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ORIGINAL ARTICLE

Hospital volume and surgical outcomes of lung cancer in Japan

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Abstract
Objective. This study aimed at analyzing results of surgery for lung cancer in relation to hospital volume to see if a straightforward relation exists between hospital volume and surgical outcome.
Methods. Two data sets collected nationwide in Japan were retrospectively studied by statistical analysis: 18 055 patients operated on during an average year for the most recent 4 years for an analysis of hospital mortality and 3233 patients operated on duraing 1989 for analysis of the 5-year survival rate. First, we examined the correlations of hospital volume with each outcome, which was estimated using the empirical Bayes (EB) method to stabilize any large variation due to the small sample. Then we estimated the volume effects using generalized regression models. Perioperative mortality and the 5-year survival rate in relation to hospital volume were measured.
Results. No statistically significant correlations between hospital volume and each outcome have been shown (EB mortality 1.51%, $P = 0.0566$; 5-year survival 48.9%, $P = 0.333$). Regarding the volume effect, only the lowest-volume subgroup showed a statistically significant higher perioperative mortality rate and a lower 5-year survival rate compared to the highest-volume counterpart, but many hospitals of the lowest-volume subgroup had operated on more patients with advanced-stage disease.
Conclusions. No straightforward correlation was seen between hospital volume and surgical outcome. Hospital volume may not be a suitable single tool to predict the outcome of lung cancer surgery. We should reserve the conclusion that low-volume hospitals offer less effective surgery. We need a risk-adjusted database to study this topic.

Key words Lung cancer · Hospital volume · Mortality · Five-year survival rate · Surgical outcome

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Introduction

It remains controversial whether hospital volume or surgeon volume is an independent predictor of outcome after lung cancer surgery. Although literature from the United States states that hospital volume has a statistically significant relation to surgical outcome,[1,2] that from Britain does not report such a straightforward relation.[3] There has been no report in this regard yet from Japan. We have analyzed two sets of accumulated data regarding lung cancer surgery to examine the relation between hospital volume and perioperative mortality or 5-year survival rates. To our knowledge this is the first such report from Japan on lung cancer surgery.

Materials

Two data sets have been analyzed. The first comprises data regarding lung cancer contained in the general thoracic surgery section of the annual statistical report collected by the Japanese Association for Thoracic Surgery (JATS). Each program director of 540 hospitals accredited by JATS had reported his or her results each year, using questionnaire forms, to the Committee of Science. Data for four consecutive years from 2000 to 2003 were subjected to our analysis by courtesy of JATS. The data contained hospital volume, histological subtype (adenocarcinoma, squamous cell carcinoma, large cell carcinoma, small cell carcinoma, others), procedure performed (wedge resection, segmentectomy, lobectomy, pneumonectomy, others), and perioperative mortality in terms of 30-day deaths and hospital deaths, where hospital deaths included those that occurred during the 30 days directly following the operation. The data contained no patient-level characteristics such as age, sex, stage of cancer, or other risk factors. Hospital volume and mortalities were expressed as the average per year. The per-annum recovery rates of the survey were within the range of 93.5%–94.1%. Hospital volume ranged from 13 to 168 patients. There were an average of 18 055 patients operated on per year. Of them, 13 609 patients underwent lobectomy, 648 pneumonectomy, and 1093 segmentectomy.

The other data set was obtained from the Japanese Association for Chest Surgery (JACS) by courtesy of Dr. T. Shirakusa, who was in charge for the survey planned in 1994 by the Association to determine the 5-year survival rate of patients operated on for lung cancer with curative intention. Data contained information from 91 of 126 central hospitals (72.2%) accredited by the Committee of Accreditation for Institutes of JACS. In this particular survey, satellite hospitals relating to each central hospital were not included. Patients who had been operated on for recurrence were also excluded. Detailed information of all patients operated on for lung cancer during the single year 1989 was collected: hospital volume, patient's age at surgery, sex, histological subtype, procedure performed, pathological cancer stage according to the TNM system valid for the year 1989, and the latest status observed. There were 3233 patients in total: 2375 male, 839 female, and 19 unknown. Hospital volume ranged from 4 to 136 patients. The overall 5-year survival reported by the Science Committee of JACS based on this survey was 47.2%.[4] It should be noted that most of the hospitals registered in this series were included also in the first data set.

Each data set was digitalized under the auspices of one of the authors (H.O.) after replacing the name of each hospital with serial numbers for statistical analysis.

Methods

Statistical analysis

JATS data

We assessed the correlation of outcome (30-day mortality and hospital mortality) and hospital volume by surgical procedure (overall, lobectomy, pneumonectomy.) In small-volume hospitals, the mortality rate could vary drastically by one death, and the data for crude mortality rates could be overly dispersed; thus, crude mortality rates should not be tested directly. We therefore calculated empirical Bayes[5] (EB) estimates of the hospital mortality rate. The EB estimate is a technique to stabilize the crude estimates close to the estimate for the whole sample. For example, the EB estimate is often used when performing disease mapping, which shows information on regional mortality or morbidity visually and has unstable estimates from thinly populated rural areas. Mortality thus adjusted by EB estimates is presented as EB-mortality. Pearson's correlation coefficient between the hospital volume and the EB-mortality rate was calculated for each outcome. We then compared each category of volume (<25, 25–49, 50–99, >99 cases per year) and estimated the volume effect using a logistic regression model. To account for the effect of overdispersion and clustering at the hospital level, we estimated parameters and standard errors using the generalized estimation equation[6] (logistic-GEE model).

JACS data

We first assessed the correlation of outcome in terms of 5-year survival and hospital volume by surgical procedure or stage of disease, (i.e., overall, lobectomy, pneumonectomy, stage I.) To test the correlation we utilized the standard mortality ratio (SMR) of each group, which is the ratio of the observed number of deaths in a population divided by the number expected if some standardized mortality rates had prevailed. The ratio is usually multiplied by 100 so if the number of deaths in the target population is exactly that predicted by the standard, the SMR is 100. For the same reason as for JATS data, we calculated EB estimates of expected 5-year mortality rates adjusting for the patient-level characteristics of age, sex, operative site, postoperative stage, type of cancer cells, and range of lymph node dissection and then estimated the EB-standardized mortality ratio (EB-SMR) beside the crude SMR. For the crude SMR, the denominators were calculated by the crude mortality ratio. Pearson's correlation coefficient between the hospital volume and EB-SMR was calculated for each outcome. Next, we compared each category of hospital volume (<20, 20–29, 30–49, 50–79, >79 cases per annum) and estimated the volume effect using the Poisson regression model, adjusting for the patient-level characteristics of age, sex, operative site, postoperative stage, type of cancer cells, and range of lymph node dissection. To account for the effect of overdispersion and clustering at the hospital level, we estimated the parameter and standard errors by GEE (Poisson-GEE model).

Categorizing the hospital volume, we set the categories to contain sufficient hospitals and patients in each category. The categorization is therefore different in the JATS and JACS data. Note that the JACS data were obtained much earlier than the JATS data, when the hospital volume was generally lower. All P values are two-sided. All analyses were performed with SAS version 8.2 (SAS Institute, Cary, NC, USA).

Results

Perioperative mortality

Crude mortality of the 540 hospitals ranged from 0% to 50%, where the average was 1.394% ± 3.333%, and EB-mortality was 1.51% ± 1.815%. Pearson's correlation coefficient between the hospital volume and the EB-mortality rate in total was –0.08211 ($P = 0.0566$), meaning that there was no statistically significant relation between hospital volume and the perioperative mortality rate. When the EB-mortality was divided into 30-day mortality and hospital mortality, average mortalities were 0.473% and 0.949%, respectively, with no statistically significant correlation to hospital volume (Table 1). Neither lobectomy nor pneumonectomy had a significant correlation between hospital volume and EB-mortality when analyzed independently in similar fashion by each procedure.

The hospital volume was then divided into four categories, (i.e., <25, 25–49, 50–99, >99 cases per annum) to compare each category in relation to mortality (Table 2). The lowest volume category showed a statistically significant higher mortality rate in total compared to the highest-volume counterpart [odds ratio 1.8298, 95%

Table 1 Perioperative mortality: analysis of JATS data

Parameter	30-Day mortality (%)	Hospital mortality (%)	Total mortality (%)
Crude mortality ± SD	0.509 ± 2.336	0.885 ± 2.109	1.394 ± 3.333
EB mortality ± SD	0.437 ± 0.219	0.949 ± 1.214	1.51 ± 1.815
Pearson's correlation coefficient	0.00581	–0.06435	–0.08211
P	0.8928	0.1353	0.0566

EB, empirical Bayes

Hospital mortality does not include 30-day mortality. Mortality in total is equal to the sum of the 30-day mortality and hospital mortality

Table 2 Odds ratios for perioperative mortality: analysis of JATS data

Hospital volume (no. of cases)	No. of hospitals	No. of patients	30-Day mortality		Hospital mortality		Total mortality	
			Odds ratio	95% Confidence limits	Odds ratio	95% Confidence limits	Odds ratio	95% Confidence limits
≤24	276	13 572	1.4300	0.9557– 2.1397	2.0897	1.5090– 2.8938	1.8298	1.3343– 2.5092
25–49	159	23 275	1.1062	0.7461– 1.6399	1.4868	1.1063– 1.9980	1.3336	0.9885– 1.7993
50–99	86	23 737	1.0809	0.7121–1.6406	1.4670	1.0511– 2.0475	1.3111	0.9372– 1.8343
≥100	19	11 633	1.0000	—	1.0000	—	1.0000	—

Comparison of each volume subclass was done to the highest-volume subclass whose odds ratio is 1.0000. When 95% confidence limits does not include 1.0000, the difference is interpreted as significant

Table 3 Standardized mortality ratio by procedure or by stage: analysis of JACS data

Parameter	Overall	Lobectomy	Pneumonectomy	Stage I
No. of hospitals	83	83	77	83
No. of patients	3233	2608	395	1507
5-Year survival rate (%)	48.9	53.3	24.6	69.6
SMR (crude), mean	114.60	112.31	361.61	112.44
EB-SMR, mean	106.06	105.16	269.16	107.79
Pearson's correlation coefficient	–0.1076	–0.1059	–0.0023	–0.1077
P	0.3330	0.3409	0.9841	0.3326

SMR, standardized mortality ratio; EB-SMR, empirical Bayes SMR
Several hospitals had performed no pneumonectomy
P values show that there was no statistically significant correlation between hospital volume and the 5-year survival rate overall or in any subgroup by procedure or stage of lung cancer

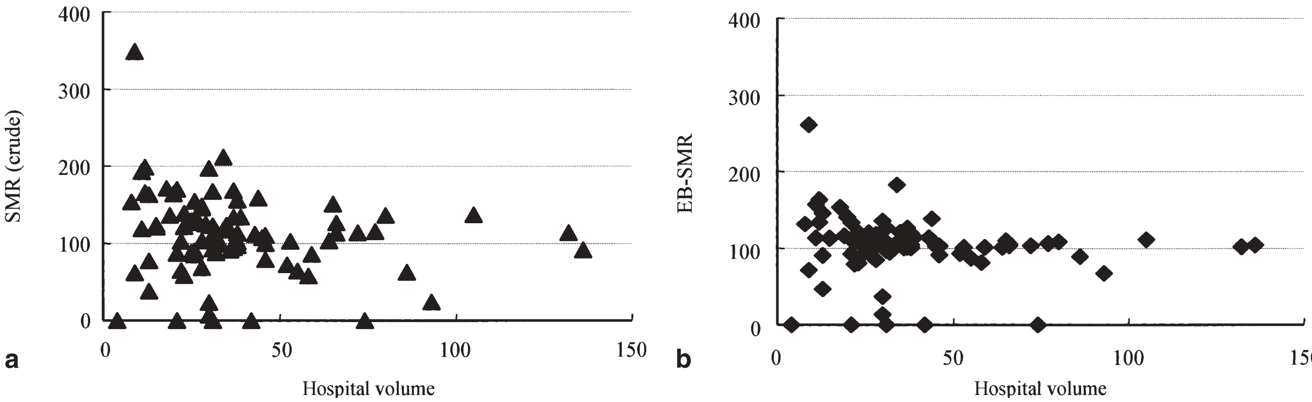

Fig. 1 **a** Distribution of crude standardized mortality ratio (*SMR*). **b** Distribution of empirical Bayes standardized mortality ratio (*EB-SMR*) Analysis of JACS data. Note that points are lining up at the 100 level

confidence interval (CI) 1.3343–2.5092), but other intermediate subgroups did not. When analysis was done by the procedure performed (i.e., lobectomy or pneumonectomy), the lowest-volume category similarly showed a statistically significant higher mortality rate in total compared to the highest-volume counterpart.

Five-year survival rate

The crude SMR and EB-SMR were calculated from JACS data (Fig. 1). Overdispersion seen in the distribution of the crude SMR became less in the EB-SMR as the result of adjustment of estimates of patients from each hospital. The EB-SMRs distributed at or much closer to 100, meaning that there is no visualized relation between mortality and hospital volume. The volume–outcome relation was then statistically examined by the correlation of hospital volume and EB-SMR (Table 3). There was no statistically significant correlation between the hospital volume and the 5-year survival rate overall (–0.1076, $P = 0.333$). Analyses by procedure, either lobectomy or pneumonectomy, or by limiting the cases to stage I also showed no correlation.

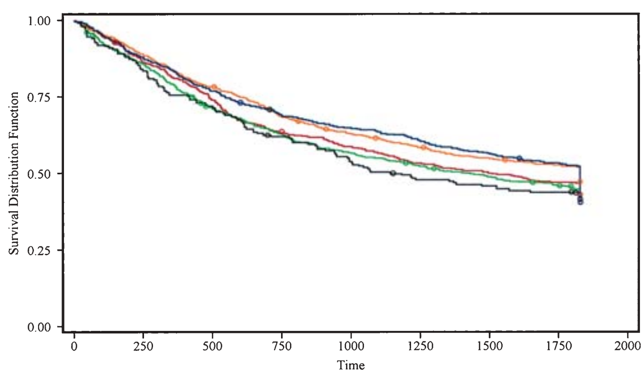

Fig. 2 Postoperative survival curves by hospital volume. *Black line*, hospitals with volume less than 20 cases per year; *red line*, hospitals with volume between 20 and 29 cases per year; *green line*, hospitals with volume between 30 and 49 cases per year; *yellow line*, hospitals with volume between 50 and 79 cases per year; *blue line*, hospitals with volume more than 79 cases per year. Analysis of JACS data. Time is shown by days after surgery. The 5-year survival curves of five groups of hospitals are quite close to each other, although the higher the volume the greater was the survival rate. Statistical comparison of these curves is shown in Table 4

Table 4 Hazard ratios for 5-year mortality rate: analysis of JACS data

Hospital volume (no. of cases)	No. of hospitals	No. of patients	Hazard ratio	95% Confidence limits
≤19	16	201	1.5589	1.0036–2.4216
20–29	22	544	1.2556	0.8012–1.9676
30–49	30	1095	1.3267	0.8657–2.0332
50–79	12	761	1.2607	0.8219–1.9340
≥80	8	632	1.0000	1.0000–1.0000

Five-year survival rates of subgroups by hospital volume as shown in Fig. 2 was compared in the form of a hazard ratio with the highest-volume subgroup, the hazard ratio of which was set as 1.0000. The lowest-volume subgroup had a statistically low 5-year survival ratio because the 95% confidence limits did not include 1.0000

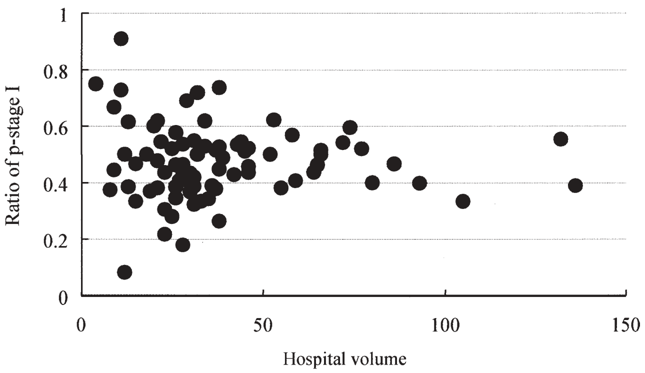

Fig. 3 Distribution of the ratio of p stage I by hospital volume. Analysis of JACS data

The hospital volume was then divided into five categories, (i.e., <20, 20–29, 30–49, 50–79, >79 cases operated on per annum) to compare the results. Survival curves for each subcategory were drawn based on crude data (Fig. 2). The difference between categories was estimated by the Poisson-GEE model (Table 4). The hazard ratio was significant in the lowest-volume category compared with the highest-volume category (hazard ratio 1.5589, 95% CI 1.0036–2.4216). Similar results were obtained after analyses of data by procedure and by stage. Although the original data did not include risk adjusted to co-morbidity, it was possible to see the percentage that contained patients of stage I disease in each hospital. The distribution of the proportions for stage I patients operated on in each hospital is shown in Fig. 3. The top eight hospitals with volumes >80 fairly uniformly had a ratio around 50%, whereas some hospitals in the lower-volume groups had much smaller values, suggesting that the latter operated on comparatively more patients with advanced-stage disease.

Discussion

The perioperative mortality rate for lung cancer surgery has been reported to be 5.3% if surgery was done by general surgeons, 3.0% if by thoracic surgeons,[7] or 3.1%[8] as 30-day mortality apparently by thoracic surgeons. The perioperative mortality rate for lung lobectomy has recently been reported to be 2.6%[3] by thoracic surgeons or 1.86%[1] by unspecified surgeons. Our data—1.39% as observed and 1.51% by the empirical Bayes estimation—seem comparable to these figures. We found no statistically significant correlation between hospital volume and perioperative mortality rate.

Treasure et al.[3] reported that the number of procedures performed by a thoracic surgeon is not related to in-hospital mortality. They reported an overall in-hospital mortality of 2.6% (95% CI 2.1%–3.1%) for the years 1999–2000 for lobectomy for primary lung cancer in the United Kingdom and concluded that in-hospital mortality is a poor tool for measuring a surgeon's performance. Apart from the difference between hospital volume and surgeon volume, the British and Japanese experiences seem to be similar. On the other hand, in the United States the observed mortality rates decreased considerably with hospital volume. Hannan et al. showed that perioperative mortality came from a high of 3.05% for the lowest-volume hospital quartile down to a low of 0.87% for the highest-volume hospital quartile.[1] It is true that in our study as well the lowest hospital volume subgroup yielded statistically significantly higher mortality when compared to the highest-volume counterpart. We speculate, however, that the difference may have resulted from inclusion of more patients with advanced-stage disease in the lowest-volume hospitals (as we discuss later regarding survival issues), although no evidence was obtained from the JATS data, which did not contain parameters such as lung cancer stage.

There was also no statistically significant correlation between hospital volume and postoperative 5-year survival rates in our study. Bach et al. observed that the 5-year survival rate was 44% for the highest-volume hospitals but 33% for the lowest-volume hospitals.[2] It was also found that life expectancy in older surgical patients increased steadily with hospital volume of surgery for pancreatic, lung, or colon cancer, and that differences in life expectancy across volume strata were largely attributable to differences in long-term survival, not operative mortality.[9] These reports make it appear that low hospital volume means less effective surgical treatment—either surgical technique or perioperative co-medical care. Back to our study, the lowest-volume subgroup again showed a significantly lower survival rate when compared to the highest-volume counterpart. It was not clear, however, whether this means low quality of surgery or less satisfactory perioperative care in those lowest-volume hospitals because some of the lowest-volume hospitals tended to operate on more patients with advanced-stage lung cancer.

The discrepancy between our results and those from the United States may be derived from the fact that in Japan most hospitals with a general thoracic surgery service have well-trained general thoracic surgeons to operate on lung cancer patients, regardless of hospital volume. In some parts of the United States, one-half of lobectomies and nearly 60% of pnemonectomies are performed by general surgeons; specialists perform these surgeries with a mortality of 3.0%, whereas the corresponding figure for general surgeons is 5.3% ($P < 0.05$).[7] In fact, a relatively even distribution of lung cancer cases across institutions was observed in 1996 in the United States,[10] from major designated cancer center hospitals to smaller community hospitals. Low-volume surgeons, who perform fewer than 24 lobectomies a year, provide 40% of the services[3] in the United Kingdom, which may mirror the situation in Japan. So long as the low-volume surgeons are well-trained qualified specialists, they can perform surgery with results comparable to those achieved by their high-volume counterparts, should the perioperative care be of comparable quality.

Another British experience published by Martin-Ucar et al.,[11] however, makes the story more complex. They reported that in a central hospital neither perioperative mortality nor the 5-year survival changed significantly before or after appointment of a specialist thoracic surgeon (mortality 7.7% and 5.5%, respectively; survival 32% and 31%, respectively), although the hospital volume increased by almost threefold, and more patients in advanced stages were operated on by the specialist. What this means may not be that a nonspecialist surgeon can do as much qualified lung cancer surgeries as can a specialist, but that a specialist can carry on surgeries for patients in an advanced stage without increased mortality or a compromised survival rate.

One can argue that our original data could be more accurate with risk adjustment beforehand and with a data-confirming process such as site visiting. The results shown are nevertheless informative.

Conclusions

No straightforward correlation was seen between hospital volume and surgical outcome in regard to lung cancer surgery. Hospital volume may not be a suitable single tool to predict the outcome of surgery for lung cancer. In other words, we should reserve the conclusion that the lowest-volume hospitals provide less effective surgery to lung cancer patients. To further examine if the low-volume hospitals are associated with a higher mortality rate and a lower 5-year survival rate compared to their high-volume counterparts, we need a risk-adjusted database.

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