Interaction Between Race and Income on Cardiac Outcomes After Percutaneous Coronary Intervention

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BACKGROUND: Compared with White Americans, Black Americans have a greater prevalence of cardiac events following percutaneous coronary intervention. We evaluated the association between race and neighborhood income on post–percutaneous coronary intervention cardiac events and assessed whether income modifies the effect of race on this relationship.

METHODS AND RESULTS: Consecutive patients (n=23,822) treated with percutaneous coronary intervention from January 1, 2000, to December 31, 2016, were included. All-cause mortality and major adverse cardiac event were assessed at 3 years. Extended 10-year follow-up was performed for those residing locally (n=1285). Neighborhood income was derived using median adjusted annual gross household income reported within the patient’s zip code. We compared differences in treatment and outcomes, adjusting for race, income, and their interaction. In total, 3173 (13.3%) patients self-identified as Black Americans, and 20,649 (86.7%) self-identified as White Americans. Black Americans had a worse baseline cardiac risk profile and lower neighborhood income compared with White Americans. Although risk profile improved with increasing income in White Americans, no difference was observed across incomes among Black Americans. Despite similar long-term outpatient cardiology follow-up and medication prescription, risk profiles among Black Americans remained worse. At 3 years, unadjusted all-cause mortality (18.0% versus 15.2%; P<0.001) and major adverse cardiac event (37.3% versus 34.6%; P<0.001) were greater among Black Americans and with lower income (both P<0.001); race, income, and their interaction were not significant predictors in multivariable models. At 10-year follow-up, increasing income was associated with improved outcomes only in White Americans but not Black Americans. In multivariable models for major adverse cardiac event, income (hazard ratio [HR], 0.97 [95% CI, 0.96–0.98]; P=0.005), Black race (HR, 1.77 [95% CI, 1.58–1.96]; P=0.006), and their interaction (HR, 0.98 [95% CI, 0.97–0.99]; P=0.003) were significant predictors. Similar findings were observed for cardiac death.

CONCLUSIONS: Early 3-year post–percutaneous coronary intervention outcomes were driven by worse risk factor profiles in both Black Americans and those with lower neighborhood income. However, late 10-year outcomes showed an independent effect of race and income, with improving outcomes with greater income limited to White Americans. These findings illustrate the importance of developing novel care strategies that address both risk factor modification and social determinants of health to mitigate disparities in cardiac outcomes.

Key Words: income ■ major adverse cardiovascular events ■ percutaneous coronary intervention ■ racial disparities ■ socioeconomic status
greater prevalence of CVD risk factors, including diabetes, obesity, and hypertension.11 In addition, Black Americans have been shown to have greater rates of heart failure and in-hospital mortality after MI, with lower rates of PCI.3

Data on the additive impact of socioeconomic status (SES), typically using estimated household income as a surrogate, on CVD outcomes are mixed. Findings from the REGARDS (Reasons for Geographic and Racial Differences in Stroke) study suggested that CVD outcomes following MI were dictated primarily by baseline comorbidities and presentation characteristics, with little impact by SES over a median 3-year follow-up.10 Over similar follow-up of 30 months, a large analysis of US veterans found that outcomes after PCI were determined by medical comorbidities and higher-acuity presentations, with minimal influence by SES.19 Conversely, 17-year follow-up from the Cooperative Cardiovascular Project, assessing patients from 1994 to 1996, found that racial differences in post-MI mortality varied significantly by area-level SES, with the largest differences observed in those living in high SES areas.7 As such, the interplay between race, income, and the nature of their influence on CVD outcomes remains debated.

Accordingly, the objectives of this analysis were to evaluate the relationship between race and income on short- and long-term CVD events following PCI and to determine whether income modifies the effect of race on this relationship after accounting for differences in baseline comorbidities, presentation characteristics, and downstream treatment.

**CLINICAL PERSPECTIVE**

**What Is New?**
- In a large cohort of patients who underwent percutaneous coronary intervention, self-identified Black patients (in comparison to White patients) and patients with lower incomes had worse baseline and follow-up risk profiles.
- The 3-year mortality and major adverse cardiac event were driven by measurable risk factors, but not race or income.
- Black race, income, and their interaction (Black individuals deriving less benefit as incomes increased) were all independent correlates of cardiac death and major adverse cardiac event at 10 years.

**What Are the Clinical Implications?**
- Strategies focusing on the socioeconomic milieu experienced by Black and poor patients may improve post-percutaneous coronary intervention outcomes.

**Nonstandard Abbreviations and Acronyms**

**MACE** major adverse cardiac event

**METHODS**

**Study Population**

The authors declare that all supporting data are available within the article and its supplemental files. The study protocol was approved by the Cleveland Clinic institutional review board; need for informed consent was waived. From our PCI database, consecutive patients treated for the first time with coronary stents at our institution were identified from January 1, 2000, to December 31, 2016. Patients with missing data on income (n=150) were excluded. Race was assigned per patient group self-identification; those who self-identified as non-Black or non-White Americans (Asian, Latino, other) were excluded (n=2144). Estimated annual neighborhood income was derived from the median adjusted annual gross household income reported within the patient’s zip code using 2017 data (data.census.gov).

Synergy between PCI with taxus and Cardiac Surgery (SYNTAX)13 and residual SYNTAX14 scores were calculated by a single physician from the Angiographic Core laboratory, masked to clinical outcome.

**Follow-Up**

Follow-up was completed to 3 years by review of the electronic medical record, annual mailed letter querying status of specific end points, and internet search and telephone call follow-up as necessary. Among those residing in local counties (Cuyahoga, Geauga, and Ashtabula), extended follow-up was completed to 10 years, as described above. These patients were chosen because of their geographic proximity to the treatment center and thus likelihood to return for follow-up and have more complete long-term data. They were enrolled relatively evenly across the study period, with the 50th percentile enrolled on November 20, 2009. The 10-year follow-up was complete in 97.0% of patients (n=1247/1285). Vital signs, outpatient cardiology follow-up, medication prescription, and laboratory test results were recorded at baseline and 5 years using data closest to the target date as possible. Data were collected by trained research nurses, technicians, or physicians on dedicated case report forms using standardized definitions.

**Statistical Analysis**

**Study End Points and Assessment**

Data are reported as mean±SD, median and interquartile range, or proportion, as appropriate, and are presented by race and income quartiles. Quartiles were determined in a prespecified manner using income levels only to
ensure similar income distribution between races in each group. The prespecified study end points were all-cause mortality and major adverse cardiac event (MACE; composite of death, MI [per the fourth universal definition], or target vessel revascularization). Among those with 10-year follow-up, detailed data on cause of death were obtained. We additionally assessed body mass index, blood pressure, low-density lipoprotein level, and diabetes and smoking status at baseline and 5 years and compared them by race and income with modified Bonferroni correction. Last, we assessed for prespecified differences in follow-up with cardiovascular medicine providers, which included follow-up 90 days after index PCI and longest duration of time between visits, by race and income.

**Multivariable Models**

The adjusted significance of Black race and neighborhood income, their directionality, and interaction were assessed for all-cause mortality and MACE. Unadjusted rates of the outcomes mentioned above were assessed via Kaplan-Meier analysis using the log-rank statistic. Multivariable Cox and Fine-Gray (to account for the competing risk of noncardiac death, when applicable) proportional hazards regression analyses were used to evaluate adjusted correlates of the study end points. For 3-year outcomes, candidate covariates for adjustment were Black race, neighborhood income, their interaction term, age, sex, diabetes, insulin dependence, renal insufficiency, peripheral vascular disease, prior coronary artery bypass surgery, ejection fraction, smoking, chronic obstructive pulmonary disease, index presentation of acute MI, year of PCI by tertiles, baseline hemoglobin, number of diseased vessels, left anterior descending artery culprit, American College of Cardiology/American Heart Association lesion score, use of debulking therapy, and use of drug-eluting stent. For 10-year outcomes, the above in addition to SYNTAX score were included. All variables were initially assessed in univariable analysis; those with a \( P < 0.10 \) and variables deemed clinically important were included in multivariable analysis. We then used backwards stepwise regression with final model selection based on the lowest Akaike Information Criterion. Collinearity was assessed with variance inflation factors. Final model assumptions were assessed by Schoenfeld residuals. Statistical analysis was performed using SYSTAT software, version 13.0 (Richmond, CA).

**RESULTS**

**Baseline Characteristics, Stratified by Race and Income**

In total, 23,822 patients were included, of whom 3,173 (13.3%) self-identified as Black American. As reflected in Table 1, Black Americans were younger and more...
likely to be women but had a worse baseline risk profile in comparison to White Americans. Neighborhood income was significantly lower ($34,717±16,780 versus $53,098±16,871; P<0.001) among Black Americans. Black Americans were more likely to present with acute MI (28.4% versus 10.8%; P<0.001) and were less likely to receive treatment with a drug-eluting stent (46.0% versus 50.8%; P<0.001) compared with bare metal stent. Rates of complete revascularization were similar. Although similar baseline findings were observed among the subset of patients with extended follow-up, the prevalence of Black Americans was significantly greater (35.1% versus 13.3%; Table S1–S2).

When assessing differences by quartile of neighborhood income, White Americans demonstrated an improved baseline risk profile with increasing income (Table 2). Conversely, there was no statistical difference in risk characteristics across income quartiles among Black Americans, including similar body mass index (P=0.16), diabetes (P=0.93), hypertension (P=0.97), peripheral vascular disease (P=0.62), and renal insufficiency (P=0.12). Similar findings were demonstrated in the extended follow-up cohort.

### Outpatient Follow-Up and Risk Factor Management

At 5-year follow-up, Black Americans received similar prescription of statin therapy and more aggressive treatment with antihypertensive and antidiabetic medications in comparison to White Americans (Table 3). Although this resulted in similar absolute reductions in blood pressure, hemoglobin A1c, and low-density lipoprotein, Black Americans achieved overall worse target control in comparison to White Americans. Black Americans had a greater absolute reduction in smoking, although they were more likely to gain weight. In addition, although Black Americans had a similar risk factor profile across income quartiles, White Americans demonstrated significant improvement with increasing income (Table 4). In terms of future appointments with a cardiology provider, Black and White Americans had

| Table 2. Baseline Characteristics of the Overall Population, Stratified by Race and Neighborhood Income by Quartiles |
|---|
| **Characteristic** | Income range, $ | <39,000 | 39,000–48,000 | 49,000–62,000 | >62,000 |
| | Black race | White race | Black race | White race | Black race | White race | Black race | White race |
| Total No. | 2209 | 3790 | 347 | 6110 | 324 | 4955 | 293 | 5794 |
| Age, y | 63±12 | 65±12 | 61±11 | 66±12 | 61±12 | 66±11 | 66±11 |
| Body mass index, kg/m² | 31±8 | 30±8 | 31±6 | 30±7 | 30±6 | 30±6 | 31±9 | 29±7** |
| Chronic obstructive pulmonary disease, % | 16.5 | 18.7 | 14.6 | 15.3 | 7.6 | 13.7 | 13.3* | 10.5* |
| Diabetes, % | 45.1 | 37.1 | 42.9 | 36.1 | 44.4 | 34 | 46.8 | 28.2** |
| Hypertension, % | 89.7 | 80.1 | 91.1 | 81.3 | 90.7 | 81.8 | 89 | 78.4* |
| Ejection fraction, % | 49±13 | 49±12 | 49±12 | 50±13 | 50±14 | 50±12 | 50±13 | 51±12* |
| Male sex, % | 53 | 65.5 | 57.6 | 70.1 | 59.6 | 70.9 | 60.4* | 74* |
| Acute myocardial infarction, % | 30.5 | 16.3 | 29.4 | 10.9 | 26.2 | 10.4 | 23.2* | 15.1 |
| Prior coronary artery bypass grafting, % | 14.5 | 27.8 | 18.2 | 31.5 | 16.4 | 32.1 | 16.4* | 25.1* |
| Peripheral vascular disease, % | 13.8 | 15.1 | 10.8 | 14.7 | 11.2 | 14.3 | 15.7 | 11.8* |
| Renal insufficiency, % | 13.4 | 6.3 | 8.9 | 6 | 10.9 | 6.1 | 11 | 4.3* |
| Smoking, % | 35.4 | 24.5 | 32.9 | 19.8 | 22.5 | 15 | 17.1* | 15.4* |
| Laboratory test results |
| Hemoglobin, mg/dL | 13±2 | 13±3 | 13±2 | 13±3 | 13±2 | 13±2 | 13±2 | 14±3* |
| Low-density lipoprotein, mg/dL | 109±43 | 98±39 | 102±40 | 96±37 | 98±37 | 95±38 | 99±37* | 98±40* |
| Treatment |
| Prior statin, % | 93.8 | 91.5 | 94.2 | 91.9 | 94.4 | 91.3 | 93.3 | 93.2* |
| Lesions | 1.5±0.8 | 1.6±0.9 | 1.6±0.9 | 1.7±0.9 | 1.5±0.8 | 1.6±0.9 | 1.6±0.8 | 1.6±0.9* |
| Bare metal stent, % | 45.6 | 44.2 | 42.1 | 42.1 | 38.7 | 40.9 | 45.9 | 39.2* |
| Drug-eluting stent, % | 45.4 | 47.6 | 55.8 | 49.8 | 47.7 | 51.3 | 44.9 | 52.6* |
| Stent length, mm | 28±19 | 29±21 | 29±19 | 31±21 | 26±16 | 30±20 | 28±17 | 29±19* |

Data are given as mean±SD unless otherwise indicated. *Statistical differences across income groups with P<0.05. †Statistical difference for race + income interaction with P<0.05.
similar rates of 90-day follow-up after index PCI (63.2% versus 65.5%; \( P=0.47 \)), with no differences stratified by income (Table S2). Overall, Black Americans had a longer time between follow-ups in comparison to White Americans (median longest time between appointments, 805 versus 631 days; \( P=0.001 \)), with more frequent follow-up with increasing income in both Black (\( P=0.010 \)) and White (\( P=0.019 \)) Americans.

### Intermediate Outcomes

At 3 years of follow-up, Black Americans had greater unadjusted rates of all-cause mortality (18.0% versus 15.2%; \( P<0.001 \); Figure 1A) and MACE (37.3% versus 34.6%; \( P<0.001 \); Figure 1B). Unadjusted rates of both all-cause mortality (\( P<0.001 \); Figure 2A) and MACE (\( P<0.001 \); Figure 2B) decreased with increasing income. In a multivariable model adjusting for age, acute

### Table 3. Five-Year Follow-Up of Risk Factors and Medication Prescription Among Black and White Americans

| Variable                        | Black Americans (n=451) | \( \Delta_{BL-5Yr} \)  | White Americans (n=834) | \( \Delta_{BL-5Yr} \)  | \( P \) value | \( P_s \) |
|---------------------------------|-------------------------|------------------------|-------------------------|------------------------|--------------|---------|
| Systolic blood pressure, mm Hg  | 134±21                  | 10±28                  | 127±16                  | 10±24                  | <0.001       | 0.89    |
| Body mass index, kg/m²          | 31±6                    | –0.7±3.4               | 30±6                    | 0.1±3.0                | 0.18         | 0.001   |
| Hemoglobin A1c, %*              | 7.8±2.1                 | 0.02±1.9               | 7.1±1.8                 | 0.3±1.6                | <0.001       | 0.095   |
| Low-density lipoprotein, mg/dL  | 94±46                   | 20±46                  | 81±34                   | 21±43                  | <0.001       | 0.67    |
| Smoking, %                      | 18.2                    | 10.2                   | 13.6                    | 5.7                    | 0.09         | 0.034   |

| Medications                     |                         |                        |                         |                        |              |         |
|---------------------------------|-------------------------|------------------------|-------------------------|------------------------|--------------|---------|
| Dual-antiplatelet therapy, %    | 51.7                    | 48.4                   | 0.4                     |                       |              |         |
| Antihypertensive medications    | 2.4±1.2                 | 1.8±1.1                | <0.001                  |                       |              |         |
| Oral antidiabetic medications*  | 0.8±0.8                 | 0.4±0.7                | <0.001                  |                       |              |         |
| Insulin, %*                     | 41.5                    | 11.1                   | <0.001                  |                       |              |         |
| Statin, %                       | 90                      | 90.5                   | 0.78                    |                       |              |         |
| Statin, high intensity, %       | 49.8                    | 50.8                   | 0.98                    |                       |              |         |

Data are given as mean±SD unless otherwise indicated. \( \Delta_{BL-5Yr} \) Represents the change at 5-year follow-up from baseline for Black and White Americans.

*Among patients with diabetes.

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### Table 4. Five-Year Follow-Up of Risk Factors and Medication Prescription Among Black and White Americans, Stratified by Quartile of Neighborhood Income

| Variable                        | Income range, $          | Black race | White race | Black race | White race | Black race | White race | Interaction \( P \) value |
|---------------------------------|--------------------------|------------|------------|------------|------------|------------|------------|--------------------------|
| Systolic blood pressure, mm Hg  | 134±21                   | 131±19     | 134±21     | 124±15     | 128±16     | 134±21     | 127±16     | 0.97                     |
| Body mass index, kg/m²          | 31±6                     | 33±9       | 31±6       | 29±5       | 31±6       | 30±6       | 31±6       | 29±4                     | 0.2                     |
| Hemoglobin A1c, %*              | 7.8±2.1                  | 7.9±2.4    | 7.8±2.1    | 7.0±1.5    | 6.8±1.6    | 7.8±2.1    | 6.8±1.8    | 0.11                     |
| Low-density lipoprotein, mg/dL  | 94±46                    | 85±34      | 94±45      | 86±35      | 94±45      | 80±36      | 94±45      | 79±32                    | 0.92                    |
| Smoking, %                      | 18.2                     | 25         | 18.3       | 20         | 18.3       | 10.4       | 18.3       | 9.4                      | 0.023                   |

| Medications                     |                         |            |            |            |            |            |            |                          |
|---------------------------------|-------------------------|------------|------------|------------|------------|------------|------------|                          |
| Dual-antiplatelet therapy, %    | 51.7                    | 51.4       | 51.9       | 52.1       | 51.9       | 46.4       | 51.9       | 47.5                     | 0.22                    |
| Antihypertensive medications    | 2.4±1.2                 | 2.0±1.1    | 2.4±1.2    | 1.9±1.2    | 2.4±1.2    | 1.9±1.1    | 2.4±1.2    | 1.7±1.0                  | 0.93                    |
| Oral antidiabetic medications*  | 0.8±0.8                 | 0.5±0.8    | 0.8±0.8    | 0.3±0.7    | 0.8±0.8    | 0.3±0.6    | 0.8±0.8    | 0.5±0.9                  | 0.15                    |
| Insulin, %*                     | 41.5                    | 20.5       | 41.5       | 8.3        | 41.5       | 12         | 41.5       | 9.6                      | 0.18                    |
| Statin, %                       | 90                      | 87.7       | 88.1       | 92.6       | 92.9       | 88         | 89.2       | 93.1                     | 0.80                    |
| Statin, high intensity, %       | 44.5                    | 47.9       | 57.1       | 47.4       | 54.8       | 47.3       | 45.9       | 46.7                     | 0.69                    |

Data are given as mean±SD unless otherwise indicated.

*Among patients with diabetes.
MI, sex, ejection fraction, use of drug-eluting stent, diabetes, year of PCI by tertiles, peripheral vascular disease, renal disease, chronic obstructive pulmonary disease, and hemoglobin, income (odds ratio [OR], 0.99 [95% CI, 0.98–1.00]; P=0.097), race (OR, 1.07 [95% CI, 0.92–1.24]; P=0.83), and their interaction (OR, 1.00 [95% CI, 1.00–1.01]; P=0.36) were not significant predictors of all-cause mortality. Similar findings for income (OR, 1.00 [95% CI, 0.99–1.00]; P=0.21), race (OR, 1.06 [95% CI, 0.85–1.04]; P=0.26), and their interaction (OR, 1.00 [95% CI, 0.99–1.00]; P=0.90) were observed in a multivariable model for predictors of MACE, respectively. Similar findings were observed at 3 years in the cohort with extended follow-up.

**Long-Term Outcomes**

Among the cohort with extended follow-up at 10 years, Black Americans had substantially higher unadjusted rates of all-cause mortality (41.0% versus 29.4%; P<0.001) and cardiac death (26.5% versus 19.3%; P=0.019) and similar unadjusted rates of MACE (47.1% versus 47.3%; P=0.37). Higher income among White Americans significantly attenuated their unadjusted rates of all-cause mortality (Figure 3A), cardiac death (Figure 3B), and MACE (Figure 3C). No such benefit was seen for Black Americans. In multivariable models, income, race, and their interaction were significant predictors for cardiac death and MACE, although not for all-cause mortality (Table 5).

**Figure 1.** Unadjusted Kaplan-Meier rates of all-cause mortality (A) and major adverse cardiac event (MACE) (B) for Black and White Americans at 3-year follow-up.

**Figure 2.** Unadjusted Kaplan-Meier rates of all-cause mortality (A) and major adverse cardiac event (MACE) (B) by increasing quartile of income at 3-year follow-up.
Figure 3. Unadjusted rates of all-cause mortality (A), cardiac death (B), and major adverse cardiac event (MACE) (C) decrease with increasing income among White Americans but not among Black Americans.
DISCUSSION

As the association between the social constructs of race and income on CVD outcomes is controversial, we sought to investigate the independent influence of self-identified race and neighborhood income on cardiac outcomes following PCI. Several key findings were observed. First, consistent with previously published data, we demonstrated that Black Americans have worse baseline comorbidities and lower income with corresponding greater incidence of downstream CVD events in comparison to White Americans. Second, despite similar outpatient care following PCI, Black Americans were less likely to reach guideline-recommended prevention targets. Third, we found that the relationship between race and income on CVD outcomes is not evident in the short-term following PCI, but both independently impact long-term CVD outcomes. Last, although increased income led to both improved cardiac risk factor profiles and outcomes for White Americans, the benefit of increasing income on health outcomes was not evident for Black Americans. Our data set has several important strengths. First, we were able to extract granular-level data, including procedural details, long-term treatment patterns, and outcomes, which often is not feasible with administrative databases. Second, there are few data sets describing outcomes over 10-year follow-up that address race and income.

Although numerous studies have described the difference in unadjusted CVD outcomes following MI and PCI, data on the independent impact of race and SES, beyond that of baseline characteristics, remain mixed. Findings from the REGARDS study suggested differences in CVD outcomes following MI over 3-year follow-up were explained by baseline comorbidities, with no impact by SES, sex, or age. Similar results were demonstrated from subgroup analyses of the Atherosclerosis Risk in Communities,15 Can Rapid Risk Stratification of Unstable Angina Patients Suppress Adverse Outcomes with Early Implementation of ACC/AHA Guidelines, 6 National Cardiovascular Data Registry Chest Pain-MI Registry,8 VA Clinical Assessment, Reporting, and Tracking System for Cath Labs registry from the Veteran Affairs system,12 and Prospective Registry Evaluating Myocardial Infarction: Events and Recovery registries,16 with follow-up durations of 3.3 years, 2.4 years, 30 days, 1 year, and 2 years, respectively. Conversely, findings from the Cooperative Cardiovascular Project7 demonstrated a significant independent association between race, SES, and CVD events at follow-up of 17 years. Our data, which demonstrated a significant association between race, SES, and cardiac events at 10-year but not 3-year follow-up, suggest that, in contrast to traditional risk factors that drive short-term outcomes, this interplay is an important, however insidious, contributor to health outcomes in cardiovascular patients. Accordingly, by comparing both intermediate and long-term outcomes, our data offer a possible explanation that mitigates discrepant findings from previously published studies.

Despite similar prescription for high-intensity statin therapy and more aggressive antihypertensive and antidiabetic therapy in our cohort, Black Americans demonstrated a higher systolic blood pressure, hemoglobin A1c, and low-density lipoprotein over 5-year

### Table 5. Multivariable Models Assessing Independent Predictors for 10-Year All-Cause Mortality, Cardiac Death, and MACEs

| Variable          | All-cause mortality | Cardiac death | MACEs          |
|-------------------|---------------------|---------------|----------------|
|                   | OR 95% CI P value   | OR 95% CI P value | OR 95% CI P value |
| Income            | 1.01 (1.00–1.03) 0.12 | 0.96 (0.95–0.97) 0.001 | 0.97 (1.01–1.03) 0.006 |
| Black race        | 1.16 (0.62–1.70) 0.42 | 2.45 (2.09–2.81) 0.003 | 1.77 (1.58–1.96) 0.006 |
| Income×race       | 1.01 (1.00–1.03) 0.06 | 0.98 (0.98–0.99) <0.001 | 0.98 (0.97–0.99) 0.003 |
| Age               | 1.06 (1.05–1.07) <0.001 | 1.06 (1.05–1.07) <0.001 | 1.01 (1.01–1.02) 0.022 |
| Ejection fraction | 0.97 (0.96–0.98) <0.001 | 0.97 (0.96–0.98) <0.001 | 0.99 (0.98–0.99) 0.002 |
| MI on presentation| 1.09 (0.65–1.19) 0.53 | 1.06 (0.74–1.39) 0.71 | 1.13 (0.85–1.61) 0.28 |
| SYNTAX score      | 1.02 (1.01–1.04) 0.002 | 1.02 (1.01–1.03) 0.018 | 0.92 (1.01–1.03) 0.001 |
| Year of PCI (tertile) | 1.08 (0.86–1.33) 0.173 | 0.82 (0.74–0.90) 0.011 | 0.84 (0.79–0.89) 0.001 |
| Prior CABG        | 1.34 (1.09–1.58) 0.028 | 1.55 (1.24–1.86) 0.005 | 1.59 (1.46–1.72) <0.001 |
| Diabetes          | 1.78 (1.51–2.05) <0.001 | 2.44 (2.27–2.61) <0.001 | 1.68 (1.56–1.80) <0.001 |
| PVD               | 1.65 (1.42–1.89) <0.001 | 1.83 (1.67–1.99) <0.001 | 1.56 (1.44–1.68) <0.001 |
| Renal disease     | 2.35 (2.08–2.62) <0.001 | 2.01 (1.81–2.21) <0.001 | 1.99 (1.83–2.15) <0.001 |
| COPD              | 1.90 (1.44–2.37) <0.001 | 1.94 (1.76–2.02) 0.002 | 1.16 (0.86–1.46) 0.27 |

CABG indicates coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; MACE, major adverse cardiac event; MI, myocardial infarction; OR, odds ratio; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; and SYNTAX, Synergy between PCI with taxus and Cardiac Surgery.
follow-up. These findings suggest that although improving area-level SES likely will improve overall patient cardiovascular outcomes, it is unlikely to eliminate racial disparities in these outcomes, particularly early after PCI. Questions remain whether Black Americans are treated to the same targets as White Americans, and whether prescribing patterns align with access and medication use. As such, focus should be aimed toward defining appropriate therapies and novel care delivery. Do Black patients, who are underrepresented in clinical trials, derive benefit from agents differently from their White counterparts, requiring more intensive or additional novel treatments? Can these differences be explained by a lack of racial diversity among the health care workforce? To understand how to deliver better care, research is needed to garner a better understanding of the factors that contribute to racial disparities across SES levels among Black and White Americans. Along these lines, a recent Presidential Advisory from the American Heart Association has called for an investigation of structural racism as a fundamental driver of health disparities.

More important, we found that Black Americans exhibit “diminishing returns” and do not receive the same improvements in cardiac outcomes as White Americans with improved SES. Because of seen and unforeseen structural barriers that Black Americans face, resources that generate health gain in White Americans do not similarly translate to Black Americans. Although not observed in prior reports with shorter duration of follow-up, our findings are similar to those reported from the longer-term Cooperative Cardiovascular Project, which studied patients post-MI from an era predating current advances in medical and procedural therapy (January 1994–February 1996). Others have reported “marginalized diminishing returns” for Black Americans in contexts outside of cardiovascular disease. The greatest disparities in CVD outcomes were seen at the highest SES, suggesting that even Black Americans living with the most area-level resources are disadvantaged in comparison to similar White Americans. The reasons for this phenomenon remain unclear. Some hypotheses suggest the “ethnic density effect,” in which wealthier Black Americans living in neighborhoods concentrated by White Americans may experience racial discrimination, stress, and/or less support and cohesion. Moreover, as the duration of follow-up is prolonged, the impact on mortality of the procedural intervention diminishes and the role of chronic conditions becomes more apparent. More important, these differences do not appear to be explained by access to cardiovascular treatment and follow-up, which was largely similar across groups, particularly at the highest income level. To address this deficiency, public policies should focus on reducing multilevel societal and structural barriers that hinder Black Americans rather than simply attempting to equalize access to resources on a surface level.

**Limitations**

Our study has several important limitations. First, we acknowledge that the impact of race and low income on outcomes may well reflect the influences of unmeasured social constraints. Second, this study is an observational, retrospective analysis and, as such, is inherently subject to unmeasured confounding. Third, although our sample is reflective of a single center, this may mitigate differences in outcomes that might occur because of differences in medical system resources, and speculatively may even mute the impact of SES on outcomes. Although our findings may not apply to other specific geographic areas, our findings are largely consistent with data published from national data sets. Fourth, we used zip code–level income rather than patient-level SES, which may encompass a spectrum of heterogeneous income profiles and differential gentrification over time. Although it remains debatable about which method is preferable, some data support area-level income may more accurately reflect health-related behaviors and quality of care. Fifth, although inferences were made using data on medication prescription, we cannot ensure that said prescriptions were filled and/or taken by the patient. More important, medication use remains an important aspect of the patient-physician relationship impacted by social determinants of health. Last, although our overall data set is large, our cohort with extended 10-year follow-up was much smaller, which may increase confounding and limit the generalizability of our data to other communities. However, this enabled accurate extraction of granular follow-up data, including laboratory test results, vital signs, prescriptions, appointments, and detailed outcome data, with little loss of follow-up, which is unique to our analysis. Moreover, the ratio of events/potential covariates was still acceptable at 25:1.

**CONCLUSIONS**

In conclusion, we found that Black Americans had a higher rate of comorbidities and downstream cardiac events following PCI. Although short-term outcomes appeared to be driven predominantly by typical atherosclerotic risk factors, race and neighborhood income were important drivers of adverse outcomes with extended 10-year follow-up. The long-term outcome benefits of increasing income seen for White Americans were not present for Black Americans. These findings demonstrate the importance of aggressive risk factor modification and implementation of novel care strategies, which target social determinants of health to mitigate racial disparities in cardiac outcomes.
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Supplemental Material
Tables S1–S2

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Table S1. Baseline characteristics of the cohort with extended 10-year follow-up, stratified by race.

|                                | Black Americans | White Americans | P-Value |
|--------------------------------|-----------------|-----------------|---------|
|                                | N = 451         | N = 834         |         |
| Age (years)                    | 62+11           | 64+12           | 0.011   |
| Body Mass Index                | 31.2+6.7        | 29.8+6.0        | 0.001   |
| Chronic Obstructive Pulmonary Disease (%) | 13.8           | 12.3            | 0.43    |
| Diabetes (%)                   | 49.4            | 31.6            | <0.001  |
| Insulin Use (%)                | 10.6            | 19              | <0.001  |
| Neighborhood Income ($1,000)   | 33.9+17.6       | 56.9+26.6       | <0.001  |
| Hypertension (%)               | 78.6            | 90.5            | <0.001  |
| Male (%)                       | 51.1            | 71.8            | <0.001  |
| Acute Myocardial Infarction (%)| 24.8            | 19.5            | 0.031   |
| Prior Coronary Artery Bypass Grafting (%) | 7.8           | 14              | <0.001  |
| Peripheral Vascular Disease (%)| 15              | 12.3            | 0.19    |
| Renal Insufficiency (%)        | 14.5            | 4.4             | <0.001  |
| Dialysis (%)                   | 7.9             | 1.5             | <0.001  |
| Smoking (%)                    | 28.4            | 19.8            | <0.001  |
| **Labs**                       |                 |                 |         |
| Hemoglobin                     | 12.8+1.9        | 13.8+1.9        | <0.001  |
| Hemoglobin A1c (in Diabetics)  | 7.8+1.8         | 7.6+1.7         | 0.59    |
| Low-Density Lipoprotein (mg/dL)| 114+44          | 100+40          | 0.026   |
| **Angiography**                |                 |                 |         |
| Baseline SYNTAX                | 10.1+6.6        | 10.3+7.1        | 0.76    |
| Ejection Fraction (%)          | 50+12           | 52+11           | 0.004   |
| **Treatment**                  |                 |                 |         |
| Coronary Lesions Treated       | 1.5+0.8         | 1.6+0.9         | 0.17    |
| Intravascular Ultrasound (%)   | 18.8            | 18              | 0.74    |
| 2nd Generation Drug Eluting Stent (%) | 65.2          | 53.3            | <0.001  |
| Residual SYNTAX                | 2.9+4.5         | 3.1+4.5         | 0.46    |
| Stent Number                   | 1.8+1.0         | 1.8+1.1         | 0.67    |
| Stent Length (mm)              | 33.2+22.5       | 32.7+20.8       | 0.67    |
Table S2. Differences in follow-up with a cardiology provider over time, stratified by race and neighborhood income.

|                     | 90-Day Follow-up after Index PCI | Max Days Between Appointments |
|---------------------|---------------------------------|------------------------------|
|                     | Black Americans | White Americans | P-Value | Black Americans | White Americans | P-Value |
| All                 | 63.2%            | 65.5%            | 0.47    | 805             | 631             | 0.001   |
| < $29,100           | 68.5%            | 72.5%            | 0.53    | 810             | 809             | 0.89    |
| $29,200-$42,400     | 60.0%            | 68.1%            | 0.21    | 912             | 645             | 0.042   |
| $42,500-$61,500     | 57.1%            | 63.5%            | 0.4     | 672             | 575             | 0.59    |
| > $61,600           | 61.2%            | 63.4%            | 0.47    | 716             | 601             | 0.95    |
| P-Value             | 0.18             | 0.12             |         | 0.01            | 0.019           |         |