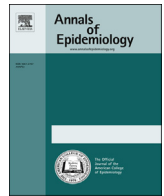




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Original article

Does maternal asthma contribute to racial/ethnic disparities in obstetrical and neonatal complications?

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ABSTRACT

Purpose: To examine whether maternal asthma contributes to racial/ethnic differences in obstetrical and neonatal complications.**Methods:** Data on white ($n = 110,603$), black ($n = 50,284$), and Hispanic ($n = 38,831$) singleton deliveries came from the Consortium on Safe Labor. Multilevel logistic regression models, with an interaction term for asthma and race/ethnicity, estimated within-group adjusted odds ratios (aORs) for gestational diabetes, gestational hypertension, pre-eclampsia, placental abruption, premature rupture of membranes, preterm delivery, maternal hemorrhage, neonatal intensive care unit admissions, small for gestational age, apnea, respiratory distress syndrome, transient tachypnea of the newborn, anemia, and hyperbilirubinemia after adjustment for clinical and demographic confounders. Nonasthmatics of the same racial/ethnic group were the reference group.**Results:** Compared with nonasthmatics, white asthmatics had increased odds of pre-eclampsia (aOR, 1.28; 95% confidence interval [CI], 1.15–1.43) and maternal hemorrhage (aOR, 1.14; 95% CI, 1.04–1.23). White and Hispanic infants were more likely to have neonatal intensive care unit admissions (aOR, 1.19; 95% CI, 1.11–1.28; aOR, 1.16; 95% CI, 1.02–1.32, respectively) and be small for gestational age (aOR, 1.11; 95% CI, 1.02–1.20; aOR, 1.26; 95% CI, 1.10–1.44, respectively), and Hispanic infants were more likely to have apnea (aOR, 1.32; 95% CI, 1.02–1.69).**Conclusions:** Maternal asthma did not affect most obstetrical and neonatal complication risks within racial/ethnic groups. Despite their increased risk for both asthma and many complications, our findings for black women were null. Asthma did not contribute to racial/ethnic disparities in complications.

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Introduction

Asthma is the most common chronic disease during pregnancy, complicating up to 12% of U.S. pregnancies annually [1,2]. Maternal asthma has been found to increase the risk of obstetrical and neonatal complications such as preterm birth, pre-eclampsia, gestational diabetes, and low birth weight [1,3–5]. Asthma also disproportionately affects certain racial/ethnic groups. For

instance, non-Hispanic blacks have a higher prevalence of asthma compared to whites (11.2% vs. 7.7%), Hispanics (6.5%), or Asians (5.2%) [6].

Racial/ethnic disparities in maternal and neonatal morbidity and mortality are also well established and have been found to persist [7–9]. For instance, although infant mortality rates have declined in the United States, the 2010 mortality rate for black infants of 11.5 deaths per 1000 live births remains more than twice the rate reported for infants born to non-Hispanic whites (5.18), Hispanics (5.25), and Asian or Pacific Islanders (4.27) [10]. In addition, a multistate analysis found that rates of severe maternal morbidity per 10,000 delivery hospitalizations among non-Hispanic black (284.26) and American Indian or Alaska Native women (225.47) were much higher than among non-Hispanic whites (113.93) with

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intermediate rates observed for Hispanic (145.28) and Asian or Pacific Islander women (131.97) [11].

Examining the extent to which underlying racial/ethnic disparities in obstetrical and neonatal outcomes may be attributed to maternal asthma could identify a key point for intervention to help reduce these persistent disparities. In addition, racial/ethnic disparities in obstetrical and neonatal outcomes among women with asthma are understudied. One prior study examined the effect of maternal asthma on obstetrical and neonatal outcomes by race or ethnicity, but this nationwide U.S. effort did not consider the underlying differences in outcome prevalence by race among women without asthma [12]. We addressed this gap in knowledge by examining the joint effect of maternal race/ethnicity and asthma on the odds of obstetrical and neonatal complications.

Methods

Study population

The Consortium on Safe Labor (CSL) was a retrospective cohort of U.S. deliveries between 2002 and 2008 [13]. The CSL took place across 12 clinical sites (19 medical centers) covering nine American College of Obstetricians and Gynecologists districts. We obtained data on 223,512 singleton deliveries. For this analysis, participants were excluded if their race/ethnicity was listed as multiracial ($n = 343$), other ($n = 4888$), or unknown or missing ($n = 9382$). Thus, our cohort for analysis consisted of 208,899 singleton deliveries and included racial/ethnic groups of white ($n = 110,603$ [52.9%]), black ($n = 50,284$ [24.1%]), Hispanic ($n = 38,831$ [18.3%]), and Asian or Pacific Islander ($n = 9181$ [4.4%]). Race/ethnicity was recorded in the electronic medical record (EMR) and is assumed to be self-reported. The reporting suggests that women of Hispanic ethnicity could be of any race. Most women contributed only one pregnancy ($n = 191,071$ [91.5%]). Asthma status was based on “International Classification of Diseases, Ninth Edition” (ICD-9) codes or delivery records, and participants could contribute deliveries to both groups if they were diagnosed with asthma between pregnancies. Institutional Review Board approval was obtained by all participating institutions.

Main outcomes

Data on maternal demographics, medical history, and obstetrical and neonatal outcomes were obtained from EMRs supplemented with ICD-9 codes in hospital discharge summaries. Codes used to identify complications have been previously described [5,14]. We evaluated neonatal and obstetrical outcomes previously identified in our data as being associated with maternal asthma and retained outcomes with sufficient numbers to support analyses by race/ethnicity [5,14]. Obstetrical outcomes examined included gestational diabetes, gestational hypertension, pre-eclampsia, maternal hemorrhage, placental abruption, premature rupture of membranes and preterm premature rupture of membranes (<37 gestational weeks), and preterm delivery (<37 weeks). Neonatal outcomes examined included neonatal intensive care unit (NICU) admission, apnea, respiratory distress syndrome, transient tachypnea of the newborn, anemia, small for gestational age (SGA), and hyperbilirubinemia. SGA was defined as the lowest 10% of birth weight for age and sex of the distribution of birth weight in our population [15].

Statistical analyses

Descriptive statistics were calculated to summarize the demographic and clinical characteristics of women by race/

ethnicity. We examined differences in the distribution of categorical demographic and clinical factors, including maternal asthma across race or ethnicity groups using χ^2 tests. The difference in mean maternal age across groups was examined using a Kruskal–Wallis test. We also calculated the prevalence of obstetrical and neonatal complications among women with and without asthma across race/ethnicity groups. Although we present the prevalence of obstetrical and neonatal complications for all groups, sample size limitations did not allow us to examine the interaction between asthma and race or ethnicity for Asian or Pacific Islander women.

We examined the main effects of maternal race/ethnicity together with asthma status on the odds of obstetrical and neonatal complications. Adjusted odds ratios (aORs) and their 95% confidence intervals (CIs) were estimated with multilevel logistic regression using generalized estimating equations and a first-order autoregressive covariance structure, adjusting for demographic and clinical variables. This allowed us to account for correlation among women who contributed more than one pregnancy throughout the study period. We tested for interaction between maternal race or ethnicity and asthma status and considered $P < .05$ as statistically significant. To ease interpretation and to allow comparison across groups, ORs for a given complication for racial/ethnic groups were derived from the same logistic regression model. To account for the varying prevalence of maternal asthma rates and obstetrical and neonatal complications across groups, we chose to use women of the same racial/ethnic group without asthma as the reference group for comparisons. Except where noted, ORs were adjusted for covariates available in the electronic medical record selected a priori based on our previous studies of obstetrical and neonatal complications among women with asthma [5,14]. These covariates included maternal age (continuous), marital status (not married, married, or missing), insurance (private, public, other, or missing), prepregnancy body mass index in kilogram per square meter (underweight: <18.5, normal: 18.5–<25, overweight: 25–<30, obese: 30–<35, severely obese: ≥ 35), smoking (yes or no) and alcohol use (yes or no) during pregnancy, history of chronic disease (pregnancy diabetes, chronic hypertension, thyroid disease, or human immunodeficiency virus), parity (nulliparous or multiparous), cesarean delivery (yes or no), and clinical site.

We excluded women with preexisting chronic disease from specific analyses when appropriate. In the model for gestational diabetes, we excluded women with ($n = 362$ [2.3%]) and without asthma ($n = 2695$ [1.4%]) with a prepregnancy diabetes diagnosis. Similarly, women with a prior diagnosis of hypertension were excluded from models for gestational hypertension. This included 479 (3%) and 3665 (1.8%) women with and without asthma, respectively. Birth weight was missing or implausible for 2393 patients, including 130 (0.8%) and 2263 (1.2%) mothers with and without asthma, respectively. We excluded these deliveries from the analyses for SGA and used infants that were appropriate for gestational age as the reference category. Information on infant apnea was not recorded at one clinical site, and we, therefore, excluded this site in analyses for this outcome ($n = 19,708$ [9.4%]). We also conducted supplemental analyses using similar methods to compare the outcomes of nonwhite mothers using white mothers (with and without asthma) as the reference group. All statistical analyses were performed using SAS, version 9.3 (SAS, Cary, NC).

Results

Overall, 7.7% of pregnancies were complicated by maternal asthma ($n = 16,099$). Asthma prevalence differed significantly

Table 1Demographic and clinical characteristics for women ($N = 208,899$) by race/ethnicity in the CSL from 2002 to 2008

Maternal characteristics	White $n = 110,603$ (52.9%)	Black $n = 50,284$ (24.1%)	Hispanic $n = 38,831$ (18.6%)	Asian/PI $n = 9181$ (4.4%)	P^*
Demographic factors					
Asthma diagnosis, n (%)	8156 (7.4)	5444 (10.8)	2288 (5.9)	211 (2.3)	<.0001
Maternal age, mean (SD)	28.5 (5.8)	25.7 (6.4)	26.8 (6.3)	30.0 (5.3)	<.0001
Marital status, n (%)					
Not married	22,707 (20.5)	36,959 (73.5)	18,962 (48.8)	1306 (14.2)	<.0001
Married	86,036 (77.8)	12,005 (23.9)	18,589 (47.9)	7740 (84.3)	
Missing	1860 (1.7)	1320 (2.6)	1280 (3.3)	135 (1.5)	
Insurance, n (%)					
Private	82,094 (74.2)	17,106 (34.0)	11,425 (29.4)	6448 (70.2)	<.0001
Public	20,760 (18.8)	26,705 (53.1)	18,801 (48.4)	1291 (14.1)	
Other	846 (0.8)	909 (1.8)	709 (1.8)	218 (2.4)	
Missing	6903 (6.2)	5564 (11.1)	7896 (20.3)	1224 (13.3)	
Clinical factors					
Prepregnancy BMI, kg/m^2 , n (%)					<.0001
Underweight, <18.5	4492 (4.1)	1209 (2.4)	1192 (3.1)	625 (6.8)	
Normal weight, 18.5–<25	44,781 (40.5)	12,421 (24.7)	14,071 (36.2)	3519 (38.3)	
Overweight, 25–<30	15,497 (14.0)	7712 (15.3)	7606 (19.6)	765 (8.3)	
Obese, 30–<35	6868 (6.2)	4418 (8.8)	3384 (8.7)	281 (3.1)	
Severely obese, ≥ 35	5071 (4.6)	4429 (8.8)	1966 (5.1)	165 (1.8)	
Unknown	33,894 (30.6)	20,095 (40.0)	10,612 (27.3)	3826 (41.7)	
Smoking during pregnancy, n (%)	8433 (7.6)	4058 (8.1)	1581 (4.1)	138 (1.5)	<.0001
Alcohol during pregnancy, n (%)	2445 (2.2)	975 (1.9)	404 (1.0)	65 (0.7)	<.0001
Any chronic disease (diabetes, hypertension, thyroid, HIV), n (%)	6867 (6.2)	3952 (7.9)	2136 (5.5)	418 (4.6)	<.0001
Parity, n (%), nulliparous	44,300 (40.1)	19,386 (38.6)	14,454 (62.8)	4502 (49.0)	<.0001
Cesarean delivery, n (%)	22,923 (25.3)	16,006 (31.8)	11,686 (30.1)	2694 (29.4)	<.0001

BMI = body mass index; HIV = human immunodeficiency virus; PI = Pacific Islander.

* P values are based on the χ^2 and Kruskal-Wallis test.

across racial/ethnic groups ($P < .0001$). Black women had the highest prevalence of asthma (10.8%) followed by whites (7.4%), Hispanics (5.9%), and Asian or Pacific Islanders (2.3%) (Table 1). Black women appeared to be younger and more frequently unmarried and experienced more prior chronic disease during pregnancy compared with other racial/ethnic groups.

As anticipated, obstetrical and neonatal complications were generally more frequent among pregnancies complicated by maternal asthma across all race/ethnicities (Table 2). Except for maternal hemorrhage, the prevalence of complications was found to be statistically different across categories of race/ethnicity (main effect of race $P < .05$). Gestational diabetes was more prevalent

among Hispanic and Asian or Pacific Islanders, whereas these groups have lower rates of gestational hypertension. Preterm birth was more prevalent among black and Hispanic mothers, and many neonatal complications were higher among black infants. In contrast, hyperbilirubinemia was higher in white and Asian or Pacific Islander infants.

Significant interactions between maternal asthma and race/ethnicity ($P < .05$) were only observed for two of the eight obstetrical complications examined (Table 2): pre-eclampsia and maternal hemorrhage. White women with asthma were more likely to experience pre-eclampsia (aOR, 1.28; 95% CI, 1.15–1.43) and maternal hemorrhage (aOR, 1.14; 95% CI, 1.04–1.23) when

Table 2Obstetrical and neonatal outcomes for singleton deliveries by asthma status among women ($N = 208,899$) in the CSL by race/ethnicity from 2002 to 2008

Outcome	White		Black		Hispanic		Asian or PI	
	No asthma ($n = 102,447$)	Asthma ($n = 8156$)	No asthma ($n = 44,840$)	Asthma ($n = 5444$)	No asthma ($n = 36,543$)	Asthma ($n = 2288$)	No asthma ($n = 8970$)	Asthma ($n = 211$)
Obstetrical outcomes, n (%)								
Gestational diabetes	4520 (4.5)	460 (5.7)	1905 (4.3)	249 (4.7)	2318 (6.5)	139 (6.3)	878 (9.9)	23 (11.3)
Gestational hypertension	3072 (3.0)	317 (4.0)	1401 (3.3)	169 (3.3)	733 (2.0)	51 (2.3)	109 (1.2)	4 (1.9)
Pre-eclampsia*	4178 (4.1)	425 (5.3)	2802 (6.5)	314 (6.1)	1617 (4.5)	115 (5.2)	373 (4.2)	10 (4.9)
Maternal hemorrhage*	7487 (7.3)	708 (8.7)	2555 (5.7)	374 (6.9)	2159 (5.9)	145 (6.3)	461 (5.1)	6 (2.8)
Placental abruption	1,429 (1.4)	160 (2.0)	977 (2.2)	168 (3.1)	532 (1.5)	32 (1.4)	104 (1.2)	2 (1.0)
Preterm delivery, <37 wk	9569 (9.3)	1021 (12.5)	7458 (16.6)	1006 (18.5)	4248 (11.6)	327 (14.3)	743 (8.3)	28 (13.3)
PROM	6869 (6.7)	530 (6.5)	3,413 (7.6)	394 (7.2)	2,292 (6.3)	188 (8.2)	830 (9.3)	19 (9.0)
PPROM	1937 (1.9)	222 (2.7)	1432 (3.2)	182 (3.3)	755 (2.1)	77 (3.4)	166 (1.9)	5 (2.9)
Neonatal outcomes, n (%)								
NICU admission*	10,718 (10.5)	1130 (13.9)	7241 (16.2)	968 (17.8)	4060 (10.5)	325 (14.2)	815 (8.9)	17 (8.1)
Apnea*	1709 (1.9)	189 (2.4)	1401 (3.2)	155 (2.9)	762 (2.1)	69 (3.3)	105 (1.7)	4 (2.2)
Respiratory distress syndrome	2882 (2.8)	297 (3.6)	2051 (4.6)	261 (4.8)	1080 (3.0)	83 (3.6)	142 (1.6)	6 (2.8)
Transient tachypnea of the newborn	3135 (3.1)	334 (4.1)	2265 (5.1)	311 (5.7)	11,167 (3.2)	89 (3.9)	178 (2.0)	5 (2.7)
Anemia	1,286 (1.3)	131 (1.6)	1,435 (3.2)	170 (3.1)	742 (2.0)	54 (2.4)	104 (1.2)	1 (0.95)
Size for gestational age, SGA*	7883 (8.8)	735 (10.2)	6452 (15.7)	859 (17.0)	3449 (10.6)	279 (13.7)	1035 (12.6)	15 (7.4)
Hyperbilirubinemia	17,827 (17.4)	1573 (19.3)	3955 (8.8)	482 (8.9)	4440 (12.2)	318 (13.9)	1853 (20.7)	46 (21.8)

LGA = large for gestational age; PI = Pacific Islander; PPRM = preterm premature rupture of membranes; PROM = premature rupture of membranes.

* Race/ethnicity $\times$ asthma $P_{\text{interaction}} \leq .05$ in fully adjusted model.

Table 3

aORs and 95% CIs for obstetrical and neonatal outcomes among women ($N = 208,899$) with asthma in the CSL within race/ethnicity groups from 2002 to 2008^a

Outcome	White ($n = 110,603$)	Black ($n = 50,284$)	Hispanic ($n = 38,831$)
Obstetrical outcomes, aOR (CI)			
Preeclampsia	1.28 (1.15–1.43)	0.91 (0.80–1.03)	1.03 (0.85–1.26)
Maternal hemorrhage	1.14 (1.04–1.23)	1.05 (0.93–1.18)	1.05 (0.87–1.26)
Neonatal outcomes, aOR (CI)			
NICU admission	1.19 (1.11–1.28)	1.02 (0.95–1.11)	1.16 (1.02–1.32)
Apnea	1.06 (0.91–1.24)	0.85 (0.71–1.00)	1.32 (1.02–1.69)
Size for gestational age, SGA	1.11 (1.02–1.20)	1.06 (0.98–1.15)	1.26 (1.10–1.44)

Bold font indicates significant values.

^a Reference group is women without asthma within each racial/ethnic group. Estimates adjusted for asthma status, race/ethnicity, maternal age, marital status, insurance, prepregnancy body mass index, smoking and alcohol use during pregnancy, history of chronic preexisting disease, parity, cesarean delivery, and clinical site.

compared with their nonasthmatic counterparts (Table 3). Obstetrical complications among black women did not differ by asthma status. Using white mothers as the reference group (Supplementary Table 1), risks for nonwhite women with asthma were generally similar to white women and attenuated compared with the findings for nonasthmatics.

Significant interactions between maternal asthma and race/ethnicity were found for three of the seven neonatal outcomes examined (Table 2): NICU admission, apnea, and SGA. Newborns of white and Hispanic mothers with asthma were found to be at increased odds of NICU admission (aOR, 1.19; 95% CI, 1.11–1.28; aOR, 1.16; 95% CI, 1.02–1.32, respectively) and SGA (aOR 1.11; 95% CI, 1.02–1.20; aOR, 1.26; 95% CI, 1.10–1.44, respectively; Table 3). In addition, newborns of Hispanic women with asthma were more likely to experience apnea (aOR, 1.32; 95% CI, 1.02–1.69). Black women with asthma were not observed to be at increased odds of neonatal complications when compared with their nonasthmatic counterparts. When the infants of white mothers with asthma were used as the comparison group (Supplementary Table 1), we observed the anticipated pattern of risk among nonasthmatics. Among the infants of asthmatics, we observed fewer differences by race/ethnicity. Black infants were less likely to have apnea and hyperbilirubinemia but more likely to have anemia and term low birth weight. Both black and Asian or Pacific Islander infants of asthmatic mothers were less likely to have a term birth weight greater than 4000 g. Hyperbilirubinemia was lower among Asian or Pacific Islander infants. Similar to our findings with obstetrical complications, risk estimates among asthmatics were generally attenuated compared with nonasthmatics.

Discussion

In this large retrospective cohort study of U.S. deliveries, we found that maternal asthma does not appear to affect the risk of most obstetrical and neonatal complications within racial/ethnic groups. However, a few notable risks for white and Hispanic women were observed. Compared with their nonasthmatic counterparts, white women with asthma were found to be at increased odds of pre-eclampsia and maternal hemorrhage. NICU admission and SGA were more frequent among newborns born to white and Hispanic mothers. Furthermore, the odds of apnea were greater among newborns born to Hispanic mothers with asthma compared to nonasthmatics. However, we did not find statistical interaction between maternal/race ethnicity and asthma status for six of the

eight obstetrical and four of the seven neonatal complications examined. Furthermore, despite the high prevalence of maternal asthma as well as obstetrical and neonatal complications among black women and their offspring, we did not observe an increased risk of complications among black women or their newborns associated with asthma. This is very reassuring and also indicates that maternal asthma may do little to explain the between-group disparities in obstetrical and neonatal outcomes among racial/ethnic groups.

Although black women have higher rates of asthma and experience higher rates of obstetrical and neonatal complications compared to whites, we did not see a significant change in adverse outcome risk among black women with asthma compared with black women without asthma [6,16–22]. Previous findings have indicated that black women experience high rates of psychosocial risks such as depression, stress, racial discrimination, and racism during pregnancy [22–29]. Reassuringly, our findings suggest that the high rate of maternal asthma among black women is not significantly contributing to their adverse outcome risk. Given their known risks, black women with asthma may be more frequently or closely monitored during prenatal care or perhaps given the large number of competing risks among black women, having asthma does not further affect their risk of complications.

Our findings suggest that maternal asthma may not be a significant contributor to the racial/ethnic disparities in obstetrical and neonatal complications in the United States. A meta-analysis summarizing the evidence for factors contributing to racial/ethnic disparities in obstetrical outcomes grouped factors into five domains which included biology, social circumstances, environmental exposures, behavioral patterns, and medical care [30]. The large number of competing risks may explain why maternal asthma does not seem to differentially affect the risk of obstetrical and neonatal complications across racial ethnic groups, especially among black women. Our clinical data do not allow for investigation of important social factors such as poverty in our analyses.

The relationship between maternal asthma and obstetrical and neonatal outcomes has been widely studied, but differences across race/ethnicity have not been examined [3,5,14,31–39]. To the best of our knowledge, our study is the first to investigate the joint effects of maternal asthma by maternal race/ethnicity on the odds of obstetrical and neonatal complications. One prior study that investigated health disparities in maternal asthma used white women as the comparison group instead of assessing the within-group difference between racial/ethnic groups [12]. We also observed that asthma prevalence is found to vary widely across racial/ethnic groups, and we decided to explore the effect maternal asthma had on the within-group risk of obstetrical and neonatal complications examined.

In general, compared with data on asthmatic women from the National Inpatient Sample (NIS), we observed higher prevalence for some obstetrical complications including gestational diabetes (Asian or Pacific Islanders 11.3% vs. 7.2%), pre-eclampsia (whites 5.3% vs. 1.6%), premature rupture of membranes (Hispanic 8.2% vs. 2.9%), and postpartum hemorrhage (whites 8.7% vs. 2.7%) [12]. The increased rates may be because of the differences in the study design and population. The NIS collects data from the Healthcare Cost and Utilization Project and only included discharge data, as opposed to our study that had access to both EMRs and discharge data. This may have allowed us to better capture the outcomes examined. In addition, temporal changes in recordkeeping or diagnostics could have influenced these differences. The NIS study was conducted between 1998 and 1999, and the CSL was conducted from 2002 to 2008.

There were several limitations to our study that should be considered. We did not have a sufficient sample of Asian Americans

to evaluate the differential effect of asthma on the outcomes examined, although our supplemental analysis compares their outcomes to whites. A study in California found differences in obstetrical outcomes exist between Asian groups with Cambodians or Laotians having the highest risk profiles compared with Japanese [40]. Maternal asthma has also been shown to vary across Hispanic subgroups. Previous studies support the finding that Puerto Rican women have higher rates of severe asthma compared with other Hispanic women, and it is important to examine whether this severity affects neonatal outcomes differentially within Hispanic subgroups [1]. The CSL did not capture information on subgroups of Hispanic ethnicity. Our data are nationwide, and few restrictions for cohort entry were imposed (e.g., gestational age ≥ 23 weeks) with no restrictions for race, asthma, or complications, although centers were located primarily in urban areas. We assume our data are fairly representative of the experience in contemporary labor and delivery practice in urban centers.

Similarly, because our study relied on delivery admission EMRs and ICD-9 codes, there was no specific information regarding asthma severity, symptoms, and medication use. Previous studies have found that women with poor asthma control are more likely to experience adverse pregnancy outcomes [4,41]. We were unable to evaluate the joint effects of maternal asthma and race/ethnicity among subgroups of women with varying levels of asthma control. However, under the assumption that they were more likely to have asthma complicating pregnancy, we conducted sensitivity analyses restricting our population to women with asthma in their discharge summary. In addition, we excluded sites with the two highest and two lowest asthma prevalence in our previous studies [5,14]. Neither scenario was found to affect our findings, giving some confidence that our findings are not due to bias in reporting by site or complication. Covariate data such as alcohol use and smoking from the EMR are also likely to be primarily based on self-report and the prevalence could be underestimated.

Despite these limitations, the availability of detailed clinical information in our study has helped to provide a better understanding of the complications experienced by women with asthma in a racially diverse contemporary U.S. cohort. For the various outcomes examined, some data were only available from the EMR, identified via hospital discharge codes, or when possible, we combined hospital discharge data with data from EMRs. Although hospital discharge data and EMRs have been found to be accurate sources of pregnancy-related outcomes, using an additional source to identify outcomes has proven to increase ascertainment [42].

Although nonwhite racial/ethnic groups are often more likely to experience obstetrical and neonatal complications compared with white women, our findings suggest that this is not the case among women with asthma. Between-group comparisons demonstrated that non-Hispanic white women with asthma and their infants had outcomes that were more similar to their white counterparts than those without asthma. In addition, we observed that maternal asthma did not increase the risk for most of the obstetrical and neonatal complications examined within nonwhite racial/ethnic groups.

In conclusion, the results of our study suggest that maternal asthma does not differentially affect the prevalence of most of the obstetrical and neonatal complications examined across racial/ethnic groups. However, given the increased risks observed for white and Hispanic women with asthma, particular attention should be given to these women during prenatal care to ensure that their asthma is being managed and controlled to reduce the likelihood of obstetrical and neonatal complications. Despite the high prevalence of asthma and increased risks for complications among black women, asthma status did not confer additional risks to black women and their infants. Future studies can examine whether

asthma does not confer additional risks to black women because of under-reporting of complications, competing risks, or greater care to control asthma among black women given their high-risk status. We also encourage additional study of Asian or Pacific Islander women, a widely understudied population in obstetrical and neonatal health which we did not have power to fully evaluate in these analyses. Future work is needed to confirm our findings, especially given the insufficient knowledge on racial/ethnic differences in obstetrical and neonatal among asthmatic women.

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Appendix

Supplementary Table 1

Fully adjusted* ORs and 95% CIs for pregnancy and infant outcomes by race or ethnicity and asthma status among singleton deliveries in the CSL from 2002 to 2008†

Outcome	Black		Hispanic		Asian or PI	
	No asthma (N = 44,840), OR (CI)	Asthma (N = 5444), OR (CI)	No asthma (N = 36,543), OR (CI)	Asthma (N = 2288), OR (CI)	No asthma (N = 8970), OR (CI)	Asthma (N = 211), OR (CI)
Pregnancy outcomes						
Gestational diabetes	0.97 (0.90–1.04)	0.92 (0.78–1.10)	1.63 (1.53–1.74)	1.28 (1.04–1.57)	2.41 (2.22–2.61)	2.00 (1.25–3.22)
Gestational hypertension	0.81 (0.75–0.88)	0.73 (0.60–0.89)	0.62 (0.57–0.68)	0.67 (0.49–0.92)	0.48 (0.39–0.58)	0.52 (0.19–1.43)
Maternal hemorrhage	1.02 (0.96–1.08)	0.94 (0.82–1.08)	0.95 (0.89–1.00)	0.87 (0.72–1.06)	1.00 (0.90–1.10)	0.44 (0.19–1.00)
Placental abruption	1.06 (0.95–1.19)	1.06 (0.84–1.35)	0.78 (0.69–0.88)	0.62 (0.81–0.93)	0.94 (0.77–1.16)	0.51 (0.13–2.03)
Preeclampsia	1.40 (1.31–1.49)	0.98 (0.84–1.15)	1.07 (1.00–1.15)	0.86 (0.69–1.07)	0.69 (0.62–0.78)	0.81 (0.42–1.58)
Preterm birth, <37 wk	1.34 (1.28–1.40)	1.22 (1.11–1.35)	0.99 (0.94–1.04)	1.00 (0.87–1.16)	0.90 (0.83–0.97)	1.06 (0.70–1.61)
PROM	1.13 (1.07–1.19)	1.12 (0.97–1.29)	1.02 (0.96–1.08)	1.08 (0.90–1.28)	1.04 (0.96–1.13)	1.24 (0.75–2.05)
PPROM	1.35 (1.24–1.47)	1.10 (0.89–1.35)	1.05 (0.95–1.16)	1.15 (0.88–1.51)	0.95 (0.81–1.12)	0.90 (0.37–2.21)
Infant outcomes						
Anemia	1.56 (1.40–1.73)	1.36 (1.07–1.73)	1.09 (0.97–1.21)	1.12 (0.80–1.55)	0.84 (0.68–1.04)	0.23 (0.03–1.82)
Apnea	0.99 (0.90–1.08)	0.79 (0.63–0.99)	0.91 (0.82–1.01)	1.13 (0.85–1.51)	0.74 (0.60–0.91)	0.81 (0.29–2.24)
Term birth weight						
Low birth weight < 2500 g‡	1.72 (1.63–1.81)	1.55 (1.38–1.74)	1.08 (1.02–1.14)	1.04 (0.88–1.23)	1.11 (1.01–1.21)	0.85 (0.48–1.50)
High birth weight ≥ 4000 g‡	0.54 (0.51–0.58)	0.46 (0.39–0.55)	0.87 (0.82–0.92)	0.83 (0.69–1.01)	0.52 (0.47–0.57)	0.46 (0.23–0.83)
Hyperbilirubinemia	0.70 (0.67–0.73)	0.65 (0.58–0.73)	1.01 (0.97–1.05)	1.07 (0.94–1.23)	1.53 (1.45–1.62)	1.61 (1.14–2.30)
NICU admission	1.28 (1.22–1.33)	1.10 (0.99–1.21)	0.99 (0.94–1.03)	0.96 (0.84–1.11)	0.86 (0.79–0.93)	0.58 (0.35–0.97)
Respiratory distress	1.20 (1.11–1.30)	1.07 (0.89–1.28)	0.87 (0.80–0.95)	1.03 (0.80–1.33)	0.61 (0.51–0.73)	0.77 (0.34–1.74)
Transient tachypnea	1.15 (1.07–1.23)	1.05 (0.89–1.24)	0.89 (0.82–0.96)	0.81 (0.64–1.04)	0.64 (0.55–0.75)	0.59 (0.24–1.45)

PPROM = preterm premature rupture of membranes; PROM = premature rupture of membranes.

Significant findings are highlighted in bold text.

* Adjusted for maternal asthma (estimates are based on the interaction of asthma and race or ethnicity) and age; marital status; insurance; prepregnancy body mass index; smoking and alcohol use during pregnancy; history of either preexisting diabetes (except for gestation diabetes), human immunodeficiency virus, chronic hypertension (except for gestational hypertension, pre-eclampsia), or thyroid disease; parity; cesarean delivery; and clinical site.

† White mothers with and without asthma are the reference categories.

‡ Birth weight was missing or implausible for 121 (0.8%) neonates.