Growing evidence suggests that disadvantaged populations have higher mortality rates after a wide range of surgical procedures. Coronary artery bypass graft (CABG) surgery is an example of a high-risk, routine procedure after which we observe significant disparities in operative mortality rates. A large study using National Inpatient Sample outcomes data from 1.2 million CABG procedures found that, compared with white men, in-hospital mortality was 55.6% higher for black women and 35.6% higher for black men. Another study using the Society of Thoracic Surgeons National Database, the largest clinical registry in this specialty, found that black patients have a 29% higher operative mortality for CABG surgery than white patients.

Although previous work has demonstrated the existence of these disparities, we have yet to understand their underlying mechanisms. Possible reasons for disparities between patient populations include differences in biology, comorbid conditions, differential treatment of nonwhite patients in hospitals, and disease severity. However, some previous evidence suggests that the area-level characteristics, such as socioeconomic status and limited access to low-mortality, high-quality hospitals, may also drive racial disparities in surgical mortality rates. Although several studies have described racial differences in outcomes, few have systematically examined the role of socioeconomic status and hospital quality in explaining these disparities.
We sought to understand the role of socioeconomic status, hospital quality, and hospital-specific patient demographics on the largely unexplained disparity in surgical outcomes between white and nonwhite patients. In this study, we used National Medicare Claims data from 2007-2008 to conduct risk-adjusted and hospital quality–adjusted analysis on data from white and nonwhite patients who underwent CABG surgery. We also compared operative mortality rates for white and nonwhite patients after stratifying hospitals according to the proportion of nonwhite patients treated.

Methods

Data Source and Population

We identified all CABG procedures performed between 2007 and 2008 in Medicare beneficiaries aged 65 years or older using the Medicare Analysis Provider and Review data files. These data files contain hospital discharge abstracts for US Medicare recipients and were used to compile patient characteristics and patient vital status at 30 days. Procedure and diagnostic codes 36.10 through 36.19 from the International Classification of Diseases, Ninth Revision, Clinical Modification were used to identify all CABG procedures, excluding those involving valve replacement. In the data analysis, patient race/ethnicity was designated as white, nonwhite, black, or Hispanic; blacks and Hispanics were studied in subgroup analysis.

Outcomes Variables

The primary outcome measure was death within 30 days or inhospital death. We then compared comorbid conditions and other factors between white and nonwhite patients. Risk adjustment involved controlling for patient factors such as age, sex, race, emergency admission, and comorbidity conditions (following the model designed by Elixhauser et al19). The Elixhauser index is a validated tool for measuring comorbidity conditions in large administrative databases. This index distinguishes comorbid conditions from complications, encompasses acute and chronic conditions, and accounts for conditions directly related to the reason for hospitalization.9 We then calculated risk-adjusted mortality rates after CABG surgery for each racial/ethnic group using multivariate logistic regression. Using 6 census variables, a summary socioeconomic status score was calculated for each zip code, with scores ranging from −20 to 20 (higher scores indicating greater socioeconomic advantage).10,11 These variables included 3 measures of wealth/income (median annual household income, median value of housing units, and proportion of households with interest, dividend, or rental income), 2 measures of education (proportions of high school and college graduates), and 1 measure of occupation/employment (proportion of employed residents with management, professional, or related occupations). A z score for each variable was estimated for every zip code and summed to obtain a summary socioeconomic score, which was then used to adjust for overall socioeconomic status.

Statistical Analysis

To explore the relative quality of hospitals that treat a disproportionate number of nonwhite patients, we organized hospitals into 3 equal-sized groups (terciles) according to the proportion of nonwhite patients undergoing CABG surgery. Within each tercile, logistic regression was used to calculate the risk-adjusted mortality rates for white and nonwhite patients.

Given the much higher mortality rates at hospitals treating the largest share of nonwhite patients, we decided to adjust for the hospitals where patients received care. We used a logistic regression model to adjust for patient factors, socioeconomic status, and hospital quality using hospital identifier variables.19 To account for variation in hospital-specific rates and identify racial differences in mortality rates between hospitals, we used fixed-effects regression to adjust for hospital-level factors. We recognized that socioeconomic status and hospital quality were potentially collinear variables and that there may be an ordering effect when we adjust for each sequentially. Therefore, it was not possible to determine their independent effects on the observed disparity.

We then calculated the proportion of the overall disparity explained by patient factors, socioeconomic status, and hospital quality. The relative change in the odds ratio (OR) between the base model and subsequently analyzed model describes this proportion and is defined as [ORu − OR]/(ORu−1), where ORu is the OR for the unadjusted mortality rate and OR is the OR after adjustment for the subsequent variable (ie, patient factors, socioeconomic status, and hospital differences). Repeating this analysis for black and Hispanic patients provided a more complete characterization of the disparities among the sample of nonwhite patients. We conducted all statistical analyses using Stata software (StataCorp) and established significance at P < .05.

Results

In the national Medicare population, CABG surgery was performed in 173,925 patients, of whom 14,882 (8.6%) were nonwhite. There was no significant difference in mean age, but there were variations in sex and comorbid conditions between white and nonwhite groups. The nonwhite group had a significantly lower proportion of male patients undergoing surgery (57.9% vs 69.5% for white patients) and higher proportions of patients with hypertension (69.8% vs 64.0%) or congestive heart failure (25.6% vs 18.2%). Nonwhite patients were more likely to present as emergency admissions (30.1% vs 24.6%) (Table 1).

The overall mortality for all patients undergoing CABG surgery was 3.6%. Nonwhite patients had a 34% higher risk of death after CABG surgery than white patients in the unadjusted analysis (OR, 1.33; 95% CI, 1.23-1.45). After grouping hospitals into terciles according to the proportion of nonwhite patients treated, the highest tercile (treating >17.7% nonwhite patients) showed the highest risk-adjusted mortality for both white and nonwhite patients (3.8% vs 4.8%). In contrast, hospitals in the lowest tercile (treating <2% nonwhite patients) had
After controlling for patient factors, nonwhite patients still had a 33% higher risk of death (OR, 1.33; 95% CI, 1.23-1.45). The effect of race on mortality rates was statistically significant with adjustment for just socioeconomic status (OR, 1.23; 95% CI, 1.13-1.34) or just hospital quality (OR, 1.13; 95% CI, 1.01-1.27). The ORs for Hispanic patients (unadjusted OR, 1.26; 95% CI, 1.05-1.50) changed as we sequentially adjusted for each variable: patient factors (OR, 1.32; 95% CI, 1.10-1.58), socioeconomic status (OR, 1.17; 95% CI, 0.96-1.41), and hospital quality (OR, 1.07; 95% CI, 0.88-1.27). The data showed that after adjustment for these 3 variables, the effect of race on mortality rates remained statistically significant for black but not for Hispanic patients (Table 2).

Further analysis allowed us to consider differences in outcomes for black and Hispanic patients independently (Table 3). The ORs for black patients (unadjusted OR, 1.35; 95% CI, 1.23-1.49) decreased after sequential adjustment for each variable: patient factors (OR, 1.32; 95% CI, 1.19-1.46), socioeconomic status (OR, 1.16; 95% CI, 1.04-1.29), and hospital quality (OR, 1.13; 95% CI, 1.01-1.27). The ORs for Hispanic patients (unadjusted OR, 1.26; 95% CI, 1.05-1.50) changed as we sequentially adjusted for each variable: patient factors (OR, 1.32; 95% CI, 1.10-1.58), socioeconomic status (OR, 1.17; 95% CI, 0.96-1.41), and hospital quality (OR, 1.07; 95% CI, 0.88-1.27). The data showed that after adjustment for these 3 variables, the effect of race on mortality rates remained statistically significant for black but not for Hispanic patients. When we evaluated the independent effects of our variables, hospital quality alone accounted for 54% of the observed disparity in Hispanic and 34% in black patients (Table 3).

Discussion
Compared with white patients, nonwhite patients have a significantly higher mortality rate after CABG surgery. Decreased access to high-quality, low-mortality hospitals explains a large proportion of the observed racial disparity in
mortality rates. When analyzed independently, differential access to high-quality care account for 35% of the disparity between white and nonwhite patients. Adjusting for comorbid conditions, socioeconomic status, and hospital quality, we were able to explain 53% of the disparity between white and nonwhite patients, 66% of that between black and white patients, and 73% of that between Hispanic and white patients. Our analysis found that hospital quality and socioeconomic status are somewhat collinear variables with similar overlapping effects. Coupled with the finding that hospitals treating a disproportionately high number of nonwhite patients have the highest mortality rates, this relationship suggests that both nonwhite and poorer populations seek care in lower-quality hospitals.

In other surgical populations, previous studies have highlighted poor hospital quality as an explanation for racial differences in outcomes. For example, Osborne et al. attributed 25% of the black-nonblack disparity in mortality after vascular surgery to black patients’ receiving care in lower-quality hospitals and 26% of the disparity to differences in socioeconomic status. Earlier studies by Bach et al. and Birkmeyer et al. suggest that black patients are less likely to receive care from board-certified physicians or high-volume surgeons, have decreased access to newer medical technology, and seek care at a smaller number of lower-quality medical centers. We conducted a contemporary analysis expanding these findings to another clinical population: a national sample of Medicare patients undergoing a common, high-risk operation. Adding to this body of work, our study showed that disparities between white and nonwhite patients can be explained in part by a lack of access to high-quality hospitals. Moreover, our stratified analysis of outcomes in black and Hispanic patients also demonstrated their tendency to go to higher-mortality hospitals.

Limitations of this study include a lack of generalizability owing to the exclusion from Medicare data of individuals younger than 65 years. Heart disease is primarily a disease of the elderly, and our study evaluated outcomes after a routine procedure performed mostly in individuals older than 65 years. The lack of patient-level socioeconomic data presents another limitation. The socioeconomic status variables in this study incorporated patient zip code-level data to estimate the effect of socioeconomic status. However, our variables allow us to understand the contextual, area-level effects of socioeconomic status. In addition, using mortality rates as our primary outcome measure and measure of hospital quality does not give us a full picture of the quality of care provided at the hospital, the reintervention rate, or the rate of complications resulting in morbidity. Despite this limitation, mortality rates are still accepted by several large states as a valid, publicly reported quality measure for this particular operation.

Although our analysis explained a large fraction of the disparity, our reliance on administrative data could not address other potential mechanisms driving it. Thus, a percentage of the disparity was left unexplained, which may be owing to patient factors not captured by the Elixhauser index. Administrative data are unable to account for disease severity, its effects on urgency of care, and ultimate outcome. For example, black patients may present at a more advanced stage of coronary artery disease or more frequently in the setting of acute myocardial infarction. This may be compounded by differential physician practices—for example, offering CABG surgery to nonwhite patients only after they have developed more severe disease relative to white patients.

Our knowledge of differences in the pathogenesis of coronary disease among ethnic groups is limited, but several large studies have examined racial differences in coronary artery disease severity or the prevalence of 3-vessel or left main disease. These studies found that white patients presenting with acute coronary syndrome were more likely than black patients to have severe obstructive coronary disease, namely, involvement of the left main artery or 3-vessel disease. This observation makes the previously mentioned limitations regarding disease severity less likely. As a result, barriers to high-quality surgical care may contribute significantly more to racial disparities in mortality rates than previously thought.

Other factors that may perpetuate racial disparities include regional variations in hospital quality, proximity to high-quality hospitals, and segregated referral patterns. Although our data could not directly address these factors, our study highlights the effects of hospital quality and serves as a springboard for further research in this area.

Racial disparities in surgical outcomes represent a significant problem in our health care system. Insight into how lower-quality hospitals widen disparities and gaps in patient care has important policy implications. Existing policies aimed at improving treatments at hospitals serving a larger proportion of low-income Medicaid patients include Disproportionate Share Hospital payments as part of the Medicare Modernization Act of 2003. Medicare calculates these payments based on a hospital’s urban or rural location, its size, and the sum of the proportions of Supplemental Security

### Table 3. Differences in Mortality Rates Stratified by Race

<table>
<thead>
<tr>
<th>Adjustment</th>
<th>White Patients (n = 159,043)</th>
<th>Black Patients (n = 9390)</th>
<th>Hispanic Patients (n = 3016)</th>
<th>Proportion of Disparity Explained, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds Ratio (95% CI)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No adjustments</td>
<td>1.35 (1.23-1.49)</td>
<td>1.26 (1.05-1.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient factors</td>
<td>1.32 (1.19-1.46)</td>
<td>1.32 (1.10-1.58)</td>
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<td>23</td>
</tr>
<tr>
<td>Socioeconomic</td>
<td>1.22 (1.10-1.46)</td>
<td>1.15 (0.96-1.38)</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>Hospital quality</td>
<td>1.23 (1.11-1.37)</td>
<td>1.12 (0.93-1.35)</td>
<td>34</td>
<td>54</td>
</tr>
</tbody>
</table>

* The ORs represent the independent effect of adjusting for patient factors, socioeconomic status, or hospital quality.
Income patient days and Medicare patient days treated. Despite these past efforts to explain and address mechanisms of disparities, the gap still remains.

More should be done at a systems level to bring higher-quality care to disadvantaged populations. To address access barriers, a recent intervention using patient navigators to help patients overcome logistical barriers to receiving care and guide distrustful patients through the health care system has shown promise. Although the efficacy of this program has not been empirically proved, it offers the possibility of community-specific, culturally sensitive intervention and of bridging communication gaps between providers and patients. Another policy option under consideration is selective referral of non-white patients to higher-quality centers. Such a program, however, may have the unintended consequence of diverting resources from already low-quality centers and exacerbating the already poor quality of care other patients receive. Pay-for-performance programs attempt to align higher-quality care with higher reimbursement. However, they may exacerbate existing disparities by administratively burdening already resource-constrained environments.

Conclusions

The demand for evidence-based policy solutions requires us to conduct further, detailed research to determine what drives disparities. Through qualitative research and focus group discussions to study interactions between patients and the health care system, we may better understand barriers that prevent patients from receiving optimal care. For example, findings from qualitative research may reveal barriers patients face while navigating the health care system, teach us more about patient-provider interactions, and help policy makers develop community-specific interventions. Perhaps there is an unaddressed communication gap that may affect patient-provider choices, adversely affecting treatment options offered to non-white patients. Future research must also address geographic determinants of access to high-quality surgical care and the compounding effects of social segregation and entrenched referral patterns. With a better understanding of the barriers to high-quality care, we will be able to design more effective programs to decrease health disparities.

REFERENCES