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SPECIAL ARTICLE

Hospital Volume and Surgical Mortality in the United States

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Over the past three decades, numerous studies have described higher rates of operative mortality with selected surgical procedures at hospitals where few such procedures are performed (low-volume hospitals).[1-4] Several recent reviews suggest that thousands of preventable surgical deaths occur each year in the United States because elective but high-risk surgery is performed in hospitals that have inadequate experience with the surgical procedures involved.[5-7] As part of a broader initiative aimed at improving hospital safety, a large coalition of private and public purchasers of health insurance — the Leapfrog Group — is encouraging patients undergoing one of five high-risk procedures to seek care at high-volume hospitals.[8] In the lay media, there has been an emphasis on the importance of experience with particular procedures,[9,10] and several consumer-oriented Web sites (e.g., http://www.healthscope.org) have begun providing patients with information about volume at hospitals near them.

Despite the recent interest in surgical volume, many question the applicability of previous research on volume and outcome to current practice.[11,12] First, many studies of volume and outcome are outdated. Given that the surgical mortality associated with many procedures has fallen considerably since these studies were conducted,[13,14] the relative importance of the volume of procedures performed may be declining. Second, most published studies on volume and outcome have used state-level data bases or regional populations that are served by a small number of high-volume centers.[6] Whether their results are broadly generalizable is uncertain. And finally, although some procedures (e.g., cardiac surgery) have been studied extensively, the relative importance of hospital volume to mortality with many other high-risk procedures either has not been explored or has been studied in samples that were too small to permit assessment of performance at all meaningful levels of hospital volume.

To address many of these limitations, we studied surgical mortality in the Medicare population, which accounts for the majority of all patients in the United States who undergo high-risk surgery and an even larger majority of those who die after surgery.[15] Using current national data (from 1994 through 1999), we studied the importance of hospital volume to the operative mortality associated with six types of cardiovascular procedures and eight types of major cancer resections.

METHODS

Subjects and Data Bases

We obtained the Medicare Provider Analysis and Review (MEDPAR) files and the denominator files from the Center for Medicare and Medicaid Services for the years 1994 through 1999. These files contain hospital-discharge abstracts for the acute care hospitalizations of all Medicare recipients covered by the hospital care program (Part A). Only patients covered by fee-for-service arrangements are included in the MEDPAR file; thus, our sample excludes the approximately 10 percent of Medicare patients who were enrolled in risk-bearing health maintenance organizations during this period. We excluded patients who were under 65 years of age or over 99 years of age. The study protocol was approved by the institutional review board of Dartmouth Medical School.

Hospital Volume

Patients undergoing each of the 14 procedures examined in our analysis were identified with the use of appropriate procedure codes from the *International Classification of Diseases, 9th Revision,* *Clinical Modification* (ICD-9-CM).[16] These procedures were selected because they are relatively complex, are associated with a nontrivial risk of operative mortality, and are most often performed on an elective basis.

We focused on the total number of each type of procedure performed at a given hospital (hospital volume), not the total number of procedures involving Medicare recipients (Medicare volume), in order to place our results in the context of the volume standards suggested by the Leapfrog Group[8] and others. To estimate total volumes, we examined data from the all-payer 1997 Nationwide Inpatient Sample. We determined the proportion of all patients undergoing each procedure who were covered by Medicare; the proportion ranged from 43 percent (for nephrectomy) to 75 percent (for carotid endarterectomy). To estimate the total volume at individual hospitals, we divided the observed Medicare volume (the total number of each type of procedure performed on Medicare patients during the six-year study period) by these procedure-specific proportions.

Hospital volume, expressed as the average number of procedures per year, was first evaluated as a continuous variable. To simplify the presentation of our results, however, we also created categorical variables, defining five categories of hospital volume: very low, low, medium, high, and very high. For each procedure, the hospitals were ranked in order of increasing total hospital volume, and then five volume groups were defined by the selection of whole-number cutoff points for annual volume that most closely sorted the patients into five groups of equal size (quintiles). The cutoff points were established before mortality was examined in order to avoid selecting cutoff points that could maximize the associations between volume and outcome.[17] To reflect most accurately the overall institutional experience with each type of operation, we combined the replacement of aortic and mitral valves (into the single category of heart-valve replacement) and lobectomy and pneumonectomy (into the category of lung resection) in determining hospital volume. However, the outcomes of these procedures were assessed separately.

Assessment of Outcomes

In creating cohorts for the analysis of outcomes, we applied several restrictions in order to increase the homogeneity of the study samples and thus minimize the potential for confounding by case mix. For the eight types of major cancer resections, we excluded patients without an accompanying cancer-diagnosis code (related to the index procedure). Patients undergoing repair of an abdominal aortic aneurysm were excluded if they had a diagnosis or procedure code suggesting rupture of the aneurysm, thoracoabdominal aneurysm, or both. Patients undergoing coronary-artery bypass grafting were excluded if they simultaneously underwent valve replacement.

Our primary outcome measure was operative mortality, defined as the rate of death before hospital discharge or within 30 days after the index procedure. Because a large proportion of surgical deaths before discharge occurred more than 30 days after surgery, we decided that 30-day mortality alone would not adequately reflect true operative mortality. Because the length of stay did not vary systematically according to hospital volume, the inclusion of late, in-hospital deaths would not be expected to bias our results. Moreover, associations between volume and outcome were largely unchanged when we repeated our analyses using 30-day mortality alone.

Statistical Analysis

We used multiple logistic regression to examine relations between hospital volume and operative mortality, with adjustment for characteristics of the patients.[18] We used the patient as the unit of analysis, with volume measured at the hospital level. We first fitted separate models for each procedure against the logarithm of volume to establish the general form of the relation. We then fitted models against the quintiles of volume for each procedure.

We adjusted for age group (65 to 69 years, 70 to 74 years, 75 to 79 years, 80 to 84 years, or 85 to 99 years), sex, race (black or nonblack), and their interactions, as well as the year of the procedure, the relative urgency of the index admission (elective, urgent, or emergency), the presence of coexisting conditions, and mean income from Social Security.[18] This last measure was assessed at the ZIP Code level (on the basis of the 1990 Census file) because patient-level information on socioeconomic status is not available.

Coexisting conditions were identified with the use of information from the index admission and any other admissions that had occurred within the preceding six months. Relative to low-volume hospitals, high-volume hospitals treat a larger number of patients who have been transferred or referred from other centers. To minimize the possibility of bias due to the identification of more previous admissions (and thus more coexisting conditions) at high-volume centers, we excluded information on coexisting conditions identified at previous admissions that occurred within two weeks before the index hospitalization. For the purposes of risk adjustment, coexisting conditions (identified by their appropriate ICD-9-CM codes) were compiled into a Charlson score (the number of coexisting conditions, weighted according to their relative effects on mortality),[19,20] which was modified to exclude conditions that were likely to reflect either the primary indication for surgery or postoperative complications.[21,22] We also explored two alternative approaches to incorporating coexisting conditions into our risk-adjustment models: including Charlson scores with weights derived empirically for each procedure and including coexisting conditions individually by inserting into each model each condition that was present in at least 2 percent of the patients. Because all three approaches yielded virtually identical results, we report only those from the model that used the Charlson score with published weights.[19]

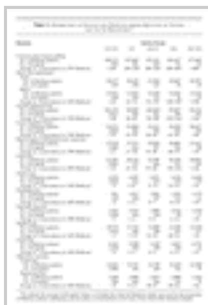
We used overdispersed binary logistic models to adjust for clustering of deaths within hospitals.[23] The net effect was to increase the width of the confidence intervals between 2 percent (cystectomy) and 44 percent (lobectomy), with a mean increase of 25 percent. We computed adjusted mortality rates on the basis of the average values of the characteristics of the patients by back-transforming predicted mortality from the logistic model. Our final risk-adjustment models had intermediate discriminative ability, with C statistics ranging from 0.60 (for pneumonectomy) to 0.71 (for nephrectomy). All P values are two-tailed.

Because the Medicare files used for this analysis reflect the use of procedures among patients with fee-for-service arrangements for health care, we may have underestimated hospital volume in regions of the country that had a high penetration of Medicare managed care during the study period (mainly southern California and the Southwest). For this reason, we repeated our analyses after restricting our data set to hospital-referral regions with a penetration of Medicare managed care of less than 10 percent. Because the adjusted odds ratios for death associated with hospital volume changed negligibly as a result of this restriction, these data are not presented.

RESULTS

Between 1994 and 1999, approximately 2.5 million Medicare patients underwent 1 of the 14 cardiovascular or cancer-related procedures that we studied. The criteria used to define the five strata of hospital volume varied markedly according to procedure, reflecting the relative frequency with which each is performed (Table 1). Medicare volume and total volume for the 14 procedures were highly correlated at the hospital level (overall correlation coefficient, 0.97).

TABLE 1



Distribution of Patients and Hospitals among Quintiles of Volume for the 14 Procedures.

The age and sex of the patients did not vary consistently among strata of hospital volume (Table 2). However, for most of the 14 procedures, black patients were more likely to undergo surgery at a lower-volume hospital. For most procedures, Charlson scores tended to be slightly higher at higher-volume hospitals. However, patients were more likely to be admitted nonelectively at lower-volume hospitals. This trend was more apparent with respect to several cancer-related resections (e.g., esophagectomy) than with respect to cardiovascular procedures.

TABLE 2

Characteristics of the Patients According to Hospital Volume.

When it was assessed as a continuous (logarithmic) variable, hospital volume was related to both observed and adjusted operative mortality rates for all 14 procedures (P<0.001 for all trends). In terms of odds ratios for death, adjustment for characteristics of the patients attenuated the associations between volume and outcome moderately for carotid endarterectomy, colectomy, gastrectomy, esophagectomy, and pulmonary lobectomy (Table 3). Risk adjustment had negligible effect with respect to the other procedures.

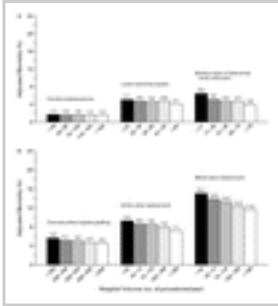
TABLE 3

Operative Mortality Rates and Their Association with Hospital Volume.

In terms of absolute differences in adjusted mortality rates, the importance of hospital volume varied markedly according to the type of procedure (Figure 1 and Figure 2). For example, for pancreatic resection, adjusted mortality rates at very-low-volume hospitals were 12.5 percent higher than at very-high-volume hospitals (16.3 percent vs. 3.8 percent) (Figure 2A). Relatively large differences in risk were also observed for esophagectomy (11.9 percent) and pneumonectomy (5.4 percent). Absolute differences in adjusted mortality rates between very-low-volume and very-high-volume hospitals were between 2 percent and 5 percent for gastrectomy, cystectomy, repair of a nonruptured abdominal aortic aneurysm, and aortic- and mitral-valve replacement, and the differences were less than 2 percent for coronary-artery bypass grafting, lower-extremity bypass, colectomy, lobectomy, and nephrectomy. The absolute difference in mortality between very-low-volume and very-high-volume hospitals was smallest for carotid endarterectomy (1.7 percent vs. 1.5 percent).

FIGURE 1

Relations between volume and outcome in the intermediate strata of hospital volume also varied widely according to the type of procedure (Figure 1 and Figure 2). For several types of procedure (including coronary-artery bypass grafting, valve replacement, and pancreatic resection), mortality declined monotonically with each stratum of increasing hospital volume. For others (including elective repair of an abdominal aortic aneurysm, gastrectomy, and pneumonectomy), differences in mortality were most apparent at the extremes of volume, whereas hospitals in the intermediate-volume strata had similar mortality rates.

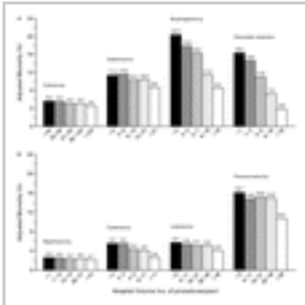


Adjusted In-Hospital or 30-Day Mortality among Medicare Patients (1994 through 1999), According to Quintile of Total Hospital Volume for Peripheral Vascular Procedures (Panel A) and Cardiac Procedures (Panel B).

DISCUSSION

In this large, national study, higher-volume hospitals had lower operative mortality rates for six types of cardiovascular procedures and eight types of major cancer resections. However, the absolute magnitude of the relation between volume and outcome varied markedly among the types of procedures. Dramatic differences in mortality between very-low-volume and very-high-volume hospitals were observed for pancreatic resection and esophagectomy (more than 12 percent, in absolute terms), whereas relatively small differences in mortality (1 percent or less) were found for 3 of the 14 procedures examined in our analysis. These findings suggest the relative importance of hospital volume for individual patients who are considering where to undergo various procedures. From the public health perspective, however, one must also consider the total number of patients who undergo each procedure. For example, in the case of coronary-artery bypass grafting (for which volume had a moderate effect but which is very common), 314 deaths would be averted in the United States each year if the mortality rate at very-low-volume hospitals were reduced to the rate at very-high-volume centers. Conversely, in the case of pancreatic resection (for which volume had a very large effect but which is performed infrequently), lowering the mortality rate at very-low-volume centers to that observed at very-high-volume centers would avert only 32 deaths annually.

FIGURE 2



Adjusted In-Hospital or 30-Day Mortality among Medicare Patients (1994 through 1999), According to Quintile of Total Hospital Volume for Resections of Gastrointestinal Cancer (Panel A) and Resections of Other Cancers (Panel B).

We believe that our results reflect real differences in the quality of surgery between high-volume and low-volume hospitals. First, the effect is large. For some procedures, mortality at low-volume centers was several times as high as at high-volume hospitals — a difference that is too great to be attributed to chance or unmeasured confounding. Second, relations between volume and outcome are remarkably consistent over time and across studies. According to one recent structured review of the literature, 123 of 128 analyses involving 40 different procedures (96 percent) found lower mortality at high-volume hospitals (differences were statistically significant in 80 percent of these analyses).[5] Only 4 of the 128 (3 percent) found higher mortality rates at high-volume hospitals, but none of these findings were statistically significant. And finally, the link between surgical volume and mortality is clinically plausible. Although the mechanisms underlying the relations between volume and outcome have not been fully characterized, high-volume hospitals may have more surgeons who specialize in specific procedures, more consistent processes for postoperative care, better-staffed intensive care units, and greater resources, in general, for dealing with postoperative complications.

Our analysis has several limitations. First, because we studied only Medicare patients, our results may not be generalizable to patients under 65 years of age. However, there is no evidence that age affects the relations between volume and outcome. Second, our measure of volume was imperfect. We estimated total hospital volume by extrapolating from Medicare volume, not by direct measurement. Although Medicare and total volumes are highly correlated at the hospital level, there probably remains some degree of misclassification of hospital-volume status, which would tend to bias our analysis toward the null hypothesis (no effect of volume on outcome). Third, because our primary goal was to estimate the potential effect of referral policies that focus exclusively on volume, we did not attempt to adjust for characteristics of the provider that are likely to be highly correlated with volume. Analyses that aimed to assess the independent effect of hospital volume would need to account for other variables that may influence mortality, including hospital size and teaching status, the volume of procedures performed by a particular surgeon, and staffing patterns in the intensive care unit.[24-27]

Finally, because we relied on administrative data, we may not have accounted adequately for differences in case mix among strata of hospital volume. Administrative data are limited in their ability to differentiate patients according to the severity of illness.[21,22,28,29] Age and the prevalence of coexisting conditions did not vary substantially according to hospital volume in our data set. However, even for conditions for which the procedure itself is almost always elective, patients at lower-volume hospitals were more likely to have been admitted nonelectively. Conversely, patients at higher-volume hospitals were more likely to have had recent nonelective admissions elsewhere. Although these findings raise the possibility of unmeasured differences in case mix among hospitals, we do not believe that confounding is a likely explanation for our main findings.

Although relations between volume and outcome have long been recognized, large-scale efforts to reduce surgical mortality by concentrating selected procedures in high-volume hospitals are only now beginning to gain momentum. The most visible of these efforts is being directed by the nonprofit Leapfrog Group, a coalition of more than 80 large public and private purchasers that insure more than 25 million persons. The coalition is encouraging both patients and payers to select hospitals that meet minimal volume standards for coronary-artery bypass surgery (500 procedures per year), coronary angioplasty (400 per year), carotid endarterectomy (100 per year), repair of abdominal aortic aneurysm (30 per year), and esophagectomy for cancer (6 per year). Although our analysis does not indicate that these specific volume thresholds are better than other alternatives, it does confirm that the proposed standards could reduce the surgical mortality associated with several of these procedures.

Many may object to such initiatives aimed at concentrating selected surgical procedures in high-volume hospitals. They may rightly point out that procedure volume is an imperfect proxy for quality — that some low-volume hospitals have excellent outcomes, whereas some high-volume hospitals have poor outcomes. Unfortunately, most patients facing high-risk surgery have no way of knowing the relative quality of the hospitals near them. Although several states currently have public reporting systems in place,[30,31] these efforts are largely restricted to reporting on cardiac surgery. Most other procedures are not performed frequently enough to allow assessment of procedure-specific mortality at the level of the individual hospital. Thus, in the absence of better information about surgical quality, patients undergoing many types of procedures can substantially improve their odds of survival by selecting a high-volume hospital near them.

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SOURCE INFORMATION

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To the Editor:

The attempt of Birkmeyer et al. (April 11 issue)[1] to correlate low procedure-specific hospital volume with increased mortality has methodologic and interpretive problems. The investigators used data from the Medicare Provider Analysis and Review (excluding those for Medicare patients enrolled in health maintenance organizations) and from the Nationwide Inpatient Sample, without verification, to estimate procedure-specific hospital volume. The correlation between Medicare volume and hospital volume (correlation coefficient, 0.97) probably resulted from mathematic coupling,[2,3] which occurs when variables are shared. Were the relations between outcome and volume significant when only Medicare volumes were analyzed?

No proof of validation of the regression models is presented. For most procedures, lower-volume institutions had higher percentages of nonelective admissions, patients over 75 years of age, and black patients (a fact that the authors erroneously interpret as indicating that black patients were more likely to be treated at low-volume hospitals). These three variables are included in the regression analysis, but they are the tip of the iceberg made up of a multitude of other unreported confounders — such as preoperative selection of patients, intraoperative management, and postoperative care. Obviously, it is impossible to assign patients randomly to hospitals, but without robust, validated regression equations, the relative importance of volume may be overestimated or underestimated.

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3 References

To the Editor:

The article by Birkmeyer et al. advances our understanding of the relation between hospital volume and outcome. We are curious, however, about whether the authors attempted to analyze surgical mortality according to the patient's level of surgical risk. In the case of coronary-artery bypass grafting, we have shown that differences in mortality rates between low-volume hospitals and high-volume hospitals might be driven predominantly by differences among patients at high surgical risk.[1] Patients who are at low risk, in contrast, might receive little or no benefit from obtaining their care at high-volume centers. This possibility has clear implications for regionalization policies, in general, and for high-volume procedures such as coronary-artery bypass grafting, in particular.[2] To avert an estimated 314 annual deaths related to coronary-artery bypass grafting, for example, very-high-volume centers would need to double their capacity by absorbing more than 31,000 additional cases per year. If high-risk patients who would clearly benefit from the expertise available at high-volume centers could be identified preoperatively and then selectively sent to such regional centers, these logistic problems would be greatly diminished.

Finally, we would caution against extrapolation of these data to patients younger than 65 years of age. Advanced age — both directly and in association with coexisting conditions — clearly increases a patient's base-line risk of death related to surgery. The population studied by Birkmeyer et al. therefore represents a high-risk group of patients, as reflected in the relatively high 30-day mortality reported for patients undergoing coronary-artery bypass grafting: 4.8 percent at very-high-volume centers, as compared with a national average of 2.9 percent.[3]

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3 References

To the Editor:

Aside from the direct costs of medical care, travel to a high-volume center can be costly and is not affordable for all patients. An uninsured patient with pancreatic cancer will probably not be accepted at a high-volume institution and will most likely not even be offered the option of going to one. Those who can afford the expense of copying medical, pathological, and radiologic records, and traveling for the consultation, procedure, and any follow-up will do so, leaving those who are less fortunate at the local center. Birkmeyer et al. controlled for coexisting conditions, but I would bet that patients who are able to travel are patients with a better prognosis.

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To the Editor:

The studies by Birkmeyer et al. and Begg et al. (April 11 issue)[1] add further evidence of the correlation between volume and quality in the delivery of certain health care services. Whereas others will certainly challenge the validity or reliability of the data sets or will question whether adequate risk adjustment would temper or invalidate the results, I instead question the policy suggestions laid out in the accompanying editorial by Epstein.[2] It seems much too premature to recommend broadly the diversion of selected procedures from low-volume hospitals, even as a "transitional strategy." Certainly, experience matters, but what else is included in the equation? It is still unclear whether volume itself is a generalizable predictor of quality at all, or whether and how much such underlying factors as organizational design, streamlined data management, or multidisciplinary care act as confounders. Without such knowledge, merely stripping further volume away from low-volume centers may be strikingly counterproductive in terms of the goal of high quality overall.

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2 References

To the Editor:

Although we generally agree with Epstein's support of targeted policies to decrease the proportion of surgical procedures performed at low-volume hospitals, such policies trouble us because volume seems a fairly crude predictor of patient outcome and the closely related measure of the quality of health care. Why not try to identify the true determinants of patient outcomes or quality of health care? Such information could be used to predict the outcome for patients treated by a particular type of physician at a particular type of hospital, reveal characteristics of the physicians and hospitals from which the best outcomes could be expected, and design interventions to improve quality (for all types of health care workers and health care facilities — not just surgeons working in hospitals).

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To the Editor:

Epstein raises some of the key dilemmas facing policy makers as they wrestle with the implications of the association between volume and outcome. In particular, interventions directed at influencing the referral of patients toward high-volume institutions, by fiat, incentive, or consumer pressure, leave unanswered the question of what to do with the lower-volume centers. It is helpful to recognize that volume alone does not presage outcome. The amount of improvement in performance that can be extracted from a given number of procedures also depends in part on how the activities related to learning are managed at a given institution.[1] We have found notable variation in the quality and quantity of management attention paid to learning in the case of the adoption of a new form of medical technology.[2] Perhaps part of the solution to the policy makers' dilemma is better management.

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2 References

To the Editor:

The editorial by Dr. Epstein is laudable in its review of recent information concerning the relation between surgical volume and outcomes, but important points are not well understood. As a case in point, six years ago, I began referring surgical and general medical patients from our small rural hospital to regional referral centers. As this practice led to what I had perceived to be improved patient care, it also created much larger problems in the community: as surgical volume decreased, the skills of the surgical team also deteriorated. The community was then left without a general surgeon. The hospital decreased in size, and the future of this community resource appears to be in danger.

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To the Editor:

I think the assumption made by Epstein that all low-volume hospitals have high mortality after high-risk surgical procedures is unjustified by the data presented. We in the medical profession have no business getting into this matter. Instead, let us use the data to look at the various hospitals and improve the quality of care. Preventing low-volume hospitals from performing surgery can have dangerous consequences. For instance, preventing low-volume surgeons from performing elective repair of abdominal aortic aneurysms will have negative consequences in the form of patients with ruptured aneurysms. Surgeons who are not performing elective aneurysm repair may not feel comfortable repairing ruptured aneurysms — a procedure requiring far more experience and skill. Patients with ruptured aneurysms may have to travel substantial distances to get to centers where the procedure is performed.

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The authors reply:

To the Editor: In our study, hospital volume was measured directly by counting Medicare procedures. To facilitate interpretation of our results, we converted hospital Medicare volumes to total hospital volumes, using data from the Nationwide Inpatient Sample to estimate the appropriate multiplier for each procedure. Because the same multiplier was applied to all hospitals, this approach does not in any way affect the magnitude of reported volume–outcome relations. Barone et al. also note the importance of accounting for potentially confounding variables, including variables related to patient selection. As we acknowledged, the extent to which data on claims capture these variables is limited. However, it would be inappropriate to adjust for variables related to operative and postoperative care. Such processes of care are most likely essential parts of the causal pathway underlying the relations between volume and outcome and thus should not be viewed as "confounders."

Nallamothu et al. wonder whether hospital volume may be most important for high-risk patients, as their research has suggested with regard to coronary-artery bypass grafting.[1] Our (unpublished) analyses support this premise when the importance of volume is expressed in terms of absolute differences in operative mortality. Differences in mortality appear to be largest for subgroups of patients with the highest base-line risk, such as the very elderly. In terms of the relative risk of death, however, we found the effect of hospital volume to be relatively uniform among subgroups defined according to base-line risk.

Senkowski suggests that lower-income patients and those without insurance may be less likely to undergo surgery at high-volume hospitals. Although previous studies have demonstrated only moderate differences between high-volume hospitals and low-volume hospitals in the socioeconomic status of patients, we agree that more work is needed to clarify the role of patient selection in the observed relations between volume and outcome. We also agree that policy makers must be careful to ensure that less fortunate patients are not left behind as volume-based referral initiatives are implemented.

Given the hundreds of articles published over the past several decades demonstrating better outcomes with selected procedures at high-volume hospitals,[2,3] we do not agree with Kocs that ongoing efforts to translate this information into policy are "premature." As he points out, hospital volume may serve as a proxy for numerous organizational characteristics associated with better quality. Efforts to identify these attributes and to ensure that they are implemented broadly would be worthwhile. Meanwhile, many unnecessary deaths could be averted by policies concentrating pancreatic resections, esophagectomies, and other high-risk procedures in high-volume centers.

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3 References

The editorialist replies:

To the Editor: Drs. Babson, Ghertner, and Kocs all express concern about the potentially deleterious consequences of diverting patients from low-volume hospitals. I share their concern. However, the relations between volume and outcome are extraordinarily strong for some surgical procedures. For example, according to data from Birkmeyer et al., risk-adjusted mortality rates for esophagectomy varied from 8.4 percent in very-high-volume hospitals to 20.3 percent in very-low-volume hospitals. Risk-adjusted mortality rates for pancreatic resection and repair of an abdominal aortic aneurysm varied from 3.8 percent to 16.3 percent and from 3.9 percent to 6.5 percent, respectively. Clearly, we need research to understand the causes of these differences and quality-improvement interventions to improve our care and reduce these differences. But the benefit from these activities may not be seen for years. For patients receiving care now, the effect of these differences on patients' health outcomes is too large to ignore.

Policy changes can often result in unanticipated consequences. Therefore, our approach should be demonstration and evaluation with close follow-up and readjustment. I recognize Dr. Ghertner's point that rural hospitals are especially vulnerable and their loss would threaten patients' access to care. I therefore proposed that efforts to divert patients to low-volume hospitals be limited to urban areas, as well as to procedures for which the relations between volume and mortality are strongest, and to institutions at the bottom end of the spectrum with very low volume. I urge that the Leapfrog Group and others who support more aggressive policies refine their current plans as they move toward interventions that go beyond education. Broad-scale regionalization is not warranted at this time.

Dr. Bohmer and colleagues and Drs. Rowe and Deming underscore the fact that volume is merely a characteristic that is associated with differences in patient outcome rather than a direct measure of quality of care. Differences in risk-adjusted mortality arise largely from differences in clinical management. Efforts to improve clinical management, reduce mortality, and diminish differences in the quality of care should be our highest priority.

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