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SUPPLEMENT ARTICLE

Adverse Pregnancy Outcomes, Maternal Complications, and Severe Illness Among US Delivery Hospitalizations With and Without a Coronavirus Disease 2019 (COVID-19) Diagnosis

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Background. Evidence on risk for adverse outcomes from coronavirus disease 2019 (COVID-19) among pregnant women is still emerging. We examined the association between COVID-19 at delivery and adverse pregnancy outcomes, maternal complications, and severe illness, and whether these associations differ by race/ethnicity, and describe discharge status by COVID-19 diagnosis and maternal complications.

Methods. Data from 703 hospitals in the Premier Healthcare Database during March–September 2020 were included. Adjusted risk ratios (aRRs) overall and stratified by race/ethnicity were estimated using Poisson regression with robust standard errors. Proportion not discharged home was calculated by maternal complications, stratified by COVID-19 diagnosis.

Results. Among 489 471 delivery hospitalizations, 6550 (1.3%) had a COVID-19 diagnosis. In adjusted models, COVID-19 was associated with increased risk for acute respiratory distress syndrome (aRR, 34.4), death (aRR, 17.0), sepsis (aRR, 13.6), mechanical ventilation (aRR, 12.7), shock (aRR, 5.1), intensive care unit admission (aRR, 3.6), acute renal failure (aRR, 3.5), thromboembolic disease (aRR, 2.7), adverse cardiac event/outcome (aRR, 2.2), and preterm labor with preterm delivery (aRR, 1.2). Risk for any maternal complications or for any severe illness did not significantly differ by race/ethnicity. Discharge status did not differ by COVID-19; however, among women with concurrent maternal complications, a greater proportion of those with (vs without) COVID-19 were not discharged home.

Conclusions. These findings emphasize the importance of implementing recommended prevention strategies to reduce risk for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection and further inform counseling and clinical care for pregnant women during the COVID-19 pandemic.

Keywords. COVID-19; race/ethnicity; risk ratios; delivery hospitalizations; retrospective cohort study.

Pregnant women are at increased risk for severe illness from coronavirus disease 2019 (COVID-19) compared with nonpregnant women [1]. Pregnancy, labor, and delivery also increase a woman's risk for medical complications [2]. Further, chronic conditions, severe maternal morbidity, and COVID-19 have disproportionately affected racial and ethnic minority groups [3–6]. Three US-based studies have investigated adverse outcomes among women with and without COVID-19 at delivery [7–9]. Among pregnant women who delivered at a hospital system in Dallas, Texas, those with COVID-19 were no more likely to have a preterm birth, severe pre-eclampsia, or a cesarean delivery for fetal complications compared with pregnant women without COVID-19 [7]. In New York City, pregnant women with COVID-19 were more likely to have postpartum fever, hypoxia, and to have a hospital readmission (12.9%) following delivery than pregnant women without COVID-19 (4.5%) [8]. Both studies were unable to evaluate if a COVID-19 diagnosis was independently associated with the adverse outcomes or adjust for underlying medical conditions. In a study of geographically diverse hospitals, rates of preterm birth, pre-eclampsia, thrombotic events, and death were higher among women with COVID-19 than those without COVID-19 at delivery [9]. These previous studies were limited in sample size [7, 8] or did not investigate differences by race/ethnicity [9].

Thus, to extend the evidence, we examined the association between documented COVID-19 diagnosis at delivery and risk of adverse outcomes, adjusting for underlying medical conditions and demographic characteristics overall and stratified by race/ethnicity. To better understand the impact of COVID-19, we also describe discharge status by COVID-19 diagnosis and select outcomes.

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METHODS

We performed a retrospective cohort analysis of all delivery hospitalizations using the Premier Healthcare Database Special COVID-19 Release (https://www.premierinc.com/; PHD-SR, release date 8 January 2021). PHD-SR is a US hospital–based, service-level, all-payer database that includes data on inpatient discharges from more than 849 geographically diverse nonprofit, nongovernmental, community, and teaching hospitals and health systems from rural and urban areas [10], representing approximately 20% of all US inpatient discharges. We included data from the 703 hospitals with delivery hospitalizations during March–September 2020.

Delivery hospitalizations among females aged 12–55 years were identified using *International Classification of Diseases, 10th Revision, Clinical Modification* (ICD-10-CM) diagnostic and procedure codes pertaining to obstetric delivery and diagnosis-related group delivery codes, excluding pregnancy losses (Supplementary Tables 1–5). Documented COVID-19 diagnosis at delivery hospitalization was identified through ICD-10-CM code U07.1 (COVID-19, virus identified) during April–September 2020 or B97.29 (Other coronavirus as the cause of disease classified elsewhere) during March–April 2020 [11].

Adverse pregnancy outcomes (preterm labor with preterm delivery, stillbirth) and maternal complications (acute renal failure, adverse cardiac events [including acute myocardial infarction, cardiomyopathy, heart failure/arrest during surgery or procedure, cardiac arrest/ventricular fibrillation, conversion of cardiac rhythm, atrial fibrillation/atrial flutter/supraventricular tachycardia, incident ventricular tachycardia, ischemia, and pulmonary edema/acute heart failure], thromboembolic disease [including deep vein thrombosis and other thromboembolic disease], acute respiratory distress syndrome, shock, and sepsis) were assessed. Additionally, we examined outcomes indicative of illness severity: mechanical ventilation, intensive care unit (ICU) admission, and discharge status (home; other care [includes discharge/transfer to other facility, eg, skilled nursing, rehabilitation facility]; other/missing [left against medical advice, discharged to court/law enforcement, still a patient, and information not available]; and death). Composite measures of any maternal complication and any indicator of severe illness were also created. Readmission was defined as any subsequent hospitalization at the same hospital within 30 days of delivery hospitalization discharge.

Discharge status was identified from the patient discharge status code. Intensive care unit admission was identified using the hospital chargemaster records (ie, the comprehensive list of all items billable to a hospital patient or to a patient's insurance provider). Mechanical ventilation was identified through a combination of the hospital chargemaster records and ICD-10-CM procedure codes. All other outcomes were identified from ICD-10-CM diagnosis and procedure codes (Supplementary Table 7).

Demographic variables included maternal age, maternal race/ethnicity, marital status, and primary payor. Maternal race and Hispanic origin were collected separately in the Premier Healthcare Database but combined for this analysis. Women who had "no" or "unknown" for Hispanic origin were considered non-Hispanic. Due to small cell sizes, non-Hispanic Asian women were combined with the non-Hispanic other/unknown category for modeling and stratification. Hospital characteristics included urban or rural hospital location and US Census Division location [12, 13]. Underlying medical conditions were assessed if an ICD-10-CM diagnosis code was present for the condition during the delivery hospitalization. Conditions assessed in this analysis included obesity, smoking, any diabetes (mutually exclusive categories of prepregnancy [including type 1 or type 2 diabetes and unknown diabetes] and gestational diabetes mellitus), asthma, other chronic lung disease (chronic obstructive pulmonary disease, cystic fibrosis, pulmonary fibrosis, chronic bronchitis, chronic respiratory failure, interstitial lung disease, obstructive sleep apnea, and sarcoidosis), and any hypertensive disorders of pregnancy (mutually exclusive categories of chronic hypertension, gestational hypertension, and pre-eclampsia/eclampsia including chronic hypertension with superimposed pre-eclampsia; pre-eclampsia; hemolysis, elevated liver enzymes, low platelet count [HELLP] syndrome; and eclampsia (Supplementary Table 8).

Pearson chi-square tests were used to ascertain differences in demographic and hospital characteristics by COVID-19 diagnosis. Median maternal age was calculated overall and stratified by COVID-19 diagnosis; a *t* test was used to determine if median maternal age differed by COVID-19 diagnosis. Poisson regression models with robust standard errors were used to calculate crude and adjusted relative risks (aRRs) for individual outcomes, accounting for within-hospital correlation [14]. Covariates included maternal age, race/ethnicity (Hispanic, non-Hispanic Black, non-Hispanic White, and non-Hispanic other/unknown), primary payor (Medicaid, private insurance, and other), obesity, any diabetes, any hypertension, and asthma. Additionally, crude and adjusted relative risks were calculated for composite measures of any maternal complication and any severity of illness stratified by race/ethnicity. Individual outcomes stratified by race/ethnicity could not be assessed due to a lack of statistical power to detect significant differences. The proportion of women not discharged home (women who died, were discharged to other care [eg, skilled nursing facility, hospice, other long-term care], and with other/missing discharge status) was calculated by maternal complications of interest, stratified by COVID-19 diagnosis. All analyses were performed in SAS version 9.4 (SAS Institute). This activity was reviewed by the Centers for Disease Control and Prevention (CDC) and was conducted consistent with applicable federal law and CDC

policy; the activity was determined to meet the requirements of public health surveillance as defined in 45 CFR 46.102(l)(2).

RESULTS

Among 489 471 delivery hospitalizations in 703 US hospitals, the median maternal age was 29 years (range: 12–55 years); 54.1% were non-Hispanic White, 47.5% were married, and 50.6% had private insurance as primary payor (Table 1). Overall, 87.2% of deliveries occurred in an urban hospital and 26.3% in the South Atlantic region. A COVID-19 diagnosis was documented in 1.3% (n = 6550) of all delivery hospitalizations. Compared with individuals without a COVID-19 diagnosis, those with a documented COVID-19 diagnosis were more likely to be Hispanic (41.2% vs 16.9%), less likely to be married (36.0% vs 47.7%), more likely to use Medicaid as the primary payor (64.1% vs 42.4%), more likely to have obesity (16.3% vs 14.5%), more likely to have diabetes (12.7% vs 10.6%) ($P < .0001$ for all), more likely to have a cesarean delivery (33.5% vs 32.0%; $P = .0093$), and less likely to have asthma (5.1% vs 6.0%; $P = .0014$). Those with a COVID-19 diagnosis were also more likely to any hypertensive disorders of pregnancy (17.0% vs 16.1%), largely driven by the occurrence of pre-eclampsia/eclampsia (9.4% vs 6.8%; $P < .0001$) compared with those without a COVID-19 diagnosis.

Overall, 4.2% of all delivery hospitalizations had any adverse pregnancy outcomes of interest (Table 2). Among all delivery hospitalizations, 0.8% had any maternal complication of interest, including 4.4% of individuals with a COVID-19 diagnosis and 0.7% of those who did not have a COVID-19 diagnosis. Indication of severe illness was observed in 1.6% of all hospitalizations, including 4.7% of individuals with COVID-19 and 1.6% of individuals without COVID-19. Those with a documented COVID-19 diagnosis were more likely to have concurrent documentation of acute respiratory distress syndrome (aRR, 34.4), sepsis (aRR, 13.6), shock (aRR, 5.1), acute renal failure (aRR, 3.5), thromboembolic disease (aRR, 2.7), adverse cardiac event or outcome (aRR, 2.2), or preterm labor with preterm delivery (aRR, 1.2); to require ICU admission (aRR, 3.6) or mechanical ventilation (aRR, 12.7); and to die (aRR, 17.0).

Most (98.9%) patients were discharged home from the delivery hospitalization (Table 2); however, 1.1% were discharged to other care, had other or missing outcomes, or died. Overall, 1.2% were readmitted within 30 days; among these, there were no differences by COVID-19 diagnosis. When comparing discharge status by maternal complications, stratified by COVID-19 diagnosis, a greater proportion of those with a documented COVID-19 diagnosis and concurrent acute renal failure (26.8% vs 10.2%), adverse cardiac event or outcome (37.5% vs 5.7%), thromboembolic disease (31.6% vs 4.8%), acute respiratory distress syndrome (18.1% vs 16.1%), shock (56.7% vs 17.5%), sepsis (28.6% vs 14.3%), or who required ICU admission (14.4% vs 3.1%) or mechanical ventilation (34.6% vs 15.1%) were not discharged home (ie, died, discharged to another facility, or with missing data) (Figure 1).

When stratifying by race/ethnicity, individuals with a documented COVID-19 diagnosis were more likely to have any maternal complication and any indicator of severe illness (Table 3). The risk for any maternal complication by race/ethnicity was highest for non-Hispanic other/unknown (aRR, 8.1), followed by Hispanic (aRR, 7.5), non-Hispanic Black (aRR, 5.1), and non-Hispanic White (aRR, 5.1). Similarly, risk for any severe disease was highest among non-Hispanic other/unknown (aRR, 4.2), followed by Hispanic (aRR, 3.5), non-Hispanic Black (aRR, 3.3), and non-Hispanic White (aRR, 2.9). However, the race/ethnicity-specific 95% confidence intervals for any maternal complication and any severe disease overlap, indicating that the risks do not vary significantly by race/ethnicity in this population.

DISCUSSION

While the absolute risk of maternal complications and severe illness was low, individuals with a documented COVID-19 diagnosis at delivery hospitalization had 17 times the risk for death, almost 14 times the risk for sepsis, 13 times the risk for mechanical ventilation, 5 times the risk for shock, 4 times the risk for acute renal failure, and more than twice the risk for adverse cardiac event or thromboembolic disease compared with those who did not have a COVID-19 diagnosis. Risks for any maternal complications or severe illness did not differ statistically by race/ethnicity.

Our estimates of the risks for adverse pregnancy outcomes, maternal complications, and severe illness are low compared with some other studies of COVID-19 among pregnant women [15, 16]. For example, in a cohort of hospitalized symptomatic pregnant women with laboratory-confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), 16.2% were admitted to an ICU, 8.5% required invasive mechanical ventilation, and 0.7% died [15]. Differences in estimates are likely due to varied population denominators of pregnant women with COVID-19–associated hospitalizations [15, 16] versus our population of all delivery hospitalizations, which provides a more appropriate denominator to establish risk. Our estimates of maternal complications and maternal severe disease were similar to a recent analysis using the same dataset [9]. However, our analysis adds to this previous work by stratifying by maternal race/ethnicity and by examining the proportion of women discharged home by maternal complications and COVID-19 diagnosis. We also directly estimated relative risks instead of using odds ratios to approximate risk; our findings are consistent with the previous study's results.

In this study, individuals with a documented COVID-19 diagnosis were 34 times more likely to have a diagnosis of acute

Table 1. Maternal Demographic, Health, and Hospitalization Characteristics and Hospital Characteristics Among Delivery Hospitalizations With and Without a Documented COVID-19 Diagnosis, March–September 2020

Characteristics	Diagnosis, n (%)			*P*
	Total (N = 489 471)	COVID-19 (n = 6550)	No COVID-19 (n = 482 921)	
Maternal characteristics				
Maternal age, median (range), years	29.0 (12-55)	28.0 (13-49)	29.0 (12-55)	<.0001[a]
Maternal race and ethnicity[b]				<.0001[c]
Non-Hispanic White	264 828 (54.1)	1780 (27.2)	263 048 (54.5)	
Hispanic	84 470 (17.3)	2696 (41.2)	81 774 (16.9)	
Non-Hispanic Black	70 892 (14.5)	1119 (17.1)	69 773 (14.4)	
Non-Hispanic Asian	21 125 (4.3)	193 (2.9)	20 932 (4.3)	
Non-Hispanic other/unknown	48 156 (9.8)	762 (11.6)	47 394 (9.8)	
Marital status				<.0001[c]
Married	232 632 (47.5)	2360 (36.0)	230 272 (47.7)	
Single	200 868 (41.0)	3123 (47.7)	197 745 (40.9)	
Unknown	55 971 (11.4)	1067 (16.3)	54 904 (11.4)	
Primary payor				<.0001[c]
Private[d]	247 578 (50.6)	1898 (29.0)	245 680 (50.9)	
Medicaid	208 774 (42.7)	4199 (64.1)	204 575 (42.4)	
Self-pay	8785 (1.8)	173 (2.6)	8612 (1.8)	
Other	24 334 (5.0)	280 (4.3)	24 054 (5.0)	
Hospital characteristics				
Hospital location[e]				<.0001[c]
Urban	426 773 (87.2)	5883 (89.8)	420 890 (87.2)	
Rural	62 698 (12.8)	667 (10.2)	62 031 (12.8)	
US Census Division[f]				<.0001[c]
East North Central	79 808 (16.3)	583 (8.9)	79 225 (16.4)	
East South Central	36 593 (7.5)	319 (4.9)	36 274 (7.5)	
Middle Atlantic	61 968 (12.7)	1548 (23.6)	60 420 (12.5)	
Mountain	31 337 (6.4)	239 (3.6)	31 098 (6.4)	
New England	9927 (2.0)	75 (1.1)	9852 (2.0)	
Pacific	49 877 (10.2)	492 (7.5)	49 385 (10.2)	
South Atlantic	128 798 (26.3)	1811 (27.6)	126 987 (26.3)	
West North Central	31 014 (6.3)	424 (6.5)	30 590 (6.3)	
West South Central	60 149 (12.3)	1059 (16.2)	59 090 (12.2)	
Health and hospitalization characteristics				
Obesity	70 997 (14.5)	1066 (16.3)	69 931 (14.5)	<.0001[c]
Diabetes (any)[g]	52 080 (10.6)	832 (12.7)	51 248 (10.6)	<.0001[c]
Prepregnancy diabetes	6820 (1.4)	126 (1.9)	6694 (1.4)	.0002[c]
Gestational diabetes	45 260 (9.2)	706 (10.8)	44 554 (9.2)	<.0001[c]
Asthma	29 369 (6.0)	332 (5.1)	29 037 (6.0)	.0014[c]
Other chronic lung disease[h]	1014 (0.2)	17 (0.3)	997 (0.2)	.3479[c]
Hypertensive disorders of pregnancy (any)[g]	78 997 (16.1)	1115 (17.0)	77 882 (16.1)	.0503[c]
Chronic hypertension	13 166 (2.7)	149 (2.3)	13 017 (2.7)	.0366[c]
Gestational hypertension	32 137 (6.6)	350 (5.3)	31 787 (6.6)	<.0001[c]
Pre-eclampsia/eclampsia[i]	33 694 (6.9)	616 (9.4)	33 078 (6.8)	<.0001[c]
Cesarean delivery	156 594 (32.0)	2193 (33.5)	154 401 (32.0)	.0093[c]

The Premier Healthcare Database includes 703 hospitals with delivery hospitalizations. Abbreviation: COVID-19, coronavirus disease 2019.

[a] *P* value associated with *t* test.

[b] Maternal race and Hispanic origin were collected separately but combined for this analysis. Women who had "no" or "unknown" for Hispanic origin were considered non-Hispanic.

[c] *P* value associated with chi-square tests.

[d] Includes managed care and commercial indemnity.

[e] The US Census defines an urban area as a territory whose core census block groups or blocks have a population density of at least 1000 people per square mile and surrounding census blocks have an overall density of at least 500 people per square mile. Rural areas are considered territory outside the definition of urban.

[f] East North Central: Indiana, Illinois, Michigan, Ohio, Wisconsin; East South Central: Alabama, Kentucky, Mississippi, Tennessee; Middle Atlantic: New Jersey, New York, Pennsylvania; Mountain: Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, Wyoming; New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Pacific: Alaska, California, Hawaii, Oregon, Washington; South Atlantic: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia; West North Central: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota; West South Central: Arkansas, Louisiana, Oklahoma, Texas.

[g] Mutually exclusive subcategories.

[h] Includes chronic obstructive pulmonary disease, cystic fibrosis, pulmonary fibrosis, asbestosis, chronic bronchitis, chronic respiratory failure, interstitial lung disease, obstructive sleep apnea, and sarcoidosis.

[i] Includes chronic hypertension with superimposed pre-eclampsia; pre-eclampsia; hemolysis, elevated liver enzymes, low platelet count (HELLP) syndrome; and eclampsia.

Table 2. Adverse Pregnancy Outcomes and Maternal Complications Associated With a Documented COVID-19 Diagnosis at Delivery Hospitalization—United States, March–September 2020

	Diagnosis, n (%)			Risk Ratio (95% CI)	
Outcomes[a]	Total (N = 489 471)	COVID-19 (n = 6550)	No COVID-19 (n = 482 921)	Unadjusted	Adjusted[b]
Any adverse pregnancy outcome[c]	20 774 (4.2)	372 (5.7)	20 402 (4.2)	1.3 (1.2–1.5)	1.2 (1.1–1.3)
Preterm labor with preterm delivery	17 707 (3.6)	315 (4.8)	17 392 (3.6)	1.3 (1.2–1.5)	1.2 (1.1–1.3)
Stillbirth	3502 (0.7)	63 (1.0)	3439 (0.7)	1.4 (1.1–1.7)	1.2 (1.0–1.6)
Any maternal complication[d]	3691 (0.8)	291 (4.4)	3400 (0.7)	6.3 (5.6–7.1)	6.3 (5.5–7.3)
Acute renal failure	775 (0.2)	41 (0.6)	734 (0.2)	4.1 (3.0–5.6)	3.5 (2.5–5.0)
Adverse cardiac event/outcome[e]	1601 (0.3)	41 (0.6)	1560 (0.3)	1.9 (1.4–2.6)	2.2 (1.6–2.9)
Thromboembolic disease[f]	546 (0.1)	19 (0.3)	527 (0.1)	2.7 (1.7–4.2)	2.7 (1.7–4.4)
Acute respiratory distress syndrome	644 (0.1)	218 (3.3)	426 (0.1)	37.7 (32.1–44.3)	34.4 (29.0–40.8)
Shock	404 (0.1)	30 (0.5)	374 (0.1)	5.9 (4.1–8.6)	5.1 (3.4–7.8)
Sepsis	476 (0.1)	85 (1.3)	391 (0.1)	16.0 (12.7–20.2)	13.6 (10.2–18.1)
Any maternal severe illness[g]	7900 (1.6)	307 (4.7)	7593 (1.6)	3.0 (2.7–3.3)	3.5 (2.8–4.3)
ICU admission	7682 (1.6)	293 (4.5)	7389 (1.5)	2.9 (2.6–3.3)	3.6 (2.8–4.5)
Mechanical ventilation	688 (0.1)	105 (1.6)	583 (0.1)	13.3 (10.8–16.3)	12.7 (9.2–17.5)
Discharge status					
Death	41 (0.0)	9 (0.1)	32 (0.0)	20.7 (9.9–43.4)	17.0 (8.2–35.4)
Discharged home	484 085 (98.9)	6403 (97.8)	477 682 (98.9)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Discharged, other care	4263 (0.9)	116 (1.8)	4147 (0.9)	2.1 (1.7–2.5)	2.1 (1.8–2.6)
Other/missing[h]	1082 (0.2)	22 (0.3)	1060 (0.2)	1.5 (1.0–2.3)	1.4 (1.0–2.1)
Readmission within 30 days	5933 (1.2)	99 (1.5)	5834 (1.2)	1.3 (1.0–1.5)	1.2 (1.0–1.4)

The Premier Healthcare Database includes 703 hospitals with delivery hospitalizations, March–September 2020. Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; ICU, intensive care unit.

[a]Outcomes are not mutually exclusive, with the exception of discharge status categories.

[b]Adjusted for hospital (to account for within facility correlation), maternal age, race/ethnicity, primary payor, obesity, any diabetes, any hypertension, and asthma.

[c]Includes preterm labor with preterm delivery and stillbirth.

[d]Includes acute renal failure, adverse cardiac event/outcome, thromboembolic disease, acute respiratory distress syndrome, shock, and sepsis.

[e]Includes acute myocardial infarction, cardiomyopathy, heart failure/arrest during surgery or procedure, cardiac arrest/ventricular fibrillation, conversion of cardiac rhythm, incident ventricular tachycardia, ischemia, pulmonary edema/acute heart failure, and atrial fibrillation/atrial flutter/supraventricular tachycardia.

[f]Includes deep vein thrombosis and other thromboembolic disease.

[g]Includes ICU admission, mechanical ventilation, and death.

[h]Includes "left against medical advice," "discharged to law enforcement," "still a patient," (n = 19), and "missing" (n = 107); none had a COVID-19 diagnosis.

respiratory distress syndrome, a well-documented complication of COVID-19 [17, 18], than those without a COVID-19 diagnosis. While COVID-19 appears to be a systemic disease [19], pulmonary disease is the most well-documented manifestation.

In our study, a greater percentage of women with COVID-19 at delivery hospitalization were Hispanic (41.0%) and had Medicaid as the primary payor (64.3%) compared with women without COVID-19 (16.7% Hispanic and 42.4% Medicaid). Our findings are similar to data reported on birth certificates from 15 jurisdictions [20] and other studies among pregnant women [7, 15]. Race and ethnicity minority populations have been disproportionately affected by COVID-19 [21]. Race and ethnicity may be markers for other factors that affect health, including neighborhood and physical environment, socioeconomic status, access to healthcare, and occupational exposure (eg, frontline, essential, and critical infrastructure work) [3]. While the risk for any maternal complication or severe illness was highest for non-Hispanic other/unknown, followed by Hispanic and non-Hispanic Black individuals, each of the 95% confidence intervals associated with race/ethnicity-specific aRRs overlapped with each other and also with non-Hispanic White. Thus, in this study, we did not find statistically significant differences in risk of any maternal complications or severe illness by race/ethnicity. Although these data provide a large sample size, the individual outcomes of interest were rare, precluding further exploration of individual outcomes by race/ethnicity at this time.

We found women with COVID-19 were at slightly increased risk of cesarean delivery and preterm labor with preterm delivery than women without COVID-19 at delivery hospitalization. However, statistical significance does not imply clinical significance, especially in studies with very large sample sizes. Previous studies of pregnant women with COVID-19 admitted for delivery showed conflicting findings related to cesarean delivery. One study found that women with COVID-19 were less likely to have a cesarean delivery (unadjusted risk ratio, .80; 95% confidence interval, .64–.99) than women without COVID-19 [7]. In contrast, cesarean delivery rates were higher among women with symptomatic (46.7%) or asymptomatic (45.5%) COVID-19 compared with women without COVID-19 (30.9%) [8]. In other studies of pregnant women admitted for delivery, those with COVID-19 were no more likely to deliver a preterm

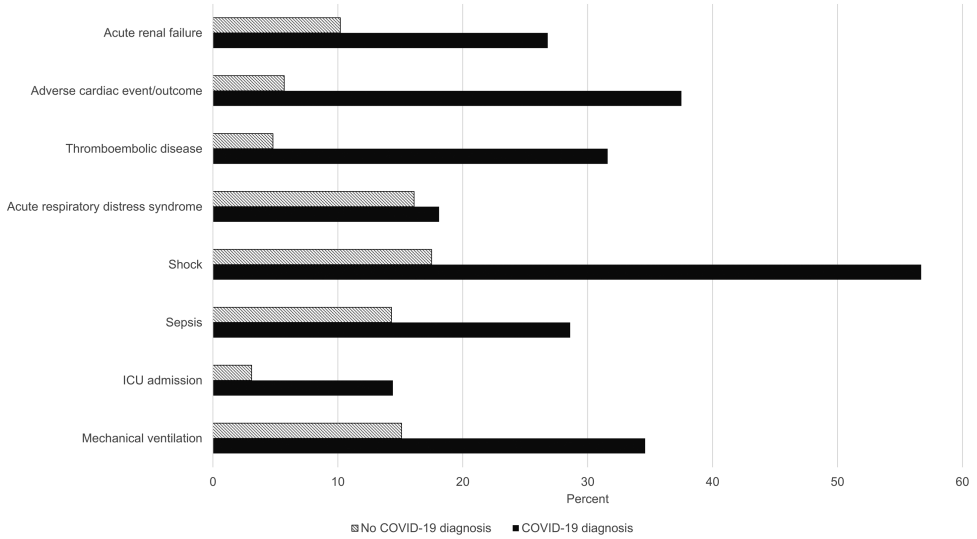

Figure 1. Percentage of women not discharged home by selected maternal complications, stratified by COVID-19 diagnosis at delivery hospitalization—Premier Healthcare Database, United States, March–September 2020. Women not discharged home include women who expired, were discharged to another facility, or who had other or missing discharge status. The Premier Healthcare Database includes 703 hospitals with delivery hospitalizations. Abbreviations: COVID-19, coronavirus disease 2019; ICU, intensive care unit.

infant [7, 8], but in a recent meta-analysis of primarily small sample sizes and case studies, preterm birth was higher among pregnant women with COVID-19 compared with those without COVID-19 [22]. Inconsistent findings may be due differences in obstetric intervention practices across populations and geography, our outcome of preterm labor with preterm delivery (not preterm birth), and our ability to adjust for underlying medical conditions.

Most women in our study population were discharged home after delivery hospitalization (98.9%). This was true even among women with an ICU admission, with 85.7% of women with and 97.6% of women without a COVID-19 diagnosis discharged home. While we did not have an indication for ICU admission at the time of delivery hospitalization, reasons for admission may include precautionary infection control in the case of COVID-19 and obstetric-related issues such as follow-up of hypertensive disorders in pregnancy, control of sepsis, and hemorrhage. Hypertensive disease, hemorrhage, and cardiomyopathy or other cardiac disease have been documented as common diagnoses associated with delivery-ICU admissions [23]. However, the proportion of individuals not discharged home who had a diagnosis of adverse cardiac event/outcome, thromboembolic disease, and shock or who required mechanical ventilation was at least 20 percentage points higher among

Table 3. Any Maternal Complication and Any Maternal Severe Disease Associated With a Documented COVID-19 Diagnosis at Delivery Hospitalization, Stratified by Maternal Race and Ethnicity—United States, March-September 2020

	Diagnosis, n (%)		Risk Ratio (95% CI)	
Maternal Race and Ethnicity	COVID-19	No COVID-19	Unadjusted	Adjusted[a]
Any maternal complication[b]				
Non-Hispanic White	61 (3.4)	1761 (0.7)	5.1 (4.0–6.6)	5.1 (3.9–6.6)
Hispanic	110 (4.1)	459 (0.6)	7.3 (5.9–8.9)	7.5 (5.9–9.7)
Non-Hispanic Black	61 (5.5)	723 (1.0)	5.3 (4.1–6.8)	5.1 (3.7–6.9)
Non-Hispanic other/unknown	59 (6.2)	457 (0.7)	9.2 (7.1–12.0)	8.1 (6.3–10.4)
Any maternal severe disease[c]				
Non-Hispanic White	58 (3.3)	3148 (1.2)	2.7 (2.1–3.5)	2.9 (2.2–3.7)
Hispanic	123 (4.6)	1683 (2.1)	2.2 (1.9–2.7)	3.5 (2.7–4.5)
Non-Hispanic Black	70 (6.3)	1451 (2.1)	3.0 (2.4–3.8)	3.3 (2.5–4.3)
Non-Hispanic other/unknown	56 (5.9)	1311 (1.9)	3.1 (2.4–4.0)	4.2 (3.0–5.9)

The Premier Healthcare Database includes 703 hospitals with delivery hospitalizations, March–September 2020. Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; ICU, intensive care unit.

[a]Adjusted for hospital (to account for within facility correlation), maternal age, primary payor, obesity, any diabetes, any hypertension, and asthma.

[b]Includes acute renal failure, adverse cardiac event/outcome, thromboembolic disease, acute respiratory distress syndrome, shock, and sepsis.

[c]Includes ICU admission, mechanical ventilation, and death.

individuals with a COVID-19 diagnosis compared with individuals without a documented COVID-19 diagnosis. These findings suggest that some individuals have had a more complicated disease course and a longer recovery. Further study is needed to understand whether these findings are reflective of complications of acute infection, postacute hyperinflammatory disease, or late sequelae [24].

In our overall sample, 1.2% of women were readmitted within 30 days and this estimate was not significantly different by COVID-19 status at delivery hospitalization. Our readmission estimate was similar to a study of 30-day readmission after discharge from delivery hospitalization in 21 states [25]. In a study of 675 pregnant women admitted for delivery, postpartum readmission differed among women with symptomatic COVID-19 (6.7%), asymptomatic COVID-19 (3.6%), and without COVID-19 (1.5%) [8]; however, this study did not have a sufficient sample size to adjust for underlying medical conditions.

Further investigation of risk factors for severe clinical outcomes to understand long-term recovery and to inform optimal treatment and management of laboratory-confirmed SARS-CoV-2 infection in pregnant women is needed. Further, whether maternal SARS-CoV-2 infection affects fetal/infant health is not well understood.

Strengths and Limitations

Using a large database of electronic health records and administrative data from geographically diverse hospitals across the United States, this study investigated the risk of a number of adverse outcomes and their association with a documented COVID-19 diagnosis, adjusting for sociodemographic characteristics and underlying chronic diseases. The large sample size also enabled stratification by race/ethnicity; however, we were limited to examining non-Hispanic White, non-Hispanic Black, Hispanic, and other non-Hispanic women due to small cell sizes. Nevertheless, interpretation of these data is subject to several limitations. First, the analysis relied on ICD-10-CM codes in electronic health records and administrative data. Thus, the exposure of interest (documented COVID-19), identified from the use of 2 ICD-10-CM codes during the study, and underlying medical conditions and outcomes could be misclassified or miscoded. However, a recent study found that the U07.1 code, used to identify COVID-19 during March–September, had a high sensitivity and specificity [26]. Second, information on timing of SARS-CoV-2 infection and course of illness was not available. The inclusion of asymptomatic cases of COVID-19 may bias our results towards the null. Third, many hospitals implemented universal SARS-CoV-2 testing among pregnant women admitted to labor units in spring 2020 [7, 27, 28], but this information was unavailable and might result in misclassification bias if hospitals had different practices during the study period. Fourth, because outpatient records were not universally available and linkage across different hospital systems was not possible, the analysis was restricted to delivery hospitalizations and did not examine COVID-19 diagnoses, underlying medical conditions recorded before the delivery hospitalization (eg, during a prenatal visit), prenatal care utilization, or maternal delivery history (eg, parity, previous cesarean delivery, or history of preterm delivery), which may impact the risk for maternal complications. Fifth, it is unknown how maternal race and ethnicity data were collected. Practices may vary by hospital and maternal race and ethnicity may have been misclassified. Last, although the Premier Healthcare Database included a large population across US Census regions, data are not nationally representative.

Conclusions

A documented COVID-19 diagnosis, identified through ICD-10-CM codes in delivery hospitalizations, was associated with multiple, concurrently documented adverse pregnancy outcomes, maternal complications, and indicators of severe illness. However, the absolute risks were low. Risk for any maternal complication or for severe illness did not differ by race/ethnicity in this study. These findings emphasize the importance of implementing prevention strategies to reduce the risk for SARS-CoV-2 infection and further inform counseling and clinical care for pregnant women during the COVID-19 pandemic.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

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