

OPERATING ROOM COSTS OF LAPAROSCOPIC CHOLECYSTECTOMY: DOES SURGEON VOLUME MATTER?

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Very few studies have addressed the issue of surgeon volume on cost savings of laparoscopic cholecystectomy (LC) in Asian countries. The objectives of the study were to analyze LC operating-room (OR) costs between two study hospitals and to examine the effect of surgeon volume on OR costs. Patients diagnosed with gallbladder disease who underwent LC in October through December 2002 at two acute tertiary-care hospitals were included. Patient demographics and clinical information were derived from patient charts. Cost information was obtained from purchasing departments or specific cost centers. Three multivariate linear regression models were performed to examine the association between surgeon volume, cost, and utilization. There were no significant differences in patient demographics and disease severity between the two hospitals. Hospital A consumed fewer resources than did hospital B (NT\$21,674 vs NT\$26,417). Direct materials cost, direct professional costs, and indirect costs varied significantly by study hospital and by surgeon volume. High-volume surgeons incurred lower costs and shorter stay as compared with low-volume surgeons. Patients who scored in the American Society of Anesthesiologists physical status (ASA PS) 3 incurred significantly higher costs and longer hospital stays than did patients with ASA PS 1. The present study supports the proposal that hospital management and experience of surgeons are of equal importance in maintaining the standing of hospitals in competitive positions. In addition to the differences in hospital management and surgeon volume, the patient severity of illness also needs to be taken into consideration in cost containment.

Key Words: cost, volume, laparoscopic cholecystectomy
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Since the introduction of laparoscopic cholecystectomy (LC) by Mouret in France in 1987, the technique has been widely used [1]. Compared with the traditional open

cholecystectomy (OC), the LC procedure has been considered a safe and efficient alternate treatment [2–4]. The minimally invasive procedure has the benefits of smaller incision, lower level of pain, and rapid recovery, which have greatly increased productivity and conserved the utilization of hospital resources. Studies conducted in the USA have indicated that LC procedures accounted for 60–71% of the total number of cholecystectomy procedures [5,6]. In Taiwan, about 10,500 cholecystectomy procedures were performed in 1996, and 54.9% of these

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were accomplished by LC. In 1998, the total number of cholecystectomy procedures in Taiwan increased to 13,000, and the percentage performed by LC increased to 61.9% [7].

Under the current National Health Insurance Program in Taiwan, LC is one of the procedures paid for by the case. Hospitals are reimbursed by a fixed rate of New Taiwan (NT) \$53,900 (about US\$1,636) for the entire LC procedure, which includes expenses associated with the operating room (OR), professional fees, and hospitalization. With the case payment scheme, hospitals have a strong motivation to contain cost and resource utilization in order to increase profit margin and maintain equivalent quality. It has also been shown that OR time is a major cost component for surgical procedures [8–10]. It appears that the area of OR cost should be the target of savings. The present study had two objectives: (1) to analyze LC OR cost components of two hospitals and (2) to examine the effect of surgeon volume on LC OR costs.

In assessing the relationship of volume to outcome, previous studies have indicated the effect of volume on quality of surgical care [11–13]. A high volume of procedures was associated with lower hospital costs and shorter lengths of stay [14–17]. The present study tested the hypothesis that surgeon volume is positively related to OR costs and its utilization (i.e. there is an inverse relationship between the volume of LCs done by a surgeon and the health care resources consumed). Economic evaluation of cholecystectomy procedures has focused mainly on comparing traditional OC to LC [4,7,18–21] and usually studied one institution only [22–25]. Very few studies have used true cost, as opposed to charge data, as the data basis for cost analysis [26]. The present study may be the first attempt to disclose pure OR costs based on a two-center study design.

METHODS

Sample and data sources

The study subjects were derived from two acute tertiary-care hospitals in southern Taiwan. One hospital is a 1,545-bed university medical center and the other is a 750-bed public teaching hospital. Patients who had an ICD-9-CM diagnosis code for gallbladder disease (codes 574.00–576.99) and a primary procedure code for LC (51.23) in October through December of 2002 were recruited for the study. A total of 76 patients underwent LC at hospital A (the university medical center); surgeon A performed 50 of

these, and the other four surgeons (grouped as surgeon B) performed the remaining 26 LCs. To generate equivalent volume for additional comparison, the LC procedures performed by the four surgeons were combined, and the mean volume of the pooled procedures was considered as the volume of surgeon B. For hospital B (the public teaching hospital), two surgeons performed 35 LCs (28 cases from surgeon C and seven cases from surgeon D). The cutoff volume suggested by Lee et al [17] was used to measure the surgeon volume. Surgeons with an average annual volume higher than 50 LCs were classified as the high-volume group, those with 30–49 LCs were intermediate volume, and those with 10–29 LCs were low-volume. Using the cutoff point and converting the year number to a quarterly number, surgeons A and C were classified as high and intermediate, respectively, whereas surgeons B and D were low-volume.

The study design was a retrospective chart review, which summarized the information on patient demographics, resource utilization, and medical outcomes. A detailed hospital bill was prepared for each patient, copies of which were obtained from the purchasing department or specific cost centers to provide cost information. For example, the purchasing department provided the direct purchase price for the disposable surgical devices (four trocars, Endo clip, and surgical needle).

Measurement

There were two variables of interest included for analysis: patient information and cost data. Patient demographics included age, gender, and the American Society of Anesthesiologists physical status (ASA PS) score (ASA PS 1–3). The ASA PS score was used as a measure of severity of illness, because it is simple and well accepted in the OR [24]. The ASA PS incorporates comorbid conditions and activity levels, and excludes the surgical or anesthetic risk. ASA PS has been validated as an efficient instrument for predicting cost [24], surgical outcome [27], and hospital days [28]. The indicators of patient resource utilization and medical outcomes included operating time, anesthesia time, hospitalization day, discharge status, and surgical complications. The surgical complications included wound infection, pleural effusion, upper gastrointestinal tract bleeding, and bile leakage.

Cost structure was divided into direct and indirect costs. Direct costs comprised direct material costs and professional costs. Direct material costs were spent on surgical instruments, anesthesia drugs, laboratory, and

others. Specifically, surgical instruments referred to disposable surgical devices (four trocars, Endo clip, and surgical needle), and the instrument costs were calculated by the number of total units multiplied by unit purchasing price. Anesthesia materials costs included all intraoperative drug costs, airway supplies, and intravenous supplies. For laboratory costs, the cost information was derived from the department ratio of cost to charges. The laboratory department ratios in the two hospitals were 0.57 and 0.60, respectively. The laboratory charges were converted into costs by using the ratios.

Direct professional costs covered salaries/wages for clinical professionals involved in the process of surgery. The clinical professionals included surgeons, anesthesiologists, anesthesia nurses, surgical nurses, and residents. At each study hospital, the OR personnel for the LC procedure consisted of one surgeon, one anesthesiologist, one surgical resident, one anesthesia nurse (technician), and two surgical nurses. All professional costs were calculated by their minute rate multiplied by the attendant time. The minute rate comprised the sum of the total salaries (basic salary, performance-based pay salary, annual bonus, and other benefits) divided by the total working hours (40 hours per week). Because the two study hospitals have been accredited by the Taiwan Joint Commission of Accreditation as teaching hospitals, resident costs were considered as teaching costs.

Indirect costs included indirect labor costs and depreciation for the study, which could not be changed by procedure volume or operation time. Labor costs consisted of the salaries/wages of OR administration, which included the supervisor, clerks, cleaning, and sterilization personnel. Depreciation was estimated for buildings and operating machines. Depreciation of building and OR equipment was generated by the operation hours multiplied by hourly rates. The depreciation criteria were based on the government accounting principle: 7-year life cycle for machines and 35 years for medical buildings.

Statistical analysis

SPSS version 8 for Windows was used to perform statistical analysis. Independent *t*-test and χ^2 test were applied to examine continuous and categorical variables, respectively. One-way analysis of variance was used to explore the differences in utilization of health care resources among four LC surgeons; post hoc analysis was also performed. Three multivariate linear regression models were performed to examine the relationship of volume, cost, and utilization, while controlling for selected covariates.

RESULTS

Table 1 shows the data collected about patient demographics and OR resources utilization and medical outcome. The mean age of the LC subjects was the early 50s for both of the study hospitals. By gender, the proportions of male and female subjects at hospital A did not differ significantly from hospital B. Hospital A had an average ASA PS score of 1.86 (SD = 0.58), as compared with 1.66 (SD = 0.48) at hospital B. In terms of ASA PS score, the severity of physical status was not statistically significantly different between the two hospitals.

For the average operating time, hospital A significantly had a shorter operation duration than hospital B (72.6 vs 100.2 minutes, $p < 0.000$). Similarly, hospital A used 108.0 minutes (SD = 36.6) on anesthesia as compared to 123.6 minutes (SD = 35.4) for hospital B; this difference also reached statistical significance ($p < 0.05$). The length of stay for hospital A was 3.24 days (SD = 2.24), which was also statistically significantly shorter than that of 5.6 days (SD = 3.75) from hospital B. One case with wound infection was found at hospital A.

Table 2 shows OR cost components analysis for the two hospitals. The OR total cost was NT \$21,674 for hospital A, which was significantly lower than that for hospital B of NT \$26,417 ($p < 0.000$). Hospital B consumed considerably more resources at all three domains of costs, direct materials, direct professional, and indirect costs. Except for the direct professional costs on operating nurses, each specific item of cost was statistically significantly different between hospitals A and B ($p < 0.05$ or lower). Hospital B incurred lower costs in the areas of laboratory, anesthesiologists, and administration than those of hospital A.

It should be noted that the proportions of the three cost components were almost the same for hospitals A and B. Direct material costs accounted for more than 50% of the total costs for the two hospitals, while direct professional costs reached 40.5% and 39.2%, respectively (as shown in Table 2). Furthermore, Figure 1 shows a comparison of the three cost components between the two study hospitals.

Patient characteristics and resource utilization were analyzed by surgeon volume as shown in Table 3. There were actually five surgeons responsible for LCs at hospital A. Surgeon A (high volume) accounted for 66% of the total procedures, whereas the other four surgeons (low volume) shared 34% of the volume. At hospital B, all LC procedures were performed by the two surgeons—surgeon C with 28 cases (intermediate volume) and surgeon D with seven cases (low volume). The distributions of patient demographics

Table 1. Patient characteristics and operating room utilization

Variables	Hospital A (n = 76)		Hospital B (n = 35)		p value
	n	%	n	%	
Patient demographics					
Sex					
Male	37	48.78	17	48.6	0.991
Female	39	51.3	18	51.4	
Age (\pm SD)	52.84 \pm 13.22		53.77 \pm 17.28		0.756
Severity of disease					
ASA PS score	1.86 \pm 0.58		1.66 \pm 0.48		0.082
1	19	25	12	34.3	
2	49	64.5	23	65.7	
3	8	10.5	0	0	
Utilization and clinical outcome					
Surgical time (min)	72.6 \pm 61.8		100.2 \pm 31.2		0.000
Anesthesia time (min)	108.0 \pm 36.6		123.6 \pm 35.4		0.034
Length of stay (days)	3.24 \pm 2.24		5.6 \pm 3.75		0.000
Complication					
Yes	2	2.7	1	2.9	0.897
No	74	97.3	35	97.1	

ASA PS score = American Society of Anesthesiologists physical status score (see text).

Table 2. Cost components analysis by hospital volume

Variables	Hospital A (n = 76)		Hospital B (n = 35)		p value
	NT \$	SD (%)	NT \$	SD (%)	
Direct materials costs					
Disposal instruments	10,901	\pm 2,167	13,232	\pm 3	0.000
Anesthesia	698	\pm 268	882	\pm 219	0.001
Laboratory	34	102	0	0	0.018
Subtotal	11,633	(53.7)	14,114	(53.4)	
Direct professional costs					
Surgeon cost	3,058	\pm 1,772	5,276	\pm 2,026	0.000
Anesthetist	1,965	\pm 415	779	\pm 141	0.000
Anesthesia nurse	1,225	\pm 269	1,377	\pm 295	0.009
Surgical nurse	1,628	\pm 556	1,667	\pm 554	0.730
Teaching cost	894	\pm 392	1,259	\pm 819	0.002
Subtotal	8,770	(40.5)	10,358	(39.2)	
Indirect costs					
Depreciation	766	\pm 262	1,522	\pm 388	0.000
Administration	505	\pm 219	423	\pm 135	0.044
Subtotal	1,271	(5.9)	1,945	(7.4)	
Total costs (NT\$)	21,674	4,793	26,417	3,439	0.000

NT\$ = New Taiwan dollars.

Table 3. Patient characteristics and resources utilization by surgeon volume

Type of hospital	Hospital A		Hospital B		p	Post hoc comparison	
	Surgeon volume	A (n = 50) High	B (n = 6.59)* Low	C (n = 28) Intermediate			D (n = 7) Low
Patient demographics							
Age (± SD)		51.6 ± 11.7	55.3 ± 15.6	54.1 ± 16.3	52.4 ± 22.2	0.733	
Sex							
Male		27 (54%)	14 (54%)	16 (57%)	2 (29%)		
Female		23 (46%)	12 (46%)	12 (43%)	5 (71%)		
ASA score		1.80 ± 0.61	1.96 ± 0.53	1.61 ± 0.5	1.86 ± 0.38	0.133	
Surgical time (min)		63.0 ± 28.2	91.7 ± 30.6	97.2 ± 30	111.6 ± 34.8	0.002	A > B, A > C A > D
Length of stay (days)		2.84 ± 1.57	4.0 ± 3.06	4.75 ± 3.04	9.0 ± 4.62	0.000	A > C > D B > D
Total cost (NT\$)		20,402 ± 4,321	23,974 ± 4,856	25,199 ± 2,939	28,140 ± 4,480	0.000	A > B, A > C A > D

ASA PS score = American Society of Anesthesiologists physical status score (see text); NT\$ = New Taiwan dollars.

*Total number of patients of four surgeons was divided by four to generate mean operation cases of 6.5 in hospital A.

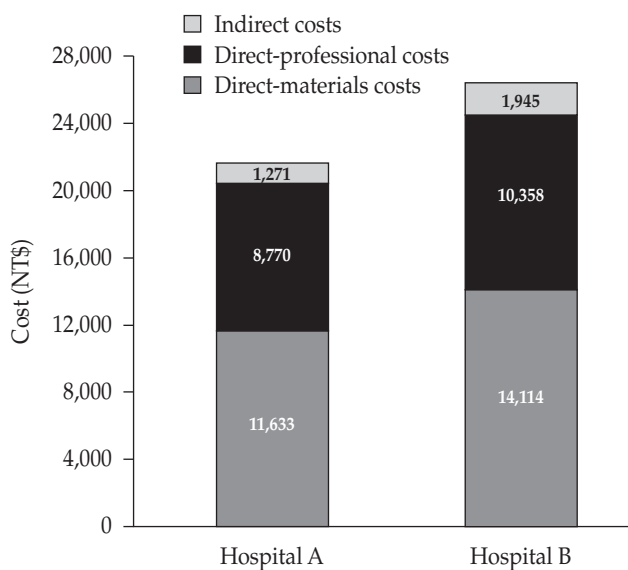


Figure 1. Operating room cost analysis by hospital.

and their severity of physical status were not statistically different between the four surgeons. Surgeons A and B, from hospital A, had lower total costs and shorter length of hospital stay than surgeons C and D from hospital B. The average operating time ranged from 63.0 to 111.6 minutes among the four surgeons. Surgeon A had a significantly shorter operating time than did the other three surgeons. As compared with 111.6 minutes for surgeon D, surgeon A required only 63 minutes on average to finish the same

procedure. Consequently, surgeon D's patients stayed more than 6 days longer than surgeon A's patients. In the comparison of surgeons B and C, surgeon B required shorter operating times and lengths of stay, although the mean volume of the four surgeons, termed surgeon B, was much lower than surgeon C.

Three multivariate regression models (Table 4) were performed to examine the relationships among volume, cost, and utilization. After controlling for covariates, surgeons B, C, and D incurred significantly higher costs of NT\$3,221, NT\$5,374, and NT\$7,716, respectively, compared with surgeon A ($p < 0.001$). The severity of illness was also significantly associated with total operating costs. The LC patients with ASA PS 3 incurred more (NT\$5,665) in total OR costs than the patients with ASA PS 1 ($p = 0.001$). After adjustment for demographic characteristics and disease variables, 40.8% of the variances in total OR costs were explained by the model.

In the direct professional cost model, surgeons B, C, and D had higher expenses compared with high-volume surgeon A after controlling for covariates. Surgeon B (low volume), from hospital A, incurred higher expenses (NT\$2,251) than did surgeon A ($p = 0.000$). In contrast, surgeon C (intermediate), from hospital B, had a higher volume than surgeon B, but incurred lower costs (NT\$1,770) compared to surgeon B and surgeon A (NT\$2,251 vs NT\$1,770). In other words, surgeon C consumed fewer resources than did surgeon B. The severity of illness was also significantly

Table 4. Multivariate linear regression models by costs and utilization

Variable	Total operating room costs model			Direct professional costs model			Length of stay		
	B	β	<i>p</i>	B	β	<i>p</i>	B	β	<i>p</i>
Constant	19,780		0.000	6,298		0.000	-0.113		0.899
Sex (male = reference)	-2,162	-0.226	0.003	-923	-0.164	0.051	-0.427	-0.071	0.329
Age	22.82	0.069	0.402	24	0.125	0.172	0.058	0.281	0.001
ASA score (1 = reference)									
2	76	0.008	0.931	-401	-0.068	0.481	-0.227	-0.036	0.668
3	5,665	0.306	0.001	2,455	0.226	0.023	3.361	0.291	0.001
Surgeon (A = reference)									
B	3,221	0.285	0.001	2,251	0.339	0.000	0.888	0.126	0.108
C	5,374	0.488	0.000	1,770	0.273	0.003	2.114	0.307	0.000
D	7,716	0.392	0.000	4,092	0.353	0.000	6.396	0.521	0.000
<i>R</i> ²			0.446			0.323			0.479
Adjusted <i>R</i> ²			0.408			0.277			0.443

ASA PS score = American Society of Anesthesiologists physical status score (see text); B = regression coefficient; β = standardized coefficient.

associated with direct professional costs. The LC patients with ASA PS 3 incurred higher (NT\$2,455) direct professional costs than did the patients with ASA PS 1 ($p = 0.023$). After adjustment for demographic characteristics and disease variables, the direct professional cost model explained 27.7% of variances.

At hospital A, the patients of surgeon B did not have a significantly longer stay than those of surgeon A. However, the patients of surgeons at hospital B had significantly longer lengths of stay than those at hospital A. Surgeon C's patients remained hospitalized 2.114 days longer than did surgeon A's patients ($p = 0.000$), and surgeon D's patients remained hospitalized 6.396 days longer than surgeon A's patients ($p = 0.000$). Significantly, the ASA PS 3 patients had a 3.36-day longer hospital stay as compared with the patients with ASA PS 1 ($p = 0.001$). After adjustment for demographic characteristics and disease variables, 44.3% of variances in length of stay were captured by the regression model.

DISCUSSION

The present study found that both hospital type and surgeon volume had significant effects on OR resources utilization and associated costs in performing LCs after controlling for patient demographics and severity of illness. As compared

with surgeon volume, hospital type may play a more important role in cost containment and resources conservation.

In the comparison of hospitals A and B, the costs of instruments and anesthesia were significantly different between the two study hospitals, even though the disposable instruments used in both hospitals were of the same brand. As with the differences in the specific item of direct materials costs, one can conclude that hospital A has more bargaining power for acquiring needed materials with relatively lower unit prices than does hospital B. Besides ownership, hospitals may also influence the price of purchased materials. Hospital B in the present study was a public teaching hospital, and public hospitals usually have less leverage in acquiring lower unit costs for materials [23].

Moreover, it should be noted that the direct materials costs accounted for more than 50% of total OR costs for both study hospitals, and more than 90% of the direct materials costs went toward disposable instruments. The high proportions of instrument costs were mainly due to the preference for using high-cost disposable instruments rather than reusable instruments, even though there is empirical evidence that reusable instruments for LC are cost effective and do not increase the risk of infection [29]. Under the cost containment pressure, hospitals might have to re-evaluate alternatives of surgical instruments for LC surgery.

The differences in direct professional costs further reflect the variations in practice patterns between the two study hospitals. As in the case of anesthesia time, hospital A patients had a shorter average anesthesia time than those at hospital B; however, the average anesthetist cost of hospital A was 2.5 times that of hospital B. The possible reason for the differences in anesthetist costs was that hospital A included specialty anesthetists on the LC operating team, whereas, at hospital B, the chief resident was responsible for performing anesthesia. The salary of a specialty anesthetist was at least three times the salary of a chief resident in Taiwan; this could explain the difference in anesthesia time and anesthetist costs between the two hospitals. The different practice pattern of anesthetists at the two hospitals also caused the differences in laboratory costs. It is customary for all LC patients to have routine blood analysis before surgery. However, anesthetists at hospital A ordered additional examinations for some patients and made analyses at the OR laboratory. The repeated ordering of laboratory examinations did not occur at hospital B. Whether the OR laboratory examination was necessary should be investigated further.

With respect to the interrelationship of volume, cost, and utilization, the three multivariate regression models indicated that surgeon-specific volume was associated with LC costs and resources utilization. In the regression models of the total costs and lengths of stay, the two surgeons (surgeons A and B) from hospital A had significantly lower costs and shorter hospital days as compared with the surgeons from hospital B (surgeons C and D) after controlling for covariates. It should be noted that surgeon C (intermediate volume) was from hospital B but had a personal higher volume of procedures as compared with surgeon B. However, the higher total costs and longer length of stay incurred by surgeon C may be due to insufficient hospital management or inadequate OR management as compared with hospital A. From the perspective of overall hospital management, all surgeons—whether high volume or low volume—require the support of efficient OR management to minimize total costs and maximize medical outcomes.

In the regression model of direct professional cost, however, surgeon volume was the most significant determinant of professional costs after controlling for covariates. Surgeon C with intermediate volume from hospital B demonstrated lower professional costs than did low-volume surgeon B from hospital A. Therefore, one can conclude that surgeon volume or experience does make a difference in OR cost savings. The present results confirm

that surgeon volume and hospital management are equally important in OR cost savings and resources; these results are in agreement with the interrelationship of volume, cost, and utilization as indicated in other studies [14–17]. As mentioned before, in Taiwan, LC is included on the list of fixed case payment procedures. Hospitals should design additional surgical training programs to standardize surgical skills and, thus, reduce direct professional costs [30].

In addition to the effect of surgeon volume, the severity of illness consistently plays an important role in predicting OR total costs, direct professional costs, and length of stay. The present findings confirm the appropriateness of using ASA PS as the measure of severity of illness in predicting hospital costs and utilization [24]. For elective surgeries such as LC, under the prospective payment system, severity of illness should be taken into consideration when adjusting reimbursement. Otherwise, hospital managers or physicians may resist providing care for more seriously ill patients.

The major weakness of the present study may be derived from the classification of surgeon volume. The mean value of the four physicians from hospital A was represented in the hypothetical surgeon B. Because of the difficulty in obtaining individual patient clinical information and associated cost data under the current health delivery system in Taiwan, the classification of high volume, intermediate volume, and low volume (or surgeons A, B, C, D) were mainly based on the availability of data for the study sample. Therefore, the interpretation of the study findings should be more cautious to specify the volume-cost-utilization relationship. Nonetheless, the cost information on each specific service item is valuable and important to uncover the real picture of LC OR costs by surgeon volume. Yet, the calculation of professional costs was derived from wage hourly rate of professional positions. Because the salary system varies by hospital, the differences in professional costs may be biased between the two study hospitals. Also, only patients undergoing LC in the last quarter of the year were considered as the study subjects. It is possible that seasonal effects could influence the volume of LC procedures. To minimize this limitation, we reviewed all the LC cases from 1999 to 2001 at both study hospitals and did not find any significant difference in the seasonal distribution of patient volume.

That there was no difference in clinical outcomes (mortality and complication rate) between the two study hospitals supports the proposal that surgeon volume plays an important role in costs and resource conservation. Moreover, the economic scale and administration policy of hospital management also contributes to the effectiveness

of cost containment. For instance, hospital A may possess more purchasing power for reducing direct materials costs, and high-volume surgeons still require the support of efficient hospital management in reducing costs and resource utilization. In conclusion, knowledge and experience of surgeons and of hospital managers are of equal importance in maintaining the ability of hospitals to compete in the market, especially under the case payment system for LC in Taiwan.

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醫師服務量對腹腔鏡膽囊切除術 手術室成本之影響

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背景：在亞洲國家中，鮮少有探討醫師服務量對腹腔鏡膽囊切除術 (laparoscopic cholecystectomy, LC) 成本控制之相關研究，因此本研究之目的在於分析不同醫院間 LC 手術室成本並進一步探討醫師服務量對 LC 手術室成本之影響。

方法：研究個案為兩家急性醫院於 2002 年 10 月至 12 月期間診斷為膽囊疾病且以腹腔鏡切除之患者，成本資料來自醫院財務相關部門，統計方法以三個複迴歸模式預測成本之影響因子。

結果：兩家醫院在病患的人口學特質與疾病嚴重度無統計之顯著差異。甲醫院和乙醫院相較，耗費較少的資源 (NT\$ 21,674 與 NT\$ 26,417)。特殊衛材成本、直接專業人力成本與間接成本在個別醫院與不同醫師服務量間皆存有顯著差異。高服務量的醫師和低服務量的醫師相較，有較低的成本與較短的住院日數。病人疾病嚴重度較高者 (ASA PS3) 和嚴重度較低者 (ASA PS1) 相較，耗用較多成本及較長住院日。

結論：本研究證實醫院管理與醫師臨床經驗對於醫院維持長期競爭力有相同的重要性。除醫師服務量與醫院管理外，醫院成本控制應將病人疾病嚴重度列為考慮因素。

關鍵詞：成本，服務量，腹腔鏡膽囊切除術
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