	37.1			484	30.3			397	24.2		
Lobectomy	745	46.4			846	53.0			1,051	64.1		
Pneumonectomy	83	5.2			77	4.8			92	5.6		
Charlson Comorbidity Index score	13											
3	689	42.9			786	49.2			809	49.4		
4	223	13.9			200	12.5			189	11.5		
5	44	2.7			40	2.5			25	1.5		
6 or more	649	40.4			571	35.8			616	37.6		

SD = standard deviation.

define in-hospital mortality as the death of a patient at any time after operation either at the operating hospital or upon transfer to another hospital.

Surgeon characteristics included the surgeon's age (as a surrogate for practice experience) and sex; hospital characteristics included hospital ownership, hospital level, and geographical location, with the hospital ownership variable being recorded as one of three types: public, private not-for-profit, and private for-profit hospitals. Within the hospital level variable, each hospital was classified as a medical center (with a minimum of 500 beds), a regional hospital (minimum 250 beds), or a district hospital (minimum 20 beds); hospital level can therefore be used as a proxy for both hospital size and clinical service capabilities. Hospital teaching status was not included in this study since all medical centers and regional hospitals in Taiwan are teaching hospitals.

Patient characteristics consisted of age, sex, severity of illness, and type of operation. Because no illness severity index is available in Taiwan, we used the Charlson Comorbidity Index (CCI) to quantify preexisting comorbidities as a means of adjusting for the higher mortality risks associated with comorbidities (the higher the score, the greater the comorbidity). The type of operation consisted of wedge resection, segmental resection, lobectomy, and pneumonectomy.

Statistical Analysis

The SAS statistical package (SAS System for Windows, version 8.2; SAS Institute, Cary, North Carolina) was

Table 2. Hospital and Patient Characteristics in Taiwan, by Hospital Lung Cancer Operation Volume Groups, 2001–2004

	Hospital Lung Cancer Operation Volume Groups											
	Low (1–135)				Medium (136–467)				High (≥468)			
Variable	No.	%	Mean	SD	No.	%	Mean	SD	No.	%	Mean	SD
Hospital characteristics (n = 79)												
Total number of hospitals	70				6				3			
Lung cancer operation volume	—		23.0	32.1	—		273.5	105.2	—		551.3	102.8
Hospital level												
Medical center	8	11.4			6	100.0			3	100.0		
Regional hospital	50	71.4			—	—			—	—		
District hospital	12	17.1			—	—			—	—		
Hospital ownership												
Public	20	28.6			3	50.0			2	66.7		
Private (not-for-profit)	32	45.7			3	50.0			1	33.3		
Private (for-profit)	18	25.7			—	—			—	—		
Hospital location												
Northern	27	38.6			—	—			3	100.0		
Central	18	25.7			2	33.3			—	—		
Southern	22	31.4			4	66.7			—	—		
Eastern	3	4.3			—	—			—	—		
Patient characteristics (n = 4,841)												
Total no. of patients	1,601	33.1			1,623	33.5			1,617	33.4		
Patient age (years)	—		63.2	11.7	—		63.7	12.1	—		64.9	11.5
<65	713	44.5			743	45.8			687	42.5		
65–74	565	35.3			570	35.1			585	36.2		
>74	323	20.2			310	19.1			345	21.3		
Patient sex												
Male	1,057	66.0			1,062	65.4			1,073	66.4		
Female	544	34.0			561	34.6			544	33.6		
Type of operation												
Segmental resection	174	10.9			183	11.3			114	7.1		
Wedge resection	484	30.2			513	31.6			479	29.6		
Lobectomy	857	53.5			831	51.2			954	59.0		
Pneumonectomy	86	5.4			96	5.9			70	4.3		
Charlson Comorbidity Index score												
3	720	45.0			834	51.4			730	45.2		
4	213	13.2			171	10.5			228	14.1		
5	44	2.8			27	1.7			38	2.4		
6 or more	624	39.0			591	36.4			621	38.4		

SD = standard deviation.

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Table 3. Crude Odds Ratios of Hospital In-Patient Deaths in Taiwan, by Surgeon and Hospital Lung Cancer Resection Volume Groups, 2001–2004 (n = 4,841)

	Discharge Status						
	Live		Deceased				
Variables	No.	%	No.	%	Crude Odds Ratio	95% CI	*p* Value
Surgeon lung cancer operation volume							
≤46	1,568	97.7	37	2.3	1.00	—	—
47–131	1,581	99.0	16	1.0	0.43	0.24–0.77	0.005
≥132	1,629	99.4	10	0.6	0.26	0.13–0.53	<0.001
Hospital lung cancer operation volume							
≤135	1,575	98.4	26	1.6	1.00	—	—
136–467	1,604	98.8	19	1.2	0.72	0.40–1.30	0.274
≥468	1,599	98.9	18	1.1	0.68	0.37–1.25	0.215

CI = confidence interval.

used to perform the statistical analysis of the data in this study. Global χ^2 analyses were conducted to examine the relationship between surgeon and hospital volume lung cancer resection groups and the unadjusted hospital in-patient fatality rates. Multivariate logistic regression analyses were also employed to assess the crude and adjusted odds ratio of hospital in-patient fatalities between surgeon and hospital lung cancer resection volume groups.

Finally, the generalized estimated equation method was also adopted as a means of accounting for any clustering of the sampled patients among particular surgeons or hospitals. Clustering would indicate the greater likelihood for a given provider's patient outcomes to be similar to each other, as opposed to being similar to the patient outcomes of a different provider. A two-sided *p* value of 0.05 or less was considered to be statistically significant.

Results

Of the 4,841 patients in Taiwan on whom pulmonary resections had been performed for lung or bronchial tumors between January 2001 and December 2004, 471 (9.7%) had undergone segmental resections, 1,476 (30.5%) had wedge resections, 2,642 (54.6%) had undergone lobectomies, and 252 (5.2%) had pneumonectomies. The mean age of the patients was 64.2 years, and the mean age of the attending surgeons was 45.4 years.

Details of the distribution of surgeons and patients for lung cancer resections, by surgeon volume, are provided in Table 1, which reveals that lung cancer resections were performed by 377 surgeons between 2001 and 2004, at a mean volume per surgeon of 13 operations. The surgeons in the high-volume group were more likely to be older ($p < 0.001$) and performed more lobectomies and pneumonectomies ($p < 0.001$). The χ^2 analyses also indicate that significant relationships exist between surgeon volume groups and patient sex ($p = 0.004$), age ($p = 0.003$), and CCI scores ($p < 0.001$).

The hospital and patient characteristics, by hospital lung cancer resection volume groups, are summarized in Table 2, which reveals that lung cancer resections were carried out by 79 hospitals between 2001 and 2004, at a mean volume of 62 resections per hospital. The vast

Table 4. Adjusted Odds Ratio of Hospital In-Patient Deaths in Taiwan by Surgeon Lung Cancer Resection Volume Groups, 2001 to 2004 (n = 4,841)

Variable	Adjusted Odds Ratio	95% CI	*p* Value
Surgeon lung cancer resection volume			
≤46 (reference group)	1.00		
47–131	0.49	0.27–0.89	0.018
≥132	0.38	0.17–0.86	0.020
Surgeon characteristics			
Physician age (years)			
<41	0.65	0.36–1.16	0.143
41–50 (reference group)	1.00		
>50	0.62	0.30–1.30	0.206
Patient characteristics			
Patient age (years)			
<65	0.56	0.29–1.11	0.096
65–74 (reference group)	1.00		
>74	1.83	1.02–3.25	0.041
Patient sex			
Male	1.47	0.78–2.77	0.231
Female (reference group)	1.00		
Type of operation			
Segmental resection	2.13	0.85–5.30	0.105
Wedge resection	3.45	1.86–6.43	<0.001
Lobectomy (reference group)	1.00		
Pneumonectomy	5.41	2.24–13.08	<0.001
Charlson Comorbidity Index score			
3 (reference group)	1.00		
4	1.13	0.55–2.31	0.735
5	1.54	0.45–5.26	0.487
6 or more	0.81	0.45–1.45	0.470

CI = confidence interval.

majority of the hospitals (89%) fell into the low-volume group; these hospitals were also more likely to be regional hospitals. Conversely, those hospitals in the high-volume group were all medical centers and were also generally located in the northern part of Taiwan. No significant relationships were observed between hospital volume groups and patient age and sex.

Table 3 provides the crude odds ratio estimates of the likelihood of hospital in-patient deaths, by surgeon and hospital lung cancer resection volume. Patients treated by low-volume surgeons had significantly higher in-hospital mortality rates than those treated by either medium-volume surgeons (2.3% versus 1.0%; $p = 0.005$) or high-volume surgeons (2.3% versus 0.6%, $p < 0.001$). However, hospital case volume alone is not a significant predictor of hospital in-patient deaths for lung cancer resections.

As Table 4 shows, with an increase in surgeon volume, there was a corresponding decline in the adjusted odds ratio of hospital in-patient deaths, with the odds for those patients treated by low-volume surgeons being 2.04 (reciprocal of 0.49) times those of medium-volume surgeons, and 2.63 (reciprocal of 0.38) times those of high-volume surgeons.

Given the relatively small number of hospitals in the medium- and high-volume groups, no adjustments were made for hospital characteristics (including hospital level, ownership, and geographical location) within the regression model. With the exception of the widening of the confidence intervals, when these results are adjusted for clustering effects by the generalized estimated equation method, all of the significant relationships remain.

Comment

This paper represents quite an uncommon example of an investigation into the volume-outcome relationship in lung cancer resections outside of the United States, with the opportunity to undertake this study having arisen from the availability of a comprehensive nationwide population-based dataset. Our results demonstrate that after adjusting for surgeon, hospital, and patient characteristics, a significant inverse relationship exists between surgeon volume and the odds of in-hospital deaths; however, we also find that hospital volume, by itself, is not a significant predictor of in-hospital mortality rates after lung cancer resections. This is a finding that does not concur with the conclusions drawn in an earlier study by Hannan and associates [10]. Their study, which took place in New York State between 1994 and 1997, found no significant differences between high- and low-volume surgeons with regard to in-hospital mortality rates in general, although, in high-volume hospitals, they did find better outcomes for both high- and low-volume surgeons.

One likely reason for our departure from the US findings on pulmonary resections is the potential confounding effect of the health insurance system in Taiwan. About 97% of all Taiwanese citizens have been covered under the NHI system since its inception in March 1995, with all patients having free access to any health care provider of their choice in Taiwan. This contrasts sharply with many other health care delivery systems around the world, where there may often be a tendency to limit a patient's choice to certain providers. Such limitations on patient choice may well result in confounding the relationship between provider volumes and patient outcomes. Furthermore, the study sample in the study by Hannan and associates [10] paper was limited to those patients who had undergone lobectomies, as compared with the four types of resections examined in this study.

The literature suggests two possible explanatory hypotheses for the inverse volume-outcome relationship [11, 12]. The first of these is "selective referral," which suggests that selective referral either by physicians or by the patients themselves will ultimately lead to the referral of more patients to providers renowned for superior treatment outcomes; thus, these providers would inevitably find themselves performing higher volumes of lung cancer resections.

As noted earlier, under the health insurance system in Taiwan, patients have the freedom to choose their preferred provider; thus, based upon word-of-mouth recommendations from relatives or friends, physicians with good reputations for superior outcomes, even those within the departments of the same hospital, will tend to attract greater numbers of patients [13]. Therefore, leaving aside physician referrals, self-referrals by patients may be a major contributor to the inverse relationship between patient outcomes and surgeon volumes, particularly in Taiwan.

The second hypothesis, "practice makes perfect," is based upon the rationale that a larger volume of patients allows providers to develop better levels of skill and expertise in the management of their operations or treatment procedures. Therefore, high-volume providers are more likely to achieve better clinical performance owing to their greater skills and experience.

In our study, the physician-specific volume is a stronger predictor of outcomes than hospital volume. Furthermore, such highly skilled, high-volume surgeons are more likely to be older and to perform more complex procedures, such as lobectomies and pneumonecotomies. Such results add support to the practice makes perfect hypothesis.

Of the total of 45,610 patients in Taiwan diagnosed with lung cancer between 2001 and 2004, only 4,841 patients (10.6%) received surgical lung or bronchial neoplasm resections. Although, all pathologic subtypes of lung cancer was included in our series, the resection rate of lung cancer was far lower than the 16.5% resection rate recently reported in Norway based upon population-based data [14]. While it is difficult to substantiate the reasons for this low resection rate in our study design, the prevalence of pulmonary tuberculosis in Taiwan may be one of the main reasons for the low lung cancer resection rate.

Surgical resection for lung cancer is still regarded as the most effective method for early-stage nonsmall-cell lung cancers, and is generally offered to all patients at stage I and II, and specific groups of patients at stage IIIa (N2) of the disease, but is not usually introduced to those at stage IIIb (N3). Ipsilateral (N2) or contralateral (N3) mediastinal lymphadenopathy is therefore a critical point with regard to the decision on whether the lung cancer can be resected.

According to the literature, patients with pulmonary tuberculosis had about 90% mediastinal lymphadenopathy [15], and even at that stage, it was difficult to differentiate between benign and malignant abnormalities by positron emission tomography [16]. In an area with a high prevalence of pulmonary tuberculosis, such as that which exists in Taiwan, the rationale for tuberculosis-related mediastinal lymphadenopathy complicates the evaluation of the preoperative clinical stage of lung cancer. As we can expect to see more patients being initially diagnosed with clinical N2/N3 lung cancer diseases than the actual numbers, that may explain why the lung cancer resection rate in Taiwan is so low.

There have been a number of recent reports documenting low postoperative mortality after lung cancer surgery [9, 10, 14, 17]. Of these, a Japanese survey showed much improved 30-day mortality rates (at 3.2% for pneumonectomies, 1.2% for lobecotmies, and only 0.8% for lesser resections) [17]. In this study, we also find improved in-hospital mortality rates, at 3.17% for pneumonectomies and just 0.57% for lobectomies (not shown in the Tables), with these figures being much lower than those contained in many of the prior reports.

This study has also examined all of the different operative types of lung cancer resections that resulted in significant hospital in-patient deaths. As compared with lobectomies, wedge resections demonstrated poor short-term outcomes; however, this finding does not gain support from the results reported by any single institute [14]. One reason for this major difference may be that more sublobar resections were performed by low-volume surgeons with high in-hospital mortality rates; that could potentially lead to wedge resections resulting in higher in-hospital mortality rates than those reported for lobectomies.

Another likely explanation for such disparity may be the differences in characteristics between lung cancer lobecotomy and wedge resection patients. In general, a wedge resection is carried out on lung cancer patients who have poor cardiopulmonary function, which would make such patients intolerant to a lobectomy of the lung. Actually, about 39% of the sample patients were in the CCI score category of “6 or more”; 44% of them received sublobar resection, a percentage that is consistent with the documented literature (not shown on Table). Although we have controlled for patient comorbidities, the administrative database adopted for this study was extremely limited in its ability to account for differences in such severity of illness.

This study suffers from two limitations that should be addressed. First of all, although the outcome measure in this study was in-hospital mortality, that did not include postdischarge deaths occurring as a direct result of the surgical procedure. The differences in mortality rates could be partly attributable to this factor. Secondly, the information on the stage of the disease, tumor size, grade, and differentiation are not available in the NHIRD. The stage of the cancer could play a crucial role in lung cancer resection outcomes.

Despite these limitations, we have provided evidence to show that after adjusting for patient, surgeon, and hospital characteristics, an inverse volume-outcome relationship does exist for surgeons, but not for hospitals, in Taiwan. However, we suggest that low volume, as an overall indicator of poor quality, must be used with considerable caution, particularly with regard to policy decision making. We should acknowledge that there are likely to be low-volume surgeons providing excellent pulmonary resection outcomes, who, according to the practice makes perfect and selective referral hypotheses, with advancing age, may ultimately become high-volume surgeons.

Because the causal mechanisms linking volume and outcomes remain unclear, we suggest that further studies should be carried out to identify the differences in the learning processes, perioperative care structures, and surgical techniques between high-volume surgeons with excellent outcomes and low-volume surgeons with poor outcomes. That may well help to reduce the differences between surgeon outcomes and improve the overall quality of care provided to their patients.

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