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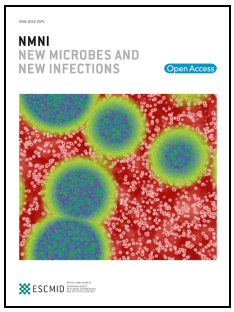

Clinical and immunological features among COVID-19 affected mother-infant pairs: antibodies to SARS- CoV- 2 detected in breast milk

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Title: Clinical and immunological features among COVID-19 affected mother-infant pairs: Antibodies to SARS- CoV- 2 detected in breast milk

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Competing Interests declaration

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Highlights

Antibodies to SARS- CoV- 2 were identified in breast milk of COVID-19 affected mothers thus infants can acquire passive immunity through ingestion. Despite other privileges of breast milk, its specific antibodies components may have potential therapeutic effect as compared to convalescent plasma.

Key words: COVID-19, Pregnancy, Breast feeding, Infectious disease, Passive immunity, Lactation period

Abstract

Background. The pandemic caused by Coronavirus disease 2019 (COVID-19) remain threatening to women and children, while clinical evidences regarding women during pregnancy, puerperium and lactation periods are limited.

Objective. We aim to discuss clinical, immunological features and breast feeding advices among mother- infant pairs.

Study design. This observational analysis was conducted in a tertiary center located in Wuhan, China. Pregnant patients with laboratory confirmed COVID-19 who delivered during hospitalization were enrolled. Clinical characteristics and serial specimens of the mother- infant pairs were examined, supplemented with follow-ups regarding recovery and breast feeding.

Results. 14 pregnant patients had live birth and achieved good recovery, four patients continued breast feeding with precautions, no neonatal infection was found. No infants observed developed COVID-19 during breastfeeding. Common maternal symptoms were fever (11/14, 78.1%) and cough (6/14, 42.9%), a pregnancy specific symptom was abnormal fetal movement, noticed in three (21.4%) patients. The mean viral shedding time was nine days (SD 6, range 1-22), SARS- CoV- 2 genome was non-detected in breast milk or maternal vaginal secretions. Immunological assay showed seroconversion of IgM on day eight of onset, IgG on day 28. Both IgM and IgM antibodies to SARS- CoV- 2 are detected in breast milk, cord blood and neonatal serum.

Conclusion. The study suggested passive acquisition of antibody against SARS- CoV- 2 through breast milk ingestion. Breast feeding role is low risk in transmission of SARS- CoV- 2 or cause maternal disease escalation, continue breast feeding with prudent precautions is encouraged.

Introduction

Severe acute respiratory virus 2 (SARS- CoV- 2), first identified in December, 2019, Wuhan, China, continued to spread rapidly causing the ongoing pandemic[1]. As corona virus disease 2019 (COVID-19) unfolded, various investigations had launched to explore the pathophysiology of SARS- CoV- 2. Up to date the viral genome had been detected in multiple kinds of body fluids, including upper respiratory droplets, bronchoalveolar lavage, saliva, tears, conjunctival secretions, faeces, urine, blood and cerebrospinal fluids[2- 4]. Breast milk, as a well studied body fluid with immunological, nutritional, cognitive and maternal- fetal emotional privileges[5], has not been fully characterized with the novel virus yet. Clinical data was also limited, Chen et al.[6] described failure of detection of SARS- CoV- 2 genome in breast milk of six affected mother in the third trimester. However, with more women of early pregnancy, puerperium and lactation periods affected and recovering from COVID-19, question raised upon the safety of breast feeding, role of breast feeding in transmission of SARS- CoV- 2, according precautions and whether maternal disease course will be interfered with breast feeding.

We aim to discuss the clinical and immunological features among COVID-19 affected mother- infant pairs, specifically test breast milk pathogen, SARS- CoV- 2 neutralizing antibody and immunologic components, facilitate exploration of breast feeding feasibilities and transmission possibilities.

Methods

Study design and participants

The ambispective, observational clinical analysis was conducted in a single tertiary center, Tongji hospital affiliated to Huazhong University of Science and technology, located in Wuhan, China. The

study retrospective collected seven pregnant patients with laboratory confirmed COVID-19 between January.19 to February 7, 2020 while 13 patients in various stages of pregnancy diagnosed subsequently were consent to the study from baseline. Follow-up investigation focused on maternal fetal outcomes, breast feeding and recovery. The last follow-up date was April 5, 2020. Patients enrolled met the following criteria[7]: 1) had positive real-time reverse transcription polymerase chain reaction (RT-PCR) test of SARS- CoV- 2 in oro- or nasalpharyngeal swabs; 2) tested positive with IgM-IgG combined antibody test for SARS-CoV-2 1 week after disease onset combined with epidemiology exposure and suspected symptoms; 3) agreed and compliant with testing and treatment protocols.

Data, specimen collection and statistics analysis

The collection and analysis of human clinical specimens had been approved by the Health and Ethnic Boards of Tongji hospital affiliated to Huazhong Universtity of Science and Technology (Code:TJ-IRB20200222). Written inform consents had been obtained by the patients and the neonates' adult proxy.

Demographical information and clinical characteristics of the enrolled patients were extracted from the electronic medical system, supplemented with telephone follow up. Within seven days postpartum breast milk were self-pumped after hand sanitization and contained. Maternal- neonatal isolation was performed immediately after cord clamping, neonates were either observed in neonatal intensive care units (NICU) or kept in a quarantine center with proxy as close contacts for minimum 14 days. Neonates in NICU were taken nasal or oropharyngeal swabs for SARS-CoV-2 twice consecutively apart from 24 hours. Neonatal feces were taken after meconium passed. All clinical specimens were

performed with RT-PCR assays of SARS-CoV-2 ORF1ab/N gene detection kits[8], authorized by Chinese center for disease control and prevention (CDC). SARS- CoV-2 IgM-IgG combined antibody tests[9], fully automated chemiluminescence immunoassay, was performed in breast milk, maternal and neonatal serum after introduced on February 26, 2020. IgM or IgG more than 10 AU/ml was considered positive, otherwise negative.

Statistics analysis was performed using SPSS (version 20.0). Continuous variables were presented as mean and standard deviations or medians and interquartile ranges (IQR). Categorical variables were expressed as percentages and counts.

Results

Clinical characteristics and perinatal outcomes

Demographical information and clinical features of 14 mothers with confirmed COVID-19 were presented in Table.1. Four patients who co-tested with immunological assays of SARS- CoV- 2 were shown in details.

In this cohort, mean maternal age was 31 years (SD 2.4, range 27- 35), all had singleton pregnancy, of which four (28.5%) were primigravidas and ten are multigravidas. All patients were Wuhan residents, two (14.2%) were health care workers, three (21.4%) had contact of confirmed or suspected cases, two (14.2%) suffered from family aggregation occurrence. The most common onset symptoms were fever (11, 78.1%) and cough (6, 42.9%), a pregnancy specific symptom was abnormal fetal movement, happened in three (21.4%) patients, one felt evidently increased fetal movement, two felt decreased. All patients had chest computed tomography(CT) abnormalities, typical findings were ground-glass opacities, multiple patches in lung fields and sub-pleural adhesions. Laboratory results showed

lymphopenia (lymphocytes <1.1*10^{12}) in seven (50%) patients, five (35.7%) patients had abnormal liver functions, of whom two had co-existing Intrahepatic cholestasis of pregnancy (ICP). We also perform immunoserological testing of other common respiratory pathogens, including respiratory syncytial virus, adenovirus, Influenza- A, Influenza- B, parainfluenza virus, mycoplasma penumoniae, Legionella pneumophila. Four (26.1%) patients tested positive of Influenza-A IgM and one (4.3%) tested positive of mycoplasma penumoniae IgM.

Respiratory support was applied for four hours after cesarean surgery as well as when blood oxygen saturation dropped below 93%. Eight (57.1%) patients received oxygen via nasal catheter, no respirator or mechanical ventilation was indicated.

All patients underwent successful term delivery with no severe complication or ICU admission. Perinatal outcomes and neonate baseline information were shown in Table.2. The mean interval from disease from onset to delivery was 5.4 days (SD 6.3, range 1-46). Two (14.2%) patients had fetal distress marked by variable decelerations observe on fetal heart tracing and third degree amniotic fetal meconium pollution. 12 (85.8%) chose cesarean and two (14.2%) patient had vagina birth without mechanical assistance. The surgeries were performed in isolated surgery room with continuous lumbar-epidural analgesia. The mean birth weight of neonates was 3224g (SD 421, range 2700- 4120), one neonate from the mother complicated with ICP had mild asphyxia at birth. One neonate had transient fever recorded as anal temperature 37.9□ at 30 hour of birth.

Maternal and neonatal RT-PCR SARS- CoV-2 detection results were shown in Table.3. Oro- or nasopharyngeal swabs were taken every 3 days during hospitalization. SARS-CoV-2 viral shedding days were described as the first positive to the first continuous negative RT-PCR results. The mean maternal viral shedding time was 9 days (SD 6, range 1-22 days). SARS- CoV- 2 nucleic acids was not

detected in maternal breast milk (n=12), vaginal secretions (n=10), neonatal oropharyngeal swabs (n=12) and meonium specimen (n=6).

SARS- CoV-2 immunoassay in breast milk, maternal and neonatal serum

Immunological features and disease courses of four mother- infant pairs were presented in Figure.1. Maternal seroconversion of IgM was observed on day eight of disease onset, IgG on day 28. Three breast milk samples were tested positive of IgM or IgG of SARS- CoV- 2. Three neonates tested positive of IgG of SARS- CoV- 2, One neonate tested positive of IgM within 24 hours of birth. IgG was detected in one cord blood sample.

Patient 1, a healthcare worker, had fever and cough on Jan.24, 32 weeks of pregnancy, tested oropharyngeal swab positive on Feb.01, chest CT showed bilateral pneumonia. She was admitted, receiving oxygen support and supportive treatment. On Feb.12 and Feb.14, she was consecutively tested negative but still complained about persistent dry cough and malaise. On Mar.3, 37^{+5} weeks of pregnancy, her SARS- CoV- 2 antibody assay showed evidently increased antibodies, IgG 280.96 AU/ml and IgM 2581.57 AU/ml while nasopharyngeal swab returned negative. Elective cesarean was planned to avoid maternal exhaustion. A male neonate was born, with Apgar score 1 and 5 minutes 8-9, birth weight 2700g. Tested within 24 hours of birth, the neonatal SARS- CoV- 2 immunological assays showed positive tiers, IgG 147.21 AU/ml and IgM 184.3 AU/ml. At 72 hour of birth, his IgG was 95.48AU/ml and IgM 188.33AU/ml. SARS- CoV- 2 nucleic acids was non- detected in neonatal oropharyngeal swab or meconium. Breast milk was examined on postpartum day 6, IgG was 145.31 AU/ml, IgM 92.01 AU/ml. The immunological components (IgA, IgM, IgG, C3, C4) of the breast milk were within normal limit. During the isolation, the neonate was fed on formula only. The mother

resumed breastfeeding when discharged with bottle feeding of expressed breast milk.

Patient 2 was asymptomatic when admitted on Feb.29, 39 weeks pregnancy. Her nasopharyngeal swab at admission was negative. She reported fever and cough during 36 weeks of pregnancy and was suggested to home quarantine, the symptoms self- resolved. She underwent elective cesarean due to scarred uterus. The surgery was uncomplicated, a male infant of 3930g was born. Antibody test of serum and breast milk were performed on postpartum day 3, both showed markly increased IgG tier and negative IgM. Breast milk level of IgG was 103.15 AU/ml, immunological component in normal range. The neonate was tested within 24 hours of birth, increased IgG (78.41 AU/ml) and negative IgM was noticed. Patient 2 continued breast feeding with expressed breast milk. The neonate was well appearing with normal weight gain according to the adult proxy when follow-up.

Patient 3 was admitted on Feb.20 with low grade fever of 37.3□, 41 weeks of pregnancy, outpatient chest CT 2 days ago showed bilateral ground glass opacities. Elective cesarean was performed and the 4120g female neonate was transferred to NICU for observation. Breast milk and maternal serum antibody test were tested on postpartum day 6, showed increased IgM antibody tier and negative IgG. Breast milk IgM level was 19.86 AU/ml and maternal serum IgM was 18.64 AU/ml. Neonatal serum antibody test on 14 days check up was negative of both IgM and IgG. The neonate was fed on formula in NICU and breast fed after isolation finished. During the follow up, she reported bottle feeding with breast milk on most occasions. She was suggested to wear a mask during direct breast feeding.

Patient 4 was a nurse in outpatient triage center, she encountered confirmed patients on Jan.27, her husband was also a confirmed case of COVID-19. She had dry cough and malaise on Feb.2, 32^{+3} weeks of pregnancy, and was tested positive subsequently. She was admitted to the quarantine center for observation with no further treatment. Her symptoms self-resolved one week later, her oropharyngeal

swabs on Feb.12 and Feb.14 were tested negative and discharged. On prenatal check up on Mar.11, her nasopharyngeal swab remained negative, CT showed clear lung fields with subpleural adhesions, antibody test of SARS- CoV- 2 showed positive IgG and negative IgM. She was considered cured and admitted to the regular obstetrics ward. On Mar.16, 39^{+5} weeks of pregnancy, she delivered a female neonate through vagina, Apgar score 8-9, weight 2900g. The cord blood was tested positive of IgG and negative IgM of SARS- CoV- 2. Breast milk was tested on postpartum day 3 with negative SARS-CoV- 2 antibody components while maternal serum at the same day was IgG 79.0 AU/ml and IgM 12.0 AU/ml. She didn't isolate with her baby and breast fed directly without a mask. The neonate at birth was tested positive with IgG of SARS- CoV- 2, negative IgM and negative nasopharyngeal swabs on the check up of birth day 14.

Discussion

The study enrolled 14 patients who delivered during hospitalization diagnosed with COVID-19 from 32 week pregnancy to postpartum day 2 in Wuhan, China. All of them achieved good recovery with no reported COVID-19 sequela. No neonate infection was noticed. SARS- CoV- 2 nucleic acids were non-detected in 12 breast milk samples of mothers with COVID-19 of various disease stages. In contrast, neutralized SARS- CoV- 2 antibodies were indentified in three breast milk samples. Among the symptomatic breast feeding mothers, profound precautions were taken to avoid postnatal infection. For recovered or cured mothers, direct breast feeding didn't result in neonatal infection.

Breast feeding is well sought out proven to have multiple maternal and infantile benefits[10]. With the ongoing pandemic of COVID-19, the general population is overall vulnerble to the novel virus. Women in pregnant and puerperium states are believed to be particular susceptible, as in other coronavirus

disease caused by SARS- CoV and MERS- CoV[11-12], poorer clinical outcomes, higher morbidity and mortality were reported. So far COVID-19 during pregnancy was reported mostly in mild presentation and good prognosis[13], but neonatal infection was reported during the Wuhan endemic[14], thus discussion focused on postnatal management and breastfeeding advices.

Known breastfeeding transmission pathogen include HIV-1, HTLV-1 and CMV, where pathogen can be isolated from breast milk and cause corresponding illness in neonates. On other occasions, breast lesions served as infection source during neonatal sucking, which can be caused by tuberculosis or varicella zoster virus[15]. In our findings, SARS- CoV- 2 was non-detected in breast milk and the mothers continued breast feeding had no breast lesion. Direct breast feeding do had certain risks, maternal respiratory droplets are considered contagious, especially during acute symptomatic stage, where exceed high viral load[16]. Viremia of SARS- CoV- 2 made breast lesion during neonatal sucking an opportunity window. Neonates also have weaker immune system and inadequate protective devices available, which makes them vulnerable to the overall environment during breast feeding. However, those risks are avoidable with certain measures. Wearing a surgical mask during breast feeding, hand wash before and after pumping, thorough sanitization of the breast expressed devices can help minimize the risks.

The effect of passive acquisition of antibody to SARS- CoV- 2 from breast milk and maternal serum remain to be sought out. Zeng et al.[17] described neonatal acquisition of both IgM and IgG antibody from COVID-19 affected mother. In our findings, antibodies were also identified in cord blood and breast milk samples, indicating passive acquisition transplacentally and through breast milk. In a prospective controlled study discussing the effect of anti-cholera antibodies in breast milk[18] showed breast milk ingestion didn't stop the colonization of vibro cholera. However, those colonized infants

had a milder disease presentation and shorter disease courses. As for enterovirus infection, study reported breast milk antibodies have specific protective effect[19]. During the combat of COVID-19, convalescent plasma (CP) therapy showed promising effects. Chen et al. [20] presented five critical ill patients achieved remission after CP therapy, concluded that CP contributed to disease remission and viral clearence. However, Concerns regarding transfusion- related allergy and possible lethal hyper-immunity attacks of CP are non-neglectable. Breast milk from recovered mothers, possess similar neutralization antibody components, are nonallergenic, easy to acquire and through oral. In addition, breast milk contained a large variety of cellular rich components, including macrophages, immunoglobulin, complement bodies and cytokines, which have wide spectrum antiviral effects.

Based on current information, we hypothesis that breast feeding role in transmission is low and passive acquisition of antibodies to SARS- CoV- 2 is beneficial for the infants. However, due to other possible infection routes during mother- infant contacts, prudent precautions should be taken.

Further investigations should focus on according regulations for COVID-19 mother-infant contacts to fit both neonatal infection prevention and emotional bonding purposes. The SARS- CoV- 2 mother-infant immunological tendency needs long term follow-up, regarding antibody classes, duration and tiers changes. Moreover, prospective study of infants with or without passive acquisition of antibodies to SARS- CoV -2 should be conducted to evaluate the immunity effects.

Conclusions

The study suggested low risk of breast feeding in transmission of SARS- CoV- 2 or causing maternal disease escalation, continue breast feeding with prudent precautions is encouraged. Infants can benefit additionally from direct acquisition of antibody against SARS- CoV- 2 through breast milk.

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271 Table.1 Baseline information of patient with COVID-19 during pregnancy

Baseline information	Patients with COVID-19 during pregnancy	Patients developed SARS- CoV- 2 neutralized IgM/IgG antibody postpartum			
	Total cases(n=14)	Patient1	Patient2	Patient3	Patient4
Age, mean,(SD, range), y	31 (2.4, 27-35)	30	33	27	30
GA at disease onset, Mean, weeks	36^{+3}	32	37	41	32^{+3}
GA at admission, Mean, weeks	38	33^{+3}	39^{+1}	41^{+2}	39^{+3}
Epidemiology exposure, No (%)					
Wuhan or Hubei travel history	14 (100)	Yes	Yes	Yes	Yes
Health care worker	2 (14.2)	Yes	No	No	Yes
Contact of confirmed or suspected	3 (21.4)	Yes	No	No	Yes
Family aggregation occurrence	2 (14.2)	No	No	No	Yes
Gestational comorbidity, No (%)					
ICP	2 (14.2)	No	No	No	No
Gestational diabetes	1 (7.1)	No	No	No	No
Thyroid dysfunction	3 (21.4)	No	No	Yes	No
Congenital heart disease	1 (7.1)	No	No	Yes	No
Chronic HBV infection	1 (7.1)	Yes	No	No	No
Tuberculosis	1 (7.1)	No	No	No	No
Signs and symptoms, No(%)					
Fever	11 (78.6)	Yes	Yes	No	No
Fever during pregnancy	8 (57.1)	Yes	Yes	No	No
Post-partum fever	8 (57.1)	No	No	No	No
Malaise	2 (14.2)	No	No	No	No
Myalgia	2 (14.2)	Yes	No	No	No
Headache	1 (7.1)	No	No	No	No
Sore throat	2 (14.2)	No	No	No	Yes
Cough	6 (42.9)	Yes	No	No	Yes
Chest fullness	2 (14.2)	No	No	No	No
Chest pain	2 (14.2)	No	No	No	No
Diarrhea	1 (7.1)	No	No	No	No
Vomiting	1 (7.1)	No	No	No	No
Anorexia	3 (21.4)	Yes	No	No	No
Abnormal fetal movement	3 (21.4)	No	No	No	No
Respiratory support	8 (57.1)	Yes	No	No	No
Laboratory results, reference value, mean (SD, range)					
Chest CT abnormalities, No(%)	13 (92.9)	Yes	Yes	Yes	Yes
WBC,3.50-9.50 * 10^9/L	8.6 (2.9, 5.0- 16.4)	5.7	9.2	8.5	NA
Neutrophils ,1.80- 6.30 * 10^9/L	6.9 (2.5, 3.0- 13.59)	4.8	7.9	6.3	NA
Lymphocytes, 1.10-3.20 * 10^9/L	1.2 (0.4, 0.6- 1.9)	0.7	0.8	1.7	NA
Platelets,125- 350 * 10^9/L	199 (64, 121- 318)	214	313	236	NA
Hemoglobulin, 115- 150 g/L	123 (15.2, 100- 155)	113	109	100	NA
CRP, <1 mg/L (n=7)	27.5 (22.1, 1.1- 70.5)	70.5	1.1	NA	NA
ESR, 0-20 mm/H (n=3)	50 (24.6, 3- 95)	95	NA	NA	NA

PCT, 0.02- 0.05 ng/L (n=6)	0.4 (0.7, 0.04- 2.05)	0.32	0.06	NA	NA
ALT, <33 U/L	105 (226, 5- 882)	18	7	5	NA
AST, <32 U/L	126 (220, 13- 783)	38	13	14	NA
LDH, 135- 214 U/L (n=10)	283.9 (159.4, 141- 686)	304	167	NA	NA
D-D, <0.5 ug/ml (n=11)	2 (0.8, 0.6-3.2)	1.7	0.65	NA	NA
Co-infection (n, %)	5 (35.7)	Yes Influ- A	No	No	No

Abbreviations: GA, Gestational age; ICP, Intrahepatic Cholestasis of Pregnancy; Co-infection, Influ-A, Influenza A virus; WBC, White blood cell; CRP, C-reactive protein; ESR, Erythrocyte sedimentation rate; PCT, Procalcitonin; ALT, Alanine transaminase; AST, Aspartate aminotransferase; LDH, lactate dehydrogenase; D-D, D-dimer.

Table.2 Perinatal outcomes of patients with COVID-19 during pregnancy

Perinatal outcomes, No (%)	Patients with COVID-19 during pregnancy	Patients developed SARS- CoV- 2 neutralized IgM/IgG antibody postpartum			
	Total cases (n=14)	Patient1	Patient2	Patient3	Patient4
GA of delivery, mean (range), weeks	38^{+3}	39	39^{+1}	41^{+2}	39^{+5}
Disease onset to delivery, mean (SD, range), days	5.4 (6.3, 1-21)	46	15	2	43
PROM	2 (14.2)	No	No	No	No
Fetal distress	2 (14.2)	No	No	No	No
Cesarean	12 (85.7)	Yes	Yes	Yes	No
Amniotic fluid pollution	6 (42.8)	No	No	No	No
Live birth	14 (100)	Yes	Yes	Yes	Yes
Hospital stay, mean (SD, range) days	19 (7.9, 9- 39)	39	16	10	9
Neonate baseline characters, No (%)					
Birth weight, mean (SD, range), g	3224 (421, 2700- 4120)	2700	3930	4120	2900
NICU admission	7 (50)	Yes	Yes	Yes	No
Neonatal asphxia	1 (7.1)	No	No	No	No
Neonatal jaundice	5 (35.7)	Yes	Yes	No	No
Fever	1 (7.1)	Yes	No	No	No
Anemia	1 (7.1)	No	No	No	No

Abbreviations: GA, Gestational age; PROM. Premature rupture of membrane

Table 3. Detection of SARS-CoV-2 nucleic acids in confirmed mother- infant pairs

Confirmed mother-Infant pairs, No	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Delivery date	Jan.19	Jan.22	Jan.24	Jan.30	Jan.31	Jan.31	Feb.3	Feb.5	Feb.09	Feb.09	Feb.20	Feb.29	Mar.5	Mar.16
Gestational age at delivery, weeks	36+ 4	38+ 4	38+ 1	36+ 5	37	38+ 2	40+ 5	38+ 4	39+ 1	39	41+ 1	39	38	39+5
Cesarean	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Maternal SARS-CoV-2 nucleic acids detection														
positive throat swab date	Jan.31	Feb.5	Jan. 28	Feb.8	Jan.31	Jan. 31	Feb. 6	Feb. 5	Feb.10	Feb. 9	N/A	N/A	Feb. 2	Feb.4
negative throat swab date	Feb.18	Feb.17	Jan.31	Feb.9	Feb.8	Feb.22	Feb. 9	Feb.13	Feb.21	Feb.12	Feb,17	Feb.03	Feb.12	Feb.12
	Feb.22	Feb.19	N/A	Feb.11	Feb.13	Feb.24	N/A	Feb.16	Feb.24	Feb.14	Feb.19	Mar.1	Mar.4	Feb.14
SARS-CoV-2 Shedding time, days	18	12	3	1	8	22	3	8	11	3	N/A	N/A	10	8
Breast milk (n=12)	N/A	N/A	—	—	—	—	—	—	—	—	—	—	—	—
Vagina secretion (n=10)	N/A	N/A	N/A	—	N/A	—	—	—	—	—	—	—	—	—
Anal swab (n=12)	N/A	—	N/A	—	—	—	—	—	—	—	—	—	—	—
Neonatal SARS-CoV-2 nucleic acids detection														
Throat swab (n=12)	—	—	N/A	—	N/A	—	—	—	—	—	—	—	—	—
meconium (n=6)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	—	—	—	—	—	—	N/A

Note: Maternal negative throat swab dates were presented as two continuous dates apart from at least 48 hours, SARS-CoV-2 shedding time counted as the duration from the first positive date to the first consecutive negative date. Symbol "—" stands for negative results. N/A, not available. Mother 11 and 12 were confirmed the diagnosis based on epidemiology exposure, characteristic symptoms and positive SARS-CoV-2 combined IgM/IgG tests, their throat swabs remained negative for two separate times.

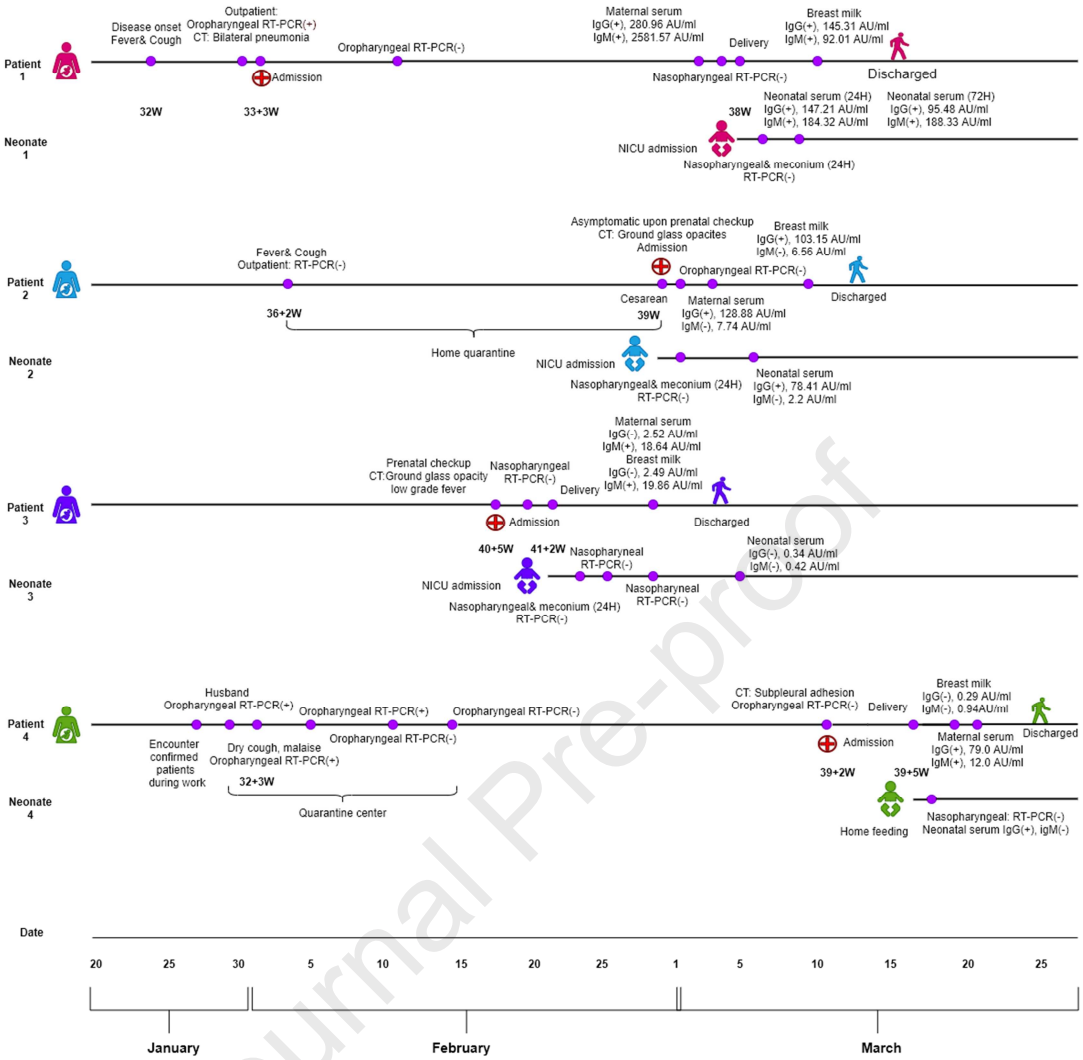

Figure1. Timeline and immunological findings in breast milk and serum among 4 mother- infant pairs

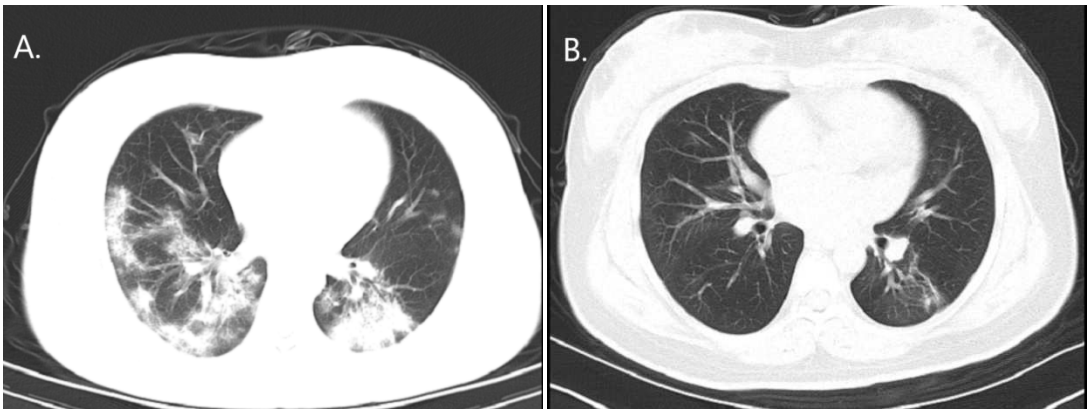

Figure 2. Chest CT image of pregnant patients diagnosed with COVID-19

Figure legend

A. Patient 1 at day 13 of disease onset (Feb.06 2020), and CT showed bilateral lung multiple patches, ground glass opacities with rugged edges.

B. Patient 1 at postpartum day four, 45 days after disease onset (Mar.09 2020), CT showed evident absorption and improvement, partial stranding on left lung subpleural area.