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ORIGINAL RESEARCH

OUTCOMES AND QUALITY

Racial and Socioeconomic Disparities in Cardiovascular Outcomes of Preeclampsia Hospitalizations in the United States 2004-2019

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ABSTRACT

BACKGROUND Preeclampsia is associated with higher in-hospital cardiovascular events and mortality with known disparities by race/ethnicity, but data on the interaction between income and these outcomes remain limited.

OBJECTIVES This study investigated racial and socioeconomic disparities in cardiovascular outcomes of preeclampsia at delivery hospitalizations.

METHODS We analyzed National Inpatient Sample data using International Classification of Diseases-9th Revision/-10th Revision codes between 2004 and 2019. We identified a total of 2,436,991 delivery hospitalizations with preeclampsia/eclampsia as a primary diagnosis representing White (43.1%), Black (18.4%), Hispanic (18.7%), and Asian or Pacific Islander (A/PI; 3.3%) women. We stratified the population based on median household income (low income, medium income, and high income). Logistic regression and propensity-matched analysis were used for reporting outcomes adjusted for age, hospital region, and baseline comorbidities.

RESULTS Black Hispanic, and A/PI women with preeclampsia had higher in-hospital mortality compared with White women across all groups of income. Hispanic women had lower odds of peripartum cardiomyopathy (PPCM) compared with White women. A significant interaction effect was observed with race/ethnicity and median household income for in-hospital mortality and PPCM with preeclampsia. Furthermore, high-income Black women had higher odds of PPCM, stroke, acute kidney injury, heart failure, cardiac arrhythmia, and venous thromboembolism compared with low-income White women.

CONCLUSIONS Women with preeclampsia experience significant racial/ethnic and socioeconomic disparities in inpatient mortality and cardiovascular outcomes at delivery. Across all income groups, Black, Hispanic, and A/PI women experience higher odds of in-hospital mortality compared with White women. Furthermore, high-income Black women had greater odds of many CV complications compared with low-income White women. (JACC Adv 2022;1:100062)

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ABBREVIATIONS AND ACRONYMS

A/PI = Asian or Pacific Islanders

AKI = Acute kidney injury

ICD = International Classification of Diseases

NIS = National Inpatient Sample

PPCM = peripartum cardiomyopathy

VTE = venous thromboembolism

Preeclampsia is a multisystem disorder characterized by pregnancy-induced hypertension and end-organ dysfunction after 20 weeks of gestation or postpartum.[1] In the United States, preeclampsia is the leading cause of maternal mortality, morbidity, and premature births. Preeclampsia has previously been shown to be associated with adverse cardiovascular complications, including peripartum cardiomyopathy (PPCM), acute ischemic heart diseases, pulmonary embolism, and cardiac arrhythmias.[2] Moreover, significant racial/ethnic disparities exist in hypertensive disorders of pregnancy in the United States, with greater risk of preeclampsia experienced by Black women, which may be driven by inequities in health care access, structural racism, and other social determinants of health (SDOH).[2,3]

It is well established that individuals with higher socioeconomic status have better health outcomes compared with lower socioeconomic groups[4-9] and greater access to preventive health care services[10]. However, recent literature suggests that higher socioeconomic status might not provide the same health benefits to Black women in the United States compared with White women.[6,11] Moreover, a phenomenon of "widening health disparity" has been described in previous studies where Black women who are highly affluent have poorer health outcomes compared with their White counterparts.[6]

There is a scarcity of data on the interaction between race/ethnicity and income for in-hospital complications with preeclampsia. In this light, our study aims to investigate disparities in outcomes of preeclampsia during delivery hospitalizations stratified by race and median household income in a real-world population study from the National Inpatient Sample (NIS).

METHODS

NIS data are publicly available. The specific data supporting this study's findings are available from the corresponding author on request.

STUDY DATA. This study used data from the NIS database from 2004 to 2019. The NIS is one of several databases managed by the Agency for Healthcare Research and Quality through a Federal-State-Industry partnership called the Healthcare Cost and Utilization Project.[12,13] The NIS contains administrative claims data from more than 7 million inpatient hospitalizations annually in 47 participating states plus the District of Columbia, representing more than 97% of the US population. As NIS data are compiled annually, the data can be used for the analysis of disease trends over time using trend weights compiled by the Healthcare Cost and Utilization Project.[14] Institutional review board approval and informed consent were not required for this study because NIS data are deidentified and publicly available.

STUDY DESIGN AND DATA SELECTION. We analyzed NIS data using International Classification of Diseases-9th Revision-Clinical Modification (ICD-9-CM) and International Classification of Diseases-10th Revision-Clinical Modification (ICD-10-CM) claims codes. ICD-9-CM codes 642x and ICD-10-CM code 014x/0.15x were used to identify all delivery hospitalizations, including those associated with preeclampsia and eclampsia (Supplemental Table 1). All eclampsia cases were categorized with preeclampsia for this analysis. All diagnosis fields were queried to select and categorize the study population. NIS provides data on the income quartile classification, which is the estimated median household income of patients residing in a zip code. The demographic data using the zip code is obtained from Claritas and is updated annually.[13,15] Based on median household income, the study population was divided into 3 groups: low income (0th-25th percentile), medium income (25th-75th percentile), and high income (75th-100th percentile). The data on median household income quartiles provided by NIS from 2002 to 2019 are shown in Supplemental Table 2. A detailed methods flowsheet is presented in **Figure 1**.

STUDY ENDPOINT. The primary study endpoint was inpatient mortality. The secondary endpoints included in-hospital cardiovascular complications (PPCM, acute coronary syndrome, acute kidney injury [AKI], stroke, acute heart failure, pulmonary

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edema, cardiac arrhythmias, and venous thromboembolism [VTE]) with preeclampsia. Trend analysis included temporal trends in the prevalence of preeclampsia during delivery hospitalizations and PPCM complicating preeclampsia at the time of delivery. Associated procedures and complications were identified using ICD-9-CM and ICD-10-CM codes (Supplemental Table 1).

STATISTICAL ANALYSIS. Descriptive statistics were presented as frequencies with percentages for categorical variables and as median (interquartile range) for continuous variables. Pearson chi-square test and Fisher exact test were used to compare baseline characteristics for categorical variables and Mann-Whitney *U* test for continuous variables. We used simple linear regression to assess temporal trends during our study period. The calendar year was included as an independent variable, whereas percentage of individuals developing peripartum complications stratified by race/ethnicity and income was used as a dependent variable. No autocorrelation between the 2 variables was observed; hence, all assumptions necessary to apply the test were fulfilled. The *P* value for the slope was used to assess temporal trends.

COMPARISON OF HOSPITALIZATION OUTCOMES STRATIFIED BY HOUSEHOLD INCOME. A multivariable logistic regression model was used to compute independent predictors of mortality and cardiovascular complications adjusted for baseline characteristics including age, hypertension, diabetes, hyperlipidemia, heart failure, chronic kidney disease, prepregnancy coronary artery disease, obesity, smoking, hospital region, multiple gestations, and cesarean delivery. The aforementioned variables were selected based on prior literature reviews that were known to be clinically relevant. White women were chosen as the reference group. A supplementary multivariable logistic regression analysis with additional adjustment for hospital characteristics such as hospital bed size, location, as well as teaching status was also performed. Similarly, a multivariable logistic regression model was used for testing the interaction between race and median household income with the primary and secondary outcomes. A 2-way interaction term (race × income) was used, and the model was adjusted for age, hypertension, diabetes, hyperlipidemia, heart failure, chronic kidney disease, coronary artery disease, obesity, smoking, hospital region, multiple gestations, and cesarean delivery.

COMPARISON OF HIGH-INCOME WHITE AND BLACK WOMEN VS LOW-INCOME WHITE AND BLACK WOMEN. A further subgroup analysis was performed to compare outcomes between high-income White and Black women compared with low-income White and Black women. Furthermore, we also compared high-income Black women with low-income White women. For this purpose, R's MatchIt package was used for propensity matching. To account for potential confounding and selection bias, a propensity score matching model was developed using logistic regression to derive 2 matched groups for comparative outcomes analysis of high-income White and Black women vs low-income White and Black women, as well as high-income Black women vs low-income White women (Supplemental Figures 1 to 7). A nearest-neighbor variable ratio, parallel, balanced propensity matching model was made using 0.2 SDs caliper width. Variables included in propensity

FIGURE 1 Study Flowchart

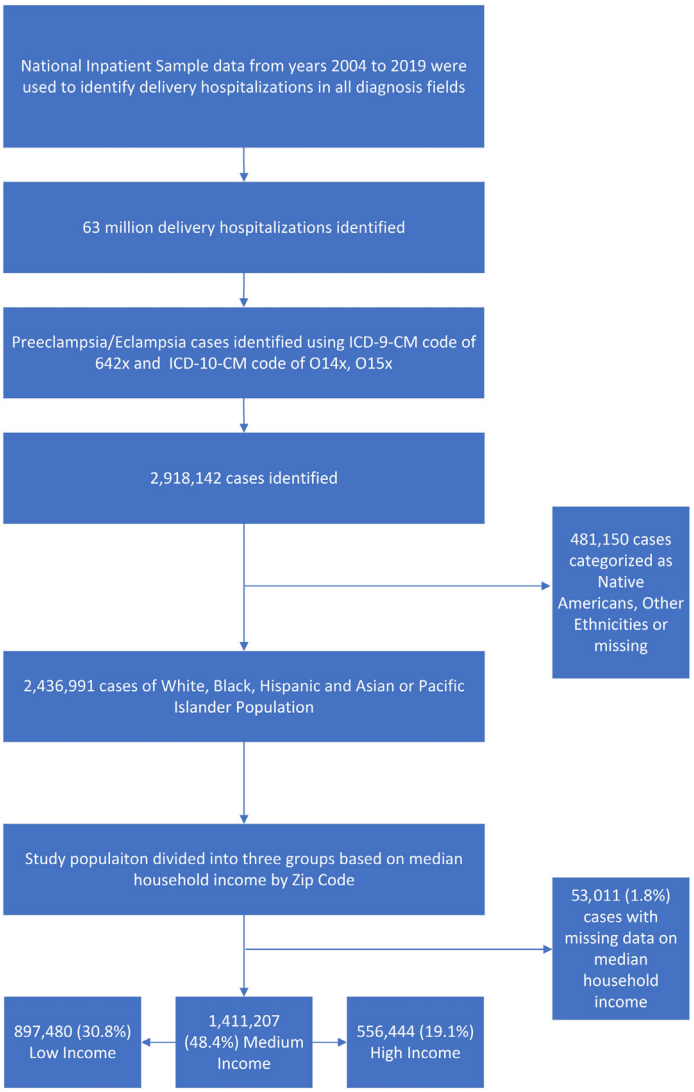


TABLE 1 Baseline Patient and Hospitalization Characteristics for Patients With Preeclampsia During Delivery Hospitalizations Stratified by Income Group

	Low Income (n = 897,480)	Medium Income (n = 1,411,207)	High Income (n = 556,444)	*P* Value
Age, y	27 (22-32)	28 (23-33)	31 (27-35)	<0.01
Race/ethnicity				
White	281,910 (36.8)	665,657 (57.1)	294,578 (63.3)	<0.01
Black	264,111 (34.5)	206,916 (17.7)	54,689 (11.7)	
Hispanic	207,846 (27.1)	252,945 (21.7)	73,516 (15.8)	
Asian or Pacific Islander	11,706 (1.5)	40,569 (3.5)	42,914 (9.2)	
Other (or missing)	11,706 (1.5)	40,569 (3.5)	42,914 (9.2)	
Hospital regions				<0.01
Northeast	115,892 (12.9)	197,550 (14.0)	123,501 (22.2)	
Midwest	167,269 (18.6)	329,785 (23.4)	99,315 (17.8)	
South	481,643 (53.7)	552,577 (39.2)	171,955 (30.9)	
West	132,677 (14.8)	331,295 (23.5)	161,674 (29.1)	
Chronic hypertension	72,526 (8.1)	93,990 (6.7)	34,651 (6.2)	<0.01
Diabetes	8,725 (1.0)	11,520 (0.8)	3,145 (0.6)	<0.01
Hyperlipidemia	3,090 (0.3)	6,360 (0.5)	3,099 (0.6)	<0.01
Heart failure	4,280 (0.5)	5,348 (0.4)	1,842 (0.3)	<0.01
Chronic kidney disease	3,874 (0.4)	5,291 (0.4)	1,719 (0.3)	<0.01
Coronary artery disease	495 (0.1)	507 (0.0)	173 (0.0)	<0.01
Obesity	103,538 (11.5)	147,223 (10.4)	44,660 (8.0)	<0.01
Smoking	25,544 (2.8)	28,789 (2.0)	5,322 (1.0)	<0.01
Multiple gestation	34,579 (3.9)	70,823 (5.0)	43,846 (7.9)	<0.01
Cesarean delivery	468,249 (52.2)	737,107 (52.2)	301,142 (54.1)	<0.01

Values are median (IQR) or n (%).

matching model were age, hypertension, diabetes, hyperlipidemia, heart failure, chronic kidney disease, coronary artery disease, obesity, smoking, hospital region, multiple gestations, and cesarean delivery.

MISSING VALUES. All missing values are reported in the baseline characteristics and study flow diagram (Table 1, Figure 1). As the overall missing values were minimal, we used listwise deletion and did not include the missing values in the logistic regression analysis. For propensity-matched analysis, we recoded missing values as "other."

A *P* value of <0.05 for considered statistically significant. All statistical analyses were performed using statistical package for social science version 27 (IBM Corp) and R software for statistical computing version 4.5 for propensity-matched analysis. Given the complex survey design of NIS, sample weights, clusters, and strata were applied to generate US national estimates.

RESULTS

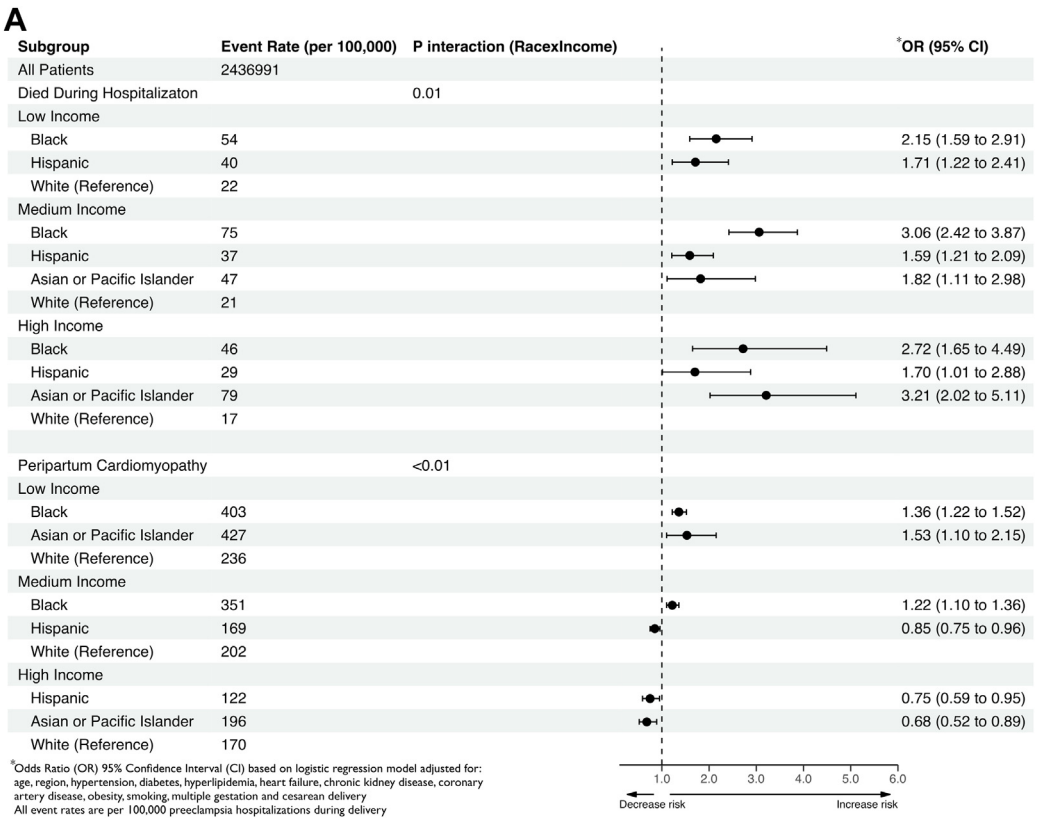
BASELINE CHARACTERISTICS OF THE POPULATION. A total of 2,436,991 weighted hospitalizations for preeclampsia were included in the analysis. Of the patients admitted with preeclampsia 1,256,726 (43.1%) were White women, whereas 53,6820 (18.4%), 54,668 (18.7%), and 54,668 (3.3%) were Black, Hispanic, and Asian or Pacific Islander (A/PI) women, respectively. In terms of median household incomes, a total of 897,480 (30.8%) were in the low income group, 1,411,207 (48.4%) in the medium income group, and 55,644 (19.1%) in the high income group. Women in the high income group had higher median age compared with low-income and medium-income women. White women had the majority representation in the high-income group (63.3%), whereas Black women predominated in the low-income group (34.5%). The detailed baseline and hospital characteristics, including the racial distribution of each income group, are presented in Table 1.

ADJUSTED ODDS OF ADVERSE HOSPITALIZATION OUTCOMES STRATIFIED BY INCOME. In-hospital mortality was associated with income, and the risk differed between race groups (*P* interaction = 0.01). A consistent trend of increased in-hospital mortality was seen in Black, Hispanic, and A/PI women compared with White women across all income groups. For example, compared with White women in the same respective income groups, Black women had 2- to 3-fold greater odds of in-hospital death across low income (adjusted OR: 2.15 [95% CI: 1.59-2.91]), medium income (3.06 [95% CI: 2.42-3.87]), and high income (2.72 [95% CI: 1.65-4.49]) groups. Hispanic women similarly had 1.6 to 1.7 greater odds of mortality across all income groups, and for A/PI women, greater risk was seen for the medium (1.82 [95% CI: 1.11-2.98]) and high (3.21 [95% CI: 2.02-5.11]) income groups (Figure 2A, Supplemental Tables 2 to 4).

Similarly, for PPCM, acute coronary syndrome, cardiac arrhythmias, and AKI were associated with income, and the risk differed between race groups (*P* interaction = 0.01). Black women had higher odds of cardiovascular complications, including PPCM, acute coronary syndrome, cardiac arrhythmias, and AKI when compared with White women of their corresponding income class. Hispanic women had a lower likelihood of development of PPCM when compared with White women. A/PI women had higher odds of cardiac arrhythmias, stroke, and AKI across all income groups (Figures 2B and 2C). A supplementary analysis with additional adjustment for hospital characteristics mirrored our primary analysis with no significant change in the primary or secondary outcomes (Supplemental Table 5).

PROPENSITY-MATCHED OUTCOMES OF HIGH-INCOME WHITE AND BLACK WOMEN VS LOW-INCOME WHITE AND BLACK WOMEN DURING PREECLAMPSIA HOSPITALIZATION. The hospitalization outcomes before and after propensity matching are shown in Supplemental Tables 6 and 7. After propensity

FIGURE 2 Adjusted Odds Ratio of In-Hospital Mortality and Cardiovascular Complications Stratified by Median Income



(A) Adjusted odds ratio for in-hospital mortality and peripartum cardiomyopathy. **(B)** Adjusted odds ratio for acute coronary syndrome, stroke, acute kidney injury, and heart failure. **(C)** Adjusted odds ratio for pulmonary edema, cardiac arrhythmias, and venous thromboembolism.

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matching, White women in the high-income group had lower odds of in-hospital mortality, PPCM, heart failure, pulmonary edema, cardiac arrhythmias, and VTE when compared with low-income White women. Among Black women, high income was associated with a trend for lower in-hospital mortality, but this was not statistically significant. Furthermore, acute coronary syndrome and AKI rates were actually higher in high-income Black women compared with low-income Black women (**Figure 3**, **Table 2**).

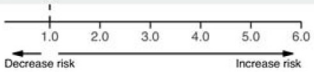
PROPENSITY-MATCHED OUTCOMES OF HIGH-INCOME BLACK WOMEN VS LOW INCOME WHITE WOMEN DURING PREECLAMPSIA HOSPITALIZATION. The hospitalization outcomes before and after propensity matching are shown in Supplemental Table 8. A nonsignificant association of increased risk of in-hospital mortality for high-income Black women compared with low-income White women was also observed. After propensity matching, Black women in the high-income group had higher odds of PPCM, acute coronary syndrome, stroke, heart failure, cardiac arrhythmias, AKI, and VTE when compared with low-income White women (**Central Illustration**, **Figure 3**, **Table 2**).

TEMPORAL TRENDS. An increase in the prevalence of preeclampsia was observed for all racial/ethnic groups across all income strata, with Black women having the highest prevalence of preeclampsia overall (**Figure 4A** for low income, Supplemental Figures 6 and 7 for medium and high income, respectively). In the low income group, the prevalence of PPCM complicating preeclampsia hospitalizations increased during the study period from 140 per 100,000 in 2004 to 618 per 100,000 ($P < 0.01$) for low-income Black women. For high-income White women, the prevalence of PPCM decreased from 228 per 100,000 to 95 per 100,000 ($P = 0.05$). No significant temporal trend was observed for PPCM for the medium income group (**Figure 4B** for low income, Supplemental Figures 8 and 9 for medium and high income).

FIGURE 2 Continued

B

Subgroup	Event Rate (per 100,000)	P interaction (RacexIncome)	*OR (95% CI)
All Patients	2436991		
Acute Coronary Syndrome			
Low Income		<0.01	
Black	42		1.45 (1.06 to 1.99)
Hispanic	7		0.41 (0.22 to 0.70)
White(Reference)	23		
High Income			
Black	55		2.45 (1.48 to 4.21)
White(Reference)	14		
Stroke		<0.01	
Low Income			
Black	257		1.92 (1.69 to 2.18)
Hispanic	198		1.43 (1.23 to 1.65)
White(Reference)	134		
Medium Income			
Black	351		1.69 (1.52 to 1.87)
Hispanic	235		1.46 (1.32 to 1.63)
Asian or Pacific Islander	191		1.51 (1.22 to 1.84)
White(Reference)	157		
High Income			
Black	258		1.67 (1.37 to 2.03)
White(Reference)	151		
Acute Kidney Injury		<0.01	
Low Income			
Black	950		2.06 (1.92 to 2.22)
Hispanic	567		1.37 (1.25 to 1.49)
Asian or Pacific Islander	906		1.96 (1.61 to 2.41)
White(Reference)	408		
Medium Income			
Black	946		2.14 (2.01 to 2.27)
Hispanic	540		1.21 (1.13 to 1.30)
Asian or Pacific Islander	784		1.53 (1.35 to 1.72)
White(Reference)	426		
High Income			
Black	991		2.29 (2.06 to 2.55)
Hispanic	495		1.14 (1.01 to 1.29)
Asian or Pacific Islander	874		1.72 (1.52 to 1.94)
White(Reference)	453		
Heart Failure		<0.01	
Medium Income			
Hispanic	279		1.77 (1.33 to 2.34)
White(Reference)	266		
High Income			
Black	464		0.48 (0.34 to 0.69)
White(Reference)	223		



*Odds Ratio (OR) 95% Confidence Interval (CI) based on logistic regression model adjusted for: age, region, hypertension, diabetes, hyperlipidemia, heart failure, chronic kidney disease, coronary artery disease, obesity, smoking, multiple gestation and cesarean delivery
All event rates are per 100,000 preeclampsia hospitalizations during delivery

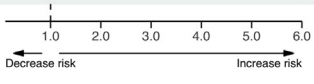
DISCUSSION

Our contemporary 15-year real-world population study of in-hospital outcomes of patients diagnosed with preeclampsia yielded the following principal findings: 1) of the patients admitted with preeclampsia during delivery hospitalizations, inpatient mortality was higher among Black, Hispanic, and A/PI women compared with White women across all income groups; 2) White women belonging to the higher income strata had better outcomes in terms of mortality and cardiovascular complications compared with White women in the lower income groups; 3) higher income Black women did not have a

FIGURE 2 Continued

C

Subgroup	Event Rate (per 100,000)	P interaction (RacexIncome)	*OR (95% CI)
All Patients	2436991		
Pulmonary Edema		<0.01	
Low Income			
Hispanic	391		0.83 (0.76 to 0.91)
Asian or Pacific Islander	888		1.82 (1.49 to 2.23)
White(Reference)	500		
Medium Income			
Black	567		1.32 (1.23 to 1.42)
Hispanic	567		1.32 (1.23 to 1.72)
Asian or Pacific Islander	611		1.45 (1.27 to 1.66)
White(Reference)	404		
High Income			
Black	496		1.17 (1.02 to 1.34)
Asian or Pacific Islander	802		1.86 (1.64 to 2.11)
White(Reference)	400		
Cardiac Arrhythmias		<0.01	
Low Income			
Black	1806		1.42 (1.36 to 1.49)
Hispanic	1600		1.37 (1.31 to 1.46)
Asian or Pacific Islander	2033		1.66 (1.46 to 1.90)
White(Reference)	1239		
Medium Income			
Black	1765		1.71 (1.64 to 1.79)
Hispanic	1417		1.41 (1.34 to 1.46)
White(Reference)	1049		
High Income			
Black	1730		1.82 (1.69 to 1.97)
Hispanic	1238		1.37 (1.26 to 1.48)
Asian or Pacific Islander	1186		1.33 (1.21 to 1.47)
White(Reference)	921		
Venous Thromboembolism		<0.01	
Low Income			
Black	103		1.76 (1.44 to 2.15)
Hispanic	75		1.34 (1.06 to 1.69)
White(Reference)	56		
Medium Income			
Black	142		2.16 (1.85 to 2.52)
Hispanic	44		0.68 (0.54 to 0.84)
White(Reference)	65		
High Income			
Black	126		1.52 (1.15 to 2.00)
Hispanic	46		0.57 (0.41 to 0.83)
Asian or Pacific Islander	23		0.23 (0.12 to 0.45)
White(Reference)	80		

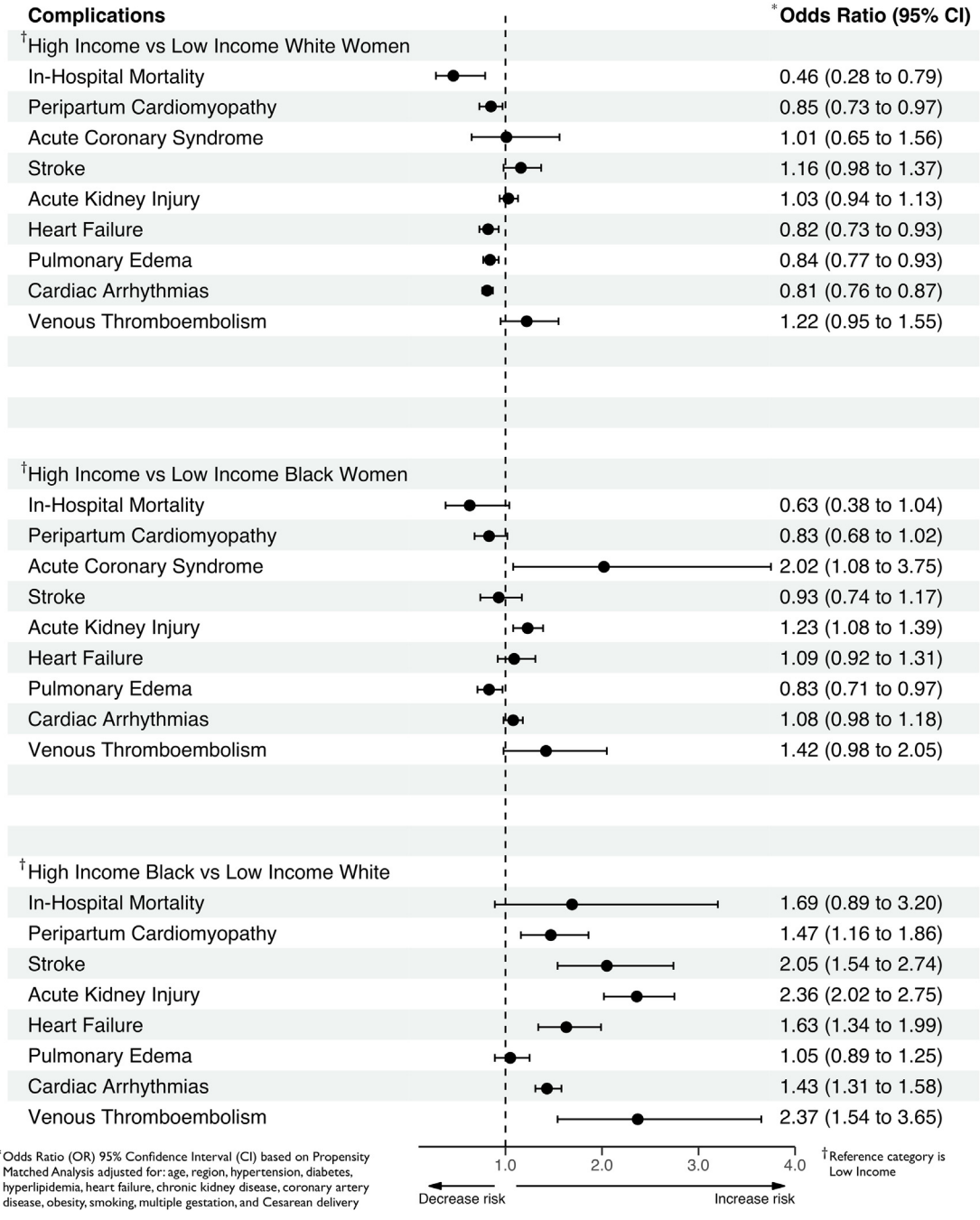


*Odds Ratio (OR) 95% Confidence Interval (CI) based on logistic regression model adjusted for: age, region, hypertension, diabetes, hyperlipidemia, heart failure, chronic kidney disease, coronary artery disease, obesity, smoking, multiple gestation and cesarean delivery
All event rates are per 100,000 preeclampsia hospitalizations during delivery

statistically significantly lower mortality compared with low-income Black women and actually had higher odds of acute coronary syndrome and AKI; 4) higher income Black women had higher cardiovascular complication rates compared with low-income White women; and 5) Hispanic women had the lowest risk of developing PPCM when compared with all other ethnicities across all income groups.

DISPARITY IN PREECLAMPSIA OUTCOMES FOR BLACK WOMEN ACROSS INCOME GROUPS. Previous literature has suggested that higher socioeconomic status confers health protective benefits in terms of all-cause mortality and incidence of cardiovascular outcomes such as hypertensive heart diseases.[16] Hence, it had been postulated that Black, Hispanic, and A/PI women that belong predominantly to lower

FIGURE 3 **Propensity-Matched Odds Ratio of In-Hospital Mortality and Cardiovascular Complications for High-Income White and Black Women vs Low-Income White and Black Women**



income groups will have worse health outcomes, and higher income individuals from underrepresented racial and ethnic groups will have better outcomes.[5] The novelty of our study is the finding that Black women, even when belonging to higher income groups, did not have a statistically significant lower in-hospital mortality rate compared with lower income Black women. Furthermore, we also report that higher income Black women had a higher risk of developing certain cardiovascular complications such as acute coronary syndrome and AKI compared with lower income Black women.

One reason underpinning these findings may be that Black women belonging to the higher income

TABLE 2 Crude and Propensity-Matched Hospitalization Outcomes Per 100,000 Preeclampsia Hospitalizations During Delivery for High-Income White and Black Women vs Low-Income White and Black Women

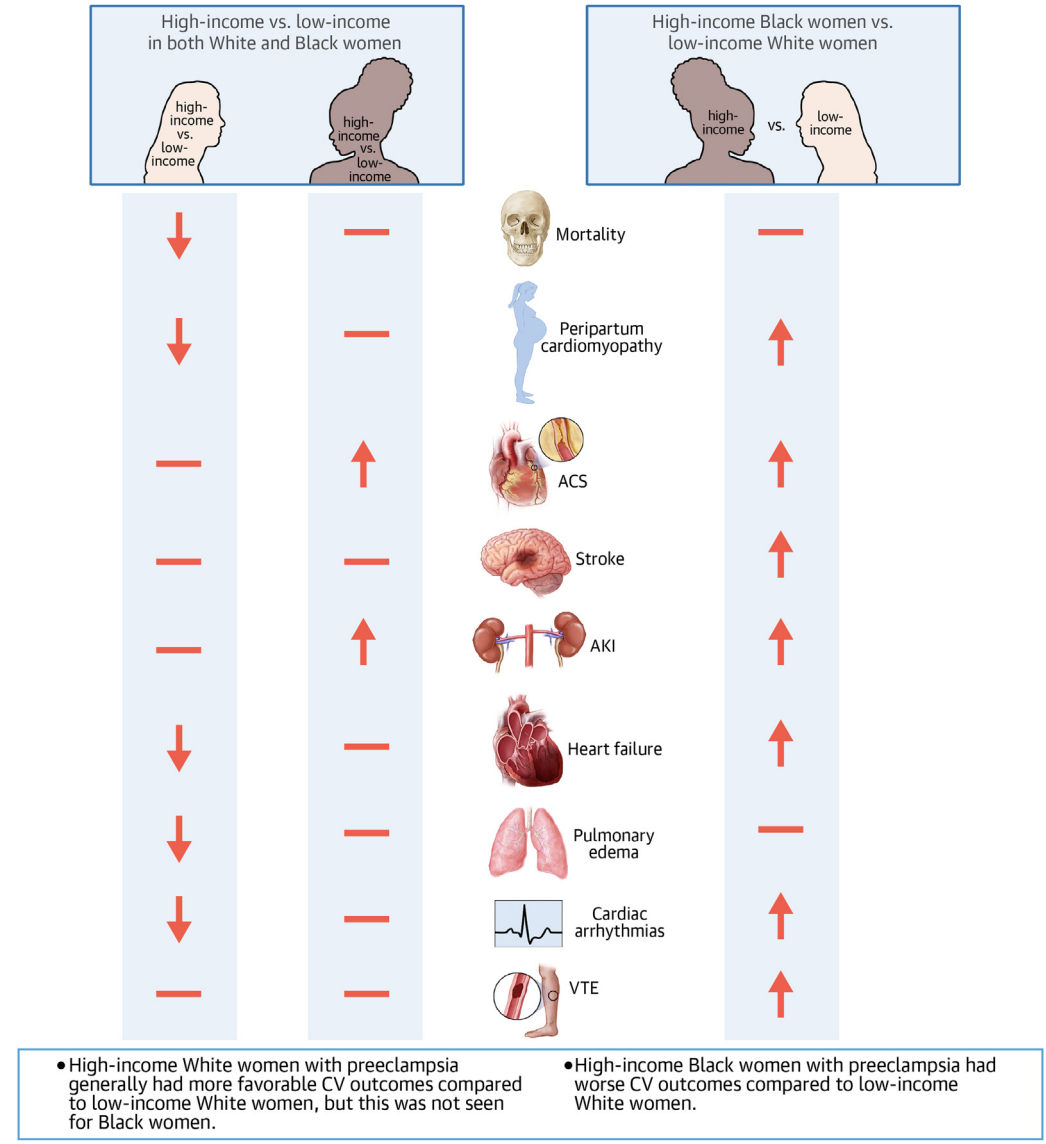
White Women	Crude			Propensity Matched		
Complications	Low Income (n = 281,910)	High Income (n = 294,578)	*P* Value	Low Income (n = 190,990)	High Income (n = 190,109)	*P* Value
In-hospital mortality	22	17	0.12	23	11	<0.01
Peripartum cardiomyopathy	236	170	<0.01	217	184	0.02
Acute heart failure	334	223	<0.01	300	247	<0.01
Acute kidney injury	408	453	<0.01	435	448	0.56
Acute coronary syndrome	23	14	<0.01	21	21	0.98
Stroke	134	151	0.09	133	154	0.09
Pulmonary edema	500	400	<0.01	502	423	<0.01
Cardiac arrhythmias	1,239	921	<0.01	1,150	938	<0.01
Venous thromboembolism	56	80	<0.01	62	76	0.11
Black Women	**Crude**			**Propensity Matched**		
Complications	Low Income (n = 264,111)	High Income (n = 54,689)	*P* Value	Low Income (n = 55,086)	High Income (n = 54,679)	*P* Value
In-hospital motility	143	25	0.43	73	45	0.07
Peripartum cardiomyopathy	1,064	169	<0.01	372	307	0.07
Acute heart failure	1,464	254	<0.01	425	461	0.32
Acute kidney injury	2,510	542	0.37	808	984	<0.01
Acute coronary syndrome	111	30	0.19	27	54	0.02
Stroke	678	141	0.96	278	256	0.52
Pulmonary edema	1,547	271	0.01	595	492	0.03
Cardiac arrhythmias	4,769	946	0.23	1,605	1,717	0.11
Venous thromboembolism	272	69	0.13	89	125	0.06
High-Income Black Women vs Low-Income White Women	**Crude**			**Propensity Matched**		
Complications	Low-Income White (n = 281,910)	High-Income Black (n = 54,689)	*P* Value	Low-Income White (n = 55,325)	High-Income Black (n = 54,689)	*P* Value
In-hospital motility	22	46	<0.01	27	46	0.12
Peripartum cardiomyopathy	236	309	<0.01	211	309	<0.01
Acute heart failure	334	464	<0.01	286	464	<0.01
Acute kidney injury	408	991	<0.01	423	991	<0.01
Acute coronary syndrome	23	55	<0.01	<11[a]	55	<0.01
Stroke	134	258	<0.01	125	258	<0.01
Pulmonary edema	500	496	0.89	470	496	0.54
Cardiac arrhythmias	1,239	1,730	<0.01	1,213	1,730	<0.01
Venous thromboembolism	56	126	<0.01	54	126	<0.01

[a]Cells with count <11 are not reportable as per Healthcare Cost and Utilization Project guidelines.

status may be exposed to higher levels of racism.[17] Previously, Colen et al[18] described this phenomenon where Black and Hispanic women belonging to the higher quartile of incomes were exposed to higher levels of racism, with racial disparities in health being more pronounced among higher socioeconomic groups. This has been shown to influence racial inequities in adverse birth outcomes. For instance, Chae et al[19] showed that Black women residing in areas with a higher level of racism have a higher risk of preterm birth. Thus, because of structural racism and other factors, Black, Hispanic, or A/PI women belonging to higher socioeconomic groups do not tend to have the same quality of health care and other benefits experienced by affluent White women.[20] This further complements the findings of our study that showed that higher income White women had lower mortality rates compared with White women of low-income group. This could explain why socioeconomic status alone could not explain the disparities in cardiovascular outcomes with preeclampsia experienced by Black women.[2]

RACIAL DISPARITY IN PREECLAMPSIA OUTCOMES AT DELIVERY FOR BLACK WOMEN COMPARED WITH WHITE WOMEN. Our stratified analysis evaluated how cardiovascular outcomes at delivery hospitalization in the setting of preeclampsia differed if Black women belonged to the same income compared with White women. A consistent trend was observed that Black women across all income strata had

CENTRAL ILLUSTRATION **Racial and Socioeconomic Disparities in Cardiovascular Outcomes of Preeclampsia Hospitalizations in the United States 2004-2019: A Propensity-Matched Analysis**



Zahid S, et al. JACC Adv. 2022;1(3):100062.

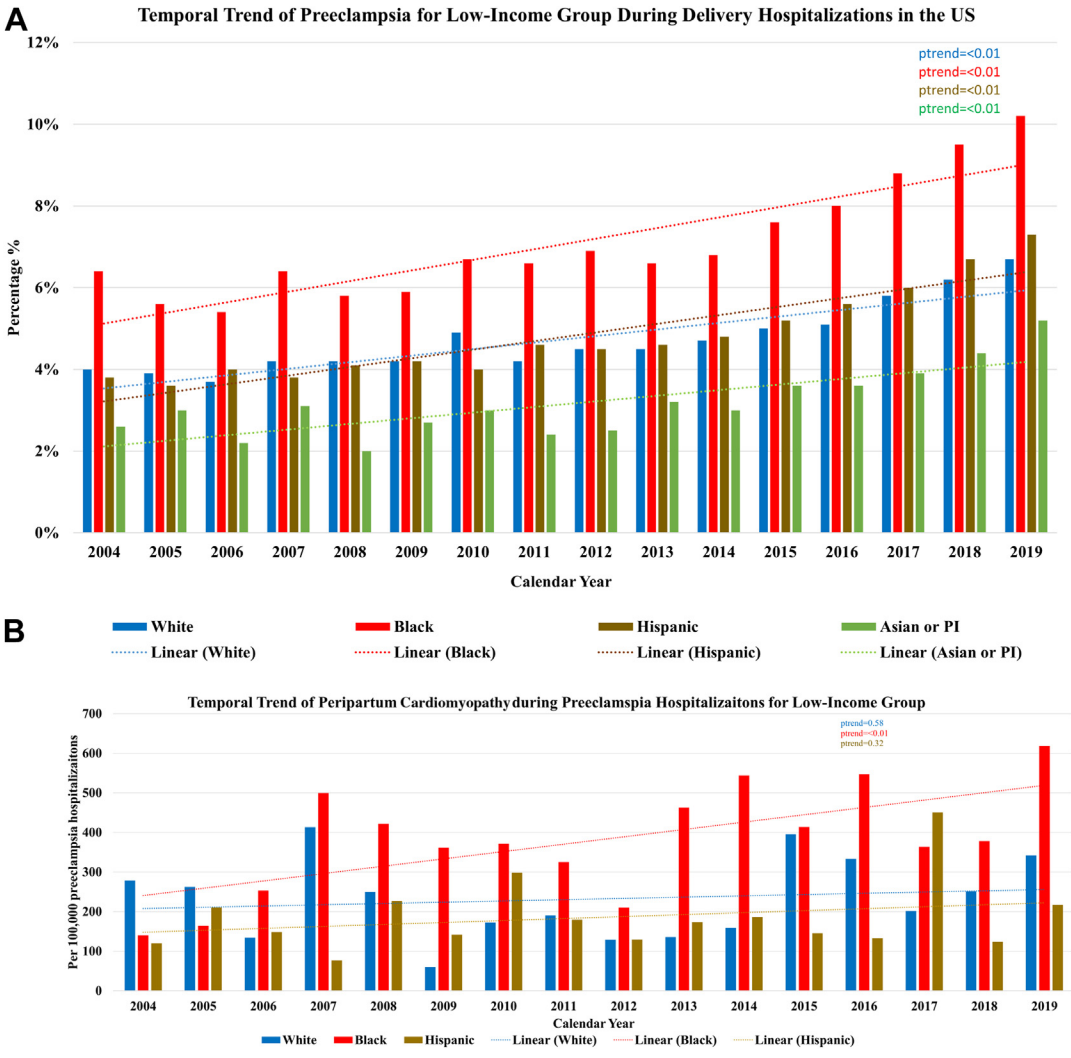
ACS = acute coronary syndrome; AKI = acute kidney injury; CV = cardiovascular; VTE = venous thromboembolism.

worse cardiovascular outcomes when compared with White women.

Even more striking, a comparison of high-income Black women with low-income White women showed that cardiovascular complication rates were higher for high-income Black women. Disparities in access to health care may be 1 reason for the worse outcomes among individuals of lower income. However, our findings suggest that being of higher socioeconomic status did not eliminate the adverse cardiovascular complications with preeclampsia associated with Black race and raises concerns that other factors beyond access to care such as structural racism[17] and bias may be contributing to the poorer outcomes experienced by Black women.

Moreover, we also observed a significant interaction effect between racial/ethnicity and median income. Hence, we postulated that a factor in addition

FIGURE 4 Temporal Trends of Preeclampsia and Peripartum Cardiomyopathy for the Low Income Group From 2004 to 2019



(A) Among low-income group, trend analysis shows the prevalence of preeclampsia has been increasing over time and the highest prevalence of preeclampsia was seen among Black women. **(B)** Among low-income group, trend analysis shows highest prevalence of peripartum cardiomyopathy was among Black women.

to income will influence adverse events in Black women. For instance, previous literature suggests that Black women are affected with a more severe form of PPCM, and there might be additional environmental and genetic factors leading to worse outcomes.[21,22] Furthermore, temporal trend analysis raised significant concern over the increased prevalence of PPCM in low-income Black women. We hypothesize that this could be because of a lack of resources and access to care among Black women with greater socioeconomic disadvantage.[4]

RACIAL DISPARITY IN PREECLAMPSIA OUTCOMES FOR HISPANIC WOMEN AND THE "HISPANIC PARADOX".

We showed that Hispanic women had the lowest prevalence of PPCM across all classes of income. It has been established that although Hispanic people have a worse risk factor profile, they tend to have lower cardiovascular mortality.[23] Some studies have indicated that despite higher levels of risk factors in terms of hypertension, hyperlipidemia, and diabetes, Hispanic individuals tend to have a higher life expectancy.[24] This is called the "Hispanic Paradox," and it is thought that favorable features, such as strong family and social support, might counter-act adverse SDOH and attenuate risk conferred by traditional cardiovascular disease

risk factors. However, the scientific literature is inconsistent with regard to the Hispanic Paradox, with some studies supporting the phenomenon[25] with other studies contradicting its existence.[26,27]

Nevertheless, Kao et al[28] also reported similar findings where they reported that Hispanic women did not have worse outcomes compared with White women and that incidence of PPCM was lower compared with Black women. Our study is perhaps the first to study the Hispanic Paradox for PPCM during preeclampsia hospitalizations in the United States. However, despite the better outcomes for PPCM among Hispanics, the odds of mortality, stroke, cardiac arrhythmias, and AKI remained high across all income categories for Hispanic women.

RACIAL DISPARITY IN PREECLAMPSIA OUTCOMES AT DELIVERY FOR ASIANS OR PACIFIC ISLANDERS. A previous NIS analysis of A/PI women reported increased severity of morbidity with preeclampsia compared with White women.[29] A recently updated NIS analysis from 2016 to 2018 reported that A/PI women have the highest adjusted relative odds of acute cardiovascular complications with preeclampsia compared with all other ethnicities.[2] In addition to reinforcing the findings of the previous study, our study reports that A/PI women have increased mortality, stroke, cardiac arrhythmias, and AKI complications across all strata of income.

CLINICAL IMPLICATIONS AND SUGGESTED FUTURE STRATEGIES. The use of race in clinical decision-making algorithms as a biological construct rather than a social construct may exacerbate providers' underlying biases against Black, Hispanic, or A/PI women.[30-32] Although it is well established that Black race is a factor associated with preeclampsia and worse outcomes, it has been shown previously that race as a biological factor is a poor proxy for genetic predisposition for diseases[33] and instead race as a marker may be capturing health care disparities and other social determinants. Hence, the American Medical Association also suggested the adoption of new policies that discourage the use of race as a surrogate marker of biology in medical education.[34] Similarly, electronic health record advisory alerts against adverse in-hospital outcomes may be inherently biased.[35] Previous literature suggests that these algorithms are based on studies that underrepresent Black, Hispanic, or A/PI women and also do not take into account SDOH, thus failing to identify much sicker Black women who need closer monitoring and a higher level of care.[36] We found that there was a significant interaction between race and income status for worse peripartum cardiovascular outcomes. Based on these observations, we suggest an approach of system-wide bias reduction exercises and training programs that focus on treating race as a social factor and discourage the use of race as a biological risk factor. Similarly, clinical prediction models should be carefully reviewed and based on data that includes a diverse representation of all ethnicities and SDOH factors.

STUDY LIMITATIONS. NIS is an administrative claim-based database that uses ICD codes for diagnosis; although we have used diagnosis codes less prone to error, coding errors cannot be excluded. NIS collects data on inpatient discharges, and each admission is registered as an independent event. NIS samples are not designed to follow patients longitudinally, so long-term outcomes could not be assessed from the present data set. Similarly, data with respect to differences in the quality of care provided to low-income groups vs high-income groups are not available. We did adjust for hospital region to account for regional differences in care, and in a supplemental model, we further adjusted for several other hospital characteristics as a surrogate for differences in medical care. In addition, there was a change in methodology of NIS to improve national estimates in 2012 and change in coding practices from ICD-9 to ICD-10 in quarter 4 of 2015; however, it did not affect disease prevalence after 2012 or 2015. Trends in the disease prevalence over time may be because of better capturing of these diagnoses over time by ICD coding or due to increased prevalence of cardiometabolic disease.

Similar to any retrospective observational database study, association does not mean causation, and study findings are only hypothesis generating. Although we accounted for many potential confounding factors using adjustment and propensity matching methods, there may still be residual confounding explaining the associations seen. The sample size for A/PI women was small, and it is possible that the study might not be powered enough to detect a statistically significant difference for this racial group and also limited the ability to perform certain subgroup analyses of A/PI women further stratified by income. In addition, the subgroup analysis based on propensity matching may be subject to selection bias. However, logistic regression and propensity-matched analysis were consistent, which adds to the robustness of the study results. The small sample size within certain racial/ethnic groups also precluded any temporal trend analysis. Furthermore, the findings should be interpreted with caution as in NIS; we were categorizing multiple ethnicities into one racial group of Asian or PI that contributes to significant

heterogeneity. We also were unable to disaggregate Hispanic individuals, and prior studies have demonstrated variation in cardiovascular outcomes across the 3 largest Hispanic subgroups in the United States (ie, Puerto Rican, Cuban, and Mexican individuals).[37]

CONCLUSIONS

Our 15-year nationally representative study reports that Black, Hispanic, and A/PI racial groups have increased in-hospital mortality and cardiovascular complications across all income classes compared with White women. White women belonging to the higher income group have better preeclampsia outcomes compared with lower income White women during delivery hospitalizations in terms of in-hospital mortality and cardiovascular complications. However, we found a significant interaction between race and income. Notably, even high-income Black women with preeclampsia experienced greater odds for many adverse cardiovascular outcomes when compared with lower income White women. Hispanic women have a low prevalence of PPCM across all qualities of income. Our study stresses the significant interaction between race/ethnicities and income in the U.S. concerning peripartum preeclampsia outcomes. Further studies are needed to clarify the role of health inequities in the context of income and socioeconomic status for women with preeclampsia.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Preeclampsia is associated with worse outcomes in terms of in-hospital mortality and cardiovascular complications for Black, Hispanic, Asian, or Pacific Islander women compared with White women. Furthermore, there is significant interaction effect of race and ethnicity with income. White women from a higher income group have a lower mortality compared with lower income White women. Notably, high-income Black women had greater odds of many cardiovascular complications compared with low-income White women. A phenomenon of "Hispanic Paradox" was observed where Hispanic women have the lowest prevalence of PPCM across all classes of income.

TRANSLATIONAL OUTLOOK: Further studies are needed to clarify the role of health inequities in the context of income and socioeconomic status among women with preeclampsia. Given worsening US trends in maternal morbidity and mortality, urgent efforts are needed to improve maternal cardiovascular health outcomes in all women, but particularly those from lower income groups and those from underrepresented racial and ethnic groups who experience the greatest health disparities.

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KEY WORDS cardiovascular disease, disparities, maternal health, preeclampsia, race/ethnicity, socioeconomic status

APPENDIX For supplemental tables and figures, please see the online version of this paper.