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Impact of Hospital Volume on Racial Disparities in Cardiovascular Procedure Mortality

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OBJECTIVES We assessed use of low-volume hospitals by race and ethnicity for major cardiovascular procedures and determined whether hospital volume is an important factor explaining racial and ethnic differences in post-procedure mortality.

BACKGROUND Low hospital volume predicts mortality for cardiovascular procedures and could be a mediator of racial and ethnic differences in procedure outcomes.

METHODS We analyzed data from 719,679 hospitalizations for cardiac artery bypass grafting (CABG), percutaneous transluminal coronary angioplasty (PTCA), abdominal aortic aneurysm (AAA) repair, and carotid endarterectomy (CEA) from 1998 to 2001 using the Nationwide Inpatient Sample. We used multivariate logistic regression to assess whether race predicts use of low-volume hospitals and the relative contribution of hospital volume to racial disparity in post-procedure in-hospital mortality.

RESULTS Black and Hispanic patients were more likely than white patients to receive cardiovascular procedures in low-volume hospitals. Black patients had greater risk-adjusted mortality than white patients after elective AAA repair (odds ratio [OR], 1.84; 95% confidence interval [CI], 1.20 to 2.84), CABG (OR, 1.19; 95% CI, 1.06 to 1.33), and CEA (OR, 1.56; 95% CI, 1.07 to 2.27), but not PTCA. Hispanic patients did not have higher risk-adjusted mortality than white patients. Adjusting for hospital volume did not substantially reduce the relative risk of death for black patients compared with white patients.

CONCLUSIONS Black and Hispanic patients were more likely to receive cardiovascular procedures in low-volume hospitals, but hospital volume did not explain a large proportion of racial differences in post-procedure mortality. Additional research is needed to determine why black patients have increased mortality after cardiovascular procedures and how these mortality rates can be reduced. (J Am Coll Cardiol 2006;47:417–24) © 2006 by the American College of Cardiology Foundation

Research over the past two decades has shown that both quality of care and health outcomes are worse for minority Americans compared with white Americans (1,2). The Institute of Medicine (1) and federal Department of Health and Human Services (3) have placed the elimination of these disparities at the forefront of the nation's health policy

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agenda. The mechanisms underlying these disparities are rooted in many historical and contemporary factors, including differential access to high-quality care, socioeconomic inequalities, and racial discrimination (4).

A prominent feature of health care in the U.S. is the stark racial and ethnic difference in the context of where care is delivered. For example, minority patients are 43% of patients seen in safety-net hospitals, but only 19% of patients seen at other hospitals (1). A recent study found that among Medicare enrollees, a relatively small proportion of physicians accounted for 80% of all primary care visits for black patients, and these physicians reported greater barriers in delivering high-quality care to their patients (5). An emerging hypothesis is that this clustering of minority patients among particular hospitals and providers may significantly contribute to observed racial disparities in health care outcomes, particularly if these hospitals have fewer resources or providers face greater systemic barriers in providing effective care for their patients.

This hypothesis is supported by findings that the site of care can be a powerful predictor of outcomes. For many medical and surgical conditions, patients who receive care in high-volume hospitals have a lower mortality rate compared with those receiving care in low-volume hospitals, even after adjusting for clinical and demographic factors (6–8). A study of hospital outcomes in California found that 600 deaths in the state could be attributed to increased mortality rates in low-volume hospitals (9). Based on these findings, some health-care purchasers have recently attempted to increase the proportion of patients who are referred to high-volume hospitals (10). Because these initiatives are

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Abbreviations and Acronyms

AAA = abdominal aortic aneurysm
AHRQ = Agency for Healthcare Research and Quality
CABG = coronary artery bypass graft
CEA = carotid endarterectomy
CON = certificate of need
ICD-9-CM = *International Classification of Diseases-9th edition-Clinical Modification*
NIS = Nationwide Inpatient Sample
PTCA = percutaneous transluminal coronary angioplasty

targeted to health plans and purchasers, they may have a greater impact on white patients, who are more likely to have employer-based private insurance, rather than minority patients, who are more likely to have Medicaid or no insurance.

The objectives of this study were to assess the use of low-volume hospitals by race and ethnicity for major cardiovascular procedures in a nationally representative cohort and to determine whether hospital volume is an important factor explaining racial and ethnic differences in post-procedure mortality.

METHODS

Sources of data. We used data from the 1998 to 2001 Nationwide Inpatient Sample (NIS), which contains information on approximately 29 million hospitalizations in nearly 1,000 non-governmental acute care hospitals (11). The data include information on patient demographics, hospital characteristics, up to 15 International Classification of Diseases (ICD-9) diagnostic and procedure codes, payer, length of stay, and vital status at discharge. The database is maintained by the Agency for Healthcare Research and Quality (AHRQ) as part of the Healthcare Cost and Utilization Project. Because this study used publicly available data without personal identifiers, it was deemed exempt from institutional review by the Committee on Human Studies at Harvard Medical School.

Patient population. We obtained data on 719,679 hospital discharges in the NIS from 1998 to 2001 in 21 states that collected data on race and had principal procedure codes for the following four vascular procedures: abdominal aortic aneurysm (AAA) repair, coronary artery bypass graft (CABG), percutaneous transluminal coronary angioplasty (PTCA), and carotid endarterectomy (CEA). We selected these four procedures based on evidence linking post-procedure mortality to hospital volume (6,7,9,12–16) and their designation as AHRQ Inpatient Quality Indicators (17). The AHRQ provides detailed information for producing these quality indicators using the data specifically available in the NIS, including diagnostic and procedure codes, as well as inclusion and exclusion criteria such as age and major diagnosis codes. The identification of major procedures using *International Classification of Diseases-9th edition-Clinical Modification* (ICD-9-CM) codes from hospital administrative data has been shown to be highly accurate in several studies (18–20).

For AAA repair we identified patients with a diagnosis of AAA (ICD-9-CM codes 441.3 and 441.4) and a procedure code of AAA repair or resection (ICD-9-CM codes 38.34, 38.44, and 38.64). For CABG surgery, we selected patients with an ICD-9-CM procedure code of 36.10 through 36.19. Percutaneous transluminal coronary angioplasty was defined as those hospitalizations that contained an ICD-9-CM procedure code of 36.01, 36.02, 36.05, or 36.06. We defined CEA cases as those hospitalizations with an ICD-9-CM procedure code of 38.12. We excluded all hospitalizations with major diagnosis code 14 (pregnancy/childbirth), major diagnosis code 15 (newborns) or age <40 years.

The NIS codes race and Hispanic ethnicity as a single data element, with the following categories: white, black, Hispanic, Asian or Pacific Islander, Native American, and other. If the source state reported race and Hispanic ethnicity as separate data elements, then ethnicity takes precedence over race in setting the NIS value for this combined variable.

Hospital volume. We determined hospital procedure volumes by calculating the total number of procedures in the sample for each unique hospital identifier per year. To minimize the likelihood of procedure coding errors, we eliminated one hospital with fewer than five CABG surgeries and 12 hospitals that had fewer than five PTCA procedures in a given year. We included all hospitals with one or more CEA or AAA procedures because these procedures are performed less frequently and therefore could potentially occur fewer than five times per year in a given institution. We divided hospitals into quartiles according to their annual volume for a given procedure and assigned this number to all patients who underwent a procedure in that hospital during the corresponding year.

Statistical analysis. To determine whether race/ethnicity was associated with receiving care in a low-volume hospital, we calculated the proportion of patients who received care within each quartile of hospital volume by race and ethnicity. We also conducted bivariate analyses to assess the likelihood of undergoing surgery in a low-volume hospital by the following covariates: age, gender, median income (based on hospital zip code), location (urban vs. rural), region (Northeast, Midwest, South, West), payer (Medicare, Medicaid, private insurance, and no payer), type of admission (elective, urgent, emergent), and number of co-morbidities. We determined the adjusted impact of race on the likelihood of receiving care in a low-volume hospital (below the median) by constructing logistic regression models that included the above covariates and indicator variables for race/ethnicity (black and Hispanic). To determine whether our findings were reproducible across different volume thresholds, we conducted sensitivity analyses

Table 1. Patient Characteristics by Procedure Type

Patient Characteristics	AAA Repair	CABG	PTCA	CEA
Sample size	21,827	227,863	378,920	91,069
Mean age, yrs	72.1	66.4	64.7	71.2
Male (%)	78	70	65	57
Race (%)				
White	91	85	84	91
Black	4	5	6	3
Hispanic	2	5	5	3
Other	3	5	5	2
Insurance type (%)				
Medicare	76	55	50	73
Medicaid	2	4	4	2
Private	20	37	41	23
Self pay	1	2	3	1
Other	2	2	2	1
Median income (%)				
<$25,000	4	5	5	5
$25,000–$34,999	31	30	29	33
$35,000–$44,999	29	29	28	30
>$45,000	35	36	38	33
Mean number of comorbidities	1.83	1.62	1.27	1.59
Admission type (%)				
Elective	59	39	31	67
Non-elective	41	61	69	33
Hospital location (%)				
Urban	94	97	97	92
Rural	6	3	3	8
Hospital region* (%)				
Northeast	25	25	24	23
Midwest	12	11	12	13
South	48	48	47	50
West	15	16	17	14

*Northeast states include CT, MA, NY, NJ, PA, RI, and VT; Midwest states include IA, KS, and MO; Southern states include FL, MD, NC, SC, TN, TX, and VA; Western states include AZ, CA, CO, and HI.

AAA = abdominal aortic aneurysm; CABG = coronary artery bypass graft; CEA = carotid endarterectomy; PTCA = percutaneous transluminal coronary angioplasty.

using the 25th and 75th percentile as cutoffs to define low-volume hospitals.

We used the chi-square test to compare unadjusted in-hospital mortality rates for black and Hispanic patients relative to white patients for each of the four procedures studied. Analyses of AAA repair mortality rates were stratified by elective or non-elective status because of the large differences in clinical selection and procedure-related mortality of these two patient groups. To adjust for severity of illness and demographic factors, we constructed a logistic regression model predicting mortality for each procedure with the following independent variables: age (three categories, <65, 65 to 79, and >79 years), gender, type of admission (elective, urgent, and emergency), presence of a principal diagnosis of myocardial infarction (CABG and PTCA only), and presence of any of 30 comorbidities using the risk adjustment method described by Elixhauser et al. (21). The C statistics for these regression models ranged from 0.78 to 0.86.

We used the predicted output from this first model as an independent variable along with indicator variables for race/ethnicity (black, white, or Hispanic) and the following specific co-morbid conditions: chronic lung disease, congestive heart failure, hypertension, diabetes, and peripheral vascular disease. We analyzed the impact of hospital volume on racial disparities in risk-adjusted outcomes by comparing regression models predicting mortality by race and ethnicity with and without adjustment for hospital volume. To further analyze the contribution of income and geography to mortality differences by race, we subsequently included median household income by zip code, census region, and rural residence in these regression models.

We used SAS-callable SUDAAN (version 8.0.1, Research Triangle Institute, Research Triangle Park, North Carolina) to account for the complex sampling scheme and generalized estimating equations to adjust for clustering of patients within hospitals. We present two-tailed p values or 95% confidence intervals for all statistical comparisons.

RESULTS

Patient and hospital characteristics. For each of the four cardiovascular procedures, patients were predominantly male and white, with minorities making up only 7% to 12% of the patient population (Table 1). The CEA and AAA repair were performed on patients who tended to be older,

Table 2. Hospital Volume for Cardiovascular Procedures by Race and Ethnicity

Procedure	White (%)	Black (%)	Hispanic (%)
AAA repair			
76th–100th percentile (>20/yr)	66	56	44
51st–75th percentile (10–20/yr)	21	24	32
26th–50th percentile (4–9/yr)	10	14	15
0–25th percentile (<4/yr)	3	6	9
p Value (relative to white patients)	NA	<0.001	<0.001
CABG			
76th–100th percentile (>528/yr)	55	56	38
51st–75th percentile (294–528/yr)	25	23	27
26th–50th percentile (175–293/yr)	14	11	20
0–25th percentile (<175/yr)	6	10	15
p Value (relative to white patients)	NA	<0.001	<0.001
PTCA			
76th–100th percentile (>769/yr)	56	51	48
51st–75th percentile (458–769/yr)	26	30	24
26th–50th percentile (238–457/yr)	14	13	20
0–25th percentile (<238/yr)	4	6	8
p Value (relative to white patients)	NA	<0.001	<0.001
CEA			
76th–100th percentile (>78/yr)	65	51	46
51st–75th percentile (37–78/yr)	23	30	29
26th–50th percentile (14–36/yr)	10	13	18
0–25th percentile (<14/yr)	2	6	7
p Value (relative to white patients)*	NA	<0.001	<0.001

*Chi-square test.
NA = not applicable. Other abbreviations as in Table 1.

have more co-morbid conditions, and have an increased prevalence of Medicare coverage. Percutaneous transluminal coronary angioplasty and CABG were performed on relatively younger patients who were less likely to have Medicare coverage. Over 90% underwent procedures in urban hospitals. Annual numbers of hospital procedures were substantially greater for PTCA and CABG than for CEA or AAA repair.

Racial and ethnic disparities in the use of high-volume and low-volume hospitals. For all four procedures, both minority groups were more likely to use low-volume hospitals relative to white patients (Table 2). The absolute difference in low-volume hospital use (defined as below the median) between white and black patients ranged from 0.6% (PTCA) to 7.3% (AAA repair). For Hispanic patients, the absolute difference in use of low-volume hospitals compared with that for white patients ranged from 9.3% (PTCA) to 15.6% (CABG).

After adjusting for multiple demographic and clinical characteristics (Table 3), black and Hispanic patients were significantly more likely to receive all four cardiovascular procedures in low-volume hospitals. This relationship was further confirmed in sensitivity analyses that defined low-volume hospitals as the lowest quartile or the lowest three quartiles. For both black and Hispanic patients, the increased use of low-volume hospitals relative to that for white patients was greatest for CEA and lowest for PTCA. Region, rural setting, Medicaid insurance, lack of insurance, and non-elective admission were significant predictors of low-volume hospital use. Patients in the West had the highest use of low-volume hospitals for all four procedures. Patients in the Northeast were less likely to use low-volume hospitals for PTCA and CABG, and patients from the Midwest and South were less likely to use low-volume hospitals for AAA repair and CEA. Age, gender, median household income, and number of co-morbid medical conditions were not consistently associated with or were weak predictors of low-volume hospital use.

Racial and ethnic disparities in cardiovascular procedure mortality. Black patients experienced increased in-hospital mortality for elective AAA repairs, CABG, and CEA (Table 4). There was no significant difference in mortality between white and black patients after PTCA. Hispanic patients had an increased unadjusted risk of death relative to white patients after AAA repair (14.9% vs. 10.8%, p = 0.01), but Hispanic mortality rates after AAA repair did not differ from rates for white patients when stratified for elective or non-elective procedures. Non-elective AAA repairs (with markedly higher mortality rates) were much more common among black patients (53%) and Hispanic patients (56%) compared with white patients (39%). Hispanic patients' risk of in-hospital death after CABG, PTCA, and CEA was not significantly different from that for white patients.

After adjusting for age, gender, co-morbidities, and urgency of admission, black patients had increased in-hospital mortality relative to that for white patients for elective AAA repair (odds ratio [OR], 2.06; 95% confidence interval [CI], 1.32 to 3.21), CABG (OR, 1.20; 95% CI, 1.06 to 1.34), and CEA (OR, 1.79; 95% CI, 1.22 to 2.62) (Table 5). Black patients did not show higher mortality rates than white patients for PTCA or non-elective AAA. Hispanic patients did not have higher adjusted mortality than did white patients for any of these four procedures (Table 5).

Volume was a significant predictor of in-hospital mortality. In unadjusted analyses, the absolute difference in post-procedure mortality between the highest and lowest quartile hospitals ranged from 0.27% (CEA) to 12.6% (non-elective AAA). After adjustment for age, gender, urgency, and co-morbidity, hospitals in the lowest volume quartile had a 28% (CABG) to 130% (AAA) increase in the risk-adjusted odds of mortality relative to high-volume hospitals. However, we found no statistically significant differences in racial disparities between high- and low-volume hospitals. For elective AAA, the adjusted black-white mortality difference was 3.5% in low-volume hospitals and 3.9% in high-volume hospitals. For CABG, the adjusted black-white mortality difference was 0.4% and 0.7% in low- and high-volume hospitals, respectively. For CEA, this difference was 0.7% in low-volume hospitals and 0.5% in high-volume hospitals.

After adjusting for hospital volume, we found little change in the relative odds of death for black and Hispanic

Table 3. Adjusted Predictors of Low-Volume Hospital Use by Procedure*

	AAA Repair	CABG	PTCA	CEA
Race				
White	Ref	Ref	Ref	Ref
Black	1.89 (1.55–2.30)	1.34 (1.27–1.41)	1.10 (1.06–1.15)	2.03 (1.83–2.25)
Hispanic	2.10 (1.66–2.65)	2.01 (1.92–2.11)	1.56 (1.50–1.62)	2.34 (2.11–2.58)
Age, yrs				
<65	0.92 (0.80–1.07)	1.07 (1.03–1.10)	1.06 (1.03–1.08)	0.94 (0.88–1.01)
65–79	Ref	Ref	Ref	Ref
>79	1.24 (1.12–1.38)	0.99 (0.95–1.03)	0.99 (0.96–1.02)	1.14 (1.08–1.20)
Gender				
Male	Ref	Ref	Ref	Ref
Female	1.12 (1.02–1.24)	1.02 (1.00–1.05)	1.05 (1.04–1.07)	1.10 (1.05–1.15)
Median income				
≥$35,000	Ref	Ref	Ref	Ref
<$35,000	1.12 (1.02–1.23)	0.86 (0.84–0.88)	1.10 (1.08–1.12)	1.01 (0.97–1.06)
Hospital location				
Urban	Ref	Ref	Ref	Ref
Rural	7.76 (6.89–8.74)	4.09 (3.93–4.25)	1.57 (1.52–1.63)	7.03 (6.68–7.41)
Hospital region				
Northeast	Ref	Ref	Ref	Ref
Midwest	0.38 (0.32–0.44)	6.33 (6.08–6.58)	4.74 (4.59–4.89)	0.45 (0.42–0.49)
South	0.56 (0.50–0.62)	2.33 (2.25–2.42)	2.38 (2.32–2.45)	0.45 (0.43–0.47)
West	1.18 (1.04–1.33)	10.91 (10.49–11.34)	7.16 (6.95–7.37)	1.49 (1.40–1.59)
Payer				
Medicare	Ref	Ref	Ref	Ref
Medicaid	2.00 (1.51–2.66)	1.07 (1.01–1.14)	1.13 (1.08–1.18)	1.45 (1.28–1.65)
Private	1.18 (1.04–1.35)	0.93 (0.90–0.97)	1.01 (0.98–1.04)	1.15 (1.07–1.23)
Uninsured	1.50 (1.03–2.18)	1.38 (1.28–1.49)	1.42 (1.35–1.50)	1.44 (1.16–1.79)
Type of admission				
Elective	Ref	Ref	Ref	Ref
Non-elective	1.66 (1.52–1.82)	0.94 (0.92–0.97)	1.42 (1.39–1.45)	1.27 (1.21–1.33)
Co-morbidities, n				
0–1	Ref	Ref	Ref	Ref
>1	0.99 (0.91–1.07)	1.00 (0.98–1.02)	0.99 (0.97–1.01)	1.07 (1.03–1.12)

*Low-volume hospitals were defined as having below the median number of procedures performed per year; odds ratios reflect results of multivariate logistic regression with adjustment for sampling weights and clustering by hospital.
Abbreviations as in Table 1.

patients relative to that for white patients (Table 5). Among the three procedures for which there was a significant difference in the adjusted risk of death between black and white patients, none of the odds ratios were reduced by more than 6% after further adjusting for hospital volume. Of note, adding median household income by zip code, census region, and rural residence to these models had minimal effects on the relative odds of death for black patients after elective AAA (OR, 1.98; 95% CI, 1.21 to 3.34), CABG (OR, 1.23; 95% CI, 1.09 to 1.39), or CEA (OR, 2.11; 95% CI, 1.43 to 3.11).

DISCUSSION

In this large, multiregional cohort, black and Hispanic patients were more likely to receive cardiovascular procedures in hospitals that performed a lower volume of these procedures. Black patients had significantly greater risk-adjusted mortality for three of the four vascular procedures that we studied. However, adjusting for hospital volume explained only a small proportion of these racial disparities in outcome.

The small contribution of hospital volume to black-white disparities in post-procedure mortality is probably attribut-

Table 4. Unadjusted In-Hospital Mortality for Cardiovascular Procedures by Race and Ethnicity

Procedure	White Mortality Rate (%)	Black Mortality Rate (%)	p Value*	Hispanic Mortality Rate (%)	p Value*
Elective AAA repair	4.0	7.8	0.01	5.3	0.39
Non-elective AAA repair	21.1	21.1	0.97	22.7	0.53
CABG	3.7	4.3	0.001	3.6	0.72
PTCA	1.5	1.6	0.50	1.7	0.17
CEA	0.8	1.5	0.002	1.1	0.08

*p values indicate unadjusted chi-square comparisons with white patients.
Abbreviations as in Table 1.

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Table 5. Impact of Hospital Volume on Risk-Adjusted Odds Ratios for Mortality by Race and Ethnicity

	Adjusted Odds Ratio (Model 1)*	Adjusted Odds Ratio (Model 2)†
Elective AAA repair		
White	Ref	Ref
Black	2.19 (1.37–3.52)	2.13 (1.32–3.42)
Hispanic	1.35 (0.67–2.71)	1.30 (0.65–2.62)
Non-elective AAA repair		
White	Ref	Ref
Black	0.94 (0.71–1.24)	0.90 (0.67–1.19)
Hispanic	1.16 (0.87–1.55)	1.06 (0.80–1.42)
CABG		
White	Ref	Ref
Black	1.27 (1.12–1.44)	1.26 (1.12–1.42)
Hispanic	1.04 (0.91–1.20)	1.01 (0.88–1.16)
PTCA		
White	Ref	Ref
Black	1.13 (0.96–1.32)	1.11 (0.95–1.30)
Hispanic	1.14 (0.98–1.32)	1.10 (0.96–1.27)
CEA		
White	Ref	Ref
Black	1.93 (1.32–2.82)	1.90 (1.30–2.78)
Hispanic	1.42 (0.92–2.17)	1.38 (0.90–2.12)

All odds ratios derived from logistic regression with adjustment for sampling weights and clustering by hospital. *Model 1: Controlling for age, gender, Elixhauser comorbidity, presence of any of five specific comorbid medical conditions (chronic lung disease, congestive heart failure, diabetes, peripheral vascular disease, and hypertension), urgency of admission (elective vs. non-elective), and presence of myocardial infarction as a principal diagnosis (PTCA and CABG only). †Model 2: All covariates of Model 1 plus hospital volume.

Abbreviations as in Table 1.

able to two factors. First, relatively few black patients were treated in low-volume hospitals. Therefore, adding terms for volume resulted in little change in the relationship between race and mortality. Second, we found that the magnitude of racial differences in mortality was very similar in low-volume and high-volume hospitals.

Hispanic patients had higher mortality than white patients after AAA repair, but this difference was largely explained by substantially higher rates of urgent and emergency procedures that were observed for Hispanic patients. Higher rates of urgent and emergency AAA repair were also observed for black patients. These findings suggest inadequate screening or delayed referrals for surgery among Hispanic and black patients with aortic aneurysms (22). Hispanic patients did not have increased mortality for CABG, PTCA, or CEA, despite receiving these procedures more frequently in low-volume hospitals.

The more frequent use of low-volume hospitals by minority patients may have several potential explanations. Because minority patients are less likely to have a usual source of care (1), they may have less opportunity to be referred to specialists who perform a high volume of cardiovascular procedures. Additionally, physicians who care for minority patients have reported more difficulty finding appropriate specialty care for their patients (5). Residential segregation may be another possible explanation. Several studies have documented the relatively diminished health resources and use in minority neighborhoods (23,24). Low-volume hospitals may also be disproportionately located in minority communities that have lower overall rates of use of procedures.

The equivalent mortality rates for Hispanic patients relative to white patients despite receiving more frequent care in low-volume hospitals is similar to results of other studies examining health outcomes for Hispanic patients. Although Hispanic adults generally have worse access to care, higher rates of non-insurance, and a lower socioeconomic profile than white adults, they do not have increased mortality for many medical conditions (25–27). This paradoxical finding may arise from a possible selection bias when studying healthier Hispanic individuals who are able to emigrate from other countries (28,29).

These findings are consistent with those from other studies indicating that minority patients may have diminished access to high-quality providers. In a study of Medicare managed care plans, black enrollees clustered within low-performing plans, and this phenomenon accounted for a substantial portion of the disparity between black and white patients in important quality indicators such as receipt of beta-blocker therapy after myocardial infarction and eye examinations for diabetic patients (30). A study of CABG surgery outcomes in New York state found that after controlling for income and hospital characteristics, black and Asian patients were more likely to receive care from surgeons with higher risk-adjusted mortality (31).

Our finding that patients in Western states were 7 to 10 times more likely to receive PTCA and CABG in low-volume hospitals is consistent with studies that have examined the association of state certificate-of-need (CON) policies regulating cardiac procedures with hospital volume (32,33). Although all but one of the seven Northeastern states in our study have CON policies restricting the number of hospitals that provide complex cardiac procedures, the three states that comprised over 99% of our Western sample—California, Arizona, and Colorado—do not have these regulations. These data suggest that the CON policy has been effective in increasing the proportion of patients who undergo cardiac procedures in high-volume institutions, but further evaluation of other contributing factors would be needed to establish this connection.

Our results have several important implications. Although numerous studies have described racial disparities in referral for major cardiovascular procedures (1), clinicians should also recognize that black patients face markedly worse outcomes after some cardiovascular procedures with up to a two-fold increase in the risk of post-procedure mortality. Although access to high-volume hospitals is unlikely to account for these racial differences, other features of the site of care or individual clinical characteristics not captured in administrative data may play important roles in mediating disparities. Some researchers have speculated that disparities in referral patterns for invasive procedures may be more pronounced among low-risk individuals, leading to a selection bias of higher risk among minority patients undergoing procedures (34). Others have hypothesized that

black individuals may be more likely to undergo a potentially more aggressive and rapidly progressive variant of vascular disease (35). Finally, institutional characteristics other than hospital volume, such as financial resources, provider staffing, and availability of ancillary services, may be different in hospitals providing care to large numbers of minority patients. Further investigation of these and other potential mediators is warranted to develop interventions to eliminate these disparities in the future.

Our analysis was strengthened by the large, representative, and diverse patient population. Although many other studies of volume and outcome have relied on Medicare fee-for-service data, this study included non-elderly patients from a variety of payers. Indeed for PTCA and CABG, nearly half of the patients in our cohort were not covered by the Medicare program. We used inclusion and exclusion criteria that have been studied and validated in the NIS by previous researchers (17). Our analysis also adjusted for a large number of covariates that could potentially confound the association between race and receipt of care in a high-volume hospital.

Although the data contained up to 15 diagnosis codes and we used a previously validated risk-adjustment tool (21,36), the primary limitation of this study is that the NIS does not contain detailed clinical information on the specific indications for procedures and severity of illness for both the principal diagnosis and co-morbid conditions. It is therefore possible that these unmeasured aspects of disease severity may have partially explained some portion of the relationship between race, volume, and post-procedure mortality. However, other studies that have used more detailed clinical data to study the relationship between volume and outcome have confirmed results from administrative data (37,38). Because identifiers for surgeons and invasive cardiologists were not consistently available, we were unable to analyze the impact of physician volume. However, physician volume and hospital volume are highly correlated (8), so our finding of minority patients receiving care at low-volume hospitals suggests that they are also receiving care from low-volume surgeons and cardiologists.

We did not have access to individual incomes. Using aggregated zip code level income data could result in misclassification or underestimates of income effects (39). Data from hospital administrative sources may misclassify patients' race and ethnicity. A prior study of hospital discharge abstracts for patients with myocardial infarction admitted to two different hospitals in New York state within six months found that the racial classifications of these patients were acceptably reliable for patients designated as black (kappa = 0.89) or white (kappa = 0.72), but much less reliable for other racial categories (40). This study suggested that racial differences in cardiac treatment and outcomes may be underestimated when patients' race is misclassified. Information on 30-day mortality was unavailable, and therefore we could not analyze potential post-procedure mortality among patients who died after discharge. Finally, we were unable to assess underuse or overuse of these procedures. Differences in appropriate use may account for a larger portion of disparities in disease outcomes between white patients and minorities than differences in use of high-volume hospitals (41).

We conclude that minority patients are more likely to undergo surgery in hospitals that have less experience with complex cardiovascular procedures. The reasons behind this differential access to high-volume hospitals deserve further investigation. Although better access to high-volume hospitals may improve outcomes for both white and minority patients, this increased use of high-volume hospitals is unlikely to reduce substantially racial differences in post-procedure mortality.

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