Volume-Outcome Relation for Physicians and Hospitals Performing Angioplasty for Acute Myocardial Infarction in New York State

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Background—An inverse relation exists between the number of coronary angioplasty procedures performed by physicians or hospitals and short-term mortality. It is not known, however, whether a similar relation holds for physicians and hospitals that perform primary angioplasty for acute myocardial infarction.

Methods and Results—We analyzed data from the 1995 New York State Coronary Angioplasty Reporting System Registry to determine the relation between the number of primary angioplasty procedures performed by physicians and hospitals and in-hospital mortality. Patients who underwent angioplasty procedures within 23 hours of onset of acute myocardial infarction without preceding thrombolytic therapy were included (n=1342). In-hospital mortality was reduced 57% among patients who underwent primary angioplasty by high-volume as opposed to low-volume physicians (adjusted relative risk 0.43; 95% CI 0.21 to 0.83). When patients with acute myocardial infarction were treated with primary angioplasty in high-volume hospitals rather than low-volume institutions, the relative risk reduction for in-hospital mortality was 44% (adjusted relative risk 0.56; 95% CI 0.29 to 1.1). Compared with patients treated at low-volume hospitals by low-volume physicians, patients treated at high-volume hospitals by high-volume physicians had a 49% reduction in the risk of in-hospital mortality (adjusted relative risk 0.51; 95% CI 0.26 to 0.99).

Conclusions—Among hospitals in New York State, a higher volume of primary angioplasty procedures performed by physicians and/or hospitals was associated with a lower mortality rate.

Key Words: angioplasty ■ risk factors ■ mortality ■ catheters

A n inverse relationship between both physician and hospital PTCA volumes and adverse outcomes has been demonstrated in numerous studies involving thousands of patients undergoing predominantly elective procedures. It is not known whether a distinct volume-outcome relation exists for PTCA performed as primary reperfusion therapy for acute myocardial infarction (AMI) (primary angioplasty). In this group of more acutely ill patients, it is possible that the experience of the physician and hospital in treating AMI patients with PTCA is more important than their experience in a less acute or elective setting. In fact, a recent study demonstrated that hospitals with the most experience at treating AMI patients with primary angioplasty have the lowest mortality.13 No study to date has examined the effect of operator volume of primary angioplasty procedures on outcomes. Because both operator and hospital primary angioplasty volumes may be independent predictors of outcome, we sought to explore the relationship and combined effects of these factors on short-term mortality of AMI patients treated with primary angioplasty. Other investigators have used the New York State Coronary Angioplasty database for studies of primary angioplasty treatment of AMI, but the relation between volume and outcome has not been evaluated in this data set. This data set was used because it represents the experience across an entire state and includes patients treated in rural and urban, teaching and nonteaching, not-for-profit and for-profit hospitals. Furthermore, the data are not dominated by one or several institutions with particular expertise in performance of primary angioplasty. Finally, the patients are those encountered in actual practice rather than the lower-risk patients frequently selected for enrollment in clinical trials.

See p 2155

Methods

Data Ascertainment
We used data from the 1995 Coronary Angioplasty Reporting System (CARS) of the New York State Department of Health (DOH). This registry was developed in 1990 to track and record important information on every patient undergoing PTCA in New York State. The responsible physician, or a designee, completes a questionnaire after each intervention, which is subsequently entered
into a computer database and sent to the DOH. The questionnaire contains information on the hospital and cardiologist, patient demographics, procedural information, risk factors, discharge status, vessels diseased, lesion location and morphology, presence of bypass grafts, preprocedural and postprocedural stenosis, and complications. The DOH is the coordinating center, and hospitals and their catheterization laboratories are responsible for the accurate documentation and transfer of data. The DOH conducts periodic site visits to check for accuracy of data entry.

Patient Population
The 1995 New York State CARS Registry includes more than 22,000 patients undergoing elective and emergent PTCA in 32 participating hospitals. On the data collection form, the time from onset of AMI to PTCA is recorded as <6 hours, 6 to 23 hours, or number of days. The 2 components of time to treatment, the time from symptom onset to presentation and the time from presentation to PTCA, cannot be identified in this data set. Because significant numbers of patients with AMI present >6 hours after symptom onset,15–17 we included patients who underwent PTCA for AMI within 23 hours of symptom onset. This definition of primary angioplasty is consistent with that used by the Second National Registry of Myocardial Infarction18 and the Society of Cardiac Angiography and Interventions.19 To eliminate patients undergoing PTCA after unsuccessful thrombolysis (rescue angioplasty), we excluded those who had received thrombolytic therapy within 7 days before the procedure.

Outcome Measure
The primary end point of this analysis was in-hospital mortality.

Statistical Analysis
Physicians and hospitals were categorized into terciles based on the volume of primary angioplasty procedures performed in 1995. Because of the small number of patients in the first tercile of both physicians and hospitals, the first and second terciles in each category were combined and labeled as low volume, with the highest tercile defined as high volume, resulting in the following 4 groups: low-volume physicians, high-volume physicians, low-volume hospitals, and high-volume hospitals. Using stepwise multiple logistic regression models to control for potential confounding factors, we studied the effect of physician and hospital volume on outcomes by comparing in-hospital mortality rates after primary angioplasty by low- or high-volume physicians or low- or high-volume hospitals. To study the interaction between physician and hospital volume, we again used stepwise multiple logistic regression models to compare the in-hospital mortality of patients treated with primary angioplasty by low-volume physicians in low-volume hospitals (reference group) with the following 3 pairings: high-volume physicians in low-volume hospitals, low-volume physicians in high-volume hospitals, and high-volume physicians in high-volume hospitals. The following potential confounders were added in a stepwise manner to the logistic regression models: demographic data (age and sex), medical history (smoking, diabetes, prior MI, prior cardiac surgery), preprocedural shock (systolic blood pressure <80 mm Hg or cardiac index <2.0 L·min⁻¹·m⁻²) or hemodynamic instability (the requirement for pharmacological or mechanical support to maintain blood pressure or cardiac output), and time to treatment (<6 or ≥6 hours). Because the cumulative risk of death was <10%, odds ratios from logistic regression models were interpreted as relative risks. Generalized-estimating-equation analyses performed to account for clustered sampling resulted in no change in the point estimates (data not shown). To determine whether the volume-outcome relation was linear, assessment was performed of whether a quadratic (centered and squared) term for volume significantly improved the fit of the model compared with a linear (centered) term.

Categorical variables were compared by χ² analysis, and continuous variables were compared by Student’s t test. Significance of trends for increasing hospital and physician volume categories was assessed with the Cochran-Armitage test. All probability values are two-tailed. Statistical significance was defined as P<0.05 or 95% CIs that do not include 1.0. All analysis was performed by use of the SPSS 8.0 and STATA 6 statistical programs.

Results
In 1995, 151 physicians attempted a total of 1342 primary angioplasty procedures in patients with AMI in 32 hospitals in New York State. Only 14 physicians performed primary angioplasty in more than one hospital. Physician and hospital terciles based on the 1995 volume are summarized in Table 1, with the number of in-hospital deaths in each tercile presented. When the first and second terciles for physician volume were combined, a low-volume group was created consisting of 100 physicians who treated 365 patients with primary angioplasty. The low-volume physicians performed 1 to 10 primary angioplasty procedures in 1995. The 51 high-volume physicians treated 977 patients and performed ≥11 PTCA procedures for AMI. The combination of the first and second terciles of hospital volume created a low-volume group of 22 hospitals that treated 533 patients. These hospitals performed 1 to 56 primary angioplasties in 1995. The high-volume group consisted of 10 hospitals that treated 809 patients. Each of these hospitals performed ≥57 primary angioplasty procedures in 1995.

Baseline clinical characteristics of patients according to physician and hospital volume (low versus high) are shown in Table 2. The majority of patients were male, and the mean age was 61 years. Age and sex did not differ between patients treated by low- and high-volume physicians. Patients treated by low-volume physicians were less often smokers (25% versus 31%, P=0.045) and were more likely to have had previous heart surgery (12% versus 7%, P=0.006) than patients treated by high-volume physicians. There were no other significant differences between patients treated by low-volume and high-volume physicians, including the prevalence of diabetes, hypertension, peripheral vascular disease, stroke, prior MI, prior PTCA, or history of congestive heart failure. There were no significantly different baseline characteristics between patients treated in low-volume and high-volume hospitals.
Procedural characteristics are presented in Table 3. The presence of shock at the time of the procedure did not differ between patients treated by low- and high-volume physicians. Before the procedure, patients treated by low-volume physicians were more likely to need an intra-aortic balloon pump (12.8% versus 8.7%, \(P=0.022\)) or vasopressor therapy (15.6% versus 11.0%, \(P=0.024\)). The proportion of patients treated within 6 hours of symptom onset was significantly less in patients treated by low-volume physicians than high-volume physicians (63% versus 75%, \(P<0.001\)). Left ventricular ejection fraction, extent of coronary artery disease, and stent use did not differ between patients treated by low- and high-volume physicians. There was a trend toward greater angiographic success and a shorter length of stay in patients treated by high-volume physicians. The presence of shock at the time of the procedure did not differ between patients treated in low- or high-volume hospitals. Before the procedure, patients treated in low-volume hospitals were more likely to need an intra-aortic balloon pump (12.0% versus 8.4%, \(P=0.038\)) but were no more likely to need vasopressor therapy. The proportion of patients treated within 6 hours of symptom onset, however, was significantly less in patients treated in low-volume than in high-volume hospitals (65% versus 75%, \(P<0.001\)). Left ventricular ejection fraction, extent of coronary artery disease, and angiographic success were similar in patients treated in low- and high-volume primary angioplasty hospitals. There was a trend toward more frequent use of stents in patients treated in high-volume hospitals (20% versus 16%, \(P=0.057\)).

The crude in-hospital mortality rate was 7.1% in patients treated by low-volume physicians compared with 3.8% in patients treated by high-volume physicians (\(P=0.01\)) (Table 3). After multivariate analysis to adjust for potentially confounding factors such as age, sex, comorbidity, cardiac history, time to presentation, and hemodynamic status on presentation, the risk of mortality was reduced by 57% in patients treated by high-volume physicians (relative risk 0.43; 95% CI 0.21 to 0.83) (Table 4). There was no significant departure from linearity after risk adjustment in the physician volume-outcome relation (\(P\) for departure from linearity = 0.06).
ty = 0.36). There was a trend toward higher mortality in patients treated in low-volume compared with high-volume hospitals (5.8% versus 4.0%, P = 0.115). After multivariate analysis, patients treated in high-volume hospitals had a relative risk of in-hospital mortality of 0.56 (95% CI 0.29 to 1.1) compared with those treated in low-volume hospitals. Again, after risk adjustment, there was no significant departure from linearity for the hospital volume-outcome relation (P for departure from linearity = 0.97).

The Figure illustrates the multivariate-adjusted relative risks comparing the in-hospital mortality of patients treated by low-volume physicians in low-volume hospitals (reference group) with that of patients treated by high-volume physicians in low-volume hospitals, low-volume physicians in high-volume hospitals, and high-volume physicians in high-volume hospitals. The crude mortality rates in the 4 groups were 7.6%, 5.8%, 4.1%, and 3.7%. After multivariate adjustment, the risk of mortality was 49% lower in patients treated by high-volume physicians in high-volume hospitals (relative risk 0.51; 95% CI 0.26 to 0.99). There was a statistically significant reduction in the relative risk for mortality as volume increased across the 4 physician-hospital groups (P for trend = 0.026).

**Discussion**

There are 3 major findings of this observational study: First, an inverse relation exists between physician primary angioplasty experience and in-hospital mortality. Performance of primary angioplasty by a physician who performed >10 procedures annually results in a savings of 33 lives per 1000 patients treated. This mortality benefit persisted after risk adjustment. Second, there is a strong trend toward a relation between hospital primary angioplasty volume and mortality such that 18 lives per 1000 patients treated would be saved by treatment in a high-volume hospital. Finally, an interaction between hospital and physician primary angioplasty volume and in-hospital mortality exists such that those AMI patients treated in high-volume hospitals by high-volume physicians have a 49% lower in-hospital mortality rate than those treated by low-volume physicians in low-volume hospitals. This lower rate, which represented ~39 fewer deaths per 1000 patients treated, persisted after adjustment for demographic, medical, and cardiac factors known to influence survival from AMI.

Multiple factors may contribute to the association between higher physician volume of primary angioplasty procedures and lower in-hospital mortality. The average mortality rate for patients treated with primary angioplasty for AMI is ~5-fold higher than patients undergoing elective PTCA. The AMI patient is more often experiencing active ischemia, manifested by chest pain, arrhythmias, and hemodynamic instability. Thus, a premium is placed on stabilization of the patient while at the same time achieving timely and complete...
reperfusion. These interventions require expertise in an array of pharmacological and mechanical therapies. Thus, it is not surprising that greater physician skill and judgment would derive from a greater experience with these cases, ultimately resulting in improved outcomes.

Several smaller studies have investigated the relation between hospital primary angioplasty volume and outcomes and have failed to discern an association after multivariate analysis. The 2 largest studies, involving >284,000 patients, however, have demonstrated a significant relation between hospital primary angioplasty volume and mortality. The results of these studies, in combination with the linear nature of the hospital volume-outcome relation demonstrated in the present study, strongly suggest that hospital primary angioplasty volume is at least a partial surrogate for the process of care, with higher-volume hospitals having systems and protocols in place that minimize delays in restoration of coronary blood flow.

Given the relation between physician and hospital volume and outcomes, it is not surprising that when these variables are combined, the results suggest a powerful demonstration of a volume-outcome relation, with a 49% reduction in inhospital mortality when the procedure is performed by high-volume physicians in high-volume hospitals rather than by low-volume physicians in low-volume hospitals. Despite the improved outcomes generally achieved by high-volume physicians, our data suggest that such benefit is muted when these physicians perform procedures in low-volume hospitals. It is only when high-volume physicians perform primary angioplasty in high-volume hospitals that the optimal outcome is achieved.

Although the present study suggests that higher-volume physicians and hospitals have better outcomes because of their greater experience with these procedures, because of its retrospective nature, this study can identify only associations, rather than causality. Referral bias is another possible explanation for our results. This form of bias occurs when patients, particularly those at low risk, are attracted to doctors and hospitals because of their reputation for good results. Higher-risk patients are then disproportionately represented in lower-volume hospitals. It is unlikely, however, that such bias is operational during an AMI, when the emergent nature of the condition would most likely preclude patients from “shopping” for the best physicians or hospitals. Furthermore, most baseline characteristics of patients were similar between patients in the low- and high-volume groups, and after adjustment for the few differences, the results did not change. Another potential limitation of the present study is related to changes in treatment of patients with AMI. Currently, stent use is much more widespread than it was in 1995. In addition, since 1995, platelet glycoprotein IIb/IIIa inhibitors have been approved for use in patients undergoing primary angioplasty. Randomized clinical trials, however, do not support a short-term mortality benefit of either of these treatments in the setting of AMI. Finally, the CARS data set does not include information on adjunctive treatments, such as aspirin and β-blockers, that have been demonstrated to improve mortality from AMI. Hospitals with more experience in treating AMI patients are generally better at prescribing such medications. Nevertheless, in the study by Canto et al., the importance of hospital volume of primary angioplasty remained significantly associated with in-hospital mortality even after adjustment for differences in medications.

Thus, on the basis of our data, patients selected for treatment of AMI with primary angioplasty should, if possible, be directed to high-volume physicians in high-volume hospitals. At the same time, these data should stimulate low-volume hospitals to seek to improve their outcomes by adopting processes of care used by higher-volume centers. In the meantime, patients in low-volume primary angioplasty centers appear to have similar mortality whether treated by PTCA or thrombolytic therapy.

In conclusion, patients with AMI treated with primary angioplasty by high-volume physicians at high-volume hospitals have the lowest in-hospital mortality. As physician and hospital primary angioplasty experience increases, in-hospital mortality is reduced.

References


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