The "occasional open heart surgeon" revisited

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Objectives: Case volume in cardiac surgery has been a concern since the term "the occasional open heart surgeon" was used more than 40 years ago, indicating one who performs cardiac surgery infrequently.

Methods: Risk-adjusted operative mortality (in-hospital or 30-day mortality) for isolated coronary artery bypass grafting procedures reported to the California CABG Outcomes Reporting Program for 2003–2004 was determined by surgeon and by hospital. Standard Society of Thoracic Surgeons item definitions were used. A total of 49,421 coronary artery bypass grafting (40,377 isolated) procedures were performed by 302 surgeons at 121 hospitals. Low-volume surgeons (n = 117) were defined as performing a total of less than 1 coronary artery bypass grafting (isolated or nonisolated) procedure per week at all hospitals (mean ± standard deviation, 22 ± 15/y). High-volume surgeons (n = 185) performed a total of 1 or more cases per week (mean ± standard deviation, 120 ± 62/y). Logistic regression and hierarchic analysis were used to compare volume cohorts.

Results: The overall risk-adjusted mortality rate was 3.62% for low-volume and 3.02% for high-volume surgeons. Analysis by surgeon per hospital produced 610 surgeon–hospital pairs. The lowest risk-adjusted mortality rates were found among surgeons performing more than 1 procedure per week at a single hospital (2.70%). When high-volume surgeons performed less than 1 procedure per week at a hospital, their mortality rates were similar to those of low-volume surgeons (3.39%–4.11%). High-volume surgeons performing procedures at multiple sites had higher mortality than high-volume surgeons working at a single institution.

Conclusion: A high-volume surgeon becomes an "occasional open heart surgeon" when working at multiple hospitals and performing a small volume of procedures at some of them. This study suggests that volume is not as important as processes of care in determining outcomes of coronary artery bypass grafting procedures and that system factors might be more important to outcomes than surgeon experience.

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The term "occasional open heart surgeon" was used by Eiseman and Spencer[1] in an editorial in *Circulation* in 1965. They quoted a survey conducted by the School of Public Health at Johns Hopkins that found that 41% of cardiac surgery teams performed less than 10 procedures per year. Over the ensuing decades, the relationship between volume and outcome has been extensively studied, often producing more questions than answers.

Provider volume has been shown to be a risk factor in a variety of complex surgical procedures.[2-4] In-hospital mortality was found to be lower in higher-volume facilities for abdominal aortic aneurysm resection, esophagectomy, pancreatic resection, and coronary artery bypass grafting (CABG), resulting in calls for volume thresholds of these procedures by purchaser groups, such as Leapfrog. Physician groups and hospitals dismissed these recommendations because of the variable statistical significance of the findings and the feasibility of volume-based referral. Furthermore, it appears that the volume–outcome conundrum is a moving target. Several recent studies have noted a weaker association in CABG[5] and abdominal aortic aneurysm.[6] Reports from the California CABG reporting programs show no statistical significance of

Abbreviations and Acronyms
CABG = coronary artery bypass grafting
RAMR = risk-adjusted mortality rate

hospital volume on risk-adjusted mortality for the years 2003–2004, whereas hospital volume as an independent variable was significant in previous reports.*

Hospitals do not perform surgical procedures. Rather, surgeons perform them, but they perform them with a team of other caregivers. The relationship between these caregivers is critical in any procedure, but especially so in cardiac surgery. The collection of data on CABG surgery for public reporting on California hospitals and surgeons provides an opportunity to observe the relationships between providers and the systems in which they do their work. California has a large number of cardiac surgical programs, most of which are low volume, performing less than 300 "open heart" cases per year. Many of the cardiac surgeons are low volume, performing less than 100 procedures per year. The present study examines these low-volume providers to study the effect of diminishing numbers of CABG procedures in cardiac surgery in California.

Materials and Methods

Data collected through the California CABG Outcomes Reporting Program was reviewed. Mandatory reporting of all CABG procedures was begun in January 2003. Hospital-specific data from 2003 were released to the public in February 2006, and both hospital- and surgeon-specific data for the years 2003–2004 were released in July 2007. Data are collected by using Society of Thoracic Surgeons National Database formats; identical procedure and risk factor definitions were used, but a unique risk model was calculated for isolated CABG procedures. Mortality was determined by using the Society of Thoracic Surgeons National Database definition of "operative mortality": death after surgical intervention in the hospital or within 30 days. Deaths were verified by means of linkage with the California death file. In addition, independent onsite reabstraction of medical charts was performed at 57 hospitals for these data years.

A total of 49,421 CABG (40,377 isolated) procedures were performed by 302 surgeons at 121 hospitals during 2003–2004. Provider total CABG volume and its relation to outcome, as measured by means of operative mortality for isolated CABG, was analyzed by hospital, surgeon, and surgeon per hospital. Low-volume surgeons were defined as those performing a total of less than 1 CABG (isolated or nonisolated) procedure per week over the 2-year period. High-volume surgeons performed 1 or more CABG procedures per week. Very low volume was defined as less than 1 procedure performed per hospital per month. We adopted the state-published risk model and conducted further descriptive analyses based on state-published hospital and surgeon risk-adjusted operative mortality results for 2003–2004. We then used a hospital-patient hierarchical prediction model to test the association between surgeon/hospital volume and risk-adjusted mortality. All data analyses were conducted with SAS 9.1.3 (SAS Institute, Inc, Cary, NC).

*http://www.oshpd.ca.gov/HQAD/Outcomes/Studies/cabg/2003Report/2003Report.pdf

Results

Procedure Volumes and Operative Mortality

The number of CABG procedures performed by low-volume and high-volume surgeons during 2003–2004 is shown in Table 1. On average, high-volume surgeons performed more than 5 times as many procedures as low-volume surgeons.

Operative mortality for isolated CABG procedures performed by low-volume and high-volume surgeons during 2003–2004 is shown in Table 2. High-volume surgeons performed nearly 90% of the procedures. Overall, low-volume surgeons had higher risk-adjusted operative mortality compared with high-volume surgeons.

Hospital Volume and Risk-adjusted Mortality Rate

The relationship of individual hospital total CABG volume to isolated CABG risk-adjusted mortality rate (RAMR) for 2003–2004 is shown in Figure 1. Only 26 of 121 hospitals in California performed more than 500 CABG procedures (250/y) over the 2-year period. Although the highest RAMRs occurred at lower-volume sites, many low-volume hospitals had outcomes that were better than those of higher-volume programs. Overall, the relationship between volume and mortality for hospitals was not statistically significant (Pearson correlation coefficient, -0.105; $P = .253$).

Surgeon Volume and RAMR

The relationship of individual surgeon total CABG volume to isolated CABG RAMR for 2003–2004 is shown in Figure 2. The highest mortality rates occur among the lowest-volume surgeons (<100/y), but many low-volume surgeons have low or zero RAMRs. As a result, individual surgeon volume was not significantly associated with RAMR (Pearson correlation coefficient, -0.096; $P = .095$).

Surgeon Volume per Hospital and RAMR

Most surgeons operated at more than 1 hospital. Low-volume surgeons operated at a mean of 2.4 hospitals (range, 1–6

TABLE 1. CABG procedures performed by low- and high-volume surgeons, 2003–2004 (annualized, mean ± SD)

	N	All CABG	Isolated CABG
Low volume	117	22 ± 15	18 ± 13
High volume	185	120 ± 62	98 ± 53
Total	302	82 ± 69	67 ± 58

CABG, Coronary artery bypass grafting; *SD*, standard deviation.

TABLE 2. Operative mortality (observed and expected) for isolated CABG, 2003–2004

	Isolated CABG	Observed deaths	Expected deaths	Observed mortality (%)	Expected mortality (%)	O/E ratio	RAMR
Low volume	4224	160	136	3.79	3.22	1.18	3.62
High volume	36,153	1084	1104	3.00	3.05	0.98	3.02
Total	40,377	1244	1240	3.08			

CABG, Coronary artery bypass grafting; *O/E*, observed/expected; *RAMR*, risk-adjusted mortality rate.

hospitals), and high-volume surgeons operated at a mean of 3.0 hospitals (range, 1–8 hospitals). This produced 610 surgeon–hospital pairs. These data are shown in Table 3. High-volume surgeons had the best risk-adjusted isolated CABG mortality rates when performing more than 1 procedure per week at a hospital. However, when high-volume surgeons performed less than 1 procedure per week at a hospital, their mortality rates were no better than those of low-volume surgeons.

The relationship between surgeon total CABG volume per hospital and RAMRs for isolated CABG is shown in Figures 3 and 4. The individual surgeon volume–outcome relationship is not significant (Pearson correlation coefficient, −0.017; $P = .677$). However, when the surgeon volume per hospital was analyzed in categorical groups by using a hierarchic logistic risk model to predict operative mortality outcome, the odds ratio was 1.52 ($P = .007$) for surgeons performing less than 1 procedure per month and 1.29 ($P = .011$) for surgeons performing less than 1 procedure per week compared with surgeons performing more than 2 CABG procedures per week.

Are high-volume surgeons who work at low-volume sites different? High-volume surgeons who work in multiple hospitals, and thus work at low-volume sites, can differ from other high-volume surgeons. Table 4 shows a breakdown of high-volume surgeons working only at high-volume sites and high-volume surgeons working at both high- and low-volume sites. High-volume surgeons working only at high-volume sites (group A) had the lowest RAMRs. Patients

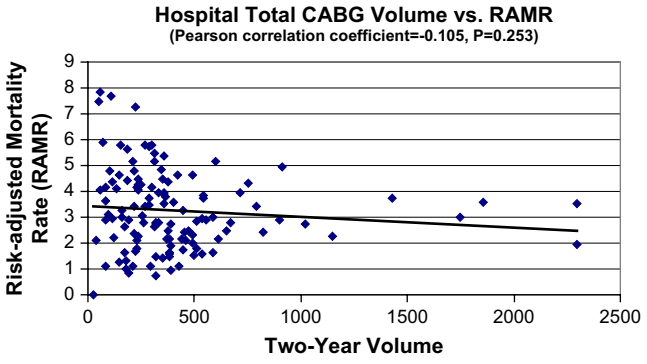

Figure 1. Hospital total coronary artery bypass grafting *(CABG)* volume versus the risk-adjusted isolated CABG operative mortality rate.

of high-volume surgeons working at multiple sites had higher mortality rates at both high-volume (group B-1: odds ratio, 1.22; $P = .043$) and low-volume (group B-2: odds ratio, 1.34; $P = .010$) sites compared with patients of group A surgeons.

Discussion

These studies illustrate the interaction between surgeons and the hospitals in which they work and the problem of statistical comparison of volume to outcome. Overall, outcomes as measured by operative mortality for isolated CABG were higher at low-volume sites, but neither hospital nor surgeon total CABG volume was significantly related to isolated CABG mortality as an independent variable by means of logistic regression analysis.

We used the total of isolated and nonisolated CABG procedures to determine volume categories for individual surgeons. When surgeon and hospital volumes are combined, certain relationships emerge within volume categories, as noted in Table 3. The difference in RAMRs between low-volume surgeon/hospital combinations compared with high-volume combinations was much greater than the overall difference. For example, high- and low-volume surgeons performing less than 1 procedure per month in a hospital had RAMRs of nearly 4%, more than 40% higher than that of high-volume surgeons working only at high-volume sites (RAMR, 2.79%), whereas the overall difference in isolated CABG mortality between low- and high-volume surgeons was 3.62% versus 3.02%.

The finding that the RAMR for isolated CABG was similar for both low-volume and high-volume surgeons when performing a low volume of procedures at a hospital suggests that system factors might be more important to outcomes than surgeon experience. We also found that high-volume surgeons who work at multiple sites have higher mortality than high-volume surgeons working at one site. This suggests that these surgeons might bring suboptimal processes with them or that the requirements of working at several hospitals negatively affect their ability to care for their patients.

The significance of surgeon volume, as opposed to hospital volume, was studied by Birkmeyer and associates[7] using Medicare data from 1994–1999. They concluded that surgeon volume accounted for a large part of the effect of facility volume on outcomes, varying widely by procedure type. These authors also examined the predictability of

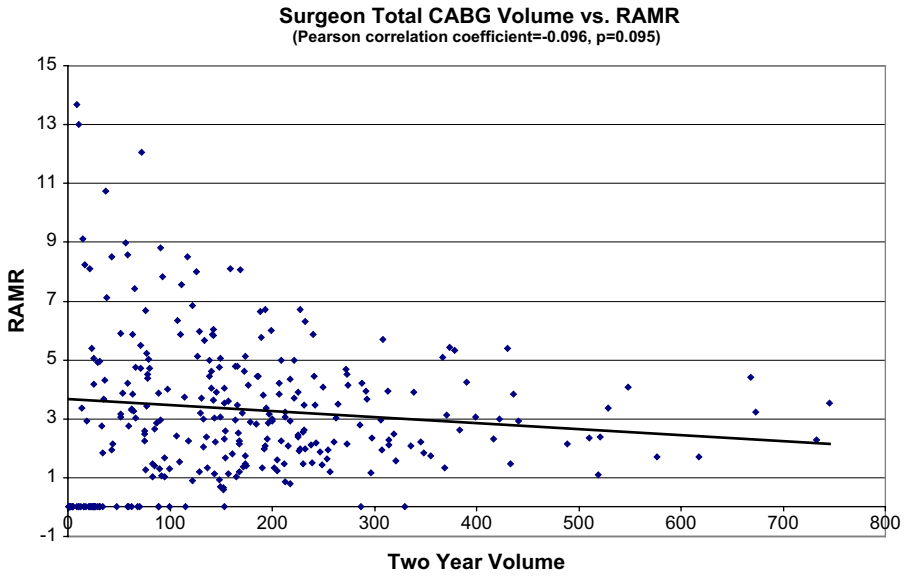

Figure 2. Surgeon total coronary artery bypass grafting *(CABG)* volume versus the risk-adjusted isolated CABG operative mortality rate *(RAMR)*.

historical hospital volume and mortality on future outcomes. They found that for CABG, historical mortality was more predictive of mortality rates in future years than historical volume.[8]

A confounding factor to be considered is the effect of "clustering" on outcomes.[9] Providers with similar volumes might have differing outcomes based on processes of care. Statistical methods have been used to adjust for this effect by several authors in volume–outcome studies.[6,8] Because such methods generally reduce the significance of the effect of volume on outcome, their use might affect the significance of the surgeon volume per hospital data. Differences in outcomes among high-volume surgeons suggest that clustering might account for findings in the data presented here.

The relationship between RAMRs and surgeon and hospital volumes was examined by Hannan and colleagues[10] using data from the New York CABG registry from 1997–1999. They also found that CABG mortality was lowest for high-volume surgeons operating in high-volume hospitals. However, their highest mortality rates (2.67% for surgeons performing less than 125 procedures annually in hospitals with annual volumes of less than 600) are comparable with the best RAMR that we report. In an earlier study comparing outcomes of CABG procedures in New York to California, we found that higher mortality rates in California were related to the large number of low-volume programs because outcomes of higher-volume programs were comparable in the 2 states.[11] In the present study we did not examine our surgeon-based mortality rates in relation to the total volume of the hospital in which the procedures were performed, and Hannan and colleagues' study[10] did not look at surgeon volume per hospital.

TABLE 3. Surgeon volume per hospital and RAMR

Surgeon procedure volume per hospital	Surgeon–hospital pairs	All CABG	Isolated CABG	Observed deaths	Expected deaths	Observed mortality (%)	Expected mortality (%)	RAMR
Low volume <1/mo/hospital	129	991	831	36	27	4.33	3.29	4.11
Low volume <1/wk/hospital	77	4078	3393	124	109	3.65	3.21	3.50
High volume <1/mo/hospital	117	923	797	32	26	4.02	3.07	3.79
High volume <1/wk/hospital	109	6346	5269	184	167	3.49	3.15	3.39
High volume 1–2/wk/hospital	107	15,428	12,587	405	399	3.22	3.11	3.13
High volume =>2/wk/hospital	71	21,655	17,500	463	512	2.65	3.01	2.79

RAMR, Risk-adjusted mortality rate; *CABG*, coronary artery bypass grafting.

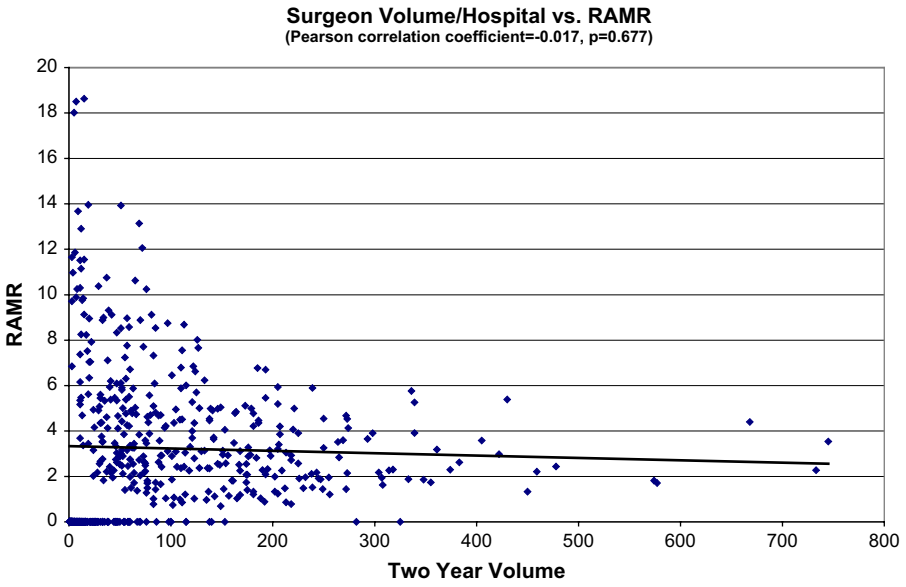

Figure 3. Individual surgeon total coronary artery bypass grafting *(CABG)* volume per hospital versus the risk-adjusted isolated CABG operative mortality *(RAMR)*.

Most studies of the relationship between volume and outcome in cardiac surgery have focused on CABG procedures and in-hospital mortality. Gammie and coworkers,[12] using data from the Society of Thoracic Surgeons National Database, identified processes of care that contributed to better outcomes at higher-volume sites for mitral valve surgery. Several studies have found that β-blocker use and the internal thoracic artery graft have contributed to better outcomes in CABG surgeries. Few other key processes have been identified.

Khuri and Henderson[13] and Shahian and Normand[14] have pointed out the pitfalls of using volume as a surrogate for quality. Studies from the National Surgical Quality Improvement Program did not find a relationship between volume and outcome across a variety of surgical specialties. Systems of care were more important in determining quality of care at an institution. Continuous quality improvement programs should seek to emulate the processes of high-volume, high-quality providers.

This study provides further evidence that volume is not as important as processes of care in determining outcomes of CABG procedures. In view of the diminishing number of CABG procedures and the inevitability of low-volume programs, more studies that focus on methodology and best practices in the wider spectrum of cardiac surgical procedures are indicated.

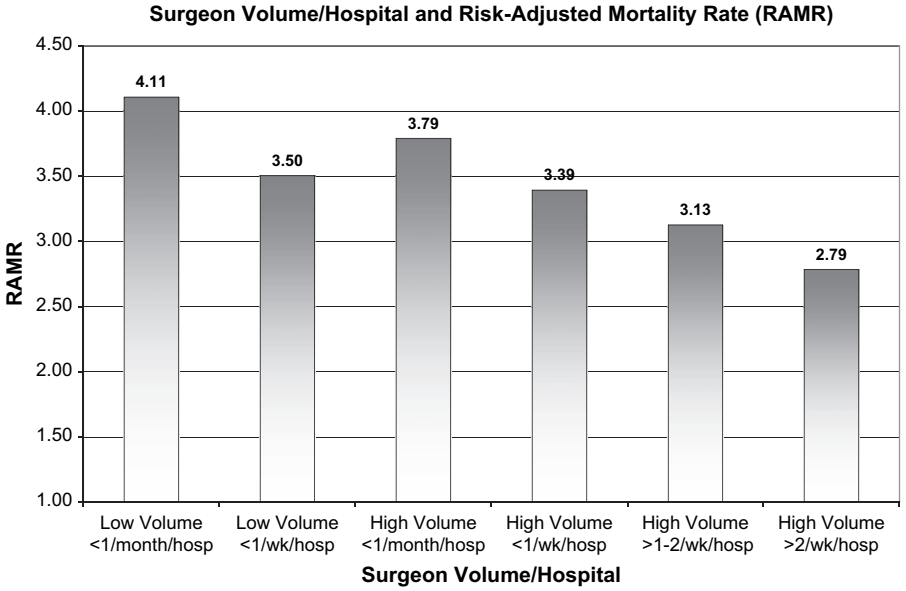

Figure 4. Categorical surgeon total coronary artery bypass grafting *(CABG)* volume per hospital versus the isolated CABG risk-adjusted mortality rate *(RAMR)*: odds ratios of 1.52 ($P = .007$) for less than 1 procedure per month, 1.29 ($P = .011$) for less than 1 procedure per week, and 1.17 ($P = .127$) for 1 to 2 procedures per week versus more than 2 procedures per week.

TABLE 4. High-volume surgeons working only at high-volume sites (group A) compared with high-volume surgeons working at both high-volume (group B-1) and low-volume (group B-2) sites

	No. of surgeons/no. of sites	Isolated CABG	Observed deaths	Expected deaths	Observed mortality (%)	Expected mortality (%)	RAMR
Group A	71/74	13,901	383	437	2.76	3.14	2.70
Group B-1 (high)	89/104	16,186	485	473	3.00	2.92	3.16
Group B-2 (low)	110/226	6066	216	193	3.56	3.18	3.45

CABG, Coronary artery bypass grafting; *RAMR*, risk-adjusted mortality rate.

Conclusions

Hospital volume of CABG procedures did not correlate significantly with RAMR in the clinical database collected by the California CABG Outcomes Reporting Program during 2003–2004. Individual surgeon total CABG volume also did not correlate with RAMR. The majority of programs in California are low volume by accepted standards, and most surgeons work at more than 1 hospital. We therefore studied the relationship of surgeon volume per hospital to RAMR.

Surgeon CABG volume per hospital appears to correlate with RAMR. High-volume surgeons who perform a small volume of CABG procedures in a hospital have no better outcomes than low-volume surgeons, suggesting that system factors are more important to outcomes than surgeon experience.

High-volume surgeons who work primarily in 1 hospital have better outcomes than high-volume surgeons who work in multiple hospitals. Processes of care that are associated with these surgeons might account for this difference.

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Discussion

Dr Ludwig Karl von Segesser *(Lausanne, Switzerland)*. I wish to congratulate Dr Carey and colleagues for providing the manuscript and for bringing up a very important issue, which might become even more critical if CABG numbers are decreasing in the future.

I believe that most of us are happy to learn that the high-volume surgeon in a low-volume environment does like others in that environment. The main concern is, of course, that if a problem occurs, the surgeon gets most of the blame, and much less goes to the other team members. I am wondering whether further subgroup analysis is possible and whether there is a difference between the high-volume generalist cardiac surgeon compared with the high-volume CABG specialist? For the future, it might be important not to be focused on CABG alone. I am also wondering whether the low-volume surgeons are treated unfavorably in the statistical analysis here. If you have a surgeon doing 10 CABG procedures a year and he loses 1 patient, his mortality will be 10%, and if he does not lose a patient in the second year, it will be 0%, and therefore the mean will be 5%. Even if he loses no patient in the following 8 years, his mortality in this analysis will be 5% compared with that of others who lose 1 of 100 patients, where the mortality will be 1%.

I have the following questions. How does a high-volume CABG surgeon perform when he does a few procedures in another high-volume program compared with those who do a lot in the other high-volume program? How does a high-volume surgeon do in CABG, valve, and other procedures compared with a high-volume surgeon doing CABG alone in a high-volume environment, and what about the same for a low-volume environment?

Thank you for the privilege to comment on this paper.

Dr Carey. Thank you very much for those comments. We did not look at how the numbers would compare if those low-volume procedures done by high-volume surgeons were done in a high-volume institution. We did not break it down. That would have been a third dimension that got me kind of confused. Therefore we might

have to look at that some point along the way, but that has not been examined.

We do not have valve data or other data for the surgeons. This is an unfortunate choice that has been made by a lot of these states. They like to look at coronary bypass surgery because it is the highest-volume operation, and they tend to ignore the valves, although I believe that they are doing some valve reporting in some of the other states now. Therefore it will eventually happen, but we do not have it in California at this time.

Dr Robert A. Guyton *(Atlanta, Ga)*. I enjoyed the paper, and this has obviously been a controversy for a long time. The Coronary Bypass Guidelines Group looked hard at this and was unable to find convincing evidence that volume was related to performance, particularly because it is very common to find low-volume surgeons who are among the very best in the cohort.

The question I have is whether you were able to separate out the patients undergoing isolated coronary bypass because about 15% or 20% of your patients undergo combined operations, presumably patients undergoing coronary valve operations. I presume that even though only 20% of your patients are combined patients, probably 40% of the deaths are in that category. Were you able to sort that out because that might be more meaningful in that the combined patients might tend to be focused on a certain group of surgeons compared with the patients undergoing isolated coronary bypass.

Dr Carey. We do not have any mortality rates for the nonisolated cases in this group. We just used the total CABG numbers to break down the high- and low-volume surgeons because there were a few surgeons who performed a lot of nonisolated CABG procedures and not very many isolated procedures. However, the risk adjustment was only for patients undergoing isolated coronary bypass. Therefore we have no information on that other group.

Dr Guyton. The risk-adjusted mortality data are only for the isolated patients in your series, even though you collected the data for the entire series? Therefore the data that you presented are only for isolated coronary bypass?

Dr Carey. Right.

Dr Guyton. I am sorry. That was not clear. Thank you.

Dr Carey. The reason for collecting all the CABG procedures is to try to plug the loophole of moving patients back and forth from isolated and nonisolated procedures and thereby gaming our data. Therefore all of those nonisolated cases were audited.

Dr R. Scott Mitchell *(Stanford, Calif)*. Thanks a lot for the information. I think the most worrisome feature that I see when I look at these data is the California performance compared with performance in the 3 other states. I wonder whether you had insight into that difference. Do you know the typical volume for cases per surgeon in the other states that report versus California, which has multiple programs and multiple surgeons?

Dr Carey. Well, they are higher, on average, and all of the states pretty much have, or at least all of the bigger states have, higher numbers of cases per program, and to some extent they have higher numbers of procedures per surgeon. It was interesting to me to see that the vast majority of procedures in California were actually performed by what we defined as high-volume surgeons. These are surgeons performing an average of 121 CABG procedures per year, and most of them are performing a lot of other operations as well. Therefore these are busy surgeons, and therefore the fact that we have a higher mortality rate is kind of hard to blame on anything related to volume. It might be related to something to do with percutaneous coronary intervention. We reported that some years ago at the Western—you might remember that—and we thought that the mortality rate for CABG was related to aggressive percutaneous coronary intervention performance. It is a little hard to prove that. In New York there are some data to suggest that they do not do a lot of aggressive percutaneous coronary interventions. That has been reported by some of the people from Michigan; they looked at that.

The data from California, or the percutaneous coronary intervention data anyway, are pretty similar to those from the rest of the country, whereas in New York they are not. Percutaneous coronary intervention mortality in New York is almost 0%, and it is $1\frac{1}{2}$ % in the rest of the country.

Dr Ralph J. Damiano *(St Louis, Mo)*. I had one quick question for you. What struck me most about your data was the tremendous variation in results in the low-volume programs, whereas most of your high-volume programs clustered very closely around the same mortality. Have you looked at the variation in mortality rates by volume of the centers; that is, could you give us an idea of the standard deviation? If there is a wide variability, can you really accept the fact that you are taking patients at the low-volume centers and subjecting them to potentially getting a surgeon with a good mortality rate but also potentially getting surgeon with an extremely high mortality rate either because of the low volume of the hospital or the low volume of the surgeon? Is that something we can live with as a profession?

Dr Carey. The variation from year to year is not that much. The better performers tend to be better performers, and the worse performers tend to be worse performers.

Dr Damiano. But I am just looking at your scatter plots. There looks like a huge variation in the low-volume centers, whereas all of your high-volume centers were clustered around the same mortality rate.

Dr Carey. To some extent that is true, although there was one slide in there with hospital volumes that showed there was a fair scatter in the higher-volume hospitals. The scatter in the lower-volume hospitals is partly related to what the discussant brought up, that one mortality makes a difference. But for the most part, there is some consistency from year to year, even in the low-volume programs, and that was looked at by Dr Birkmeyer, who has done a lot of this volume-outcome work. He found that mortality in previous years would predict mortality in future years. We are running some statistics on that.

What was the second part of your comment?

Dr Damiano. It was just my own impression, but I do not know whether you tried to quantify the variation by volume.

Dr Carey. We have not really looked at the details of that yet.