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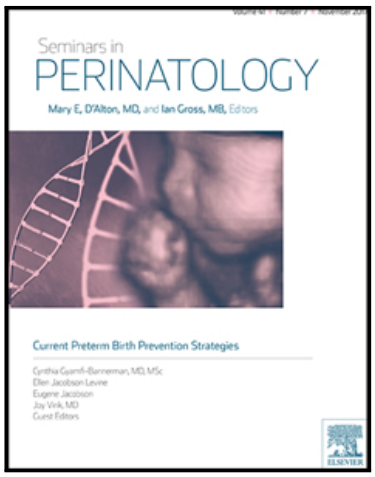

A Review of Newborn Outcomes During the COVID-19 Pandemic

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A Review of Newborn Outcomes During the COVID-19 Pandemic

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Abstract

As the COVID-19 pandemic continues to spread worldwide, it is crucial that we determine populations that are at-risk and develop appropriate clinical care policies to protect them. While several respiratory illnesses are known to seriously impact pregnant women and newborns, preliminary data on the novel SARS-CoV-2 Coronavirus suggest that these groups are no more at-risk than the general population. Here, we review the available literature on newborns born to infected mothers and show that newborns of mothers with positive/suspected SARS-CoV-2 infections rarely acquire the disease or show adverse clinical outcomes. With this evidence in mind, it appears that strict postnatal care policies, including separating mothers and newborns, discouraging breastfeeding, and performing early bathing, may be more likely to adversely impact newborns than they are to reduce the low risk of maternal transmission of SARS-CoV-2 or the even lower risk of severe COVID-19 disease in otherwise healthy newborns.

Introduction

The COVID-19 pandemic, caused by the novel SARS-CoV-2 Coronavirus, has, to date (June 11, 2020), infected over 7 million people worldwide and resulted in over 413,000 deaths.[1] In the United States (U.S.) alone, there have been over 2 million cases and 113,000 deaths.[2] As the world faces an unprecedented public health crisis, an important focus has become the protection of our most vulnerable populations, including pregnant women and newborns. Data on these groups are more limited than from the general adult population, but preliminary reports from our medical center suggest that up to one in eight pregnant women may test positive for SARS-CoV-2.[3] Given the increased risk that many respiratory viruses impose on newborns with immature immune systems,[4] elucidating clinical features and practices associated with favorable outcomes in newborns born to mothers with positive/suspected SARS-CoV-2 infection is essential for informing evidence-based postnatal care practices.

Following the rapid spread of SARS-CoV-2, many hospitals have rushed to implement strict policies of postnatal infection control practices in newborns born to infected mothers (for a full discussion of infection control policies, see **Chapter** *Infection Prevention and Control for Labor and Delivery, Well Baby Nurseries, and the Neonatal Intensive Care Units*). In short, published guidelines tend towards separation of mothers and newborns, immediately bathing newborns, and avoiding direct breastfeeding.[5-7] As such, in most of the literature that has reported on babies born to mothers with positive/suspected SARS-CoV-2 infection thus far, hospital policies treat the newborn as a person under investigation (PUI), isolating newborns and allowing formula feeding only (Table 1). Some groups do report care practices that allow direct breastfeeding with masks and rooming-in

of newborns and mothers with positive/suspected SARS-CoV-2 infection,[8-11] but these studies are in the minority.

These strict neonatal care practices are similar to those followed during prior severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS) outbreaks,[12,13] which, based on limited data, had serious adverse effects on pregnant women and newborns.[13,14] However, the necessity of such practices in light of the current data on SARS-CoV-2, which are more expansive and show little evidence of perinatal transmission or adverse newborn outcomes (Table 1), must be called into question. In the majority of cases, SARS-CoV-2 seems unlikely to infect or adversely impact newborns of infected mothers, and neonatal infection rates do not seem to differ between strict and more lenient postnatal care practices (Table 1). On the other hand, a large body of cross-species literature illustrates the dangers of early life separation of newborns from their mothers.[15-24] Moreover, the evidence supporting the developmental benefits of direct breastfeeding and delayed newborn bathing is vast.[25-28] In caring for newborns in the age of the SARS-CoV-2 pandemic, it is imperative that clinicians empirically weigh the existing evidence regarding perinatal transmission and newborn outcomes against the decades of evidence that have contributed to our knowledge of beneficial postnatal care practices.

Outcomes in newborns born to mothers with positive/suspected SARS-CoV-2 infection: what is known

Newborn health and infection outcomes

Several reports on newborns born to mothers with positive/suspected SARS-CoV-2 infection have been released in recent weeks. While the original data came primarily from

China and consisted of small samples of case studies, recent studies reporting on larger cohorts representing four diverse epicenters, China (including Wuhan and additional regions; n=86 newborns tested),[29] Northern Italy (n=42),[8] the United Kingdom (n=244),[30] and New York City (n=101),[31] have provided more robust evidence. Together, the published literature (Table 1) suggests that newborns are unlikely to be affected by maternal SARS-CoV-2 infection. Of 836 total newborns studied to date (with attempt made to exclude studies with repeat populations), 35 newborns (4.2%) tested positive via polymerase chain reaction (PCR). Further, the majority of studies reported no respiratory or other illness in newborns born to mothers with positive/suspected SARS-CoV-2 infection (Table 1). General indicators of newborn health, where reported, also seem promising. Apgar scores were at least 7 at 5 minutes in 98.8% of newborns, which is consistent with the U.S. national average of 98.9%.[32] Notably, the only six neonates with 5 minute Apgars below 7 were born very premature,[8,33-35] and even several studies including critically ill mothers reported normal Apgar scores in newborns.[29,31,34,36,37] SARS-CoV-2 in mothers does appear to be associated with a slightly higher risk of delivering preterm, but this difference seems to be driven by maternal disease severity in critically ill mothers. Approximately 22% of newborns studied thus far were born premature (gestational age less than 37 weeks), compared to the U.S. national average of 10%.[38] This number, however, is confounded by several studies that report only on severely and critically ill mothers and their newborns. It is currently unclear if asymptomatic or mildly symptomatic mothers, which comprise approximately 80-90% of cases,[3,9,31] have an increased risk of delivering prematurely. On the other hand, preterm birth has been reported in up to 29% of mothers with severe disease and 88% of mothers with critical disease,[39] and likely occurs iatrogenically, as a result of acute respiratory distress and other severe complications in this subset of women.

The few studies in which newborns have become infected report favorable outcomes. PCR-confirmed infected newborns have been documented to show typical mild to moderate symptoms associated with SARS-CoV-2, including cough, respiratory distress, fever, and pneumonia,[36,40-42] but some newborns are asymptomatic.[8,35,39,43-45] Symptomatic newborns generally recover in one to two weeks with no subsequently reported negative health outcomes, though long-term follow-up is currently lacking. One exception is a neonate born at 30 5/7 weeks gestation to a critically ill mother who tested negative at birth, but developed pneumonia and tested positive at day of life (DOL) 7. As of publication, at approximately one month of age, this neonate was still intubated, but in stable condition.[36] Notably, three of the PCR-confirmed SARS-CoV-2 positive newborns tested negative at birth but positive upon retesting two to 15 days later, suggesting routes of infection other than direct vertical transmission from the mother.[36,39,44] Nine additional newborns have shown elevated levels of SARS-CoV-2 IgG or IgM antibodies in cord blood,[30,46-48] which was reported as evidence of vertical transmission. However, the reliability of serology tests to diagnose SARS-CoV-2 is disputed[49] and some of these antibodies may have passively crossed the placental barrier from the mother, thus potentially conferring protection rather than disease.[50] Furthermore, these newborns tested negative via PCR and showed no symptoms suggestive of infection (note these newborns are not considered positive in Table 1). To our knowledge at the time of publication, no newborn critical illness or death can be attributed solely to SARS-CoV-2, as severely afflicted neonates have all been premature and/or suffered from other comorbidities.[33,36]

Although newborns infected with SARS-CoV-2 seem to recover and fare well, there are a few cases of poor outcomes or death due to critical maternal disease status, irrespective of neonatal infection. Hantoushzadeh and colleagues[36] reported on nine critically ill pregnant women infected with SARS-CoV-2 in Iran, of whom seven mothers died. Unfortunately, three neonates of two of the mothers who died (including one set of twins) also died. Both mothers were intubated for acute respiratory distress syndrome (ARDS) and one spontaneously delivered a stillborn neonate at 30 3/7 weeks gestation, while the other suffered septic shock and an intrauterine fetal death (IUFD) of both twins at 24 0/7 weeks gestation. Yan and colleagues[29] reported a similar case from China of a neonate born to a mother intubated with severe pneumonia and septic shock, in which the neonate died of asphyxia shortly after birth. Although alarming, these cases are indeed rare and the risk of severe outcomes does not appear to be associated with pregnancy: a recent study from New York found that 9.8% of pregnant women were admitted to the ICU for worsening respiratory status in one hospital, compared to 15.1% of non-pregnant women,[51] and data from our group[3,9,31] suggest that pregnant women may present asymptomatically or with mild symptoms at a higher rate (90%) than the general population estimate reported by Wu and McGoogan (81%).[52]

Routes of potential perinatal transmission and postnatal infection in newborns

Preventing potential neonatal infection and developing appropriate guidelines for neonatal care relies on understanding the potential routes of transmission from mother to newborn. Toward this effort, several groups have tested placenta specimens, amniotic fluid, maternal vaginal secretions, and breast milk for SARS-CoV-2.[29,46,48,53-58] Of these studies, most report negative results in all specimens in addition to negative newborn nasopharyngeal samples.[29,46,48,53-57] Interestingly, in one case report, the newborn became infected, but these specimens tested negative,[40] providing evidence against the

possibility of perinatal transmission through breast milk or vaginal delivery. Of note, Wu and colleagues[58] reported one SARS-CoV-2 viral RNA positive breast milk sample in the mother of a non-infected newborn, but other studies that tested breast milk do not corroborate this finding.[40,48,53,54,56,59,60] Taken together, while reassuring in supporting the safety of vaginal birth and, largely, breastfeeding, these findings of negative maternal specimens leave the route of transmission unclear in the few newborns who do test positive. Most likely, these newborns become infected via the same route as the rest of the population, via community or household-acquired transmission.

As mentioned above, three of the PCR-positive newborns in the literature to date seemingly acquired the virus postnatally, following negative neonatal testing. An additional five newborns were not tested at birth, but tested positive one to seventeen days later after varying postnatal practices were employed. These cases of delayed positive swabs are rare, but important in considering potential transmission routes and appropriate postnatal care. One newborn who was directly breastfed and whose nasopharyngeal swab, maternal breast milk, placental, and amniotic fluid samples were PCR-negative after birth became positive upon retest at DOL15.[44] Interestingly, however, this newborn remained asymptomatic, and the cord blood and maternal breast milk tested positive for IgG antibodies at birth, leading the authors to speculate that maternal breast milk antibodies actually protected the newborn from more severe, symptomatic infection. The one neonate who remained intubated at the time of publication[36] also tested negative at birth before developing pneumonia at DOL2 and testing positive at DOL7. This neonate remained isolated in the neonatal intensive care unit (NICU) following birth, so it is unlikely that infection was acquired postnatally. Likewise, a newborn born to a severely ill mother in the United States tested negative at birth and

positive at DOL2,[39] but because postnatal care practices were not included in the report, potential routes of transmission cannot be speculated on. Although these cases raise the concern that SARS-CoV-2 infection may not be detected in the first test, other studies that followed up on both positive and negative newborns provide evidence to the contrary: one study found that three SARS-CoV-2-infected newborns were positive at DOL2 and negative by DOL7,[33] while several studies that repeatedly tested negative newborns did not find infection in retests.[31,48,57,60] Additional late and/or distinct positives include two newborns in Italy who tested positive on DOL1 and DOL3, respectively, after their mothers were diagnosed with SARS-CoV-2 during the postpartum period and thus had contact with newborns without personal protective equipment prior to maternal diagnosis.[8] Similarly, two newborns in China who had been discharged from the hospital subsequently tested positive at DOL5 and DOL17.[61]

Although such instances of late positive swabs may raise concern regarding postnatal care that allows for mother-newborn contact, available data from groups who allow rooming-in and breastfeeding are encouraging. Our group has published data on a relatively large cohort of women and newborns in which breastfeeding with masks and appropriate hand and breast hygiene was encouraged and newborns were housed in isolettes kept six feet away from mothers.[9,31] Although two of these newborns tested indeterminate, or “presumptive positive,” they showed no clinical evidence of infection and no infants in the study tested positive on re-test.[31] In the same study that showed two cases of newborn infection due to unprotected contact with undiagnosed mothers,[8] the authors reported ten instances of mothers who directly breastfed with a mask whose newborns did not become infected, suggesting that respiratory droplets are more likely to spread the virus from mother to newborn than breast milk. Lowe and Bopp[11] also

reported on a newborn who was breastfed and not isolated from the mother, who was not retested after a negative swab at 24 hours but was followed for 10 days postnatally and remained well and asymptomatic. The first case study from India also allowed breastfeeding and postnatal contact between mother and newborn, and the newborn tested negative for SARS-CoV-2 at DOL7.[10] In total, none of the studies that allowed breastfeeding and mother-newborn contact with masks and handwashing reported any subsequently positive newborns, whereas almost all of the studies with infected newborns had employed formula-feeding and separation policies postnatally.

While this preliminary data on limited postnatal infection transmission are promising, additional follow-up data beyond the immediate postnatal period is needed. The current newborn testing data relies primarily on nasopharyngeal swabs performed at birth or within the first few days of life with varying numbers of repetitions (Table 1). With the exception of the aforementioned instances of delayed positive swabs, studies that do report repeated testing and longer follow-up periods generally show negative newborns continue to test negative, and positive newborns do not seem to have any additional complications. To our knowledge, however, only seven studies report follow-up periods beyond approximately the first two weeks of life.[31,36,41,57,61-63] Immediate and long-term clinical outcomes in both infected and non-infected newborns born to mothers with positive SARS-CoV-2 infection will be an essential topic for research in the coming months and years.

Returning to evidence-based practices of neonatal care

The understandable trepidation regarding unknown effects of COVID-19 on newborns has thus far driven policies of strict separation between newborns and mothers with

positive/suspected SARS-CoV-2 infection, but the body of evidence on neonatal outcomes that we review here suggests these practices may be unnecessary. A recent New England Journal of Medicine opinion article expressed the importance of relying on scientific evidence, particularly as the uncertainty and fear surrounding a global pandemic leaves physicians, as well as the general public, more likely to succumb to cognitive error and weigh anecdotal reports disproportionately.[64] While frightening case studies of critically ill mothers and inexplicably infected newborns do exist, they must be considered within the greater context of newborns and SARS-CoV-2-infected mothers studied. Direct breastfeeding following hand and breast hygiene in combination with mask wearing has not been reported to cause neonatal SARS-CoV-2 infection to date. The 35 newborns reported as SARS-CoV-2-positive in the literature did not seem to become infected as a result of these policies: most were either in the presence of their mothers prior to maternal diagnosis and therefore without protective policies in place, or were solely formula-fed and separated from their mothers postnatally.

Further, there is significant evidence suggesting the danger of isolating newborns early in life. Mother-newborn separation during the immediate postpartum period is associated with long-lasting deficits in maternal behavior and feelings of competency,[23] as well as infant self-regulation and mother-infant relationships.[22] Additionally, newborns show altered heart rate variability during separation from their mothers,[24] and a plethora of evidence from animal models shows that early life mother-offspring contact regulates the development of autonomic and neuroendocrine systems in mammals.[15-21] Interventions that enhance mother-infant contact are also associated with short- and long-term improved neurodevelopmental and behavioral outcomes in newborns and children,[65,66]

further underscoring the importance of this early exposure to the mother during development.

Breastfeeding practices

Evidence of the importance of direct breastfeeding and, imperatively, of its ability to protect against infection during neonatal development is also expansive. Breastfeeding has repeatedly been shown to lower rates of upper and lower respiratory tract and gastrointestinal infections in newborns.[25,67,68] The mechanism of this protection likely stems from bioactive factors in breast milk, including maternal immune cells, proteins, healthy bacteria, and human milk oligosaccharides, that support the development of the immune response, mucosal barrier, and microbiome in newborns.[26] The assortment of oligosaccharides in human breast milk, in particular, provides nutrients for microbiota in the colon, supporting the establishment of a healthy microbiome in newborns,[28] which is linked to improved health and reduced risk of obesity, diabetes, and other metabolic diseases for the duration of the child's life.[69,70]

Although some published guidelines recommend that mothers with positive/suspected SARS-CoV-2 infection feed expressed breast milk as an alternative to direct breastfeeding,[5] there is significant evidence to suggest that the mode of breastfeeding is an essential component of promoting a healthy newborn microbiome. One study found that exposure to areola skin in addition to maternal milk was necessary to developing the microbiome, and that newborns fed a mix of formula and breast milk had a microbiome composition that was more similar to those that were exclusively formula-fed.[71] Other studies have shown that feeding methods other than direct, exclusive breastfeeding were associated with increased risk of asthma[72] and negative microbiota parameters including depletion of bifidobacteria and enrichment of potential pathogens.[73]

Bathing practices

While few studies have reported on newborn bathing in the context of SARS-CoV-2, some published guidelines encourage immediate bathing of newborns in an effort to reduce risk of infection spread.[5-7] The studies that have discussed the timing of bathing do not differ in newborn outcomes: two studies that bathed newborns immediately after birth[54,74] reported no SARS-CoV-2-positive newborns, but our group also reported no positive results in our larger cohort of newborns who had delayed bathing, while the two newborns with indeterminate results received early baths.[31] Delayed bathing, which is defined as delaying the first bath until at least 24 hours of life, is recommended by the World Health Organization and has a range of benefits for newborns.[75] Delaying the first bath has been shown to decrease rates of hypothermia and hypoglycemia in newborns,[27,76] while improving exclusive breastfeeding.[27,77-79] Retaining the vernix and amniotic fluid by delaying bathing aids in temperature regulation, and the scent of amniotic fluid helps to guide newborns during breastfeeding.[80] Importantly, delayed bathing allows sustained postnatal contact with maternal microbes from vaginal secretions, as well as amniotic fluid and fetal membranes, which has been shown to contribute to the development of the newborn's microbiome.[81] While a major impetus to bathe early as an infection control policy is to reduce the risk of exposure to pathogens for both newborns and hospital staff, several groups have tested vaginal secretions and amniotic fluid and shown that SARS-CoV-2 is not detected in these specimens.[29,40,46,48,53,55-57,82]

Conclusions

The available data on newborn outcomes, and the postnatal care practices used in the context of these outcomes, suggest that a re-framing of the perceived neonatal risk

imposed by SARS-CoV-2 is necessary. In the over 800 newborns reported on in the literature, the incidence of vertical transmission has proven to be low. Additionally, adverse newborn outcomes seem to be a function of maternal disease status in the small subset of newborns with critically ill mothers, rather than illness due to SARS-CoV-2 infection. Furthermore, postnatal transmission through any route other than respiratory particles shared between mother and newborn appears to be unlikely. The benefits conferred by early exposure to the mother, direct breastfeeding, and delayed bathing have a far more substantial body of supporting evidence, and therefore, the established benefits of these practices appear to outweigh the risk of viral transmission to the newborn. While more long-term follow-up data and studies on routes of transmission in the few newborns who are infected at birth are greatly needed, the preliminary evidence on outcomes in newborns born to SARS-CoV-2-infected mothers is reassuring.

Disclosure statement

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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Table 1. Infants born to SARS-CoV-2 positive mothers and reported in the literature[a,b]

Reference	Country	Date published	Total N infants tested	N born via cesarean	N born preterm	N PCR-infected infants	Number of times swabbed	Antibody differences	Infected infant symptoms	Infant outcomes	Maternal severity	N Apgar score <7 at 5 min	Feeding	Mother-infant isolation	Early bathing	Latest follow-up
Zhu et al.[83]	China	2/10/20	10	7	6	0	1	NR			Mild	0	Presumed formula	Yes	NR	DOL14
Liu, Wang et al.[82]	China	2/25/20	3	2	0	0	1	NR			Mild	0	Formula	Yes	Yes	DOL1
Wang, Zhou et al.[57]	China	2/28/20	1	1	1	0	3	NR			Severe	0	Formula	Yes	NR	DOL20
Liu, Chen et al.[84]	China	3/4/20	13	10	6	0	NR	NR			Mild to moderate	0	NR	NR	NR	NR*
Li, Zhao et al.[60]	China	3/5/20	1	1	1	0	7	NR			Mild	NR	NR	NR	NR	DOL2
Chen, Guo et al.[53]	China	3/7/20	9	9	4	0	1	NR			Mild	0	NR	NR	NR	NR*
Zhang et al.[61]	China	3/7/20	10	10	NR	0	1	NR			Mild to severe	0	NR	NR	NR	NR*
Wang, Guo et al.[40]	**China**	**3/12/20**	**1**	**1**	**0**	**1**	**1**	**NR**	**Thickened lung texture**	**Recovered in 2 weeks**	**Mild**	**0**	**Formula**	**Yes**	**NR**	**DOL15**
Chen, Peng et al.[37]	China	3/16/20	4	3	0	0	1	NR			Mild to severe	0	Formula	Yes	NR	NR*
Chen, Zhang et al.[74]	China	3/16/20	17	17	3	0	2	NR			Mild to moderate	0	Presumed formula	Yes	Yes	DOL7
Fan et al.[56]	China	3/17/20	2	2	1	0	1	NR			Mild	0	Presumed formula	Yes	NR	DOL20
Liu, Li et al.[85]	China	3/18/20	11	10	NR	0	NR	NR			Mild	0	NR	NR	NR	NR*
Yu et al.[41]	**China**	**3/24/20**	**3**	**3**	**0**	**1**	**1**	**NR**	**Mild pulmonary infection**	**Recovered in 2 wks**	**Mild**	**0**	**NR**	**NR**	**NR**	**DOL28**
Zambrano et al.[86]	Honduras	3/25/20	1	0	1	0	1	NR			Mild	NR	NR	NR	NR	DOL14

Dong et al.[48]	China	3/26/20	1	1	0	0	5	↑IgG, ↑IgM				0	Presumed formula	Yes	NR	DOL16
Liao et al.[55]	China	3/26/20	1	1	1	0	1	NR			Mild	NR	NR	NR	NR	NR*
Zeng, Xia et al.[33]	**China**	**3/26/20**	**33**	**26**	**4**	**3**	**3**	**NR**	**Pneumonia, lethargy, fever, SOB**	**Recovered in 1-2 wks**	**Mild**	**1**	**Presumed formula**	**Yes**	**NR**	**DOL7**
Zeng, Xu et al.[47]	China	3/26/20	6	6	NR	0	1	↑ IgG (n=5), ↑IgM (n=2)				0	Presumed formula	Yes	NR	NR*
Chen, Liao et al.[87]	China	3/28/20	5	2	0	0	1	NR			Mild	0	Formula	Yes	NR	NR*
Li, Han et al.[88]	China	3/30/20	3	3	0	0	2	NR			Mild	0	NR	NR	NR	DOL14
Zhang, Yu et al.[61]	**China**	**4/8/20**	**4**	**4**	**0**	**4**	**NR**	**NR**	**SOB, fever, cough**	**Recovered in 2-4 wks**	**Mild**	**NR**	**Formula (n=3), BF (n=1)**	**Yes (n=2)**	**NR**	**~2 wks-1 mo**
Schnettler, Ahwel, & Suhag[89]	U.S.(OH)	4/14/20	1	1	1	0	2	NR			Severe	NR	Presumed formula	Yes	NR	DOL9
Carosso et al., 2020[46]	Italy	4/14/20	1	0	0	0	2	↑IgG				0	NR	NR	NR	NR*
Lowe & Bopp[11]	Australia	4/15/20	1	0	0	0	1	NR			Mild	0	BF	No	NR	DOL10
Chen, Li et al.[59]	China	4/17/20	8	NR	NR	0	1	NR			NR	NR	NR	NR	NR	NR*
Zamaniyan et al.[90]	**Iran**	**4/17/20**	**1**	**1**	**1**	**1**	**4**	**NR**	**Fever**	**Recovered in 1 wk**	**Critical**	**0**	**Formula**	**Yes**	**NR**	**DOL7**
Alzamora et al.[42]	**Peru**	**4/18/20**	**1**	**1**	**1**	**1**	**2**	**Tested**	**Mild**	**Recovered,**	**Severe**	**0**	**Formula**	**Yes**	**NR**	**DOL6**

								and neg	**respiratory distress, cough**	**time NR**						
Lyra et al.[91]	Portugal	4/20/20	1	1	0	0	3	NR			Mild	0	Formula	Yes	NR	DOL7
Yan et al.[29]	China	4/23/20	86	85	20	0	1	NR			Mild to critical	0	NR	NR	NR	NR*
Kelly et al.[34]	U.S. (MO)	4/23/20	1	1	1	0	1	NR			Critical	1	NR	NR	NR	NR, until publication
Sharma et al.[10]	India	4/23/20	1	1	0	0	1	NR			Asx	NR	BF	No	NR	NR*
Hu et al.[43]	**China**	**4/24/20**	**7**	**6**	**0**	**1**	**NR**	**NR**	**None**	**No sx**	**Mild**	**0**	**Presumed formula**	**Yes**	**NR**	**DOL14**
Hantoushzadeh et al.[36]	**Iran**	**4/24/20**	**6**	**6**	**5**	**1**	**1-2**	**NR**	**Pneumonia**	**Intubated but stable, time NR**	**Critical**	**0**	**NR**	**NR**	**NR**	**1 mo**
Lu et al.[92]	China	4/24/20	1	1	0	0	3	NR			Asx	0	Formula	Yes	NR	DOL14
Vintzileos et al.[93]	U.S. (NY)	4/25/20	29	NR	NR	0	1	NR			Two-thirds asx	NR	NR	NR	NR	NR*
Ferrazzi et al.[8]	**Italy**	**4/27/20**	**42**	**18**	**12**	**2**	**NR**	**NR**	**None**	**No sx**	**Mild to moderate**	**2**	**BF in asx & mild sx mothers**	**NR**	**NR**	**NR, until discharge**
Buonsenso et al.[44]	**Italy**	**5/2/20**	**2**	**2**	**1**	**1**	**3**	**↑IgG (n=1)**	**None**	**No sx**	**Mild to moderate**	**0**	**Formula**	**Yes**	**NR**	**DOL18**
Wu et al.[58]	China	5/5/20	5	NR	2	0	1	NR			NR	NR	NR	NR	NR	NR*
Piersigilli et al., 2020[63]	**Belgium**	**5/7/20**	**1**	**1**	**1**	**1**	**2**	**NR**	**Stable**		**NR**	**0**	**Expressed BF**	**Yes**	**NR**	**DOL 28**
Pierce-Williams	**U.S. (NY,**	**5/8/20**	**33**	**24**	**19**	**1**	**1-2**	**NR**	**None**	**No sx**	**Severe to**	**NR**	**NR**	**NR**	**NR**	**NR***

et al.[39]	**NJ, PA, OH)**										**critical**					
Vallejo et al., 2020[94]	**U.S. (NY)**	**5/8/20**	**1**	**1**	**1**	**1**	**1**	**NR**	**None**	**No sx**	**Critical**	**0**	**NR**	**NR**	**NR**	**NR***
Knight et al., 2020[30]	**U.K.**	**5/11/20**	**244**	**144**	**63**	**12**	**NR**	**↑IgM (n=3)**	**Mild symptoms**	**Recovered**	**Mild to critical**	**NR**	**Rec. BF w/ mask**	**Rec. no**	**NR**	**NR***
Polónia-Valente et al., 2020[95]	Portugal	5/11/20	1	0	0	0	NR	NR			Mild	0	Formula	Yes	NR	DOL 3
Baergen & Heller, 2020[96]	U.S. (NY)	5/12/20	21	6	4	0	NR	NR			Mild to moderate	0	NR	NR	NR	NR*
Taghizadieh et al., 2020[97]	Iran	5/13/20	1	1	1	0	NR	NR			Severe	NR	NR	NR	NR	NR*
Kirtsman et al., 2020[62]	**Canada**	**5/14/20**	**1**	**1**	**1**	**1**	3	**NR**	**Mild symptoms**	**Recovered**	**Moderate**	**0**	**BF with mask**	**No**	**NR**	**DOL 30**
Dória et al., 2020[98]	Portugal	5/15/20	10	6	0	0	NR	NR			Asx to mild	0	NR	NR	NR	NR*
Mehta et al., 2020[35]	**U.S. (NJ)**	**5/16/20**	**2**	**2**	**2**	1	**NR**	**NR**	**None**	**No sx**	**Critical**	**2**	**Formula**	**Yes**	**NR**	**NR***
Patanè et al., 2020[45]	**Italy**	**5/18/20**	**22**	**NR**	**NR**	**2**	**2-3**	**NR**	**None**	**No sx**	**Mild**	**NR**	**Some BF, some formula**	**No**	**NR**	**NR***
London et al., 2020[99]	U.S. (NY)	5/19/20	48	22	9	0	NR	NR			Asx to moderate		NR	NR	NR	NR*
Joudi et al., 2020[100]	U.S. (CA)	5/20/20	1	0	0	0	NR	NR			Mild	0	BF with mask	No	NR	DOL 2
Qadri et al.,	U.S. (MI)	5/20/20	16	4	1	0	1	NR			Asx to	0	NR	Yes	NR	DOL 7

2020[101]											severe					
Dumitriu et al.[31]**	**U.S. (NY)**	**In press**	**101**	**46**	**11**	**2**	**1-4**	**NR**	**None**	**No sx**	**Asx to critical**	**0**	**BF**	**No**	**No**	**DOL25**
		Total:	**836**	**501**	**185**	**35**						**6**				

[a]Abbreviations and symbols used in table: NR = not reported, DOL = day of life, Rec. = recommended, U.S. = United States, U.K. = United Kingdom, SOB = shortness of breath, sx = symptoms, asx = asymptomatic, BF = breastfeeding, neg = negative, wk(s) = week(s), mo = month, ↑ = elevated, * = presumed immediate postnatal period only, ** = manuscript in press

[b]Red highlighted rows represent studies with SARS-CoV-2-positive newborns