Socioeconomic Position, Not Race, Is Linked to Death After Cardiac Surgery

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***Background*—**Health disparities have been associated with the prevalence of cardiovascular disease. In cardiac surgery, association has been found between race, sex, and poorer prognosis after surgery. However, there is a complex interplay between race, sex, and socioeconomic position (SEP). In our investigation we sought to identify which of these was the driver of risk-adjusted survival.

***Methods and Results*—**From January 1, 1995, and December 30, 2005, 23 330 patients (15 156 white men, 6932 white women, 678 black men, and 564 black women) underwent isolated coronary artery bypass grafting, valve, or combined coronary artery bypass grafting and valve procedures. Median follow-up was 5.8 years (25th and 75th percentiles: 3 and 8.6 years). Effect of race, sex, and SEP on all-cause mortality was examined with 2-phase Cox model and generalized propensity score technique. As expected, blacks and women had lower SEP as compared with whites and men for all 6 SEP indicators. Patients with lower SEP had more atherosclerotic disease burden, more comorbidity, and were more symptomatic. Lower SEP was associated with a risk-adjusted dose-dependent reduction in survival after surgery (men, $P<0.0001$; women, $P=0.0079$), but black race, once adjusted for SEP, was not.

***Conclusions*—**Our large investigation demonstrates that disparities in SEP are present and significantly affect health outcomes. Although race per se was not the driver for reduced survival, patients of low SEP were predominantly represented by blacks and women. Socioeconomically disadvantaged patients had significantly higher risk-adjusted mortality after surgery. Further investigation and targeted intervention should focus specifically on patients of low SEP, their health behaviors, and secondary prevention efforts. **(*Circ Cardiovasc Qual Outcomes*. 2010;3:267-276.)**

Key Words: socioeconomic position ■ race ■ cardiac surgery ■ survival

It has been generally accepted that race and sex affect outcomes of cardiac surgery: Blacks and women are almost uniformly reported to have poorer prognosis than whites and men. However, these obvious demographic differences in skin color and sex (universally included in our medical records) hide race sex diversity in socioeconomic position (SEP). Metrics such as income, value of housing, and level of education are considered sensitive, private information that is rarely included in medical records. Yet, SEP may be an important barrier to cardiovascular health rather than biologically implausible surrogates of race and sex. Therefore, our objectives were to (1) examine race-sex–related differences in distribution of SEP measures, (2) delineate its impact on mortality after cardiac surgery, and (3) determine whether the true risk factor was demographic or socioeconomic.

Women, black (versus white) racial groupings, younger patients and those with higher body mass index had lower overall SEP (Table 2). Patients with lower SEP had more atherosclerotic disease burden and serious cardiovascular disease with more prior myocardial infarctions, more left ventricular dysfunction and heart failure, and were more symptomatic, as represented by higher New York Heart Association (NYHA) functional class. In addition, they had more comorbidities, such as hypertension, prior stroke, peripheral arterial disease, and treated diabetes, and were more often smokers with more chronic obstructive pulmonary disease.

Methods

Patients

From January 1, 1995, to December 30, 2005, 23 330 patients (15 156 white men, 6932 white women, 678 black men, and 564 black women) underwent isolated coronary artery bypass grafting (CABG), isolated heart valve procedures, or combined CABG and valve procedures at the Cleveland Clinic. Patients of other racial groups, international patients, and patients for whom socioeconomic position information were not available from the US Census Data-

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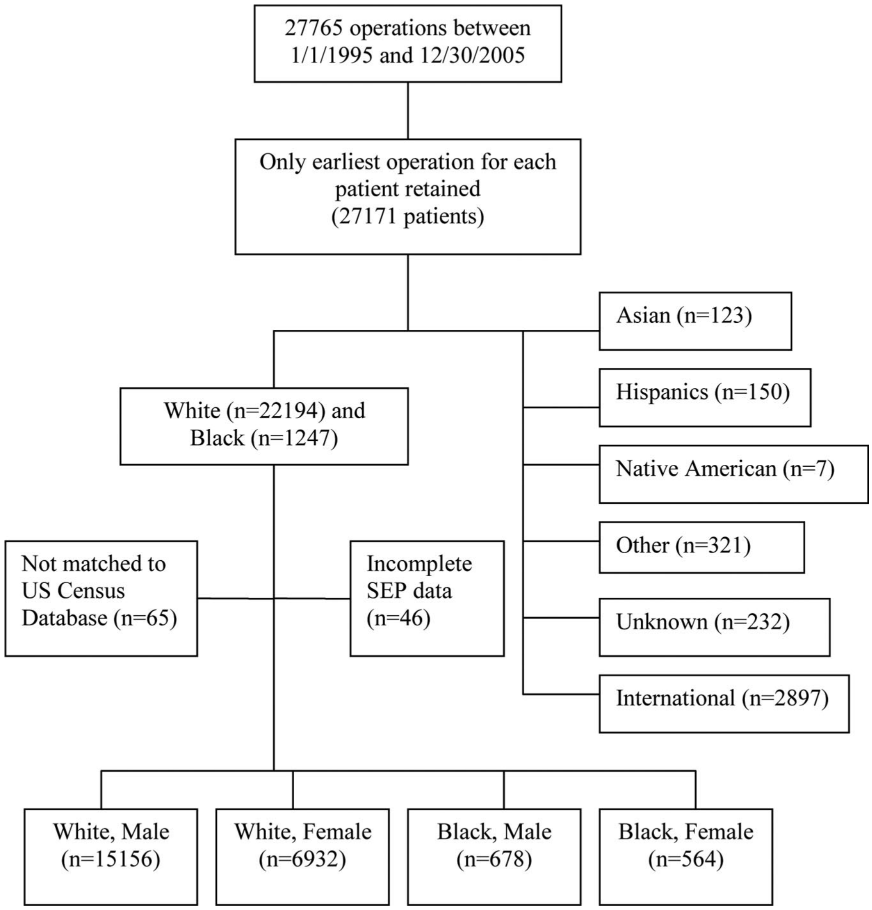

Figure 1. CONSORT-style diagram of race and ethnicity groupings for the patient population.

base were a small percentage of the total population and were excluded from the statistical analysis (Figure 1). Race and sex were self-reported by the patient on hospital admission, and the database was populated with this information from the Cleveland Clinic's Master Patient Index. Patients were given the opportunity to refuse documenting their race; these patients are represented in Figure 1 by "unknown." Race and sex were verified by the data abstractor and entered into the Cleveland Clinic Cardiovascular Information Registry. Clinical variables and perioperative factors were also prospectively collected concurrently with patient care by individuals trained in database management and entered into the Cardiothoracic Anesthesia Registry. Additional clinical variables were obtained from the Cardiovascular Medicine Information registries. All these databases have been approved for use in research by our institutional review board with individual patient consent waived.

Socioeconomic Position

From the 2000 US Census,[1] we used census block socioeconomic data, a geographical unit containing approximately 1000 residents, as a surrogate for individual-level SEP.[2] Overall neighborhood SEP score was calculated with use of previously validated methods from 6 census block characteristics: median household income; median value of housing unit; proportion of households receiving interest, dividend, or net rental income; the proportion of adults 25 years of age or older who had completed high school; proportion of adults 25 years of age or older who had completed college; and the proportion of employed persons 16 years of age or older in executive, managerial, or professional specialty occupation.[1] Each characteristic was transformed into a standardized *Z* score by first subtracting its mean and then dividing it by its standard deviation. It is customary to use an overall *Z* score for SEP of census blocks by summing all 6 component *Z* scores with equal weights.[1] Nevertheless, in this study we validated this equal weighting approach with our data through a principal component factor analysis of the 6 individual *Z* scores, which identified a single principal component, expressed as a weighted sum of the 6 *Z* scores, that can explain nearly 80% of the variation in the data (data not shown). Weights for 6 *Z* scores were similar, which justified the definition of the overall SEP *Z* score as a summation of the individual *Z* scores.

End Point

The end point of this investigation was time to death (all-cause mortality) after operation. Vital status was ascertained from the Social Security Death Index (SSDI) with the closing date of August 27, 2007. The 23 330 patients had a median follow-up of 5.8 years (25th and 75th percentiles: 3 and 8.6 years).

Statistical Methods

Patients were divided into 4 race-sex groups and compared: white men, white women, black men, and black women (Table 1). Continuous variables were summarized by median, 25th, and 75th percentiles and tested by Wilcoxon rank-sum tests; categorical variables were summarized by frequencies and percentages and tested by χ^2 tests. The distribution of each of the 6 SEP characteristics for the entire patient cohort or for the 4 racial sex subgroups was summarized by histograms and cumulative density functions (Figures 2, 3, and 4). Survival after surgery was by the Kaplan-Meier method and subgroups were compared using the log-rank test stratified on racial sex groups or SEP *Z* score levels (Figure 5). A linear model was developed to identify demographic and clinical variables associated with overall SEP *Z* score (Table 2). The list of variables considered is provided in Online Data Supplement, Table 1. Because men and women naturally differ in many demographic and clinical variables, and preliminary analyses suggested that there might be complex interactions between sex and race, the primary analyses were conducted among men and women separately, which

Table 1. Comparison of 4 Race–Sex Groups on Demographics, Comorbidity, and Procedure

Variable	White Male (n=15 156)	White Female (n=6932)	Black Male (n=698)	Black Female (n=564)
Demographics				
Age, y	65 (56, 73)	68 (57, 75)	61 (53, 69)	61 (52, 70)
Body mass index, kg/m^2	27.5 (24.9, 30.8)^{14}	26.7 (23.1, 31.2)^{7}	27.7 (24.9, 31.6)^{2}	28.9 (25.1, 33.7)
Preoperative laboratory				
Hematocrit, %	40.7 (3, 43.4)^{2246}	36.4 (33, 39.6)^{992}	38 (33, 41.4)^{106}	35 (31.1, 38.3)^{74}
Creatinine, mg/dL	1.1 (0.9, 1.3)^{305}	0.9 (0.7, 1.1)^{139}	1.2 (1, 1.5)^{10}	1 (0.8, 1.2)^{16}
Bilirubin, mg/dL	0.6 (0.5, 0.9)^{2741}	0.5 (0.4, 0.8)^{1182}	0.6 (0.4, 0.8)^{174}	0.5 (0.3, 0.7)^{138}
Cardiac morbidity				
Prior myocardial infarction	6972 (46)	2478 (36)^{1}	378 (56)	253 (45)
Abnormal LV function	8153 (54)^{56}	3167 (45.9)^{30}	448 (66.6)^{5}	318 (56.8)^{4}
Heart failure	4331 (28.6)	3021 (43.6)	295 (43.5)	306 (54.3)
NYHA functional class				
1	2778 (18.3)^{4}	848 (12.2)^{1}	95 (14)	61 (10.8)
2	7823 (51.6)	3320 (47.9)	325 (47.9)	257 (45.6)
3	2465 (16.3)	1767 (25.5)	141 (20.8)	138 (24.5)
4	2086 (13.8)	996 (14.4)	117 (17.3)	108 (19.1)
Atrial fibrillation	1019 (6.72)	697 (10.1)	33 (4.87)	27 (4.79)
Carotid disease	4993 (32.9)	2608 (37.6)	195 (28.8)	181 (32.1)
Aortic valve regurgitation	4539 (30.6)^{303}	2341 (35)^{242}	183 (27.4)^{10}	161 (29.4)^{17}
Aortic valve stenosis	3007 (20.6)^{531}	1889 (28.9)^{390}	73 (11)^{12}	75 (14)^{27}
Mitral valve regurgitation	7947 (53.1)^{197}	4650 (68)^{93}	317 (47)^{3}	357 (63.6)^{3}
Mitral valve stenosis	259 (1.79)^{651}	710 (10.8)^{335}	10 (1.52)^{19}	28 (5.18)^{23}
Tricuspid valve regurgitation	4975 (33.9)^{487}	3578 (53.7)^{270}	221 (33.4)^{17}	283 (51.7)^{17}
Coronary disease >70% stenosis				
Left main trunk	1570 (10.9)^{704}	455 (7)^{429}	62 (9.63)^{34}	49 (9.46)^{46}
Left anterior descending	8815 (60.9)^{688}	2950 (45.3)^{416}	435 (67.3)^{32}	282 (54.4)^{46}
Left circumflex	7670 (53.1)^{702}	2448 (37.7)^{432}	386 (59.8)^{32}	240 (46.4)^{47}
Right coronary artery	8150 (56.4)^{714}	2691 (41.5)^{440}	399 (61.9)^{33}	258 (50)^{48}
Comorbidity				
Hypertension	9747 (66.4)^{485}	4614 (68.4)^{189}	580 (86.6)^{8}	461 (83.1)^{9}
Stroke	1074 (7.09)	651 (9.39)	102 (15)	65 (11.5)
PAD	5519 (36.4)	2859 (41.2)	247 (36.4)	214 (37.9)
Smoking	9767 (65.2)^{170}	3157 (46.1)^{86}	499 (74.7)^{10}	348 (62.4)^{6}
COPD	2777 (22.4)^{2777}	1512 (26.2)^{1157}	158 (27.2)^{97}	170 (35.1)^{79}
Treated diabetes	3126 (21.2)^{381}	1673 (24.6)^{133}	203 (30.8)^{18}	200 (35.8)^{6}
Renal disease	749 (4.94)	338 (4.88)	89 (13.1)	61 (10.8)
Clinical presentation				
Emergency surgery	217 (1.43)	119 (1.72)	27 (3.98)	23 (4.08)
Procedures				
Surgery type				
CABG	7652 (50.5)	2337 (33.7)	433 (63.9)	255 (45.2)
Valve	4416 (29.1)	3036 (43.8)	152 (22.4)	204 (36.2)
Combined	3088 (20.4)	1559 (22.5)	93 (13.7)	105 (18.6)
Reoperation	3790 (25)	1496 (21.6)	95 (14)	90 (16)

LV indicates left ventricular; PAD, peripheral arterial disease; COPD, chronic obstructive pulmonary disease; and CABG, coronary artery bypass grafting. For continuous variables, 50th (25th, 75th) percentiles are presented; for categorical variables, counts (proportion) are presented. The number of missing or nonapplicable values is shown in superscript.

included (1) propensity score matching between white men and black men on a list of established confounders of mortality including SEP *Z* score to study the causal effect of race among men; (2) similar propensity score matching between white women and black women to study the causal effect of race among women; (3) studying the causal effect of SEP *Z* score among men by generalized propensity score subclassification; and (4) studying the causal effect of SEP *Z* score among women similarly. To further confirm the results obtained from analyses (1) through (4) and to compare the relative magnitude of causal effects of race and SEP, we conducted 2

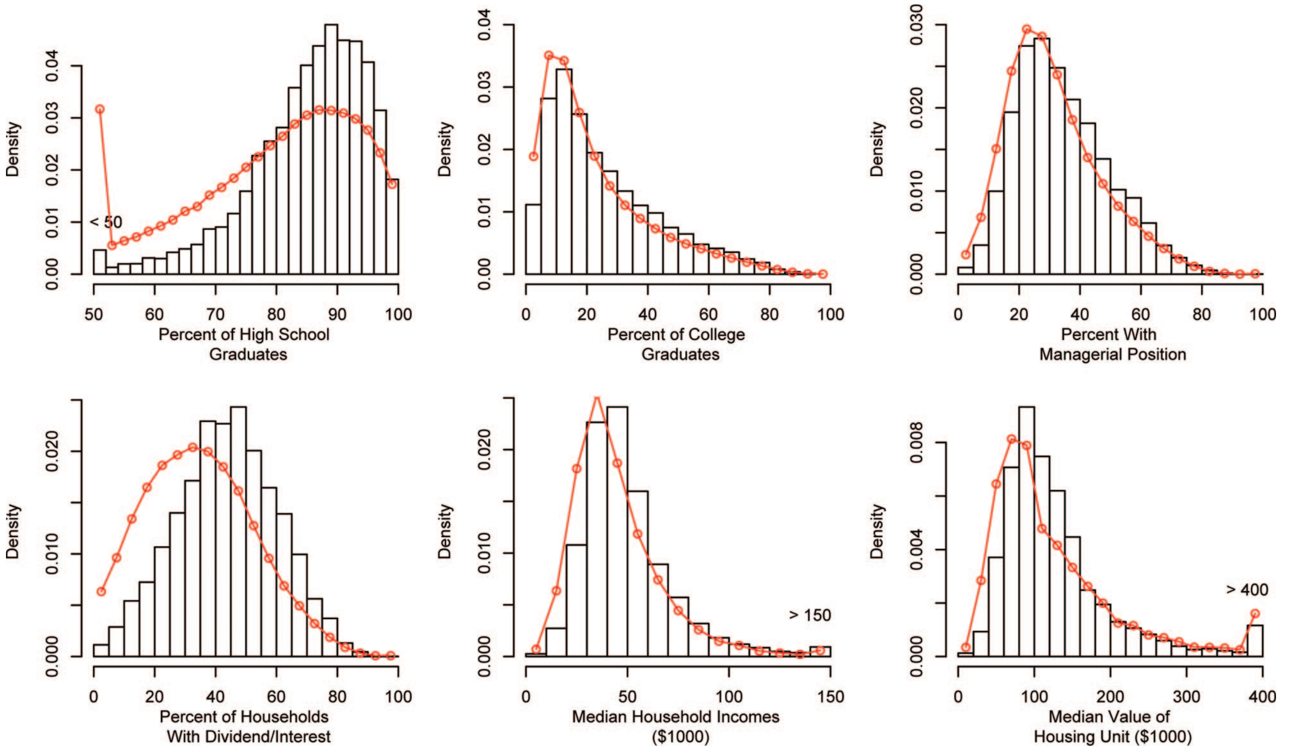

Figure 2. Distributions of 6 components of the SEP score (histograms) of the patient population in comparison with the corresponding distributions in the general US population (red line).

additional analyses: (5) subclassifying male patients on generalized propensity scores of both race and SEP *Z* score and comparing the 2 causal effects; and (6) similar analyses among women. The causal effects of race and SEP were visually illustrated and compared in a plot of Kaplan-Meier survival curves before and after matching on race (Figure 6) and a plot of predicted 5-year survival calculated from the models in analyses (5) and (6) (Figure 7). The results of analyses (1) through (6) are included in Tables 3, 4, and 5.

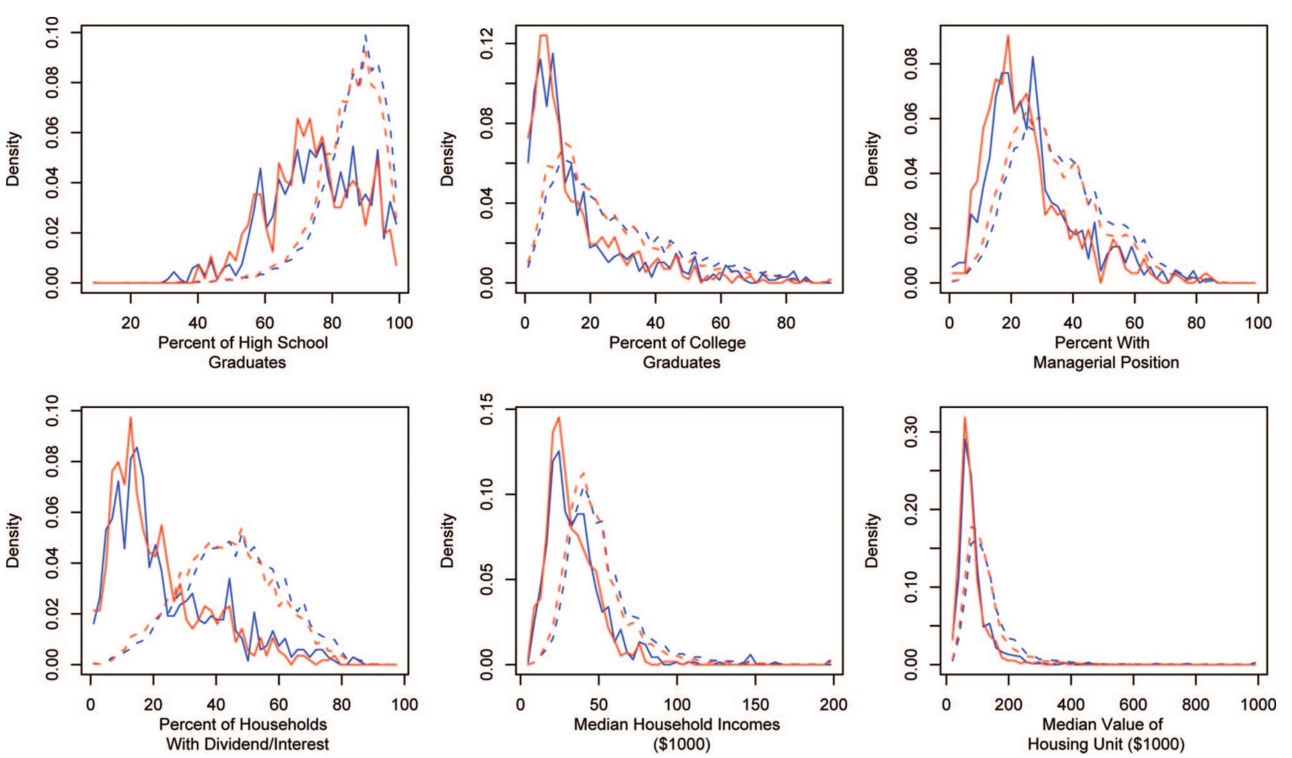

Figure 3. Probability density distributions (histograms) of the 6 components of SEP score, stratified by 4 race-sex groups: Women are indicated by red; men, blue; black patients, solid line; and white patients, dashed line. Whiskers along the horizontal axis are the cut-points used to define the histogram.

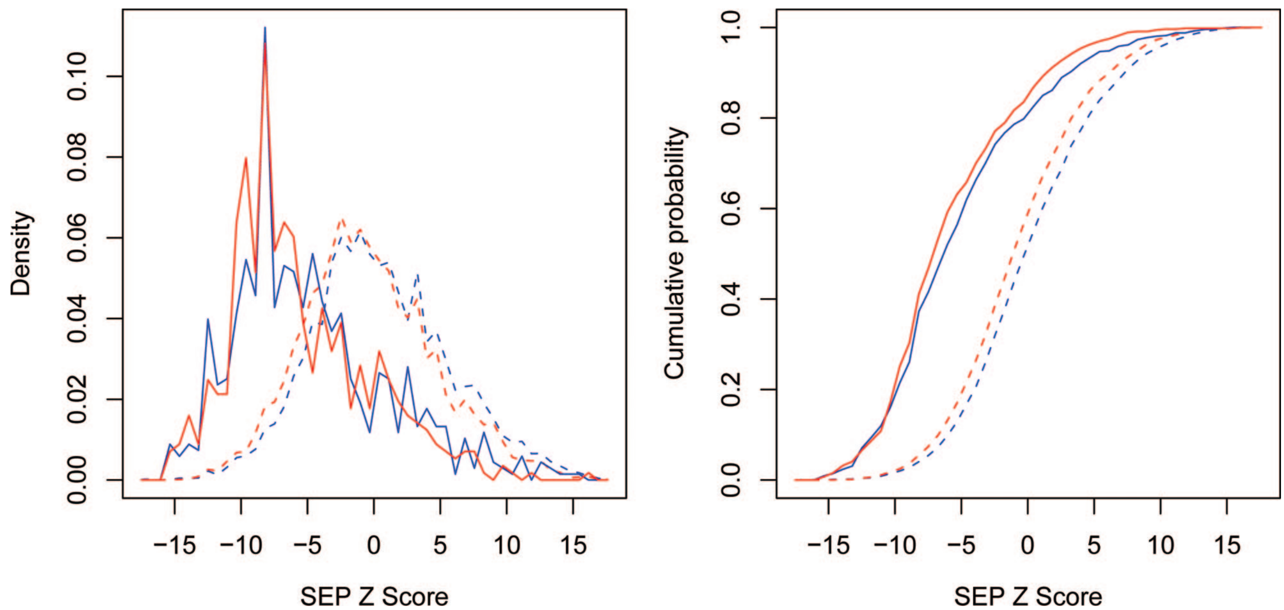

Figure 4. Probability distribution (left) and cumulative probability distribution (right) of the SEP *Z* score, stratified by 4 race-sex groups: Women are indicated by red; men, blue; black patients, solid line; and white patients, dashed line.

The propensity score matching generally followed the proposal by Rosenbaum and Rubin.[3] The generalized propensity score subclassification generally followed the proposal by Imai and van Dyk.[4] Further details on these procedures are included in the Online Data Supplement.

The outcome variable of analyses (1) through (6) was survival, because it has been found in previous studies that the effect of prognostic factors on survival after cardiac surgery often vary over an extended follow-up period, thus violating the proportional hazard assumption of the standard Cox model. Based on an unadjusted Kaplan-Meier analysis, an early high-risk phase of mortality extended from operation to approximately 6 months, at which time this phase transitioned to a lower phase of risk. Thus, we used a time-segmented 2-phase Cox model. The early phase was a Cox model within the first 6 months of operation. If the patient was still alive at 6 months, that patient's data were artificially right-censored. The late phase was a Cox model applied to data beyond 6 months, excluding those who died or were lost to follow-up within the first 6 months.

There were sporadic missing data for some clinical variables that were imputed 5 times by multiple imputations. All above analyses, except the descriptive statistics, were repeated 5 times with the 5 imputed data sets.

All results in this report were from combined analyses of the 5 imputations unless otherwise noted. Probability values <0.05 were considered statistically significant. Because this is an observational cohort study with prespecified end points, no adjustment for multiple probability values was used. The statistical analysis was performed by SAS 9.1 and R 2.6.2.

Results

Race–Sex Diversity

White women were older on average than the other race-sex groups; black men had higher baseline creatinine values and more prior myocardial infarctions; and both black women and men more frequently had left ventricular dysfunction, more heart failure, higher NYHA functional class IV symptoms, and more frequently presented for emergency surgery compared with either white women or white men (Table 1). In addition, black women and black men had more hypertension, prior stroke, treated diabetes, and renal disease compared with white women and white men.

Correlates of SEP

The SEP of the study population was generally slightly higher than the general US population (Figure 2). SEP was lowest

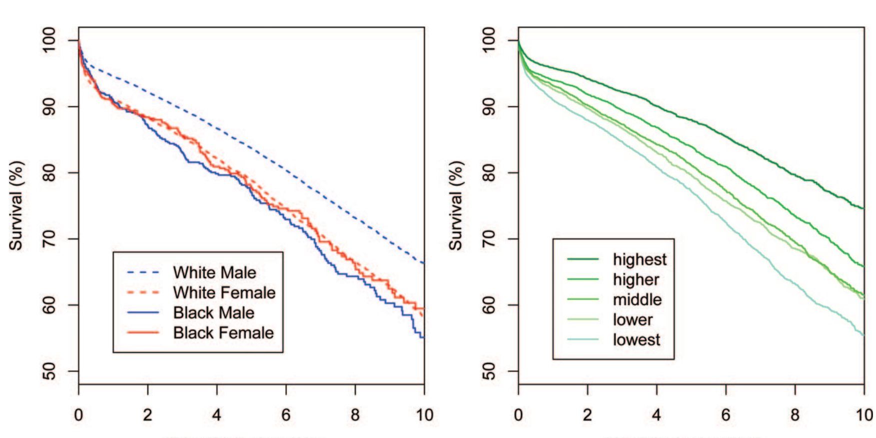

Figure 5. Kaplan-Meier survival curves by race-sex groups (left) and SEP groups (right). SEP groups were defined by 20th, 40th, 60th, and 80th percentiles of the marginal distribution of the SEP *Z* score.

Table 2. Factors Associated With Overall Socioeconomic Position *Z* Score

Predictor	Coefficient	Standard Error	*P* Value
Demographics			
White male	0		
White female	−0.93	0.086	$<$0.0001
Black male	−4.74	0.20	$<$0.0001
Black female	−5.48	0.22	$<$0.0001
Age, y	0.023	0.0031	$<$0.0001
Body mass index, kg/m^2	−0.052	0.0064	$<$0.0001
Cardiac morbidity			
Prior myocardial infarction	−0.45	0.075	$<$0.0001
Abnormal LV function	−0.44	0.072	$<$0.0001
Heart failure	−0.70	0.082	$<$0.0001
NYHA functional class 1	0		
NYHA functional class 2	−0.43	0.094	$<$0.0001
NYHA functional class 3	−0.86	0.11	$<$0.0001
NYHA functional class 4	−1.11	0.12	$<$0.0001
Atrial fibrillation	−0.078	0.13	0.55
Carotid disease	0.18	0.18	0.31
Aortic valve regurgitation	−0.19	0.085	0.026
Aortic valve stenosis	−0.25	0.092	0.0068
Mitral valve regurgitation	0.43	0.082	$<$0.0001
Mitral valve stenosis	−0.90	0.17	$<$0.0001
Tricuspid valve regurgitation	0.22	0.086	0.0097
Coronary disease $>$70% stenosis			
Left main trunk	−0.16	0.13	0.23
Left anterior descending	−0.23	0.088	0.010
Left circumflex	−0.18	0.084	0.034
Right coronary artery	−0.28	0.088	0.0018
Comorbidity			
Hypertension	−0.29	0.078	0.0002
Stroke	−0.37	0.12	0.0028
PAD	−0.62	0.18	0.0004
Smoking	−0.45	0.070	$<$0.0001
COPD	−0.67	0.081	$<$0.0001
Treated diabetes	−0.68	0.086	$<$0.0001
Renal disease	−0.40	0.18	0.021
Preoperative laboratory values			
Hematocrit, %	0.0065	0.0077	0.40
Creatinine, mg/dL*	0.15	0.11	0.18
Bilirubin, mg/dL*	0.16	0.068	0.016
Clinical presentation			
Emergency surgery	−0.32	0.26	0.22

LV indicates left ventricular; PAD, peripheral arterial disease; and COPD, chronic obstructive pulmonary disease. The SEP *Z* scores of this population have approximately normal distribution with mean 0 and interquartile range 6.8. A negative coefficient indicates that increased value of the (continuous) variable or presence of the condition (binary) is associated with decreased socioeconomic position.

*Log-transformed value was used.

among black patients and women for all 6 indicators: median income, median home value, percent high school and college graduates, percent in managerial positions and percent receiving dividend income (Figure 3). As a result, blacks and women had lower overall SEP *Z* scores compared with white patients and men (Figure 4).

Unadjusted Survival

There were differences in survival among the four sex-race groups (Figure 5A, $P<0.0001$). White women had worse survival than white men and black men had the worst overall survival after surgery. To at least 10 years after surgery, patients with lower SEP had worse survival than those with higher SEP, in a near dose-response fashion (Figure 5B, $P<0.0001$).

Causal Effect of Race and SEP on Survival

No statistically significant effect of race was identified in the propensity score–matched data (Table 3 and Figure 6). In contrast, a decreasing level of SEP demonstrated a causal effect, by stratified Cox regression (Table 4>). Specifically, both men and women in lower SEP had higher hazard and thus worse long-term survival. The direction of this effect was the same in the early phase, but SEP was not statistically significant, suggesting that clinical variables played a larger role than SEP in recovery from surgery.

The causal effects of race and SEP in Tables 3 and 4 are not directly comparable because Table 3 was based on the subset of matched data and Table 4 on a particular stratification of the entire population. To better compare the magnitude of these 2 causal effects, we conducted a generalized propensity score analysis of the 2 factors simultaneously as detailed in the Online Data Supplement. This analysis corroborated the stratified analyses (Table 5), but in addition revealed that any interaction between race and SEP was not statistically significant. A visual illustration of the relative magnitude of the causal effects of race and SEP, based on these results, is presented in Figure 7. The horizontal axis represents the percent of patients in the study sample that had lower SEP *Z* score than a hypothetical patient. As the hypothetical patient's SEP increases, survival increases steadily. Race of the hypothetical patient predicts somewhat different increases in survival among men and women, but this difference is not significant, as evidenced by the confidence intervals displayed.

Discussion

Principal Findings

The present large study revealed surprising results concerning disparities in SEP in patients with cardiovascular disease undergoing cardiac surgery and has provided a link between these disparities and death. Patients with lower SEP were more commonly female, black, and had more cardiovascular disease burden. On presentation for surgery, these groups of socioeconomically disadvantaged patients had more heart failure, more symptoms, and more comorbidity. Mediating pathways between demographics, SEP, and processes that

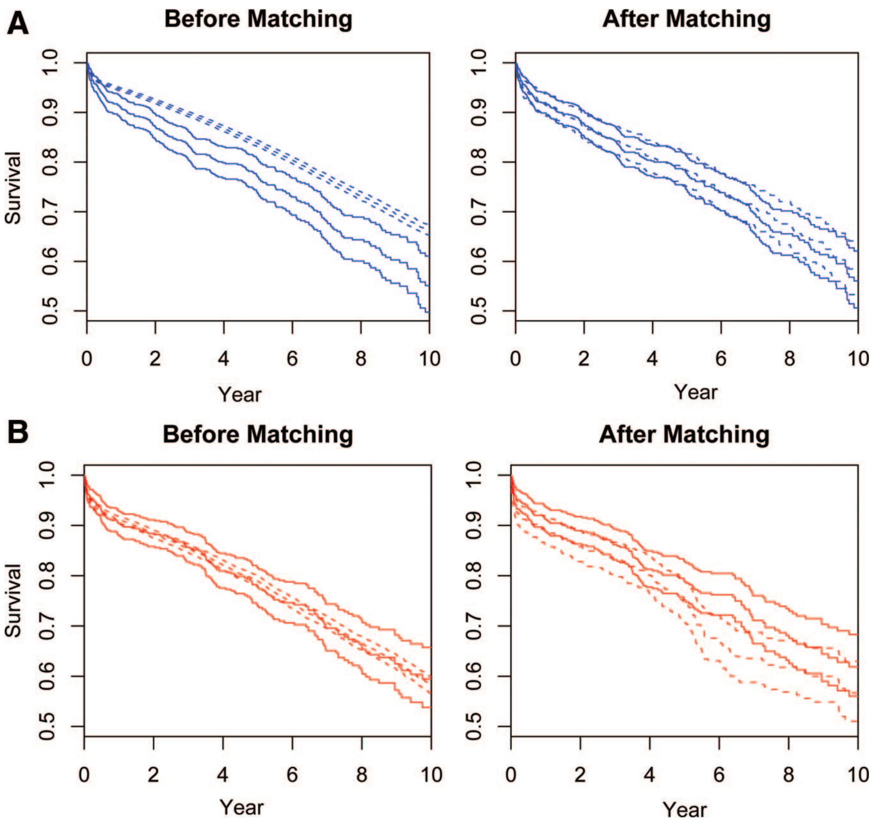

Figure 6. Kaplan-Meier survival curves with point-wise 95% confidence intervals by race (solid line, black patients; dashed line, white patients) for men (A, blue) and women (B, red), before and after propensity score matching.

contribute to cardiovascular disease are uncertain.[5] Others have noted that patients of low SEP are at higher cardiovascular disease risk despite the fact that the measurement is crudely related to biological processes.[6]

Unadjusted survival was lowest for black men compared with other sex-race groupings, and white men had the best survival for the duration of the follow-up period. Lower survival for white women compared with white men is concerning because women have better expected survival than men in the general population.[7] Although SEP was the driving determinant of risk-adjusted survival rather than race per se, black patients were disproportionately represented in lower SEP. This socioeconomic disparity, when present, was associated with similar early risks of surgery but increased late risk of death for at least 10 years, the duration of follow-up period.

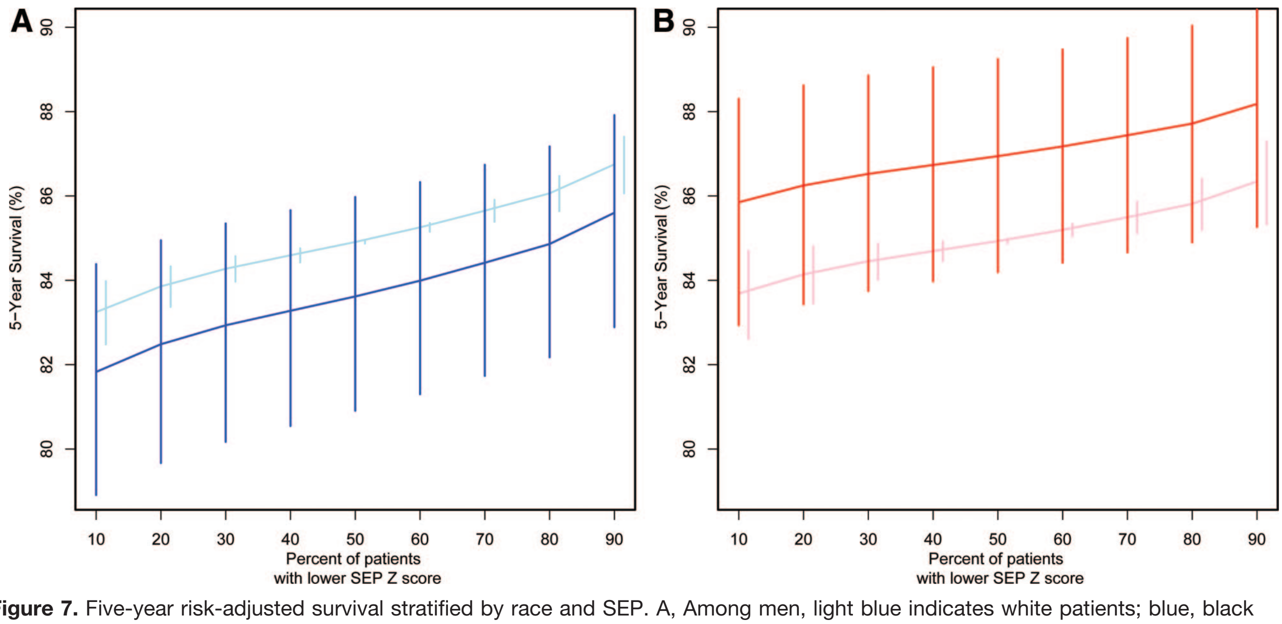

Figure 7. Five-year risk-adjusted survival stratified by race and SEP. A, Among men, light blue indicates white patients; blue, black patients. B, Among women, light red indicates white patients; red, black patients. Vertical bars represent 95% confidence intervals. The baseline (white patients, SEP Z score=0) 5-year survival is assumed to be 85%.

Table 3. Association of Race on Risk of Mortality Among Men and Women After Propensity Score Matching

	Early Risk of Mortality (<6 mo)				Late Risk of Mortality (>6 mo)			
Population	Estimate†	Lower CL	Upper CL	P	Estimate†	Lower CL	Upper CL	P
Among men (1292–1328)*	−0.11	−0.54	0.32	0.61	0.052	−0.19	0.30	0.67
Among women (1024–1048)*	−0.43	−0.94	0.071	0.091	−0.16	−0.44	0.12	0.25

CL indicates 95% confidence limits.

*Minimum and maximum sample sizes of 5 matched data sets in which white and black patients were matched in 1:1 ratio.

†Estimates represent the log hazard ratio of race in the Cox model, black versus white.

Immediate Postoperative Outcome

Our investigation demonstrated similar immediate postoperative outcomes among patients of differing SEP. A systematic bias against patients of low SEP with regard to perioperative management decisions is unlikely because patients come to surgery with a well-defined disease necessitating a specific well-standardized surgical intervention. Among limitations with prior work has been an exclusion of SEP or race from statistical modeling, as well as use administrative data sets, which have inherent limitations. Hartz et al[8] reported higher risk-adjusted operative mortality for women and non-white race in CABG patients from the Society of Thoracic Surgeons database; however, their investigation did not account for indicators of SEP. Similarly, SEP information was not included in the analysis of data from the Coronary Artery Surgery Study (CASS), in which higher mortality was noted among African Americans.[9] Race was a significant risk factor influencing outcomes in a Veterans Health Administration data set, in which the authors examined effects of African American race and Hispanic American ethnicity on mortality and complications in CABG surgery.[10] Outcomes included 30-day and 6-month mortality and 30-day complications. The authors reported lower 30-day mortality risk for Hispanic American ethnicity compared with white patients. African American patients had similar risk-adjusted 30-day and 6-month mortality. However, among low-risk surgical patients, African American race was associated with higher mortality and more postoperative complications.[10]

Finally, in an administrative data set of Medicare beneficiaries, Konety et al[11] examined race-related disparities in mortality and repeat revascularization after CABG. SEP was measured by incorporating zip code–level median household income. Although their data set was incomplete in terms of important clinical variables associated with survival such as left ventricular ejection fraction, they reported similar risk-adjusted in-hospital mortality among blacks and whites after adjusted for household income. However, survival 1 year after surgery was lower for black patients, leading the authors to speculate that blacks received suboptimal care after surgery.[11]

Long-Term Survival

Our investigation reported a risk-adjusted reduction in long-term survival for patients of lower SEP out to 10 years of follow-up. Zacharias et al[12] used Medicaid status as a surrogate for SEP. Similar to our investigation, race was not associated with worse operative or late outcomes after CABG; rather, Medicaid status, which was more common among African-Americans, was associated with worse late survival.

In contrast, Gray et al[13] reported higher risk-adjusted long-term mortality at 1 and 5 years for blacks in a predominantly medically insured patient population after CABG. Similarly, Brooks et al[14] identified black race as an important factor associated with increased risk for mortality in the Bypass Angioplasty Revascularization Investigation (BARI). Five-year mortality was associated with a number of factors including black race; however, SEP information was not analyzed in their study.[14]

Guru et al[15] reported higher early mortality for women and similar long-term mortality risk for women and men after CABG. However, when they examined a subset of patients with body surface area data and SEP information, women were not at greater early risk for death. It appeared that only income data were available for SEP information. The authors did not indicate whether SEP predicted survival after CABG.[15] Other investigations have reported higher in-hospital mortality for women after surgery[16,17] and less functional recovery,[18,19] whereas others report similar outcomes for women and men.[20,21] Much of this variability may result from lack of complete SEP and race information for statistical modeling.

Clinical Implications

In a review of surgical outcomes in African Americans, Bridges[22] noted that despite publications reporting higher risk

Table 4. Association of SEP *Z* Score on Risk of Mortality Among Men and Women After Subclassification by Generalized Propensity Score

	Early Risk of Mortality (<6 mo)				Late Risk of Mortality (>6 mo)			
Population	Estimate†	Lower CL	Upper CL	P	Estimate†	Lower CL	Upper CL	P
Among men (3805/15834)*	−0.0090	−0.024	0.0065	0.25	−0.018	−0.025	−0.011	<0.0001
Among women (2211/7496)*	−0.010	−0.028	0.0084	0.29	−0.014	−0.025	−0.0037	0.0079

CL indicates 95% confidence limits.

*Number of deaths per sample size.

†Estimate represents the log hazard ratio of *Z* in the Cox model.

Table 5. Association of Both SEP *Z* Score and Race on Risk of Mortality, After Subclassification by Generalized Propensity Scores

	Early Risk of Mortality (<6 mo)				Late Risk of Mortality (>6 mo)			
Population	Estimate*	Lower CL	Upper CL	*P*	Estimate*	Lower CL	Upper CL	*P*
Among men								
Race (black vs white)	0.069	−0.26	0.40	0.68	0.090	−0.080	0.26	0.30
SEP *Z* score	−0.011	−0.027	0.0045	0.16	−0.019	−0.026	−0.011	<0.0001
Among women								
Race (black vs white)	−0.25	−0.61	0.10	0.16	−0.15	−0.36	0.054	0.15
SEP *Z* score	−0.0088	−0.028	0.010	0.36	−0.014	−0.025	−0.0034	0.010

CL indicates 95% confidence limits.
*Estimate represents the log hazard ratio of *Z* in the Cox mode.

for African Americans, these studies were limited by failure to adjust for socioeconomic status and failed to examine disparities in postoperative medical care. Our results indicate that when risk-adjusted for comorbidity, perioperative factors, and SEP, early and late survival for black and white patients is similar. That is, white patients of low SEP have equal decrement in survival to black patients. Socioeconomic disparity clearly influences an individual patient's health,[5] and in our investigation this is reflected in inferior survival after cardiac surgery for socioeconomically disadvantaged patients. Hence, although it is convenient to label patients by skin color and sex, it is factors that relate to SEP (poor education, low income, inadequate housing, lack of discretional funds for investment, and not being "in charge" at work) that are more important.

A recent commentary on lack of progress in reducing health care disparities noted that disparities in health care involve patient-level factors as well as provider and health care system factors.[23] An intense focus should be directed toward socioeconomically disadvantaged patients; regardless of race and patient and health system factors that create disparity in health outcomes. We can only speculate on process of care factors in the postoperative follow-up period that may confer a survival disadvantage for patients of lower SEP. Cardiac rehabilitation is known to reduce mortality rates, improve functional outcomes, and contribute to better management of risk factors; yet, despite these benefits, it is considerably underused.[24–26] It is important to note that patients with lower SEP are reported to participate less in cardiac rehabilitation programs.[27,28] These findings present an opportunity for targeted intervention to increased referral to cardiac rehabilitation, which is currently underused by disadvantaged patients. A recent editorial notes that socioeconomic issues coupled with access to care and completeness of coverage must be addressed.[29] The authors suggest that these may facilitate a more proactive approach to risk factor management, which could lead to better health outcomes.[29]

Limitations

This investigation was from a single quaternary referral center, and results may not be broadly generalizable. However, patients in our investigation were largely representative of the spectrum of SEP distributions for all 6 SEP indicators (see Figure 2). Although the Society of Thoracic Surgeons National Cardiac Surgery Database has a number of risk factors, it is deidentified, so socioeconomic data are unavailable. We are able to only speculate on the reasons for the strong influence of SEP on survival in our patient population because this was a cohort investigation. Although our patient sample size was large and data registries detailed and prospectively collected, we did not have information on longitudinal care after discharge, such as participation in cardiac rehabilitation programs, or whether this group had less access to follow-up care and secondary prevention education. Certainly these factors could influence outcomes. Additionally, SEP is a multidimensional construct, and data on individual level education, power, social class, and prestige were not assessed on hospital admission.[30] However, census block data have been shown to be a powerful predictor of coronary artery disease and cardiovascular outcomes and have an excellent correlation with individual-level SEP.[2,31,32] Furthermore, it has been argued that census block socioeconomic data as a surrogate for individual level SEP may actually underestimate the severity of individual level SEP.[2,32] Unique features of our investigation are the ability to examine and model SEP as it relates to both sex and race in addition to the detailed and in-depth data on the perioperative state of the patient. We are among the busiest heart centers in the United States, and the number of cases allowed us to examine in detail the interplay of race, sex, SEP, and comorbidity on survival.

Blacks constituted a small portion of the data, which decreases statistical power of the analysis of race. This is evident in Figure 7, in which the confidence intervals of the black population are much wider than those of the white population. The smaller sample size of black patients influences the power of both unadjusted and causal analyses. However, in the unadjusted analysis of race, the difference in survival was significant between black and white men, but that difference diminished in the causal analyses. In contrast, in the unadjusted analysis of SEP, the difference was significant across SEP levels, and that difference remained significant in the causal analyses. Note that the causal analysis in this report was performed with propensity score methods, which are valid only when all confounders were properly accounted for. For demographic risk factors such as race, it is impossible to exhaust all the quantities relevant to both race and mortality in the propensity score model. We have deliberately selected well-established strong risk factors for the CABG/valve surgery patients. Therefore, the estimated causal effect in this report is interpretable only in reference to these confounders.

Conclusion

We have linked disparity in SEP to survival after cardiac surgery. Although black patients and women had significantly lower SEP, when survival was adjusted for traditional risk factors and patient SEP, race was not a risk factor for survival; rather, low SEP remained a significant predictor for reduced survival. Factors that link SEP and survival are unclear, and the influence on long-term follow-up should be an area for future investigation. Changes in time-related survival for patients of low SEP necessitate a change in our approach to health care delivery because low SEP places the patient at risk for death out to 10 years after surgery. This necessitates access and delivery of primary prevention, early identification of cardiovascular risk factors and effective delivery of secondary prevention, and access to long-term interventions after treatment that might affect survival.

Disclosures

None.

References

1. Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, Sorlie P, Szklo M, Tyroler HA, Watson RL. Neighborhood of residence and incidence of coronary heart disease. *N Engl J Med*. 2001;345:99–106.
2. Krieger N, Chen JT, Waterman PD, Soobader MJ, Subramanian SV, Carson R. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter? The Public Health Disparities Geocoding Project. *Am J Epidemiol*. 2002;156:471–482.
3. Rosenbaum P, Rubin D. The central role of the propensity score in observational studies for causal effects. *Biometrika*. 1983;70:41–55.
4. Imai K, Van Dyk D. Causal inference with general treatment regimens: generalizing the propensity score. *J Am Stat Assoc*. 2004;99:854–866.
5. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. *Circulation*. 1993;88:1973–1998.
6. Diez Roux AV. Persistent social patterning of cardiovascular risk: rethinking the familiar. *Circulation*. 2005;111:3020–3021.
7. Arias E. United States life tables, 2003. *Natl Vital Stat Rep*. 2006;54:1–40.
8. Hartz RS, Rao AV, Plomondon ME, Grover FL, Shroyer AL. Effects of race, with or without gender, on operative mortality after coronary artery bypass grafting: a study using The Society of Thoracic Surgeons National Database. *Ann Thorac Surg*. 2001;71:512–520.
9. Taylor HA Jr, Mickel MC, Chaitman BR, Sopko G, Cutter GR, Rogers WJ. Long-term survival of African Americans in the Coronary Artery Surgery Study (CASS). *J Am Coll Cardiol*. 1997;29:358–364.
10. Rumsfeld JS, Plomondon ME, Peterson ED, Shlipak MG, Maynard C, Grunwald GK, Grover FL, Shroyer AL. The impact of ethnicity on outcomes following coronary artery bypass graft surgery in the Veterans Health Administration. *J Am Coll Cardiol*. 2002;40:1786–1793.
11. Konety SH, Vaughan Sarrazin MS, Rosenthal GE. Patient and hospital differences underlying racial variation in outcomes after coronary artery bypass graft surgery. *Circulation*. 2005;111:1210–1216.
12. Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah A, Habib RH. Operative and late coronary artery bypass grafting outcomes in matched African-American versus Caucasian patients: evidence of a late survival-Medicaid association. *J Am Coll Cardiol*. 2005;46:1526–1535.
13. Gray RJ, Nessim S, Khan SS, Denton T, Matloff JM. Adverse 5-year outcome after coronary artery bypass surgery in blacks. *Arch Intern Med*. 1996;156:769–773.
14. Brooks MM, Jones RH, Bach RG, Chaitman BR, Kern MJ, Orszulak TA, Follmann D, Sopko G, Blackstone EH, Califf RM. Predictors of mortality and mortality from cardiac causes in the bypass angioplasty revascularization investigation (BARI) randomized trial and registry, for the BARI Investigators. *Circulation*. 2000;101:2682–2689.
15. Guru VFS, Tu J. Time-related mortality for women after coronary artery bypass graft surgery: A population-based study. *J Thorac Cardiovasc Surg*. 2004;127:1158–1165.
16. Vaccarino V, Abramson JL, Veledar E, Weintraub WS. Sex differences in hospital mortality after coronary artery bypass surgery: evidence for a higher mortality in younger women. *Circulation*. 2002;105:1176–1181.
17. Blankstein R, Ward RP, Arnsdorf M, Jones B, Lou YB, Pine M. Female gender is an independent predictor of operative mortality after coronary artery bypass graft surgery: contemporary analysis of 31 Midwestern hospitals. *Circulation*. 2005;112(9 Suppl):I323–I327.
18. Vaccarino V, Lin ZQ, Kasl SV, Mattera JA, Roumanis SA, Abramson JL, Krumholz HM. Gender differences in recovery after coronary artery bypass surgery. *J Am Coll Cardiol*. 2003;41:307–314.
19. Koch CKF, Cywinski J, Ishwaran H, Estafanous F, Loop F, Blackstone E. Health-related quality of life after coronary artery bypass grafting: a gender analysis using the Duke Activity Status Index. *J Thorac Cardiovasc Surg*. 2004;128:284–295.
20. Koch CG, Weng YS, Zhou SX, Savino JS, Mathew JP, Hsu PH, Saidman LJ, Mangano DT. Prevalence of risk factors, and not gender per se, determines short- and long-term survival after coronary artery bypass surgery. *J Cardiothorac Vasc Anesth*. 2003;17:585–593.
21. Woods SE, Noble G, Smith JM, Hasselfeld K. The influence of gender in patients undergoing coronary artery bypass graft surgery: an eight-year prospective hospitalized cohort study. *J Am Coll Surg*. 2003;196:428–434.
22. Bridges CR. Cardiac surgery in African Americans. *Ann Thorac Surg*. 2003;76:S1356–S1362.
23. Voelker R. Decades of work to reduce disparities in health care produce limited success. *JAMA*. 2008;299:1411–1413.
24. Pasquali SK, Alexander KP, Coombs LP, Lytle BL, Peterson ED. Effect of cardiac rehabilitation on functional outcomes after coronary revascularization. *Am Heart J*. 2003;145:445–451.
25. Brown TM, Hernandez AF, Bittner V, Cannon CP, Ellrodt G, Liang L, Peterson ED, Pina IL, Safford MM, Fonarow GC. Predictors of cardiac rehabilitation referral in coronary artery disease patients: findings from the American Heart Association's Get With The Guidelines Program. *J Am Coll Cardiol*. 2009;54:515–521.
26. Wenger NK. Current status of cardiac rehabilitation. *J Am Coll Cardiol*. 2008;51:1619–1631.
27. Harlan WR III, Sandler SA, Lee KL, Lam LC, Mark DB. Importance of baseline functional and socioeconomic factors for participation in cardiac rehabilitation. *Am J Cardiol*. 1995;76:36–39.
28. Nielsen KM, Faergeman O, Foldspang A, Larsen ML. Cardiac rehabilitation: health characteristics and socio-economic status among those who do not attend. *Eur J Public Health*. 2008;18:479–483.
29. Peterson E, Yancy CW. Eliminating racial and ethnic disparities in cardiac care. *N Engl J Med*. 2009;360:1172–1174.
30. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, Posner S. Socioeconomic status in health research: one size does not fit all. *JAMA*. 2005;294:2879–2888.
31. Rehkopf DH, Haughton LT, Chen JT, Waterman PD, Subramanian SV, Krieger N. Monitoring socioeconomic disparities in death: comparing individual-level education and area-based socioeconomic measures. *Am J Public Health*. 2006;96:2135–2138.
32. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Comparing individual- and area-based socioeconomic measures for the surveillance of health disparities: a multilevel analysis of Massachusetts births, 1989–1991. *Am J Epidemiol*. 2006;164:823–834.