JAMA Pediatrics | Original Investigation

Outcomes of Neonates Born to Mothers With Severe Acute Respiratory Syndrome Coronavirus 2 Infection at a Large Medical Center in New York City

Dani Dumitriu, MD, PhD; Ukachi N. Emeruwa, MD, MPH; Erin Hanft, MD; Grace V. Liao, MD; Elizabeth Ludwig, MD; Lauren Walzer, DO; Brittany Arditi, MD, MSCR; Minna Saslaw, MD; Maria Andrikopoulou, MD, PhD; Tessa Scripps, MD; Caitlin Baptiste, MD; Adrita Khan, MD; Noelle Breslin, MD; David Rubenstein, MD; Lynn L. Simpson, MD; Margaret H. Kyle, BA; Alexander M. Friedman, MD, MPH; Daniel S. Hirsch, MD; Russell S. Miller, MD; Cristina R. Fernández, MD, MPH; Karin M. Fuchs, MD, MHA; M. Kathleen Keown, MD; Melissa E. Glassman, MD, MPH, IBCLC; Ashley Stephens, MD; Archana Gupta, MD; Sally Sultan, MD; Caroline Sibblies, MD; Susan Whittier, PhD; Wanda Abreu, MD, IBCLC; Francis Akita, MD; Anna Penn, MD, PhD; Mary E. D'Alton, MD; Jordan S. Orange, MD, PhD; Dena Goffman, MD; Lisa Saiman, MD, MPH; Melissa S. Stockwell, MD, MPH; Cynthia Gyamfi-Bannerman, MD, MSc

IMPORTANCE Limited data on vertical and perinatal transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and health outcomes of neonates born to mothers with symptomatic or asymptomatic coronavirus disease 2019 (COVID-19) are available. Studies are needed to inform evidence-based infection prevention and control (IP&C) policies.

OBJECTIVE To describe the outcomes of neonates born to mothers with perinatal SARS-CoV-2 infection and the IP&C practices associated with these outcomes.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort analysis reviewed the medical records for maternal and newborn data for all 101 neonates born to 100 mothers positive for or with suspected SARS-CoV-2 infection from March 13 to April 24, 2020. Testing for SARS-CoV-2 was performed using Cobas (Roche Diagnostics) or Xpert Xpress (Cepheid) assays. Newborns were admitted to well-baby nurseries (WBNs) (82 infants) and neonatal intensive care units (NICUs) (19 infants) in 2 affiliate hospitals at a large academic medical center in New York, New York. Newborns from the WBNs roomed-in with their mothers, who were required to wear masks. Direct breastfeeding after appropriate hygiene was encouraged.

EXPOSURES Perinatal exposure to maternal asymptomatic/mild vs severe/critical COVID-19.

MAIN OUTCOMES AND MEASURES The primary outcome was newborn SARS-CoV-2 testing results. Maternal COVID-19 status was classified as asymptomatic/mildly symptomatic vs severe/critical. Newborn characteristics and clinical courses were compared across maternal COVID-19 severity.

RESULTS In total, 141 tests were obtained from 101 newborns (54 girls [53.5%]) on 0 to 25 days of life (DOL-0 to DOL-25) (median, DOL-1; interquartile range [IQR], DOL-1 to DOL-3). Two newborns had indeterminate test results, indicative of low viral load (2.0%; 95% CI, 0.2%-7.0%); 1 newborn never underwent retesting but remained well on follow-up, and the other had negative results on retesting. Maternal severe/critical COVID-19 was associated with newborns born approximately 1 week earlier (median gestational age, 37.9 [IQR, 37.1-38.4] vs 39.1 [IQR, 38.3-40.2] weeks; $P = .02$) and at increased risk of requiring phototherapy (3 of 10 [30.0%] vs 6 of 91 [7.0%]; $P = .04$) compared with newborns of mothers with asymptomatic/mild COVID-19. Fifty-five newborns were followed up in a new COVID-19 Newborn Follow-up Clinic at DOL-3 to DOL-10 and remained well. Twenty of these newborns plus 3 newborns followed up elsewhere had 32 nonroutine encounters documented at DOL-3 to DOL-25, and none had evidence of SARS-CoV-2 infection, including 6 with negative retesting results.

CONCLUSIONS AND RELEVANCE No clinical evidence of vertical transmission was identified in 101 newborns of mothers positive for or with suspected SARS-CoV-2 infection, despite most newborns rooming-in and direct breastfeeding practices.

JAMA Pediatr. doi:10.1001/jamapediatrics.2020.4298
Published online October 12, 2020.

Editorial
Supplemental content

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Authors: Cynthia Gyamfi-Bannerman, MD, MSc, Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, 622 W 168th St, PH 16-66, New York, NY 10032 (cg2231@cumc.columbia.edu); Melissa S. Stockwell, MD, MPH, Division of Child and Adolescent Health, Department of Pediatrics, Columbia University Irving Medical Center, 622 W 168th St, VC 417, New York, NY 10032 (mss2112@cumc.columbia.edu).

New York, New York, has been an epicenter of the coronavirus disease 2019 (COVID-19) pandemic, with 9401 deaths as of April 27, 2020.[1] Although much has been written about the course of COVID-19 in adults, fewer data are available for pregnant women and their newborns. For other viral infections, pregnancy confers increased risk of morbidity, with a well-described risk of vertical transmission and adverse outcomes in newborns.[2-5] However, studies evaluating the potential for vertical and/or postnatal transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are few in number, have small sample sizes, and come primarily from China, from which results might not generalize to all populations. Although some studies[6-10] have shown no evidence of vertical transmission, a few others occasionally describe newborns with SARS-CoV-2 detected by polymerase chain reaction assay from upper respiratory tract swabs and mild respiratory disease[11-13] or self-resolving pneumonia.[14,15] In the first series outside of China, Breslin et al[16] evaluated an initial 2 weeks of confirmed SARS-CoV-2 infection in pregnant women with similarly reassuring findings, suggesting no evidence for vertical transmission immediately post partum. Given continued worldwide spread of SARS-CoV-2, rapid dissemination of the experiences of large medical centers with pregnant women positive for SARS-CoV-2 and their newborns is imperative.

Multiple organizations have released interim guidance for the management of pregnant women with SARS-CoV-2 infection and their newborns.[17-21] Recommended practices have included mother-newborn separation, no direct breastfeeding, and early bathing of newborns. These conservative recommendations were undertaken in the context of the absence of data on rates of vertical and perinatal transmission. Furthermore, recommendations sometimes conflict with each other. Studies to date have not described implementation of infection prevention and control (IP&C) measures and their effects on transmission.

We herein present our experience with mothers who tested positive for SARS-CoV-2 and their newborns in a medical center located in New York City during the first 6 weeks of the COVID-19 pandemic. The objectives of this study are to (1) describe the rate of vertical transmission among newborns born to mothers with perinatal SARS-CoV-2 infection, (2) detail institutional IP&C practices associated with these outcomes, and (3) report the clinical characteristics and clinical courses of neonates in the immediate postpartum period.

Key Points

Question What is the risk of mother-to-newborn transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)?

Findings In this cohort analysis of the first 101 neonates born to mothers with perinatal SARS-CoV-2 infections at a single institution, 2 (2.0%) had positive test results for SARS-CoV-2, but none had clinical evidence of coronavirus disease 2019 (COVID-19), despite most infants rooming-in with mothers and direct breastfeeding. Fifty-five infants were followed up in the first 2 weeks of life in a new COVID-19 Newborn Follow-up Clinic, all of whom remained healthy.

Meaning These findings suggest that during the COVID-19 pandemic, separation of affected mothers and newborns may not be warranted, and direct breastfeeding appears to be safe.

Methods

Study Design, Study Sites, and Study Population

We conducted a retrospective cohort analysis of all newborns born to mothers positive for or with suspected SARS-CoV-2 infection at the NewYork-Presbyterian Morgan Stanley Children's Hospital or NewYork-Presbyterian Allen Hospital from March 13 (first diagnosed maternal COVID-19 case at Morgan Stanley Children's Hospital) to April 24, 2020. These hospitals are both located in northern Manhattan and affiliated with Columbia University Irving Medical Center. This study was approved by the institutional review board of Columbia University Irving Medical Center with a waiver of informed consent because the study was retrospective. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

From March 13 to March 21, only women who were symptomatic on presentation and those with unexplained peripartum respiratory findings were tested for SARS-CoV-2. Universal SARS-CoV-2 testing of women admitted to labor and delivery was implemented on March 22. A publication of the pooled New York City experience reported outcomes of 67 women and their 68 infants from our center.[22] Of those 67 mothers, data were previously published on 43 with only 18 infants described because most of the women in that series did not deliver.[16]

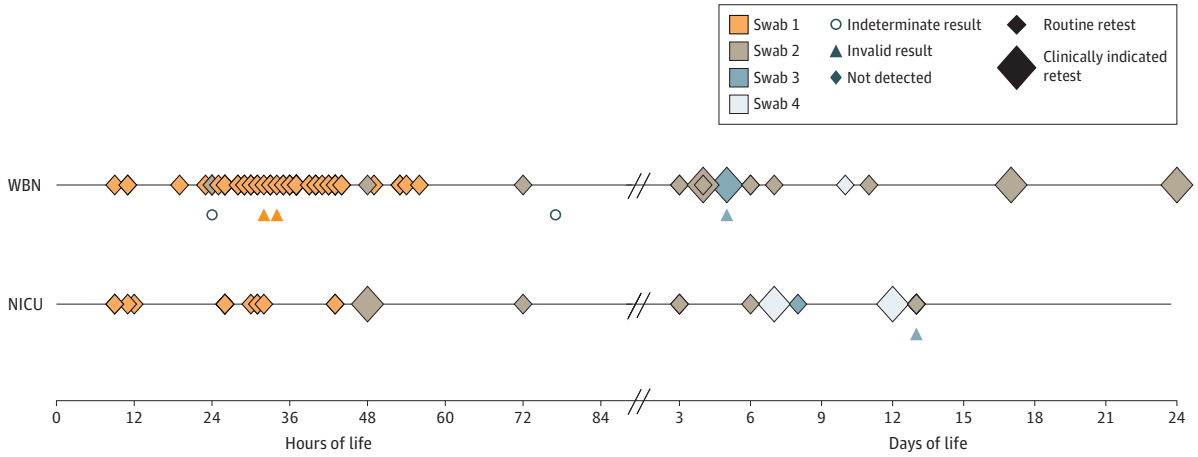
Maternal Testing for SARS-CoV-2

Nasopharyngeal swab specimens were tested for SARS-CoV-2 at the Clinical Microbiology Laboratory at Columbia University Irving Medical Center. The Cobas SARS-CoV-2 polymerase chain reaction assay (Roche Diagnostics) was initially used exclusively and continues to be used in preadmission testing. On April 10, the Xpert Xpress SARS-CoV-2 polymerase chain reaction assay (Cepheid) replaced testing in the labor and delivery unit, owing to its more rapid turnaround time. Both assays received emergency use authorization from the US Food and Drug Administration. Testing occurred either on admission to the labor and delivery unit, at a preadmission testing clinic the day before scheduled deliveries, or on presentation for evaluation of COVID-19 symptoms.

Newborn COVID-19 Testing

A minimum of 1 nasopharyngeal swab specimen was obtained from each newborn and tested for SARS-CoV-2 using the Cobas or Xpert Xpress tests described above (**Figure**). Newborn swabbing was standardized to ensure adequate sampling.[23-26] Number of times and exact age at which newborns were tested changed during the study period owing to evolving insights about transmission and availability of test collection kits. Additional testing of newborns was performed for changes in clinical status. Newborns with invalid test results

Figure. Newborn Testing for Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)



A total of 141 SARS-CoV-2 nasopharyngeal swabs were obtained and tested from 101 newborns born to mothers with positive or presumptive positive findings for SARS-CoV-2. Owing to evolving recommendations, clinical indications, and availability of swabs, newborns were tested 1 to 4 times each. A total of 135 tests (95.7%) resulted as not detected. Initial test results in 2 infants were indeterminate, considered a low viral load by the assay manufacturer. Initial test results in 4 infants were invalid and negative on repeated testing. NICU indicates neonatal intensive care unit; WBN, well-baby nursery.

underwent retesting.[16] Newborns with indeterminate results, reflecting low viral load per the assay manufacturer, were presumed to have positive findings and variably underwent retesting.

Obstetric and Newborn Care

The IP&C practices to minimize patient-to-staff and mother-to-child transmission are described in **Table 1**. With the exception of implementation of appropriate transmission precautions and use of personal protective equipment, obstetric care remained per usual standard. Unless otherwise contraindicated, practices continued to include delayed cord clamping, vaginal delivery (including in severe COVID-19 illness), mother-infant skin-to-skin contact, and direct breastfeeding after appropriate hand and breast hygiene (consisting of washing hands and breast with soap and water). However, all mothers, including those with COVID-19, were discharged a mean of 1 day earlier if determined to be medically and socially appropriate (ie, postpartum day 1 after vaginal deliveries and postoperative day 2 after cesarean deliveries). All mothers received a follow-up telephone call within 48 to 72 hours of discharge.

The newborns of mothers who were positive for SARS-CoV-2 were admitted to the well-baby nursery (WBN) (n = 82) unless they required neonatal intensive care unit (NICU) admission (n = 19) for standard indications. Aside from 6 mothers requiring ICU-level care, 76 mothers roomed-in with their newborns on the postpartum unit/WBN in private rooms placed on contact and droplet precautions. Newborns were in isolettes approximately 180 cm away from mothers' beds. Delayed bathing remained optional. In the NICU, mothers positive for SARS-CoV-2 were not permitted to visit during the 14-day isolation period. A COVID-19 Newborn Follow-up Clinic was established at Morgan Stanley Children's Hospital on March 23 for newborns of mothers positive for SARS-CoV-2 born at either hospital to accommodate newborn visits if their pediatrician could not accommodate them during the 14-day observation period.

Outcomes and Statistical Analyses

All maternal data were collected from the electronic medical records. Extracted demographics include age, gravidity, parity, body mass index, and maternal comorbidities (diabetes, chronic hypertension, hypertensive disorders of pregnancy, asthma). Self-reported race and ethnicity data were collected from electronic medical records and are reported given known COVID-19 racial/ethnic disparities. Extracted clinical courses include gestational age at presentation and delivery, SARS-CoV-2 testing and symptoms, antenatal complications (intrauterine growth restriction, oligohydramnios, or fetal anomalies identified on ultrasonography), and obstetric complications (preterm premature rupture of membranes, preterm labor, preterm delivery, chorioamnionitis). COVID-19 illness was classified in accordance with the summary by Wu and McGoogan[27] (eMethods in the Supplement). Women were grouped as having asymptomatic/mildly symptomatic or severe/critical illness.

The primary study outcome investigated was the newborn SARS-CoV-2 test results. Vertical transmission was defined as positive SARS-CoV-2 test results on initial newborn swab, and postnatal transmission was defined as subsequent positive SARS-CoV-2 test results, either during hospitalization or after discharge as available within our records. We also looked for associations between maternal COVID-19 severity and newborn characteristics (mode of delivery, sex, birth weight, small for gestational age, large for gestational age) and clinical courses (NICU admissions, Apgar scores, breastfeeding frequency, hour of life at newborn bath, need for resuscitation, phototherapy if performed, weight loss, laboratory and radiology data as applicable for NICU courses, and age at dis-

Table 1. Infection Prevention and Control Strategies for SARS-CoV-2–Positive Mothers and Their Infants

IP&C strategies	Description
Staff	
Self-monitor for symptoms	Every 12 h, self-monitor for temperature 37.8 °C, fever, cough, sore throat, shortness of breath, myalgia, fatigue, diarrhea, loss of smell or taste
PPE	Fit check N95 respirator before each use
	Extended use and reuse of N95 respirators
	Surgical face mask or face shield worn over N95 respirator to extend N95 use
PPE education	Videos, graphics, memos, huddles
Patients	
Room placement	
L&D	Single-patient room
WBN	Single-patient room, infants in isolettes >180 cm from mother
NICU	Single-patient room in isolettes
	When single room unavailable, cohort in isolettes >180 cm apart
Transmission precautions	
L&D	Contact/droplet precautions plus airborne precautions for aerosol-generating procedures (negative pressure room preferred)
	Mothers wear mask at all times
WBN	Contact/droplet precautions for mothers and their infants
	Mothers continue to wear mask when interacting with staff or infant
NICU	Contact/droplet precautions plus airborne precautions for aerosol-generating procedures until DOL-14 (negative pressure room preferred)
Visitors	
Restrictions	
L&D	Only 1 asymptomatic support person permitted
WBN	No visitors permitted
NICU	Only 1 asymptomatic parent/guardian permitted (mother not permitted until DOL-14)
Screening	Every 12 h, monitor for temperature 38.7 °C, fever, cough, sore throat, shortness of breath, myalgia, fatigue, diarrhea, loss of smell or taste
PPE	
L&D	Surgical face mask, gown, gloves in patient room
WBN	NA
NICU	Surgical face mask, gown, gloves in patient room

Abbreviations: DOL, day of life; IP&C, infection prevention and control; L&D, labor and delivery; NA, not applicable; NICU, neonatal intensive care unit; PPE, personal protective equipment; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; WBN, well-baby nursery.

charge). We also examined encounters that occurred in the COVID-19 Newborn Follow-up Clinic and nonroutine encounters (telehealth, emergency department, hospitalizations, or clinic) identified through April 27 at our medical center.

Statistical Analysis

Maternal and newborn demographic and clinical characteristics were compared for women classified with asymptomatic/mild illness vs severe/critical disease. Owing to the small sample size, continuous variables were compared using the Wilcoxon rank sum test. We used the Fisher exact test to compare dichotomous variables. A binomial test was used to estimate the probability of a positive test result in infants. All analyses were conducted using R, version 3.6.1 (R Foundation). Two-sided $P < .05$ indicated significance.

Results

Maternal Demographic and Clinical Characteristics

One hundred women who delivered 101 live newborns (99 singletons and 1 twin pair) from March 13 to April 24, 2020, were included in the study. Ninety-nine women had positive test results for SARS-CoV-2, and 1 woman who presented with symptoms and chest radiographic findings consistent with COVID-19 tested negative for SARS-CoV-2 but was treated as presumptive positive. Seventy-three women (73.0%) underwent testing on admission to labor and delivery; 5 (5.0%), in preadmission clinic; and 22 (22.0%), for symptoms (**Table 2**).

Demographic and clinical characteristics of women with asymptomatic/mild illness (90 [90.0%]) were compared with women with severe/critical disease (10 [10.0%]) (Table 2). Overall, median maternal age was 28.5 (interquartile range [IQR], 24.0-34.0; range, 18-47) years. A total of 63 women were Hispanic or Latinx; 36 had asthma, diabetes, chronic hypertension, and/or hypertensive disorder of pregnancy; and 54 had a body mass index (calculated as weight in kilograms divided by height in meters squared) greater than 30.0. When compared with women with asymptomatic/mild infections, women with severe/critical disease were less likely to be identified by universal testing (3 of 10 [30.0%] vs 75 of 90 [83.3%]; $P < .001$), were older (median age, 34.0 [IQR, 30.8-35.0] vs 28.0 [IQR, 24.0-33.0] years; $P = .04$), were more likely to have pregestational diabetes (2 of 10 [20.0%] vs 1 of 90 [1.1%]; $P = .03$), and had infants with a lower gestational age at delivery (median,

Table 2. Characteristics of Mothers With Asymptomatic/Mild vs Severe/Critical COVID-19

Variable	Mothers by severity of COVID-19			Difference (95% CI)	*P* value
	All (n = 100)	Mild/asymptomatic (n = 90)	Severe/critical (n = 10)		
SARS-CoV-2 clinical characteristics					
Gestational age at diagnosis, median (IQR), wk	39.0 (37.4 to 40.0)	39.0 (37.4 to 39.9)	38.0 (37.1 to 38.1)	1.4 (-3.6×10^{-5} to 2.4)	.053
Indication for testing, No. (%)					
COVID-19 symptoms	22 (22.0)	15 (16.7)	7 (70.0)	0.09 (0.01 to 0.4)	<.001
Universal testing	78 (78.0)	75 (83.3)	3 (30.0)	0.09 (0.01 to 0.4)	<.001
Asymptomatic[a]	67 (85.9)	66 (88.0)	1 (33.3)	0.07 (0.001 to 1.5)	.051
Atypical presentation[b]	14 (14.0)	13 (14.4)	1 (10.0)	NA	.35
Diagnosis to delivery interval, d					
COVID-19 symptoms, median (IQR)	7.0 (0.0 to 15.0)	14.0 (2.5 to 16.0)	0 (0 to 5.3)	8.0 (-1.8×10^{-5} to 19.0)	.10
Universal testing, median (IQR)	1.0 (0.0 to 1.0)	1.0 (0.0 to 1.0)	1.0 (1.0 to 1.0)	NA	.32
Demographics, median (IQR)					
Maternal age, y	28.5 (24.0 to 34.0)	28.0 (24.0 to 33.0)	34.0 (30.8 to 35.0)	5.0 (1.5×10^{-6} to 10.0)	.04
Gravidity	2.0 (1.0 to 3.3)	2.0 (1.0 to 3.0)	3.0 (2.0 to 4.8)	1.0 (-6.8×10^{-6} to 2.0)	.07
Parity	1.0 (0.0 to 2.0)	1.0 (0 to 2.0)	1.0 (0.3 to 2.0)	NA	.35
Ethnicity, No. (%)					
Hispanic or Latinx	63 (63.0)	56 (62.2)	7 (70.0)	NA	.74
Not Hispanic or Latinx	18 (18.0)	16 (17.8)	2 (20.0)	NA	.61
Unknown, not reported, or undefined	19 (19.0)	18 (20.0)	1 (10.0)	NA	.68
Race, No. (%)					
American Indian/Alaska Native	0	0	0	NA	NA
Asian	2 (2.0)	2 (2.2)	0	NA	>.99
Native Hawaiian/other Pacific Islander	1 (1.0)	1 (1.1)	0	NA	>.99
Black or African American	13 (13.0)	13 (14.4)	0	NA	.59
White	31 (31.0)	28 (31.1)	3 (30.0)	NA	>.99
Other combinations not described	9 (9.0)	8 (8.9)	1 (10.0)	NA	.58
Unknown, not reported, or undefined	47 (47.0)	41 (45.6)	6 (60.0)	NA	.34
BMI, median (IQR)	30.4 (28.1 to 34.5)	30.4 (28.1 to 34.1)	29.8 (28.7 to 35.3)	NA	.87
Comorbid conditions, No. (%)					
Asthma	11 (11.0)	9 (10.0)	2 (20.0)	NA	.30
Pregestational diabetes	3 (3.0)	1 (1.1)	2 (20.0)	20.7 (1.0 to 1312.0)	.03
Gestational diabetes	9 (9.0)	7 (7.8)	2 (20.0)	NA	.22
Chronic hypertension	2 (2.0)	2 (2.2)	0	NA	>.99
Gestational hypertension	6 (6.0)	6 (6.7)	0	NA	>.99
Preeclampsia	5 (5.0)	3 (3.3)	2 (20.0)	7.0 (0.5 to 71.1)	.08
Obesity	54 (54.0)	50 (55.6)	4 (40.0)	NA	.73
Antenatal and obstetric clinical data					
Gestational age at delivery, median (IQR), wk	39.0 (37.9 to 40.1)	39.1 (38.3 to 40.2)	37.9 (37.1 to 38.4)	1.4 (0.3 to 2.3)	.02
IUGR, No. (%)	3 (3.0)	2 (2.2)	1 (10.0)	NA	.27
Oligohydramnios, No. (%)	5 (5.0)	5 (5.6)	0	NA	>.99
Prenatally diagnosed fetal anomalies, No. (%)	11 (11.0)	9 (10.0)	2 (20.0)	NA	.30
Preterm premature rupture of membranes, No. (%)	5 (5.0)	5 (5.6)	0	NA	>.99
Preterm labor, No. (%)	3 (3.0)	3 (3.3)	0	NA	>.99
Preterm delivery, No. (%)	11 (11.0)	10 (11.1)	1 (10.0)	NA	>.99
Chorioamnionitis, No. (%)	9 (9.0)	7 (7.8)	2 (20.0)	NA	.22

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by square of height in meters); COVID-19, coronavirus disease 2019; IQR, interquartile range; IUGR, intrauterine growth restriction; NA, not applicable; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[a] Includes the 78 women who underwent universal testing.

[b] Includes patients whose initial and sole symptom was an intrapartum or postpartum fever. These women were asymptomatic before and on admission to labor and delivery.

37.9 [IQR, 37.1-38.4] vs 39.1 [IQR, 38.3-40.2] weeks; *P* = .02) (Table 2).

Newborn SARS-CoV-2 Testing

The 101 neonates born to these mothers (54 girls [53.5%] and 47 boys [46.5%]) had 141 tests for SARS-CoV-2 during the study period within our hospital system (median, 1 [IQR, 1-2] test/newborn) (Figure). An initial test was performed on all newborns and obtained on 0 days of life (DOL-0) (24 hours of life [HOL-0 to HOL-24]) for 15 newborns, DOL-1 (HOL-25 to HOL-48) for 79 newborns, and DOL-2 or later (after HOL-48) for 7 newborns (median, HOL-32 [IQR, HOL-26 to HOL-38]). Seventy infants underwent testing only once. Among the newborns who underwent multiple tests, 10 tests (1 test each for 6 newborns; 2 tests each for 2 newborns) were obtained for clinical indications, including fever and new respiratory symptoms. The remainder were obtained as part of routine additional surveillance in the NICU or COVID-19 Newborn Follow-up Clinic. Of the newborns who underwent retesting, 4 had been previously described, including 1 with indeterminate results, 1 with invalid findings, 1 per a NICU protocol, and 1 in the emergency department, seen for fever on DOL-25.[16]

No detection of SARS-CoV-2 viral RNA was found in 135 of 141 specimens (95.7% of tests) from 100 newborns. The initial test results of 4 newborns (2.8% of tests) were ruled invalid, new specimens were sent, and all findings were negative; 1 of these 4 tests was previously reported.[16] Two tests in 2 newborns (1.4% of tests) had indeterminate results, and only 1 infant underwent retesting and had negative results, as previously reported.[16] Overall incidence of transmission was 2.0% (95% CI, 0.2%-7.0%) in 2 newborns. Details of calculated vertical and perinatal transmission rates based on testing and clinical courses can be found in **Table 3**.

The clinical courses of the 2 newborns with indeterminate results were not previously described in detail. Newborn 1 was born via vaginal delivery before universal SARS-CoV-2 testing and underwent testing on DOL-3 after the development of maternal symptoms.[16] No IP&C practices had been put in place until DOL-3. The newborn received a bath at HOL-3 for reasons unrelated to SARS-CoV-2, had a normal WBN course, and was discharged on DOL-4. Newborn 1 did not undergo retesting but was seen in the COVID-19 Newborn Follow-up Clinic on DOL-6, and no issues were identified. This newborn was only breastfed once.

Newborn 2 was born via nonemergent cesarean delivery for nonreassuring fetal heart tracing to a mother who was asymptomatic at admission but subsequently developed intrapartum fevers.[16] This newborn had indeterminate test results at DOL-0. On DOL-2 retesting, SARS-CoV-2 was not detected. Newborn 2 had received a bath at HOL-40 and had a similarly uncomplicated WBN course. No issues were identified at the COVID-19 Newborn Follow-up Clinic on DOL-6. The mother breastfed directly in the WBN and at home but reported mainly formula feeds. This newborn presented to the pediatric emergency department on DOL-13 with excessive crying, but had normal examination results, and no further testing was performed. A follow-up telehealth visit on DOL-23 did not identify any issues.

Newborn Characteristics and Postpartum Newborn Care

Eighty-two newborns (81.2%), including 14 previously reported,[16] were admitted to the WBN. Nineteen neonates (18.8%), including 4 previously reported,[16] were admitted to the NICU for reasons unrelated to maternal SARS-CoV-2 infection. This relatively high rate is consistent with our usual NICU admission rate and common for tertiary referral centers. Ninety-one infants (90.1%; 75 in the WBN and 16 in the NICU) were born to asymptomatic/mildly symptomatic mothers, and 10 (9.9%; 7 in the WBN and 3 in the NICU) were born to mothers with severe/critical COVID-19 disease. The demographic and clinical characteristics of these 2 groups of newborns were compared (Table 3 and eTable in the Supplement). Characteristics were generally similar, except maternal COVID-19 severity was associated with increased risk of newborn hyperbilirubinemia requiring phototherapy (3 of 10 [30.0%] vs 6 of 91 [7.0%]; *P* = .04). This was only significant among newborns admitted to the WBN (4 of 82 [4.9%]; *P* = .03) (eTable in the Supplement).

A minority of newborns (27 [26.7%]) were bathed earlier than HOL-24. Most mothers (91 [90.1%]) breastfed at least partially, with 41 (40.6%) breastfeeding exclusively or mostly. Newborns were discharged from the WBN on a mean of HOL-50 (IQR, HOL-40 to HOL-64), with those born vaginally discharged at HOL-43 (IQR, HOL-33 to HOL-43) and those born via cesarean at HOL-60 (IQR, HOL-50 to HOL-81). As of April 27, 11 infants in the NICU (57.9%) were discharged on a mean (SD) of DOL-6.8 (DOL-4.3), and 34 newborns (33.7%) included in this study were older than 14 days.

NICU Courses

Nineteen neonates required NICU admission for primary diagnoses of prematurity (8 [42.1%]), congenital malformations (8 [42.1%]), respiratory distress (2 [10.5%]), or sepsis concerns (1 [5.3%]). A total of 12 neonates in the NICU (63.2%) required respiratory support at variable times for transient tachypnea of the newborn (n = 2), culture-negative sepsis (n = 1), congenital malformations (n = 6), and respiratory distress syndrome (n = 3). All 12 had chest radiography findings that were either normal or consistent with their diagnosis. Rule-out sepsis evaluation was performed on admission in 10 neonates. The mothers of 5 of these neonates had been diagnosed with chorioamnionitis and/or group B *Streptococcus* infection. One neonate with transposition of the great arteries developed fever while receiving prostaglandin and underwent full sepsis workup. Results of multiple repeated tests for SARS-CoV2 were negative on DOL-2 through DOL-8.

Newborn Follow-up

Fifty-five newborns (54.5%) had newborn follow-up in the COVID-19 Newborn Follow-up Clinic at DOL-3 to DOL-10 (median, DOL-6.0 [IQR, DOL-4.3 to DOL-6.8]). Twenty-six of these newborns (47.3%) had regained or surpassed their birth weight, 29 (52.7%) remained below birth weight by a mean (SD) of 4.3% (2.7%), and no newborn had excessive weight loss (>10% decrease from birth weight). No other issues were identified.

Twenty of the newborns seen in the COVID-19 Newborn Follow-up Clinic and 3 additional newborns followed up else-

Table 3. Characteristics of Neonates Born to Mothers With Asymptomatic/Mild Illness vs Severe/Critical COVID-19

Variable	Maternal severity of COVID-19			Difference (95% CI)	*P* value
	All	Asymptomatic/mild[a]	Severe/critical[a]		
SARS-CoV-2 transmission					
Testing-based transmission, No./total No. (%) [95% CI]					
Total newborns	2/101 (2.0) [0.2 to 7.0]	2/91 (2.2)	0/10	NA	>.99
Total tests given	2/141 (1.4) [0.2 to 5.0]	2/123 (1.6)	0/18	NA	>.99
Vertical transmission					
Tested ≤ HOL-23	1/15 (7.0) [0.2 to 32.0]	1/14 (7.1)	0/1	NA	>.99
Tested ≥ HOL-24	1/86 (1.2) [0.03 to 6.3]	1/77 (1.3)	0/9	NA	>.99
Perinatal transmission, retesting	0/31 [0.0 to 11.2]	0/26	0/5	NA	NA[b]
Clinical-based transmission, No./total No. (%) [95% CI]					
Vertical transmission	0/101 [0.0 to 3.6]	0/91	0/10	NA	NA[b]
Perinatal transmission	0/55 [0.0 to 6.5]	0/49	0/6	NA	NA[b]
Characteristics					
Cesarean delivery, No./total No. (%)	46/101 (45.5)	37/91 (40.7)	5/10 (50.0)	NA	>.99
Male, No./total No. (%)	47/101 (46.5)	43/91 (47.3)	4/10 (40.0)	NA	.75
Birth weight, median (IQR), g	3295 (2875 to 3605)	3320 (2945 to 3630)	2958 (2868 to 3150)	320 (−15 to 650)	.06
SGA, No./total No. (%)	8/101 (7.9)	8/91 (8.8)	0/10	NA	>.99
LGA, No./total No. (%)	7/101 (6.9)	6/91 (6.6)	1/10 (10.0)	NA	.53
Newborn clinical data					
NICU admission, No./total No. (%)	19/101 (18.8)	16/91 (17.6)	3/10 (30.0)	NA	.39
Apgar score at 1 min, median (IQR)	9.0 (8.0 to 9.0)	9.0 (8.0 to 9.0)	9.0 (8.0 to 9.0)	NA	.92
1-min Apgar score >7, No./total No.(%)	98/101 (97.0)	89/91 (97.8)	9/10 (90.0)	NA	.27
Apgar score at 5 min, median (IQR)	9.0 (9.0 to 9.0)	9.0 (9.0 to 9.0)	9.0 (9.0 to 9.0)	NA	.94
5-min Apgar >7, No. (%)[c]	101/101 (100)	91/91 (100)	10/10 (100)	NA	NA[c]
Any breastfeeding, No./total No. (%)	91/101 (90.1)	83/91 (91.2)	8/10 (80.0)	NA	.26
Most or all breastfeeding, No./total No. (%)	41/101 (40.6)	39/91 (42.9)	2/10 (20.0)	NA	.19
Complications during initial hospitalization					
Resuscitation, No./total No. (%)	12/101 (11.9)	10/91 (11.0)	2/10 (20.0)	NA	.34
Phototherapy received, No./total No. (%)	9/101 (8.9)	6/91 (6.6)	3/10 (30.0)	5.9 (0.8 to 36.1)	.04
Maximum weight loss, median (IQR), %	4.6 (3.0 to 6.2)	4.5 (3.0 to 6.1)	5.2 (3.8 to 6.3)	NA	.89
Excessive weight loss, No./total No. (%)	6/101 (5.9)	5/91 (5.5)	1/10 (10.0)	NA	.47

Abbreviations: COVID-19, coronavirus disease 2019; HOL, hours of life; IQR, interquartile range; LGA, large for gestational age; NA, not applicable; NICU, neonatal intensive care unit; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SGA, small for gestational age.

[a] Proportions are reported as number/total number (percentage) only.

[b] No newborns showed evidence of these characteristics, so a comparison could not be performed.

[c] All newborns had an Apgar score of 7 or greater at 5 minutes.

where (23 [22.7%]) had a total of 32 additional nonroutine encounters within our medical center on DOL-3 to DOL-25, including 4 newborns requiring admission, 3 for fever and 2 for hyperbilirubinemia (**Table 4**). Six underwent retesting for SARS-CoV-2 during these encounters, and findings were negative. Four of these newborns were previously described.[16]

Discussion

We herein present, to our knowledge, the largest series of newborns born to mothers positive for or with suspected SARS-CoV-2 infection to date and show low rates of testing-based vertical or perinatal transmission and no clinical evidence for neonatal SARS-CoV-2 infection. These data are particularly reassuring given that we describe mothers with a range of clinical presentations. Contrasting a previous report,[12] the small number of mothers with severe/critical COVID-19 in this cohort did not transmit SARS-CoV-2 to their newborns. Neonates born to mothers with severe/critical illness were born at an earlier gestational age, a shift that did not appear to be driven by the NICU population. Maternal severe/critical disease was also associated with overall higher incidence of hyperbilirubinemia requiring phototherapy in WBN newborns for unclear reasons.

Table 4. Nonroutine Encounters in the Medical Center

Infant No.[a]	DOL	Setting	Chief complaint	Admitted	Outcome	SARS-CoV-2 retesting	SARS-CoV-2 test result
1[b]	25	ED to hospital	Fever	Yes	ROS negative, antibiotics	Yes	Not detected
2[b]	23	Telehealth	Rash	No	Presciption for nystatin	No	NA
3[b]	13	ED	Loud crying	No	Anticipatory guidance given	No	NA
3[b]	23	Telehealth	ED follow-up	No	Anticipatory guidance given	No	NA
4[b]	18	ED	Choking/respiratory distress	No	Anticipatory guidance given	No	NA
4[b]	20	Telehealth	ED follow-up	No	No more choking	No	NA
5	3	Hospital	Hyperbilirubinemia	Yes	Phototherapy	Yes	Not detected
6	12	Telehealth	Constipation	No	Anticipatory guidance given	No	NA
7	4	ED	Congestion, belly breathing	No	Anticipatory guidance given	No	NA
7	9	Telehealth	Breastfeeding concern	No	Breastfeeding counseling	No	NA
8	14	Telehealth	Fussiness	No	Anticipatory guidance given	No	NA
8	19	Clinic	Abnormal NBS result	No	Laboratory draw for repeated TFTs	No	NA
9	7	Telehealth	Breastfeeding concern	No	Breastfeeding counseling	No	NA
10	13	Telehealth	Breastfeeding concern	No	Breastfeeding counseling	No	NA
11	14	Telehealth	Constipation	No	Anticipatory guidance given	No	NA
11	18	ED to hospital	Fever	Yes	Antibiotics, negative ROS workup findings	Yes	Not detected
12	12	Telehealth	Umbilical drainage	No	Anticipatory guidance given	No	NA
12	15	Telehealth	Umbilical drainage	No	Anticipatory guidance given	No	NA
13	6	Hospital	Fever	Yes	Positive ROS finding, UTI, antibiotics	Yes	Not detected
13	10	COVID-19 clinic	Weight loss	No	Minimal weight gain	No	NA
13	15	COVID-19 clinic	Weight loss	No	Gaining weight	No	NA
14	9	Email	Feeding concerns	No	Anticipatory guidance given	No	NA
15	9	Telehealth	Excessive stool	No	Anticipatory guidance given	No	NA
16	7	Telehealth	Bloody vaginal discharge	No	Anticipatory guidance given	No	NA
17	7	Telehealth	Breastfeeding concern	No	Breastfeeding counseling	No	NA
18	11	COVID-19 clinic	Weight loss	No	Gaining weight	Yes	Not detected
18	12	Telehealth	Fussiness, spit up	No	Anticipatory guidance given	No	NA
19	10	Telehealth	Breastfeeding concern, infant sleep	No	Breastfeeding counseling, anticipatory guidance given	No	NA
20	10	Telehealth	Breastfeeding concern	No	Breastfeeding counseling	No	NA
21	5	COVID-19 clinic	Weight loss	No	Gaining weight	No	NA
22	6	ED	Repeated bilirubin level measurement	No	Bilirubin level decreased	No	NA
23	3	ED	Hyperbilirubinemia	No	Phototherapy	Yes	Not detected

Abbreviations: COVID-19, coronavirus disease 2019; DOL, days of life; ED, emergency department; NA, not applicable; NBS, newborn screening; ROS, rule-out sepsis; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; TFTs, thyroid function tests; UTI, urinary tract infection.

[a] Numbering refers to the order in which these 22 infants had encounters identified in our electronic medical record and is not reflective of newborn order in the cohort.

[b] Newborn was previously described.

For the 82 WBN newborns, the lack of evidence for vertical or postnatal transmission was observed while allowing mother-newborn rooming-in, encouraging delayed bathing, and promoting direct breastfeeding with appropriate hygiene. Our IP&C guidance was developed in consideration of several factors. First, we needed to accommodate a large number of mothers positive for SARS-CoV-2 hospitalized concurrently on the postpartum unit, precluding universal separation. Second, we considered the lack of available data supporting SARS-CoV-2 vertical transmission and severe disease in newborns. Third, we considered the clear benefits of breastfeeding, mother-infant contact, and delayed bathing. To mitigate the risk of postnatal transmission, we implemented social distancing, personal protective equipment requirements, and breast and hand hygiene practices; developed educational materials for mothers; and shortened hospital stays, as appropriate. Our findings suggest that mothers positive for SARS-CoV-2, including those with clinical symptoms, and their newborns may not need to be separated in the WBN. We did, however, implement separation in the NICU in consideration of inability for rooming-in, the shared structure of the unit, and lack of data about COVID-19 in this more vulnerable population.

Our findings also support retaining evidence-based newborn care practices and avoiding potentially harmful prac-

tices. Thus far, 13 infants positive for SARS-CoV-2 have been described.[11-14,28-30] Twelve of these were born by cesarean delivery and most were isolated from their mothers and received formula feeding.[12,14,28-30] Breast milk might play a protective role against newborn SARS-CoV-2 infection. Breast milk is known to be protective against numerous pathogens,[31,32] most studies have not found SARS-CoV-2 in breast milk,[6,28,30,33] and breast milk has been found to contain anti-SARS-CoV-2 IgA.[34] In addition, maternal vaginal secretions and skin-to-skin contact are involved in development of infant immunogenic responses.[35,36] Delayed bathing has significant benefits, including potential to increase rates of exclusive breastfeeding,[37-41] and early bathing has significant risks, including hypothermia and hypoglycemia.[39,42]

The 2 infants with indeterminate test results, considered presumptive positive by Roche Diagnostics, were both followed up at our medical center, and neither developed any symptoms suggestive of COVID-19. No IP&C practices were put in place for 1 of the newborns whose test result was indeterminate until DOL-3, owing to postpartum COVID-19 diagnosis in the mother. This is consistent with possible mother-to-infant transmission when the mother does not use a mask and appropriate hand and breast hygiene and mirrors a similar recent report from Italy.[13]

Limitations and Strengths

There are several limitations to this study. Findings from a pandemic epicenter may not be generalizable to other areas. Another limitation is that our cohort consisted entirely of women infected in the third trimester, with most at term. Further studies are needed to evaluate the congenital neonatal risks of vertical transmission in utero. In addition, our study design does not allow comparison of outcomes in newborns of mothers positive vs negative for SARS-CoV-2. However, characteristics of our cohort are consistent with national means for gestational age,[43] Apgar scores,[44] birth weight,[43] percentage requiring resuscitation at delivery,[45] mean maximum weight loss at WBN discharge,[46] and proportion of newborns requiring phototherapy.[47] Finally, most newborns admitted to the WBN did not undergo retesting for SARS-CoV-2 at the end of their 14-day observation period. However, those who underwent retesting all had negative findings, including many who returned to our medical center for nonroutine encounters and 4 who were hospitalized. The strengths of the study include large sample size, follow-up beyond newborn discharge home, and well-characterized obstetric outcomes of SARS-CoV-2-positive mothers.

Conclusions

In this cohort study, no evidence of vertical transmission of SARS-CoV-2 was identified in the first 101 newborns born to mothers positive for or with suspected SARS-CoV-2 infections at a large medical center in an epicenter of the COVID-19 pandemic. This study endorses the benefits of rooming-in, establishing breastfeeding, and delaying bathing on newborn outcomes and suggests that separating mothers positive for SARS-CoV-2 and their newborns and avoiding direct breastfeeding may not be warranted to prevent SARS-CoV-2 transmission.

ARTICLE INFORMATION

Accepted for Publication: June 24, 2020.

Published Online: October 12, 2020. doi:10.1001/jamapediatrics.2020.4298

Author Affiliations: Division of Child and Adolescent Health, Department of Pediatrics, Columbia University Irving Medical Center, New York, New York (Dumitriu, Walzer, Saslaw, Scripps, Khan, Fernández, Keown, Glassman, Stephens, Sultan, Abreu, Stockwell); NewYork–Presbyterian Hospital, New York, New York (Dumitriu, Emeruwa, Ludwig, Walzer, Arditi, Saslaw, Andrikopoulou, Scripps, Baptiste, Khan, Breslin, Rubenstein, Simpson, Friedman, Hirsch, Miller, Fernández, Fuchs, Keown, Glassman, Stephens, Gupta, Sultan, Sibblies, Abreu, Akita, Penn, D'Alton, Orange, Goffman, Saiman, Stockwell, Gyamfi-Bannerman); Division of Developmental Neuroscience, Department of Psychiatry, Columbia University Irving Medical Center, New York, New York (Dumitriu, Kyle); Sackler Institute, Zuckerman Institute, and the Columbia Population Research Center, Columbia University, New York, New York (Dumitriu); Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, New York, New York (Emeruwa, Arditi, Andrikopoulou, Baptiste, Breslin, Simpson, Friedman, Miller, Fuchs, Goffman, Gyamfi-Bannerman); Division of Neonatology, Department of Pediatrics, Columbia University Irving Medical Center, New York, New York (Hanft, Liao, Rubenstein, Hirsch, Gupta, Sibblies, Akita, Penn); Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, New York, New York (Ludwig, D'Alton, Goffman); Department of Pathology and Cell Biology, Columbia University Irving Medical Center, New York, New York (Whittier); Department of Pediatrics, Columbia University Irving Medical Center, New York, New York (Orange); Division of Pediatric Infectious Diseases, Department of Pediatrics, Columbia University Irving Medical Center, New York, New York (Saiman); Department of Population and Family Health, Mailman School of Public Health, Columbia University Irving Medical Center, New York, New York (Stockwell).

Author Contributions: Drs Dumitriu and Emeruwa contributed equally to this study. Drs Dumitriu and Emeruwa had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Dumitriu, Emeruwa, Liao, Walzer, Arditi, Andrikopoulou, Scripps, Simpson, Friedman, Hirsch, Miller, Glassman, Akita, Penn, D'Alton, Orange, Goffman, Saiman, Stockwell, Gyamfi-Bannerman.
Acquisition, analysis, or interpretation of data: Dumitriu, Emeruwa, Hanft, Liao, Ludwig, Walzer, Arditi, Saslaw, Andrikopoulou, Scripps, Baptiste, Khan, Breslin, Rubenstein, Kyle, Hirsch, Fernandez, Fuchs, Keown, Stephens, Gupta, Sultan, Sibblies, Whittier, Abreu, Penn, Goffman, Stockwell, Gyamfi-Bannerman.
Drafting of the manuscript: Dumitriu, Emeruwa, Hanft, Liao, Ludwig, Arditi, Saslaw, Scripps, Khan, Rubenstein, Simpson, Kyle, Miller, Glassman, Akita, Gyamfi-Bannerman.
Critical revision of the manuscript for important intellectual content: Dumitriu, Emeruwa, Hanft, Liao, Walzer, Arditi, Saslaw, Andrikopoulou, Scripps, Baptiste, Khan, Breslin, Rubenstein, Friedman, Hirsch, Miller, Fernandez, Fuchs, Keown, Glassman, Stephens, Gupta, Sultan, Sibblies, Whittier, Abreu, Penn, D'Alton, Orange, Goffman, Saiman, Stockwell, Gyamfi-Bannerman.
Statistical analysis: Dumitriu, Emeruwa, Liao, Ludwig, Arditi, Kyle.
Administrative, technical, or material support: Dumitriu, Liao, Walzer, Arditi, Saslaw, Scripps, Baptiste, Breslin, Rubenstein, Kyle, Hirsch, Fernandez, Fuchs, Keown, Stephens, Sibblies, Whittier, Abreu, Akita, Penn, D'Alton, Orange, Goffman, Saiman.
Supervision: Dumitriu, Miller, Glassman, Sultan, Penn, D'Alton, Orange, Goffman, Saiman, Stockwell, Gyamfi-Bannerman.
Other - research for discussion section: Gupta.

Conflict of Interest Disclosures: Dr Miller reported receiving personal fees from UpToDate and Medicolegal for consulting work outside the submitted work. Dr D'Alton reported a paid advisory board member for Merck for Mothers, Merck & Co, outside the submitted work. Dr Orange reported receiving stock options for service on the advisory board of GigaGen outside the submitted work. Dr Gyamfi-Bannerman reported receiving grants from the Eunice Kennedy Shriver National Institute of Child Health and Human Development

outside the submitted work. No other disclosures were reported.

Additional Contributions: We acknowledge the exceptional work of the entire team on the front line, including physicians, nurses, and staff at Columbia University Irving Medical Center and New York-Presbyterian Hospital. We thank Caroline Torres, MD, and Cynthia Masson, BA, Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, without whom this work could not have been completed. They were not compensated for this work. Finally, we thank the mothers who placed their trust in us to care for them and their newborns during this extraordinary time.

REFERENCES

1. Centers for Disease Control and Prevention. Daily updates of totals by week and state: provisional death counts for coronavirus disease 2019 (COVID-19). National Vital Statistics System. Updated April 28, 2020. Accessed April 28, 2020. https://www.cdc.gov/nchs/nvss/vsrr/covid19/index.htm

2. Arora N, Sadovsky Y, Dermody TS, Coyne CB. Microbial vertical transmission during human pregnancy. *Cell Host Microbe*. 2017;21(5):561-567. doi:10.1016/j.chom.2017.04.007

3. Mor G, Cardenas I. The immune system in pregnancy: a unique complexity. *Am J Reprod Immunol*. 2010;63(6):425-433. doi:10.1111/j.1600-0897.2010.00836.x

4. Silasi M, Cardenas I, Kwon JY, Racicot K, Aldo P, Mor G. Viral infections during pregnancy. *Am J Reprod Immunol*. 2015;73(3):199-213. doi:10.1111/aji.12355

5. Gilbert GL. 1: Infections in pregnant women. *Med J Aust*. 2002;176(5):229-236. doi:10.5694/j.1326-5377.2002.tb04381.x

6. Chen H, Guo J, Wang C, et al. Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records. *Lancet*. 2020;395(10226):809-815. doi:10.1016/S0140-6736(20)30360-3

7. Liu D, Li L, Wu X, et al. Pregnancy and perinatal outcomes of women with coronavirus disease (COVID-19) pneumonia: a preliminary analysis. *AJR Am J Roentgenol*. 2020;215(1):127-132. doi:10.2214/AJR.20.23072

8. Chen R, Zhang Y, Huang L, Cheng BH, Xia ZY, Meng QT. Safety and efficacy of different anesthetic regimens for parturients with COVID-19 undergoing cesarean delivery: a case series of 17 patients. *Can J Anaesth*. 2020;67(6):655-663. doi:10.1007/s12630-020-01630-7

9. Yan J, Guo J, Fan C, et al. Coronavirus disease 2019 (COVID-19) in pregnant women: a report based on 116 cases. *Am J Obstet Gynecol*. 2020;223(1):111.e1-111.e14. doi:10.1016/j.ajog.2020.04.014

10. Vintzileos WS, Muscat J, Hoffmann E, et al. Screening all pregnant women admitted to labor and delivery for the virus responsible for coronavirus disease 2019. *Am J Obstet Gynecol*. 2020;223(2):284-286. doi:10.1016/j.ajog.2020.04.024

11. Yu N, Li W, Kang Q, et al. Clinical features and obstetric and neonatal outcomes of pregnant patients with COVID-19 in Wuhan, China: a retrospective, single-centre, descriptive study. *Lancet Infect Dis*. 2020;20(5):559-564. doi:10.1016/S1473-3099(20)30176-6

12. Alzamora MC, Paredes T, Caceres D, Webb CM, Valdez LM, La Rosa M. Severe COVID-19 during pregnancy and possible vertical transmission. *Am J Perinatol*. 2020;37(8):861-865. doi:10.1055/s-0040-1710050

13. Ferrazzi E, Frigerio L, Savasi V, et al. Vaginal delivery in SARS-CoV-2-infected pregnant women in Northern Italy: a retrospective analysis. *BJOG*. 2020. doi:10.1111/1471-0528.16278

14. Zeng L, Xia S, Yuan W, et al. Neonatal early-onset infection with SARS-CoV-2 in 33 neonates born to mothers with COVID-19 in Wuhan, China. *JAMA Pediatr*. 2020. doi:10.1001/jamapediatrics.2020.0878

15. Castagnoli R, Votto M, Licari A, et al. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in children and adolescents: a systematic review. *JAMA Pediatr*. Published online April 22, 2020. doi:10.1001/jamapediatrics.2020.1467

16. Breslin N, Baptiste C, Gyamfi-Bannerman C, et al. COVID-19 infection among asymptomatic and symptomatic pregnant women: two weeks of confirmed presentations to an affiliated pair of New York City hospitals. *Am J Obstet Gynecol MFM*. 2020;100118. doi:10.1016/j.ajogmf.2020.100118

17. Puopolo KM, Hudak ML, Kimberlin DW, Cummings J. *Initial Guidance: Management of Infants Born to Mothers with COVID-19.* American Academy of Pediatrics Committee on Fetus and Newborn, Section on Neonatal Perinatal Medicine, and Committee on Infectious Diseases; 2020.

18. Centers for Disease Control and Prevention. Coronavirus disease 2019 (COVID-19) and breastfeeding. Published March 4, 2020. Accessed April 25, 2020. https://www.cdc.gov/breastfeeding/breastfeeding-special-circumstances/maternal-or-infant-illnesses/covid-19-and-breastfeeding.html

19. World Health Organization. Pregnancy, childbirth, breastfeeding and COVID-19. Published 2020. Accessed April 28, 2020. https://www.who.int/reproductivehealth/publications/emergencies/COVID-19-pregnancy-ipc-breastfeeding-infographics/en/

20. Society for Maternal-Fetal Medicine; Dotters-Katz S, Hughes BL. Coronavirus (COVID-19) and pregnancy: what maternal-fetal medicine subspecialists need to know. Published April 11, 2020. Accessed April 25, 2020. https://s3.amazonaws.com/cdn.smfm.org/media/2317/COVID19-What_MFMs_need_to_know_revision_4-11-20_(final)_PDF.pdf

21. American College of Obsetricians and Gynecologists. Outpatient assessment and management for pregnant women with suspected or confirmed novel coronavirus (COVID-19). Published March 30, 2020. Accessed April 25, 2020. https://www.acog.org/-/media/project/acog/acogorg/files/pdfs/clinical-guidance/practice-advisory/covid-19-algorithm.pdf

22. Khoury R, Bernstein PS, Debolt C, et al. Characteristics and outcomes of 241 births to women with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection at five New York City medical centers. *Obstet Gynecol*. 2020;136(2):273-282. doi:10.1097/AOG.0000000000004025

23. World Health Organization. Laboratory testing for coronavirus disease 2019 (COVID-19) in suspected human cases: interim guidance. Published March 2, 2020. Accessed April 28, 2020. https://apps.who.int/iris/handle/10665/331329

24. Centers for Disease Control and Prevention. CDC 2019-Novel Coronavirus (2019-nCoV): real-time RT-PCR diagnostic panel. Published July 13, 2020. Accessed September 16, 2020. https://www.fda.gov/media/134922/download

25. Yelin I, Aharony N, Shaer Tamar E, et al. Evaluation of COVID-19 RT-qPCR test in multi-sample pools. *Clin Infect Dis*. 2020;ciaa531. Published online May 2, 2020. doi:10.1093/cid/ciaa531

26. Lippi G, Simundic AM, Plebani M. Potential preanalytical and analytical vulnerabilities in the laboratory diagnosis of coronavirus disease 2019 (COVID-19). *Clin Chem Lab Med*. 2020;58(7):1070-1076. doi:10.1515/cclm-2020-0285

27. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA*. Published February 24, 2020. doi:10.1001/jama.2020.2648

28. Wang S, Guo L, Chen L, et al. A case report of neonatal COVID-19 infection in China. *Clin Infect Dis*. 2020;71(15):853-857. doi:10.1093/cid/ciaa225

29. Zhang ZJ, Yu XJ, Fu T, et al. Novel coronavirus infection in newborn babies aged <28 days in China. *Eur Respir J*. 2020;55(6):2000697. doi:10.1183/13993003.00697-2020

30. Hu X, Gao J, Luo X, et al. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vertical transmission in neonates born to mothers with coronavirus disease 2019 (COVID-19) pneumonia. *Obstet Gynecol*. 2020;136(1):65-67. doi:10.1097/AOG.0000000000003926

31. Lawrence RM, Lawrence RA. Breastfeeding: more than just good nutrition. *Pediatr Rev*. 2011;32(7):267-280. doi:10.1542/pir.32-7-267

32. WHO Collaborative Study Team on the Role of Breastfeeding on the Prevention of Infant Mortality. Effect of breastfeeding on infant and child mortality due to infectious diseases in less developed countries: a pooled analysis. *Lancet*. 2000;355(9202):451-455. doi:10.1016/S0140-6736(00)82011-5

33. Wu Y, Liu C, Dong L, et al. Coronavirus disease 2019 among pregnant Chinese women: case series data on the safety of vaginal birth and breastfeeding. *BJOG*. 2020;27(9):1109-1115. doi:10.1111/1471-0528.16276

34. Fox A, Marino J, Amanat F, et al. Evidence of a significant secretory-IgA-dominant SARS-CoV-2 immune response in human milk following recovery from COVID-19. medRxiv. Preprint posted online May 8, 2020. doi:10.1101/2020.05.04.20089995

35. Mueller NT, Bakacs E, Combellick J, Grigoryan Z, Dominguez-Bello MG. The infant microbiome development: mom matters. *Trends Mol Med*. 2015;21(2):109-117. doi:10.1016/j.molmed.2014.12.002

36. Dunn AB, Jordan S, Baker BJ, Carlson NS. The maternal infant microbiome: considerations for labor and birth. *MCN Am J Matern Child Nurs*. 2017; 42(6):318-325. doi:10.1097/NMC.0000000000000373

37. Long K, Rondinelli J, Yim A, Cariou C, Valdez R. Delaying the first newborn bath and exclusive breastfeeding. *MCN Am J Matern Child Nurs*. 2020; 45(2):110-115. doi:10.1097/NMC.0000000000000606

38. DiCioccio HC, Ady C, Bena JF, Albert NM. Initiative to improve exclusive breastfeeding by delaying the newborn bath. *J Obstet Gynecol Neonatal Nurs*. 2019;48(2):189-196. doi:10.1016/j.jogn.2018.12.008

39. Warren S, Midodzi WK, Allwood Newhook LA, Murphy P, Twells L. Effects of delayed newborn bathing on breastfeeding, hypothermia, and hypoglycemia. *J Obstet Gynecol Neonatal Nurs*. 2020;49(2):181-189. doi:10.1016/j.jogn.2019.12.004

40. Turney J, Lowther A, Pyka J, Mollon D, Fields W. Delayed newborn first bath and exclusive breastfeeding rates. *Nurs Womens Health*. 2019; 23(1):31-37. doi:10.1016/j.nwh.2018.12.003

41. World Health Organization. *WHO Recommendations on Postnatal Care of the Mother and Newborn*. World Health Organization; 2013.

42. Chamberlain J, McCarty S, Sorce J, et al. Impact on delayed newborn bathing on exclusive breastfeeding rates, glucose and temperature stability, and weight loss. *J Neonat Nurs*. 2019;25 (2):74-77. doi:10.1016/j.jnn.2018.11.001

43. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK. *Births: Final Data for 2018*. National Center for Health Statistics;2019.

44. Chen HY, Blackwell SC, Chauhan SP. Association between Apgar score at 5 minutes and adverse outcomes among low-risk pregnancies. *J Matern Fetal Neonatal Med*. Published online April 16, 2020. doi:10.1080/14767058.2020.1754789

45. International Liaison Committee on Resuscitation. The International Liaison Committee on Resuscitation (ILCOR) consensus on science with treatment recommendations for pediatric and neonatal patients: pediatric basic and advanced life support. *Pediatrics*. 2006;117(5):e955-e977. doi:10.1542/peds.2006-0206

46. Flaherman VJ, Schaefer EW, Kuzniewicz MW, Li SX, Walsh EM, Paul IM. Early weight loss nomograms for exclusively breastfed newborns. *Pediatrics*. 2015;135(1):e16-e23. doi:10.1542/peds.2014-1532

47. Kuzniewicz MW, Greene DN, Walsh EM, McCulloch CE, Newman TB. Association between laboratory calibration of a serum bilirubin assay, neonatal bilirubin levels, and phototherapy use. *JAMA Pediatr*. 2016;170(6):557-561. doi:10.1001/jamapediatrics.2015.4944