Gen Thorac Cardiovasc Surg (2007) 55:483–492
DOI 10.1007/s11748-007-0172-0

ORIGINAL ARTICLE

An attempt to analyze the relation between hospital surgical volume and clinical outcome

Committee for Scientific Affairs

Teruhisa Kazui, MD · Hiroaki Osada, MD
Hiromasa Fujita, MD

Received: 2 March 2007 / Accepted: 14 August 2007

Abstract
Objectives. The aim of this study was to investigate the relation between hospital volume and clinical surgical outcome for 10 cardiac, lung, and esophageal surgical procedures.
Methods. The Committee for Scientific Affairs of the Japanese Association for Thoracic Surgery collected the pooled data on cardiac, lung, and esophageal surgical procedures between 2000 and 2004 from the annual reports. The relation between operative mortality (30-day or in-hospital mortality) and hospital volume was analyzed using a logistic regression model. The surgical procedures studied were surgery for acquired cardiac diseases [coronary artery bypass grafting (CABG), valve procedures, acute type A dissection surgery], total CABG (elective + emergency), elective CABG, emergency CABG, single-valve surgery, acute type A dissection surgery, open heart surgery for the newborn, open heart surgery for the infants, lung cancer surgery, and esophageal cancer surgery. The data used in this study were not risk-adjusted.
Results. The data on the relation between hospital volume and operative mortality generally tended to show an inverse correlation for all 10 cardiac, lung, and esophageal surgical procedures; that is, the higher was the volume the lower was the mortality. However, wide variations in operative mortality were noted among the very-low-volume hospital groups.
Conclusion. An inverse correlation was noted between hospital volume and operative mortality in the present study, although wide variations in clinical outcome were noted among the very low-volume hospitals. Further analysis is warranted using risk-adjusted data.

Key words Hospital volume · Clinical outcome · Cardiac surgery · Lung cancer surgery · Esophageal cancer surgery

Introduction

There has been increasing interest and awareness among health care consumers and purchasers about the quality of health care. Over the past few decades, numerous studies, most of them in the United States, have focused on the association between the volume of health services provided by hospitals and physicians and patient outcomes.[1–9] Most of these studies have indicated that higher volume is associated with better outcomes, although others have found no relation between them.[10,11] The trend has been explained by the hypotheses that physicians as well as hospitals develop better skills as they deal with more patients of a particular type and that centers

This report was prepared by the Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery

T. Kazui (✉)
First Department of Surgery, Hamamatsu University School of Medicine, 1-20-1 Handayama, Hamamatsu 431-3192, Japan
Tel. +81-53-435-2276; Fax +81-53-435-2272
e-mail: tkazui@hama-med.ac.jp

H. Osada
Department of Surgery, Division of Chest Surgery, St. Marianna University School of Medicine, Kawasaki, Japan

H. Fujita
Department of Surgery, Kurume University School of Medicine, Fukuoka, Japan

that achieve better results with a particular procedure tend to receive more patients of that type through increasing referrals.[12] A question remains, however, regarding the generalized applicability of the inferences derived from these studies. Some of these studies have worked with regional populations served by a small number of high-volume centers. Moreover, although some conditions or procedures have been studied extensively, there are many other high-risk procedures that have remained relatively unexplored.

In 2002, the Japanese government's Ministry of Health, Labor, and Welfare put into effect a policy of reducing the reimbursement of health insurance money by 30% for the hospitals that deal with fewer than 100 patients of open heart surgery in a year. This reflected the government's perception that the lower-volume hospitals fared worse in terms of surgical outcome. However, many surgeons and institutions across the country voiced their concern about this policy because in their opinion there was no scientific basis that could justify such an action. The policy was later abolished. It is therefore clear that an objective assessment of the volume–outcome relation is now a matter of great practical importance to both health professionals and health care consumers in Japan. Although some previous studies have tried to investigate this issue,[13–15] they worked with limited data on selected procedures only. The Japanese Association for Thoracic Surgery (JATS) has been collecting, analyzing, and publishing nationwide patient data on thoracic surgery every year, giving us a unique opportunity to work with the national thoracic surgical database. Taking advantage of this possibility, we analyzed the data for all cardiothoracic surgical procedures and report the relation between hospital volume and surgical outcome for 10 thoracic and cardiovascular surgical procedures. This is the first attempt at analyzing these data from this perspective.

Subjects and methods

The Committee for Scientific Affairs of the JATS conducts an annual survey of cardiothoracic and esophageal surgery among its member institutions across the country and accumulates data. The subjects of the present study are patients undergoing the following 10 cardiac and thoracic procedures.

1. Surgery for acquired cardiac diseases (CABG, valve procedures, acute type A dissection surgery)
2. Total CABG (elective + emergency)
3. Elective CABG
4. Emergency CABG
5. Single-valve surgery
6. Acute type A dissection surgery on an emergency basis
7. Open heart surgery for newborns
8. Open heart surgery for infants
9. Lung cancer surgery
10. Esophageal cancer surgery

The study was conducted using a database that was compiled over a 5-year period, from 2000 to 2004. A written questionnaire was sent to the participating institutions at a designated time every year with the aim of collecting surgical data. The average response rates from participating institutions during the study period were 94.9% for cardiac surgery, 93.5% for lung surgery, and 87.4% for esophageal surgery. The number of cases for each procedure and the number of institutes participating are listed in Table 1.

Statistical analysis

Data analysis was performed in a uniform way for all procedures. Only the institutions providing data for a

Table 1 Subjects of the study

Surgical procedure	No. of patients	No. of institutions
Acquired heart disease surgery	153 616	556
Elective + emergency CABG	101 321	551
Elective CABG	84 468	483
Emergency CABG	13 900	509
Single-valve surgery	40 619	485
Acute type A dissection surgery	10 097	439
Open heart surgery in newborns	2 611	131
Open heart surgery in infants	8 586	135
Lung cancer surgery	94 854	526
Esophageal cancer surgery	21 020	551

CABG, coronary artery bypass grafting

Table 2 Stratification of the participating institutions based on the annual number of surgical procedures

Surgery for acquired cardiac diseases (CABG, single-valve surgery, acute type A dissection surgery)
$n = 1–24$, $n = 25–49$, $n = 50–74$, $n = 75–99$, $n \geq 100$
Total CABG (elective + emergency)
$n = 1–24$, $n = 25–49$, $n = 50–74$, $n = 75–99$, $n \geq 100$
Elective CABG
$n = 1–24$, $n = 25–49$, $n = 50–74$, $n = 75–99$, $n \geq 100$
Emergency CABG
$n = 1–4$, $n = 5–9$, $n = 10–14$, $n = 15–19$, $n \geq 20$
Single-valve surgery
$n = 1–14$, $n = 15–29$, $n = 30–44$, $n = 45–59$, $n \geq 60$
Acute type-A aortic dissection surgery on an emergency basis
$n = 1–4$, $n = 5–9$, $n = 10–14$, $n = 15–19$, $n \geq 20$
Open heart surgery in newborns
$n = 1–4$, $n = 5–9$, $n = 10–19$, $n \geq 20$
Open heart surgery in infants
$n = 1–4$, $n = 5–19$, $n = 20–49$, $n \geq 50$
Lung cancer surgery
$n = 1–9$, $n = 10–24$, $n = 25–49$ $n = 50–74$, $n = 75–99$, $n = 100–149$, $n \geq 150$
Esophageal cancer surgery
$n = 1–4$, $n = 5–9$, $n = 10–14$, $n = 15–19$, $n = 20–29$, $n = 30–39$, $n \geq 40$

minimum of 4 years were included. Case volume was determined on the basis of the mean number of cases each year for 5 years. Mortality for heart and lung surgery was defined as the 30-day mortality, whereas that for esophageal surgery was in-hospital mortality. However, risk adjustment in terms of age, preoperative conditions, co-morbidities, and disease severity, among after factors was not done for these patients. Table 2 shows a stratification of the participating institutions based on the mean annual number of surgical procedures.

We assessed the correlation between clinical outcomes (30-day mortality and in-hospital mortality) and hospital volume for each surgical procedure. We represented the categories of volume by the dummy variables and estimated the volume effect using logistic regression model. To account for the 5-year longitudinal data, we estimated parameters and standard errors using generalized estimating equations.[16] We put the dummy variables that represent the years in the model and estimated the effects for each year. When estimation of the model with the dummy variables of the years did not converge, we used the model without the dummy variables. All *P* values are two-sided. We then assessed the unstratified volume–outcome relation for all patients with a procedure irrespective of their institutions using the Pearson's correlation coefficient method. All analyses were performed with SAS version 9.1 (SAS Institute, Cary, NC, USA).

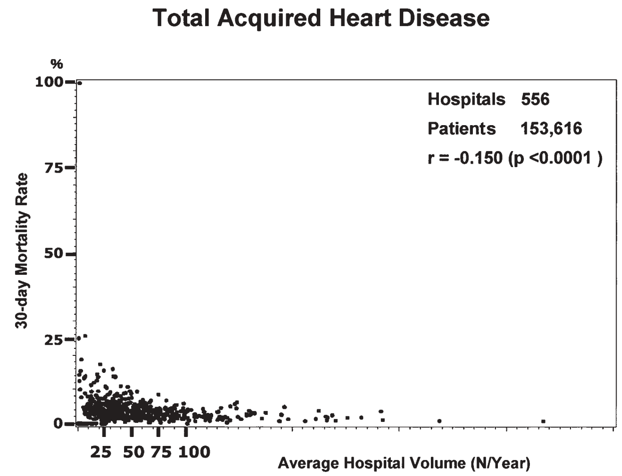
Based on the relation between volume and operative mortality, scatter diagrams were prepared. The vertical axis of the scattergrams represents the operative mortality, and the horizontal axis represents the case number or average annual hospital volume. Numbers along the horizontal axis indicate the average annual case volume for an institution. One dot represents one institute. The odds ratio (OR) was calculated in relation to that of the highest-volume centers, which was considered to be 1.00. The OR and mortality rates are cited in the corresponding table. Statistical significance was conferred only when the lower limit of the 95% confidence interval (95% CI) was >1.00, which is marked with an asterisk in the corresponding table.

Results

The results for each procedure are depicted in scattergrams 1 through 10 each with their corresponding tables.

Acquired heart disease surgery

Scattergram and corresponding table in Fig. 1 shows the relation between hospital volume and 30-day mortality in the case of surgery for acquired heart disease. A total of 153 616 patients were operated on at 556 institutions across the country with an average mortality of 3.9%. Altogether, 76 hospitals had more than 100 cases per year, with a mortality rate of 2.3%; those with fewer than 25 cases had a mortality rate of 4.9% (OR 2.15, 95%CI 1.74–2.66). This was statistically significant when compared with the mortality rate of the highest-volume hospitals. However, among the low-volume hospitals, the mortality rates varied widely (from as low as 0% to as high as 100%). Pearson's correlation coefficient for the



	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-24	160	9,711	4.90	9.00	1.82	2.15*	1.74	2.66
2:25-49	166	29,816	4.30	2.80	0.66	2.03*	1.70	2.43
3:50-74	91	26,963	3.40	1.90	0.57	1.56*	1.29	1.89
4:75-99	63	27,250	3.00	1.50	0.51	1.40*	1.15	1.69
5:100-	76	59,876	2.30	1.30	0.57	1	.	.
ALL	556	153,616	3.90	5.20	1.34			

Fig. 1 Scattergram for total acquired heart disease surgery showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates. *r*, Pearson's correlation coefficient; *S.D.*, standard deviation; *C.V.*, coefficient of variance; *LCL*, lower confidence limit; *UCL*, upper confidence limit; *statistically significant

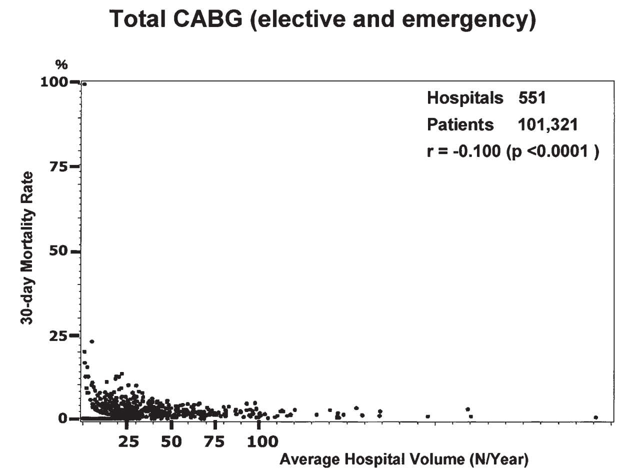
volume–outcome relation of the whole group was –0.150 ($P < 0.0001$).

CABG (elective and emergency)

Scattergram and corresponding table in Fig. 2 show the relation between hospital volume and 30-day mortality in the case of total CABG (elective + emergency). A total of 101 321 cases were operated on at 551 institutions across the country with an average mortality of 2.8%. Altogether, 29 hospitals had more than 100 cases with a mortality rate of 1.3%; those with fewer than 25 cases (249 institutions) had a mean mortality of 3.4% (OR 2.4, 95%CI 1.80–3.22). This was statistically significant when compared with the mortality rate of the highest-volume hospitals. The mortality rate varied widely among the low-volume hospitals (0% to >25%). Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.100 ($P < 0.0001$).

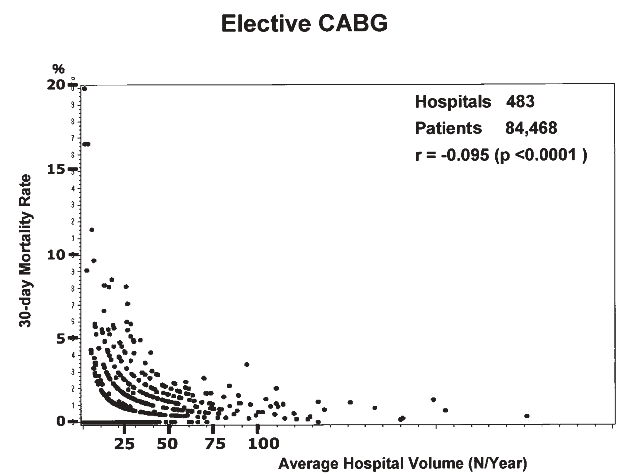
Elective CABG

The scattergram and corresponding table in Fig. 3 show the relation between hospital volume and 30-day mortal-



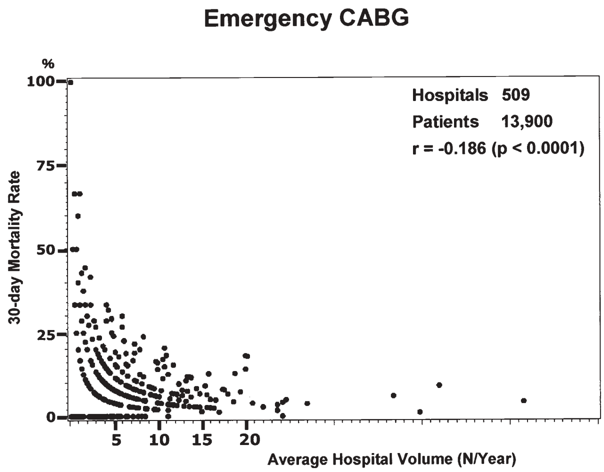
	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-24	249	15,633	3.40	7.20	2.09	2.40*	1.80	3.22
2:25-49	172	30,195	2.50	1.90	0.78	1.88*	1.42	2.50
3:50-74	70	21,482	1.90	1.10	0.60	1.47*	1.09	1.98
4:75-99	31	13,423	1.90	1.10	0.59	1.46*	1.04	2.06
5:100-	29	20,588	1.30	0.80	0.63	1	.	.
ALL	551	101,321	2.80	5.00	1.82			

Fig. 2 Scattergram for total coronary artery bypass grafting (CABG) (elective and emergency) showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates



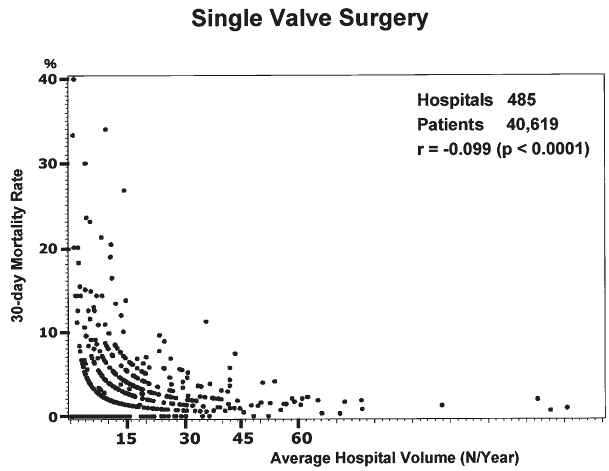
	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-24	222	15,599	2.00	2.80	1.44	2.64*	2.01	3.46
2:25-49	153	25,960	1.30	1.40	1.03	1.91*	1.46	2.51
3:50-74	67	19,827	1.00	0.70	0.69	1.47*	1.10	1.95
4:75-99	18	7,686	1.00	0.80	0.81	1.45	1.00	2.10
5:100-	23	15,396	0.70	0.50	0.71	1	.	.
ALL	483	84,468	1.50	2.10	1.38			

Fig. 3 Scattergram for elective CABG showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates



	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-4	303	3,094	13.2	18.9	1.43	2.04*	1.30	3.19
2:5-9	121	4,148	7.90	6.30	0.81	1.32	0.84	2.09
3:10-14	52	3,055	7.40	5.30	0.71	1.24	0.77	1.99
4:15-19	18	1,501	6.00	3.80	0.64	0.96	0.57	1.62
5:20-	15	2,102	6.30	5.80	0.92	1	.	.
ALL	509	13,900	10.9	15.3	1.40			

Fig. 4 Scattergram for emergency CABG showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates



	# of Hospitals	# of Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-14	290	10,841	4.60	6.10	1.33	3.58*	2.57	4.98
2:15-29	123	12,736	2.70	2.10	0.78	2.15*	1.56	2.97
3:30-44	45	8,021	2.30	2.10	0.92	1.82*	1.28	2.59
4:45-59	14	3,632	1.50	1.20	0.80	1.25	0.82	1.93
5:60-	13	5,389	1.30	0.70	0.52	1	.	.
ALL	485	40,619	3.70	5.00	1.35			

Fig. 5 Scattergram for single-valve surgery showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates

ity for elective CABG. A total of 84 468 patients were operated on at 483 institutions, with an average mortality of 1.5%. A total of 23 hospitals dealt with 100 cases or more. The mean mortality at these institutions was 0.7%; those with fewer than 25 cases per year had a mortality of 2.0% (OR 2.64, 95%CI 2.01–3.46). The difference was statistically significant. The trend of variation in mortality among the low-volume hospitals was maintained (from as low as 1% to as high as >20%). Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.095 ($P < 0.0001$).

Emergency CABG

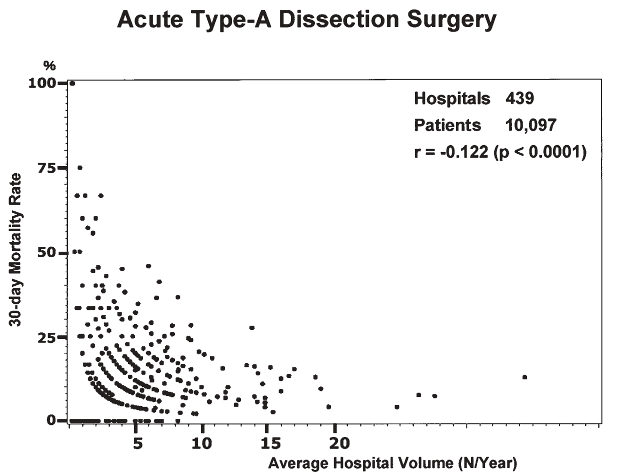
The relation between hospital volume and 30-day mortality for emergency CABG is represented in the scattergram and its corresponding table in Fig. 4. A total of 13 900 patients were operated on at 509 institutions, with an average mortality of 10.9%. Altogether, there were 15 hospitals that dealt with an annual mean of 20 cases or more. The mean mortality at these institutions was 6.3%; those with fewer than 5 cases in a year (303 institutions) had a mortality rate of 13.2% (OR 2.04, 95%CI 1.30–3.19). The difference was statistically significant. The mortality at some of the low-volume hospitals was zero but was 100% at some other centers with a similar case volume. Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.186 ($P < 0.0001$).

Single-valve surgery

The scattergram and corresponding table in Fig. 5 show the relation between hospital volume and 30-day mortality for single-valve surgery. A total of 40 619 patients were operated on at 485 institutions, with an average mortality of 3.7%. Altogether, 13 hospitals dealt with 60 cases or more in a year. The mean mortality at these institutions was 1.3%; those with fewer than 15 cases had a mortality that was almost four times as high (4.6%) (OR 3.58, 95%CI 2.57–4.98). The difference proved statistically significant. The trend of variation in mortality among the low-volume hospitals was maintained (from as low as 0% to as high as 40%). Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.099 ($P < 0.0001$).

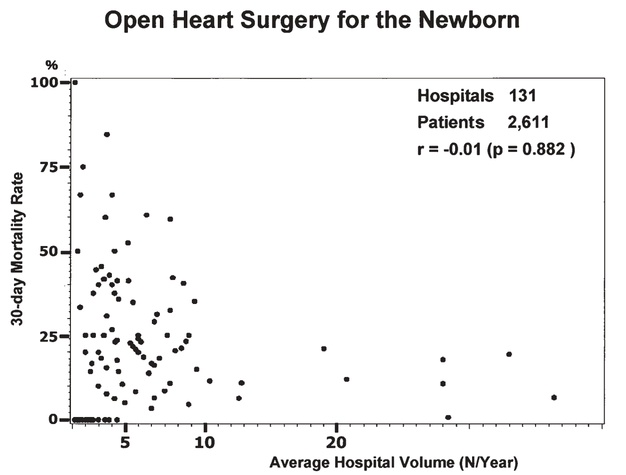
Acute type A dissection surgery

The relation between hospital volume and 30-day mortality for acute type A dissection surgery is represented in the scattergram and its corresponding table in



			Mortality (%)			Odds	95%	95%
	Hospitals	Patients	Mean	S.D.	C.V.	Ratio	LCL	UCL
1:1-4	273	3,085	18.5	19.0	1.02	2.16*	1.48	3.16
2:5-9	130	4,282	13.3	9.20	0.69	1.63*	1.11	2.38
3:10-14	23	1,422	10.5	6.00	0.57	1.23	0.81	1.86
4:15-19	9	767	10.5	4.70	0.45	1.26	0.80	1.99
5:20-	4	541	7.90	3.60	0.46	1	.	.
ALL	439	10,097	16.3	16.1	0.99			

Fig. 6 Scattergram for acute type A dissection surgery showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates



			Mortality (%)			Odds	95%	95%
	Hospitals	Patients	Mean	S.D.	C.V.	Ratio	LCL	UCL
1:1-4	95	809	19.3	23.0	1.19	2.20	0.95	5.09
2:5-9	28	956	24.1	14.1	0.59	2.84*	1.23	6.59
3:10-19	4	274	12.5	6.20	0.50	1.40	0.51	3.85
4:20-	4	572	9.70	8.00	0.82	1	.	.
ALL	131	2,611	19.8	20.9	1.05			

Fig. 7 Scattergram for open heart surgery for newborns showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates

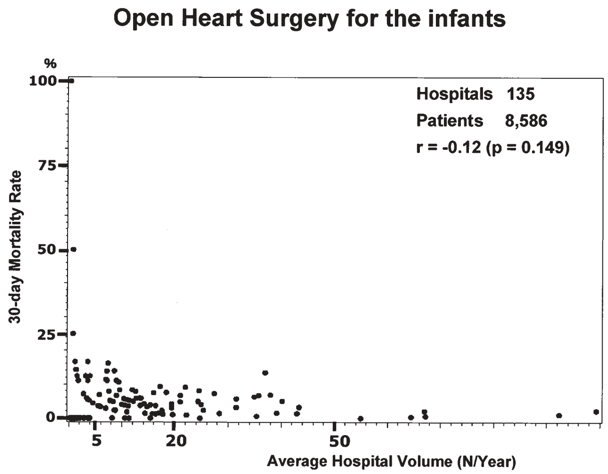
Fig. 6. A total of 10 097 patients were operated on at 439 institutions, with an average mortality of 16.3%. There were only four hospitals dealing with an annual average of 20 cases or more. The mean mortality at these institutions was 7.9%; those with fewer than 5 cases (273 institutions) had a mortality of 18.5% (OR 2.16, 95%CI 1.48–3.16). The difference between the high-volume and low-volume centers proved statistically significant. Some of the low-volume hospitals achieved very low mortality rates, whereas others had figures reaching as high as 100%. Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.122 ($P < 0.0001$).

Open heart surgery in newborns

The scattergram and corresponding table in Fig. 7 show the volume–mortality relation for open heart surgery in newborns. A total of 2611 patients were operated on at 131 institutions, with an average mortality of 19.8%. Only four hospitals dealt with an annual average of 20 cases or more. The mean mortality at these institutions was 9.7%; those with five to nine cases had a mortality of 24.1% (OR 2.84, 95%CI 1.23–6.59). The difference proved statistically significant. Centers with fewer than five cases per year had a mortality of 19.3% (OR 2.20, 95%CI 0.95–5.09). The trend of wide variation in mortality among the low-volume hospitals was also maintained (from as low as 0% to as high as 100%). Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.01 ($P = 0.882$).

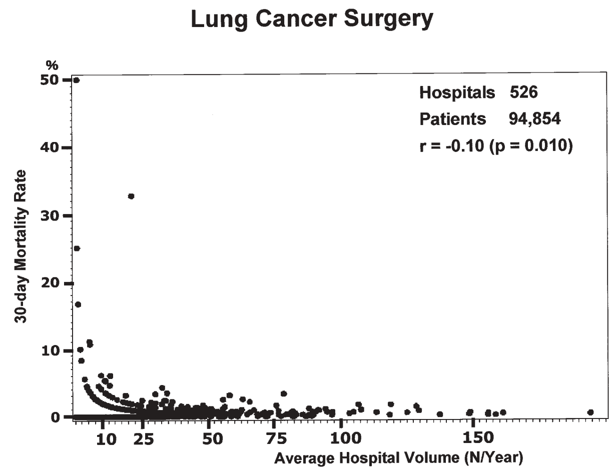
Open heart surgery in infants

The relation between hospital volume and 30-day mortality for open heart surgery in infants is represented in the scattergram and its corresponding table in Fig. 8. A total of 8586 patients were operated on at 135 institutions, with an average mortality of 5.9%. Altogether, five hospitals dealt with an annual average of 50 cases. The mean mortality at these institutions was 1.3%, whereas those with fewer than five cases (57 institutions) per year had a mortality rate that was nearly seven times as high (7.7%) (OR 3.69, 95%CI 2.02–6.73). This difference between the high-volume and low-volume centers proved statistically significant. Some of the low-volume hospitals achieved low mortality rates, whereas others had a practically 100% mortality. Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.12 ($P = 0.149$).



	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-4	57	493	7.70	19.8	2.57	3.69*	2.02	6.73
2:5-19	52	3,033	5.20	3.80	0.73	3.69*	2.22	6.14
3:20-49	21	3,172	4.30	2.70	0.63	3.09*	1.81	5.26
4:50-	5	1,888	1.30	0.80	0.66	1	.	.
ALL	135	8,586	5.90	13.2	2.21			

Fig. 8 Scattergram for open heart surgery for infants showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates



	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-9	101	3,011	1.96	6.06	3.09	4.94*	3.10	7.86
2:10-24	166	15,025	0.95	2.73	2.88	3.41*	1.85	6.26
3:25-49	154	29,745	0.60	0.76	1.26	2.25*	1.56	3.25
4:50-74	55	17,680	0.63	0.64	1.02	2.11*	1.39	3.20
5:75-99	32	13,995	0.52	0.64	1.24	1.77*	1.05	2.96
6:100-149	13	10,236	0.73	0.54	0.73	2.32*	1.43	3.78
7:150-	5	5,162	0.26	0.13	0.49	1	.	.
ALL	526	94,854	0.97	3.13	3.23			

Fig. 9 Scattergram for lung cancer surgery showing the 30-day mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates

Lung cancer surgery

The scattergram and corresponding table in Fig. 9 show the relation between hospital volume and 30-day mortality for lung cancer surgery. A total of 94 854 patients were operated on at 526 institutions across the country, with an average mortality of 0.97%. A total of five hospitals dealt with 150 cases or more each year. The mean mortality at these institutions was only 0.26%, and those with fewer than 10 cases had a mean mortality rate of 1.96% (OR 4.94, 95%CI 3.10–7.86). The differences in mortality at the low-volume centers (mean 10–100 cases) compared to the highest-volume centers (mean of 150 cases or more) proved statistically significant. A wide variation in mortality among the low-volume hospitals was noted (from as low as 0% to as high as 50%). Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.10 ($P < 0.010$).

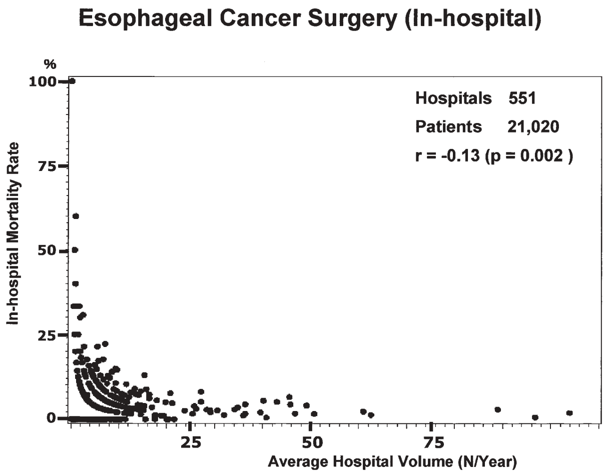
Esophageal cancer surgery

The relation between hospital volume and in-hospital mortality for esophageal cancer surgery is represented in the scattergram and its corresponding table in Fig. 10. A total of 21 020 patients were operated on at 551 institutions, with an average mortality of 5.8%. There were 14 hospitals that dealt with 40 cases or more per year. The mean mortality at these institutions was 2.95%; those with fewer than five cases had a mean mortality rate of 6.85% (OR 2.27, 95%CI 1.54–3.33). The differences in mortality at the low-volume centers (mean of fewer than five cases) compared to the highest-volume centers (mean of 40 cases or more) proved statistically significant. A wide variation in mortality among the low-volume hospitals was noted. Pearson's correlation coefficient for the volume–outcome relation of the whole group was –0.13 ($P = 0.002$).

Discussion

Since 1986, JATS has been collecting and publishing data regarding heart, lung, and esophageal surgery performed at its board-certified member institutions ($n = 408$ at present) and at their affiliated hospitals ($n = 335$ at present) across the country.[17] Since 1996, these data have been published in English.[18]

Until 2001, operative mortality was used as the indicator of clinical outcome. However, in-hospital mortality has been added to the outcome parameters since



	Hospitals	Patients	Mortality (%) Mean	S.D.	C.V.	Odds Ratio	95% LCL	95% UCL
1:1-4	277	3,114	6.85	13.2	1.92	2.27*	1.54	3.33
2:5-9	158	5,290	5.52	4.80	0.87	2.21*	1.53	3.21
3:10-14	55	3,141	4.16	2.83	0.68	1.82*	1.22	2.70
4:15-19	19	1,538	4.02	3.70	0.92	1.61	0.94	2.76
5:20-29	17	2,022	3.16	2.57	0.81	1.20	0.73	1.98
6:30-39	11	1,830	2.43	1.14	0.47	0.96	0.62	1.49
7:40-	14	4,085	2.95	1.97	0.67	1	.	.
ALL	551	21,020	5.80	9.79	1.69			

Fig. 10 Scattergram for esophageal cancer surgery showing the in-hospital mortality rate according to the number of operations. The associated table shows the actual number of operations and the mortality rates

2001, depending on the disease and type of surgery, which means that both 30-day mortality and in-hospital mortality are now published for all procedures. JATS informed the participating institutions that the data are published as a composite. However, at this point, the Committee for Scientific Affairs of JATS decided that it was time to investigate the relation between the hospital volume and clinical outcome to provide more information to the health care consumers.

As part of that initiative, we have accumulated 5-year data (2000–2004) on cardiac (acquired and congenital), lung (particularly lung cancer), and esophageal (particularly esophageal cancer) surgery.[19–23] First, we tried to evaluate the relation between hospital volume and operative mortality in an attempt to find out whether higher hospital volume was associated with lower mortality. The results of the present study suggest an inverse correlation between hospital volume and operative mortality for all procedures. Moreover, procedures that had higher case volumes (e.g., surgery for acquired cardiac diseases, lung cancer) tended to have lower mortality compared with those having a relatively lower case volume (e.g., emergency CABG, acute type A dissection surgery, open heart surgery in newborns). The OR was generally higher for the very low-volume institutes (e.g., 3.58 for single-valve surgery, 3.69 for open heart surgery in infants, and 4.94 for lung surgery). However, for elective CABG, the difference between the highest-volume centers (≥100 cases per year) and the lowest-volume centers (<25 cases per year) in terms of mortality was clinically not significant (0.7% vs. 2.0%), although it proved statistically significant (OR 2.64) compared with the highest-volume centers. Pearson's correlation coefficient test revealed a weakly positive correlation between volume and mortality for all procedures except for newborn and infant open heart surgery. However, wide variation in terms of operative mortality for all procedures was noted among the low-volume centers.

We also tried to compare the surgical outcome of our cardiac, lung, and esophageal surgery with standardized data from abroad. The Society for Thoracic Surgery (STS) has published data on 503 478 elective and emergency CABG procedures (1997–1999).[24] The unadjusted 30-day mortality was 3.05%. In the STS spring 2006 report for isolated CABG (emergency and elective) performed between 1996 and 2006, the unadjusted operative mortality was 3.2% in 1996, which came down to 2.2% in 2005.[25] Our unadjusted average CABG mortality was 2.8% for cases between 2000 and 2004. Even at the lowest volume centers (<25 cases/year), the mortality was 3.4%.

Similarly, the STS spring 2006 report shows mortality figures of 3.0%–4.0% for single aortic valve surgery, 5.2%–6.0% for mitral valve replacement, and 10.0%–12.6% for tricuspid valve replacement; JATS data for single valve surgery shows an average mortality of 3.7%. Even at the lowest volume centers (<15 cases/year), the mortality was 4.6%. The International Registry for Acute Aortic Dissection (IRDS) collected data on acute type A dissection surgery from 18 specialized centers around the world.[26] Among 526 patients operated on between 1996 and 2001, the average mortality was 25.1%. Our data shows that the average 30-day mortality for this procedure was 16.3% in Japan. Even at the lowest-volume centers, the figure stood at 18.5%.

According to the data published by the New York Statewide Planning and Research Cooperative System, the operative mortality for lobectomy for lung cancer was 1.9%.[8] Another report involving 4028 cases from 36 UK hospitals puts the in-hospital mortality for the same procedure at 2.6%.[11] The present study shows that the operative mortality for this procedure was 0.97% in Japan (1.96% at the lowest volume centers).

For esophageal surgery, a meta-analysis of 13 reports published between 1998 and 2003 showed operative mortality of 18.0% for very-low-volume centers (<5 cases), 13.8% for low volume centers (5–10 cases), 11.0% for medium-volume centers (11–20 cases), and 4.9% for high-volume centers (>20 cases)[9]. According to the JATS data, the in-hospital mortality for this procedure was 5.8%; it was 6.85% for the very-low-volume centers (<5 cases/year).

The above data suggest that the results of cardiac, lung, and esophageal surgery in Japan were internationally comparable; and for some procedures, they were even superior to those coming from well-known sources abroad.

However, the present study has inherent limitations. No risk-adjustment of data was done with regard to age, co-morbidities, severity of disease, or other risk factors. Moreover, it is a retrospective study. The JATS Data Committee is now working on risk-adjusted data. We expect to publish these data in the near future.

Conclusion

We evaluated the correlation between hospital volume and clinical outcome, particularly operative mortality for 10 common cardiac, lung, and esophageal surgical procedures. Volume-outcome analysis suggested an inverse correlation, which means that the higher the volume the lower the mortality. However, among the lowest-volume hospitals, there were wide variations in mortality, with some achieving almost 0% mortality whereas others had figures over 10%–15% for all procedures. Therefore, it is not possible to infer from this study that low-volume centers were always performing worse than their higher-volume counterparts. Although it is obvious that there is room for improvement at some of the low-volume centers, their results may still be acceptable when compared with data from abroad. This may imply that the definition of operative mortality should be different for the lowest-volume centers while working with non-risk-adjusted data. Despite its limitations, the basic findings of the study may still be meaningful because of the fact that a large pool of data was analyzed that was able to exclude automatically some of the statistical biases.

Acknowledgment We thank Ms. Etsuko Yamakoshi, who works for the Japanese Healthcare Policy Institute, for performing the statistical analyses of this study.

References

1. Luft HS, Bunker JP, Enthoven AC. Should operations be regionalized? The empirical relation between surgical volume and mortality. N Engl J Med. 1979;301(25):1364–9.
2. Luft HS. The relation between surgical volume and mortality: an exploration of causal factors and alternative models. Med Care 1980;18(9):940–59.
3. Begg CB, Crammer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. JAMA 1998;280(20):1747–51.
4. Birkmeyer JD, Siewers AE, Finlayson EVA, Stukel TA. Hospital volume and surgical mortality in the United States. N Engl J Med 2002;346(15):1128–38.
5. Cowan JA Jr, Dimick JB, Henke PK, Huber TS, Stanley JC, Upchurch GR Jr. Surgical treatment of intact thoracoabdominal aortic aneurysms in the United States: hospital and surgeon volume-related outcomes. J Vasc Surg 2003;37(6): 1169–74.
6. Halm EA, Lee C, Chassin MR. Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. Ann Intern Med 2002;137(6):511–20. Review: summary for patients in: Ann Intern Med 2002;137(6):I52.
7. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med 2003; 349(22):2117–27.
8. Hannan El, Radzyner M, Rubin D, Dougherty J, Brennan M. The influence of hospital and surgeon volume on in-hospital mortality for colectomy, gastrectomy and lung lobectomy in patients with cancer. Surgery 2002;131:6–15.
9. Metzger R, Bollschweiler E, Vallbohmer D, Maish M, DeMeester TR, Holscher AH. High volume centers for esophagectomy: what is the number needed to achieve low postoperative mortality? Dis. Esophagus 2004;17:310–4.
10. Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah A, Papadimos TJ, et al. Is hospital procedure volume a reliable marker of quality for coronary artery bypass surgery? A comparison of risk and propensity adjusted operative and midterm outcomes. Ann Thorac Surg 2005;79:1961–9.
11. Treasure T, Utley M, Baily A. Assessment of whether in-hospital mortality for lobectomy is a useful standard for quality of lung cancer surgery: retrospective study. BMJ 2003; 327:73–5.
12. Dudley RA, Johansen KL, Brand R, Rennie DJ, Milstein A. Selective referral to high-volume hospitals: estimating potentially avoidable deaths. JAMA 2000;283(9):1159–66.
13. Nishida H, Yoshida E. Suggestions from non-pandering governmental health care policy groups: across-the-board 30% cut of surgeon's fee according to number of operation-pandering fool and disguised health care cost-cutting policy under fiscal crisis. Cardiovasc Med Surg 2005;7:417–29.
14. Osada H, Yamakoshi E. Hospital volume and surgical outcome: lung cancer in Japan. Gen Thorac Cardiovasc Surg 2007;55:360–5.
15. Hatori S, Yanagawa T. Martel-Haenszel projection method estimator for sparse data. Presented at the International Biometric Conference, Montreal, July 2006.
16. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika 1986;73:13–22.
17. Wada J, Nakajima H. Current status of thoracic and cardiovascular surgery in Japan 1964, 1965 National Database Analysis. Jpn J Thorac Cardiovasc Surg 1987;35:918–9.
18. Yasui H, Osada H, Ando U, Koyanagi H. Thoracic and cardiovascular surgery in Japan during 1996: annual report by the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 1988;46:406–20.
19. Yasuda K, Ayabe H, Ide H, Yasui H. Thoracic and cardiovascular surgery in Japan during 2000: annual report by the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 2002;50:398–412.

20. Yada I, Wada H, Shinoda M, Yasuda K. Thoracic and cardiovascular surgery in Japan during 2001: annual report of the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 2003;51:699–716.
21. Yada I, Wada H, Fujita H. Thoracic and cardiovascular surgery in Japan during 2002: annual report of the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 2004;52:491–508.
22. Kazui T, Wada H, Fujita H. Thoracic and cardiovascular surgery in Japan during 2003: annual report of the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 2005;53:517–36.
23. Kazui T, Osada H, Fujita H. Thoracic and cardiovascular surgery in Japan during 2004: annual report by the Japanese Association for Thoracic Surgery. Jpn J Thorac Cardiovasc Surg 2006;54:363–86.
24. Shroyer ALW, Coombs LP, Eric D, Peterson ED, Eiken MC, DeLong ER, et al. The Society of Thoracic Surgeons: 30-day operative mortality and morbidity risk models. Ann Thorac Surg 2003;75:1856–65.
25. STS Adult CV Surgery National Database—Spring 2006 Executive Summer Contents, STS Spring 2006 Report.
26. Trimarchi S, Nienaber CA, Rampoldi V, Myrmel T, Suzuki T, Mehta RH, et al. Contemporary results of surgery in acute type A aortic dissection experience. J Thorac Cardiovasc Surg 2005;129:112–22.