Can Experience Improve Hospital Management?

HARUSHIKA FUKUDA, KAZUHIDE OKUMA, YUICHI IMANAKA

1 Department of Health Care Administration and Management, Graduate School of Medical Sciences, Kyushu University, Higashi-ku, Fukuoka, Japan, 2 Department of Healthcare Economics and Quality Management, School of Public Health, Graduate School of Medicine, Kyoto University, Yoshida Konoe-cho, Sakyo-ku, Kyoto, Japan

Abstract

Background: Experience curve effects were first observed in the industrial arena as demonstrations of the relationship between experience and efficiency. These relationships were largely determined by improvements in management efficiency and quality of care. In the health care industry, volume-outcome relationships have been established with respect to quality of care improvement, but little is known about the effects of experience on management efficiency. Here, we examine the relationship between experience and hospital management in Japanese hospitals.

Methods: The study sample comprised individuals who had undergone surgery for unruptured abdominal aortic aneurysms and had been discharged from participant hospitals between April 1, 2006 and December 31, 2008. We analyzed the association between case volume (both at the hospital and surgeon level) and postoperative complications using multilevel logistic regression analysis. Multilevel log-linear regression analyses were performed to investigate the associations between case volume and length of stay (LOS) before and after surgery.

Results: We analyzed 909 patients and 849 patients using the hospital-level and surgeon-level analytical models, respectively. The odds ratio of postoperative complication occurrence for an increase of one surgery annually was 0.981 (P < 0.001) at the hospital level and 0.982 (P < 0.001) at the surgeon level. The log-linear regression analyses showed that shorter postoperative LOS was significantly associated with high hospital-level case volume (coefficient for an increase of one surgery: −0.006, P = 0.009) and surgeon-level case volume (coefficient for an increase of one surgery: −0.011, P = 0.022). Although an increase of one surgery annually at the hospital level was statistically associated with a reduction of preoperative LOS by 1.1% (P = 0.006), there was no significant association detected between surgeon-level case volume and preoperative LOS (P = 0.504).

Conclusion: Experience at the hospital level may contribute to the improvement of hospital management efficiency.

Introduction

“Practice makes perfect” is a widely accepted axiom, but the specifics of this concept can vary among the different industries. In the 1960s, an analysis of the aircraft industry demonstrated that the labor input required to manufacture one aircraft was reduced by 20% whenever the manufacturing quantity was doubled [1], indicating the existence of “learning curve” effects in this field. A decade later, the Boston Consulting Group discovered that production and sales costs were also associated with manufacturer experience (represented by accumulated production quantity); this relationship between experience and efficiency was described as an “experience curve” [2]. Possible determinants of experience curve effects include (1) improvement in yield rates, (2) improvement in employee efficiency, (3) improvements in work specialization and methods of operation, (4) changes to the distribution of utilized resources, and (5) standardization of products and services.

Studies within the health care industry have demonstrated that higher patient case volumes are associated with better outcomes, such as shorter length of stay (LOS) [3–5] and lower hospital charges [3]. This suggests that experience curve effects may also apply to the field of health care provision, possibly through two separate effects: the first effect is where an increase in experience improves yield rates, given by Determinant 1 of the experience curve effects as outlined above. The second effect is where an increase in experience improves hospital management, given by Determinants 2 to 5. Several studies have provided evidence supporting the existence of experience curve effects in health care by documenting associations between increased hospital or physician experience and reductions in postoperative complications and mortality rates [6–12]. However, it remains unclear if the effects are due to improvements in yield rate or improvements to hospital management efficiency.
Therefore, this study attempts to first confirm the traditional hypothesis that “experience improves yield rates” in a health care setting and to verify a new hypothesis that “experience improves hospital management” through an analysis of hospital-level and surgeon-level surgical experience, represented by the respective case volumes at each level. If the first hypothesis holds true, increases in hospital-level and surgeon-level case volumes should be accompanied by reductions in postoperative LOS, partly due to improvements arising from increased yield rates (such as reductions in the occurrence of complications). If the second hypothesis holds true, increases in hospital-level case volumes should be accompanied by reductions in preoperative LOS due to improvements arising from increased hospital management efficiency. Since we assume that management efficiency (given by determinants 2–5) is associated with hospital-level experience rather than surgeon-level experience, preoperative LOS would be expected to be associated with hospital-level case volume, but not with surgeon-level case volume. In our study, preoperative LOS was used as a representative indicator of hospital management efficiency, based on the assumption that preoperative LOS should generally be kept to a minimum to reduce unnecessary costs and utilization of medical resources.

Methods

Data Sources

The database used in this study was constructed from two different data sources. Hospitals in Japan that use the comprehensive payment system known as the Diagnosis Procedure Combination/Per-Diem Payment System (DPC/PDPS) are mandated to produce and submit a combination of claims and clinical data to the national government. These data are known as DPC data, and were used as one of the data sources for this study. DPC data include some information on medical treatment content, patient characteristics, and patient outcomes. The data were obtained from the Quality Indicator/Improvement Project (QIP), which is managed by the Department of Healthcare Economics and Quality Management, Kyoto University. The QIP database is constructed using hospitals that voluntarily participate in the program, and the data are produced in the same format as the data submitted to the government. Although the period for data submission to the government is from July to December each year, the QIP also collects data throughout the year from a portion of the institutions.

Because not all hospitals (including QIP hospitals) produce DPC data throughout the year, there are severe limitations in obtaining information regarding hospital-level and surgeon-level annual case volumes. Therefore, this study used a second data source in the form of a questionnaire survey targeting participant hospitals. Using this survey, we identified the surgeon at each participant hospital who performed the highest number of abdominal aortic aneurysm (AAA) surgeries in FY2008. We then determined the total number of AAA surgeries conducted by each of these surgeons during the 3-year period between April 1, 2006 and December 31, 2008, and used this number as the surgeon-level case volume of each hospital. We also calculated the total number of AAA surgeries performed by all surgeons at each participant hospital during the 3-year period, and used this number as the hospital-level case volume. Therefore, in hospitals with two or more surgeons that perform AAA surgeries, the surgeon-level case volume would be lower than the hospital-level case volume. If there is only one surgeon in a hospital, the surgeon-level case volume would be equal to the hospital-level case volume.

Study Subjects

We focused on individuals who had undergone surgery for unruptured AAA and had been discharged from the participant hospitals between April 1, 2006 and December 31, 2008. Using the DPC data, unruptured AAA cases were identified as those with the disease name “unruptured abdominal aortic aneurysm” in any of the following disease designations: “principal disease”, “disease resulting in admission”, “disease that required the most medical resources during hospitalization”, “disease that required the second most medical resources during hospitalization”, or “comorbidity present on admission”; alternatively, AAA cases were identified if their records contained the International Classification of Diseases 10th revision (ICD-10) code “I714”. However, patients were excluded if they had died during hospitalization or presented with other conditions of the aorta (in addition to AAA). Furthermore, patients were identified as subjects if their records contained the surgery codes K5607 (Abdominal aorta surgery [reconstruction of branching blood vessels]) or K5608 (Abdominal aorta surgery [others]). Patients who had undergone other surgeries in addition to unruptured AAA surgery were excluded from analysis. Patients whose records indicated preoperative LOS durations of 0 days were also excluded because these values could not be logarithmically transformed, which was required for the statistical analysis described below.

Variables

This study was conducted using the following three response variables: preoperative LOS (days), postoperative LOS (days), and postoperative complication occurrence. The two LOS variables were calculated from DPC data using the hospitalization periods before and after the date of unruptured AAA surgery. Postoperative complications were identified by first extracting all DPC data items that indicated post-admission complications in the study subjects, and then identifying the following complications as those associated with AAA surgery: cardiovascular diseases (blood pressure disorder, heart failure, ischemic heart disease, and arrhythmia), respiratory diseases (pneumonia, respiratory failure, pulmonary collapse, and pulmonary embolism), shock and diseases of the vital organs (multiple organ dysfunction syndrome or shock, bleeding diathesis, cerebrovascular disease, and postoperative nerve degeneration), gastrointestinal diseases (gastric ulcer, gastritis, or gastrointestinal hemorrhage; ileus; liver disease; pancreatitis; and iatrogenic harm due to thoracic surgery), urologic diseases (postoperative renal failure, urinary tract infection, neurogenic bladder dysfunction, and dysuria), and postoperative infections (surgical site infection, postoperative infection of unknown cause, and other surgical and wound complications).

The two exposure variables used were hospital-level case volume and surgeon-level case volume. Surgeon-level case volume was calculated as the case volume of the most experienced surgeon (highest annual case volume) at each hospital. The covariates to account for patient variations were obtained from DPC data and included patient sex, age at admission, emergency admission, and comorbidities present at admission. Comorbidities present at admission were analyzed using the Charlson comorbidity index [13,14].

Statistical Analysis

The three response variables were preoperative LOS (days), postoperative LOS (days), and postoperative complications; the exposure variables were hospital-level case volume and surgeon-level case volume. Six analytical models were developed based on the different combinations of these variables.
First, hospitals were categorized into the following three groups based on their annual case volumes: $\leq 19$ cases, 20–29 cases, and $\geq 30$ cases. Using ANOVA and Chi-squared tests, the associations between case volumes and the covariates were examined.

Next, we analyzed the association between case volume (both at the hospital and surgeon level) and postoperative complications using multilevel logistic regression analysis. Our database comprises hierarchical data composed of individual health care institutions, with patients nested within each institution. Because employee-associated factors, allocation of facilities, and treatment processes are likely to vary to a large degree among the hospitals, the associations between case volume and patient outcomes are also likely to be inconsistent at the hospital level. In order to account for these hospital-level variations, we employed a multilevel model for analysis, using case volume as the fixed effect and the individual hospitals as the random intercept.

Thirdly, the response variables of preoperative and postoperative LOS were logarithmically transformed before being analyzed using multilevel regression models to investigate their associations with case volume.

Statistical significance was set at $P < 0.05$. Statistical analyses were performed using Stata version 13.1 (StataCorp, College Station, Texas, USA).

**Table 1.** Patient characteristics.

| Annual case volume by hospital | Total | P-value |
|--------------------------------|-------|---------|
| **≤19 cases**                  | 273   | 8       |
| **20–29 cases**                | 257   | 7       |
| **≥30 cases**                  | 379   | 37      |
| **Number of patients**         | 909   |         |
| **Number of hospitals**        |       |         |
| Female [N (%)]                 | 54 (19.8%) | 46 (17.9%) | 69 (18.2%) | 169 (18.6%) | 0.830 |
| Patient age, yr [Mean (SD)]    | 74.0 (7.7) | 74.6 (7.9) | 73.5 (8.4) | 74.0 (8.1) | 0.189 |
| CCS at admission [Mean (SD)]   | 0.7 (0.8) | 0.7 (1.0) | 0.7 (0.9) | 0.7 (0.9) | 0.657 |
| Emergency admission [N (%)]    | 26 (9.5%) | 19 (7.4%) | 26 (6.9%) | 71 (7.8%) | 0.438 |
| Preoperative LOS, Days [Mean (SD)] | 7.7 (7.7) | 6.3 (7.0) | 3.7 (2.7) | 5.6 (6.1) | <0.001 |
| Postoperative LOS Days [Mean (SD)] | 21.6 (14.9) | 19.0 (20.3) | 17.9 (12.3) | 19.3 (15.8) | 0.012 |
| Total LOS, Days [Mean (SD)]    | 29.3 (17.8) | 25.3 (22.3) | 21.6 (13.0) | 25.0 (17.8) | <0.001 |
| Postoperative complication $\geq 1$ [N (%)] | 171 (62.6%) | 144 (56%) | 152 (40.1%) | 467 (51.4%) | <0.001 |

CCS, Charlson Comorbidity Score; LOS, length of stay.
doi:10.1371/journal.pone.0106884.t001

**Ethics Statement**

This study was approved by the Ethics Committee of the Graduate School and Faculty of Medicine, Kyoto University. The study was conducted with a waiver of patient consent. Patient records/information was anonymized and de-identified prior to analysis. The study complied with the Ethical Guidelines for Epidemiological Research of the Japanese national government, which include guidelines on protecting patient anonymity, and all the necessary conditions were satisfied for informed consent to be waived.

**Results**

**Response Rate**

The questionnaire was sent to 107 QIP participant hospitals. Of these, 37 hospitals (response rate: 34.6%) responded regarding hospital-level case volume and 36 hospitals (33.6%) responded regarding patient-level case volume. After combining the results of the questionnaire responses with the DPC data, the numbers of study subjects included in the multilevel logistic regression models were 909 for hospital-level case volume (3 cases were excluded because their preoperative LOS was 0 days) and 849 for surgeon-level case volume (3 cases were excluded because their preoperative LOS was 0 days).

**Table 2.** Results of multilevel logistic regression analysis of the impact of case volume on postoperative complication occurrence.

| Outcome: postoperative complication | Hospital-level case volume (37 hospitals, 909 cases) | Surgeon-level case volume (36 hospitals, 849 cases) |
|-----------------------------------|-----------------------------------------------|-----------------------------------------------|
| **Odds Ratio**                   | **95% CI**                                    | **P-value**                                   |
| Hospital-level case volume       | 0.981                                         | 0.975, 0.988                                 | <0.001                                       |
| Surgeon-level case volume        | -                                             | -                                             | -                                            |
| Emergency admission              | 0.928                                         | 0.560, 1.538                                 | 0.771                                        |
| Charlson Comorbidity Score       | 1.497                                         | 1.284, 1.746                                 | 0.001                                        |
| Age                               | 1.017                                         | 1.000, 1.034                                 | 0.051                                        |

doi:10.1371/journal.pone.0106884.t002
Multilevel Analysis: Case Volume and Length of Stay

The associations between case volume and patient outcomes have been addressed in previous studies, which have focused on procedures such as carotid endarterectomy [7], tumor resection [7,8], coronary artery bypass grafting (CABG) [1], and AAA surgery [7,9-12]. In this study, we opted to focus on unruptured AAA surgeries, the accumulation of experience may improve the technical skills of the surgeons and surgery teams. Furthermore, the results showed that only hospital-level case volume was significantly associated with reduced preoperative LOS, suggesting that experience at the hospital level may contribute to the improvement of hospital management.

The associations between case volume and patient outcomes have been addressed in previous studies, which have focused on procedures such as carotid endarterectomy [7], tumor resection [7,8], coronary artery bypass grafting (CABG) [1], and AAA surgery [7,9-12]. In this study, we opted to focus on unruptured AAA surgery cases for two reasons. The first reason is that it was possible to analyze the disease severity of AAA patients; the most important factor that can influence the severity of these patients is whether an aneurysm has ruptured or not. As our database uses

Patient Characteristics

The basic characteristics of the study sample are shown in Table 1. The hospital-level case volumes ranged from 0.7 to 86.3 surgeries per year, with a mean of 34.0 surgeries per year. To describe the basic characteristics of the study subjects, patients were allocated into three groups based on their hospitals' case volumes. There were 273 cases from 22 hospitals (59.5% of all hospitals) with 19 or fewer surgeries per year, 257 cases from 8 hospitals with 20–29 surgeries per year, and 379 patients from 7 hospitals with 30 or more surgeries per year.

The results showed no significant differences among the three groups with respect to patient sex, average age on admission, average Charlson comorbidity score on admission, and proportion of emergency admissions. However, hospitals with a high case volume tended to have a lower, albeit non-significant, proportion of emergency admissions. In contrast, higher case volume was found to be significantly associated with shorter postoperative LOS (P < 0.001), shorter preoperative LOS (P = 0.012), and shorter total LOS (P < 0.001).

Multilevel Analysis: Case Volume and Complications

Table 2 shows the results of the multilevel logistic regression analysis of the association between case volume and postoperative complications. An increase of one surgery annually at the hospital level was significantly associated with a reduction in postoperative complication occurrence (odds ratio [OR]: 0.981; P < 0.001). The OR of postoperative complication occurrence for an increase of one surgery annually at the surgeon level was 0.982. Similar to the hospital-level analysis, this increase in case volume was significantly associated (P < 0.001) with a reduction in postoperative complication occurrence. No significant association between emergency admission and postoperative complication occurrence was observed.

Multilevel Analysis: Case Volume and Length of Stay

Scatter plots of hospital-level case volume against postoperative LOS and preoperative LOS (Figures 1A and 1B, respectively) illustrate negative relationships between case volume and both types of LOS. The scatter plots show wide variations in the data at lower case volumes, followed by a plateau in the effect of case volume on LOS; this plateau appeared between 35 and 50 operations per year. The results of the multilevel regression analysis estimating the effects of hospital-level or surgeon-level case volume on postoperative LOS are shown in Table 3. Because sex did not show any statistical association with LOS, it was excluded from the multivariable analysis. The regression analysis showed that shorter postoperative LOS was significantly associated with high hospital-level case volume (P = 0.009) and surgeon-level case volume (P = 0.022). An increase of one surgery annually at the hospital level was estimated to reduce postoperative LOS by 0.6%.

The associations between case volume and preoperative LOS are also shown in Table 3. The analysis showed that hospitals with high case volumes tended to have significantly shorter preoperative LOS (P = 0.006). An increase of one surgery annually at the hospital level was estimated to reduce preoperative LOS by 1.1%. In contrast, there was no significant association detected between surgeon-level case volume and preoperative LOS.

Discussion

This study showed that increases in both hospital-level and surgeon-level case volumes were associated with reductions in postoperative LOS durations. The findings suggest that one of the reasons for the shorter postoperative LOS is the reduction of postoperative complications due to increased yield rates. In addition, the study showed that a reduction in preoperative LOS was associated with higher case volumes at the hospital level, but not at the surgeon level. An interpretation of these findings is that for unruptured AAA surgeries, the accumulation of experience may improve the technical skills of the surgeons and surgery teams. Furthermore, the results showed that only hospital-level case volume was significantly associated with reduced preoperative LOS, suggesting that experience at the hospital level may contribute to the improvement of hospital management.

The associations between case volume and patient outcomes have been addressed in previous studies, which have focused on procedures such as carotid endarterectomy [7], tumor resection [7,8], coronary artery bypass grafting (CABG) [1], and AAA surgery [7,9-12]. In this study, we opted to focus on unruptured AAA surgery cases for two reasons. The first reason is that it was possible to analyze the disease severity of AAA patients; the most important factor that can influence the severity of these patients is whether an aneurysm has ruptured or not. As our database uses
Table 3. Results of multilevel regression analysis of the impact of case volume on length of stay before and after AAA surgery.

| Outcome: Postoperative LOS | | Outcome: Preoperative LOS | |
|---------------------------|----------------|--------------------------|-----------------|
|                           | (37 hospitals, 909 cases) | (36 hospitals, 849 cases) | (37 hospitals, 906 cases) | (36 hospitals, 846 cases) |
|                           | Coef. 95% CI P-value | Coef. 95% CI P-value | Coef. 95% CI P-value | Coef. 95% CI P-value |
| Hospital-level case volume | -0.006 -0.010 -0.00010.009 | -0.011 -0.020 -0.0030.006 | -0.006 -0.025 -0.012 0.504 |
| Surgeon-level case volume | - | -0.011 -0.020 -0.0030.002 | - | -0.006 -0.025 -0.012 0.504 |
| Emergency admission | 0.220 0.118 0.321 <0.001 | 0.199 0.099 0.298 <0.001 | 0.785 0.649 0.921 <0.001 | 0.833 0.695 0.971 <0.001 |
| Charlson Comorbidity Score | 0.057 0.027 0.086 <0.001 | 0.062 0.033 0.092 <0.001 | 0.018 0.021 0.056 0.374 | 0.028 0.012 0.068 0.168 |
| Age | 0.007 0.004 0.001 <0.001 | 0.007 0.003 0.010 <0.001 | 0.007 0.003 0.012 0.002 | 0.008 0.003 0.012 0.001 |

LOS, length of stay.

Can Experience Improve Hospital Management?
hospitals also had higher proportions of emergency admissions, but this relationship was not statistically significant. Despite our attempt to adjust for disease severity, reimbursement claims data do not include clinical information such as the size of the aneurysm or its detailed location. As we were unable to account for these factors, we could not determine if some hospitals tended to accept patients with lower severities. As a result, it is possible that there may be some degree of bias in the study due to data constraints. The third limitation is that a relatively large number of hospitals did not respond to the questionnaire survey (69 hospitals). As a result, there is a possibility that the data used in the analysis are not representative of all hospitals in the QIP. For example, the mean number of annual AAA surgeries per hospital in our sample was 8.2 cases. According to an annual survey conducted by the Japanese Association for Thoracic Surgery (JATS) in 2009 on all 582 hospitals in Japan accredited by the Japanese Board of Cardiovascular Surgery (JBCS), the mean number of type A acute aortic dissections conducted annually in 485 respondent hospitals (response rate 83.3%) was 7.4 cases [35]. The case volume of our study hospitals was therefore slightly higher than that of JBCS-accredited hospitals. Finally, this study focused on only one surgery type: AAs. Although the inclusion of multiple surgery types may be useful for analysis, doing so would require highly complicated risk adjustments to account for the various disease severities accompanying each different surgery type. In addition, there would be practical limitations in acquiring the necessary data and examining the large patient populations required for multiple surgery analysis. For these reasons, we have focused on AAA surgery alone. These limitations should be considered when interpreting the findings of this study.

Despite some limitations, this study was able to provide new insight on the volume-outcome relationship, as we investigate whether experience can improve the effectiveness of hospital management through an analysis of preoperative and postoperative LOS. In the US, the functional differentiation of health care has advanced greatly, resulting in a substantial reduction in LOS durations in acute care hospitals. In that context, it would be difficult to conduct research that focuses on preoperative LOS as a means of evaluating hospital management. As this study was conducted in Japan, which has markedly protracted LOS durations when compared to the US and Europe, we were able to use this distinctive characteristic in order to elucidate the association between experience and hospital management.

Author Contributions
Conceived and designed the experiments: HF YI. Performed the experiments: HF KO YI. Analyzed the data: HF. Contributed reagents/materials/analysis tools: HF KO. Wrote the paper: HF.

References
1. Hirschmann WB (1964) Profit from the Learning Curve. Harvard Business Review 42: 125–139.
2. Boston Consulting Group (1972) Perspectives on Experience. Boston: BCG.
3. Dardik A, Lie JW, Gordon TA, Williams GM, Perler BA (1999) Results of elective abdominal aortic aneurysm repair in the 1990s: A population-based analysis of 2335 cases. J Vasc Surg 30: 985–995.
4. Dinick JB, Stanley JC, Axelrod DA, Kazmers A, Henke PK, et al. (2002) Variation in death rate after abdominal aortic aneurysm surgery in the United States: impact of hospital volume, gender, and age. Ann Surg 235: 579–585.
5. Men SW, Simunovic M, Williams JJ, Johnston KW, Naylor CD (1996) Hospital volume, calendar age, and short term outcomes in patients undergoing repair of abdominal aortic aneurysms: the Ontario experience, 1988–92. J Epidemiol Community Health 50: 207–213.
6. Luft HS, Bunker JP, Entenhof AC (1979) Should operations be regionalized? The empirical relation between surgical volume and mortality. N Engl J Med 303: 1361–1369.
7. Chowdhury MM, Daga, H, Pierro A (2007) A systematic review of the impact of volume of surgery and specialization on patient outcome. Br J Surg 94: 143–161.
8. Killen SD, O’Sullivan MJ, Coffey JC, Kirwan WD, Redmond HP (2005) Provider volume and outcomes for oncological procedures. Br J Surg 92: 389–402.
9. Henebiens M, van den Broek TA, Vahl AC, Koelmay MJ (2007) Relation between hospital volume and outcome of elective surgery for abdominal aortic aneurysms: a systematic review. Eur J Vasc Endovasc Surg 33: 283–292.
10. Young EL, Holt PJ, Polonecki JD, Loftus IM, Thompson MM (2007) Meta-analysis and systematic review of the relationship between surgeon annual caseload and mortality for elective open abdominal aortic aneurysm repairs. J Vasc Surg 46: 1279–1284.
11. Killen SD, Andrews EJ, Redmond HP, Fulton GJ (2007) Provider volume and outcomes for abdominal aortic aneurysm repair, carotid endarterectomy, and lower extremity revascularization procedures. J Vasc Surg 45: 615–626.
12. Holt PJ, Polonecki JD, Gerrard D, Loftus IM, Thompson MM (2007) Meta-analysis and systematic review of the relationship between volume and outcome in abdominal aortic aneurysm surgery. Br J Surg 94: 395–403.
13. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40: 373–383.
14. Sundararajan V, Henderson T, Perry C, Muggivan A, Quan H, et al. (2004) New ICD-10 version of the Charlson comorbidity index predicted in-hospital mortality. J Clin Epidemiol 57: 1288–1294.
15. Pronovost PJ, Jurkovic MW, Dorman T, Garrett E, Breslow MJ, et al. (1999) Organizational characteristics of intensive care units related to outcomes of abdominal aortic aneurysm surgery. N Engl J Med 311: 1310–1317.
16. Ducek AD, Kacey DS, Johnston KW, Alter D, Laupacis A (2004) Survival after ruptured abdominal aortic aneurysm: effect of patient, surgeon, and hospital factors. J Vasc Surg 39: 1253–1260.
17. Ducek AD, Kacey DS, Johnston KW, Alter D, Laupacis A (2004) Long-term survival and temporal trends in patient and surgeon factors after elective and ruptured abdominal aortic aneurysm surgery. J Vasc Surg 39: 1261–1267.
18. Hill JS, McPhie JT, Messina LM, Ciccoa RG, Eldami MH (2008) Regionalization of abdominal aortic aneurysm repair: evidence of a shift to high-volume centers in the endovascular era. J Vasc Surg 48: 29–36.
19. Rigberg DA, Zimpson DS, McGory ML, Maggard MA, Agustin M, et al. (2006) Age stratified, perioperative, and one-year mortality after abdominal aortic aneurysm repair: a statewide experience. J Vasc Surg 43: 224–229.
20. Dinick JB, Pronovost PJ, Cowan J, Aalswadi G, Upchurch GR Jr (2002) The volume-outcome effect for abdominal aortic surgery: differences in case-mix or complications? Arch Surg 137: 826–832.
21. Dardik A, Burleyson GP, Bownan H, Gordon TA, Williams GM, et al. (1998) Surgical repair of ruptured abdominal aortic aneurysms in the state of Maryland: factors influencing outcome among 327 recent cases. J Vasc Surg 28: 413–420.
22. Manheim LM, Soin MH, Feinglass J, Ujiki M, Parker MA, et al. (1998) Hospital vascular surgery volume and procedure mortality rates in California, 1962–1994. J Vasc Surg 28: 45–56.
23. Kroun I, Lepanto M, Salenius JP, Matzke S, Luther M, et al. (1998) Influence of surgical experience on the results of carotid surgery. Euro J Vasc Endovasc Surg 15: 155–160.
24. Kazmers A, Jacobs L, Perkins A, Lindenauer SM, Bates E. (1996) Abdominal aortic aneurysm repair in Veterans Affairs medical centers. J Vasc Surg 23: 191–200.
25. Hanaan EL, Killburn HI, O’Donnell JF, Bernard HR, Shields EP, et al. (1992) A longitudinal analysis of the relationship between in-hospital mortality in New York State and the volume of abdominal aortic aneurysm surgeries performed. Health Serv Res 27: 517–542.
26. Cho JS, Kim JY, Rhee HY, Gupta N, Marone LD, et al. (2002) Contemporary results of open repair of ruptured abdominal aortic aneurysms: effect of surgeon volume on mortality. J Vasc Surg 38: 10–17.
27. Ts JV, Austin PC, Johnston KW (2003) The influence of surgical specialty training on the outcomes of elective abdominal aortic aneurysm surgery. J Vasc Surg 33: 447–452.
28. Pearce WH, Parker MA, Feinglass J, Ujiki M, Manheim LM (1999) The importance of surgeon volume and training in outcomes for vascular surgical procedures. J Vasc Surg 29: 768–776.
29. Dinick JB, Cowan JA Jr, Stanley JC, Henke PK, Pronovost PJ, et al. (2003) Surgeon specialty and provider volumes are related to outcome of intact abdominal aortic aneurysm repair in the United States. J Vasc Surg 38: 739–744.
30. Rutledge R, Oller DW, Meyer AA, Johnson GJ Jr (1996) A statewide, population-based time-series analysis of the outcome of ruptured abdominal aortic aneurysm surgery. Ann Surg 224: 592–597.
31. Sollano JA, Gelijns AC, Moskowitz AJ, Heitjan DF, Cullinan S, et al. (1999) Volume-outcome relationships in cardiovascular operations: New York State, 1990–1995. J Thorac Cardiovasc Surg 117: 419–426.
32. Khuri SF, Daley J, Henderson W, Hur K, Hossain M, et al. (1999) Relation of surgical volume to outcome in eight common operations: results from the VA National Surgical Quality Improvement Program. Ann Surg 230: 414–429.

33. Ward MM, Jaana M, Wakefield DS, Ohsfeldt RL, Schneider JE, et al. (2004) What would be the effect of referral to high-volume hospitals in a largely rural state? J Rural Health 20: 344–354.

34. Elixhauser A, Steiner C, Fraser I (2003) Volume thresholds and hospital characteristics in the United States. Health Aff 22: 167–177.

35. Results of Scientific Surveys in 2009 Annual Report by the Japanese Association for Thoracic Surgery (2009) Available: http://www.jpats.org/. Accessed 29 July 2014.