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SPECIAL TOPIC

Association of High-Volume Surgeons Working in High-Volume Hospitals with Cost of Free Flap Surgeries

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Background: We examined the associations of surgeon and hospital volume with total cost, length of stay (LOS), and cost per day for free tissue transfer (FTT) surgeries. Evidence demonstrates a higher likelihood of success for FTT in higher volume hospitals. Little, however, is known about volume-outcome associations for surgical costs and LOS. We hypothesized that higher provider volume is associated with lower cost and shorter LOS.

Methods: Using Taiwan's national data (2001–2012), we conducted a retrospective cohort study of all adults 18–64 years of age who underwent FTT during the study period. We used hierarchical regression modeling for our analyses. Our 3 outcome variables were total cost of FTT surgery, LOS in hospital, and cost per day.

Results: Except for functional muscle flap, in which LOS was 12 days shorter in high-volume compared with low-volume hospitals ($P = 0.017$), no association between hospital volume and LOS was found. Contrary to our hypothesis, our results for all FTT cases demonstrate positive associations of medium-volume hospitals (OR = 1.31; CI, 1.11–1.55) and high-volume surgeons (OR = 1.16; CI,1.03–1.32) with total cost and cost per day, respectively. The interactions of hospital volume and surgeon volume show that in medium- and high-volume hospitals, surgeons with the highest volume had the lowest predicted cost per day among hospitals in that category; but all differences in cost were small.

Conclusions: There were no substantial variations based on different hospital or surgeon volume in LOS, total cost, or cost per day for FTT operations performed in Taiwan. *(Plast Reconstr Surg Glob Open 2017;5:e1520; doi: 10.1097/GOX.0000000000001520; Published online 25 October 2017.)*

Research demonstrates a strong and positive association between provider volume and health outcomes for high-risk surgical procedures. The majority of research on volume-outcome associations has focused on outcomes among high-risk surgical procedures such as pancreatic or esophageal cancer resections. With health

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care costs rising, there is increasing interest among payers, policy makers, and patient advocate groups in expanding the body of research on volume-outcome associations to a wider range of complex surgical procedures. Recently, some studies have suggested a higher volume led to more efficiency in the surgical process, shorter LOS, and thus less cost.[1–4] Others, however, demonstrate the opposite association.[5,6] Longer LOS in the hospital is usually associated with higher costs for an episode of care. However, the association between provider volume and LOS or cost is not as straight forward as those between provider volume and surgical mortality.[1,7]

Free tissue transfer (FTT) is an expensive and resource-intensive procedure, commonly used to reconstruct anatomic defects after removing a cancerous tumor[8] or in the reconstruction of extremity wounds in response to burn, trauma, or digital amputation.[9–11] With the growing prevalence of conditions requiring microvascular reconstruction to replace a tissue defect such as after breast cancer surgery, research predicts that utilization of FTT operations will continue to increase.[12] For example, hospitals have observed a 2-fold increase in the number of patients undergoing bilateral free flap breast reconstructions over the past decade in concurrence with an increase in the number of contralateral prophylactic mastectomies.[13]

Compared with the United States, medical and surgical costs are much lower in Taiwan. For example, in the United States, FTT for breast reconstruction and related care for up to 18 months after surgery incurred a mean total cost of $56,205,[14] whereas the mean resection and reconstruction cost for FTT relating to head and neck cancer (relatively more complicated procedures) are reported to be $9,528 ± 5,051 in Taiwan.[15] Research has shown that the high cost of FTT procedures, regardless of the country in which they are performed, is attributable to the complexity of the procedure and the high risk of complications.[16,17] In the context of volume-cost associations, a recent study related to pancreaticoduodenectomy indicates that higher hospital volume is associated with lower cost and shorter LOS.[18] However, other studies show contradictory results for other surgical procedures.[19,20] Little is known about association of provider volume with LOS and cost of FTT procedures.

Using 2001–2012 data from Taiwan's National Health Insurance Research Database (NHIRD), we analyzed the associations of total cost, LOS, and inpatient cost per day for various types of FTT procedures with hospital and surgeon volumes. We hypothesized that higher provider volume are associated with lower cost and shorter LOS. This study has important policy implications for both the regionalization of care and optimal distribution of FTT operations among available hospitals and surgeons performing these complex surgeries.

METHODS

Data

The NHIRD, maintained by the National Health Research Institutes in Taiwan, contains population-based data derived from the medical claims data of the National Health Insurance program. Owing to mandatory enrollment and a single-payer system, this dataset covers more than 99% of Taiwan's population of over 23 million.[21] The NHIRD is the ideal database to use in conducting longitudinal studies to evaluate various treatment outcomes such as cost of treatments and LOS.[22–25] According to several validity studies, the NHIRD has proven to be a reliable and valid source of information for population-based research.[22,26] Our institution and the National Taiwan University Hospital Research Ethics Committee approved the protocol for the present study.

We pooled the 2001–2012 NHIRD data to create a large sample of hospitals and surgeons for all patients who underwent an FTT surgery. We linked the claims data with 2001–2012 hospital and surgeon registries to add additional information (such as surgeon's years of experience and hospital status). Patients were defined as those who underwent an FTT procedure and were included in the analysis if they had at least 1 hospital admission with a procedure code of FTT within 365 calendar days and were between 18 and 64 years of age (**see table, Supplemental Digital Content 1**, which displays List of Free Flap Codes, ***http://links.lww.com/PRSGO/A574***). Throughout, a P value of less than 0.05 was considered to indicate statistical significance. We used SAS version 9.4 for all our modeling and analyses.

Study Sample

From patients who underwent an FTT surgery between 2001 and 2012, we excluded all burn patients and patients younger than 18 years or older than 65 years of age from the study sample because of confounding issues affecting the LOS or cost of FTT. Our final sample size included 877 surgeons who performed 25,327 surgeries in 127 hospitals (**See figure, Supplemental Digital Content 2**, which displays the flowchart for Patient Selection, ***http://links.lww.com/PRSGO/A575***).

Dependent Variables

LOS in a hospital and cost of inpatient procedure were our main outcomes of interest. LOS was measured in days by using dates of admission to and discharge from the hospital recorded in the claims data. Cost of operation included total costs associated with FTT while the patient was staying in a hospital.

Independent Variables

Our main explanatory variables of interest were hospital and surgeon operative volumes. We categorized hospital and surgeon volume in a similar manner. We first ranked the hospitals and surgeons based on their annual volumes. Then, we categorized the total number of operations performed annually into 3 equal groups for hospitals and surgeons (low, medium, high). For patients, we included age at the time of the operation, gender, number of comorbid conditions based on the Elixhauser comorbidity index within a year of the operation,[27] and type of admission (emergency versus nonemergency). For surgeons, we included the surgeon's years of experience. For hospitals, we included hospital ownership (private versus public) and regional location.

Statistical Analysis

We present the outcomes of our analyses using unadjusted average and partially and fully adjusted regression modeling. We adjusted for patients' age, sex, and number of comorbid conditions in our partially adjusted models. For our fully adjusted regressions, we applied a Generalized Linear Mixed Model,[28] using 3 hierarchical levels. This allowed us to adjust the standard errors for repeated measures of hospital and surgeon characteristics. Level 1 includes patients; surgeons and hospitals were levels 2 and 3, respectively. We fitted different models for each type of FTT procedure, including muscle flap, skin flap, fascia flap, and functioning muscle transfer.

To adjust for the inherent skew in health care costs and inconsistent cost variation (heteroskedasticity), we used gamma and Poisson distributions for cost and LOS measures, respectively.[29] Using the average annual exchange rate, all cost measures were converted from Taiwan's national dollar to U.S. dollar amounts.[30] We then used the Consumer Price Index to inflate all dollar values across the study period to 2015 U.S. dollar values (**see table, Supplemental Digital Content 3**, which displays Consumer Price Index and New Taiwan Dollar/USD rates from 2001 to 2012, ***http://links.lww.com/PRSGO/A576***). All regression models are presented in the SDC 4–7 (**see table, Supplemental Digital Content 4**, which displays Results of Partially Adjusted Regression Models for Length of Stay in Hospital †, ***http://links.lww.com/PRSGO/A577***; (**see table, Supplemental Digital Content 5**, which displays Results of Partially Adjusted Regression Models for Total Hospital Costs of Free Tissue Transfer †, ***http://links.lww.com/PRSGO/A578***; **see table, Supplemental Digital Content 6**, which displays Results of Fully Adjusted Regression Models for Length of Stay in Hospital †, ***http://links.lww.com/PRSGO/A579***; **see table, Supplemental Digital Content 7**, which displays results of Fully Adjusted Regression Models for Total Hospital Costs of Free Tissue Transfer †, ***http://links.lww.com/PRSGO/A580***).

RESULTS

The distribution of patients, hospitals, and surgeons clustered by hospital volume for FTT is shown in Table 1. Over a 12-year study period, among individuals aged 18–64 years, skin (18,750) was the most common and fascia (998) was the least common FTT operation. The majority of hospitals (68–89%) had fewer than 94 annual FTT operations (low volume) and only 3 had more than 156 annual operations (3–9%). More than half (56%) of all surgeons who performed FTT operation worked in low-volume hospitals (fewer than 94 annual FTTs).

Table 2 summarizes characteristics of FTT patients clustered by hospital annual volume. The average age of patients was about 46, and the majority of patients were male (> 70%). More than 90% of all FTT operations were scheduled (versus being emergency operations). The emergency admission rate was low, especially for functional muscle transfer. About 23% of all FTT patients had more than 3 comorbid conditions. However, medium-volume hospitals (between 95 and 156 annual operations) had more patients with 3 or more comorbid conditions (26%) compared with low-volume (23%) and high-volume (21%) hospitals.

Table 3 demonstrates predicted LOS in hospital, clustered by annual hospital volume. Depending on the specific type of FTT surgery, the unadjusted average LOS varies between 15 and 37 days, with muscle FTT having the longest (37 days) and functional muscle transfer having

Table 1. Number of Patients, Hospitals, and Surgeons, Clustered by Hospital Volume*

	Hospital Volume				
Procedure	**Low, ≤ 94**	**Medium, 95–156**	**High, > 156**	**Total**	***P***
No. patients	8,744	7,829	8,754	25,327	
Muscle free flap (%)					
No. patients	1,827 (45)	1,359 (34)	863 (21)	4,049	< 0.001†
No. hospitals	92 (88)	9 (9)	3 (3)	104	< 0.001†
No. surgeons	333 (59)	150 (26)	85 (15)	568	< 0.001†
Skin free flap (%)					
No. patients	6,072 (32)	5,562 (30)	7,116 (38)	18,750	< 0.001†
No. hospitals	100 (89)	9 (8)	3 (3)	112	< 0.001†
No. surgeons	404 (53)	222 (29)	141 (18)	767	< 0.001†
Fascia free flap (%)					
No. patients	389 (39)	557 (56)	52 (5)	998	< 0.001†
No. hospitals	47 (80)	9 (15)	3 (5)	59	< 0.001†
No. surgeons	99 (45)	94 (42)	29 (13)	222	< 0.001†
Functional muscle transfer					
No. patients	415 (35)	256 (21)	529 (44)	1,200	< 0.001†
No. hospitals	23 (68)	8 (24)	3 (9)	34	< 0.001†
No. surgeons	47 (37)	51 (40)	29 (23)	127	0.039†
All FTTs (%)					
No. patients	8,744 (35)	7,829 (31)	8,754 (35)	25,327	< 0.001†
No. hospitals	115 (91)	9 (7)	3 (2)	127	< 0.001†
No. surgeons	490 (56)	237 (27)	150 (17)	877	< 0.001†

*2001–2012 NHIRD in Taiwan.

†Significantly different at alpha = 0.05 level among 3 hospital volume groups.

Table 2. Characteristics of the Patients According to Hospital Volume*

	Hospital Volume				
Procedure	Low, ≤ 94	Medium, 95–156	High, > 156	Total	*P*
No. total patients	8,744	7,829	8,754	25,327	
Muscle free flap					
Average age (SD)	46 (12)	48 (11)	46 (12)	47 (12)	0.003†
Age > 60 (%)	188 (10)	142 (10)	82 (10)	342 (100)	0.754
Female sex (%)	414 (23)	254 (19)	135 (16)	803 (100)	< 0.001†
Emergency admission (%)	171 (9)	50 (4)	31 (4)	252 (100)	< 0.001†
Elixhauser score ≥ 3 (%)	443 (24)	401 (30)	178 (21)		< 0.001†
Skin free flap					
Average age (SD)	46 (11)	48 (10)	46 (11)	47 (11)	< 0.001†
Age > 60 (%)	444 (7)	498 (9)	532 (7)	1,474 (100)	0.001†
Female sex (%)	701 (12)	528 (9)	1,028 (14)	2,257 (100)	< 0.001†
Emergency admission (%)	279 (5)	83 (1)	187 (3)	549 (100)	< 0.001†
Elixhauser score ≥ 3 (%)	1,350 (22)	1,405 (25)	1,581 (22)	4,336 (100)	< 0.001†
Fascia free flap					
Average age (SD)	44 (11)	48 (9)	41 (13)	46 (11)	< 0.001†
Age > 60 (%)	22 (6)	50 (9)	2 (4)	74 (100)	0.096
Female sex (%)	59 (15)	42 (8)	16 (31)	117 (100)	< 0.001†
Emergency admission (%)	40 (10)	5 (1)	5 (10)	50 (100)	< 0.001†
Elixhauser score ≥ 3 (%)	76 (20)	117 (21)	5 (10)	198 (100)	0.141
Functional muscle transfer					
Average age (SD)	47 (11)	49 (10)	35 (12)	42 (13)	< 0.001†
Age > 60 (%)	41 (10)	27 (11)	10 (2)	78 (100)	< 0.001†
Female sex (%)	36 (9)	20 (8)	146 (28)	202 (100)	< 0.001†
Emergency admission (%)	6 (1)	2 (1)	4 (1)	12 (100)	0.529
Elixhauser score ≥ 3 (%)	99 (24)	77 (30)	34 (6)	210 (100)	< 0.001†
All FTTs					
Average age (SD)	46 (11)	48 (10)	45 (11)	46 (11)	< 0.001†
Age > 60 (%)	697 (8)	727 (9)	645 (7)	2,069 (100)	< 0.001†
Female sex (%)	1,212 (14)	853 (11)	1,378 (16)	3,443 (100)	< 0.001†
Emergency admission (%)	496 (6)	142 (2)	229 (3)	867 (100)	< 0.001†
Elixhauser score ≥ 3 (%)	1,983 (23)	2,040 (26)	1,870 (21)	5,893 (100)	< 0.001†

*2001–2012 NHIRD in Taiwan.
†Significantly different at alpha = 0.05 level among 3 hospital volume groups.

Table 3. Predicted LOS after FTT Operation, Clustered by Annual Hospital Volume

	Length of Stay					
	Hospital Volume Categories					
Procedure	Low, ≤ 94	95% CI	Medium, 95-156	95% CI	High, > 156	95% CI
Muscle free flap						
Observed (d)	37		36		37	
Partially adjusted (d)	37	(34–40)	37	(29–47)	37	(25–56)
Fully adjusted (d)	41	(36–45)	42	(36–49)	46	(36–60)
Skin free flap						
Observed (d)	25		28		26	
Partially adjusted (d)	26	(24–28)	27	(23–33)	26	(19–37)
Fully adjusted (d)	28	(25–31)	31	(26–36)	33	(25–43)
Fascia free flap						
Observed (d)	27		32		24	
Partially adjusted (d)	28	(25–31)	26	(21–32)	25	(17–35)
Fully adjusted (d)	31	(26–36)	30	(26–35)	30	(23–40)
Functional muscle transfer						
Observed (d)	30		23		15	
Partially adjusted (d)	28	(24–33)	29	(22–38)	16	(10–24)*
Fully adjusted (d)	34	(26–43)	37	(27–50)	22	(13–37)
All free tissue transfers						
Observed (d)	28		30		27	
Partially adjusted (d)	29	(27–31)	29	(23–38)	28	(18–44)
Fully adjusted (d)	32	(29–35)	34	(28–40)	35	(26–47)

Variables in the partially adjusted table: patient age, gender, Elixhauser comorbidity, hospital volume group. Variables in the fully adjusted table: patient age, gender, Elixhauser comorbidity, emergency or not, surgeon experience. Surgeon volume group, hospital type, hospital region, hospital volume group.
*Significant at alpha = 0.05 level.
Note: 2001–2012 NHIRD in Taiwan.

the shortest (15 days) LOS. Based on our partially adjusted model for functional muscle transfer, LOS was 12 days shorter in high-volume compared with low-volume hospitals ($P = 0.017$). Except for functional muscle transfer, our results did not indicate any substantial or significant difference in LOS among different clusters of hospitals.

Table 4. Estimated Cost of FTT Clustered by Hospital Volume*

	Estimated Cost					
	Hospital Volume Categories					
Procedure	**Low, ≤ 94**	**95% CI**	**Medium, 95–156**	**95% CI**	**High, > 156**	**95% CI**
Muscle free flap						
Observed ($)	10,596		11,692		12,391	
Partially adjusted ($)	9,377	(8,763–10,034)	11,663	(9,984–13,625)†	11,408	(8,738–14,893)
Fully adjusted ($)	10,702	(9,678–11,833)	13,395	(11,727–15,299)†	13,948	(11,128–17,482)†
Skin free flap						
Observed ($)	9,323		11,228		10,480	
Partially adjusted ($)	7,160	(6,621–7,742)	10,399	(8,356–12,946)†	9,555	(6,546–13,947)
Fully adjusted ($)	8,169	(7,257–9,195)	9,450	(7,532–11,856)	9,623	(6,577–14,080)
Fascia free flap						
Observed ($)	10,022		13,474		7,621	
Partially adjusted ($)	8,357	(7,533–9,272)	10,038	(8,501–11,853)	7,944	(6,048–10,434)
Fully adjusted ($)	8,947	(7,729–10,357)	10,777	(9,344–12,430)†	8,515	(6,673–10,864)
Functional muscle transfer						
Observed ($)	12,531		10,974		6,635	
Partially adjusted ($)	10,265	(8,878–11,868)	10,718	(8,741–13,142)	5,663	(4,253–7,542)†
Fully adjusted ($)	13,380	(10,750–16,654)	11,801	(9,530–14,613)	11,593	(8,414–15,973)
All FTTs						
Observed ($)	8,744		7,829		8,754	
Partially adjusted ($)	7,657	(7,134–8,218)	10,747	(8,671–13,320)†	9,714	(6,700–14,082)
Fully adjusted ($)	8,821	(7,994–9,734)	10,083	(8,246–12,330)	9,950	(7,089–13,966)

Variables in the partially adjusted regressions: patient age, gender, Elixhauser comorbidity, hospital volume group. Variables in the fully adjusted regressions: patient age, gender, Elixhauser comorbidity, emergency or not, surgeon experience, surgeon volume group, hospital type, hospital region, hospital volume group.
*2001–2012 NHIRD in Taiwan.
†Significant at alpha = 0.05 level.

Predicted values for total costs of inpatient stay for FTT are presented in Table 4. The most expensive type of FTT operation was functional muscle transfer that was generally performed for nerve injuries to replace missing muscle function. Our partially adjusted model shows a lower total cost of $4,602 in high-volume compared with low-volume hospitals ($5,663 versus $10,265; $P < 0.001$) for functional muscle transfer. However, for other types of FTT, higher hospital volume was associated with higher cost. For example, cost of muscle FTT was $2,693 ($P = 0.011$) and $3,246 ($P = 0.001$) higher in middle- and high-volume hospitals compared with low-volume hospitals, respectively (using the fully adjusted model). For fascia FTT, cost was higher by $1,830 ($P = 0.016$) in middle-volume hospitals (with 94–156 annual operations) compared with low-volume hospitals (< 94 annual operations). For all FTT cases (pooled together), there was no significant difference between low- and high-volume hospitals, but the cost of operations was higher by $3,090 ($P = 0.003$) in medium- compared with low-volume hospitals (using the partially adjusted model). However, in the fully adjusted model, our results did not show any significant volume-based differences in cost.

Sensitivity Analysis

To disentangle the effect of LOS in hospital from cost, we estimated total cost and cost per day (total cost/LOS) for all types of FTTs pooled together. **Supplemental Digital Content 8 and 9** show the regression results, with hospital and surgeon volume interaction terms. Our results support our previous findings, showing a positive association (as 1 variable increase the other variable increases as well) between medium-volume hospitals and cost per day (OR = 1.31; CI, 1.11–1.55; $P = 0.002$; **see table, Supplemental Digital Content 8**, which displays regression Results for Total Costs of Free Tissue Transfer †, ***http://links.lww.com/PRSGO/A581***; **see table, Supplemental Digital Content 9**, which displays regression Results for Cost Per Day for Free Tissue Transfer Procedure †, ***http://links.lww.com/PRSGO/A582***). For surgeons, high volume was associated with higher cost per day (OR = 1.16; CI, 1.03–1.32; $P = 0.018$).

The adjusted predicted cost per day clustered by the interactions among different volumes of surgeons and hospitals ranged from $283 to $396 (Figure 1). Among high-volume hospitals, cost of FTT was lowest among surgeons with high volume ($314 versus $371; $P = 0.031$). The variations in cost per day among surgeons and hospitals, however, were not substantial.

DISCUSSION

We examined the associations of provider volume (surgeon and hospital) with LOS in hospital, total cost, and cost per day for FTT. Our findings yielded 3 main results. First, we did not find substantial differences in provider volume and LOS in hospital (except for functional muscle transfer, which shows high-volume hospitals had shorter LOS). Second, depending on the type of FTT, the results for association between hospital volume and total cost were mixed. Finally, for all types of FTT, a combination of high-volume surgeons working in high- or medium-volume hospitals indicated a lower cost per day for surgeries performed in high- and medium-volume hospitals. Nevertheless, the differences in LOS, cost, and cost per day among different volume hospitals and surgeons were insubstantial.

First, our results did not show any associations between LOS and provider volume. Prior research on complex and high-mortality procedures reported mixed results

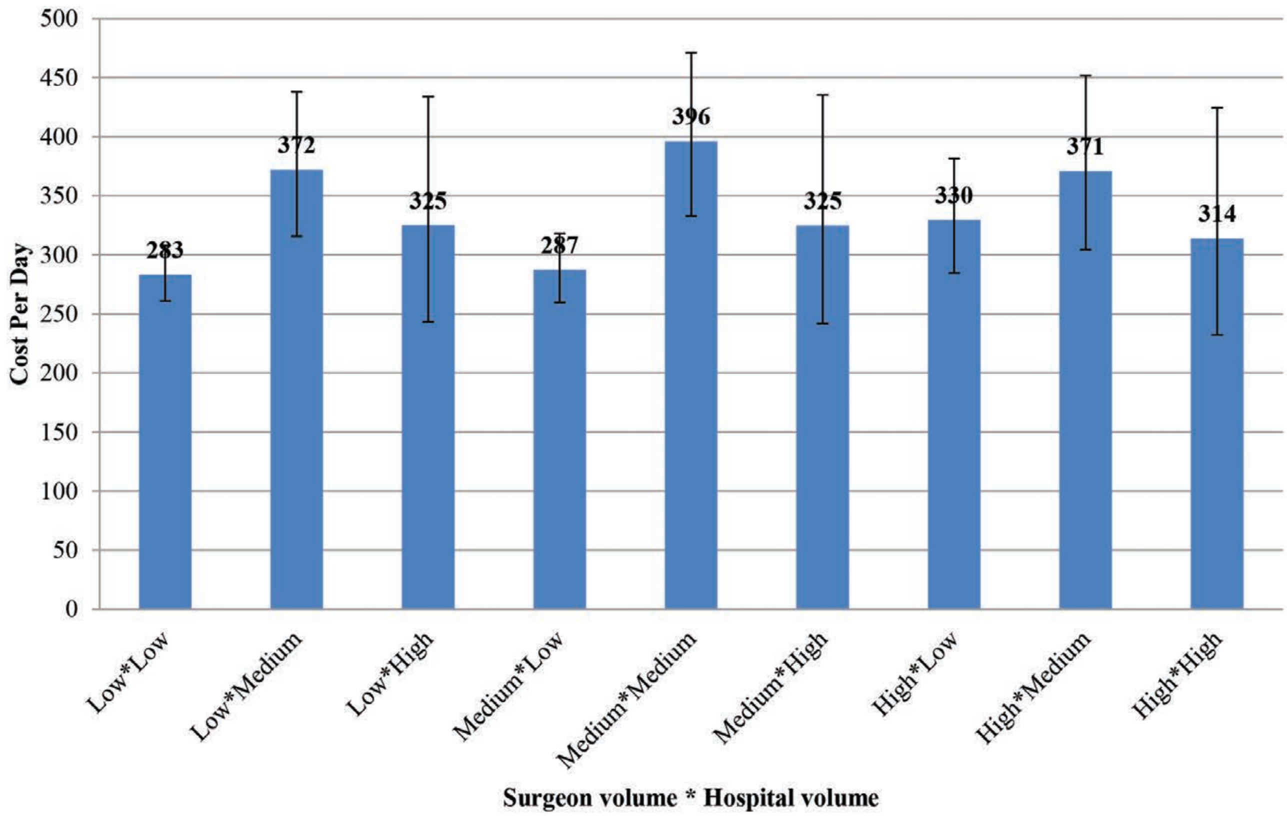

Fig. 1. Least square means of adjusted predicted cost per day based on interactions of surgeon and hospital volume. Source: 2001–2012 NHIRD in Taiwan.

on association between LOS and provider volume.[7,31–33] The relative importance of volume-outcome associations might change depending on the specific outcome. For example, although higher provider volume would most probably reduce mortality rates associated with high-risk procedures,[34] it might not necessarily have the same relationship with LOS or cost of operation for the same procedure.[35] Plausibly, in certain procedures, LOS is more related to the nature and complexity of patient's case than to the quality of the hospital. Similarly, our study indicates that LOS was associated with patient characteristics such as comorbidities and the urgency of FTT than with hospital or surgeon volume.

Second, our results for association of provider volume and cost of FTT were mixed. For all FTTs—pooled together—our results did not indicate any associations between hospital volume and cost. Having a greater number of physicians/surgeons with a high level of expertise and fully equipped intensive care units, typical attributes of higher-volume hospitals, may affect cost of care in 2 opposing directions. On the one hand, more efficient systems of care may reduce total costs by reducing preventable complications. On the other hand, it is probable that having a more experienced medical team (physicians, nurses, and other staff), advanced infrastructure, and perhaps a large residency program (typical in teaching hospitals) may lead to increases in costs. Typically, in higher volume hospitals, fixed costs would be divided among a greater number of procedures, so the cost should be lower in higher volume compared with lower volume hospitals. This argument might be true for certain procedures such as cardiac surgery where regardless of the number of operations only a certain number of cardiopulmonary bypass machines are required.[35] However, in many surgical procedures, as volume increases certain variable costs associated with the number of intensive care unit beds, nurses, physicians, and staff might increase further, leading to a higher average cost per procedure as volume increases. Our findings did not show any strong association between provider volume and cost of FTT.

Finally, our results indicate small but significant associations between combinations of high-volume surgeons working in high- or medium-volume hospitals with lower costs in those hospitals. Surgeon volume or experience might have a positive effect on not only the success of the operation but postoperative care as well.[36,37] Providing better postoperative care might lead to a lower rate of complications and therefore lower cost. Having a better structure and process in place to avoid potential complications is more common in high- versus low-volume hospitals.[38,39] In their recent study, Toomey et al.[40] found a positive association between outcomes of pancreaticoduodenectomies and high-volume surgeons, regardless of hospital volume. They concluded that surgeon volume and experience are better predictors of outcomes than hospital volume as surgeons are the ones who directly engage in the process of care for patients. For FTT, only a combination of high-volume surgeons working in medium- or high-volume hospitals was associated with lower cost of care. This perhaps reveals the combined importance of a surgical team and postsurgical processes in FTT, compared with an isolated effect of one without the other.

Our study had several limitations. Most importantly, owing to differences in policy and culture, many of our findings may not be applicable to the United States. For example, compared with the United States, LOS in hospital after an FTT operation was much longer in Taiwan.[41] Second, we did not control for the complexity of FTT in our models. Similar to other studies on volume-outcome associations that used administrative claims data, we had no way of measuring the complexity of the operation or the severity of the patient's condition. It is plausible that greater complexity of FTT cases in medium-level hospitals is the main driving force behind their higher cost of operation compared with lower volume centers. Although this is an important confounding variable, we controlled for a range of variables used in the literature for risk adjustment (e.g., age, sex, number of comorbid conditions, and urgent nature of the operation). Lastly, owing to a high level of competition among hospitals in Taiwan under its universal single-payer system, complex surgeries such as FTT had been already regionalized. Therefore, our results, not showing any meaningful associations between provider's volume and cost, might be due to a lack of substantial difference in quality between low- and high-volume surgeons and hospital groups. Additionally, hospital stay in Taiwan is not expensive. Often, to attract more patients, hospitals compete with one another by providing a better service and longer LOS.[42] Despite these limitations, this was the first study using 100% of a nation's data to measure both surgeon and hospital volume to find their associations with LOS and cost of operation.

Improving quality and efficiency of care, especially for complex and/or expensive surgical procedures, continues to be a high priority. Quality of care is the most important aspect of an ongoing dialogue on volume-outcome association. Being a high volume provider is used as a proxy for high quality with a general notion that the more procedures a surgeon or a hospital performs, the higher the probability of improvement in the quality and/or efficiency of the process. However, it is important to note that this is not a causal relationship; it is not clear whether high-volume providers have high volumes because of a higher level of quality or whether their high quality increases the demand for their services (and thus increases their volume). Each of these hypotheses has a different policy implication. However, one thing is clear: regionalization of care may not be the only policy implication associated with positive volume-outcome association. Disseminating the experiences of high-volume surgeons working in high-volume hospitals, techniques and procedures that are applied by high-volume hospitals during the postsurgical process and that lead to better outcomes should be studied and used in other settings as well.

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