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Following Heterologous COVID-19 Vaccination**

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Original article

Antibody Levels in Thai Pregnant Women and Cord Blood Following Heterologous COVID-19 Vaccination

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Abstract

Objective: To assess maternal and cord blood SARS-CoV-2 anti-receptor binding domain (RBD) IgG levels in Thai pregnant women following different COVID-19 vaccine regimens, and identify factors influencing these levels.

Material and Methods: A cross-sectional study was conducted at a quaternary care hospital in Thailand between April 2022 and February 2023 to evaluate anti-RBD immunoglobulin G (IgG) levels at delivery among singleton pregnant women. Participants received either two doses of COVID-19 vaccines, ChAdOx1, BNT162b2, or mRNA-1273 in any combination, or three doses, with one of these vaccines administered as the final dose. Spearman's correlation was used to assess the relationship between the maternal and cord blood antibody levels. Non-linear least squares regression estimated the effect of time since the last vaccination, while multivariable models identified factors influencing antibody concentrations. Significance was set at $p\text{-value} < 0.05$.

Results: Eighty-five pregnant women were enrolled. Median (interquartile ranges [IQR]) SARS-CoV-2 anti-RBD IgG levels were 1,123 (552–2,707) AU/mL in maternal blood and 2,100 (888–4,687) AU/mL in cord blood ($\text{BAU/mL} = \text{AU/mL} \times 0.142$), with a positive correlation and an antibody transfer ratio of 1.63. From the second trimester, shorter intervals since the last vaccine dose were linked to higher antibody levels—maternal levels rose by 14% per week and cord levels by 17.8% ($p\text{-value} = 0.016$). Maternal obesity was associated with lower antibody levels. The highest levels were seen with a regimen of one inactivated and two viral vector vaccines.

Conclusion: Maternal and cord blood anti-RBD IgG levels were positively correlated and influenced by vaccine timing, regimen, and maternal obesity.

Keywords: antibody, heterologous vaccination, COVID-19 vaccination, pregnancy

Introduction

The COVID-19 pandemic, caused by SARS-CoV-2, has posed a significant global health challenge since December 2019, resulting in over 7 million deaths worldwide.¹ Pregnant women infected with SARS-CoV-2 are at increased risk of developing severe symptoms and face higher

chances of complications, such as hypertension and preterm birth.² Between December 1, 2020, and May 31, 2022, a total of 14,037 pregnant women in Thailand were infected, with 13% experiencing moderate to severe symptoms and a mortality rate of 0.5%.³

Vaccination has been essential in reducing the burden of disease, with multiple vaccines shown to be safe and effective during pregnancy.^{4–6} In March 2021, the Thai government launched its national COVID-19 vaccination program, initially deploying inactivated vaccines—CoronaVac (Sinovac) and Sinopharm BIBP—as well as the viral vector-based vaccine ChAdOx1 nCoV-19 (AstraZeneca).^{7–8} To address vaccine shortages, heterologous (mix-and-match) regimens were introduced, and booster doses of two mRNA vaccines—BNT162b2 (Pfizer-BioNTech) and mRNA-1273 (Moderna)—became available in August and November 2021, respectively.^{9–10} The Thai Ministry of Public Health and the Royal Thai College of Obstetricians and Gynecologists recommend that all pregnant women receive at least one dose of a COVID-19 vaccine after the first trimester.¹¹

The immunogenicity of COVID-19 vaccines may vary between pregnant and nonpregnant women.¹² Importantly, vaccine-induced antibodies can cross the placenta and have been detected in umbilical cord blood and infant circulation, providing protective effects against COVID-19 during the first six months of life.^{13–17} Given the limited number of studies evaluating antibody responses in pregnant women in Thailand who received heterologous vaccine regimens, we aimed to investigate the levels of SARS-CoV-2 anti-receptor binding domain (RBD) IgG antibodies in maternal serum and cord blood. We assessed the correlation between maternal and cord blood antibody levels, calculated the antibody transfer ratio (cord blood to maternal serum), and examined factors influencing antibody levels among Thai pregnant women who received different vaccination regimens.

Material and Methods

A cross-sectional study was conducted at a quaternary university hospital in Southern Thailand, following approval of the study protocol by the Faculty Institutional Review Board (IRB No. REC. 64-469-12-1, dated 11 November 2021). The study was conducted in accordance with the Declaration of Helsinki (1975), as revised in 2000. From 1 April 2022 to 3 February 2023, singleton

pregnant women, aged 18 to 45 years, gestational age at 28 weeks or more confirmed by an ultrasonography during the first trimester, had been vaccinated with COVID-19 vaccines which could be any of the following (1) two doses of vaccines in any combination of ChAdOx1, BNT162b2 or mRNA-1273, or (2) three doses of vaccines with ChAdOx1, BNT162b2 or mRNA-1273 vaccine as the last dose, and delivered at our hospital were recruited. Those who needed emergency or urgent management (e.g., in severe pain, bleeding per vagina or hypo/hypertension), had a history of COVID-19 infection, had vaccine allergy, had received immunomodulating agents or steroids, or had severe immunocompromised conditions were excluded from the study. Women who agreed to participate were directly interviewed. We collected data on demographics, obstetrics, vaccination, comorbidities, and delivery outcomes. After delivery, neonatal outcomes within 28 days of life were followed by telephone calls.

Maternal blood was drawn within 24 hours before delivery, while umbilical cord blood was collected immediately after the delivery. Maternal blood and umbilical cord samples (2-3 mL) were labeled immediately after the collections, kept in paired 'clotted blood' tubes at room temperature, then sent to the serology unit of our faculty on the same working day for the laboratory assessment of SARS-CoV-2 anti-RBD IgG measured in arbitrary units (AU/mL) using the Abbott Alinity i SARS-CoV-2 IgG II Quant CMIA (Abbott Laboratories, USA). To facilitate comparisons with studies reporting binding antibody units per milliliter (BAU/mL), we note that results from this assay can be converted using the established factor ($\text{BAU/mL} = \text{AU/mL} \times 0.142$), which is traceable to the WHO International Standard for anti-SARS-CoV-2 immunoglobulin.¹⁸

Previous studies^{19,20} determined an initial total sample size of 150 participants, comprising 30 participants in each set of the vaccine types. However, we decided to discontinue recruiting after it was found that nearly every pregnant woman visiting the hospital had previously been infected with COVID-19.

The levels of maternal and cord blood SARS-CoV-2 anti-RBD IgG antibodies are shown in median values and interquartile ranges (IQR). The Spearman correlation coefficient was used to evaluate the correlation between maternal and cord blood antibody levels.

Because of the evidently different effect of the vaccination period, non-linear least squares estimation was used to assess the piece-wise unadjusted relationship between time prior to delivery of the most recent vaccination and levels of SARS-CoV-2 anti-RBD IgG antibodies in maternal serum and cord blood. Subsequently, the influence on antibody levels of other variables, namely age, BMI, gravidity, parity, maternal comorbidity, and pattern and timing of each vaccination, was explored in a series of multivariable models generated by adding each variable separately to the unadjusted models. All data analyses were conducted using Stata release 14.2. A P-value of < 0.05 was considered as indicating statistical significance.

Results

From 1 April 2022 to 3 February 2023, 85 women met the study's inclusion criteria and agreed to participate. The majority were in their thirties and without underlying health conditions, all delivering at term (Table 1).

Two women experienced postpartum hemorrhage. Three newborns required NICU admission, for transient tachypnea of newborn (n=1), low birthweight (n=1), and persistent pulmonary hypertension (n=1). There were no cases of neonatal COVID-19 infection. We categorized the vaccination regimens received by pregnant women into eight distinct patterns, which were 1) two viral vector vaccines (n=6); 2) one viral vector vaccine plus one mRNA vaccine (n=6); 3) two mRNA vaccines (n=28); 4) two viral vector vaccines plus one mRNA vaccine (n=3); 5) one inactivated vaccine plus two viral vector vaccines' (n=5); 6) two inactivated vaccines plus one viral vector vaccine (n=9); 7) two inactivated vaccines plus one mRNA vaccine (n=14); 8) one inactivated vaccine plus one viral vector vaccine plus one mRNA vaccine (n=14). The most common vaccination pattern observed was 'two mRNA vaccines,' followed by 'two inactivated vaccines and one mRNA vaccine,' and 'one inactivated vaccine, one viral vector vaccine, and one mRNA vaccine' (Table 1).

The median time elapsed (IQR) from the most recent vaccination to delivery was 167 (140, 323) days, and from the first (n = 85), second (n = 85), and third (n = 45) doses of vaccination, respectively, 348 (277, 404), 311 (163, 377), and 228 (144, 325) days.

Median (IQR) of maternal serum and cord blood SARS-CoV-2 anti-RBD IgG levels were 1,123 (552, 2,707) and 2,100 (888, 4,687) AU/mL, respectively, and the median (IQR) for antibody transfer ratio was 1.63 (1.26, 1.97) (Table 1).

We found that the timing of the last vaccination was significantly associated with both maternal and cord blood SARS-CoV-2 anti-RBD IgG levels.

Specifically, if the last vaccination occurred after 92 days of gestation (13.1 weeks), there was a notable increase of 14.0% in maternal anti-RBD IgG levels per week (95% CI: 2.5 to 26.6%, $p = 0.016$), as the date of the last vaccination approached the delivery date. However, if the vaccination occurred before 92 days of gestation, there were no significant changes in antibody levels, regardless of timing (-1.7% per week, 95% CI: -6.1 to +3.0%, $p = 0.477$). Median (IQR) maternal anti-RBD IgG levels were 752 (379, 2,018) AU/mL and 1,670 (697, 3,147) AU/mL for pregnant women who received the last vaccination before and after 92 days of gestation, respectively (Figure 1).

For the cord blood antibody level, we found that SARS-CoV-2 anti-RBD IgG levels increased by 17.8% per week (95% CI: 6.9% to 30.0%, $p = 0.001$) as the date of last vaccination approached the delivery date, but only if the last vaccination occurred after 79 days of gestational age (11.3 weeks). For women vaccinated before 79 days of gestation, there were no significant changes in cord blood antibody levels regardless of the timing (-1.9% per week, 95% CI: -6.1% to +2.4%, $p = 0.367$). Median (IQR) cord blood anti-RBD IgG levels were 950 (387, 2,809) AU/mL and 3,216 (1,564, 5,587) AU/mL for pregnant women who received the last vaccination before and after 79 days of gestation, respectively (Figure 2).

Our analysis revealed a significant correlation between maternal and cord blood antibody levels, with a Spearman correlation coefficient of 0.923 ($p < 0.001$).

Beyond the timing of the last vaccination, pre-pregnancy maternal obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) was significantly associated with lower maternal SARS-CoV-2 anti-RBD IgG levels (relative antibody concentration 0.27; 95% CI: 0.10–0.78). Also, the patterns of vaccinations had significant effects on both maternal and cord blood anti-RBD levels, as indicated by combined Wald P-values of 0.006 and 0.042, respectively. The vaccination pattern of 'one inactivated

vaccine plus two viral vector vaccines' yielded the highest antibody levels for both maternal and umbilical cord blood, with relative antibody concentration of 6.26 (95% CI: 1.97–19.85) and 4.89 (95% CI: 1.62–14.73), respectively. The factors potentially influencing maternal and umbilical cord blood antibodies and the multiplicative factor by which antibody levels were altered are presented in Tables 2 and 3, respectively.

Discussion

Our evaluation of SARS-CoV-2 anti-RBD IgG levels in singleton pregnant women who received eight different vaccination patterns showed median concentrations at delivery of 1,123 AU/mL in maternal serum and 2,100 AU/mL in cord blood, corresponding to a transfer ratio of 1.63. Maternal and cord blood antibody levels were strongly correlated (Spearman $\rho = 0.923$, $p < 0.001$). The timing of vaccination significantly influenced anti-RBD IgG concentrations in both maternal and cord blood, with higher levels observed when the interval between the final vaccine dose and delivery was shorter from the end of the first trimester onward. Maternal obesity was associated with lower maternal anti-RBD IgG levels. Among the vaccination patterns examined, the regimen consisting of one inactivated vaccine followed by two viral vector vaccines produced the highest antibody levels in both maternal and cord blood.

It is not surprising that longer intervals from vaccination to delivery led to lower antibody levels. In our study, the shortest duration from the last vaccination to delivery was 76 days. This exceeds the typical antibody peak, which occurs about one-month post-vaccination.^{21,22} In this study, the longest duration from the last vaccination to delivery was 436 days, with maternal and cord blood SARS-CoV-2 anti-RBD IgG levels of 126.7 AU/mL and 190.2 AU/mL at delivery. This is consistent with literature reporting antibody levels below 1,000 AU/mL after 220 days.²²

Consistent with our findings, studies by Chayachinda et al. (2023)²³ and Lertvanavit et al. (2025),²⁴ conducted in Thailand, found a negative correlation between the duration from the last vaccination to delivery and antibody levels in both maternal serum and cord blood. Both studies found a positive correlation, with cord blood antibody levels equal to or higher than maternal levels.^{23,24} In contrast to the two previous studies, our study evaluated antibody levels in a real-world setting, involving participants with eight distinct vaccination patterns. Initiated in April

2022, 64 (75.3%), 53 (62.4%), and 17 (20.0%) participants received their first, second, and third vaccine doses prior to pregnancy, respectively. Chayachinda et al. (2023) conducted a randomized trial in which pregnant participants received two doses of either BNT162b2-BNT162b2, ChAdOx1-BNT162b2, or CoronaVac-BNT162b2 during pregnancy.²³ Meanwhile, Lertvanavit et al. (2025) included participants who received two or three doses of CoronaVac, Sinopharm BIBP, ChAdOx1 nCoV-19, BNT162b2, or mRNA-1273 exclusively during pregnancy, with no vaccinations administered prior to conception; their study began in May 2022.²⁴

Conversely, Gray et al. (2021) found that a longer duration from the last vaccination to delivery significantly positively affected cord blood spike-specific IgG levels, but not anti-RBD IgG levels. This discrepancy may be due to their shorter duration from vaccination to delivery (median of 14 days), during which antibody levels are still rising.²⁵

The effects of vaccination patterns in our study differ from previous findings. Chayachinda et al. (2023) reported no significant variation in anti-RBD IgG levels across vaccination patterns, but their study involved different vaccine combinations and a shorter interval from last dose to delivery (3–15 weeks vs. our 11–62 weeks).²³

Barin et al. (2022) reported that mRNA vaccines produced the highest anti-spike RBD IgG levels, with slower antibody decline compared to viral vector and inactivated vaccines.²¹ Wei et al. (2023) found mRNA-1273 yielded the highest peak levels among mRNA and viral vector vaccines.²⁶ In contrast, our study showed that the 'one inactivated plus two viral vector vaccines' pattern resulted in the highest antibody levels, with no observed correlation between dose count and antibody levels. This suggests that vaccine platform mixing, rather than dose count or vaccine type alone, may have influenced the observed antibody levels.

Regarding the influence of maternal obesity on lowering antibody levels, a 2021 systematic review also found that obesity was significantly linked to reduced antibody levels post-COVID-19 vaccination.²⁷ This could be **due to** excess adipose tissue inducing chronic inflammation, which impairs normal immune function.²⁸ Moreover, increased upper-arm adiposity may compromise vaccine delivery with standard needles, resulting in incomplete intramuscular

injection.²⁹ These mechanisms may therefore have contributed to the attenuated immunogenicity seen in the obese subgroup of our cohort.

The limitations of our study include the potential inclusion of women with past asymptomatic COVID-19 infections, which could result in higher and more slowly declining antibody levels after vaccination. Additionally, most women had already received some form of vaccination by the time our project began, preventing us from evaluating baseline antibody levels. The number of participants for each vaccination pattern was also low, as we had to stop recruiting due to the high prevalence of prior COVID-19 infections. The reduced overall sample size and the small number of participants in some vaccination-sequence subgroups limit the statistical power of regimen-specific comparisons, and estimates derived from these smaller groups should be interpreted with caution. Moreover, the data were collected during an earlier phase of the COVID-19 vaccination program, when Omicron was the predominant circulating variant in Thailand. Although our study included several vaccine sequences, vaccination recommendations and booster formulations have continued to adapt to emerging variants, which may influence how broadly our findings apply to current practice.

Since maternal IgG placental transfer can persist in infant sera for up to 6 months and potentially offers protection against COVID-19, our finding of an inverse relationship between the duration from the last vaccination to delivery and cord blood anti-RBD IgG levels supports the recommendation of booster doses during pregnancy. A 2023 prospective study found higher IgG levels in infants whose mothers were vaccinated in the third trimester compared to the second trimester, though it did not find a significant association between infants' IgG levels and the development of COVID-19 infection.¹⁷ Previous studies have shown that a time-lapse of more than 220 days since the last vaccination and antibody levels below 1,000 AU/mL are associated with a higher risk of COVID-19 infections.²² Our study confirmed this association, showing that participants with anti-RBD IgG levels below 1,000 AU/mL had a duration from vaccination to delivery ranging from 119 to 436 days. This underscores the importance of vaccine boosters and highlights the need to practice good hygiene and maintain physical distance during pregnancy.

Future studies should focus on booster vaccination during different trimesters, long-term evaluation of infants' antibody trends, and clinical outcomes to ensure proper COVID-19 immunization recommendations in pregnancy. Additionally, a detailed evaluation of pregnant women with comorbidities, such as immunosuppressive conditions, is needed.

Conclusion

This study shows that maternal and cord blood SARS-CoV-2 anti-RBD IgG levels at delivery are positively correlated and are influenced by the timing of the last COVID-19 vaccine dose, the type of vaccine regimen received, and maternal obesity. Shorter intervals between vaccination and delivery were associated with higher antibody concentrations in both maternal and cord blood. Mixed vaccine regimens that included inactivated and viral vector vaccines produced the highest antibody levels, while maternal obesity was associated with lower concentrations.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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Figure legends

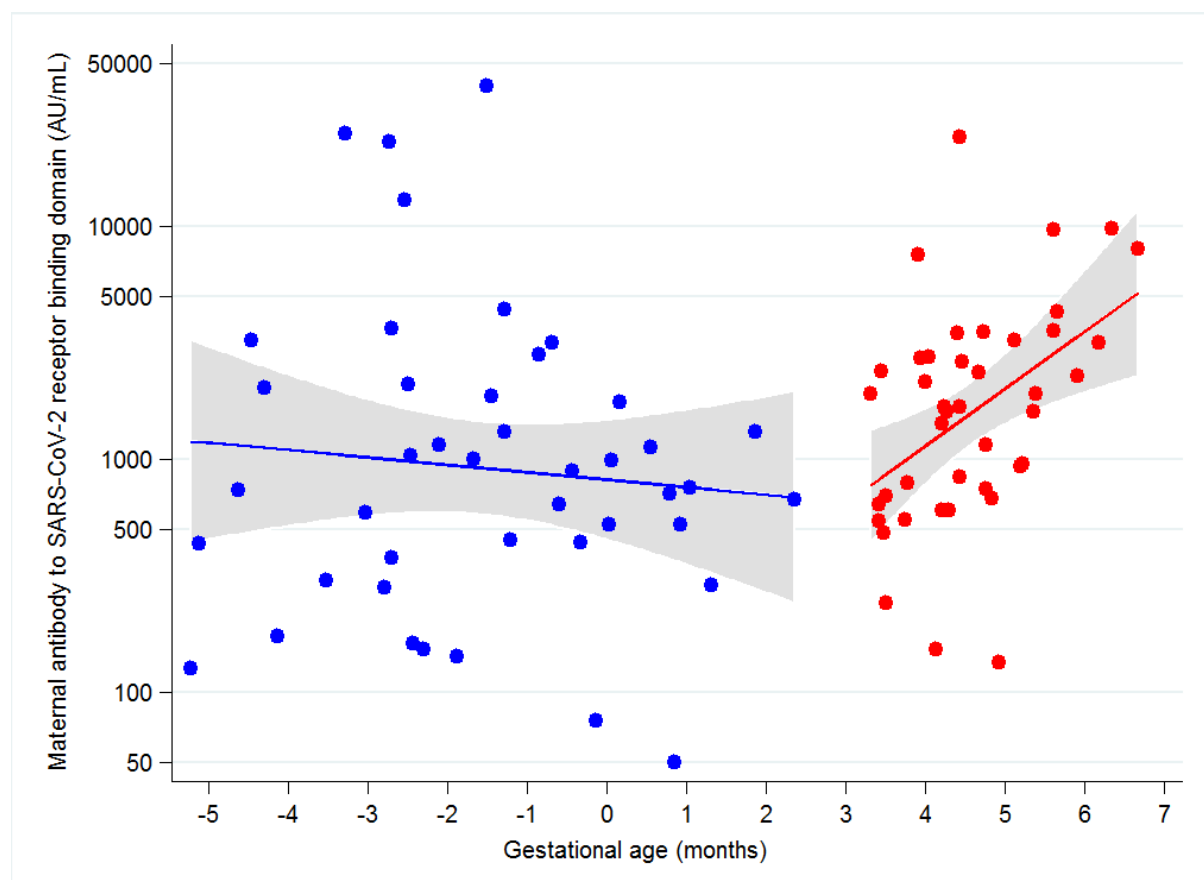


Figure 1 Scatter plot illustrating the relationship between gestational age at the time of the last COVID-19 vaccination and maternal antibody levels to the SARS-CoV-2 receptor-binding domain (in AU/mL). (Blue dots indicate women who received the final vaccination before 92 days of gestation, while red dots indicate those vaccinated after 92 days. The lines represent the predicted mean, with grey shading depicting the 95% confidence interval around the mean.)

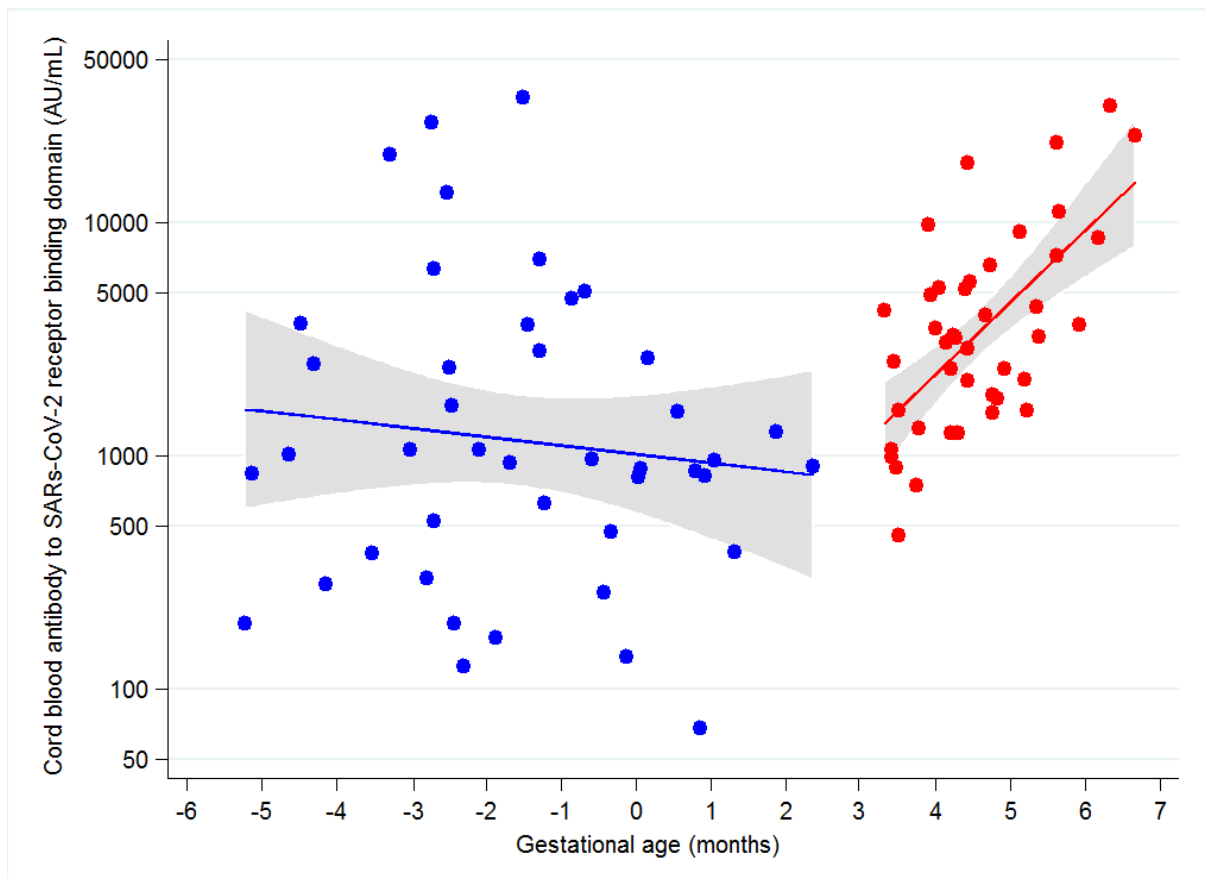


Figure 2 Scatter plot illustrating the relationship between gestational age at the time of the last COVID-19 vaccination and cord blood antibody levels to the SARS-CoV-2 receptor-binding domain (in AU/mL). (Blue dots indicate the cord blood antibodies of women vaccinated before 79 days of gestation, while red dots indicate those vaccinated after 79 days. The lines represent the predicted mean, with grey shading depicting the 95% confidence interval around the mean.)

Table 1 Demographic data, obstetric and vaccination information, delivery outcomes, and neonatal outcomes

Characteristic	N = 85
Age (years) (median [IQR])	33 (30, 35)
Pre-pregnancy body mass index (BMI, kg/m ²) (mean±SD)	23.28±6.17
Gravidity (median [IQR])	2 (1, 3)
Number of gravida (n (%))	
1	27 (31.8)
2	34 (40.0)
≥3	24 (28.2)
Parity (median [IQR])	1 (0, 1)
0 (n (%))	32 (37.6)
1 (n (%))	40 (47.1)
2 (n (%))	13 (15.3)
Presence of maternal comorbidity (n (%))	10 (11.8)
- Gestational diabetes mellitus	1 (1.2)
- Asthma	2 (2.4)
- Others (allergic rhinitis (n=4), anemia (n=1), migraine headache (n=1), papillary thyroid carcinoma (n=1))	7 (8.2)
Pattern of vaccination (n (%))	
- Two viral vector vaccines	6 (7.1)
- One viral vector vaccine + one mRNA vaccine	6 (7.1)
- Two mRNA vaccines	28 (32.9)
- Two viral vector vaccines + one mRNA vaccine	3 (3.5)
- One inactivated vaccine + two viral vector vaccines	5 (5.9)
- Two inactivated vaccines + one viral vector vaccine	9 (10.6)
- Two inactivated vaccines + one mRNA vaccine	14 (16.5)
- One inactivated vaccine + one viral vector vaccine + mRNA vaccine	14 (16.5)
Timing of vaccination (gestational age, GA in weeks) (median [IQR])	
1 st vaccination (n = 85)	-9.9 (-19.1, -1.6)
2 nd vaccination (n = 85)	-5.3 (-15.4, 15.1)
3 rd vaccination (n = 45)	8.1 (-6.6, 18.6)
Last vaccination (n = 85)	14.4 (-6.6, 19.3)
Receipt of influenza vaccination during this pregnancy (n (%))	73 (85.9)
Receipt of tetanus, diphtheria, and pertussis (Tdap) vaccination during this pregnancy (n (%))	82 (96.5)

Gestational age at delivery (weeks) (n (%))	
37	9 (10.6)
38	40 (47.1)
39	24 (28.2)
40	10 (11.8)
41	2 (2.4)
Cesarean delivery (n (%))	64 (75.3)
Birthweight (median [IQR])	3,122 (2,915, 3,409)
APGAR score (median [IQR])	
APGAR score at 1 minute	9 (8, 9)
APGAR score at 5 minutes	9 (9, 9)
Postpartum complication (both postpartum hemorrhage) (n (%))	2 (2.4)
Neonatal intensive care unit admission (n (%))	3 (3.5)
Maternal SARS-CoV-2 receptor binding domain antibody (IgG) level (AU/mL) at delivery (median [IQR])	1,123 (552, 2,707)
Cord blood SARS-CoV-2 receptor binding domain antibody (IgG) level (AU/mL) at delivery (median [IQR])	2,100 (888, 4,687)
Antibody transfer ratio (cord blood antibody/maternal antibody) (median [IQR])	1.63 (1.26, 1.97)

* Negative value indicates weeks before the onset of pregnancy

Table 2 Univariate linear regression analysis of factors associated with maternal SARS-CoV-2 receptor binding domain antibody (IgG) levels

Potential influencing factor	Relative antibody concentration (95%CI)	Combined Wald P
Pre-pregnancy body mass index (BMI, kg/m²)		0.017 (trend)
< 18.5 (n=13, 15.3%)	1	-
18.5-29.9 (n = 62, 72.9%)	0.58 (0.27, 1.24)	
≥ 30 (n = 10, 11.8%)	0.27 (0.10, 0.78)	
Pattern of COVID-19 vaccination		0.006
<i>Two-dose regimens</i>		
Two mRNA vaccines	1 ^a	
Two viral vector vaccines	0.29 (0.10, 0.84) ^c	
One viral vector vaccine + one mRNA vaccine	1.04 (0.35, 3.05) ^a	
<i>Three-dose regimens</i>		

Two inactivated vaccines + one viral vector vaccine	0.71 (0.27, 1.83) ^a	
Two inactivated vaccines + one mRNA vaccine	1.65 (0.75, 3.63) ^a	
One inactivated vaccine + two viral vector vaccines	6.26 (1.97, 19.85) ^b	
One inactivated vaccine + one viral vector vaccine + mRNA vaccine	1.31 (0.58, 2.94) ^a	
Two viral vector vaccines + one mRNA vaccine	2.44 (0.58, 10.20) ^{ab}	
Other vaccinations during this pregnancy:		
Influenza vaccination	1.49 (0.65, 3.42)	0.343
Tetanus, diphtheria, and pertussis (Tdap) vaccination	1.28 (0.28, 6.15)	0.719

Relative antibody concentration = exponentiated coefficient from linear regression of log-transformed antibody level; 95% CI = 95% confidence interval.

a, b, c Superscripts indicate statistically significant differences between vaccination patterns. Groups that do not share a superscript differ significantly from each other based on pairwise comparisons using the Wald test ($p < 0.05$).

Table 3 Univariate linear regression analysis of factors associated with umbilical cord SARS-CoV-2 receptor binding domain antibody (IgG) levels

Potential influencing factor	Relative antibody concentration (95%CI)	Combined Wald P
Pre-pregnancy body mass index (BMI, kg/m²)		0.094 (trend)
< 18.5 (n=13, 15.3%)	1	-
18.5-29.9 (n = 62, 72.9%)	0.67 (0.33, 1.36)	
≥ 30 (n = 10, 11.8%)	0.44 (0.16, 1.17)	
Pattern of COVID-19 vaccination		0.042
<i>Two-dose regimens</i>		
Two mRNA vaccines	1 ^{ac}	
Two viral vector vaccines	0.42 (0.15, 1.15) ^c	
One viral vector vaccine + one mRNA vaccine	1.03 (0.37, 2.89) ^{ac}	

Three-dose regimens

Two inactivated vaccines + one viral vector vaccine	0.80 (0.32, 1.98) ^{ac}
Two inactivated vaccines + one mRNA vaccine	1.37 (0.65, 2.91) ^a
One inactivated vaccine + two viral vector vaccines	4.89 (1.62, 14.73) ^b
One inactivated vaccine + one viral vector vaccine + mRNA vaccine	1.21 (0.56, 2.63) ^{ac}
Two viral vector vaccines + one mRNA vaccine	2.59 (0.66, 10.18) ^{ab}

Other vaccinations during this pregnancy:

Influenza vaccination	1.26 (0.58, 2.72)	0.551
Tetanus, diphtheria, and pertussis (Tdap) vaccination	1.59 (0.38, 6.55)	0.518

Relative antibody concentration = exponentiated coefficient from linear regression of log-transformed antibody level; 95% CI = 95% confidence interval.

a, b, c Superscripts indicate statistically significant differences between vaccination patterns.

Groups that **do not share a superscript** differ significantly from each other based on pairwise comparisons using the Wald test ($p < 0.05$).