

OBSTETRICS

Maternal outcomes by race during postpartum readmissions



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BACKGROUND: Maternal race may be an important risk factor for postpartum readmissions and associated adverse outcomes.

OBJECTIVE: To determine the association of race with serious complications during postpartum readmissions.

STUDY DESIGN: This repeated cross-sectional analysis used the National (Nationwide) Inpatient Sample from the Healthcare Cost and Utilization Project from 2012 to 2014. Women ages 15–54 readmitted postpartum after a delivery hospitalization were identified by Centers for Disease Control and Prevention criteria. Race and ethnicity were characterized as non-Hispanic white, non-Hispanic black, Hispanic, Asian or Pacific islander, Native American, other, and unknown. Overall risk for readmission by race was determined. Risk for severe maternal morbidity during readmissions by race was analyzed. Individual outcomes including pulmonary edema/acute heart failure and stroke also were analyzed by race. Log-linear regression models including demographics, hospital factors, and comorbid risk were used to analyze risk for severe maternal morbidity during postpartum readmissions.

RESULTS: Of 11.3 million births, 207,730 (1.8%) women admitted postpartum from 2012 to 2014 were analyzed, including 96,670 white, 47,015 black, and 33,410 Hispanic women. Compared with non-Hispanic white women, non-Hispanic black women were at 80% greater risk of postpartum readmission (95% confidence interval, 79%–82%) whereas Hispanic women were at 11% lower risk of readmission (95% confidence

interval, 10%–12%). In unadjusted analysis, compared with non-Hispanic white women, non-Hispanic black women admitted postpartum were at 27% greater risk of severe maternal morbidity (95% confidence interval, 24%–30%) whereas Hispanic women were at 10% lower risk (95% confidence interval, 7%–13%). In the adjusted model, non-Hispanic black women were at 16% greater risk for severe maternal morbidity during readmission than non-Hispanic white women (95% confidence interval, 10%–22%), whereas Hispanic women were at 7% lower risk (95% confidence interval, 1%–12%). Differences in severe maternal morbidity risk between other racial groups and non-Hispanic white women were not significant. In addition to overall morbidity, non-Hispanic black women were at significantly greater risk for eclampsia, acute respiratory distress syndrome, and renal failure than other racial groups ($P < .05$ all). Black women were at 126% greater risk for pulmonary edema/acute heart failure than white women (95% confidence interval, 117%–136%).

CONCLUSION: Black women were more likely (1) to be readmitted postpartum, (2) to suffer severe maternal morbidity during readmission, and (3) to suffer life threatening complications such as pulmonary edema/acute heart failure. At-risk women including black women with cardiovascular risk factors may benefit from short-term postpartum follow-up.

Key words: disparities, ethnicity, postpartum readmissions, race, severe maternal morbidity

Obstetric readmissions may be of increasing clinical importance. Overall risk for postpartum readmission is increasing, with a recent study finding an increase from 1.7% in 2004 to 2.2% in 2011.¹ The American College of Obstetricians and Gynecologists recently has updated recommendations regarding postpartum care, stating “To optimize the health of women and infants, postpartum care should become an ongoing process, rather than a single encounter, with services and support tailored to each woman’s individual needs.”²

Traditional approaches to postpartum care are being reconsidered in hopes of reducing adverse postpartum maternal outcomes and risk for readmission.³

An important consideration in optimizing postpartum care is appropriately characterizing maternal risk. Previous studies have identified a range of risk factors for readmission, including advanced age, socioeconomic status, chronic comorbidities, multiple gestation, cesarean delivery, and other high-risk pregnancy conditions.^{1,4,5} Maternal race may represent a particularly important risk factor for postpartum readmissions and associated complications. Maternal race is a major risk factor adverse obstetric outcomes, and a number of previous analyses have addressed disparities in overall risk for severe morbidity and mortality.^{6–8} Although race has been associated with

increased risk for postpartum risk in smaller samples,⁴ national estimates of postpartum readmissions and associated complications have not been well characterized. A better understanding of how race is associated with postpartum risk may be useful in risk stratification and designing improvements in maternal care.

Given the knowledge gap regarding race and postpartum readmissions, the objectives of this study were to characterize (1) risk for postpartum readmissions by race, and (2) describe risk for severe, life-threatening complications during these hospitalizations.

Materials and Methods

The National (Nationwide) Inpatient Sample (NIS) from the Healthcare Cost and Utilization Project for the years 2012–2014 was used for this repeated

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AJOG at a Glance

Why was the study conducted?

To evaluate whether there are racial disparities in postpartum readmissions.

Key findings

Black women were more likely to be readmitted, more likely to experience severe morbidity, and were at greater risk for life-threatening complications such as pulmonary edema and heart failure.

What does this add to what is known?

Black women are at particularly high risk for specific postpartum readmission complications.

cross-sectional analysis. The NIS is a large, publicly available, all-payer inpatient contains a sample of approximately 20% of all hospitalizations in the United States. These hospitalizations are selected via a stratified systemic random sample to generate a population representative of the entire United States across medical specialties that includes academic, community, nonfederal, general, and specialty-specific centers. Weights can be applied to create national estimates. Approximately 8 million hospital stays from a total of 45 states were included in the NIS in 2010.⁹

For this analysis, postpartum readmissions after a delivery hospitalization were captured with *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) diagnosis codes. The Centers for Disease Control and Prevention (CDC) provided the algorithm used to identify postpartum hospitalizations.^{10,11} We included women aged 15–54 years. The primary exposure of interest was self-reported maternal race and ethnicity. Maternal race is categorized by the NIS as non-Hispanic white, non-Hispanic black, Hispanic, Asian or Pacific Islander, Native American, other, or unknown. The years 2012–2014 were used for the analysis, given that the proportion of missing data for race in the NIS for these years is small compared with preceding iterations. Women with a code for a delivery hospitalization (ICD-9-CM 650 or V27.x) were excluded. The Columbia University Institutional Review Board deemed this analysis exempt given that the data are deidentified.

The primary outcome of this study was risk for severe maternal morbidity (SMM) as defined by the CDC during a postpartum readmission. The composite CDC definition of SMM includes 21 diagnoses, including shock, stroke, heart failure, transfusion, and other conditions all identified using ICD-9-CM codes.¹¹ A sensitivity analysis was performed excluding transfusion and retaining the remaining 20 diagnoses, given that transfusion is the most common complication in the composite. In addition to the primary outcome of SMM, we evaluated 2 secondary outcomes. First, we evaluated overall risk for postpartum readmissions. Because the NIS is cross-sectional and does not allow linkage of hospitalizations for individual patients, readmission risk was calculated with the number of deliveries each year as denominator for each racial category. Second, we evaluated risk for 11 individual severe morbidity outcomes within the CDC composite: (1) acute renal failure, (2) acute respiratory distress syndrome, (3) disseminated intravascular coagulation, (4) eclampsia, (5) stroke, (6) hysterectomy, (7) shock, (8) embolism, (9) sepsis, (10) pulmonary edema and acute heart failure, and (11) transfusion. These conditions were chosen because they represent a broad range clinical pathology and were anticipated to be sufficiently prevalent to make meaningful comparisons.¹⁰

Demographic factors, hospital characteristics, and comorbidity were evaluated by NIS race categories and compared using the χ^2 test or Fisher exact test as appropriate. Hospital

characteristics included bed size (small, medium, or large), location and teaching status (urban teaching, urban non-teaching, and rural), and region (Northeast, Midwest, South, or West). Demographic categories included year of delivery, insurance status (Medicaid, private, Medicare, other, uninsured), and ZIP code income quartile.

Comorbidity was evaluated using an obstetric comorbidity index that measures underlying patient risk.¹² An important consideration in evaluating population-based outcomes is appropriate risk adjustment. For evaluating morbidity and death, there are comorbidity indices that have been developed in medical and surgical populations that account for underlying risk. This comorbidity index has been developed specifically for an obstetric population.

In creating the obstetric comorbidity index, a list of maternal comorbidities possible associated with increased risk for maternal morbidity and mortality was developed. These risk factors were analyzed within an initial obstetric sample population and used to construct an adjusted model using a fully stepwise selection algorithm for both entry and retention in the model. The outcome was either severe maternal morbidity or mortality during the delivery hospitalization or postpartum. Potential risk factors included 24 maternal comorbidities and maternal age categorized as <19, 20–34, 35–39, 40–44, and >44 years of age.

Risk factors found to be significant were retained in the model and then tested in a validation cohort of the same population. The final model includes 20 maternal conditions and maternal age. This comorbidity index provides weighted scores for comorbidity for obstetric patients based on specific diagnosis codes and demographic factors that can be ascertained in administrative data. Greater scores are associated with increased risk for severe morbidity. In the initial study validating the comorbidity index in a general obstetric population, patients with the lowest score of 0 had a 0.7% risk of severe morbidity whereas scores of >10 were associated with a risk of severe morbidity of 10.9%.

TABLE 1
Demographics of patients readmitted postpartum

	White non-Hispanic 96,670	Black non-Hispanic 47,015	Hispanic 33,410	Asian/Pacific Islander 6930	Native American 1855	Other 8985	Unknown 12,865
All patients (n)	%	%	%	%	%	%	%
Maternal age, y							
15–17	1.8%	2.4%	4.0%	0.6%	2.2%	1.9%	2.5%
18–24	26.9%	31.5%	33.1%	12.3%	36.1%	27.7%	26.7%
25–29	26.9%	25.6%	25.6%	23.4%	27.5%	26.7%	27.8%
30–34	26.3%	22.5%	21.4%	35.0%	19.1%	25.4%	26.7%
35–39	13.7%	13.1%	12.3%	21.6%	11.6%	13.8%	12.5%
≥40	4.5%	4.9%	3.6%	7.1%	3.5%	4.6%	3.8%
Year							
2012	33.7%	32.7%	34.5%	33.6%	37.7%	36.0%	31.8%
2013	32.6%	33.4%	32.1%	31.0%	32.3%	30.6%	35.5%
2014	33.7%	33.9%	33.4%	35.4%	29.9%	33.4%	32.7%
Hospital bed size							
Small	12.8%	9.9%	11.9%	10.5%	13.5%	11.9%	13.4%
Medium	26.6%	29.2%	28.6%	29.4%	26.1%	28.2%	27.1%
Large	60.6%	60.9%	59.5%	60.1%	60.4%	60.0%	59.5%
Insurance status^a							
Medicare	1.8%	4.1%	0.9%	0.8%	0.8%	1.2%	3.7%
Medicaid	39.8%	62.9%	62.5%	32.9%	59.3%	54.1%	38.8%
Private	51.3%	27.1%	25.4%	60.4%	23.7%	35.1%	49.9%
Self-pay	3.0%	3.2%	7.4%	3.2%	5.9%	6.0%	3.1%
Other	3.9%	2.5%	3.5%	2.6%	10.0%	3.4%	4.2%
Hospital location							
Rural	11.4%	3.9%	3.9%	3.2%	25.6%	4.6%	12.6%
Urban non-teaching	31.8%	24.3%	33.6%	28.4%	26.7%	29.2%	20.2%
Urban teaching	56.7%	71.8%	62.5%	68.4%	47.7%	66.2%	67.2%
ZIP income quartile							
1st (lowest)	25.1%	49.1%	36.2%	14.2%	45.3%	30.3%	23.7%
2nd	27.0%	22.3%	25.8%	18.0%	24.5%	23.2%	29.8%
3rd	24.9%	16.1%	22.9%	26.8%	15.9%	23.9%	25.8%
4th (highest)	21.8%	10.2%	12.2%	39.4%	7.8%	19.8%	18.9%
Unknown	1.2%	2.2%	2.9%	1.7%	6.5%	2.8%	1.7%
Hospital region							
Northeast	18.5%	19.1%	15.9%	19.8%	4.6%	30.8%	4.4%
Midwest	22.4%	19.4%	7.4%	11.5%	14.6%	17.0%	60.3%
South	41.6%	53.3%	37.0%	20.6%	31.8%	36.0%	16.7%
West	17.6%	8.1%	39.7%	48.0%	49.1%	16.2%	18.7%

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019.

(continued)

TABLE 1
Demographics of patients readmitted postpartum (continued)

	White non-Hispanic	Black non-Hispanic	Hispanic	Asian/Pacific Islander	Native American	Other	Unknown
	96,670	47,015	33,410	6930	1855	8985	12,865
All patients (n)	%	%	%	%	%	%	%
Comorbidity index							
0	82.2%	74.5%	86.4%	88.2%	76.3%	85.7%	81.5%
1 or 2	16.7%	21.8%	12.7%	9.3%	23.2%	13.0%	16.9%
>2	1.2%	3.6%	0.9%	2.5%	0.6%	1.3%	1.5%
Preeclampsia							
Mild	6.1%	9.2%	4.1%	5.9%	2.7%	6.1%	4.6%
Severe	4.9%	8.0%	4.1%	5.9%	5.4%	6.5%	6.0%
Superimposed	1.8%	4.2%	1.5%	1.9%	1.6%	2.3%	1.6%

Comorbidity index excludes maternal age and hypertensive diagnoses.

^a Unknown insurance status not demonstrated given cell size <10.

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019.

This comorbidity index was subsequently validated in an external population.¹³

We categorized women based on comorbidity index scores: 0 (lowest risk), 1 or 2, and >2 (highest). Because maternal age is presented separately in our analysis to demonstrate the effect of this factor, this variable was omitted in calculating the comorbidity index score. A supplemental analysis includes the full comorbidity score and excludes maternal age as a separate variable. Adding the comorbidity index score to the adjusted analysis allows for the analysis to better characterize the effect of race accounting for other underlying risk factors. Adjusted risk ratios (aRRs) for severe morbidity including transfusion with 95% confidence intervals (CIs) as measures of effect accounting for comorbidity, demographic characteristics, and hospital factors were derived from fitting a log-linear regression model. Population weights can be applied to data in the NIS to create national estimates; these weights were applied in this study. All analyses were performed with SAS 9.4 (SAS Institute, Cary, NC).

Results

From 2012 to 2014, an estimated 11.3 million births and 207,730 (1.8%) postpartum readmissions were

ascertained from the NIS and included in the analysis. The proportion of non-Hispanic black women readmitted relative to delivery hospitalizations was significantly larger (3.09%; 95% CI, 3.06%–3.12%; n=47,015/1,523,190) than other groups, including non-Hispanic white women (1.71%; 95% CI, 1.70%–1.72%; 96,670/5,650,075), Hispanic women (1.52%; 95% CI, 1.50%–1.54%; 33,410/2,194,500), Asian or Pacific Islander women (1.17%; 95% CI, 1.14%–1.20%; 6930/592,025), Native American women (2.25%; 95% CI, 2.15%–2.35%; 1855/82,315), and women of other and unknown race (1.74%; 95% CI, 1.70%–1.78%; 8895/516,450 and 1.83%; 95% CI, 1.80%–1.86%; 12,865/702,315, respectively) ($P<.01$). Overall, readmissions for non-Hispanic black women relative to delivery hospitalizations were 80.4% more likely than for non-Hispanic white women (95% CI, 78.5%–82.4%, $P<.01$).

Among readmissions, Hispanic women were younger than non-Hispanic black and non-Hispanic white women, whereas Asian or Pacific Islander women were the oldest (Table 1). Non-Hispanic black and Hispanic women were more likely to receive Medicaid insurance than Asian or Pacific Islander or non-Hispanic white women

(62.9% vs 62.5% vs 32.9% vs 39.8%, respectively, $P<.01$) and more likely to be from the lowest ZIP code income quartile (49.1% vs 36.2% vs 14.2% vs 25.1%, respectively, $P<.01$). Compared with non-Hispanic white, Hispanic, and Asian or Pacific Islander women, non-Hispanic black women had the greatest rates of mild, severe, and superimposed preeclampsia ($P<.01$). Finally, excluding age and preeclampsia, non-Hispanic black women had greater comorbidity scores; 3.6% of non-Hispanic black women had a score >2 and 21.8% a score of 1 or 2 compared with 1.2% and 16.7% of non-Hispanic white women, 0.9% and 12.7% of Hispanic women, and 2.5% and 9.3% of Asian or Pacific Islander women ($P<.01$).

During readmissions, non-Hispanic black women were at greater risk for severe maternal morbidity, including transfusion (24.3%), than all other groups including non-Hispanic white (19.1%), Asian or Pacific Islander (20.5%), Native American women (21.0%), and Hispanic women (17.2%) as well as women of unknown (20.2%) or other (19.1%) race ($P<.01$). In the unadjusted model with non-Hispanic white women as the reference, this difference translated into a 27% increased risk (risk ratio [RR], 1.27; 95% CI, 1.24–1.30) for non-Hispanic black

TABLE 2
Unadjusted and adjusted models for severe morbidity during postpartum readmissions

	RR	95% CI	aRR	95% CI
Race				
Non-Hispanic white	1.00	Reference	1.00	Reference
Non-Hispanic black	1.27	1.24–1.30	1.16	1.10–1.22
Hispanic	0.90	0.87–0.93	0.93	0.88–0.99
Asian or Pacific Islander	1.09	1.03–1.15	1.05	0.95–1.17
Native American	1.10	0.99–1.21	1.08	0.89–1.32
Other	1.00	0.95–1.05	1.03	0.93–1.13
Unknown	1.05	1.01–1.10	1.02	0.94–1.11
Year				
2012	1.00	Reference	1.00	Reference
2013	1.05	1.03–1.08	1.04	0.99–1.09
2014	1.06	1.03–1.08	1.03	0.98–1.08
Hospital bed size				
Small	1.00	Reference	1.00	Reference
Medium	1.05	1.01–1.08	1.02	0.95–1.09
Large	1.11	1.07–1.14	1.06	0.99–1.12
Insurance status				
Private	1.00	Reference	1.00	Reference
Medicare	1.37	1.30–1.45	1.18	1.06–1.30
Medicaid	0.98	0.96–1.00	0.98	0.94–1.02
Other	0.85	0.81–0.90	0.87	0.78–0.97
Uninsured	1.00	0.95–1.06	1.03	0.93–1.14
Hospital location				
Urban non-teaching	1.00	Reference	1.00	Reference
Rural	0.96	0.93–1.00	0.99	0.91–1.07
Urban teaching	1.02	1.00–1.04	0.97	0.93–1.02
Income quartile				
1st (lowest)	1.00	Reference	1.00	Reference
2nd	0.97	0.94–0.99	1.00	0.95–1.05
3rd	0.94	0.92–0.96	0.97	0.92–1.02
4th (highest)	0.92	0.90–0.95	0.94	0.88–1.00
Hospital region				
Northeast	1.00	Reference	1.00	Reference
Midwest	1.19	1.16–1.24	1.20	1.12–1.29
South	1.25	1.22–1.29	1.25	1.18–1.33
West	1.18	1.15–1.22	1.27	1.18–1.36

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019. (continued)

women aged 35–39 years were at increased risk for severe morbidity compared with women 18–24 years of age (RR, 1.53; 95% CI, 1.46–1.59; RR, 1.24; 95% CI, 1.20–1.28). Greater obstetric comorbidity index scores of 1–2 or >2 also were associated with increased risk for severe morbidity (RR, 1.35; 95% CI, 1.32–1.38; RR, 2.61; 95% CI, 2.54–2.69, respectively). In the adjusted analysis, many of these risk factors retained significance. Non-Hispanic black women were at increased risk for severe morbidity compared with non-Hispanic white women (aRR, 1.16; 95% CI, 1.10–1.22) whereas Hispanic women were at slightly lower risk (aRR, 0.93; 95% CI, 0.88–0.99). Medicare insurance was retained as a risk factor (aRR, 1.18; 95% CI, 1.06–1.30) (Table 2). Women age 40 years or older and women age 35–39 years were similarly at increased risk for severe morbidity compared with women 18–24 years of age (aRR, 1.40; 95% CI, 1.29–1.52; aRR, 1.18, 95% CI, 1.11–1.26). Finally, comorbidity index score of 1 or 2 and >2 were associated with increased risk compared with scores of 0 (aRR, 1.28; 95% CI, 1.23–1.34; aRR, 2.47, 95% CI, 2.34–2.60, respectively). When the analysis was repeated excluding maternal age as a separate variable and incorporating it into the obstetric comorbidity index, the estimate for comorbidity index score >2 compared with 0 was greater (aRR, 3.14; 95% CI, 2.98–3.31) whereas estimates for other factors in the analysis was similar (Supplemental Table 1). When the sensitivity analysis was performed restricted to severe morbidity without transfusion, the risk differential was larger. Non-Hispanic black women were at 41.8% increased risk for severe morbidity excluding transfusion compared with non-Hispanic white women (21.0% vs 14.8%) with risk also lower for Hispanic (13.3%), Asian or Pacific Islander (16.3%), and Native American women (16.7%) ($P<.01$).

Evaluating individual severe morbidity outcomes, we found that non-Hispanic black women were at significantly increased risk compared with

women while Hispanic women were at 10% lower risk (RR, 0.90; 95% CI, 0.87–0.93). Women with Medicare compared with private insurance were at increased risk (RR, 1.37; 95% CI, 1.30–1.45). Women age 40 or older and

TABLE 2
Unadjusted and adjusted models for severe morbidity during postpartum readmissions (continued)

	RR	95% CI	aRR	95% CI
Maternal age				
15-17	0.96	0.90–1.03	0.97	0.84–1.11
18-24	1.00	Reference	1.00	Reference
25-29	1.05	1.02–1.08	1.03	0.98–1.09
30-34	1.14	1.11–1.17	1.11	1.05–1.17
35-39	1.24	1.20–1.28	1.18	1.11–1.26
>39	1.53	1.46–1.59	1.40	1.29–1.52
Comorbidity index				
0	1.00	Reference	1.00	Reference
1-2	1.35	1.32–1.38	1.28	1.23–1.34
>2	2.61	2.54–2.69	2.47	2.34–2.60

aRR, adjusted risk ratio; CI, confidence interval; RR, risk ratio.

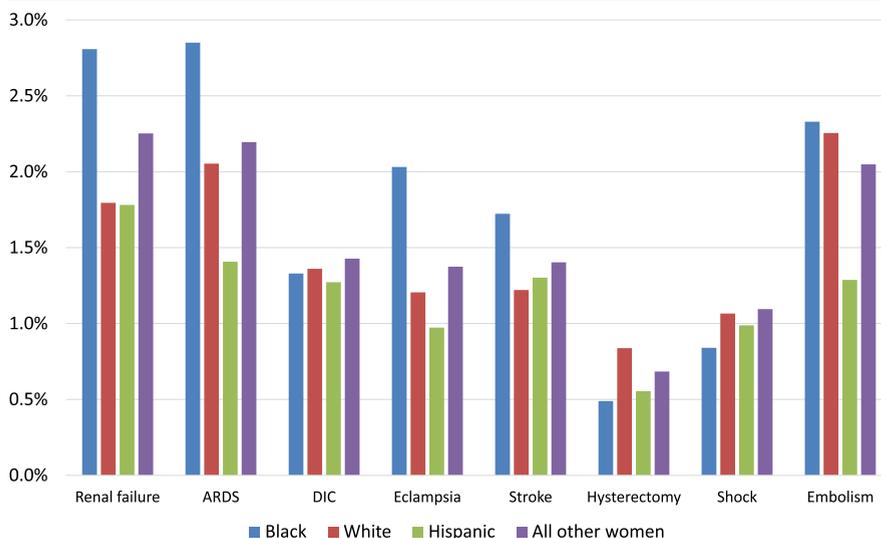
Adjusted model included all factors in this table (year, bed size, insurance status, hospital location, income quartile, hospital region, hospital teaching status, maternal age, and race). Comorbidity index excludes maternal age.

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019.

non-Hispanic white women for several outcomes. Non-Hispanic black women were at increased risk for acute renal failure (RR, 1.56; 95% CI, 1.46–1.68),

acute respiratory distress syndrome (RR, 1.38; 95% CI, 1.30–1.49), eclampsia (RR, 1.69; 95% CI, 1.55–1.83), and stroke (RR, 1.41; 95% CI, 1.29–1.54)

FIGURE 1
Risk for individual severe morbidity diagnoses by maternal race



Compared with non-Hispanic white women, non-Hispanic black women were at significantly increased risk for acute renal failure, ARDS, eclampsia, and stroke ($P < .01$ for all). Black women were at significantly decreased risk for hysterectomy and shock ($P < .01$), whereas differences in DIC and embolism were not significantly different.

ARDS, acute respiratory distress syndrome; DIC, disseminated intravascular coagulation.

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019.

(Figure 1) with non-Hispanic white women as the reference. Non-Hispanic black women were at particularly high risk for pulmonary edema and acute heart failure, with 8.4% readmissions receiving diagnosis compared with 3.7% of non-Hispanic white women (RR, 2.26; 95% CI, 2.17–2.36) (Figure 2). Comparing these groups, we found that non-Hispanic black women were at significantly lower risk for shock (RR, 0.79; 95% CI, 0.70–0.89), transfusion (RR, 0.88; 95% CI, 0.85–0.93), sepsis (RR, 0.85; 95% CI, 0.80–0.90), and hysterectomy (RR, 0.58; 95% CI, 0.50–0.68). Differences for risk between non-Hispanic black and white women were not significant for disseminated intravascular coagulation and embolism.

Discussion

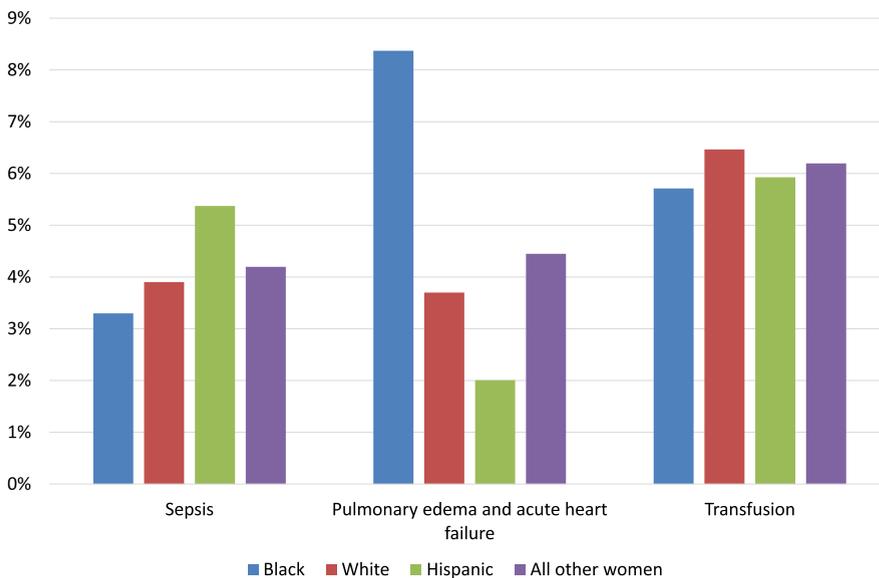
Main findings

In this analysis of postpartum readmissions, non-Hispanic black women were at significantly greater risk (1) to be readmitted postpartum, (2) to suffer severe maternal morbidity during readmission, and (3) to suffer a range of life-threatening complications. Although non-Hispanic black women were at lower risk for complications such as sepsis, shock, hysterectomy, and transfusion, they were particularly likely to receive a diagnosis of pulmonary edema/acute heart failure, with risk more than twice as high as that of non-Hispanic white women.

Implications of the findings and future research directions

The differential risk found in this analysis may have a number of implications for optimizing postpartum care. First, because non-Hispanic black women were at much greater risk for readmissions relative to the number of births in the population, efforts to reduce maternal risk in this demographic may represent an important component of overall strategies to reduce postpartum risk and racial disparities. Although this dataset is not able to link readmissions across hospitalizations, identifying preceding obstetric, medical, and social risk factors among non-Hispanic black women that contribute to differentials

FIGURE 2
Risk for individual severe morbidity diagnoses by maternal race



Compared with non-Hispanic white women, non-Hispanic black women were at significantly increased risk pulmonary edema and acute heart failure but decreased risk for transfusion or sepsis.

Aziz et al. Maternal outcomes by race during postpartum readmissions. *Am J Obstet Gynecol* 2019.

will be necessary to identify who may most benefit from more intensive postpartum care and surveillance.

Second, non-Hispanic black women were at particularly high risk for cardiopulmonary complications. Because this dataset does not include outpatient data and chart reviews are not possible, we are not able to determine to what degree these conditions were preceded by outpatient symptoms or whether changes in management could have prevented readmissions. However, it is reasonable to assume that for at-risk women who develop cardiopulmonary complications, optimal postpartum care may facilitate timely diagnosis, multidisciplinary care, and transfer to an appropriate level of inpatient care.

Third, the relatively large differentials in risk for adverse outcomes supports the American College of Obstetricians and Gynecologists' recommendation that postpartum care be tailored. In comparison with intrapartum management, where a small number of conditions such as hemorrhage, hypertensive diseases of pregnancy, and thromboembolism account for the majority of risk among most women, postpartum risk

may be more differentially distributed and comparative effectiveness research is needed to determine which interventions may most benefit individual populations. Specifically, further data are needed to determine potential benefits of longer inpatient stays for particularly high-risk women, shorter office follow-up, mobile health interventions, increased coordination with medical specialists, and other approaches to reducing maternal risk. Fourth, although non-Hispanic black women were at lower risk than non-Hispanic white women for hysterectomy, sepsis, shock, and transfusion during readmissions, on a population basis relative to delivery hospitalizations non-Hispanic black women were at similar risk for hysterectomy and increased risk for the latter 3 conditions, given overall likelihood of readmission.

Strengths and limitations

There are several limitations that are important to consider in interpreting this study's findings. First, as noted, these data are cross-sectional, and we are not able to account for factors that occurred during the delivery or after

hospital discharge prior to the readmission. We are not able to determine whether a complication occurred on an outpatient basis or during the readmission. As a result, although there were clear differentials in outcomes noted between racial groups, we are not able to make inferences related to preventability or when a complication occurred. Second, this administrative data set does not provide information on hospital resources, infrastructure, protocols and staffing, all of which contribute to maternal outcomes and risk.

Third, because administrative data are used primarily for billing data both underascertainment and misclassification of secondary diagnoses are concerns. Although administrative data are appropriate in assessing population-level resource use and disease burden, granularity of many important clinical factors is often limited. Fourth, data on race was missing for 6% of patients of this study. If outcomes based on race differed significantly for patients with unknown compared with known race, the disparities reported may be biased.

The Healthcare Cost and Utilization Project provides a number of recommendations for addressing missing data, including imputation.¹⁴ We decided not to perform imputation because it was unlikely that missing data on race were (1) randomly related to other measurable factors and (2) nondifferential across the years of NIS included in this analysis. In determining whether to perform imputation important considerations are (1) whether specific outcomes in the actual population are related to the greater likelihood that data are missing, and (2) whether factors associated with the outcome of interest are related differentially to missing and non-missing data. HCUP documents support that specific outcomes may in fact have been related to missingness; for these missing data, differential associations may be present between other measured factors.¹⁴ To address these concerns, HCUP in part suggests incorporating data outside the NIS, an approach beyond the scope of this analysis.

Fifth, because hospitalizations are not linked, we are not able to determine the time interval between delivery hospitalization discharge and readmission; subsequent analyses with data sources that allow evaluation of duration between discharge and readmissions may be important in optimizing care. Sixth, many complications that are primarily managed on an outpatient basis, such as wound complications, cannot be captured using this data. Seventh, we cannot control for the effect of multiple pregnancies occurring to individual women. We elected to use the NIS because it is a large, nationally representative sample, and for the 3 years of the study there were low rates of missing data compared with prior iterations in which data on race were missing for >20% of all hospitalizations. Other strengths of this study include measurement of readmissions, which are an adverse event in and of themselves, and assessment of a broad range of outcomes demonstrating major differentials in risk.

In conclusion, this analysis demonstrated increased risk among non-Hispanic black women for postpartum readmission and associated complications. Addressing this risk aligns with urgent priorities of optimizing postpartum care for at-risk women and reducing racial disparities in adverse obstetric outcomes. At-risk women, including black women with cardiovascular risk factors, may in particular benefit from closer surveillance,

including short-term postpartum follow up. ■

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SUPPLEMENTAL TABLE 1

Adjusted models for severe morbidity during postpartum readmissions with comorbidity index inclusive of maternal age

	Adjusted risk ratio	95% CI
Race		
Non-Hispanic white	1.00	Reference
Non-Hispanic black	1.20	1.14–1.26
Hispanic	0.93	0.88–0.99
Asian or Pacific Islander	1.06	0.95–1.18
Native American	1.09	0.90–1.33
Other	1.05	0.95–1.16
Unknown	1.04	0.96–1.13
Year		
2012	1.00	Reference
2013	1.04	0.99–1.09
2014	1.04	0.99–1.09
Hospital bed size		
Small	1.00	Reference
Medium	1.03	0.96–1.10
Large	1.07	1.00–1.13
Insurance status		
Private	1.00	Reference
Medicare	1.01	0.91–1.12
Medicaid	0.95	0.91–0.99
Other	0.99	0.90–1.10
Uninsured	0.83	0.74–0.92
Hospital Location		
Urban non-teaching	1.00	Reference
Rural	1.00	0.93–1.09
Urban teaching	1.00	0.96–1.05
Income quartile		
1st (lowest)	1.00	Reference
2nd	1.00	0.95–1.05
3rd	0.98	0.93–1.03
4th (highest)	0.95	0.89–1.01
Hospital region		
Northeast	1.00	Reference
Midwest	1.21	1.13–1.29
South	1.27	1.19–1.34
West	1.26	1.17–1.35

Aziz et al. Maternal outcomes by race during postpartum readmissions. Am J Obstet Gynecol 2019. (continued)

SUPPLEMENTAL TABLE 1**Adjusted models for severe morbidity during postpartum readmissions with comorbidity index inclusive of maternal age** *(continued)*

	Adjusted risk ratio	95% CI
Comorbidity index		
0	1.00	Reference
1–2	1.30	1.24–1.35
>2	3.14	2.98–3.31

CI, confidence interval.

Adjusted model included all factors in this table (race, year, bed size, insurance status, hospital location, income quartile, hospital region, and comorbidity index score).

Aziz et al. Maternal outcomes by race during postpartum readmissions. *Am J Obstet Gynecol* 2019.