Journal of Communicable Diseases
Volume 56, Issue 4 - 2024, Pg. No. 132-138
Peer Reviewed & Open Access Journal

Research Article

Estimation of Immunoglobulins in Iraqi SARS-CoV-2-Infected Mothers and Their Infants

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DOI: https://doi.org/10.24321/0019.5138.202483

I N F O

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How to cite this article:
Sayah S N, Al-azzawi R H. Estimation of Immunoglobulins in Iraqi SARS-CoV-2-Infected Mothers and Their Infants. J Commun Dis. 2024;56(4):132-138.

Date of Submission: 2024-05-03
Date of Acceptance: 2024-06-21

A B S T R A C T

Objectives: The study aimed to estimate the levels of specific immunoglobulins (IgG, IgM, and IgA) in mothers and their infants affected by COVID-19 and to examine the impact of vaccination on antibody levels.

Method: It was a case-control study conducted among Iraqi pregnant women who gave birth at Saint Raphael Hospital in Baghdad. A total of 148 Iraqi pregnant women were included, with 122 females previously infected with SARS-CoV-2 (group 1) and 26 healthy controls (group 2). Blood samples were collected from mothers before birth and from newborns after birth. The diagnosis of COVID-19 in patients was based on clinical characteristics and PCR results. IgG, IgM, and IgA were detected using the ELISA technique. Real-time PCR was used to detect SARS-CoV-2 RNA in nasopharyngeal swabs.

Results: IgG was detected in both mothers and their infants, while IgA was detected in mothers only. IgM was not detected in either mothers or infants. The study also examined the impact of vaccination on antibody levels.

Conclusions: The study concludes that IgG and IgA were identified only in mothers, with IgM being undetectable in both mothers and their infants. The most robust immune responses were observed in mothers who had received the AstraZeneca vaccine.

Keywords: IgG, IgM, IgA, Sars-Cov-2 Infection, Pregnancy, Infants

Introduction

The new SARS-CoV-2, which emerged in Wuhan, China in December 2019, is a beta coronavirus that belongs to the same family as the earlier severe acute respiratory syndrome (SARS) virus.[1] and the Middle East Respiratory Syndrome (MERS) virus.[2] Because SARS-CoV-2 is a new virus, there is a lack of data on the impact of the infection in pregnant women, including differences from other infections in adults, the risk of vertical transmission to the foetus, and the impact on foetal health, if any. Most pregnant women with COVID-19 disease have mild or moderate flu-like symptoms.[3] Understanding the neonatal immune response to SARS-CoV-2 and the transmission of maternally derived passive immunity to newborns is critical to inform current infection prevention and vaccination strategies against COVID-19. This knowledge is essential to protecting pregnant women and children. A crucial aspect of immunity against infectious pathogens in young children depends on the sufficient production of maternal antibodies, their passage through the placenta to the foetus, and the persistence of passive immunity in

the newborn. Recent publications have shown evidence of the transmission of maternal antibodies against SARS-CoV-2 across the placenta.[4-6]

Protection against early neonatal infection depends on the extent of passage of the infectious agent across the placenta and the transfer of maternal antibodies to the foetus. Transplacental transfer of maternal IgG may protect the newborn from infection.[7]

Our aim was to examine the transmission of maternal antibodies to infants born to women infected with SARS-CoV-2 during pregnancy. In this evaluation, SARS-CoV-2 antibodies were measured in maternal serum, infant blood samples, and breast milk during postpartum hospitalisation.

Method

This case-control study was conducted at Saint Raphael Hospital (Al-Rahibat) in Baghdad, Iraq, from October 20, 2022, to March 1, 2023. A total of 148 pregnant Iraqi women, aged 18 to 37 years, were included, regardless of their SARS-CoV-2 status or symptoms. Upon admission, all women underwent SARS-CoV-2 screening with nasopharyngeal (NP) swab. A venous blood sample was taken from the mother shortly before delivery. The diagnosis was based on clinical characteristics and PCR results. Approval for the study was obtained from the Ethics Committee of the Faculty of Biology (University of Baghdad) [CSEC/1022/0126 on October 17, 2022], and consent was obtained from patients.

Inclusion Criteria

Mothers with a negative SARS-CoV-2 PCR test result (previously infected) were assigned to the patient group, while those without an infection formed the control group.

Exclusion Criteria

History of cancer

History of autoimmune disease

Real-Time PCR

SARS-CoV-2 RNA was detected using a qualitative real-time PCR test kit (Biocomma® Nucleic Acid Purification Kit, CMC Medical Devices & Drugs S.L.C./Horacio, Malaga, Spain). RNA isolated from a nasopharyngeal swab was detected using the Real Line SARS-CoV-2 kit. Internal controls were included in all PCR tests. PCR analyses were conducted within 24 hours of sample collection.

Serum Collection

Venous blood samples were collected from mothers before birth and from newborns after birth. Serum was isolated by centrifugation and stored at -20°C until analysis. IgG, IgM, and IgA were detected using ELISA.

IgG, IgM, and IgA Detection by ELISA

ELISA tests were performed using kits from Siemens (Germany), following the manufacturer's instructions. The tests detect specific antibodies targeting the nucleocapsid and spike proteins of SARS-CoV-2.

SERION ELISA Agile Test Principle

Microplate test strips coated with antigens specific to the pathogen are used. Diluted samples are incubated in the coated wells, and specific antibodies present in positive samples bind to antigens. Secondary antibodies labelled with alkaline phosphatase detect these bound antibodies. The enzymatic reaction produces a coloured product, which is measured photometrically at 405 nm to determine antibody concentration.

Results and Discussion

One hundred and forty-eight women were included, with 122 previously infected with SARS-CoV-2 and 26 uninfected controls, non-smokers, without prior abortions, chronic diseases, or vaccine doses. Most women underwent caesarean sections at Saint Raphael Hospital. Table 1 shows detailed characteristics of women and infants.

Amid the widespread transmission of SARS-CoV-2 globally, infections among pregnant women are becoming more common. Despite this, there are limited reports on infections in pregnant women and their newborns, for instance, among 34 pregnant women diagnosed with SARS-CoV-2 in Wuhan hospitals, 30 were in the third trimester and four were in the second trimester. Foetal health was closely monitored in eight cases, revealing complications such as vaginal bleeding and premature rupture of membranes (PROM) in some instances, alongside other conditions like gestational hypertension and preeclampsia.[8]

In our study, all participants had a history of exposure to COVID-19, with the majority showing negative findings on chest CT scans. Notably, caesarean delivery was prevalent, accounting for 92.6% of cases, while vaginal delivery occurred in only nine instances. Fortunately, no maternal deaths were recorded.

Our findings indicate a notable elevation in IgG levels among mothers previously infected with SARS-CoV-2 compared to the control group (Table 2 and Figure 1). Conversely, IgM results were consistently negative across both patient and control groups.

Protection against early neonatal infection relies on the transfer of maternal antibodies across the placenta.[9] During the second trimester, IgG antibodies are typically passed from mother to foetus, with umbilical cord levels often higher than maternal levels, especially post-vaccination.[10,11] However, in cases of infection, this transfer may be less

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202483

efficient. The transfer ratio varies based on factors like placental health, time of infection to delivery, and maternal antibody levels.[12]

Detection of IgM occurs within 3–6 days post-SARS-CoV-2 infection, while IgG detection follows after eight days.[13,14] IgM indicates recent exposure, while IgG suggests prior infection, aiding in clinical diagnosis, especially when RT-PCR results are negative.[15,16]

Both natural infection and vaccination trigger the production of SARS-CoV-2-specific antibodies, notably IgA, IgM, and IgG against viral proteins.[17,18] IgG levels may remain elevated for over a year, with titers correlating with disease severity.[19] Notably, symptomatic patients tend to have higher and longer-lasting antibody responses.[20]

Infants born to mothers with COVID-19 often carry anti-COVID-19 antibodies, primarily IgG, suggesting placental transfer. Studies report varying antibody prevalence among newborns, irrespective of maternal symptoms, indicating a consistent transfer of antibodies across the placenta.[21,22]

Table 3 exhibits IgA levels in previously infected mothers and their infants. The results display that 87.7% were positive in serum and 86.1% in milk, while it was not detected in the serum of infants (Figure 2).

Infants typically have low IgA levels in serum samples taken immediately after birth, necessitating follow-up to assess antibody titers. Passive immunity, acquired from maternal antibodies via the placenta and breast milk, offers protection for 3–9 months until the infant's active immune response develops.[23]

Breast milk, a complex mixture of nutrients and antibodies, primarily contains IgA, crucial for mucosal defence.[24,25] However, IgG and other antibodies are also present, contributing to immune protection. The exact amounts and quality of transferred antibodies remain uncertain but breastfeeding has been linked to protection against various infections, potentially including SARS-CoV-2.[26]

A significant anti-SARS-CoV-2 response was observed in both serum and breast milk of infected mothers, characterised by IgA predominance in milk and IgG dominance in serum.[27,28]

Table 4 outlines data from 64 vaccinated women and 58 non-vaccinated mothers, with the highest IgG concentration observed in non-vaccinated mothers (29.8 g/L). Differences in serum IgA and IgA levels in milk were non-significant across vaccinated and non-vaccinated groups.

Table 5 reveals that there is a significant (P > 0.05) rise in IgG concentration in babies delivered from non-vaccinated moms (36.5 g/dL) previously infected with the SARS-CoV-2 virus as compared to the vaccinated group (27.2 g/ dL). No significant differences were recorded in the levels of IgG, IgA, or weight of the babies delivered from mothers suffering from chronic diseases and intact moms infected with the SARS-CoV-2 virus. The AstraZeneca vaccine induced an immune response in vaccinated mothers, as evidenced by increased serum IgG levels in previously infected patients who received the AstraZeneca vaccine in Iraq.[29] Additionally, studies have demonstrated efficient transmission of SARS-CoV-2 IgG antibodies across the placenta in mothers vaccinated with the Pfizer mRNA vaccine during pregnancy, suggesting potential immunity transfer to newborns. This suggests that maternal vaccination not only protects mothers from COVID-19 but also confers immunity to newborns.[30] However, further research is needed to assess the effectiveness of humoral response in this context.

Table 1.Characteristics of Sars-Cov-2 Mothers and Their Infants at Birth

N = 122

Variables		Mothers' group		Probability
		Patients group n (%)	Control group n (%)	
Age mean ± SE (Years)		28.99 ± 0.49	28.50 ± 0.49	P > 0.05
Pregnancy	1st time	48 (39.3)	0(0.0)	Uncountable
	2nd time	32 (26.2)	0(0.0)	
	3rd time	23 (18.9)	0(0.0)	
	4th time	12 (9.8)	0 (0.0)	
	5th time	6 (4.9)	0 (0.0)	
	> 5 times	1 (0.8)	0 (0.0)	
Previous abortions	Yes	37 (30.3)	0 (0.0)	P < 0.001
	No	85 (69.7)	26(100)	
Smoking status	Yes	9 (7.4)	0 (0.0)	P < 0.001
	No	113 (92.6)	26 (100)	

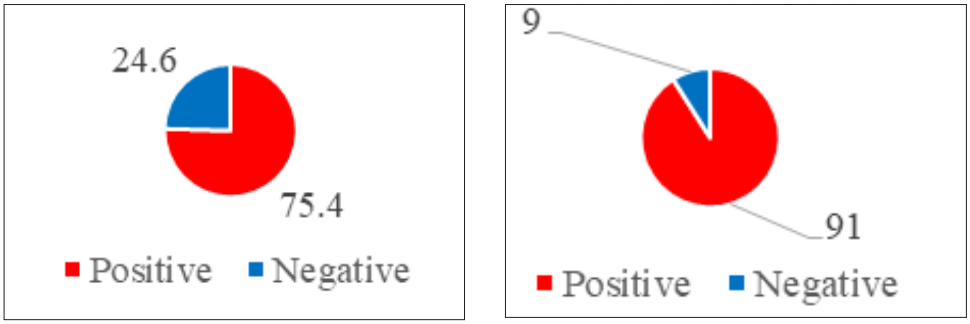
ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202483

Previous abortions	None	85 (69.7)	26(100)	P > 0.05
	1 time	22 (18.0)	0 (0.0)	
	2 times	8 (6.6)	0 (0.0)	
	3 times	2 (1.6)	0 (0.0)	
	4 times	2 (1.6)	0 (0.0)	
	> 4 times	3 (2.5)	0 (0.0)	
Chronic diseases	Nil	114 (93.4)	26 (100.0)	P < 0.001
	Diabetes	2 (1.6)	0 (0.0)	
	Asthma	5 (4.1)	0 (0.0)	
	Epilepsy	1 (0.8)	0 (0.0)	
COVID-19 vaccination status	Yes	64 (52.5)	0 (0.0)	P < 0.001
	No	58 (47.5)	26 (100)	
COVID-19 vaccination status	Nil	58 (47.5)	0 (0.0)	P < 0.001
	Pfizer	51 (41.8)	26 (100)	
	AstraZeneca	5 (4.1)	0 (0.0	
	Sinopharm	8 (6.6)	0 (0.0)	
Type of feeding	Artificial	9 (7.4)	19 (73.1)	P < 0.001
	Natural	105 (86.1)	7 (26.9)	
	Mixed	8 (6.6)	0 (0.0)	
Birth type	Natural	9 (7.4)	6 (23.1)	P < 0.001
	Caesarean	113(92.6)	20 (76.9)	
Variables		**Infants' group**		**Probability**
		Patients group n (%)	**Control group n (%)**	
Weight (kg)		3.25 ± 0.03	3.26 ± 0.03	P > 0.05
Infants' sex	Males	67 (54.9%)	19 (73.1%)	P < 0.001
	Females	55 (45.1%)	7 (26.9%)	
Infants' status	Intact	121 (99.2)	26 (100)	P < 0.05
	Premature	1 (0.8)	0(0.0)	

Table 2.Means of IgM and IgG Levels of Mothers Infected with Sars-Cov-2 Virus and Healthy Control

Mothers/Infants	**COV IgG (mean ± SE) (BAU*/mL)**		**Probability**
	Patient group	**Control group**	
Mothers	24.46 ± 2.39	0.0 ± 0.0	P < 0.001
Infants	31.66 ± 2.22	-	-
COV IgM (mean ± SE) (BAU*/mL)			
Mothers	0.11 ± 0.02	0.0 ± 0.0	P < 0.001
Infants	-	-	-

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202483

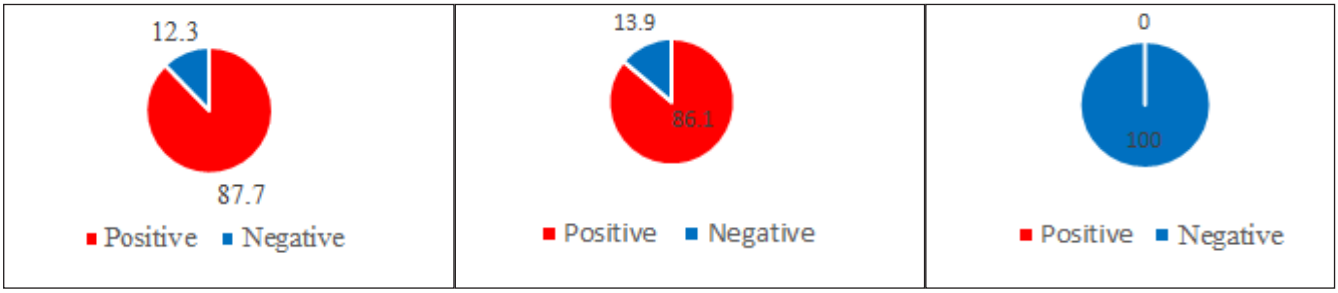


(a) (b)

Figure1.IgG Levels in IgG, (a) Mothers and (b)Their Infants

Table 3.IgA Levels in Previously Infected Mothers and Their Infants

IgA	Mothers' group		Infants' Group
	Serum n (%)	Milk n (%)	(Serum) n (%)
Positive	107 (87.7)	105 (86.1)	0 (0.0)
Negative	15 (12.3)	17 (13.9)	122 (100.0)



(a) (b) (c)

Figure 2.Levels of IgA i+++n (a).Serum of Mothers, (b).Mothers' Milk, and (c).Their Infants

Table 4.Means of Serum IgM, IgG, IgA, and IgA Levels in the Milk of Mothers Infected Previously with SARS-CoV-2 Virus and Vaccinated Previously with Pfizer, AstraZeneca, Sinopharm, and Non-Vaccinated Mothers

Group	No. of samples	IgM (BAU/mL)	IgG (BAU/mL)	IgA (IU/mL)	IgA milk (IU/mL)
Vaccinated with Pfizer	51	0.138 ± 0.2	21.6 ±10	0.41 ± 0.1	0.51 ± 0.2
Vaccinated with AstraZeneca	3	0.76 ± 0.3	24 ± 11	0.56 ± 0.2	0.63 ±0.2
Vaccinated with Sinopharm	10	0.06 ± 0.1	7.8 ± 8	0.50 ± 0.1	0.66 ± 0.1
Non-vaccinated	58	0.07 ± 0.1	*29.8±12	0.46 ± 0.1	0.58 ± 0.2

* Significant at P ≤ 0.05

Table 5.Means of IgG, IgA of Babies from Vaccinated and Non- Vaccinated Mothers

Group	No. of samples	IgA baby serum (IU/mL)	IgG baby (BAU/mL)
Babies from vaccinated mothers	64	0.06 ± 0.3	27.2 ± 40
Babies from non-vaccinated mothers	58	0.07 ± 0.04	*36.5 ± 50

* Significant at P ≤ 0.05

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202483

Conclusion

IgG was detected in both mothers and their infants, IgA was detected in mothers only, while IgM was undetectable in both mothers and their infants. Additionally, the most robust immune responses were observed in mothers who had received AstraZeneca vaccines, and these responses were passed on to their infants, resulting in elevated levels of IgG.

Source of Funding: None

Conflict of Interest: None

References

1. Hon KL, Li AM, Cheng FW, Leung TF, Ng PC. Personal view of SARS: confusing definition, confusing diagnoses. Lancet. 2003;361(9373):1984-5. [PubMed] [Google Scholar]
2. Chan JF, Yuan S, Kok KH, To KK, Chu H, Yang J, Xing F, Liu J, Yip CC, Poon RW, Tsoi HW, Lo SK, Chan KH, Poon VK, Chan WM, Ip JD, Cai JP, Cheng VC, Chen H, Hui CK, Yuen KY. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet. 2020;395(10223):514-23. [PubMed] [Google Scholar]
3. Ovalı F. SARS-CoV-2 infection and the newborn. Front Pediatr. 2020;8:294. [PubMed] [Google Scholar]
4. Flannery DD, Gouma S, Dhudasia MB, Mukhopadhyay S, Pfeifer MR, Woodford EC, Triebwasser JE, Gerber JS, Morris JS, Weirick ME, McAllister CM, Bolton MJ, Arevalo CP, Anderson EM, Goodwin EC, Hensley SE, Puopolo KM. Assessment of maternal and neonatal cord blood SARS-CoV-2 antibodies and placental transfer ratios. JAMA Pediatr. 2021;175(6):594. [PubMed] [Google Scholar]
5. Edlow AG, Li JZ, Collier AR, Atyeo C, James KE, Boatin AA, Gray KJ, Bordt EA, Shook LL, Yonker LM, Fasano A, Diouf K, Croul N, Devane S, Yockey LJ, Lima R, Shui J, Matute JD, Lerou PH, Akinwunmi BO, Schmidt A, Feldman J, Hauser BM, Caradonna TM, Flor DD, D'Avino P, Regan J, Corry H, Coxen K, Fajnzylber J, Pepin D, Seaman MS, Barouch DH, Walker BD, Yu XG, Kaimal AJ, Roberts DJ, Alter G. Assessment of maternal and neonatal SARS-CoV-2 viral load, transplacental antibody transfer, and placental pathology in pregnancies during the COVID-19 pandemic. JAMA Netw Open. 2020;3(12):e2030455. [PubMed] [Google Scholar]
6. Kubiak JM, Murphy EA, Yee J, Cagino KA, Friedlander RL, Glynn SM, Matthews KC, Jurkiewicz M, Sukhu AC, Zhao Z, Prabhu M, Riley LE, Yang YJ. Severe acute respiratory syndrome coronavirus 2 serology levels in pregnant women and their neonates. Am J Obstet Gynecol. 2021;225(1):e1-7. [Google Scholar]
7. Fouda GG, Martinez DR, Swamy GK, Permar SR. The impact of IgG transplacental transfer on early life immunity. Immunohorizons. 2018;2(1):14-25. [PubMed] [Google Scholar]
8. Yu Y, Chen P. Coronavirus Disease 2019 (COVID-19) in neonates and children from China: a review. Front Pediatr. 2020;8:287. [PubMed] [Google Scholar]
9. Nielsen SY, Petersen LH, Murra M, Hvidman L, Helmig RB, Møller JK, Khalil MR, Kirkeby M, Henriksen TB. Transplacental transfer of SARS-CoV-2 antibodies: a cohort study. Eur J Clin Microbiol Infect Dis. 2023;42(3):277-85. [PubMed] [Google Scholar]
10. Munoz FM, Bond NH, Maccato M, Pinell P, Hammill HA, Swamy GK, Walter EB, Jackson LA, Englund JA, Edwards MS, Healy CM, Petrie CR, Ferreira J, Goll JB, Baker CJ. Safety and immunogenicity of Tetanus diphtheria and Acellular pertussis (Tdap) immunization during pregnancy in mothers and infants: a randomized clinical trial. JAMA. 2014;311(17):1760-9. [PubMed] [Google Scholar]
11. Castanha PM, Souza WV, Braga C, Araujo TV, Ximenes RA, Albuquerque MD, Montarroyos UR, Miranda-Filho DB, Cordeiro MT, Dhalia R, Marques Jr ET, Rodrigues LC, Martelli CM; Microcephaly Epidemic Research Group. Perinatal analyses of Zika- and dengue virus-specific neutralizing antibodies: a microcephaly case-control study in an area of high dengue endemicity in Brazil. PLoS Negl Trop Dis. 2019;13(3):e0007246. [PubMed] [Google Scholar]
12. Lee HK, Lee BH, Seok SH, Baek MW, Lee HY, Kim DJ, Na YR, Noh KJ, Park SH, Kumar DN, Kariwa H, Nakauchi M, Heo SJ, Park JH. Production of specific antibodies against SARS-coronavirus nucleocapsid protein without cross reactivity with human coronaviruses 229E and OC43. J Vet Sci. 2010;11(2):165-7. [PubMed] [Google Scholar]
13. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, Ren R, Leung KS, Lau EH, Wong JY, Xing X, Xiang N, Wu Y, Li C, Chen Q, Li D, Liu T, Zhao J, Liu M, Tu W, Chen C, Jin L, Yang R, Wang Q, Zhou S, Wang R, Liu H, Luo Y, Liu Y, Shao G, Li H, Tao Z, Yang Y, Deng Z, Liu B, Ma Z, Zhang Y, Shi G, Lam TT, Wu JT, Gao GF, Cowling BJ, Yang B, Leung GM, Feng Z. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med. 2020;382(13):1199-207. [PubMed] [Google Scholar]
14. Dong X, Cao YY, Lu XX, Zhang JJ, Du H, Yan YQ, Akdis CA, Gao YD. Eleven faces of coronavirus disease 2019. Allergy. 2020;75(7):1699-709. [PubMed] [Google Scholar]
15. To KK, Tsang OT, Leung WS, Tam AR, Wu TC, Lung DC, Yip CC, Cai JP, Chan JM, Chik TS, Lau DP, Choi CY, Chen LL, Chan WM, Chan KH, Ip JD, Ng AC, Poon RW, Luo CT, Cheng VC, Chan JF, Hung IF, Chen Z, Chen H, Yuen KY. Temporal profiles of viral load in

posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study. Lancet Infect Dis. 2020;20(5):565-94. [PubMed] [Google Scholar]
16. Wu K, Werner AP, Koch M, Choi A, Narayanan E, Stewart-Jones GB, Colpitts T, Bennett H, Boyoglu-Barnum S, Shi W, Moliva JI, Sullivan NJ, Graham BS, Carfi A, Corbett KS, Seder RA, Edwards DK. Serum neutralizing activity elicited by mRNA-1273 vaccine. N Engl J Med. 2021;384(15):1468-70. [PubMed] [Google Scholar]
17. Xiao X, Xiao X, Zhou Y, Zhao X, Chen G, Liu Z, Wang Z, Lu C, Hu M, Nashalian A, Shen S, Xie K, Yang W, Gong Y, Ding W, Servati P, Han C, Dou SX, Li W, Chen J. An ultrathin rechargeable solid-state zinc ion fiber battery for electronic textiles. Sci Adv. 2021;7(49):eabl3742. [PubMed] [Google Scholar]
18. Choe YJ, Lee JS, Lee Y, Park KH, Yoo Y, Im GJ, Lee SW, Park JE. Building of pediatric COVID-19 module clinic: a novel operation model in response to COVID-19 pandemic. J Korean Med Sci. 2023;38(13):e96. [PubMed] [Google Scholar]
19. Batra K, Sharma M, Dai CL, Khubchandani J. COVID-19 booster vaccination hesitancy in the United States: a multi-theory-model (MTM)-based national assessment. Vaccines (Basel). 2022;10(5):758. [PubMed] [Google Scholar]
20. Lucas C, Wong P, Klein J, Castro TB, Silva J, Sundaram M, Ellingson MK, Mao T, Oh JE, Israelow B, Takahashi T, Tokuyama M, Lu P, Venkataraman A, Park A, Mohanty S, Wang H, Wyllie AL, Vogels CB, Earnest R, Lapidus S, Ott IM, Moore AJ, Muenker MC, Fournier JB, Campbell M, Odio CD, Casanovas-Massana A; Yale IMPACT Team; Herbst R, Shaw AC, Medzhitov R, Schulz WL, Grubaugh ND, Cruz CD, Farhadian S, Ko AI, Omer SB, Iwasaki A. Longitudinal analyses reveal immunological misfiring in severe COVID-19. Nature. 2020;584(7821):463-9. [PubMed] [Google Scholar]
21. Zeng H, Xu C, Fan J, Tang Y, Deng Q, Zhang W, Long X. Antibodies in infants born to mothers with COVID-19 pneumonia. JAMA. 2020;323(18):1848-9. [PubMed] [Google Scholar]
22. Vendola N, Stampini V, Amadori R, Gerbino M, Curatolo A, Surico D. Vertical transmission of antibodies in infants born from mothers with positive serology to COVID-19 pneumonia. Eur J Obstet Gynecol Reprod Biol. 2020;253:331-2. [PubMed] [Google Scholar]
23. Pullen KM, Atyeo C, Collier AR, Gray KJ, Belfort MB, Lauffenburger DA, Edlow AG, Alter G. Selective functional antibody transfer into the breastmilk after SARS-CoV-2 infection. Cell Rep. 2021;37(6):109959. [PubMed] [Google Scholar]
24. Fox A, Marino J, Amanat F, Krammer F, Hahn-Holbrook J, Zolla-Pazner S, Powell RL. Robust and specific secretory IgA against SARS-CoV-2 detected in human milk. iScience. 2020;23(11):101735. [PubMed] [Google Scholar]
25. Pace RM, Williams JE, Järvinen KM, Belfort MB, Pace CD, Lackey KA, Gogel AC, Nguyen-Contant P, Kanagaiah P, Fitzgerald T, Ferri R, Young B, Rosen-Carole C, Diaz N, Meehan CL, Caffe B, Sangster MY, Topham D, McGuire MA, Seppo A, McGuire MK. COVID-19 and human milk: SARS-CoV-2, antibodies, and neutralizing capacity. medRxiv [Preprint]. 2020 [cited 2024 Feb 27]. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7523143/ [PubMed] [Google Scholar]
26. Lyons KE, Ryan CA, Dempsey EM, Ross RP, Stanton C. Breast milk, a source of beneficial microbes and associated benefits for infant health. Nutrients. 2020;12(4):1039. [PubMed] [Google Scholar]
27. Binsker U, Lees JA, Hammond AJ, Weiser JN. Immune exclusion by naturally acquired secretory IgA against pneumococcal pilus-1. J Clin Investig. 2020;130(2):927-41. [PubMed] [Google Scholar]
28. Caballero-Flores G, Sakamoto K, Zeng MY, Wang Y, Hakim J, Matus-Acuña V, Inohara N, Núñez G. Maternal immunization confers protection to the offspring against an attaching and effacing pathogen through delivery of IgG in breast milk. Cell Host Microbe. 2019;25(2):313-23. [PubMed] [Google Scholar]
29. Nir O, Schwartz A, Toussia-Cohen S, Leibovitch L, Strauss T, Asraf K, Doolman R, Sharabi S, Cohen C, Lustig Y, Regev-Yochay G, Yinon Y. Maternal-neonatal transfer of SARS-CoV-2 immunoglobulin G antibodies among parturient women treated with BNT162b2 messenger RNA vaccine during pregnancy. Am J Obstet Gynecol MFM. 2022;4(1):100492. [PubMed] [Google Scholar]
30. Ibraheem ZK, AL-Azzawy RH. Comparative study of immunoglobulin g and gender between COVID-19 patients and vaccinated Iraqi individuals with Pfizer, AstraZeneca and Sinopharm vaccine. Egypt J Hosp Med. 2022;89(1):5758-63. [Google Scholar]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.202483