

CLINICAL RESEARCH

Interventional Cardiology

Effect of Physician Volume on the Relationship Between Hospital Volume and Mortality During Primary Angioplasty

V. S. Srinivas, MBBS,* Susan M. Hailpern, DRPH, MS,† Elana Koss, MD,* E. Scott Monrad, MD,* Michael H. Alderman, MD†

Bronx, New York

- Objectives** We sought to examine the combined effect of hospital and physician volume of primary percutaneous coronary intervention (PCI) on in-hospital mortality.
- Background** An inverse relationship between volume and outcome has been observed for both hospitals and physicians after primary PCI for acute myocardial infarction.
- Methods** Using the New York State PCI registry, we examined yearly hospital volume, physician volume, and risk-adjusted mortality in 7,321 patients undergoing primary PCI for acute myocardial infarction. Risk-adjusted mortality rates for high-volume hospitals (>50 cases/year) and high-volume physicians (>10 cases/year) were compared with their respective low-volume counterparts.
- Results** Primary PCI by high-volume hospitals (odds ratio [OR]: 0.58; 95% confidence interval [CI]: 0.38 to 0.88) and high-volume physicians (OR: 0.66; 95% CI: 0.48 to 0.92) was associated with lower odds of mortality. Furthermore, there was a significant interaction between hospital and physician volume on adjusted mortality ($p = 0.02$). Although unadjusted mortality was lower when primary PCI was performed by high-volume physicians in high-volume hospitals compared with low-volume physicians in low-volume hospitals (3.2% vs. 6.7%, $p = 0.03$), the risk-adjusted mortality rate was not statistically significant (3.8% vs. 8.4%, $p = 0.09$). In low-volume hospitals, the average risk-adjusted mortality rate for low-volume physicians was 8.4% versus 4.8% for high-volume physicians (OR: 1.44; 95% CI: 0.68 to 3.03). However, in high-volume hospitals, the risk-adjusted mortality rate for high-volume physicians was 3.8% versus 6.5% for low-volume physicians (OR: 0.58; 95% CI: 0.39 to 0.86).
- Conclusions** During primary PCI, physician experience significantly modifies the hospital volume-outcome relationship. Therefore, policymakers need to consider physician experience when developing strategies to improve access to primary PCI. (J Am Coll Cardiol 2009;53:574-9) © 2009 by the American College of Cardiology Foundation

As a result of the proven efficacy of timely primary percutaneous coronary intervention (PCI) over fibrinolysis, increasing patient access to primary PCI is now considered a

See page 580

priority by many (1-5). In response to this need, several community-based programs designed to increase patient access to primary PCI in the U.S. and Canada have been reported (6,7). However, in any given community, several

hospitals and cardiologists are potentially capable of delivering these services. Therefore, whether preferential triage to centers specializing in primary PCI or increasing the number of hospitals capable of performing primary PCI best accomplishes this goal remains an area of debate. Preferential triage has been advocated by some because both hospitals and physicians that perform a greater volume of primary PCI for acute myocardial infarction demonstrate better outcomes (8-13). Others recommend increasing the number of programs because recent studies have demonstrated the efficacy of primary PCI when performed by experienced physicians in community hospitals (14,15). A critical assumption in these arguments is that there exists an interaction between physician and hospital volume so that physician experience could offset the risks of primary PCI in low-volume hospitals and vice versa. To our knowledge, evidence of this interaction between hospital volume and physician volume of primary PCI has never been fully

From the *Department of Medicine, Division of Cardiology, Montefiore Medical Center, and the †Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York. Dr. Srinivas was partially supported by the American Heart Association Martin Leon/Cordis Corporation Interventional Fellowship Grant. The authors wish to disclose that results herein do not necessarily reflect the views of the New York State Department of Health or its Cardiac Advisory Committee.

Manuscript received April 8, 2008; revised manuscript received September 22, 2008, accepted September 29, 2008.

explored in contemporary practice. Therefore, we present herein the results of our examination of the interaction between hospital and physician volume of primary PCI for acute myocardial infarction using the New York State PCI reporting system.

Methods

Database. The 2000 to 2002 New York State PCI reporting system was used for this study, the details of which have been published in earlier reports (13,16). Patients who underwent PCI in 41 centers by 266 physicians and who were discharged between January 1, 2000, and December 31, 2002, formed the study base (n = 128,230). From this study base, 7,321 patients with acute myocardial infarction presenting within 12 h of chest pain, excluding those receiving thrombolytics, were defined as having primary PCI.

Definitions. We calculated yearly hospital volume as the total number of patients undergoing primary PCI at each hospital divided by the number of years of observation for that hospital. Similarly, total primary PCI for each physician was divided by the number of years of observation per physician to calculate yearly physician volume.

Outcome measure. The outcome measure for the study was in-hospital mortality, which included death from any cause.

New York State PCI risk score. New York State PCI risk score was calculated for each patient based on the models developed by Wu et al. (17). The risk score estimated underlying risk for hospital mortality by the use of 9 characteristics: age, sex, hemodynamic status, ejection fraction, pre-procedural myocardial infarction status, peripheral arterial disease, congestive heart failure, renal failure, and left main coronary disease (c-statistic for derivation dataset = 0.886).

Statistical analysis. Hospital volume was categorized by hospital volume ≤ 50 cases/year versus > 50 cases/year and physician volume categories into ≤ 10 cases/year, 10 to 20 cases/year, and > 20 cases/year, respectively. Differences in baseline characteristics were compared with 1-way analysis of variance for continuous variables and chi-square tests for categorical variables. Continuous variables were expressed as mean \pm standard deviation and categorical variables as percent. In-hospital mortality was predicted for each patient using the following formula:

$$p = \frac{1}{1 + e^{-(-7.6697 + risk_score \times 0.3175)}}$$

Next, the predicted probabilities were averaged within each hospital/physician-volume subgroup. The risk-adjusted mortality rate was calculated as the ratio of observed mortality to predicted mortality multiplied by the statewide mortality rate of 3.72%. Yearly hospital and physician volumes were then plotted against risk-adjusted mortality using robust locally weighted regression and smoothing scatterplots (18). For

physician data, the average risk-adjusted mortality for each 2-U increase in aggregated physician volume was measured. On the basis of the graphical appearance of the hospital and physician volume-outcome relationship, thresholds of high versus low hospital and physician volume were identified. For hospital volume, potential thresholds explored were 25, 50, and 75 cases/year, and for physician volume, 10, 20, and 40 cases/year. The independent effect of hospital and physician volume on mortality was then tested with the use of multivariable logistic regression models for hospital and physician thresholds (as noted previously) while adjusting for New York State PCI risk score.

The joint effect of physician and hospital volume was examined for the hospital threshold of 50 cases/year and physician threshold of 10 cases/year and 20 cases/year in 2 separate analyses. In the first analysis, we calculated the observed and risk-adjusted mortality for each physician based upon his or her volume status and the hospital setting. Next, the average unadjusted and risk-adjusted mortality for all physicians within the 4 combinations of hospital and physician volume was calculated. Statistical significance of the difference between these mortality rates was assessed using the Mann-Whitney test. In another analysis, we modeled an interaction between hospital and physician volume using product interaction terms. These were entered into separate logistic regression models with main effect terms and New York State PCI risk score. To account for clustering by physicians, standard errors were estimated using generalized estimating equations (19). All statistical tests used a 2-tailed α of 0.05. Statistical analyses were performed with STATA 9.2 (StataCorp LP, College Station, Texas).

Results

Between 2000 and 2002, 7,321 patients in New York State underwent primary PCI at 41 hospitals (range 1 to 172 primary PCIs/year) by 266 physicians (range 1 to 55/year).

Baseline characteristics. A comparison of baseline characteristics of patients by hospital and physician volume categories is shown in Table 1. Overall, there were significant differences in the case-mix between high versus low volume hospitals and between high- and low-volume physicians. Patients presenting to low-volume hospitals were significantly more likely to be of Hispanic ethnicity, have diabetes, need dialysis, or demonstrate hemodynamic instability. Patients who had primary PCI at low-volume hospitals also had a significantly greater mortality than those in high-volume hospitals. Patients who received PCI from low-volume physicians were older and were more likely to be of Hispanic ethnicity or demonstrate unstable hemodynamics, cardiogenic shock, and greater New York State PCI risk

Abbreviations and Acronyms

- CI = confidence interval
- OR = odds ratio
- PCI = percutaneous coronary intervention

Table 1 Pre-Procedural Characteristics of Patients Undergoing Primary Angioplasty in New York State by Hospital and Physician Volume Categories*

	Hospital Volume (Primary PCIs/yr)		Physician Volume Categories (Primary PCIs/yr)			All Patients
	≤50 (n = 18)	>50 (n = 23)	≤10 (n = 174)	11–20 (n = 63)	>20 (n = 29)	
Patients (n)	1,148	6,173	2,083	2,708	2,530	7,321
Age, mean (SD)	61.1 (13.0)	61.2 (13.0)	61.7 (13.3)	60.7 (13.2)	61.4 (13.0)†	61.2 (13.0)
Female sex	30.3	28.3	29.7	27.9	28.5	28.6
Hispanic ethnicity	13.0	6.7‡	8.4	9.6	5.0‡	7.7
Black race	9.4	5.2	6.1	6.0	5.4	5.9
Hypertension	62	60	59.8	58.3	63.2§	60.4
Diabetes	22.4	18.2§	20.3	18.2	18.4	18.9
Current smoker	29.4	32	31.1	31.8	31.8	31.6
Previous myocardial infarction	15.2	16.5	17.5	15.2	16.4	16
Previous PCI	16.7	17.2	18.4	16	17.2	17.1
Previous cardiac surgery	5.8	7.7†	8.5	6.7	7.2	7.4
Renal failure	1.1	1.2	1.3	1.3	1.1	1.2
Need for dialysis	1.3	0.65†	0.9	0.8	0.4	0.7
Current heart failure	8.9	9.2	9.9	9.3	8.4	9.2
Previous heart failure	2.8	2.3	2.6	2.4	2.1	2.4
Chronic lung disease	5.3	5.7	5.4	5.9	5.6	5.7
Vascular disease	4.2	6.6	5.7	6.5	6.4	6.3
Prior stroke	4.3	3.9	4.3	3.9	3.9	4.0
Malignant arrhythmia	4.3	3.4	3.5	3.8	3.3	3.5
Hemodynamic unstable	7.4	5.8†	6.5	7.2	4.6‡	6.1
Cardiogenic shock	2.5	2.1	3.1	1.9	1.7	2.2
Cardiopulmonary resuscitation	0.7	1.5	1.3	1.1	1.8	1.4
Balloon pump	6.3	6.3	6.8	6.7	5.3	6.3
Stent thrombosis	2.2	3.0	2.9	2.6	3.1	2.8
Myocardial infarction ≤6 h	72	75.4†	70.3	74.5	79.3‡	75
Ejection fraction						
<20%	1.9	1.2	1.8	1.1	1.6	1.3
20% to 29%	7.6	6.8	6.5	7.7	6.5	6.9
Single-vessel disease	53.3	56.4	54.1	56.1	57.1	55.6
Left main disease	1.2	1.9	2.2	1.7	1.5	1.8
Stent used	91.1	90.9	90.1	91.7	90.8	90.9
PCI risk score, mean (SD)	10.4 (4.1)	10.2 (3.8)	10.5 (4.1)	10.2 (3.9)	10.1 (3.6)	10.3 (4.0)
Hospital mortality	5.4	3.4§	4.9	3.6	2.8§	3.72

Analysis compares categories within hospital and physician volume. *Statistical analyses for categorical variables performed with the use of chi-square analysis and continuous variables with 1-way analysis of variance; †p < 0.05; ‡p < 0.0001; §p < 0.001; ||p < 0.01.

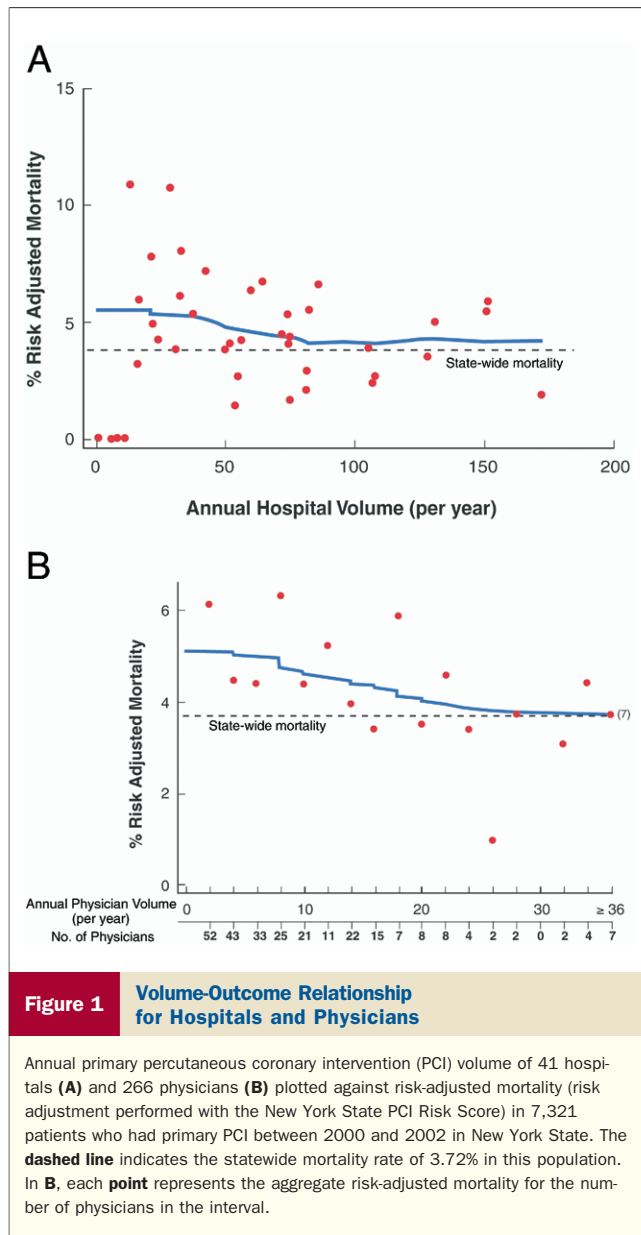
PCI = percutaneous coronary intervention.

score. Similar to the low-volume hospitals, in-hospital patient mortality was significantly greater for low-volume physicians compared with high-volume physicians.

Volume-outcome relationship for hospitals and physicians. The bivariate relationship between hospital and physician volume versus risk-adjusted mortality is shown in Figures 1A and 1B, respectively. When hospital volume was plotted against risk-adjusted mortality, a weak trend relating greater volume and lower mortality was observed above volumes of 50 primary PCIs/year (Fig. 1A). Similarly, an inverse relationship also was observed for physician volume and risk-adjusted mortality, with physicians performing >10 primary PCIs/year demonstrating better outcomes (Fig. 1B). Using these relationships, we categorized hospital and physician volumes into high versus low volume at different thresholds, as seen in Table 2. Although the risk-adjusted odds for in-hospital mortality were consis-

tently lower in high-volume hospitals, only high-volume hospitals performing more than 50 primary PCIs/year achieved statistically significant reductions in mortality (odds ratio [OR]: 0.58; 95% confidence interval [CI]: 0.38 to 0.88) compared with their low-volume counterparts. However, both high-volume physicians performing >10 primary PCIs/year and those performing >20/year demonstrated a 34% and 37% reduction in risk-adjusted mortality, respectively, compared with their respective low-volume counterparts.

Interaction between hospital and physician volume. We examined the capacity of high-volume physicians to offset the risks of low-volume hospitals and vice versa by modeling their interaction in 2 separate analyses. In the first analysis, the average unadjusted and risk-adjusted mortality for each combination of physician volume ≤10/year versus >10/year and hospital volume of ≤50/year versus >50/year was



calculated (Table 3). Less than one-third of the physicians were high-volume operators that performed >10 primary PCIs/year, whereas more than one-half of the hospitals were high-volume hospitals performing >50 primary PCIs/year. All high-volume physicians performed primary PCI at high-volume hospitals, and one-third also performed primary PCI in low-volume hospitals. On the other hand, nearly two-thirds of low-volume physicians performed primary PCI in low-volume hospitals only. Primary PCI by high-volume operators in high-volume hospitals was associated with the lowest unadjusted and risk-adjusted mortality rate, followed by high-volume physicians in low-volume hospitals, low-volume physicians in high-volume hospitals, and finally, low-volume physicians in low-volume hospitals. High-volume physicians performed consistently better than their low-volume colleagues both in low- and in high-

volume hospitals. Although the difference in unadjusted mortality between high-volume physicians in high-volume hospitals and low-volume physicians in low-volume hospitals was statistically significant both for those performing >10/year (3.2% vs. 6.7%, $p = 0.03$) and for those performing >20/year (2.8% vs. 6.1%, $p = 0.01$), after risk adjustment, only a statistical trend toward lower mortality was observed for physicians performing >10/year in high-volume hospitals (3.8% vs. 8.4%, $p = 0.09$). On the other hand, physicians performing >20/year in high-volume hospitals continued to demonstrate significantly lower mortality (3.5% vs. 7.9%, $p = 0.01$).

In the second analysis, we created a logistic regression model that included the interaction between hospital and physician volume as a product-interaction term along with the main effect terms (hospital volume, physician volume) adjusted for underlying risk. In this analysis, only the product interaction term of hospital volume 50/year and physician volume 10/year was statistically significant ($p = 0.02$). The estimated odds ratios for physician volume categories stratified by low- and high-volume hospitals demonstrated no significant difference in outcome between high- and low-volume physicians (>10/year vs. ≤ 10 /year) in hospitals performing ≤ 50 primary PCIs/year (OR: 1.44; 95% CI: 0.68 to 3.03). However, in hospitals performing >50 primary PCIs/year, high-volume physicians had significantly lower risk-adjusted mortality compared with low-volume physicians (OR: 0.58; 95% CI: 0.39 to 0.86).

Discussion

We analyzed the interaction between hospital and physician volume of primary PCI and observed that in-hospital mortality was greater when primary PCI was performed by low-volume physicians in low-volume hospitals compared with high-volume physicians in high-volume hospitals. Furthermore, even in high-volume hospitals, primary PCI by low-volume physicians was associated with significantly worse outcomes compared with high-volume physicians.

These results suggest that policymakers developing strategies to improve access to primary PCI ought to include physician experience in their decision-making framework. The major difference between this and other previous studies that have examined volume-outcome relationship for hospitals and physicians during primary PCI is that only one, performed in the pre-stent era, has reported the combined effect of hospital and physician volume (10). Other strengths of our analysis include the fact that participation in the New York registry is mandatory, and therefore, hospitals most likely to have low-volume or worse outcomes are just as likely to participate as higher-volume or better-outcome institutions, thus reducing the chances for gamesmanship. Furthermore, a comprehensive auditing process ensures that the data reported are accurate, reducing the opportunity for bias related to self-report. However, because of the certificate of need statute, there are likely

Table 2 Risk-Adjusted* Odds Ratio for In-Hospital Mortality by Various Annual Hospital and Physician Volume Thresholds for Primary PCI

Threshold	Group	Hospitals (n)	Patients (n)	Mortality (%)	OR (95% CI)
25/yr	≤25/yr	11	410	5.37	Reference
	>25/yr	30	6,911	3.62	0.61 (0.34–1.10)
50/yr	≤50/yr	18	1,148	5.40	Reference
	>50/yr	23	6,173	3.40	0.58 (0.38–0.88)
75/yr	≤75/yr	29	3,159	4.24	Reference
	>75/yr	12	4,162	3.32	0.82 (0.57–1.17)
Physicians (n)					
10/yr	≤10/yr	174	2,083	4.90	Reference
	>10/yr	92	5,238	3.25	0.66 (0.48–0.92)
20/yr	≤20/yr	237	4,791	4.17	Reference
	>20/yr	29	2,530	2.85	0.63 (0.44–0.91)
30/yr	≤30/yr	253	5,855	3.96	Reference
	>30/yr	13	1,466	2.73	0.87 (0.56–1.33)

*Risk adjusted for the New York State PCI Risk Score.

CI = confidence interval; OR = odds ratio; other abbreviation as in Table 1.

to be few truly low-volume hospitals and providers in New York State compared with other states without similar regulations. Nonetheless, both hospital and physician volume remained independent predictors of outcome, albeit at a greater threshold than has been reported in the other studies.

Physician volume was a powerful effect modifier of hospital volume on outcome. Potential explanations as to why low-volume physicians had worse outcomes in low-volume hospitals include a disproportionate case mix of high-risk patients, care-related differences in low-volume hospitals, or operator inexperience. We performed risk adjustment to account for differences in case mix and stratified analyses to equalize the effect of care-related differences. Despite these measures, low physician volume was an independent predictor, leaving physician inexperience as the most plausible explanation for this effect. It is generally accepted that primary PCI requires a discrete set of clinical judgments, adjunctive medication use, and procedural skills from elective PCI. It is also reflected in the minimum volume recommendations in current guidelines for performance of PCI (20,21). The threshold at which benefit was observed in this analysis is similar to that in the current recommendations for minimum procedural volume for

initial credentialing and maintenance of competency in primary PCI (21). Thus, it would appear from our analysis that, all else being equal, a minimum level of practice in primary PCI is required to achieve better outcomes.

Because low-volume hospitals demonstrated worse outcome than high-volume hospitals in this analysis, it does not necessarily follow that primary PCI in community hospitals ought to be avoided. Only 4 of 41 hospitals performed primary PCI in New York State at this time without surgical backup, limiting our statistical power to demonstrate significant differences in outcome. Similar considerations were also likely to have resulted in the seeming equivalence in outcome between low- and high-volume physicians in low-volume hospitals. However, unlike previous studies of community hospital primary PCI, where the majority of procedures were performed by experienced physicians (14,15), in this unselected “real-world” experience, primary PCI in low-volume hospitals was performed equally by high- and low-volume physicians. On the other hand, high-volume hospitals did not entirely equalize outcomes between low- and high-volume operators (Table 3). Although these results remain to be validated, they would suggest that once system-related efficiencies are accessible to all

Table 3 Average Mortality by Physician and Hospital Volume

Physician Volume	Hospital Volume	Patients, n	Observed Mortality*	Risk-Adjusted Mortality Rate†
>10/yr (n = 90)	>50/yr	4,712	3.2 (0.33)	3.8 (0.42)
>10/yr (n = 36)	≤50/yr	526	3.5 (0.90)	4.8 (1.23)
≤10/yr (n = 140)	>50/yr	1,461	4.2 (0.90)	6.5 (2.12)
≤10/yr (n = 97)	≤50/yr	622	6.7 (1.6)‡	8.4 (2.73)§
>20/yr (n = 29)	>50/yr	2,424	2.8 (0.40)	3.5 (4.27)
>20/yr (n = 10)	≤50/yr	106	3.0 (1.9)	2.6 (1.39)
≤20/yr (n = 201)	>50/yr	3,749	4.0 (0.6)	5.7 (1.50)
≤20/yr (n = 123)	≤50/yr	1,042	6.1 (1.2)	7.9 (2.16)

*Average primary PCI mortality rate for physicians in the volume category is presented with the SEM within parentheses. †Adjusted for the New York State PCI Risk Score. ‡p = 0.03 compared with physician volume >10/year and hospital volume >50/year category. §p = 0.09 compared with physician volume >10/year and hospital volume >50/year category. ||p = 0.01 compared with physician volume >20/year and hospital volume >50/year category.

Abbreviations as in Table 1.

physicians, operator experience may be an important determinant of outcome.

Study limitations. Although we examined the statewide practice of primary PCI by using a well-characterized public dataset, several limitations need to be acknowledged. To begin with, currently measured metrics of system-wide quality, such as door to balloon time, were unavailable to us for this time period (22). Therefore, the extent to which volume-related differences in outcome were confounded by delays in treatment and other processes of care cannot be determined. Because of the stringent certificate of need program, the number of centers performing a low volume of PCI procedures was few and may have resulted in a higher volume threshold than has been recommended in the guidelines. Thus, whether these thresholds for low-volume hospitals might apply to other states with a different spread in hospital and physician volume warrants further investigation. Finally, although we focused the effect on in-hospital mortality as measure of outcome, other reasonable outcome measures exist that could capture the effect of hospital or physician experience; these include post-procedural major adverse cardiac events and in-hospital bleeding.

Despite these limitations, our results support the existence of a dynamic interaction among hospital volume, physician volume, and in-hospital mortality after primary PCI. They suggest possible targets for policymakers wishing to improve patient access to primary PCI without sacrificing safety. These include the need to adhere to current guidelines for minimum volume requirements for both hospitals and physicians performing primary PCI and the monitoring of primary PCI performance by low-volume operators.

Reprint requests and correspondence: Dr. V. S. Srinivas, Montefiore Medical Center, 1825 Eastchester Road, Suite W1-120, Bronx, New York 10461. E-mail: vsriniva@montefiore.org.

REFERENCES

1. Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). *J Am Coll Cardiol* 2004;44:E1-211.
2. Keeley EC, Boura JA, Grines CL. Primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction: a quantitative review of 23 randomised trials. *Lancet* 2003;361:13-20.
3. Jacobs AK, Antman EM, Ellrodt G, et al. Recommendation to develop strategies to increase the number of ST-segment-elevation myocardial infarction patients with timely access to primary percutaneous coronary intervention. *Circulation* 2006;113:2152-63.
4. Jacobs AK. Regionalized care for patients with ST-elevation myocardial infarction: it's closer than you think. *Circulation* 2006;113:1159-61.
5. Wharton TP Jr. Should patients with acute myocardial infarction be transferred to a tertiary center for primary angioplasty or receive it at qualified hospitals in community? The case for community hospital angioplasty. *Circulation* 2005;112:3509-20, discussion 3534.
6. Ting HH, Rihal CS, Gersh BJ, et al. Regional systems of care to optimize timeliness of reperfusion therapy for ST-elevation myocardial infarction: the Mayo Clinic STEMI Protocol. *Circulation* 2007;116:729-36.
7. Le May MR, So DY, Dionne R, et al. A citywide protocol for primary PCI in ST-segment elevation myocardial infarction. *N Engl J Med* 2008;358:231-40.
8. Canto JG, Every NR, Magid DJ, et al., for the National Registry of Myocardial Infarction 2 Investigators. The volume of primary angioplasty procedures and survival after acute myocardial infarction. *N Engl J Med* 2000;342:1573-80.
9. Magid DJ, Calonge BN, Rumsfeld JS, et al. Relation between hospital primary angioplasty volume and mortality for patients with acute MI treated with primary angioplasty vs thrombolytic therapy. *JAMA* 2000;284:3131-8.
10. Vakili BA, Kaplan R, Brown DL. Volume-outcome relation for physicians and hospitals performing angioplasty for acute myocardial infarction in New York State. *Circulation* 2001;104:2171-6.
11. Spaulding C, Morice MC, Lancelin B, et al. Is the volume-outcome relation still an issue in the era of PCI with systematic stenting? Results of the greater Paris area PCI registry. *Eur Heart J* 2006;27:1054-60.
12. Tsuchihashi M, Tsutsui H, Tada H, Shihara M, Takeshita A, Kono S. Volume-outcome relation for hospitals performing angioplasty for acute myocardial infarction: results from the Nationwide Japanese Registry. *Circ J* 2004;68:887-91.
13. Hannan EL, Wu C, Walford G, et al. Volume-outcome relationships for percutaneous coronary interventions in the stent era. *Circulation* 2005;112:1171-9.
14. Wharton TP Jr., Grines LL, Turco MA, et al. Primary angioplasty in acute myocardial infarction at hospitals with no surgery on-site (the PAMI-No SOS study) versus transfer to surgical centers for primary angioplasty. *J Am Coll Cardiol* 2004;43:1943-50.
15. Aversano T, Aversano LT, Passamani E, et al. Thrombolytic therapy vs primary percutaneous coronary intervention for myocardial infarction in patients presenting to hospitals without on-site cardiac surgery: a randomized controlled trial. *JAMA* 2002;287:1943-51.
16. Hannan EL, Raciz MJ, Arani DT, McCallister BD, Walford G, Ryan TJ. A comparison of short- and long-term outcomes for balloon angioplasty and coronary stent placement. *J Am Coll Cardiol* 2000;36:395-403.
17. Wu C, Hannan EL, Walford G, et al. A risk score to predict in-hospital mortality for percutaneous coronary interventions. *J Am Coll Cardiol* 2006;47:654-60.
18. Cleveland W. Robust locally weighted regression and smoothing scatterplots. *J Am Stat Assoc* 1979;74:829-36.
19. Zeger SL, Liang KY, Albert PS. Models for longitudinal data: a generalized estimating equation approach. *Biometrics* 1988;44:1049-60.
20. King SB 3rd, Smith SC Jr., Hirshfeld JW Jr., et al. 2007 focused update of the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (2007 Writing Group to Review New Evidence and Update the ACC/AHA/SCAI 2005 Guideline Update for Percutaneous Coronary Intervention). *J Am Coll Cardiol* 2008;51:172-209.
21. King SB 3rd, Aversano T, Ballard WL, et al. ACCF/AHA/SCAI 2007 update of the Clinical Competence Statement on Cardiac Interventional Procedures: a report of the American College of Cardiology Foundation/American Heart Association/American College of Physicians Task Force on Clinical Competence and Training (Writing Committee to Update the 1998 Clinical Competence Statement on Recommendations for the Assessment and Maintenance of Proficiency in Coronary Interventional Procedures). *J Am Coll Cardiol* 2007;50:82-108.
22. Brodie BR, Hansen C, Stuckey TD, et al. Door-to-balloon time with primary percutaneous coronary intervention for acute myocardial infarction impacts late cardiac mortality in high-risk patients and patients presenting early after the onset of symptoms. *J Am Coll Cardiol* 2006;47:289-95.

Key Words: primary angioplasty ■ coronary disease ■ outcome ■ hospital volume ■ physician volume.