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Race and outcomes after percutaneous coronary intervention: Insights from the Blue Cross Blue Shield of Michigan Cardiovascular Consortium

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Race and outcomes after percutaneous coronary intervention: Insights from the Blue Cross Blue Shield of Michigan Cardiovascular Consortium

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Background Current studies show similar in-hospital outcomes following percutaneous coronary intervention (PCI) between Black and White patients. Long-term outcomes and the role of individual and community-level socioeconomic factors in differential risk are less understood.

Methods We linked clinical registry data from PCIs performed between January, 2013 and March, 2018 at 48 Michigan hospitals to Medicare Fee-for-service claims. We analyzed patients of Black and White race. We used propensity score matching and logistic regression models to estimate the odds of 90-day readmission and Cox regression to evaluate the risk of postdischarge mortality. We used mediation analysis to evaluate the proportion of association mediated by socioeconomic factors.

Results Of the 29,317 patients included in this study, 10.28% were Black and 89.72% were White. There were minimal differences between groups regarding post-PCI in-hospital outcomes. Compared with White patients, Black patients were more likely to be readmitted within 90-days of discharge (adjusted OR 1.62, 95% CI [1.32-2.00]) and had significantly higher risk of all-cause mortality (adjusted HR 1.45, 95% CI 1.30-1.61) when adjusting for age and gender. These associations were significantly mediated by dual eligibility (proportion mediated [PM] for readmission: 11.0%; mortality: 21.1%); dual eligibility and economic well-being of the patient's community (PM for readmission: 22.3%; mortality: 43.0%); and dual eligibility, economic well-being of the community, and baseline clinical characteristics (PM for readmission: 45.0%; mortality: 87.8%).

Conclusions Black patients had a higher risk of 90-day readmission and cumulative mortality following PCI compared with White patients. Associations were mediated by dual eligibility, community economic well-being, and traditional cardiovascular risk factors. Our study highlights the need for improved upstream care and streamlined postdischarge care pathways as potential strategies to improve health care disparities in cardiovascular disease. (Am Heart J 2022;255:106–116.)

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Tweet: Black patients have increased risk of readmission and mortality following PCI mediated by many factors. #HealthDisparities #BMC2

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Racial disparities in the management and outcomes of cardiovascular diseases like coronary artery disease (CAD) and acute myocardial infarction (AMI) are well-documented and pervasive.[1–7] For instance, Black patients are less likely to be referred for invasive angiography[8,9] and undergo percutaneous revascularization[5] compared with White patients.

Racial disparities in long-term outcomes following percutaneous coronary intervention (PCI) are less understood. Some investigations have shown short and long-term outcomes following PCI vary by race and are not fully explained by differences in baseline risk factors,[10–13] while others have failed to show an association with post-PCI outcomes once accounting for comorbid-

ity burden.[3,14–16] Importantly, very few studies to date have addressed the gap in our understanding of the social and economic drivers of racial disparities in PCI that are not captured by traditional cardiovascular risk factors.[10] Knowledge of such factors is critical for developing interventions to achieve better health equity and mitigate excess risk associated with PCI in Black patients.[17]

In this context, we sought to evaluate the association between race and postdischarge PCI outcomes, including 90-day readmission and mortality, using contemporary data from all PCIs performed at nonfederal hospitals in the state of Michigan. We hypothesize that Black patients undergoing PCI have higher rates of adverse long-term outcomes after PCI compared with White patients. We also hypothesize that variation in outcomes between Black and White patients is mediated by personal socioeconomic status and community-level economic well-being of the patient and hospital, in addition to differences in baseline clinical characteristics and comorbidities.

Methods

We performed a retrospective analysis using data from the Blue Cross Blue Shield of Michigan Cardiovascular Consortium (BMC2), a multicenter, statewide registry of patients who underwent PCI at 48 nonfederal hospitals in Michigan. The details of this registry, including the abstraction and auditing process, have been previously described.[18 19] The University of Michigan Institutional Review Board has approved the research conducted in this registry as not meeting the definition of research requiring informed consent.

We linked the BMC2 clinical PCI data with Medicare fee-for-service 90-day episodes of care made available through the Michigan Value Collaborative (MVC). The 2 data sources and matching algorithm have been previously described in detail.[20] Briefly, the MVC is a statewide quality improvement collaborative focused on improving the value of care in Michigan. MVC has developed and maintained a validated claims-based registry with 90-day episodes of care. We obtained all 90-day episodes for conditions where PCI may have occurred during the index hospitalizations/procedure, which included 90-day episode of care defined by MVC for 2 clinical episodes: AMI and PCI. Next, we linked data between the 2 data sources through indirect matching of the index PCI procedure using multiple variables including hospital and operator National Provider Identifier numbers, admission, discharge, and procedure dates for the index hospitalization, and patient sex and date of birth.

Study population

The study cohort included all patients who underwent PCI between January 1, 2013, and March 1, 2018, and could be matched to 90-day Medicare fee-for-service clinical episodes (Supplemental Figure S1). The registry allows for multiple race/ethnicity categories to be listed for a given patient. For this analysis, patients were included if they identified as either "Black/African American" or "White" in the registry, but not both, so that biracial patients with both "Black/African American" and "White" categories indicated were excluded. In our final dataset, after excluding biracial patients recorded as both Black and White race, only 327 (1.12%) patients listed multiple races (ie, Black or White and 1 or more other race/ethnicity: Asian, NativeAmerican, Native Hawaiain/Pacific Islander, or Hispanic origin). In our analysis, 318 of these patients were categorized for analysis as White race and 9 as Black race. Race/ethnicity was collected per the NCDR CathPCI v 4.4 Coder's data dictionary.[21]

Outcomes

Primary outcomes included 90-day all-cause readmission and postdischarge long-term mortality. Readmission was defined as an admission to an acute care hospital for any reason within 90 days of discharge after the index PCI. Long-term mortality was obtained from the Medicare beneficiary file using the date of death of the beneficiary. Vital status data were available through December 21, 2019.

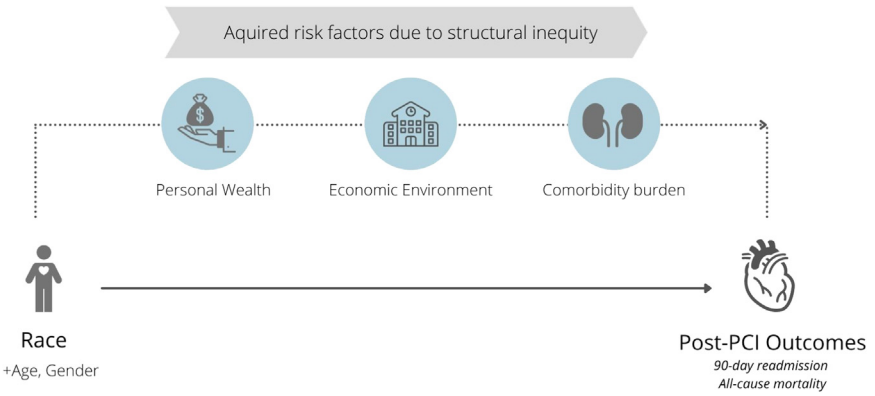
Proposed mediators of racial disparities

Based on prior literature, we proposed that the association between race and PCI postdischarge outcomes may be mediated by individual socioeconomic status, economic well-being of the patient's and hospital's community, in addition to baseline clinical characteristics and comorbidities, such that these factors are on the pathway through which race may be associated with postdischarge outcomes after PCI (Figure 1). These factors were chosen as they are known to track with race and have a plausible association with access to health care that decreases cardiovascular risk.[14,15] We sought explain this mediation framework by using sequential analyses to successively account for each of these factors when evaluating the relationship between race and postdischarge outcomes after PCI.

Table I includes a list of variables that were used in the regression model to represent these 3 mediators. Briefly, we first created a propensity score model matching on age and gender which are considered confounders in the relationships between race and PCI outcomes. Next, to account for patient-level socioeconomic status, we included Medicare and Medicaid dual eligibility in the propensity score (Cohort A).

We subsequently added the distressed communities index (DCI) to the propensity score to account for community economic well-being of the patient and the hospital where the patient underwent PCI (Cohort B). Briefly, the DCI was created by the Economic Innovation Group

Figure 1



Potential mediators of racial disparities in postdischarge outcomes after percutaneous coronary intervention. Personal wealth, economic well-being of the community, and comorbidity burden are acquired throughout lifetime and contribute to differential outcomes following percutaneous coronary intervention.

Table I. Sequential adjustments to assess proposed mediators of racial disparities

	Propensity model	Proposed mediators of racial disparities
Baseline model	Age and gender	—
Cohort A	Matched on Medicare and Medicaid Dual-Eligibility	Personal economic well-being
Cohort B	Matching as in Cohort A + additional covariate of Distressed Communities Index (patient and hospital zip code)	Economic well-being of health care community
Cohort C	Matching as in Cohort B + addition of baseline demographic and clinical characteristics* in propensity score model	Patient comorbidities

*Glomerular filtration rate, coronary artery disease presentation, cardiogenic shock at start of PCI, cardiogenic shock prior to PCI, peripheral arterial disease, prior PCI, prior coronary artery bypass graft, prior myocardial infarction, prior congestive heart failure, diabetes, PCI status (elective, urgent, emergent, salvage), current dialysis, left ventricular ejection fraction, hypertension, dyslipidemia, current tobacco use, chronic lung disease.

to provide comparative measures of economic well-being across communities and is a composite ranking of 7 complementary economic indicators, including education level, housing vacancy, unemployment, poverty rate, median income, job growth, and business establishments.[19,22] The 7 variables are weighted evenly to create a ZIP code's rank compared to peers and then normalized to obtain a distress score that ranges from 0 (no distress) to 100 (severe distress). The 2020 edition is built from the American Communities Survey (ACS) 5-year estimates and the Census Bureau Business Patterns. Lastly, to account for baseline patient comorbidities, we included several clinical and demographic variables in the regression model (Cohort C; Supplemental S2). Since comorbidities at the time of presentation for PCI are likely impacted by race and level of economic deprivation, we added comorbidities last into our sequential matching in an effort to analyze how comorbidities mediate the association between race and PCI outcomes, separate from the effect of socioeconomic factors. A complete description of the mediational model and the steps used can be found in the Supplemental Methods (S3).

Statistical analysis

Baseline characteristics between Black and White patients were compared using Pearson X^2 or Fisher exact tests for categorical variables and *t* tests or Wilcoxon rank sum test for continuous variables. For the analysis of postdischarge outcomes, propensity score matching and multivariable logistic regression were used to assess for any direct and fully or partially mediated effects of race on these outcomes. A propensity score was developed using a logistic regression model with race as the outcome and including baseline clinical and demographic variables as predictors. Black and White patients with similar propensity scores were then matched 1:1 without replacement within a caliper of 0.25 standard deviations using the greedy algorithm as implemented in the R package "Matching" to create a matched analysis cohort where Black and White patients had similar distributions of age and gender.[23]

Table 1 includes a full description of the sequential adjustments that were utilized. First, according to the proposed sequential modeling approach, dual enrollment in Medicare and Medicaid was added as a covariate to the

propensity score model to account for social risk factors that may contribute to disparate outcomes, and matching was repeated to produce a second matched cohort (Cohort A). Next, the DCI of the patient's and hospital's zip code was added to account for the economic well-being of the community (Cohort B). Lastly, clinical characteristics were added to assess the extent of patient comorbidities on post-PCI outcomes (Cohort C).

Outcome analysis through multivariable logistic and Cox regression models adjusting for all variables utilized in matching was performed to assess the extent that the observed impact of race was reduced or rendered nonsignificant after adjustment, thus implying that the observed racial disparity in the outcome is partially or completely mediated by those variables. R version 3.4.1 was utilized for all analysis.[23]

Mediation analysis

Mediation analysis was performed to assess the magnitude by which the proposed mediators explain the association between race and PCI outcomes (90-day readmission and all-cause mortality). The full details of the mediation analysis have been previously described.[24–26] Briefly, we used a weighting approach to assess the effect of race on PCI outcomes through several mediators considered jointly. We chose a multiple-mediator approach to account for exposure-mediator and mediator-mediator interaction. Additionally, this approach allows for the magnitude of each mediator to be inferred when applying the approach sequentially.[26]

In the weighting approach, the marginal natural direct effect (NDE) size and marginal natural indirect effect (NIE) size were calculated. The NIE size represents the effect size mediated through each mediator and from there the proportion mediated (PM) was calculated. The PM reflects the magnitude of the effect size mediated by each socioeconomic variable. Bootstrapping was performed for the confidence intervals. R code for the mediation analysis is available upon request.

Results

Patient characteristics

Our study consisted of 30, 206 Medicare fee-for-service patients undergoing PCI at 48 hospitals across Michigan between January 2013 and March 2018. Patients who identified as multiple races, or races other than Black or White (Asian, Native-American, or Hispanic/Latinx ethnicity), were excluded (n = 889, 2.9%). Of the remaining patients (n = 29,317), 10.28% were Black and 89.72% were White (Supplemental Figure S1). Black patients were more likely to be female (53.9% vs 38.5%, P < .001) and more likely to be current or recent smokers (27.7% vs 19.5%, P < .001). Additionally, Black patients were more likely to have cardiovascular comorbidities including hypertension (96.6% vs 88.4%, P < .001), diabetes mellitus (54.8% vs 39.9%, P < .001), peripheral arterial disease (24.0% vs 17.5%, P < .001) and chronic kidney disease requiring hemodialysis (8.0% vs 1.7%, P < .001). Black patients were more likely to present with non-ST elevation myocardial infarction (30.0% vs 23.9%) whereas White patients were more likely to present with stable angina (8.1% vs 10.0%) or unstable angina (43.1 vs 44.8%; P < .001) (Table II).

Process measures and in-hospital outcomes

We also evaluated several hospital process measures. Black patients were more likely than White patients to be prescribed clopidogrel (72.5% vs 67.7%, P < 0001; Table III), whereas White patients were more likely to be prescribed prasugrel (6.7% vs 10.2%, P < .001). Black patients were more likely to be prescribed lipid-lowering agents (94.5% vs 93.2%, P = .021) and beta-blockers for history of prior myocardial infarction or left ventricular ejection fraction less than 40% (94.4% vs 90.7%, P < .001) (Table 3). Notably, there was a higher percentage of referrals to cardiac rehabilitation among White patients (58.5% vs 75.2%, P < .001).

Regarding in-hospital outcomes, White patients were more likely to experience heart failure (2.4% vs 3.2%, P = .035; Table III), however, Black patients were more likely to require transfusion (3.6% vs 2.2%, P < .001). Otherwise, there were no significant differences in in-hospital PCI outcomes between Black and White patients. Process measures and in-hospital outcomes for matched cohorts can be found in Supplemental Table S4.

Ninety-day readmissions

Black patients were significantly more likely than White patients to be readmitted within 90-days of discharge when accounting for age and gender (adjusted odds ratio [aOR] 1.62, 95% CI 1.32-2.00; Figure 2). This association persisted but was attenuated after adjustment for Medicare and Medicaid Dual eligibility (Cohort A: aOR 1.55, 95% CI 1.25-1.93) and community economic well-being (Cohort B: aOR 1.37, 95% CI 1.14-1.63). The association between race and readmission was rendered nonsignificant after adjusting for baseline characteristics and comorbidities (Cohort C: aOR 1.15, 95% CI 0.95-1.38).

Long-term postdischarge mortality

Median follow-up time for mortality was 3.9 years (interquartile range 2.43-5.46). Black patients had a significantly higher risk of all-cause mortality (adjusted hazard ratio [aHR] 1.45, 95% CI 1.30-1.61; Figure 3). This relationship was attenuated but still statistically significant when adjusting for Medicare and Medicaid dual eligibility (Cohort A: aHR 1.34, 95% CI 1.21-1.50; Figure 3) and community economic well-being (Cohort B: aHR: 1.22 95% CI 1.09-1.37). The association between race and all-cause mortality following PCI was further attenuated and

Table II. Baseline characteristics between Black and White patients, prior to matching

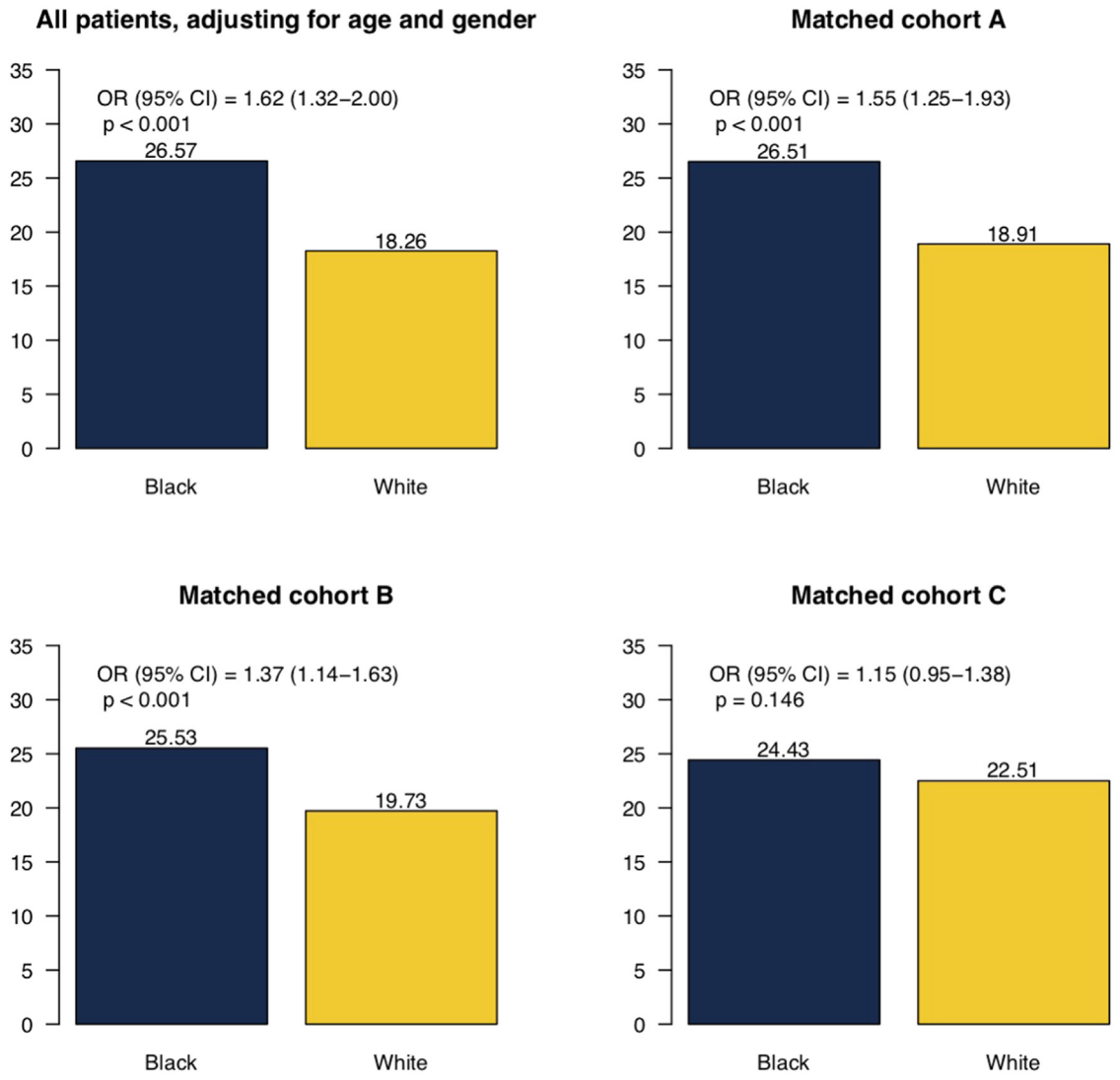
	Black patients (n = 3,015)	White patients (n = 26,302)	*P*-value
Characteristics			
Age, *Years (SD)*	68.9 (10.3)	72.3 (9.4)	<.001
Male sex, *n (%)*	1390 (46.1)	16176 (61.5)	<.001
Comorbidities, *n* (%)			
Current/recent smoker w/in 1 Y	836 (27.7)	5130 (19.5)	<.001
Hypertension	2912 (96.6)	23246 (88.4)	<.001
Dyslipidemia	2488 (82.5)	21761 (82.8)	.725
Family history of premature CAD	280 (9.3)	2969 (11.3)	.001
Prior MI	997 (33.1)	8009 (30.5)	.004
Prior heart failure	904 (30.0)	4594 (17.5)	<.001
Prior PCI	1197 (39.7)	10985 (41.8)	.030
Prior CABG	430 (14.3)	5122 (19.5)	<.001
Currently on dialysis	242 (8.0)	446 (1.7)	<.001
Cerebrovascular disease	694 (23.0)	4874 (18.5)	<.001
Peripheral artery disease	725 (24.0)	4611 (17.5)	<.001
Chronic lung disease	714 (23.7)	5852 (22.3)	.079
Diabetes mellitus	1651 (54.8)	10488 (39.9)	<.001
Coronary artery disease presentation, *n* (%)			
No symptoms, no angina	89 (3.0)	814 (3.1)	<.001
Symptoms, unlikely to be ischemic	63 (2.1)	787 (3.0)	
Stable angina	245 (8.1)	2641 (10.0)	
Unstable angina	1299 (43.1)	11786 (44.8)	
NSTEMI	904 (30.0)	6290 (23.9)	
STEMI or equivalent	414 (13.7)	3979 (15.1)	
Periprocedural variables			
Preprocedure creatinine (mg/dL)	1.66 (1.99)	1.14 (0.81)	<.001
Preprocedure hemoglobin (g/dL)	12.27 (1.89)	13.33 (1.85)	<.001
Cardiogenic shock at start of PCI	58 (1.9)	456 (1.7)	.495
Intraaortic balloon pump	48 (1.6)	316 (1.2)	.080
Other mechanical ventricular support	53 (1.8)	239 (0.9)	<.001
Arterial access site			
Femoral	1982 (65.8)	17056 (64.9)	.655
Radial	1024 (34.0)	9160 (34.8)	
Brachial	7 (0.2)	64 (0.2)	
Other	1 (0.0)	20 (0.1)	

Table III. Process measures and in-hospital outcomes between Black and White patients, prior to matching

	Black patients (n = 3,015)	White patients (n = 26,302)	*P*-value
Process Measures, *n* (%)			
Prescription of antiplatelet			
Clopidogrel	2130 (72.4)	17350 (67.6)	<.001
Prasugrel	196 (6.7)	2626 (10.2)	<.001
Ticagrelor	589 (20.0)	5309 (20.7)	.410
Beta-blocker if prior MI or LVEF<40	1239 (94.5)	9288 (90.8)	<.001
ACE-I/ARB if LVEF<40% or DM	1358 (73.1)	9375 (74.2)	.324
Lipid lowering agent at discharge	2798 (95.1)	23949 (93.3)	<.001
Referral to cardiac rehabilitation	1730 (58.4)	19511 (75.4)	<.001
Smoking cessation among eligible pts.	747 (89.4)	4674 (91.2)	.094
In-Hospital Outcomes, *n* (%)			
Myocardial infarction	38 (1.3)	348 (1.3)	.838
Cardiogenic shock	46 (1.5)	488 (1.9)	.224
Heart failure	73 (2.4)	837 (3.2)	.025
Stroke	10 (0.3)	92 (0.4)	1.000
RBC/Whole blood transfusion	109 (3.6)	566 (2.2)	<.001
Bleeding event w/in 72 H	108 (3.6)	881 (3.4)	.542

Percentages reported for discharge medications and cardiac rehabilitation referral are calculated excluding from the denominator in-hospital mortality cases, patients with recorded medication contraindications, and patients recorded as ineligible for rehabilitation. MI=myocardial infarction, LVEF=left ventricular ejection fraction, ACE-angiotension coverting enzyme inhibitor, ARB=angiotension receptor blocker, DM=diabetes mellitus, RBC = red blood cells.

Figure 2



Bar graph depicting odds of 90-day readmission following percutaneous coronary intervention by race for Black (blue) and White (maize) patients. Odds ratio, confidence interval, and *P*-value are listed for each cohort. Baseline Cohort: Age and gender, Matched Cohort A: Medicare and Medical dual eligibility, Matched Cohort B: Cohort A + Distressed Communities Index of hospital & patient community, Matched Cohort C: Cohort B + baseline demographic and clinical factors. CI, confidence interval; OR, odds ratio.

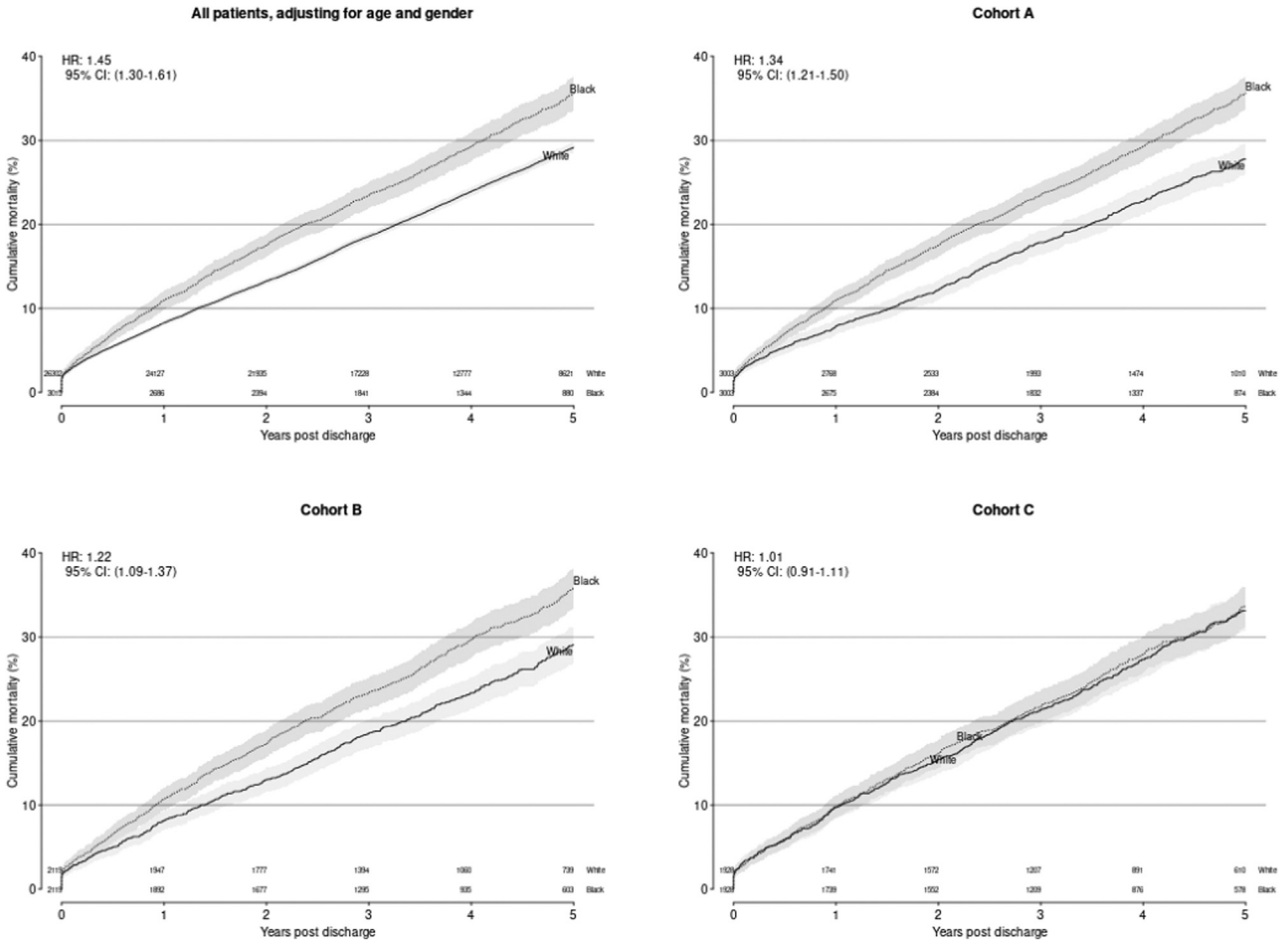
no longer statistically significant when adjusting for patient comorbidities (Cohort C: aHR 1.01, 95% CI 0.91-1.11).

Mediation analysis

The proportion-mediated (PM) by each proposed mediator was calculated using the multiple mediation analysis described in the Methods section. Medicare and Medicaid dual eligibility mediated 11.0% of the association between race and 90-day readmission following PCI (Figure 4; 95% CI 4.89%-17.37%). The combination of dual eligibility and community economic status mediated 22.3% of the association (95% CI 12.11%-33.44%). Dual eligibility, community economic status, and patient comorbidities mediated 45.0% of the association (95% CI 27.00%-60.30%).

Medicare and Medicaid dual eligibility mediated 21.1% of the observed association between race and 1-year mortality (95% CI 8.24%-35.62%). Dual eligibility and community economic well-being combined mediated 43.0% of the association (95% CI 24.31%-65.98%). Together all 3 mediators of dual eligibility, community economic well-

Figure 3



Kaplan-Meier Hazard of long-term mortality following percutaneous coronary intervention for Black (dark gray) and White (light gray) patients. Hazard ratio and 95% confidence interval are listed for each cohort. Baseline Cohort: Age and gender, Matched Cohort A: Medicare and Medical dual eligibility, Matched Cohort B: Cohort A + Distressed Communities Index of hospital & patient community, Matched Cohort C: Cohort B + baseline demographic and clinical factors. CI, confidence interval; HR, hazard ratio.

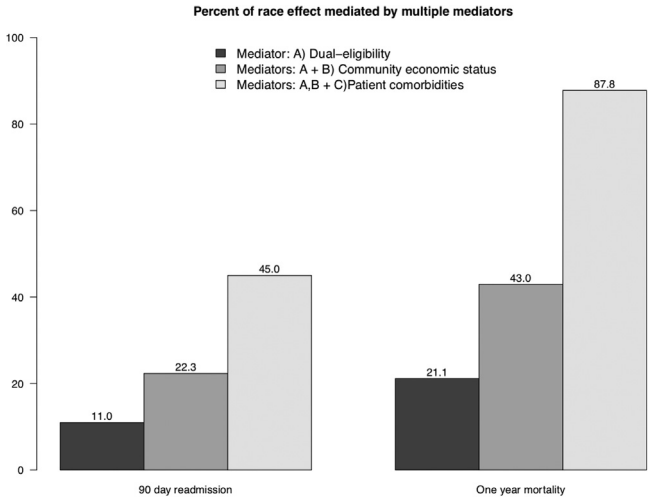
being, and patient comorbidities mediated 87.8% (95% CI 60.23%-123.28%).

Discussion

Our study highlights several key findings in the relationship between race and PCI outcomes. First, among patients undergoing PCI in contemporary practice, there was minimal difference in in-hospital postprocedure outcomes by race. Second, compared with White patients, Black patients had a higher risk of 90-day readmission and long-term mortality after PCI. These associations were attenuated and no longer statistically significant after adjusting for dual eligibility, economic well-being of the patient's community, and baseline comorbidities. Lastly, mediation analysis revealed that while dual eligibility and economic well-being of the health care community partially explain the observed racial disparities in PCI outcomes, comorbidity burden mediates the greatest proportion of this differential risk.

The present study provides an important advance in our understanding of racial disparities in outcomes following PCI by evaluating mediators that may lay on the causal pathway between race and 90-day readmission and mortality. Prior studies, including a recent analysis of pooled data from 10 prospective randomized control trials from Golomb et al, found that risk for adverse clinical outcomes following PCI persists even after adjustment for baseline comorbidities, suggesting race is an independent predictor of worse outcomes.[10] However, these studies did not account for nontraditional cardiovascular risk factors including personal and community

Figure 4



Bar graph depicting estimated percent of race effect on 90-day readmission (left) and 1-year mortality (right) mediated by proposed mediators. Percent mediated is listed above each bar. Proposed mediators are sequentially added from left to right: percent mediated by dual eligibility (A - dark gray), percent mediated by dual eligibility + community economic status (A+B - gray), percent mediated by dual eligibility, community economic status, and patient comorbidities (A+B+C - light gray).

economic status, which reflect poverty and potentially poor access to quality health care resulting from longstanding policies and practices that systematically marginalize Black patients.[27] As a result of structural racism, Black patients experience a higher burden of detrimental social determinants of health so these risk factors must be accounted for to adequately address risk of adverse outcome following PCI.[28,29] Our study uniquely adds to our understanding of the relationship between race and PCI outcomes by applying a mediation framework to understand the magnitude of impact of not only traditional cardiovascular risk factors, but also a range of personal and community social determinants of health – including personal wealth, insurances status, economic distress of the community (capturing employment rates, poverty rate, education level, and housing vacancy of the community) – which all have prominent roles in evaluation and management of CAD across the care continuum. It is possible that our study has even underestimated the association of socioeconomic factors and cardiovascular outcomes as our sample includes only patients who underwent PCI, a procedure with barriers to access for minority patients.[5,30]

While our study supports the role of economic disadvantage in differential outcomes by race, the data also suggests that comorbidity burden continues to mediate the largest proportion of the observed racial disparities in PCI outcomes. Our study utilized a similar framework to an analysis from Kobayashi et al which used sequential adjustment to assess the influence of comorbidities, socioeconomic status, and site-level racial breakdown on post-PCI outcomes between Black and White patients treated at US Veterans Affairs Hospitals. The authors found that baseline comorbidities primarily account for differences in unadjusted mortality difference.[14] Our sequential regression approach showed similar results, in which the relationship between race and 90-day readmission and cumulative mortality was rendered statistically nonsignificant by adjustment for baseline clinical characteristics and comorbidities. Additionally, our mediation framework demonstrated that baseline comorbidities had the greatest magnitude of impact on the observed racial disparities in 90-day readmission and cumulative morality following PCI. It remains difficult to disentangle the role of baseline clinical risk from economic factors as these mediators are likely highly interrelated with bidirectional effects.[30] Lower socioeconomic status portends worse health, just as illness undermines financial security and economic opportunity, especially within communities of color.[31] To address this complexity, we utilized a multiple mediator approach in our study, which is designed to address mediator-mediator interaction,[26] although it is possible that the impact of baseline comorbidities is still overestimated and in some part due to the economic consequences of poor health. Preventive efforts must nevertheless begin with traditional risk factor modification and address the complex social, environmental, and behavioral factors that contribute to them.

While our data demonstrated racial disparities in 90-day readmission and mortality, there were minimal differences in process measures and in-hospital outcomes. The main difference observed in peri-procedural care was a lower rate of prasugrel use in Black patients, which reflects previous studies showing underutilization of newer P2Y12 inhibitors in this population and may be due to socioeconomic and insurance factors.[15,32] We also noted that compared with White patients, Black patients were less likely to receive a referral to cardiac rehabilitation prior to hospital discharge. This finding requires further investigation to understand the potential factors leading to this important disparity. However, Black patients were slightly more likely than White patients to receive other guideline-directed medical therapy, including beta blockers and lipid-lowering agents, but otherwise, there were no major differences in in-hospital PCI process measures. While earlier studies assessing racial disparities in PCI outcomes found differences in periprocedural care and prescription of evidence-based-treatments,[33] our contemporary study shows more marked disparities in longer-term outcomes rather than differences at the time of care.[1] This could reflect improving adherence to well-established inpatient guidelines for treatment of acute coronary syndrome and coronary artery disease. Our findings are aligned with prior studies that have found little opportunity for improvement in PCI-specific process measures, which are poorly correlated with hospital variation in long-term outcomes.[33,34] Future studies that characterize care in the outpatient setting are needed to better understand the difference in postdischarge outcomes.

Our study findings highlight the important opportunity for reducing disparities outside of the acute hospital setting, including the critical need to address gaps in pre- and postprocedural care, which are often a result of social determinants of health, including personal and community-level poverty.[17,35] From a prevention standpoint, policies need to reinforce and expand programs that have been developed to reduce the burden of chronic cardiovascular conditions, including obesity, hypertension, chronic kidney disease, and diabetes mellitus, in minority groups. Enhanced care coordination and patient navigation, which have been studied in the oncology patient population, are important for managing complex comorbidities that are often rooted in social risk and can be applied to the cardiovascular care setting.[36–38] Health care teams can also address disparities by promoting pathways out of poverty and eliminating barriers to access through transportation support, elimination of co-pays and collaboration with social support agencies. Ongoing cultural competence and implicit bias training for our cardiovascular providers is also paramount[38–40]; it is possible the observed differences we saw in rate of cardiac rehabilitation referrals may reflect unconscious racial biases that impact referral patterns. Deeper investigation into the potential causes of important healthcare disparities, such as the difference in rates of cardiac rehabilitation referral, is required. Finally, cardiovascular providers must continue to use data and registries to monitor outcomes, identify disparities, and track the effectiveness of such interventions over time.

Limitations

Our findings should be taken in the context of some important limitations. As an observational study, our analysis is subject to unmeasured confounding; however, we were able to account for a wide range of demographic, clinic, and procedural variables by merging clinical registry and administrative claims data. Second, we categorized race as Black and White, which does not account for other racial minorities (eg, Latinx, Asian/Pacific Islander, Native American) or those who identify as biracial or multiracial. Third, despite using a multicenter registry that includes hospitals across diverse geographic areas, our findings are limited to a single state and may not be generalizable to other states. Fourth, we only used 1 variable to account for patient-level socioeconomic status, however, Medicare and Medicaid dual eligibility has been previously used as a measure of a mix of social, economic, and functional health factors in prior studies.[41,42] Lastly, all hospitals participate in the BMC2 collaborative quality improvement initiative for PCI. As a group, we share best practices and routinely evaluate quality of care measures with ongoing quality improvement projects.[43] Thus, engagement in these quality improvement activities may limit the generalizability of our findings to other states without such collaborative quality improvement programs.

Conclusions

We found that Black patients had a higher risk of 90-day readmission and cumulative mortality following PCI compared with White patients. These associations were mediated by personal socioeconomic status, economic well-being of the health care community, and to the greatest extent, baseline comorbidity burden. Hospitals and policymakers need to invest in programs that not only promote prevention of disease, but also address disparities in postacute care and outcomes to mitigate the adverse health outcomes associated with socioeconomic status and community factors. Future research is needed to identify and evaluate interventions that address these mediators to promote health equity in PCI outcomes.

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Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ahj.2022.10.001.

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