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Abbreviations
AAP American Academy of Pediatrics
ACE2 angiotensin-converting enzyme 2
CDC Centers for Disease Control and Prevention
COVID-19 coronavirus disease 2019
ECMO extracorporeal membrane oxygenation
ICU intensive care unit
MERS Middle East respiratory syndrome
MIS-C multisystem inflammatory syndrome associated with COVID-19
PCR polymerase chain reaction
RT-PCR reverse transcriptase polymerase chain reaction
SARS severe respiratory syndrome
SARS-CoV-2 severe acute respiratory syndrome coronavirus 2

Education Gap(s)
Because of their unique immunologic and physiologic states, pregnant women and neonates may be at risk for worse outcomes related to COVID-19 infection. Unfortunately, the outcomes specific to pregnant women and their neonates are understudied. Clinicians should be able to recognize and describe the clinical presentations and outcomes of COVID-19 in pregnant women and neonates and recognize the potential risks of maternal-fetal and maternal-neonatal transmission of SARS-CoV-2.

Objectives
After completing this article, readers should be able to:
1. Describe the clinical presentations, diagnoses, and outcomes of COVID-19 infection in pregnant women and neonates.
2. Describe the current obstetric and neonatal management of COVID-19.

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3. Recognize the potential for SARS-CoV-2 transmission during pregnancy, delivery, breastfeeding, and at home childcare.

4) Identify methods to reduce the vertical and horizontal transmission of SARS-CoV-2 from the pregnant woman to the neonate.

Abstract
Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for coronavirus disease 2019 (COVID-19), is highly contagious and can cause serious respiratory illness and other clinical manifestations. Unfortunately, the outcomes specific to pregnant women and their neonates are understudied. Because of their unique immunologic and physiologic states, pregnant women and neonates may be especially vulnerable to the effects of COVID-19. The aim of this review is to summarize the clinical presentation, diagnosis, and outcomes of COVID-19 in pregnant women and neonates and to discuss what is known about the potential maternal-fetal and maternal-neonatal transmission of SARS-CoV-2.

Epidemiology of COVID-19 in Pregnant Women and Children
Starting in December 2019, increasing numbers of patients were reported to be admitted to hospitals in Wuhan, Hubei Province, China, with a pneumonialike disorder of unknown etiology. (1)(2)(3) By the end of January 2020, it was estimated that over 7,734 cases had been confirmed in China, and similar cases had been identified in numerous countries around the world. (1) The illness, known as coronavirus disease 2019 (COVID-19), is caused by a novel β-coronavirus called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The condition was associated with symptoms such as fever, dry cough, shortness of breath, weakness, and diarrhea. (1)(2)(4)(5) By the beginning of August 2020, over 18 million people worldwide have been infected with SARS-CoV-2, and 690,181 (3.8%) infected individuals have died globally. (6)

SARS-CoV-2 is thought to affect the respiratory system by binding to the angiotensin-converting enzyme 2 (ACE2) receptor. (7)(8)(9) The ACE2 receptor is thought to be highly expressed in lung tissue; thus, binding of SARS-CoV-2 allows for the virus to be transported into lung epithelia, subsequently damaging the infected tissue. (9)(10) In adult patients with severe
COVID-19, lymphopenia has been observed and substantially elevated proinflammatory cytokines, termed “cytokine storm,” are thought to contribute to further lung tissue injury. (7)(8)(9)(11) SARS-CoV-2 is highly contagious and mainly transmitted via respiratory droplets, though it can be airborne under some conditions. (2)(9)(12)(13) SARS-CoV-2 is estimated to have a reproduction number ranging from 2.2 to 5.7, meaning that without sustained physical distancing measures 1 person with COVID-19 can infect, on average, 2.2 to 5.7 other individuals. (2) Importantly, the reproduction number of SARS-CoV-2 can drastically be reduced to below 1 if appropriate measures are taken (ie, mandatory mask wearing in public, cancellation of social gatherings, stay-at-home policies, and universal symptom screening). (14) Because of the severe respiratory complications caused by SARS-CoV-2 and its highly contagious nature, pregnant women and neonates may be 2 populations at risk for serious complications related to COVID-19. (5)

Few studies have investigated how pregnancy and infancy modify the risks associated with COVID-19. (15) During pregnancy, women have changes in cellular immunity, which make them more susceptible to severe infections. (16)(17) Furthermore, physiologic changes in the cardiovascular and respiratory systems during pregnancy increase the risk for adverse effects of respiratory infections. (16)(17)(18)(19) Newborns are also vulnerable to respiratory infections because their immature immune systems are still developing. (5)(20)(21)(22) The aim of this review is to discuss what is known about the potential for perinatal maternal-fetal and maternal-neonatal transmission of SARS-CoV-2 and offer evidence-based guidelines for safe maternal and neonatal care during the COVID-19 pandemic.
Clinical Presentation, Diagnosis, and Outcomes in Obstetric Patients with COVID-19

Clinical Presentation and Diagnosis in Pregnant Women

Pregnant and nonpregnant women have similar manifestations of COVID-19 symptoms. Both present with symptoms such as fever, dry cough, sore throat, myalgia, malaise, gastrointestinal symptoms, anosmia, and shortness of breath. (18)(19)(23) Pregnant women most frequently report experiencing dry cough (65.6%), fever (48.3%), myalgia (37.9%), or no symptoms at all (33%). (3)(23) The Centers for Disease Control and Prevention (CDC) surveillance data showed that in 91,412 women of reproductive age (15–44 years) who were infected with SARS-CoV-2, there were no differences in the frequency of cough or shortness of breath between pregnant and nonpregnant women. Interestingly, pregnant women reported headaches, muscle aches, fevers, chills, and diarrhea symptoms less frequently than their nonpregnant counterparts. (16) Of particular importance is the large percentage of asymptomatic SARS-COV-2–positive pregnant patients. First described in the epicenter in New York, Breslin et al reported that 14 (33%) of 43 pregnant women testing positive for COVID-19 were asymptomatic or presymptomatic at the initial COVID-19 testing. (23) Thore, universal diagnostic testing for COVID-19 via a nasopharyngeal swab for polymerase chain reaction (PCR) is encouraged for all pregnant women in locations where the prevalence of SARS-CoV-2 is high, to prevent potential nosocomial spread to other patients as well as health care workers. (23)

Outcomes of COVID-19 in Pregnant Women

Although the prognosis of COVID-19 infection is favorable in most pregnant women, (24) recent research raises concerns that pregnant women may be at greater risk for severe COVID-19–
related morbidities than their nonpregnant counterparts. (16)(25) Even though up to 86% of obstetric patients with COVID-19 report mild symptoms, pregnant women, particularly those who are overweight or obese, are more vulnerable to severe SARS-CoV-2 infection. (16)(23)(25) The CDC surveillance data found that pregnant women with COVID-19 were 5.4 times more likely to be hospitalized, 1.5 times more likely to be admitted to the intensive care unit (ICU), and 1.7 times more likely to undergo mechanical ventilation than nonpregnant women with COVID-19. (16) In this study, the reason for hospitalization was not disclosed, thus it is impossible to determine if increased rates of hospitalizations in pregnant women with COVID-19 were related to SARS-CoV-2 infection or pregnancy itself, such as childbirth. Similarly, Sentihes et al described a higher proportion of severe morbidity in pregnant women with COVID-19 than in the general obstetric population. (25) In 54 pregnant women with COVID-19, 24.1% required oxygen supplementation and 9.3% were admitted to the ICU. (25) The most severe cases reported by Sentihes et al occurred in pregnant women more than 35 years of age or with comorbidities such as asthma or obesity. (25) Individual case reports of pregnant women with severe adverse outcomes related to COVID-19 have also been reported. Hosier et al described a 35-year-old woman with COVID-19 at 22 weeks’ gestation who presented with preeclampsia, placental abruption, and disseminated intravascular coagulopathy. SARS-CoV-2 invasion of the placenta was noted, which contributed to placental inflammation, early-onset preeclampsia, and worsened maternal health. (26) Evidence has shown life-threatening complications of SARS-CoV-2 infection in obstetric patients, especially those older than 35 years or with comorbidities; thus all pregnant women need to be counseled on symptoms associated with COVID-19 and should immediately contact their physician if they become symptomatic.
It is hypothesized that COVID-19 may exacerbate comorbidities common to pregnancy such as hypertensive diseases of pregnancy, coagulopathies, and respiratory changes, which can lead to an increased risk of preterm deliveries among pregnant women with COVID-19.

Pierce-Williams et al found that 88% of women with severe COVID-19 infections had preterm deliveries. Other studies have reported preterm deliveries in 24% to 47% of pregnant women who had symptoms of COVID-19. Many of these deliveries were iatrogenic and not associated with spontaneous preterm labor; however, systemic illness in general, has been shown to increase the rate of preterm labor and preterm delivery.

At this time, for pregnant women who have been infected with COVID-19, obstetrical professionals should obtain serial fetal growth scans and evaluate amniotic fluid volume 2 weeks after symptom resolution, for the theoretical concern of fetal growth restriction with SARS-CoV-2 infection. Data on the usefulness of routine antenatal surveillance (with biophysical profile or nonstress test) is unclear for SARS-CoV-2–infected pregnant women. Furthermore, COVID-19 status is not an indication for delivery, and the delivery mode should be dictated by routine obstetrical indications. If preterm labor begins, the decision about magnesium sulfate for fetal neuroprotection at less than 32 weeks’ gestation must be individualized. This is especially important in COVID-19–positive patients with renal injury, who undergo intubation and are receiving benzodiazepines, and those with hypervolemia, because of the confounding risks associated with maternal pulmonary edema and COVID-19. The neonatal benefit of antenatal glucocorticoids for fetal lung maturity for patients at risk for preterm delivery within a week is very well-established. In light of COVID-19–specific data, regardless of pregnancy, recent evidence supports the use of an early, short course of glucocorticoids for patients who
require mechanical ventilation or oxygen support. (36) As such, the National Institutes of Health
COVID-19 Treatment Guidelines Panel recommended 6 mg of dexamethasone for up to 10 days
in patients with COVID-19 who are receiving mechanical ventilation or supplemental oxygen.

This recommendation does not address pregnant or lactating women specifically. For this reason,
administration of antenatal glucocorticoids for fetal lung maturity is recommended for up to 33
6/7 weeks of gestation in patients anticipated to deliver within 7 days; however, the benefit of
antenatal steroids for late preterm fetuses between 34 0/7 and 36 6/7 weeks’ gestation is not
apparent because glucocorticoids have only been investigated with betamethasone, not
dexamethasone in this gestational age. (37)

Caring for the Pregnant Women with COVID-19
For pregnant women with severe COVID-19 illness requiring hospitalization, multidisciplinary
care teams, including maternal-fetal medicine and neonatology, should have discussions with the
patient and family regarding goals of care should the woman go into preterm labor or become
critically ill. (38) Conversations with the patient and family should include discussion of
prioritization of maternal or fetal life, in the event that one might be at severe risk if providing
care that benefits the other. Options that should be discussed in cases of severe maternal
hypoxemia include prone positioning, advanced ventilatory methods, and extracorporeal
membrane oxygenation (ECMO), especially with lower gestational ages, when delivery would
pose significant neonatal morbidity. (39) Studies to date have not shown that maternal ECMO
poses specific increased risk to the fetus, outside of preterm delivery and need for NICU
admission. (40)
However, there are theoretical increased risks to the neonate such as infection, complications related to maternal bleeding complications, or thromboembolic events, as well as altered placental/fetal hemodynamics (e.g., nonpulsatile flow on venoarterial ECMO), though the long-term outcomes of these infants have not been reported. (40)(41) These conversations will allow care teams to appropriately plan the mode of delivery and minimize potential SARS-CoV-2 exposure to healthcare workers by clarifying if resuscitation of an infant is desired at the extremes of prematurity (gray zone of viability). Moreover, these discussions help guide clinical care, even when there is no immediate threat to the pregnant woman or fetus, such as regarding administration of magnesium for preterm labor, maternal steroid use (dexamethasone for acute respiratory distress secondary to COVID-19 vs betamethasone for fetal lung maturity), prophylaxis with unfractionated heparin for thromboembolism, and use of remdesivir. These care guidelines are described in Table 1. (42)(43)(44) Otherwise, supportive cardiorespiratory support to the pregnant woman is always indicated to help support both nutrient and oxygen provision to the woman and the growing fetus.

**Neonatal Outcomes in Infants Born to Mothers with COVID-19**

Neonates who are born to mothers with COVID-19 and test negative for SARS-CoV-2 at birth have promising outcomes. Approximately 2% to 5% of infants born to mothers with COVID-19 test positive for SARS-CoV-2 infection within 24 to 96 hours after birth and most have favorable outcomes. (45) Yu et al described 7 neonates born via caesarean delivery to mothers with COVID-19. (3) All 7 neonates had birthweights greater than 3,000 g and Apgar scores between 8 and 9 at 1 minute and 9 and 10 at 5 minutes after birth. One neonate tested positive for SARS-
CoV-2 based on a nucleic acid test at 36 hours after birth, but no other neonatal complications were identified. (3) Although most infants born to mothers with COVID-19 do well, complications such as respiratory distress and low birthweight may be seen at higher proportions in neonates born to mothers with COVID-19 compared with those born to mothers without COVID-19. (46) Zhu et al reported that of 10 infants born to 9 women with COVID-19, 6 were born preterm, 6 demonstrated intrauterine fetal distress, 6 had respiratory distress at birth, and 2 had thrombocytopenia, even though all infants tested negative for COVID-19 via pharyngeal swab. (47) In addition, 6 pregnant women who were positive for COVID-19 presented with preterm labor. Thore, medical teams able to provide care for high-risk neonates should be available for complicated or preterm deliveries of neonates born to women with COVID-19, especially for deliveries in which pregnant women are critically ill. (38)

Clinical Presentation, Diagnosis, Outcomes, and Treatment of Neonates with COVID-19

Clinical Presentation and Diagnosis

In general, COVID-19 is thought to have a child-sparing pattern, and infected children are largely asymptomatic or have mild symptoms. (22)(48)(49) Researchers estimate that only about 1% of all confirmed or suspected COVID-19 cases have been in children younger than 10 years. (49)(50) It is hypothesized that pediatric populations with COVID-19 infections have milder manifestations compared to adults, because the ACE2 receptor in children may be immature and have lower binding affinity than in adults. (48) Children infected with SARS-CoV-2 most commonly had fever (65%), dry cough/upper respiratory symptoms (50%), and gastrointestinal
symptoms (22%) such as abdominal pain, nausea, and/or vomiting. (4)(5)(51)(52) It is estimated that approximately 16% of children infected with SARS-CoV-2 remain asymptomatic. (5)(51) Although most children are asymptomatic or report mild symptoms, pediatric multisystem inflammatory syndrome associated with COVID-19 (MIS-C) has developed in over 145 children in New York City alone as of May 18, 2020. (53)(54) MIS-C is a severe inflammatory syndrome occurring after SARS-CoV-2 infection in children and is characterized by inflammation of 2 or more organ systems and can present with severe shock. (53)(54)(55) Thus, all children with COVID-19 need to be closely monitored for clinical worsening.

Importantly, infants seem more vulnerable to COVID-19 than other pediatric populations. (56) It is estimated that 18% of all pediatric COVID-19 cases are in infants younger than 1 year. (50) In addition, manifestations of COVID-19 in neonates are often atypical and insidious. (49)(52) Many neonates with COVID-19 present with nonspecific symptoms such as poor feeding, diarrhea, or other mild gastrointestinal symptoms, making COVID-19 challenging to diagnose in this population. (22) Further, case reports describe that infants with COVID-19 may have more severe symptoms than children older than 1 year, and can present with late-onset sepsis, fever, and leukopenia. (56)(57)(58)(59)(60) Because of its atypical presentation, standardized protocols are important for the diagnosis of COVID-19 in neonates. Wu et al found that unlike adults, pediatric patients with COVID-19 did not have systemic inflammation. (61) Other studies have reported lymphopenia, neutropenia, and thrombocytosis in neonates and children with COVID-19. (50)(61)(62)(63)(64)
Thus, potential SARS-CoV-2 infection should be investigated in neonates presenting with sepsis, lymphopenia, or neutropenia without an identifiable cause, and neonates with normal proinflammatory cytokine levels should not be excluded from SARS-CoV-2 testing. SARS-CoV-2 infection should also be suspected if infants have at least 1 clinical symptom, chest radiographic imaging showing ground glass opacities (in term infants) or pneumonia, or a history of close contact with a relative or caretaker with confirmed COVID-19. (51)(63) The diagnosis of COVID-19 can be made in children using reverse transcriptase polymerase chain reaction (RT-PCR) on nasopharyngeal or nasal samples to detect the presence of SARS-CoV-2. (65)

**Outcomes of COVID-19 in Children**

Children appear to be less susceptible to COVID-19 than adults and have good overall outcomes. (4)(52) Children are estimated to begin showing symptoms around 6 days after infection. (52) Children infected with SARS-CoV-2 may have fevers that typically resolve within 24 hours and other mild symptoms dissipating within 1 to 2 weeks, though fecal viral shedding can persist. (52)(66)(67) Of note, neonates, children with underlying conditions, and children with coexisting viral infections are especially vulnerable to severe complications associated with COVID-19. (4)(5) Neonates may be at an increased risk for COVID-19 symptoms because of underdeveloped immune systems. (5)(20)(21)(22) Götzinger et al found that infants younger than 1 month had more severe manifestations of SARS-CoV-2 infections and were more likely to be admitted to the ICU. (5) Pandey et al also found that children younger than 5 years were more likely to have higher SARS-CoV-2 viral loads than older children. (68) A recent multicenter, observational cohort study from New York City described 149 maternal-neonatal dyads hospitalized from March 1 to May 10, 2020. In this study, 12% of neonates required admission
to the NICU, with 10% of these neonates delivered preterm and 3% requiring mechanical ventilation. Of note, neonates born to symptomatic mothers were more likely to be born preterm (16% vs 3%) and require intensive care (19% vs 2%). (69) The potential complications of COVID-19 in infants make it imperative for physicians to counsel parents and caregivers on the symptoms associated with COVID-19 in neonates and consider testing for COVID-19 if they have been in close proximity with other infected individuals.

Management
Currently, there are no vaccines proven to be effective against SARS-CoV-2. (63) Remdesivir is a promising antiviral drug that has shown potential benefit against SARS-CoV-2 infection in adults and is available for compassionate use in children and pregnant women. (70)(71) Additional treatments such as convalescent plasma with neutralizing antibodies and dexamethasone have been studied in adults and may have some benefit in certain situations. For example, in a study of 5 adults who were critically ill with COVID-19 and treated with convalescent plasma, all 5 patients had dissipated fevers within 3 days after transfusion, and improved oxygenation and decreased viral loads within 12 days after transfusion. (72) Though this was a preliminary study, it shows promising results for the use of neutralizing antibodies in critically ill patients. However, these treatment modalities remain unstudied in neonates and as such, there are no guidelines for their use in neonates and children. It is important to note that none of these treatments have been recommended by the World Health Organization or the CDC in the United States. (63) In children and obstetric patients with mild to moderate COVID-19
infection, supportive treatment such as appropriate fluid and caloric intake and oxygen supplementation are the mainstays of management. (63)

SARS-CoV-2 Transmission During Pregnancy, Delivery, and Postdelivery
Maternal-fetal and maternal-neonatal transmission of SARS-CoV-2 are central concerns during the COVID-19 pandemic. Vertical transmission of viruses can occur via intrauterine transmission (ie, blood, transplacental), intrapartum, or through breastfeeding. (22)(26)(73)(74) Respiratory viruses also can be transmitted postnatally via droplets from mother to child. (75) In past coronavirus outbreaks such as severe respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), no cases of vertical transmission were reported. (76)(77) Similarly, early studies on vertical transmission of SARS-CoV-2 showed that the risk was low, though other recent studies have indicated biological plausibility of intrauterine transmission of SARS-CoV-2. (26)(74)(78) To date, it is believed that most neonates with COVID-19 are infected though horizontal transmission of SARS-CoV-2 by a parent or other close contact.

Intrauterine Transmission of SARS-CoV-2
Rates of intrauterine transmission of SARS-CoV-2, if it occurs at all, are extremely low, though SARS-CoV-2 placental invasion and cases of probable SARS-CoV-2 intrauterine transmission have been reported. (8)(22)(26)(73)(74) To date, SARS-CoV-2 has not been identified in most samples of amniotic fluid, umbilical cord blood, or placenta. (18)(77)(78) Chen et al reported that 6 of 6 samples of amniotic fluid and umbilical cord blood tested for SARS-CoV-2 from
symptomatic pregnant women with confirmed COVID-19 infections were negative. (79) Similarly, Simões E Silva et al found that the SARS-CoV-2 virus was not detected in 18 of 18 samples of amniotic fluid, umbilical cord, and/or placenta across 5 different studies. (77) In addition, Simões E Silva et al found that 85 (95.5%) of 89 neonates tested negative for SARS-CoV-2 via nasopharyngeal swab performed within 0 hours to 9 days after birth to mothers with COVID-19, thus providing evidence that intrauterine transmission of SARS-CoV-2 is unlikely. (77) In 4 of the 5 neonates who tested positive for SARS-CoV-2, swabs were collected 3 to 9 days after birth and 3 of the 4 neonates were in close contact with infected mothers after birth; thus, intrauterine transmission could not be assumed and SARS-CoV-2 infection was likely the result of horizontal transmission. (60)(77)(80) Importantly, all of these studies have small sample sizes and vary in their inclusion criteria as well as their mode of detection of infection in the neonate.

Although rare, cases of transplacental transmission and reports of SARS-CoV-2 in amniotic fluid, placenta samples, and positive nasopharyngeal swabs at birth indicate that intrauterine transmission may be possible. Vivanti et al reported a case of transplacental transmission of SARS-CoV-2 in a 23-year-old pregnant woman with known SARS-CoV-2 infection. (78) At birth, SARS-CoV-2 was identified via RT-PCR in samples of amniotic fluid, placental tissue, maternal and neonatal blood, and neonatal nasopharyngeal swab. The viral load detected in placental tissue was substantially higher than that found in amniotic fluid or maternal blood. Immunohistochemistry of placental tissue also showed considerable invasion of trophoblastic cells by SARS-CoV-2 and coexisting placental inflammation. Evidence of high viral load in placental tissue and presence of SARS-CoV-2 in trophoblastic cells support transplacental
transmission in this case of neonatal congenital infection. (78) Patanè et al described 2 neonates testing positive for SARS-CoV-2 at birth. (74) In both cases, invasion of the fetal side of the placental tissue by SARS-CoV-2 was observed. (74) Similarly, Hosier et al reported a case in which SARS-CoV-2 was identified in the syncytiotrophoblast of the placenta, though fetal lung, heart, liver, and kidney tissues were negative for SARS-CoV-2. (26) Zamaniyan et al also reported that amniotic fluid collected during cesarean delivery of a pregnant woman with COVID-19 tested positive for SARS-CoV-2 on RT-PCR. (81) These reports demonstrate that intrauterine transmission of SARS-CoV-2 may be possible. Further research on the incidence of intrauterine transmission, with an emphasis on transplacental transmission, is imperative.

All neonates born to mothers who are infected with or suspected to have COVID-19 should be tested for COVID-19 via nasopharyngeal or nasal swab RT-PCR and monitored for COVID-19 symptoms after delivery. (82) The CDC recommends testing the neonate at approximately 24 hours of age, then again at 48 hours of age if the initial test results are negative. (82) Importantly, the optimal timing for testing the neonate remains unclear, and early testing can increase the chances of both false positives (ie, contamination of the naso-/oro-pharynx by SARS-CoV-2 RNA in maternal fluids) and false negatives (RNA may not be immediately detectable after birth). (82) Caregivers for these neonates should use appropriate personal protective equipment until testing confirms lack of infection. Also, large-scale studies need to test amniotic fluid, umbilical cord blood, placental tissue, and neonatal pharyngeal swabs for SARS-CoV-2 to determine the rate of intrauterine transmission.
SARS-CoV-2 Transmission During Delivery

Maternal-neonatal transmission of SARS-CoV-2 is unlikely in both vaginal and cesarean deliveries. (18)(42)(83) A large proportion of deliveries for obstetric patients with COVID-19, especially those who are critically ill, have been via cesarean section. (19)(24)(83)(84) Khoury et al reported that in a cohort of 241 pregnant women with COVID-19, 41.5% had cesarean births. In the same study, obstetric patients with severe or critical manifestations of COVID-19 were more likely to be delivered via cesarean section than those who were asymptomatic or had mild COVID-19 infection. (85) However, given the lack of evidence that cesarean delivery is superior to vaginal delivery for pregnant women with COVID-19, the potential short- and long-term risks of cesarean delivery for both the woman and neonate are important to consider. Obstetric patients with COVID-19 who had cesarean deliveries were more likely to experience worse postpartum complications than those who had vaginal deliveries. (86) Moreover, cesarean delivery requiring transportation of patients from the ICU to the operating room may increase the risk of SARS-CoV-2 transmission to both hospital workers and other patients. (83) Vaginal delivery has been proven safe for both pregnant women with COVID-19 and their neonates. (86)

SARS-CoV-2 has not been identified in vaginal secretion samples (18)(77)(87) and has only been identified in a few fecal samples from pregnant women, (18)(87) reducing the likelihood of maternal-neonatal transmission during delivery. Successful vaginal deliveries have been reported, even in patients critically ill with COVID-19, and so, mode of delivery should be dictated by routine obstetrical indications and not the COVID-19 status of the pregnant woman. (43)(83)
Transmission of SARS-CoV-2 Through Breast Milk

It is unlikely that SARS-CoV-2 is transmitted through breast milk. (88) In previous coronavirus epidemics, both SARS and MERS were not identified in breast milk. (76) Similarly, SARS-CoV-2 was not detected in 63 of 64 breast milk samples examined in 18 women with COVID-19 via RT-PCR. (88) Other individual cases of SARS-CoV-2 in breast milk have been identified in China and Germany, though mothers were not wearing masks during breast milk collection and the sample may have become contaminated. (89) The safety of breastfeeding by mothers with COVID-19 is further supported by the findings of Salvatore et al who observed that in 64 infants breastfed by mothers with COVID-19 who used surgical masks and washed their hands and breasts before feeding, all infants tested negative for SARS-CoV-2 at 5 to 7 days and 14 days after birth. (90) Though current research results show promise for the safety of breastfeeding by mothers with COVID-19 if proper precautions are followed, further research is still needed to investigate how detection and viral load of SARS-CoV-2 in breast milk may change as a mother’s SARS-CoV-2 infection progresses.

Current research indicates that the risk of transmission through breast milk remains low and thus, breastfeeding should be supported for all mothers and neonates. (45) Breast milk is very important for the proper nutrition and immunologic development of the neonate. (89) However, breastfeeding requires close maternal-neonatal contact that can potentially increase the risk of transmission. If mothers with COVID-19 wish to directly nurse their infants, physicians need to advise parents on the risks of transmission of SARS-CoV-2 during in-person breastfeeding and preventive measures must be followed, including washing of hands and breasts, wearing masks during feeding, and the use of a well-ventilated room during feeding. (45)(89) In accordance
with the American Academy of Pediatrics (AAP) recommendations, mothers infected with SARS-CoV-2 should breastfeed, either directly or through expressed breast milk. (89)(91)(92)

When expressing breast milk, mothers should practice proper hygiene including mask wearing and thorough washing of hands, breasts, pumps, and bottles. Ideally, expressed breast milk can be fed to the neonate by an uninfected caregiver, as recommended by the AAP. (45)(91)

**Horizontal Transmission of SARS-CoV-2**

Close contact with an infected person, usually the parent, is the most likely cause of SARS-CoV-2 transmission to a neonate. In a study of 582 children positive for COVID-19, infected parents were identified as the infection source in 56% of cases. (5) Wu et al found that 95.6% of COVID-19 cases in children were caused by transmission from an infected parent. (62) Physical distancing from infected family members is extremely challenging, especially for parents of newborns. Maternal-neonatal skin contact has lifelong mental, emotional, and physical health benefits. (8) To prioritize skin-to-skin contact while also preventing possible SARS-CoV-2 transmission between the neonate and a mother with a known or suspected SARS-CoV-2 infection in the immediate postpartum period, we recommend working with parents and the health care team to balance the risks and benefits of various rooming options while the dyad is still hospitalized after delivery. (82) To facilitate this decision, the CDC recommends that care teams discuss with parents the benefits of rooming-in, such as improved mother-infant bonding, identification of infant feeding behaviors, and improved family-centered care. (82) Of note, infants rooming-in with mothers with COVID-19 are not at increased risk for contracting SARS-CoV-2 when proper prevention measures are followed compared with infants who are separated. (45) If the neonate is healthy and the mother with COVID-19 has mild-to-moderate symptoms,
the neonate can safely room with the infected mother and the mother should maintain a reasonable distance from the infant when possible.

The neonate can be placed in a closed isolette at least 6 feet from the mother, if needed, to facilitate distancing. (8)(82) When the mother is holding or breastfeeding her neonate, she should wear a mask and practice proper hand hygiene. (8) Importantly, neonates should not wear face shields or masks. (82) If the neonate requires NICU admission, the neonate should be isolated until viral tests are confirmed negative, with consideration to continue isolation practices up to 14 days after birth. Appropriate precautions should be used in the decision to allow the noninfected parent to visit the NICU, balancing the risks of exposure to the infected individual with an appropriate observation period without symptoms. (8) Visiting parents should practice proper hand hygiene, wear masks, and stay next to their neonate while in the NICU. (8) Any parent testing positive for COVID-19 should not be allowed in the NICU unless that parent meets criteria for discontinuing home isolation. (8) See Table 2 for more recommendations.

After a mother with COVID-19 and an uninfected neonate are discharged from the hospital, home isolation and physical distancing should be practiced until the mother’s symptoms have improved and she remains afebrile for 24 hours and has been isolated for 10 days since symptom onset. (93) When possible, the infected mother should maintain a physical distance of at least 6 feet from her child and should practice hand hygiene and mask wearing when caring for the infant. Other household members with suspected SARS-CoV-2 infection should immediately get tested for SARS-CoV-2 and follow the CDC’s home isolation and physical distancing guidelines before caring for the infant. (93) Parents should be counseled on the symptoms and risks of

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COVID-19 in neonates and immediately contact their physician should SARS-CoV-2 infection be suspected.

**Conclusion**

SARS-CoV-2, the virus responsible for COVID-19, is highly contagious and can cause serious respiratory illness. Research indicates that pregnant women may be at risk for more severe SARS-CoV-2 infection, and COVID-19 may lead to preterm deliveries, especially in critically ill pregnant women. Young children, especially neonates, may also be at risk for more severe manifestations of COVID-19. Though maternal-fetal vertical transmission is possible, it seems unlikely. Rather, close contact with an infected individual in the immediate postnatal period is more likely responsible for SARS-CoV-2 infections in neonates. Parents and health care professionals need to work together to balance the risks and benefits of skin-to-skin contact and breastfeeding. The recommendations in this review article are not definitive given the small sample sizes in studies published so far on pregnant women and infants and COVID-19. Further research is needed to determine the risks of COVID-19 in pregnant women and infants and to investigate the possibility of intrauterine transmission of SARS-CoV-2.

**American Board of Pediatrics Neonatal-Perinatal Content Specification**

1. Identify risks associated with SARS-CoV-2 infections in both obstetric patients and neonates
2. Identify care management recommendations for obstetric patients and neonates with COVID-19
3. Recognize the possible modes of transmission for maternal-fetal and maternal-neonatal transmission of SARS-CoV-2.
4. Describe current recommendations about breastfeeding, rooming-in, and NICU visitation to limit transmission of SARS-CoV-2 to patients and healthcare workers

**References**

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Table 1. Recommended Care Management of Pregnant Women During the COVID-19 Pandemic

<table>
<thead>
<tr>
<th>Category of Care</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>Screening and diagnosis</td>
<td>Use telehealth appointments when deemed appropriate for prenatal care in all obstetric patients to limit transmission of SARS-CoV-2 infections to both patients and health care workers.</td>
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<td>If obstetric patients require in-person appointments, screen all patients for COVID-19 symptoms before each prenatal appointment.</td>
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<td>Counsel patients on symptoms associated with COVID-19 and advise patients to contact their physician if they develop COVID-19 symptoms. (42) If obstetric patients with COVID-19 are asymptomatic or have mild</td>
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<th>Treatment and pharmacologic management</th>
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<td>symptoms, patients should self-quarantine for 10 days and monitoring in the outpatient setting can be considered. Test all pregnant women requiring admission to the hospital for active COVID-19 infection via SARS-CoV-2 reverse transcriptase polymerase chain reaction nasopharyngeal or nasal swab. Provide supportive care, including appropriate fluid and caloric intake. (42) For pregnant patients with a known or potential COVID-19 diagnosis who require chest imaging for improved medical care, avoid withholding radiography and CT. Single radiographs and CT scans with abdominal shielding expose the fetus to low levels of radiation and have not been shown to have teratogenic effects. (43) Administer high-dose corticosteroids, such as dexamethasone, when clinically indicated. Pregnant women should, however, be monitored for preterm labor. (3)(42) Recognize that remdesivir, IL-6 modulators, and convalescent plasma administration have not been extensively studied in pregnant women. Compassionate use of these medications in pregnant women who are critically ill with COVID-19 can be considered. Administer prophylactic treatment for venous thromboembolism (unfractionated heparin) to pregnant women hospitalized for COVID-19. (44) Individualize care of pregnant women with COVID-19 experiencing labor before 32 weeks’ gestation to determine the efficacy of magnesium sulfate for neuroprotection, especially in cases of renal injury, intubated patients with benzodiazepine exposure, and hypervolemia. Administer antenatal glucocorticoids for fetal lung maturity to obstetric patients with COVID-19 before 33 6/7 weeks of gestation who are anticipated to deliver within 7 days; however, ACOG does not recommend using antenatal steroids after 34 0/7 weeks’ gestation. (35) Monitor oxygen and carbon dioxide levels frequently; maintaining SpO295% and Pco2 between 27 and 32 mm Hg (3.6–4.3 kPa). (42) Administer supplemental oxygenation if pregnant woman is unable to maintain SpO295% and PCO2 between 27 and 32 mm Hg (3.6–4.3 kPa). (42) Notify designated airway team immediately of pregnant COVID-19–positive patients at risk for intubation, as intubation of pregnant individuals may result in oropharyngeal edema and require additional measures. (42) Determine timing and mode of delivery based on routine obstetrical indications. Delivery should not be used as a treatment to improve maternal respiratory symptoms, except in cases of maternal cardiac arrest. (27)(42) Request that the neonatology team attend deliveries of women who are critically ill with COVID-19 to provide immediate care for potentially high-risk neonates.</td>
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ACOG=American College of Obstetricians and Gynecologists; COVID-19=coronavirus disease 2019; CT=computed tomography; IL-6=interleukin 6; Pco2=partial pressure of carbon dioxide; SARS-CoV-2=severe acute respiratory syndrome coronavirus 2; Spo2=oxygen saturation.

Table 2. Recommended Guidelines for Delivery and Postdelivery Neonatal Care in Obstetric Patients with COVID-19

<table>
<thead>
<tr>
<th>Patients</th>
<th>Recommendations</th>
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<tr>
<td><strong>Asymptomatic COVID-19–positive obstetric patients and obstetric patients with mild COVID-19 symptoms</strong></td>
<td>Delivery: Vaginal delivery of asymptomatic patients or patients with mild COVID-19 should be promoted when cesarean delivery is not clinically indicated. (42)(83)(94) Rooming: Neonates can safely room-in with mothers with COVID-19 if proper precautions are taken. The neonate should remain 6 feet from the infected mother and ideally be placed in a closed incubator. (8) Breastfeeding: Neonates born to mothers with COVID-19 should be breastfed, ideally using expressed breast milk fed to the neonate by an uninfected caregiver using a bottle. (91) When expressing breastmilk, mothers should practice proper hygiene including mask wearing and thorough washing of hands, breasts, pumps, and bottles. Mothers who prefer to directly nurse their infants should follow stringent hygiene measures, including washing of hands and breasts, wearing masks during feeding, and the use of a well-ventilated or negative pressure room during feeding. (89) NICU policy: If the neonate requires NICU admission, only noninfected parents should be allowed to visit the NICU if they have not developed symptoms and have not tested positive for COVID-19. (8) Visiting parents should practice proper hand hygiene, wear masks, and stay next to their neonate while in the NICU. (8) Parents with COVID-19 should not be allowed to visit until they have properly isolated for 10 days after onset of symptoms or date of positive RT-PCR test and have been afebrile for 24 hours. (91)(94)(95)</td>
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<td><strong>Obstetric patients with severe or critical COVID-19 symptoms</strong></td>
<td>Delivery: Timing of delivery should be individualized and based on maternal status, critical illness, gestational age, and shared decision-making with patient and/or health care proxy. Need for mechanical ventilation of the pregnant woman is not an indication for delivery. (42)(83) Rooming: Neonates should be allowed to room-in with mothers with suspected or confirmed COVID-19. Mothers should maintain a reasonable distance from infants when possible. When providing hands-on care, the mothers and noninfected partners/other family members should wear masks and use appropriate hand hygiene. If separation is not possible, the neonate can be placed in a closed isolette to facilitate distancing and for additional protection. (8) Breastfeeding: Neonates born to mothers with COVID-19 can be breastfed or receive breast milk by having an uninfected caregiver provide expressed breastmilk to the neonate using a bottle. (91) When expressing breastmilk or breastfeeding, mothers should practice proper hygiene including mask wearing and thorough washing of hands, breasts, pumps, and bottles.</td>
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NICU policy: Some parents may choose to use formula or breast milk provided by a milk bank. Though not preferred, if this is the only option, all bottles for feeding require extensive cleaning before use, as per standard practice. (96)

COVID-19=coronavirus disease 2019; RT-PCR= reverse transcriptase polymerase chain reaction.