Seminars in Fetal and Neonatal Medicine 28 (2023) 101430

Contents lists available at ScienceDirect

Seminars in Fetal and Neonatal Medicine

journal homepage: www.elsevier.com/locate/siny

Clinical features of neonatal COVID-19

Alfonso Galderisi [a,b], Gianluca Lista [c], Francesco Cavigioli [c], Daniele Trevisanuto [a,*]

[a] Department of Woman and Child's Health, University of Padova, Padova, Italy
[b] Yale University, Department of Pediatrics, New Haven, CT, USA
[c] Neonatal Intensive Care Unit, Buzzi Children's Hospital, Milan, Italy

A B S T R A C T

The COVID-19 (SARS-Cov-2) pandemic has put a strain on healthcare systems around the world from December 2019 in China, and then rapidly spreading worldwide. The impact of the virus on the entire population and its differential effect on various age groups was unknown at the outset, specifically its severity in elders, children or those living with other comorbidities, thus defining the syndemic, rather than pandemic, character of the infection. The effort of clinicians was initially to organize differential paths to isolate cases or contacts. This impacted the maternal-neonatal care adding an additional burden to this dyad and raising several questions. Can SARS-Cov-2 infection in the first days of life put the health of the newborn at risk? Could the separation of a healthy newborn from an infected mother create further physical and psychological health problems in the dyad? The rapid and massive research effort in these three years of the pandemic has provided wide answers to these initial questions. In this review, we report epidemiological data, clinical features, complications, and management of the neonates affected by SARS-Cov-2 infection.

1. Background

In December 2019 in Wuhan, China an outbreak of pneumonia of an unknown cause was reported. Using an unbiased next generation sequencing, an unknown beta coronavirus was discovered in the lower airways of these patients [1]. The virus was initially called 2019-novel Coronavirus (2019-nCov), then SARS-Cov 2 (from the English acronym *severe Acute Respiratory Syndrome COronaVirus 2*). The transmission of this coronavirus was thought to be by direct contact with infected people (respiratory droplets) and indirect contact with fomites.

The World Health Organization (WHO) named the resultant disease as COVID-19 [2] and on March 2020, WHO declared COVID-19 a pandemic, since the disease spread rapidly across the globe, becoming a public health emergency of international concern. In fact, after China, many other Asian countries were involved (e.g., Thailand, India etc.). In February 2020, the SARS-CoV-2 was discovered in Italy and then in all over Europe, with high mortality rate in many countries [3,4].

During 2021 and 2022, we experienced five waves of the disease from different viral genetic variants and wave-specific features including different morbidities resulting in mortality for millions of infected people. The syndemic nature of the infection, with higher mortality among individuals with comorbidities (such as diabetes and obesity) [5], shaped the geographical distribution of disease's severity.

The predominant clinical presentation was different during the five waves: first, respiratory failure was prominent, then at the second wave, gastrointestinal symptoms prevailed on the third wave, this was replaced by neurological manifestations with peripheral involvement, and on the last 2 waves, central nervous system manifestations dominated the affected. As the waves developed, there appeared to be a significant reduction in the mean age of the patients as well as a transition from predominantly males then to females [6]. Further, the delay in developing a vaccine specific to the pediatric population resulted in an increase infection in younger groups as the unintended consequence of the vaccination campaign. Despite the delay, the implementation of infection control policies and the availability of RNA-based vaccines slowed the further spread and severity of the pandemic [7].

1.1. COVID-19 and pediatric population

The pediatric population seems to be less affected by severe acute respiratory syndrome due to SARS- CoV-2 than adults [8–10]. The neonatal population is susceptible to vertical, *in utero* transmission of SARS-CoV-2 but such transmission is rare [11]. More frequently, an early postnatal (horizontal) transmission from infected mothers has been detected [12,13]. Updated recommendations support skin-to-skin practice, rooming-in and breast feeding with asymptomatic or mildly symptomatic mothers [14,15] in order to encourage physiological bonding. But out of concern for infection, it is irrefutable that

Abbreviations: SARS-Cov2, *severe Acute Respiratory Syndrome COronaVirus2*; COVID, Coronavirus Disease; MIS-N, *neonatal multisystem inflammatory syndrome*.

* Corresponding author.
E-mail address: daniele.trevisanuto@unipd.it (D. Trevisanuto).

https://doi.org/10.1016/j.siny.2023.101430

Available online 24 March 2023

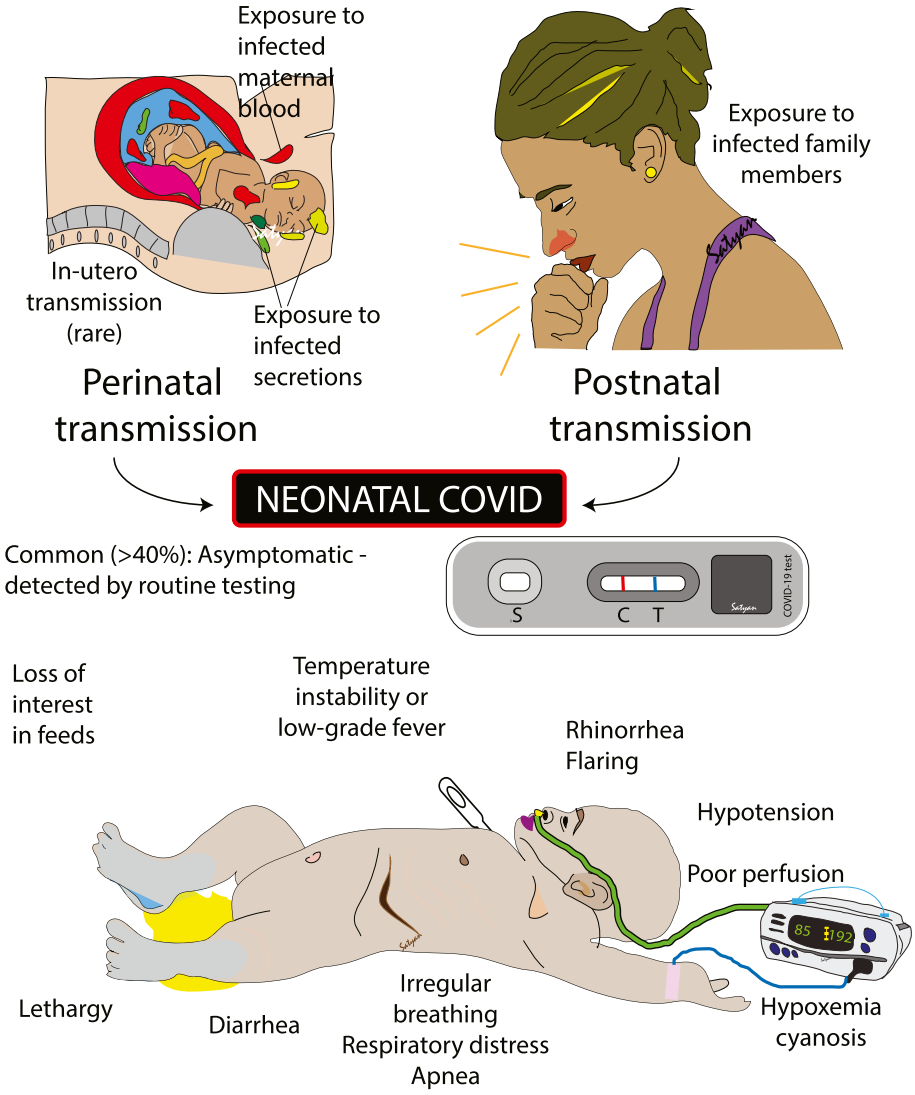

Fig. 1. Patterns of transmission and manifestations of neonatal COVID-19 infection. Some features such as cardiac dysfunction and hypoperfusion are more common with early-onset and fever is more common with late-onset infections. Modified from Sankaran et al. Neoreviews (2021) 22 (5): e284–e295 [35] Copyright Satyan Lakshminrusimha.

coronavirus-related restrictions in the delivery room and nursery (e.g. fathers kept out of the delivery room, prolonged isolation of suspected or infected mothers with their babies, etc.) had a psychological impact on parents [16].

Neonatal SARS-CoV-2 infection is uncommon in babies admitted to hospital [17]. However, infants less than 1 year old seem to be more vulnerable to SARS-CoV-2 infection with a greater severity of illness compared with other pediatric age groups [18–20]. As the pandemic evolved, reports of neonatal acute respiratory distress syndrome, associated with SARS-CoV-2 infection, have been increasingly published [14,21,22]. Symptomatic neonates with suspected COVID-19 should be isolated in a designated area to reduce risk of virus dissemination. In some countries, a higher proportion of symptomatic neonates has been observed in certain ethnic groups such as African-American, Asian, and Hispanic suggesting a role for ethnicity as a primary driver in the development of symptomatic disease [23] or as a shared risk factor for other comorbidities whose effect on the disease severity has been well described.

1.2. Clinical features of neonatal SARS-CoV-2 infections

The heterogeneity of clinical presentation of neonatal SARS-CoV-2 infection and its impact on perinatal care is still a major challenge. Available evidence derived from isolated case reports or series collected in different healthcare contexts are susceptible to diagnostic biases and focused on local practices. The patterns of disease transmission, timing of diagnosis, the frequency of clinical symptoms, and complications will be described in this section.

Disease transmission: Neonates can be infected by SARS-CoV-2 by vertical (via placenta or genital tract) or horizontal (through respiratory droplets) transmission [24,25]. The definition and the categorization of the timing of mother-to-child transmission of the infection has been proposed by a multidisciplinary, international panel of experts on behalf of the WHO [12]. Vertical transmission remains infrequent and mostly asymptomatic, with most of the reported cases due to postnatal infection.

Timing of presentation: Mirroring the classification adopted for neonatal sepsis, SARS-CoV-2 infections can be classified as early (≤48–72 h of birth) or late-onset (>72 h) according to the time of diagnosis [12]. Such an approach can identify two groups that differ for the infection's transmission and the clinical course. Indeed, early-onset SARS-CoV-2 is mostly due to vertical transmission (either in-utero or intrapartum), while late-onset disease is generally due to horizontal transmission from caregivers including the parents [12].

Early neonatal SARS CoV-2 can result from *in utero*, intrapartum or postnatal infection. *In utero* transmission has been described in fetuses of mothers with severe disease [26,27], as a consequence of viral placental infection through the placental expression of the viral receptors [angiotensin-converting enzyme 2 (ACE-2) and transmembrane protease serine 2 (TMPRSS2)] or from the vascular damage associated with the virus [28–30]. Intrapartum transmission is relatively unlikely as SARS CoV-2 is rarely detected in vaginal swabs. However, distinguishing intrapartum infection from contamination during the immediate postpartum period remains difficult. Late neonatal infection, due to postnatal exposure, remains the common source of neonatal SARS-CoV2 infection [12].

The actual prevalence of SARS-CoV-2 infection remains controversial, as case series are largely biased by the screening protocol adopted by each institution as well as by the diagnostic methodology adopted. The increased prevalence of vaccination among mothers is expected to decrease neonatal infections.

Lastly, a **neonatal multisystem inflammatory syndrome (MIS-N)** has been described as the result of neonatal hyperresponsiveness to the SARS-CoV-2 specific maternal IgG antibodies [31–33] in both early and late-onset MIS-N. The diagnosis of MIS-N secondary to maternal infections remains debatable. For children with multisystem inflammatory syndrome (MIS-C), the definitions are slightly different between various organizations [WHO, CDC (Centers for Disease Control and Prevention), CHKD (Children's Hospital of The King's Daughters) and IDSA (Infectious Disease Society of America), American Academy of Pediatrics (AAP), American College of Rheumatology (ACR) and Helen DeVos Children's Hospital Foundation (HDVCH) [21]. The frequency of accompanying symptoms varies by age [8,23]. Among neonates, cardiac and hematological manifestations are more frequently observed in neonates with fever, skin rashes and pulmonary hypertension are observed after the first week of life. Acute kidney injury is rarely observed in neonates in the most recent metanalyses, while fever still is present in half of the affected neonates, thus suggesting that this may not be a major criterion for the suspicion of MIS-N [34].

1.3. Clinical presentation (*Fig. 1*)

More than 40% of neonates remain asymptomatic or may develop mild symptoms (cough, rhinorrhea, low-grade fever, vomiting) [13,36] with less than 15% of the neonates developing moderate to severe symptoms like respiratory distress, lethargy, poor feeding, vomiting, diarrhea, and hemodynamic instability [37]. Early infection is more likely than late infection to remain asymptomatic or mildly symptomatic. Most symptomatic neonates present with hyperthermia, respiratory (tachypnea, distress), apnea, poor perfusion, and gastrointestinal (diarrhea, vomiting) symptoms, while neurological manifestations (seizures) are rare [23,38,39].

Laboratory. Laboratory findings include leukocytosis or lymphopenia, thrombocytopenia, and elevated inflammatory markers (CRP, procalcitonin, IL-6, ferritin), however these findings are oftentimes present during the first days of life and their specificity is very low.

In presence of a suspected MIS-N, besides an increase of inflammatory markers (CRP, procalcitonin, ferritin, D-dimer, LDH), elevated NT-pro-BNP and troponin can be observed, and detectable SARS CoV2 IgG (in the absence of maternal immunization) is highly specific.

Imaging. X-ray findings are generally present in more than 60% of infected neonates with respiratory distress and consist of an interstitial-alveolar pattern at lung ultrasound or ground-glass opacities at CT-scan [13,36].

2. Complications

Prematurity is still a debated complication of maternal infection, with more severe clinical presentations described in preterm infants. However, the capacity of maternal infection to induce preterm delivery has not been established [40].

A *neonatal multisystem inflammatory syndrome* (MIS-N) has been described in neonates as the result of neonatal hyper-responsiveness to the SARS-CoV-2 specific maternal IgG antibodies [31–34]. Even though the detection of maternal SARS-CoV-2 IgG antibodies in neonates with suspected MIS-N is frequent, other mechanisms have been accounted to sustain the multiorgan inflammatory reactions including a hyper-responsiveness to a perinatal or early post-natal infection [41,42].

The multiorgan involvement, the presence of signs of inflammation, and IgG SARS-CoV-2 antibodies are the hallmarks of MIS-N presentation even though specific criteria for neonatal MIS-C have not been defined. Cardiac involvement in MIS-N may include myocarditis, pericarditis, or coronary aneurysm, thus echocardiogram is always advised in case of suspected MIS-N. Respiratory, renal and neurological symptoms overlap those described for the primary infection from SARS CoV-2, while gastrointestinal involvement may present with necrotizing enterocolitis-like symptoms.

The diagnosis of MIS-N remains a challenge as most the neonates remain asymptomatic during the primary infection. MIS-N occurs in the absence of a well-defined medical history of SARS CoV-2 (50) The widespread vaccination limits the use of anti-S IgG (antibody to spike protein) in neonates. (27) Anti-nucleoprotein antibodies have been proposed as a potential alternative, though the evidence is still limited (27). Inflammatory markers including D-dimer have been found to be consistently elevated in the majority of patients (86%) (37, 40, 41), however, the specificity of D-dimer remains very low during the neonatal period. Considerations can be applied to other inflammatory markers such as ferritin, LDH, CRP and procalcitonin (34, 40) whose increase should be interpreted cautiously as these are similarly affected by other more frequent neonatal conditions.

There are no specific recommendation for treatment of MIS-N and the available evidence is derived from pediatric studies. (34, 40, 41) The use of IVIG (1–2 gm/kg) and IV methylprednisolone (1–2 mg/kg/day) are considered as a first-line treatment for moderate to severely ill children and could be considered for the treatment of MIS-N. The decision has to weigh the negative effect of neonatal steroids on neurodevelopment. Differential diagnoses should be considered in the presence of a low degree of clinical evidence for an ongoing MIS-N. Echocardiography should accompany the MIS-N follow-up during and after the treatment. Pediatric patients rapidly respond to this treatment (24–48 h). In the absence of a prompt recovery, a step-up increase of methylprednisolone (10–20 mg/kg/day) or the use of other immunomodulators such as IL-1 receptor antagonists (anakinra) or TNF-a inhibitors (infliximab) can be evaluated, despite the lack of evidence for their effectiveness in MIS-N.

2.1. Mother-neonate management

As transmission through maternal milk remains debated and the benefits of breastfeeding largely outweigh the risk of infection, WHO and American Academy of Pediatrics (AAP) recommend breastfeeding for mothers with suspected or confirmed COVID-19 infection. Similarly, mother-neonate separation is discouraged even in presence of confirmed SARS CoV-2 infection [12], though the use of face-mask for infected mothers continues to be recommended during neonatal care [42].

The implementation of vaccination has largely reduced the number of infected neonates, because of increased maternal immunity and reduced prevalence of infection among healthcare personnel. Despite vaccination, the frequency and characteristics of the infection have not changed over time for neonatal and pediatric patients [43].

The maternal diagnosis of COVID-19 challenges the prenatal management, delivery room approach as well as the care for the mother-child dyad after birth. While the early recommendation of the AAP was in favor of separating mothers with SARS CoV-2 infection from their newborns, the current recommendation promotes maternal breastfeeding and the preservation of the mother-child dyad regardless of the

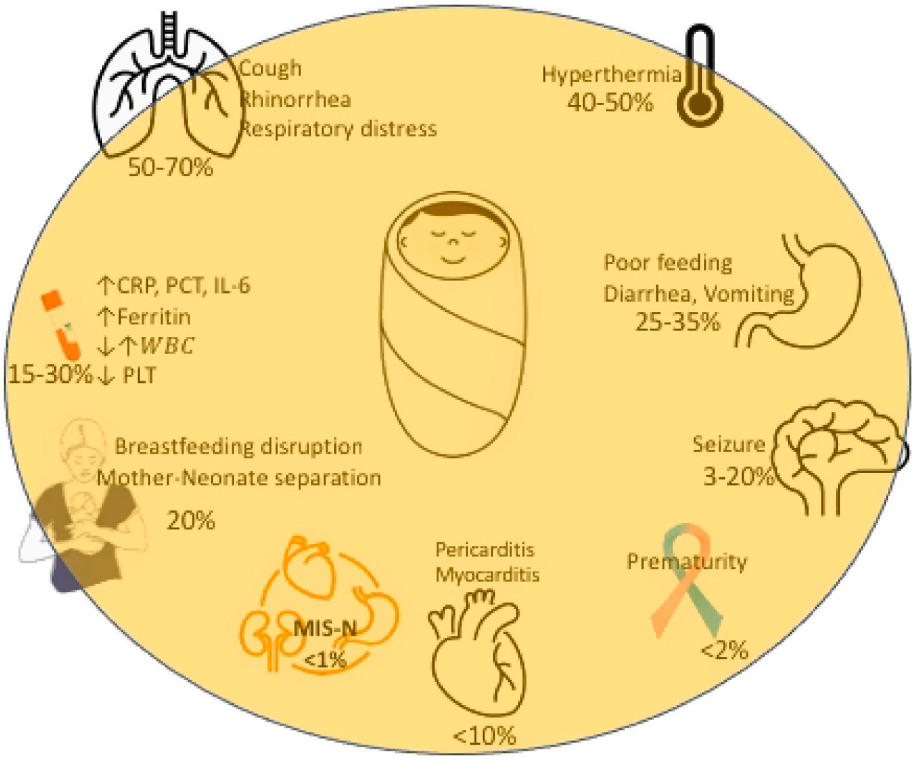

Fig. 2. Incidence of various clinical manifestations and laboratory findings in neonates with COVID-19.

infective status as long as this is compatible with the maternal health [44]. Maternal vaccination during pregnancy or after delivery is recommended [44]. The immunization in early pregnancy has been proven to be more protective for the baby than in late pregnancy or in the postpartum period [44]. Longitudinal observations show that SARS CoV-2 is rarely detectable in maternal milk and, even in the presence of SARS CoV-2 RNA, a milk-transmitted infection is unlikely [45] as breast milk contains secretory IgA antibodies against SARS CoV-2.

At discharge, if the infant has a positive SARS-CoV-2 test in the absence of clinical signs of the disease, the infant can be discharged with close follow-up for 14 days· [46].

3. Conclusions (Fig. 2)

The majority of cases of neonatal COVID-19 are asymptomatic or mildly symptomatic and do not require any specific treatment.

There is no evidence in favor of separating mothers from their newborns regardless their SARS CoV-2 infective status (unless maternal infection is severe) as the benefits of rooming-in and breastfeeding outweigh the risks of a neonatal infection.

There is no evidence to support SARS CoV-2 -specific treatments other than supportive care according to the individual characteristics of the case.

MIS-N is a rare but a severe complication of maternal or neonatal SARS CoV-2 infection, however we lack reliable markers to identify those at risk for MIS-N or to confirm the diagnosis. With anticipated emergence of newer strains of SARS CoV-2, the disease pattern in neonates is likely to change and yearly boosters of vaccination (similar to influenza) may be needed.

Funding source

None.

Declaration of competing interest

The authors do not have any personal or financial conflicts of interest with the content of this article.

References

[1] Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med 2020;(8):382. https://doi.org/10.1056/NEJMoa2001017. 02/20/2020.
[2] Organization Wh. Naming the coronavirus disease (COVID-19) and the virus that causes it. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it.
[3] Fauci A, Lane H, Redfield R. Covid-19 - navigating the uncharted. N Engl J Med 2020;(13):382. https://doi.org/10.1056/NEJMe2002387. 03/26/2020.
[4] Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med 2020;(13):382. https://doi.org/10.1056/NEJMoa2001316. 03/26/2020.
[5] Horton R. Offline: COVID-19 is not a pandemic. Lancet 2021;26(396):874. https://doi.org/10.1016/S0140-6736(20)32000-6.
[6] Amin R, Sohrabi M, Zali A, Hannani K. Five consecutive epidemiological waves of COVID-19: a population-based cross-sectional study on characteristics, policies, and health outcome. BMC Infect Dis 2022;22(1). https://doi.org/10.1186/s12879-022-07909-y. 12/05/2022.
[7] Ayouni I, Maatoug J, Dhouib W, et al. Effective public health measures to mitigate the spread of COVID-19: a systematic review. BMC Publ Health 2021;21(1). https://doi.org/10.1186/s12889-021-11111-1. 05/29/2021.
[8] Docherty A, Harrison E, Green C, et al. Features of 20 133 UK patients in hospital with covid-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. BMJ 2020:369. https://doi.org/10.1136/bmj.m1985. 05/22/2020.
[9] Wu Z, McGoogan J. 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 2020;(13):323. https://doi.org/10.1001/jama.2020.2648. 04/07/2020.
[10] Shekerdemian L, Mahmood N, Wolfe K, et al. Characteristics and outcomes of children with coronavirus disease 2019 (COVID-19) infection admitted to US and Canadian pediatric intensive care units. JAMA Pediatr 2020;(9):174. https://doi.org/10.1001/jamapediatrics.2020.1948. 09/01/2020.
[11] Pietrasanta C, Artieri G, Ronchi A, et al. SARS-CoV-2 infection and neonates: evidence-based data after 18 months of the pandemic. 2022 Jan Pediatr Allergy Immunol : Off Publ Eur Soc Pediatr Allergy Immunol 2022;33(Suppl 27). https://doi.org/10.1111/pai.13643. Suppl 27.

[12] World Health Organization. Definition and categorization of the timing of mother-to-child transmission of SARS-CoV-2. https://www.who.int/publications-detail-redirect/WHO-2019-nCoV-mother-to-child-transmission-2021.1.
[13] Raschetti R, Vivanti A, Vauloup-Fellous C, Loi B, Benachi A, De Luca D. Synthesis and systematic review of reported neonatal SARS-CoV-2 infections. Nat Commun 2020;11(1). https://doi.org/10.1038/s41467-020-18982-9. 10/15/2020.
[14] Ronchi A, Pietrasanta C, Zavattoni M, et al. Evaluation of rooming-in practice for neonates born to mothers with severe acute respiratory syndrome coronavirus 2 infection in Italy. JAMA Pediatr 2021;175(3). https://doi.org/10.1001/jamapediatrics.2020.5086. 03/01/2021.
[15] Salvatore C, Han J, Acker K, et al. Neonatal management and outcomes during the COVID-19 pandemic: an observation cohort study. Lancet Child Adolesc Health 2020;4(10). https://doi.org/10.1016/S2352-4642(20)30235-2. 2020 Oct.
[16] Polloni L, Cavallin F, Lolli E, et al. Psychological wellbeing of parents with infants admitted to the neonatal intensive care unit during SARS-CoV-2 pandemic. Children 2021;8(9). https://doi.org/10.3390/children8090755. 08/30/2021.
[17] Gale C, Quigley M, Placzek A, et al. Characteristics and outcomes of neonatal SARS-CoV-2 infection in the UK: a prospective national cohort study using active surveillance. Lancet Child Adolesc Health 2021;(2):5. https://doi.org/10.1016/S2352-4642(20)30342-4. 2021 Feb.
[18] Dong Y, Mo X, Hu Y, et al. Epidemiology of COVID-19 among children in China. Pediatrics 2020;(6):145. https://doi.org/10.1542/peds.2020-0702. 2020 Jun.
[19] Götzinger F, Santiago-García B, Noguera-Julián A, et al. COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. Lancet Child Adolesc Health 2020;(9):4. https://doi.org/10.1016/S2352-4642(20)30177-2. 2020 Sep.
[20] Ludvigsson J. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. Acta Paediatr 2020;(6):109. https://doi.org/10.1111/apa.15270. 2020 Jun.
[21] Frauenfelder C, Brierley J, Whittaker E, Perucca G, Bamford A. Infant with SARS-CoV-2 infection causing severe lung disease treated with remdesivir. Pediatrics 2020;(3):146. https://doi.org/10.1542/peds.2020-1701. 2020 Sep.
[22] Coronado Munoz A, Nawaratne U, McMann D, Ellsworth M, Meliones J, Boukas K. Late-onset neonatal sepsis in a patient with covid-19. N Engl J Med 2020;(19):382. https://doi.org/10.1056/NEJMc2010614. 05/07/2020.
[23] Gale C, Quigley M, Placzek A, et al. Characteristics and outcomes of neonatal SARS-CoV-2 infection in the UK: a prospective national cohort study using active surveillance. Lancet Child Adolesc Health 2021;(2):5. https://doi.org/10.1016/S2352-4642(20)30342-4. 2021 Feb.
[24] Sheth S, Shah N, Bhandari V. Outcomes in COVID-19 positive neonates and possibility of viral vertical transmission: a narrative review. Am J Perinatol 2020;(12):37. https://doi.org/10.1055/s-0040-1714719. 2020 Oct.
[25] Kulkarni R, Valvi C, Dawre R, et al. Clinical profile of SARS-CoV-2-infected neonates. Cureus 2022;14(6). https://doi.org/10.7759/cureus.26298. 06/24/2022.
[26] Andersson M, Arancibia-Carcamo C, Auckland K, et al. SARS-CoV-2 RNA detected in blood products from patients with COVID-19 is not associated with infectious virus. Wellcome Open Res 2020:5. https://doi.org/10.12688/wellcomeopenres.16002.2. 10/12/2020.
[27] Conti M, Terreri S, Piano Mortari E, et al. Immune response of neonates born to mothers infected with SARS-CoV-2. JAMA Netw Open 2021;4(11). https://doi.org/10.1001/jamanetworkopen.2021.32563. 11/01/2021.
[28] Vivanti A, Vauloup-Fellous C, Prevot S, et al. Transplacental transmission of SARS-CoV-2 infection. Nat Commun 2020;11(1). https://doi.org/10.1038/s41467-020-17436-6. 07/14/2020.
[29] Komine-Aizawa S, K T, S H. Placental barrier against COVID-19. Placenta 2020:99. https://doi.org/10.1016/j.placenta.2020.07.022. 09/15/2020.
[30] Sharps M, Hayes D, Lee S, et al. A structured review of placental morphology and histopathological lesions associated with SARS-CoV-2 infection. Placenta 2020:101. https://doi.org/10.1016/j.placenta.2020.08.018. 2020 Nov.
[31] Lima A, Cardoso C, Bentim P, et al. Maternal SARS-CoV-2 infection associated to systemic inflammatory response and pericardial effusion in the newborn: a case report. J Pediatr Infect Dis Soc 2021;10(4). https://doi.org/10.1093/jpids/piaa133. 04/30/2021.
[32] Kappanayil M, Balan S, Alawani S, et al. Multisystem inflammatory syndrome in a neonate, temporally associated with prenatal exposure to SARS-CoV-2: a case report. Lancet Child Adolesc Health 2021;(4):5. https://doi.org/10.1016/S2352-4642(21)00055-9. 2021 Apr.
[33] More K, Aiyer S, Goti A, et al. Multisystem inflammatory syndrome in neonates (MIS-N) associated with SARS-CoV2 infection: a case series. OriginalPaper. Eur J Pediatr 2022;181(5):1883–98. https://doi.org/10.1007/s00431-022-04377-z. 2022-01-14.
[34] Molloy E, Nakra N, Gale C, Dimitriades V, Lakshminrusimha S. Multisystem inflammatory syndrome in children (MIS-C) and neonates (MIS-N) associated with COVID-19: optimizing definition and management. Pediatr Res 2022. https://doi.org/10.1038/s41390-022-02263-w. 09/01/2022.
[35] Sankaran D, Nakra N, Cheema R, Blumberg D, Lakshminrusimha S. Perinatal SARS-CoV-2 infection and neonatal COVID-19: a 2021 update. NeoReviews 2021;22:e284–95.
[36] Trevisanuto D, Cavallin F, Cavicchiolo M, Borellini M, Calgaro S, Baraldi E. Coronavirus infection in neonates: a systematic review. Arch Dis Child Fetal Neonatal Ed 2021;106(3). https://doi.org/10.1136/archdischild-2020-319837. 2021 May.
[37] Gale C, Ma Q, A P, et al. Characteristics and outcomes of neonatal SARS-CoV-2 infection in the UK: a prospective national cohort study using active surveillance. Lancet Child Adolesc Health 2021;(2):5. https://doi.org/10.1016/S2352-4642(20)30342-4. 2021 Feb.
[38] Molloy EJ, Nakra N, Gale C, Dimitriades VR, Lakshminrusimha S. Multisystem inflammatory syndrome in children (MIS-C) and neonates (MIS-N) associated with COVID-19: optimizing definition and management. Pediatr Res 2022 Sep 1:1–10. https://doi.org/10.1038/s41390-022-02263-w. Epub ahead of print. PMID: 36050390; PMCID: PMC9436161.
[39] Raschetti R, Vivanti A, Vauloup-Fellous C, B L, A B, D Dl. Synthesis and systematic review of reported neonatal SARS-CoV-2 infections. Nat Commun 2020;11(1). https://doi.org/10.1038/s41467-020-18982-9. 10/15/2020.
[40] Kulkarni R, Valvi C, Dawre R, et al. Clinical profile of SARS-CoV-2-infected neonates. Cureus 2022;14(6). https://doi.org/10.7759/cureus.26298. 06/24/2022.
[41] Lakshminrusimha S, Hudak M, Vr D, Higgins R. Multisystem inflammatory syndrome in neonates following maternal SARS-CoV-2 COVID-19 infection. Am J Perinatol 2022;39(11). https://doi.org/10.1055/a-1682-3075. 2022 Aug.
[42] Krishnan P, Greshma SGG. Neonatal MIS-C. 2022. 2022 Jan.
[43] Meyer M, Ruebsteck E, Dewald F, et al. Clinical aspects of the subsequent SARS-CoV-2 waves in children from 2020 to 2022-data from a local cohort in Cologne, Germany (n = 21,635). Viruses 2022;14(8). https://doi.org/10.3390/v14081607. 07/23/2022.
[44] Chen M, Cheema R, Hoyt-Austin A, Agnoli A, Kuhn-Riordon K, Kair L. Vaccination and treatment options for SARS-CoV2 infection affecting lactation and breastfeeding. Semin Fetal Neonatal Med 2023. https://doi.org/10.1016/j.siny.2023.101425. 02/13/2023.
[45] Krogstad P, Contreras D, Ng H, et al. No infectious SARS-CoV-2 in breast milk from a cohort of 110 lactating women. OriginalPaper. Pediatr Res 2022;92(4):1140–5. https://doi.org/10.1038/s41390-021-01902-y. 2022-01-19.
[46] American Academy Pediatrics. American Academy of Pediatrics. FAQs: management of infants born to mothers with suspected or confirmed COVID-19. 2022. Updated 11/20/22, https://www.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/clinical-gu idance/faqs-management-of-infants-born-to-covid-19-mothers/.