Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Characteristics and treatment of hospitalized pregnant women with COVID-19

Ahlia Sekkarie, PhD, MPH; Rebecca Woodruff, PhD, MPH; Michael Whitaker, MPH; Michael R. Kramer, PhD; Lauren B. Zapata, PhD; Sascha R. Ellington, PhD; Dana M. Meaney-Delman, MD, MPH; Huong Pham, MPH; Kadam Patel, MBBS, MPH; Christopher A. Taylor, PhD; Shua J. Chai, MD, MPH; Breanna Kawasaki, MPH; James Meek, MPH; Kyle P. Openo, DrPH; Andy Weigel, MSW; Lauren Leegwater, MPH; Kathryn Como-Sabetti, MPH; Susan L. Ropp, PhD; Alison Muse, MPH; Nancy M. Bennett, MD, MS; Laurie M. Billing, MPH; Melissa Sutton, MD, MPH; H. Keipp Talbot, MD, MPH; Mary Hill, MPH; Fiona P. Havers, MD, MHS; On behalf of the COVID-19-Associated Hospitalization Surveillance Network COVID-NET Surveillance Team

BACKGROUND: Pregnant women less frequently receive COVID-19 vaccination and are at increased risk for adverse pregnancy outcomes from COVID-19.

OBJECTIVE: This study aimed to first, describe the vaccination status, treatment, and outcomes of hospitalized, symptomatic pregnant women with COVID-19, and second, estimate whether treatment differs by pregnancy status among treatment-eligible (ie, requiring supplemental oxygen per National Institutes of Health guidelines at the time of the study) women.

STUDY DESIGN: From January to November 2021, the COVID-19-Associated Hospitalization Surveillance Network completed medical chart abstraction for a probability sample of 2715 hospitalized women aged 15 to 49 years with laboratory-confirmed SARS-CoV-2 infection. Of these, 1950 women had symptoms of COVID-19 on admission, and 336 were pregnant. We calculated weighted prevalence estimates of demographic and clinical characteristics, vaccination status, and outcomes among pregnant women with symptoms of COVID-19 on admission. We used propensity score matching to estimate prevalence ratios and 95% confidence intervals of treatment-eligible patients who received remdesivir or systemic steroids by pregnancy status.

RESULTS: Among 336 hospitalized pregnant women with symptomatic COVID-19, 39.6% were non-Hispanic Black, 24.8% were Hispanic or Latino, and 61.9% were aged 25 to 34 years. Among those with known COVID-19 vaccination status, 92.9% were unvaccinated. One-third (32.7%) were treatment-eligible. Among treatment-eligible pregnant women, 74.1% received systemic steroids and 61.4% received remdesivir. Among those that were no longer pregnant at discharge (n=180), 5.4% had spontaneous abortions and 3.5% had stillbirths. Of the 159 live births, 29.0% were preterm. Among a propensity score–matched cohort of treatment-eligible hospitalized women of reproductive age, pregnant women were less likely than nonpregnant women to receive remdesivir (prevalence ratio, 0.82; 95% confidence interval, 0.69–0.97) and systemic steroids (prevalence ratio, 0.80; 95% confidence interval, 0.73–0.87).

CONCLUSION: Most hospitalized pregnant patients with symptomatic COVID-19 were unvaccinated. Hospitalized pregnant patients were less likely to receive recommended remdesivir and systemic steroids compared with similar hospitalized nonpregnant women. Our results underscore the need to identify opportunities for improving COVID-19 vaccination, implementation of treatment of pregnant women, and the inclusion of pregnant women in clinical trials.

Key words: remdesivir, SARS-CoV-2 steroids, stillbirth, surveillance, vaccination

Introduction

Pregnant women with COVID-19 are at increased risk for adverse pregnancy outcomes including preterm birth and stillbirth.[1,2] The National Institutes of Health (NIH) provides COVID-19 treatment guidelines for hospitalized adults.[3] At the time of this study, these guidelines recommend dexamethasone or alternate systemic steroids and remdesivir to decrease disease severity among hospitalized patients who require supplemental oxygen or mechanical ventilation.[3,4] The Society for Maternal-Fetal Medicine supports the NIH COVID-19 treatment guidelines and recommends that remdesivir and dexamethasone be offered to pregnant patients with COVID-19 who require supplemental oxygen.[5] However, the extent to which these guidelines are followed in hospitalized pregnant patients with COVID-19 is unknown.

Our objectives were to first, describe the demographic and clinical characteristics, vaccination status, and in-hospital outcomes of hospitalized pregnant patients with symptomatic laboratory-confirmed SARS-CoV-2 infection from January to November 2021 using data from the COVID-19-Associated Hospitalization Surveillance Network (COVID-NET). Second, in a propensity score–matched cohort of treatment-eligible pregnant and nonpregnant women of reproductive age, we compared the prevalence of receiving remdesivir or systemic steroids.

Materials and Methods

Data source and study design

COVID-NET conducts population-based surveillance of laboratory-confirmed COVID-19–associated hospitalizations in 99 counties across 14 states (CA, CO, CT, GA, IA, MD, MI, MN, NM, NY, OH, OR, TN, and UT).[6,7] The COVID-NET case definition includes

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AJOG MFM at a Glance

Why was this study conducted?

The extent to which COVID-19 treatment guidelines in hospitalized pregnant patients are followed is not known. In addition, the vaccination rate of hospitalized pregnant women is not well-described.

Key findings

One-fifth of treatment-eligible hospitalized pregnant patients did not receive recommended treatment, and most symptomatic pregnant women hospitalized with COVID-19 were unvaccinated.

What does this add to what is known?

This study confirms undertreatment of hospitalized pregnant patients with COVID-19 and underscores the importance of COVID-19 vaccination in pregnant patients to prevent hospitalization.

all hospitalizations with a positive real-time reverse transcription-polymerase chain reaction or rapid antigen detection test result for SARS-CoV-2 during hospitalization or within the 14 days preceding admission among patients residing in the COVID-NET catchment area.[8] Using previously described methods,[6] each month data were collected from a random sample of COVID-19 −associated hospitalizations, stratified by age and site. Some sites used modified procedures to identify and abstract information for all pregnant patients, including those not sampled by COVID-NET. Sampling weights were based on the probability of selection; sample sizes varied by surveillance month, site, and age group, and were based on the total number of patients identified in each of these strata.

Detailed demographic and clinical data on sampled patients were abstracted from patient medical records by trained surveillance officers using a standardized case report form. This activity was reviewed, considered exempt from institutional review board approval, and was conducted in accordance with applicable federal law and Centers for Disease Control and Prevention policy (45 C.F.R. part 46, 21 C.F.R. part 56; 42 U.S.C. Sect. 241(d); 5 U.S.C. Sect. 552a; 44 U.S.C. Sect. 3501 et seq.).

Inclusion and exclusion criteria

For the first objective, we included both sampled and nonsampled pregnant patients aged 15 to 49 years with complete medical chart abstraction who were admitted from January 1 to November 30, 2021. We included nonsampled pregnant patients from a specific site if full medical chart information was collected from all pregnant women in that site for that month. If a site did not collect all pregnancy information from nonsampled patients, their original sample weight was applied, and only sampled patients were included in analyses. The inclusion of nonsampled patients allowed COVID-NET to retain a representative sample while allowing for more precise estimates regarding pregnancy data.

We excluded individuals who did not have complete medical chart abstraction. We also excluded women who did not have COVID-19 symptoms recorded at admission to limit the scope of this analysis to women with at least mild disease; COVID-NET patients can include asymptomatic infections detected through routine laboratory testing of pregnant women at admission. Women were considered symptomatic for COVID-19 if their medical chart documented symptoms at admission (Table S1) or they developed clinical manifestations of COVID-19 during hospitalization as indicated by a discharge diagnosis of pneumonia, acute respiratory failure, or acute respiratory distress syndrome.

For the second objective, we included all symptomatic women aged 15 to 49 years who were hospitalized from January to November 2021. We then further restricted our sample to those who were eligible for treatment with remdesivir and systemic steroids per NIH criteria.[3] Being "treatment-eligible" was defined as having an oxygen saturation of <94% on admission or receiving supplemental oxygen on admission (nasal cannula, face mask, continuous positive airway pressure [CPAP] or bilevel positive airway pressure [BIPAP], high-flow nasal cannula, invasive mechanical ventilation, nonrebreather mask) or during the hospital stay (mechanical ventilation, extracorporeal membrane oxygenation, BIPAP/CPAP, or high-flow nasal cannula). Because COVID-NET does not collect data on nasal cannula or face mask use in the intensive care unit (ICU), we additionally classified 3 patients (2 pregnant, 1 nonpregnant) who were admitted to the ICU as treatment-eligible, even if higher-level oxygen support was not specifically noted.

Variable specification

Socio-demographic characteristics. COVID-NET collects data on age, race and Hispanic ethnicity group, and smoking status. All demographic data were primarily self-reported, and were obtained from multiple sources, including notifiable disease, laboratory, and hospital databases.[9] Race and ethnicity were based on National Center for Health Statistics bridged race categories.[10] We also included a category for people who identified as more than one or unknown race and ethnicity.

Underlying medical conditions and pregnancy characteristics. COVID-NET abstracted information on underlying medical conditions for all sampled patients (Table S2). Among pregnant patients, COVID-NET collected gestational age in weeks at the time of hospital admission based on the medical record, which was used to classify patients into first (<14 weeks), second (14−27 weeks), and third (≥28 weeks) trimester. Information on pregnancy-associated conditions and plurality

(singleton, multiple, or unknown) was also collected. Among women who were no longer pregnant at discharge, COVID-NET ascertained mode of delivery and the following birth outcomes: live birth, fetal loss, or unknown. A spontaneous abortion and stillbirth were defined as intrauterine death at <20 or ≥20 gestational weeks, respectively. Live-born infants were further classified as preterm (<37 weeks of gestation) or term (≥37 weeks).

Vaccination status. COVID-19 vaccination status (doses, dates administered, and product) was determined from state immunization information systems for all sampled COVID-NET patients. Fully vaccinated adults with a COVID-19 −associated hospitalization were persons who had received the second dose of a 2-dose COVID-19 vaccine series or a single dose of a 1-dose product ≥14 days before the specimen collection date of the positive SARS-CoV-2 test result associated with their hospitalization. Adults whose positive SARS-CoV-2 test date was ≥14 days after the first dose of a 2-dose series and <14 days after receipt of the second dose were considered partially vaccinated. If the SARS-CoV-2 test date was not available, hospital admission date was used. Adults without documented receipt of any COVID-19 vaccine dose before the test date were considered unvaccinated. One site did not collect vaccination information and was excluded from analysis including vaccination status. COVID-NET methods for determining vaccination status have been described previously.[11]

In-hospital clinical interventions and outcomes. Information on oxygen saturation and supplemental oxygen received at admission, highest level of respiratory support received during hospitalization, other clinical interventions (vasopressor, renal replacement therapy/dialysis), ICU admission, and in-hospital death was collected. Information on in-hospital COVID-19 treatment with remdesivir, systemic steroids, tocilizumab, casirivimab/imdevimab, convalescent plasma, and baricitinib was also collected. Treatment with remdesivir and systemic steroids among treatment-eligible women of reproductive age by pregnancy status was a primary outcome of this study.

Statistical analysis

Analyses were conducted using SAS statistical software (version 9.4; SAS Institute, Cary, NC). For the first objective, unweighted sample size (n), weighted percentages, and 95% confidence intervals (CIs) accounting for the age- and site-stratified sampling were used to describe demographic and clinical characteristics, interventions, and in-hospital clinical outcomes among all symptomatic pregnant patients hospitalized with COVID-19 in our sample. We compared characteristics between included symptomatic and excluded asymptomatic pregnant patients using bivariate log-linked Poisson generalized estimating equations that accounted for clustering by COVID-NET site and complex sample weights. Variances were estimated using the Taylor series linearization method.

For the second objective, to compare prevalence of treatment with remdesivir and systemic steroids between treatment-eligible pregnant and nonpregnant women, we conducted propensity score matching to balance pregnant and nonpregnant women on demographic and underlying medical conditions.[12,13] First, we calculated propensity scores for each patient using multivariable logistic regression to estimate the probability of pregnancy on the basis of baseline covariates, among all women regardless of pregnancy status. The model included the following covariates: age group, site, race and Hispanic ethnicity group, underlying medical conditions, and complex sampling weight. Second, to match pregnant and nonpregnant women, we used a SAS macro to do nearest-neighbor 1-to-1 matching without replacement in which the algorithm matches a pregnant woman to the nonpregnant woman with the closest propensity score.[14] To assess balance between pregnant and nonpregnant women before and after propensity score matching, we calculated standardized differences.[12] Finally, using the matched dataset, we estimated the prevalence ratio of COVID-19 treatment comparing treatment-eligible pregnant and nonpregnant women using log-linked binomial generalized estimating equations to account for clustering of hospitalizations within COVID-NET sites. In these models we adjusted for month and accounted for complex sample weights. To determine the robustness of our findings, we also conducted sensitivity analyses using two alternate methods (multivariable regression and inverse probability treatment weights[12]) to assess the association between pregnancy status and COVID-19 treatment (Table S5).

Results

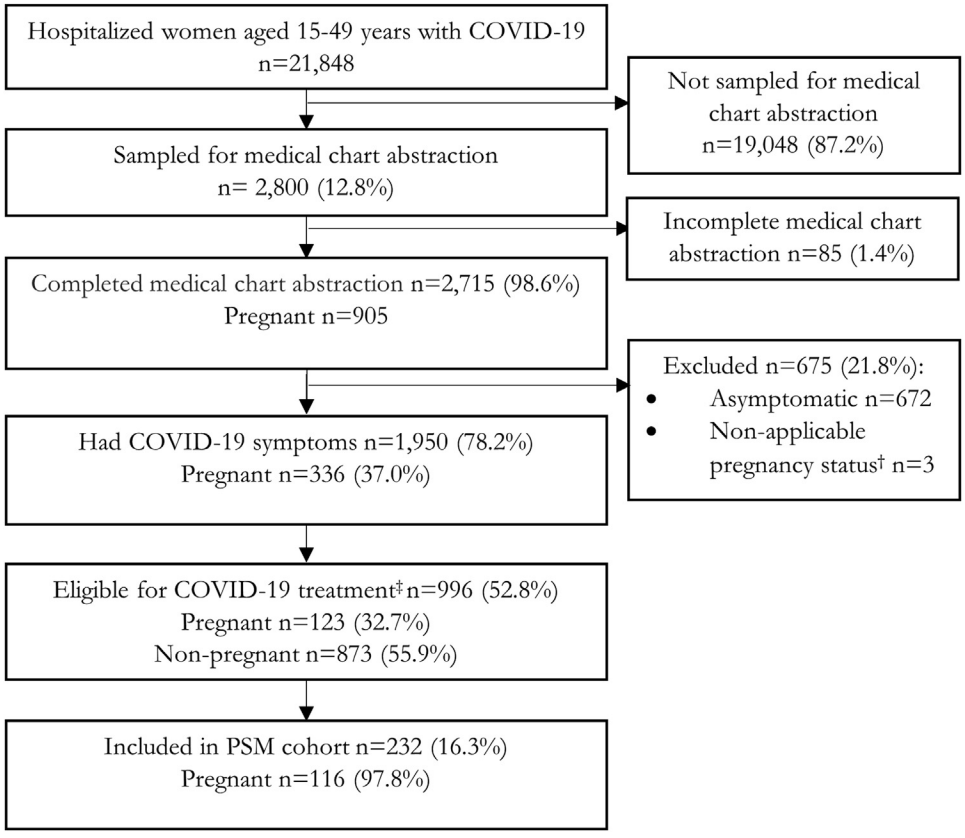
Characteristics of hospitalized symptomatic pregnant patients with COVID-19

Among 21,848 hospitalized women aged 15 to 49 years with COVID-19 identified from January to November 2021, medical chart abstraction was completed for 2715 of 2800 sampled patients, of which 905 were pregnant (Figure 1). Of these pregnant women, 336 (37.0%) had symptoms of COVID-19. Of the symptomatic women, 123 (32.7%) were treatment-eligible (Figure 1).

Pregnant women of American Indian/Alaska Native or Black non-Hispanic race with COVID-19 were more likely to be symptomatic compared with White non-Hispanic pregnant women with COVID-19 (Table S3). Women in the first and third trimester were more and less likely to be symptomatic, respectively, than those in the second trimester. Women with liver disease were more likely to be symptomatic compared with those without liver disease.

Of the 336 symptomatic pregnant women, the median age was 27.9 years (interquartile range, 23.0−33.0). The largest race or ethnicity group was non-Hispanic Black (39.6%) followed by Hispanic or Latino (24.8%) (Table 1). One-third (32.6%) had an underlying medical condition; asthma (12.5%) and hypertension (8.9%) were the most

FIGURE 1
Flow chart for hospitalized, symptomatic women



COVID-19-Associated Hospitalization Surveillance Network (COVID-NET), 14 states, January to November 2021. All percentages are weighted, except for the percent sampled and not sampled for medical chart abstraction. All percentages are percent included or excluded from previous denominator.

† Represents postpartum (n=2) or post-termination (n=1).

‡ Denotes being treatment-eligible was defined as an oxygen saturation of <94% on admission, receiving supplemental oxygen on or during the hospital stay. Because COVID-NET does not collect data on nasal cannula or face mask use in the ICU, we additionally classified 3 pregnant patients who were admitted to the ICU as treatment-eligible, even if they did not receive higher-level oxygen support.

ICU, intensive care unit; *PSM*, propensity score–matched.

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prevalent underlying conditions. Most (70.7%) were hospitalized during the third trimester. The most common pregnancy-associated conditions were hypertensive disorders of pregnancy (10.3%) and gestational diabetes mellitus (5.9%). The median hospital length of stay was 3 days (interquartile range, 2–5) overall and 4 days for patients in the ICU (interquartile range, 3–16) (data not shown).

Of the 336 symptomatic pregnant women, 333 (98.5%) had known COVID-19 vaccination status; 92.9% (n=322) were unvaccinated, 2.2% (n=2) were partially vaccinated, and 4.9% (n=9) were fully vaccinated (Table 1). Among the 9 fully vaccinated pregnant women, 3 had >1 underlying medical condition (including 1 immunocompromised). The patient with an immunocompromizing condition was the only fully vaccinated patient to require oxygen but did not receive remdesivir or systemic steroids. No fully vaccinated pregnant women were admitted to the ICU. Eight of the 9 fully vaccinated women gave birth during their hospitalization; 7 were term live births, 1 was a preterm live birth, and 1 pregnancy ended by induced abortion. In sensitivity analysis using data only from May to November 2021, when vaccinations were more widely available to pregnant women, 89.3% were unvaccinated.

Approximately half of the symptomatic pregnant women were no longer pregnant at discharge (n=180; 51.9%). Of these pregnancies, 88.2% ended in live births, 3.5% ended in stillbirth, and 5.4% ended in spontaneous abortion (Table 2). Of the 159 live births, 29.0% were preterm. There were no in-hospital maternal deaths. Of pregnant women, 12.6% were admitted to the

TABLE 1
Characteristics of hospitalized pregnant women with symptomatic COVID-19[a]

Variable	Unweighted n Overall n=336	Weighted %	(95% CI)
Age group (y)			
15-24	100	20.6	(14.9–27.4)
25-34	179	61.9	(53.0–70.2)
35-49	57	17.5	(11.6–24.9)
Race/ethnicity			
American Indian or Alaska Native, non-Hispanic	8	2.4	(0.6–6.3)
Asian or Pacific Islander, non-Hispanic	26	5.2	(2.8–8.7)
Black, non-Hispanic	90	39.6	(29.8–50.1)
Hispanic or Latino	87	24.8	(17.9–32.8)
White, non-Hispanic	102	22.3	(15.7–30.1)
None of the above[b]	23	5.6	(2.8–10.0)
Vaccine status[c]			
Unvaccinated	322	92.9	(83.2–98.0)
Partially vaccinated	2	2.2	(0.1–9.9)
Fully vaccinated	9	4.9	(0.9–14.0)
Underlying medical conditions[d]			
Any condition or conditions	123	32.6	(24.7–41.3)
Asthma	38	12.5	(7.6–19.2)
Hypertension	30	8.9	(4.5–15.4)
Chronic metabolic disease[e]	21	4.7	(1.8–9.7)
Cardiovascular disease[e]	15	3.0	(1.3–5.7)
Diabetes mellitus	10	2.6	(0.5–7.9)
Neurologic condition	13	2.5	(1.0–5.0)
Thyroid dysfunction	13	2.1	(0.7–4.9)
Other disease	10	1.8	(0.6–4.0)
Liver disease	7	0.9	(0.2–2.6)
Chronic lung disease[e]	2	0.1	(0.0–1.3)
Smoking			
Current smoker	19	7.7	(3.4–14.6)
Former smoker	43	8.9	(5.3–13.8)
Not a smoker/unknown smoking history	274	83.4	(76.1–89.2)
Pregnancy trimester at hospital admission			
First	30	10	(5.3–16.7)
Second	65	19.3	(12.6–27.7)
Third	241	70.7	(61.5–78.8)
Current pregnancy plurality			
Singleton pregnancy	309	90.7	(82.7–95.8)
Multiple pregnancy	7	1.1	(0.2–3.3)
Unknown	20	8.2	(3.3–16.4)

(continued)

ICU and 6.6% required invasive mechanical ventilation. Over one-third (38.2%) of all symptomatic pregnant women in the sample received systemic steroids (36.1%) or remdesivir (27.4%). Among those symptomatic pregnant women receiving systemic steroids, the most frequently administered was dexamethasone (90.1%). Among those who received dexamethasone and had a live birth (n=39), 55.0% had preterm births (data not shown).

Receipt of remdesivir or systemic steroids among treatment-eligible pregnant women hospitalized with COVID-19. Among the 123 pregnant women who were treatment-eligible, 22.2% did not receive either remdesivir or systemic steroids (Table 3). There was a higher number of women aged 35 to 49 years, those with underlying medical conditions, and those with non-Hispanic Black or other race who received treatment compared with women in the youngest age category, those without underlying medical conditions, and those of non-Hispanic White ethnicity, respectively (Table 3).

Differential receipt of remdesivir or systemic steroids among treatment-eligible women of reproductive age hospitalized with COVID-19 by pregnancy status. After propensity score matching, the distribution of characteristics between treatment-eligible pregnant and nonpregnant women, was better balanced, except in the 15-to-24-years age group, Black non-Hispanic, and liver disease categories (Table S4).

In the matched cohort, remdesivir was administered to 61.9% (95% CI, 47.5–75.0) and 80.6% (95% CI, 69.9–88.7) of pregnant and nonpregnant women, respectively. Systemic steroids were administered to 74.3% (95% CI, 61.3–84.8) of pregnant women (Table 4). The most frequently administered systemic steroid was dexamethasone (91.5%). Among nonpregnant women, 94.0% (95% CI, 88.0–97.6) received systemic steroids, of which dexamethasone was most commonly administered (97.7%). Results from

TABLE 1
Characteristics of hospitalized pregnant women with symptomatic COVID-19[a] *(continued)*

Variable	Unweighted n Overall n=336	Weighted %	(95% CI)
Pregnancy-associated conditions[d]			
Any condition or conditions	70	19.0	(12.1–27.7)
Hypertensive disorders of pregnancy	44	10.3	(6.2–15.9)
Unknown	22	6.8	(3.0–13.0)
Gestational diabetes mellitus	25	5.9	(3.2–9.6)
Intrauterine growth restriction	9	4.5	(0.5–15.4)

CI, confidence interval.

[a] Data are from the COVID-19-Associated Hospitalization Surveillance Network (COVID-NET), 14 states, January to November 2021; [b] None of the above included multiracial, non-Hispanic, or unknown categories. Individuals without ethnicity information were categorized as non-Hispanic[15]; [c] Vaccination status missing for 3 patients because one site did not collect that information; [d] Underlying medical conditions and pregnancy-associated conditions percentage columns do not add up to 100% because multiple options could be chosen per patient; [e] Chronic metabolic disease does not include diabetes mellitus or thyroid dysfunction; cardiovascular disease does not include hypertension; and chronic lung disease does not include asthma (Table S2).

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adjusted models showed that pregnant women had lower prevalence of treatment with remdesivir (prevalence ratio [PR], 0.82; 95% CI, 0.69–0.97) and systemic steroids (PR, 0.80; 95% CI, 0.73–0.87) compared with nonpregnant women (Table 4). All sensitivity analyses with various methods for adjustment had prevalence ratios of similar direction and magnitude, although the precision varied (Table S5).

Comment

Principal findings

In this investigation of hospitalized, symptomatic pregnant women with COVID-19, we identified adverse outcomes including ICU admission, stillbirths, and spontaneous abortions. Nearly all (>90%) were unvaccinated. In addition, approximately 1 in 5 treatment-eligible pregnant patients did not receive remdesivir or systemic steroids.[3] Among our propensity score–matched cohort of treatment-eligible women, pregnant women were 18% less likely to receive remdesivir and 21% less likely to receive systemic steroids than nonpregnant women.

Results

Although clinical presentation, in-hospital disease outcomes, and severity among hospitalized pregnant patients are well documented,[1,16,17] most previous studies have not described vaccination status or treatment in hospitalized pregnant patients. The vast majority (>90%) of symptomatic pregnant women who were hospitalized for COVID-19 in 2021 in this network were unvaccinated, and those with breakthrough infections (n=9) experienced milder disease. No fully vaccinated pregnant women were admitted to the ICU. This is consistent with multiple studies that have shown that COVID-19 vaccines are highly effective in preventing hospitalization in pregnant women.[18–21] In addition,

TABLE 2
Symptoms, interventions, and outcomes of hospitalized pregnant women with symptomatic COVID-19[a]

Variable	Unweighted n Overall n=336	Weighted %	(95% CI)
Symptoms on admission			
Cough	179	59.9	(50.7–68.6)
Shortness of breath	147	49.3	(39.8–59.0)
Fever	123	36.2	(27.4–45.9)
Congestion/rhinorrhea	58	18.5	(12.2–26.2)
Loss of taste/smell	56	16.9	(10.4–25.3)
Abdominal pain	70	15.8	(10.6–22.3)
Sore throat	34	8.8	(5.3–13.7)
New clinical discharge diagnosis			
Acute respiratory distress syndrome	11	2.3	(0.9–4.7)
Acute respiratory failure	61	19.8	(12.5–28.9)
Pneumonia	89	31.8	(22.7–42.1)
Sepsis	11	2.0	(0.7–4.5)

(continued)

TABLE 2
Symptoms, interventions, and outcomes of hospitalized pregnant women with symptomatic COVID-19[a] *(continued)*

Variable	Unweighted n Overall n=336	Weighted %	(95% CI)
Interventions			
High-flow nasal cannula[b]	24	7.5	(4.0–12.8)
BIPAP/CPAP[b]	7	1.4	(0.4–3.6)
Invasive mechanical ventilation[b, c]	22	6.6	(3.2–11.8)
Vasopressor	34	11.1	(5.0–20.5)
Renal replacement therapy or dialysis	1	0.3	(0.0–1.8)
COVID-19 treatments			
Remdesivir	94	27.4	(19.7–36.2)
Systemic steroids	137	36.1	(27.6–45.2)
Dexamethasone	120	91.0	(81.2–96.7)
Hydrocortisone	4	6.2	(1.3–16.9)
Methylprednisolone	14	7.1	(3.0–13.8)
Prednisolone	1	0.4	(0.0–3.5)
Prednisone	3	1.3	(0.1–5.0)
Betamethasone	4	0.9	(0.0–4.2)
Tocilizumab	12	4.0	(1.5–8.6)
Casirivimab/imdevimab	7	1.3	(0.4–3.3)
Convalescent plasma	2	1.3	(0.1–5.7)
Baricitinib	2	0.5	(0.1–2.0)
Severe outcomes			
ICU admission	44	12.6	(7.8–19.0)
In-hospital maternal death	0	0	
Pregnancy status at discharge[d]			
Still pregnant	155	48.1	(38.5–57.8)
No longer pregnant	180	51.9	(42.2–61.5)
Live birth	159	88.2	(89.1–94.3)
Term	114	69.4	(53.9–82.3)
Preterm (<37 wk of gestation)	36	29.0	(16.2–44.8)
Unknown	9	1.6	(0.3–5.0)
Induced abortion	1	0.3	(0.0–2.6)
Stillbirth	11	3.5	(1.3–7.3)
Spontaneous abortion	5	5.4	(1.1–15.2)
Unknown	4	2.6	(0.5–7.6)
Mode of delivery[e]			
Vaginal	105	56.5	(43.4–68.9)
Cesarean delivery	68	36.8	(25.2–49.5)
Unknown	7	6.8	(1.8–16.5)

BIPAP/CPAP, bilevel positive airway pressure/continuous positive airway pressure; *CI*, confidence interval; *ICU*, intensive care unit.

[a] Data are from the COVID-19-Associated Hospitalization Surveillance Network (COVID-NET), 14 states, January to November 2021; [b] Mutually exclusive of other oxygen support categories. The highest level of oxygen support was chosen for each patient (invasive mechanical ventilation>BiPAP/CPAP>high-flow nasal cannula); [c] Five (0.9%, 95% CI, 0.2–2.6) patients that received mechanical ventilation also received extracorporeal membrane oxygenation; [d] One missing pregnancy status at discharge; [e] Among the 180 that gave birth.

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TABLE 3
Characteristics of treatment-eligible hospitalized pregnant women with COVID-19 by receipt of treatment[a]

	Overall (n=123, 32.7%)		Received treatment[b] (n=87, 77.8%)		No treatment (n=36, 22.2%)	
Variable	n	Weighted %	n	Weighted %	n	Weighted %
Age group (y)						
15-24	28	17.4	14	11.2	14	39.2
25-34	71	64.3	53	68.3	18	50.4
35-49	24	18.2	20	20.5	4	10.4
Race/ethnicity						
Black, non-Hispanic	25	26.0	19	27.8	6	19.8
Hispanic	24	23.0	16	21.7	8	27.6
White, non-Hispanic	44	26.1	25	20.7	19	44.8
None of the above[c]	30	24.9	27	29.7	3	7.8
Underlying medical conditions						
Yes	50	29.5	38	32.2	12	19.8
No	73	70.5	49	67.8	24	80.2

[a] Data are from the COVID-19-Associated Hospitalization Surveillance Network (COVID-NET), 14 states, January to November 2021; [b] Treatment included receipt of remdesivir (n=63, 61.4%) or systemic steroids (n=83, 74.1%); [c] None of the above categories included American Indian/Alaska Native, non-Hispanic; Asian/Pacific Islander, non-Hispanic; multiracial, non-Hispanic; and unknown racial categories. Individuals without ethnicity information were categorized as non-Hispanic.[15] These categories were collapsed in models because of small cell sizes.

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vaccination is not associated with pregnancy loss, preterm birth, or small-for-gestational-age infants.[22] Furthermore, maternal COVID-19 vaccination has been associated with a reduced risk of COVID-19 hospitalization among infants aged <6 months.[23,24] Low coverage of vaccination in pregnant women (11.1%) compared with nonpregnant women (24.9%) has been shown in nonhospitalized women; vaccination completion was even lower in our sample of hospitalized pregnant patients.[25] Although vaccination coverage in pregnant women is increasing, it remains low, with an estimated 67.8% of pregnant women fully vaccinated as of February 5, 2022.[26] Low vaccination coverage in pregnant women could be owing to a variety of factors, including theoretical concerns about

TABLE 4
COVID-19 treatment among propensity-matched[a] symptomatic and treatment-eligible women[b]

Outcome	Prevalence				Multivariable model[c]		
	Pregnant (n=116, 50%)		Nonpregnant (n=116, 50%)				
	n	Weighted % (95% CI)	n	Weighted % (95% CI)	PR	95% CI	*P* value
Remdesivir							
No	56	38.1 (25.0–52.5)	33	19.4 (11.3–30.1)	ref		
Yes	60	61.9 (47.5–75.0)	83	80.6 (69.9–88.7)	0.82	(0.69–0.97)	.024
Systemic steroids							
No	37	25.7 (15.2–38.7)	17	6.0 (2.4–12.0)	ref		
Yes	79	74.3 (61.3–84.8)	99	94.0 (88.0–97.6)	0.80	(0.73–0.87)	<.001

CI, confidence interval; *PR*, prevalence ratio; *ref*, reference group.

[a] Propensity score models to create propensity score adjusted for age group, race and ethnic group, site, asthma, chronic lung disease not including asthma, cardiovascular disease, diabetes mellitus, thyroid dysfunction, hypertension, liver disease, and neurologic disease, and complex sample weights. To match pregnant and nonpregnant women, we used nearest-neighbor 1-to-1 matching without replacement; [b] Data are from the COVID-19-Associated Hospitalization Surveillance Network (COVID-NET), 14 states, January to November 2021; [c] Generalized estimating equation model to estimate PR comparing pregnant with nonpregnant women, adjusted for month, and accounting for clustering by site and complex sample weights.

Sekkarie. Hospitalized pregnant women with COVID-19. Am J Obstet Gynecol MFM 2022.

safety stemming from the lack of inclusion in clinical trials and potential for greater vaccine hesistancy among healthcare providers and pregnant women.

This study was conducted after the effectiveness and safety of treatments for COVID-19 were established.[27] Previous studies have shown remdesivir to be effective in preventing severe disease in pregnant patients.[28,29] However, very little is known about treatment patterns in hospitalized pregnant women. We found that not all treatment-eligible women received remdesivir or systemic steroids and that there is evidence of differential use of these treatments in pregnant and nonpregnant women. The reasons for differential treatment practices by pregnancy status are unknown but may be related to severity of disease, lack of availability of treatment protocols during pregnancy, lack of familiarity of providers with initiation of treatment during pregnancy, potential concerns about fetal safety by providers or patients leading them to decline recommended therapy, or perceived risks owing to pregnant women generally being excluded from clinical trials of new treatment protocols.

Clinical implications

There is a need for patient and clinical education and targeted communication about and improved processes for the vaccination and treatment of pregnant women.

Research implications

Additional qualitative or quantitative research exploring factors that influence healthcare systems, provider practice patterns, and hospital protocols specific to the treatment of hospitalized pregnant women with COVID-19 would be informative. Additional studies focused on the safety and efficacy of COVID-19 treatment during pregnancy and the potential maternal and infant benefits would be critically important. In the future, the voluntary inclusion of pregnant patients in clinical studies of new treatment protocols could prevent disparities in access to recommended care for pregnant patients.[30]

Strengths and limitations

Our observational study required robust methods to limit biases given that pregnant women hospitalized with COVID-19 are systematically different from nonpregnant women. To minimize confounding, we limited our sample to symptomatic women that required supplemental oxygen and for whom treatment was thus recommended. We also used propensity score matching to balance comparison groups. Despite these methods, there may have been residual confounding. Reassuringly, sensitivity analysis with a variety of regression and propensity score methods to adjust for confounding yielded similar results. A second limitation is that COVID-19 cases might have been missed because of testing practices and test availability. Third, information on obesity as an underlying prepregnancy condition was not available, thus this underlying health condition could not be described. Fourth, information was abstracted from medical charts and might not have been complete. For example, only one oxygen saturation value and corresponding support were provided per hospitalization outside of ICU stays. Information on previous pregnancies was not available. Fifth, we could not establish the indications for the use of systemic steroids that are also used to promote fetal lung maturity in the management of preterm labor; thus, the actual use rates of systemic steroids for COVID-19 treatment may have been even lower. Finally, any maternal deaths after discharge were not captured.

Conclusions

Despite current recommendations, most symptomatic pregnant women hospitalized with COVID-19 were unvaccinated, and one-fifth of treatment-eligible hospitalized pregnant patients did not receive recommended treatment, underscoring the need for increased targeted communication about and improved processes for the vaccination and treatment of pregnant women.

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The COVID-NET Surveillance Team group authorship includes the following authors: Pam Daily Kirley, MPH, California Emerging Infections Program, Oakland, CA; Nisha B. Alden, MPH, Colorado Department of Public Health Environment, Denver, CO; Kimberly Yousey-Hindes, MPH, Connecticut Emerging Infections Program, Yale School of Public Health, New Haven, CT; Emily Fawcett, MPH, Division of Infectious Diseases, Emory University School of Medicine, Atlanta, GA, Georgia Emerging Infections Program, Georgia Department of Public Health, Atlanta, GA, and Foundation for Atlanta Veterans Education and Research, Atlanta Veterans Affairs Medical Center, Decatur, GA; Kenzie Teno, MPH, Iowa Department of Public Health, Des Moines, IA; Chloe Brown, MPH, Michigan Department of Health and Human Services, Lansing, MI; Erica Bye, MPH, Minnesota Department of Health, Saint Paul, MN; Yadira Salazar-Sánchez, MPH, New Mexico Emerging Infections Program, University of New Mexico Health Sciences Center, Albuquerque, NM; Nancy Spina, MPH, New York State Department of Health, Albany, NY; Christina B. Felson, MS, University of Rochester School of Medicine and Dentistry, Rochester, NY; Eli Shiltz, MPH, Ohio Department of Health, Columbus, OH; Nasreen Abdullah, MD, MPH, Public Health Division, Oregon Health Authority, Portland, OR; William Schaffner, MD, Vanderbilt University Medical Center, Nashville, TN; Andrea George, MPH, Salt Lake County Health Department, Salt Lake City, UT.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajogmf.2022.100715.

References

1. Allotey J, Stallings E, Bonet M, et al. Clinical manifestations, risk factors, and maternal and perinatal outcomes of coronavirus disease 2019 in pregnancy: living systematic review and meta-analysis. BMJ 2020;370:m3320.

2. DeSisto CL, Wallace B, Simeone RM, et al. Risk for stillbirth among women with and without COVID-19 at delivery hospitalization - United States, March 2020-September 2021. MMWR Morb Mortal Wkly Rep 2021;70:1640–5.

3. National Institutes of Health. Therapeutic management of hospitalized adults with COVID-19. 2022. Available at: https://www.covid19treatmentguidelines.nih.gov/management/clinical-management/hospitalized-adults–therapeutic-management/. Accessed February 16, 2022.

4. United States Food & Drug Administration. Coronavirus (COVID-19) update: FDA issues emergency use authorization for potential COVID-19 treatment. 2020. Available at: https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-issues-emergency-use-authorization-potential-covid-19-treatment. Accessed March 8, 2022.

5. Society for Maternal-Fetal Medicine. COVID-19 task force. 2021. Available at: https://www.smfm.org/covidclinical. Accessed February 16, 2022.

6. Garg S, Kim L, Whitaker M, et al. Hospitalization rates and characteristics of patients hospitalized with laboratory-confirmed coronavirus disease 2019 - COVID-NET, 14 states, March 1-30, 2020. MMWR Morb Mortal Wkly Rep 2020;69:458–64.

7. Kim L, Garg S, O'Halloran A, et al. Risk factors for Intensive Care Unit admission and in-hospital mortality among hospitalized adults identified through the US coronavirus disease 2019 (COVID-19)-associated hospitalization surveillance network (COVID-NET). Clin Infect Dis 2021;72:e206–14.

8. Centers for Disease Control and Prevention. Coronavirus disease. 2019 (COVID-19)-Associated Hospitalization Surveillance Network (COVID-NET) purpose and methods. 2022. Available at: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covid-net/purpose-methods.html. Accessed February 16, 2022.

9. Acosta AM, Garg S, Pham H, et al. Racial and ethnic disparities in rates of COVID-19-associated hospitalization, intensive care unit admission, and in-hospital death in the United States From March 2020 to February 2021. JAMA Netw Open 2021;4:e2130479.

10. Ingram DD, Parker JD, Schenker N, et al. United States Census 2000 population with bridged race categories. Vital Health Stat 2003;2:1–55.

11. Havers FP, Pham H, Taylor CA, et al. COVID-19-associated hospitalizations among vaccinated and unvaccinated adults ≥18 years – COVID-NET, 13 states, January 1 – July 24, 2021. medRxiv 2021.

12. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate Behav Res 2011;46:399–424.

13. Karabon P. Applying propensity score methods to complex survey data using. 2019. Available at: https://www.sas.com/content/dam/SAS/support/en/sas-global-forum-proceedings/2019/3634-2019.pdf. Accessed February 16, 2022.

14. Parsons L. Reducing bias in a propensity score matched-pair sample using greedy matching techniques. Cary, NC: SAS Institute Inc; 2001.

15. Yoon P, Hall J, Fuld J, et al. Alternative methods for grouping race and ethnicity to monitor COVID-19 outcomes and vaccination coverage. MMWR Morb Mortal Wkly Rep 2021;70:1075–80.

16. Savasi VM, Parisi F, Patanè L, et al. Clinical findings and disease severity in hospitalized pregnant women with coronavirus disease 2019 (COVID-19). Obstet Gynecol 2020;136:252–8.

17. Pierce-Williams RAM, Burd J, Felder L, et al. Clinical course of severe and critical coronavirus disease 2019 in hospitalized pregnancies: a United States cohort study. Am J Obstet Gynecol MFM 2020;2:100134.

18. Shimabukuro TT, Kim SY, Myers TR, et al. Preliminary findings of mRNA Covid-19 vaccine safety in pregnant persons. N Engl J Med 2021;384:2273–82.
19. Zauche LH, Wallace B, Smoots AN, et al. Receipt of mRNA Covid-19 vaccines and risk of spontaneous abortion. N Engl J Med 2021;385:1533–5.
20. Dagan N, Barda N, Biron-Shental T, et al. Effectiveness of the BNT162b2 mRNA COVID-19 vaccine in pregnancy. Nat Med 2021; 27:1693–5.
21. Morgan JA, Biggio JR, Jr Martin JK, et al. Maternal outcomes after severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in vaccinated compared with unvaccinated pregnant patients. Obstet Gynecol 2022;139:107–9.
22. Lipkind HS, Vazquez-Benitez G, DeSilva M, et al. Receipt of COVID-19 vaccine during pregnancy and preterm or small-for-gestational-age at birth - eight integrated health care organizations, United States, December 15, 2020-July 22, 2021. MMWR Morb Mortal Wkly Rep 2022;71:26–30.
23. Halasa NB, Olson SM, Staat MA, et al. Effectiveness of maternal vaccination with mRNA COVID-19 vaccine during pregnancy against COVID-19-associated hospitalization in infants aged <6 months - 17 states, July 2021-January 2022. MMWR Morb Mortal Wkly Rep 2022;71:264–70.
24. Halasa NB, Olson SM, Staat MA, et al. Maternal vaccination and risk of hospitalization for COVID-19 among infants. N Engl J Med 2022;387:109–19.
25. Razzaghi H, Meghani M, Pingali C, et al. COVID-19 vaccination coverage among pregnant women during pregnancy - eight integrated health care organizations, United States, December 14, 2020-May 8, 2021. MMWR Morb Mortal Wkly Rep 2021;70:895–9.
26. Centers for Disease Control and Prevention. COVID-19 vaccination among pregnant people aged 18-49 years overall, by race/ethnicity, and date reported to CDC - Vaccine Safety Datalink,* United States. 2022. Available at: https://covid.cdc.gov/covid-data-tracker/#vaccinations-pregnant-women. Accessed February 16, 2022.
27. RECOVERY Collaborative GroupHorby P, Lim WS, et al. Dexamethasone in hospitalized patients with Covid-19. N Engl J Med 2021;384:693–704.
28. Eid J, Abdelwahab M, Colburn N, et al. Early administration of remdesivir and intensive care unit admission in hospitalized pregnant individuals with coronavirus disease 2019 (COVID-19). Obstet Gynecol 2022;139:619–21.
29. Burwick RM, Yawetz S, Stephenson KE, et al. Compassionate use of remdesivir in pregnant women with severe coronavirus disease 2019. Clin Infect Dis 2021;73: e3996–4004.
30. Taylor MM, Kobeissi L, Kim C, et al. Inclusion of pregnant women in COVID-19 treatment trials: a review and global call to action. Lancet Glob Health 2021;9:e366–71.

Author and article information

From the COVID-19 Response Team, Centers for Disease Control and Prevention, Atlanta, GA (Drs Sekkarie and Woodruff, Mr Whitaker, Drs Zapata, Ellington, and Meaney-Delman, Ms Pham, Mr Kadam, and Drs Taylor and Havers); Epidemic Intelligence Service, Centers for Disease Control and Prevention, Atlanta, GA (Dr Sekkarie); United States Public Health Service Commissioned Corps, Rockville, MD (Drs Woodruff, Zapata, and Havers); Epidemiology Department, Rollins School of Public Health, Emory University, Atlanta, GA (Dr Kramer); General Dynamics Information Technology, Atlanta, GA (Mr Patel); California Emerging Infections Program, Oakland, CA (Dr Chai); Career Epidemiology Field Officer Program, Centers for Disease Control and Prevention, Atlanta, GA (Dr Chai); Colorado Department of Public Health and Environment, Denver, CO (Ms Kawasaki); Connecticut Emerging Infections Program, Yale School of Public Health, New Haven, CT (Mr Meek); Division of Infectious Diseases, Emory University School of Medicine, Atlanta, GA (Dr Openo); Georgia Emerging Infections Program, Georgia Department of Public Health, Atlanta, GA (Dr Openo); Foundation for Atlanta Veterans Education and Research, Atlanta Veterans Affairs Medical Center, Atlanta, GA (Dr Openo); Iowa Department of Public Health, Des Moines, IA (Mr Weigel); Michigan Department of Health and Human Services, Lansing, MI (Ms Leegwater); Minnesota Department of Health, Saint Paul, MN (Ms Como-Sabetti); New Mexico Department of Health, Santa Fe, NM (Dr Ropp); New York State Department of Health, Albany, NY (Ms Muse); University of Rochester School of Medicine and Dentistry, Rochester, NY (Dr Bennett); Ohio Department of Health, Columbus, OH (Ms Billing); Public Health Division, Oregon Health Authority, Portland, OR (Dr Sutton); Vanderbilt University School of Medicine, Nashville, TN (Dr Talbot); Salt Lake County Health Department, Salt Lake City, UT (Ms Hill).

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Corresponding author: Ahlia Sekkarie, PhD, MPH xby7@cdc.gov