

# COVID-19 Vaccination During Pregnancy

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## ABSTRACT

A global health crisis named coronavirus disease-2019 (COVID-19) pandemic was caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). COVID-19 pandemic created an immediate occasion to establish strategies for vaccination. Increasing evidence suggests the pregnancy-related COVID-19 risks substantially above the risk of non-pregnant woman. Women with pregnancy and lactation were not included in COVID-19 vaccination studies. To date, subsequent data from pregnant COVID-19 vaccinated women showed safety and efficacy during pregnancy. There is no evidence of harmful effects on pregnancy, fetal development, parturition and postnatal development both directly and indirectly for the COVID-19 vaccines. Vaccination for pregnant women is a healthy and safe way to prevent infection of SARS-CoV-2 and should be considered. From the knowledge of similar prior non-COVID-19 vaccine trials' experience, reproductive and developmental toxicology trials from animals, datas from trials of humans and different advisory committees of healthcare have published guidelines supporting vaccination for COVID-19 during pregnancy and breastfeeding.

**Keywords:** Pregnancy, SARS-CoV-2, vaccination, COVID-19

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## Introduction

The extraordinary years of 2020 to 2022 will never be forgotten due to the impacts of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). A global health crisis named coronavirus disease-2019 (COVID-19) pandemic was caused by SARS-CoV-2. Human lives, global economies and public healthcare systems have been devastated by COVID-19 (1). To date, more than 452 million confirmed illness and 6 million deaths have been globally attributed to COVID-19 (2). The most promising control patterns for this pandemic were personal hygiene, social distancing, face mask, isolation and vaccination (3). For this reason, pandemic of COVID-19 created an immediate occasion to establish strategies for vaccination.

Multiple vaccines were developed, manufactured and approved for global COVID-19 pandemic use. In this process, many vaccines have been researched for safety and efficacy. It has been shown that vaccination reduces SARS-CoV-2 infection risk and reduces the disorder severity (4). It is critical to mention that women with pregnancy and lactation were not included in COVID-19 vaccine trials. Since the start of the pandemic, millions of people have had pregnancy and labor. This has become an ethical and clinical situation to protect them with lacked empirical evidence. Therefore, the COVID-19 pandemic and rapid developed novel vaccines need to decode the vaccine-induced immunity and safety for pregnancy.

### Pregnancy and Infection of SARS-CoV-2

A RNA virus named SARS-CoV-2 causes an infectious process. The host receptor for cell entry is a receptor named angiotensin-converting enzyme-2 (ACE-2). This receptor is found mostly in the alveolar stroma and epithelium. Variants have evolved in two years period (3). Person to person direct transmission is the primary way to SARS-CoV-2 transmission. The routes of transmission, infectious period, immune response and reinfection risk are the same for pregnant and non-pregnant women. Most related COVID-19 issues are the same for women with and without pregnancy, with a few exceptions (5).

Pregnancy includes complex immunological differences, involving immun system modulation to tolerate the fetus as semiallograft (6). The infections could be more complex because of this immune tolerance state. Pregnancies with the infection of SARS-CoV-2 may be asymptomatic or symptomatic. An increased risk factor for severe sequelae of COVID-19 and some pregnancy complications is common in symptomatic pregnancy infection. It is known that SARS-CoV-2 infected pregnant women are increased probability of hospitalization, severe illness, ventilation support, intensive care unit

admission and preterm labor compared with uninfected women pregnancy. Miscarriage and congenital anomalies do not appear to be increased in infected pregnancy. In utero vertical transmission is rare, and the neonatal outcome is usually good. Pregnant women are potential candidates for COVID-19 prevention (3).

To date, all the available evidence supports the assurance of administering current vaccines of SARS-CoV-2 during pregnancy (7). The known limited data, World Health Organization (WHO), American College of Obstetricians and Gynecologists, Centers for Disease Control and Prevention (CDC), Advisory Committee on Immunization Practices, American Academy of Pediatrics and the Republic of Turkey Ministry of Health have published guidelines indicating that current COVID-19 vaccines should not be retained from the women with pregnancy (8,9,10,11,12).

### COVID-19 Vaccines

Multiple effective vaccines have been unprecedentedly developed by the scientists, governments, and pharmaceutical companies. None of these vaccines contained replicative live viruses. They do not cause SARS-CoV-2 infection (7). The vaccines can be separated mainly into three various categories with their action mechanism. These main groups are mRNA, viral vector and inactivated COVID-19 virus vaccines.

#### i- mRNA Vaccines

These are vaccines of mRNA with lipid nanoparticle. The mRNA vaccine codes for SARS-CoV-2 spike protein, that holds this virus for ACE-2 receptor to start the infective process. At the site of vaccine injection, nanoparticles of lipid simplify to enter the cell of host. Then, the mRNA transcribed in this cell to produce the spike protein, that is presenting to T and B lymphocytes on the cell surface for the immune response (13,14,15). Food and Drug Administration and WHO approved mRNA vaccines (16,17). mRNA-based vaccines have presented strong immunity reaction and prevention against severe illness. Moderna and Pfizer-BioNTech vaccines use mRNA technology. In Turkey, Pfizer-BioNTech (Pfizer, Inc. Philedelphia, PA, USA) is the only available mRNA vaccine for COVID-19 protection to date. Pfizer-BioNTech vaccine's reported efficacy is 95% in phase III clinical trials for protecting COVID-19. Injection site reactions (most common), muscle pain, fatigue, chills, headache, fever, joint pain are common side effects. All of the side effects generally resolve within two days. Most of these side effects were observed after the second dose. mRNA-based vaccines may rarely cause Bell's palsy, anaphylaxis, pericarditis and myocarditis (18). Because of this reason, CDC recommended monitoring recipients for 15-30 minutes after the COVID-19 mRNA vaccine. Pfizer-BioNTech

confirmed for people 12 years old and above. Pfizer-BioNTech mRNA vaccine requires two doses, 21 days apart (19). Moderna (ModernaTX, Inc., Cambridge, MA, USA) is another form of mRNA vaccine that can be used in the United States of America and different countries.

### ii- Inactivated Virus Vaccines

Such vaccine uses an inactivated virus of COVID-19 to activate an immune reaction. The inactivated vaccines do not include a live COVID-19 virus. Therefore, these vaccines may not cause the disorder. Aluminum hydroxide is used as an adjuvant in these vaccines. In Turkey, Coronavac (Sinovac, Beijing, China) is the first available inactivated vaccine for COVID-19 protection. The phase III trials reported the efficacy of Sinovac as 83.5%. The vaccine requires doses for twice. More common side effects are injection site reaction, headache, fatigue, chills, muscle pain, fever and joint pain. These side effects usually resolve within two days. Sinopharm (Sinopharm, Beijing, China) is another form of inactivated virus vaccine that can be used in different countries. Sinovac and Sinopharm are not confirmed for usage in the United States of America and some of the European countries (7). In Turkey, another form of inactivated virus vaccine named Turkovac (ERUCOV-VAC, Kayseri, Turkey) was applied for emergency use by the Turkish Minister of Health on 2021 November (20).

### iii- Viral Vector Vaccines

These types of vaccines used viral vectors to deliver the spike protein mRNA into the host cell. A non-replicated modified version of adenovirus is used as a viral vector in such vaccine. The vaccine product finally contains SARS-CoV-2 spike protein and eliminated as an immune response with the same mechanism as mRNA vaccines (7). Oxford/AstraZeneca (AstraZeneca, Cambridge, UK) and Janssen (Janssen Biotech, Inc, Johnson & Johnson, New Brunswick, NJ, USA) are two forms of viral vector vaccines. The vaccine of Oxford/AstraZeneca requires doses twice. The vaccine named Janssen requires a single dose (21). The reported efficacy of Janssen is 72% and Oxford/AstraZeneca is 63.1% from the phase III trials. The Janssen vaccine's side effects include injection site pain, myalgia, fatigue and headache. These side effects usually resolve within two days. On rare, this vaccine may cause thrombotic thrombocytopenic purpura, radiculitis, Guillain-Barré syndrome. The side effects of thrombosis cases have been noted in women. Pregnancy, oral contraceptives, hormonal therapeutics are thrombotic risk factors. Therefore, pregnant women have increased thrombosis risk with Janssen

vaccine (22,23). In Turkey, there is no available viral vector vaccine for COVID-19 protection to date.

### COVID-19 Vaccine Studies During Pregnancy

Women with pregnancy are generally excluded from COVID-19 vaccine studies, because of liability and safety concerns about mother and fetus. Systemic non-inclusion of this wide population from clinical studies means available very limited data on COVID-19 vaccines' safety and efficacy during pregnancy (24,25). Increasing evidence suggests that pregnancy-related COVID-19 risks substantially above the risk of non-pregnant woman. Pregnancy-related risks may be minimized and reduced by standard preventive strategies, including COVID-19 vaccines (26). Previous studies with non-COVID-19 mRNA-based vaccines on human, including influenza, rabies and Zika virus noted good safety and immunogenic profile in pregnant women (5).

To date, subsequent data from pregnant COVID-19 vaccinated women showed safety during pregnancy. There is no evidence of harmful effects on pregnancy, fetal development, parturition and postnatal development both directly and indirectly for the COVID-19 vaccines (27,28,29). After the vaccine administration during pregnancy; a maternal immune response, a reduced incidence of maternal COVID-19 and a reduced severe and critical infection of SARS-CoV-2 incidence was demonstrated. Also, the transfer of maternal vaccine-induced antibodies across the placenta to confer passive immunity against SARS-CoV-2 infection for fetus/newborn. Protective vaccine-induced antibodies have been demonstrated in umbilical cord serum after the 15<sup>th</sup> day of the first maternal COVID-19 vaccination (30).

Although pregnant women were not included from the vaccination studies and participants were warned to avoid pregnancy, 53 accidental pregnancy occurred in these trials. The miscarriage rates are comparable with the non-vaccinated groups vaccination does not have any effect on early pregnancy complications (31).

The CDC has recommended an application named V-safe after vaccination health checker for smartphones. The app includes pregnant people, to register adverse events following vaccination. The V-safe COVID-19 vaccine pregnancy registry has greater than 50,000 data from completed pregnancies. There are no obvious safety signals with congenital abnormalities, miscarriage, fetal growth, preterm labor, stillbirth and neonatal mortality (32). And also Vaccine Adverse Event Reporting System (VAERS) of the CDC has 154 pregnancy data. There was no excess observed in adverse and side effects compared with the CDC national birth data. The

Clinical Immunization Safety Assessment and Vaccine Safety Datalink of CDC have almost 40,000 pregnancy data. These data mostly for mRNA vaccines and have not shown adverse outcomes (33). Developmental and reproductive toxicity studies' early data have also not shown adverse effects for women reproduction, fertility, miscarriages, embryonal/fetal/postnatal development (17,34).

Shimabukuro et al. (35) studied the data on 35,691 vaccinated pregnancy from the registries of safety surveillance, including VAERS and V-safe. They noted fatigue, headache, injection site pain, myalgia and fever as common reactions to vaccines. The reactions were more common after the second vaccine dose. They reported that these patterns were similar in women who were not pregnant. Only vomiting and nausea were more slightly common in pregnant individuals compared with non-pregnant women after a second dose of vaccines (35).

In another study, 2,456 pregnant women who received COVID-19 mRNA vaccine before conception or before 20 weeks of gestation have cumulative miscarriage risk of 12.8%. This is a similar rate in the general obstetric population (36). A different trial demonstrated that 13,000 miscarriages from 92,000 pregnant women had similar odds with and without mRNA COVID-19 vaccine exposure (29). Similar safety data were noted for viral vector vaccines (37).

Another study has noted poor pregnancy outcomes in non-vaccinated and infected women. COVID-19 related hospital admission was 77.4%, COVID-19 related critical care admission was 98%, perinatal death was 100% for the non-vaccinated at the time of SARS-CoV-2 infection. The perinatal death rate of COVID-19 vaccinated women was similar to obstetrics population rates (38).

In another study, the authors noted that mRNA vaccines caused a strong humoral immune response during pregnancy. Antibody responses were quickly developed after vaccine administration. This quick response was not shown with the natural infection of SARS-CoV-2. Reactogenicity and immunogenicity were similar in women with or without pregnancy. The authors also noted the passed preventive immunoglobulins (Ig) to the fetus/newborn by the placenta (39).

Lastly, Pfizer declared a global phase 2/3 study to evaluate the vaccine's immunogenicity, safety, and tolerability in pregnancy. This trial was placebo-controlled, observer-blind, randomized. It is planned to include 4,000 healthy women with pregnancy vaccinated between 24-34 weeks of gestation. The estimated completion date of the study is August 2022 (40). The other companies are planning similar studies.

### **Impact of COVID-19 Vaccination on the Fetus**

Vaccination in pregnancy (e.g. pertusis, influenza, Zika) is a well known factor to protect to mother and fetus from infection (5). Experts suggest that mRNA based, viral vector and inactivated vaccines do not have indicative risk to newborn and fetus. There are directly no data that particles of vaccines pass the placenta and cross into fetal tissues. Trials on different vaccinations of lipid nanoparticle showed that they may not pass the placental barrier (41,42).

In Shimabukuro's study, pregnancy loss and adverse pregnancy results of small size for gestational age and preterm birth have similar incidences before the COVID-19 pandemic. They did not report any neonatal deaths (35).

Many experts suggest that vaccine-induced Ig antibodies can cross to the breastmilk and protect the infant against infection of SARS-CoV-2. A study noted the existence of vaccine-induced IgA in milk after four weeks of mRNA-based vaccine administration. They also reported IgA levels in milk were similar between vaccination and infection (43). Another study showed anti-spike antibody transfer via the placenta after maternal mRNA-based vaccination (44).

### **Hesitancy of COVID-19 Vaccination**

The COVID-19 vaccines' acceptance level is inadequate to meet necessity for developing global immunity against SARS-CoV-2 infection. The number of infected individuals are affecting the herd immunity. The community level of vaccination to stop the pandemic needs to reach a level of 75% and above in a time period (45). WHO has categorized hesitancy of COVID-19 vaccination as one of the prior global health threat. It is critical to address and understand the reasons for vaccination hesitancy (46).

Skjefte et al. (46) noticed the causes for women with pregnancy to decline vaccines of COVID-19 in pregnancy as (i) not to sustain developing fetus to probable harmful effects, (ii) approve of the vaccines could be hurried for political causes, (iii) to have effectiveness and safety data during pregnancy.

Hesitancy for vaccination is a complex problem based on region, race, education level, ethnicity, social influence and pregnancy status (47). It is important to improve vaccine acceptance with effective and consistent public steps.

### **Choice of Vaccine**

If both an mRNA and inactivated virus vaccine are available, pregnant are advised to select the vaccine beyond the benefits and risks. Some inactivated COVID-19 vaccines contain adjuvants. Insoluble aluminum salt, is one of the inactivated vaccine adjuvant, has a good safety profile (48).



Novel adjuvants containing vaccines are generally avoided during pregnancy. There is a lack of safety data of novel adjuvants. This theory must be balanced with the risk of COVID-19 pandemic, severe infection of SARS-CoV-2 and mortality risk in pregnancy.

CDC commends that pregnant with an early allergic and severe reaction to an mRNA-based vaccine's first dose, should not approve mRNA-based vaccines without evaluation by an immunology specialist (10).

Thrombosis is slightly more common in pregnancy, therefore pregnant people should be warned sensitive for the thromboembolic event's increased risk with Janssen vaccine (7).

### Timing of the Vaccine

It is an appropriate advice that women planning pregnancy should be vaccinated as soon as possible. The current available COVID-19 vaccines do not have any effect on fertility. It is not necessary to receive a pregnancy test before vaccination. There is no data to delay pregnancy after vaccination for COVID-19. If a female has pregnancy after receiving the COVID-19 vaccine series' first dose, the secondary dose could be carried out at the exact time as non-pregnant persons (3).

### Other Vaccine and Anti-D Ig Administration with COVID-19 Vaccines

A separation between other and COVID-19 vaccines is unnecessary. The vaccines of COVID-19 can be carried out at the same period as routine-administered vaccines. The immunoglobulin of anti-D does not change the immun response to vaccines. A separation period between the COVID-19 vaccines and anti-D Ig is also unnecessary. Standard protocols can be used for alloimmunization prevention with COVID-19 vaccines (3,8).

### Lactation and COVID-19 Vaccines

Lactation should not effect timing of COVID-19 vaccines. Vaccine induced maternal serum antibodies of SARS-CoV-2 may pass into milk and can protect newborn with passive immunization. Although breastfeeding women excluded from vaccine studies, available COVID-19 vaccines are unlikely to get a risk to the lactated child. The vaccines do not contain infectious viruses and a minimal amount can pass into milk, but they are inactivated by the child's digestive system (49).

### Conclusion

Pregnant women should be offered the vaccination for COVID-19 where the benefits outweigh few potential risks. Women with SARS-CoV-2 infection and pregnancy are more likely to have severe disease, need intensive care, deliver preterm and because of these newborns are more likely to be hospitalized to neonatal unit. Vaccination can reduce these risks. Vaccination for pregnant women is a healthy and safe way to prevent infection of SARS-CoV-2 and should be considered. From the knowledge of similar prior non-COVID-19 vaccine trials' experience, reproductive and developmental toxicology trials from animals, datas from trials of humans and different advisory comitees of healthcare have published guidelines supporting vaccination for COVID-19 during pregnancy and breastfeeding.

### Ethics

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## REFERENCES

- Joubert E, Kekeh AC, Amin CN. COVID-19 and novel mRNA vaccines in pregnancy: an updated literature review. *BJOG* 2022;129:21-28.
- WHO. WHO coronavirus (COVID-19) dashboard. Geneva: WHO; 2022 March.
- Berghella V, Hughes BL. COVID-19: overview of pregnancy issues. In: UpToDate, Lockwood CJ (Ed), UpToDate, Waltham, MA. Accessed March 13th, 2022.
- Falsaperla R, Leone G, Familiari M, Ruggieri M. COVID-19 vaccination in pregnant and lactating women: a systematic review. *Expert Rev Vaccines* 2021;20:1619-1628.
- Shook LL, Fallah PN, Silberman JN, Edlow AG. COVID-19 vaccination in pregnancy and lactation: current research and gaps in understanding. *Front Cell Infect Microbiol* 2021;11:735394.
- Than NG, Hahn S, Rossi SW, Szekeres-Bartho J. Editorial: fetal-maternal immune interactions in pregnancy. *Front Immunol* 2019;10:2729.
- Garg I, Shekbar R, Sheikh AB, Pal S. COVID-19 vaccine in pregnant and lactating women: a review of existing evidence and practice guidelines. *Infect Dis Rep* 2021;13:685-699.
- American College of Obstetricians & Gynecologists. Vaccinating pregnant and lactating patients against COVID-19. 2020. Available from: <https://www.acog.org/clinical/clinical-guidance/practice-advisory/articles/2020/12/covid-19-vaccination-considerations-for-obstetric-gynecologic-care> Accessed March 14th, 2022.
- American Academy of Pediatrics. COVID-19 vaccines in children and adolescents. Available from: <https://pediatrics.aappublications.org/content/pediatrics/early/2021/05/11/peds.2021-052336.full.pdf> Accessed March 14th, 2022.
- Centers for Disease Control and Prevention. COVID-19 vaccines: interim clinical considerations for use of COVID-19 vaccines currently authorized in the United States. Available from: <https://www.cdc.gov/vaccines/covid-19/clinical-considerations/covid-19-vaccines-us.html> Accessed March 14th, 2022.
- Republic of Turkey Ministry of Health COVID-19 Vaccination Information Platform. Can pregnant women receive the inactivated COVID-19 vaccine? Available from: <https://covid19asi.saglik.gov.tr/EN-78316/frequently-asked-questions.html?Sayfa=2#collapseOne80417> Accessed March 14th, 2022.
- Republic of Turkey Ministry of Health COVID-19 Vaccination Information Platform. Could the mRNA vaccine to be applied to pregnant women? Available from: <https://covid19asi.saglik.gov.tr/EN-78316/frequently-asked-questions.html?Sayfa=2#collapseOne80430> Accessed March 14th, 2022.
- Dai L, Gao GF. Viral targets for vaccines against COVID-19. *Nat Rev Immunol* 2021;21:73-82.
- Kaur SP, Gupta V. COVID-19 Vaccine: A comprehensive status report. *Virus Res* 2020;288:198114.
- Xia S, Zhu Y, Liu M, et al. Fusion mechanism of 2019-nCoV and fusion inhibitors targeting HR1 domain in spike protein. *Cell Mol Immunol* 2020;17:765-767.
- Baden LR, El Sahly HM, Essink B, et al. Efficacy and Safety of the mRNA-1273 SARS-CoV-2 Vaccine. *N Engl J Med* 2021;384:403-416.
- Polack FP, Thomas SJ, Kitchin N, et al. Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. *N Engl J Med* 2020;383:2603-2615.
- Walsh EE, Frenck R, Falsey AR, et al. RNA-Based COVID-19 vaccine BNT162b2 selected for a pivotal efficacy study. *medRxiv* 2020. doi: 10.1101/2020.08.17.20176651.
- Thompson MG, Burgess JL, Naleway AL, et al. Interim estimates of vaccine effectiveness of BNT162b2 and mRNA-1273 COVID-19 vaccines in preventing SARS-CoV-2 infection among health care personnel, first responders, and other essential and frontline workers - eight U.S. locations, December 2020-March 2021. *MMWR Morb Mortal Wkly Rep* 2021;70:495-500.
- Pavel STI, Yetiskin H, Uygut MA, et al. Development of an inactivated vaccine against SARS-CoV-2. *Vaccines (Basel)* 2021;9:1266.
- FDA. Janssen Biotech. Available from: <https://www.fda.gov/media/146303/download> Accessed March 14th, 2022.
- John Hopkins Medicine. Thrombosis. Available from: <https://www.hopkinsmedicine.org/health/conditions-and-diseases/thrombosis> Accessed March 14th, 2022.
- CDC. Available from: <https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/JJUupdate.html> Accessed: March 14th, 2022.
- Bianchi DW, Kaeser L, Cernich AN. Involving pregnant individuals in clinical research on COVID-19 vaccines. *JAMA* 2021;325:1041-1042.
- Beigi RH, Krubiner C, Jamieson DJ, et al. The need for inclusion of pregnant women in COVID-19 vaccine trials. *Vaccine* 2021;39:868-870.
- Maruggi G, Zhang C, Li J, Ulmer JB, Yu D. mRNA as a transformative technology for vaccine development to control infectious diseases. *Mol Ther* 2019;27:757-772.
- Collier AY, McMahan K, Yu J, et al. Immunogenicity of COVID-19 mRNA vaccines in pregnant and lactating women. *JAMA* 2021;325:2370-2380.
- Morgan JA, Biggio JR Jr, Martin JK, et al. Maternal outcomes after severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in vaccinated compared with unvaccinated pregnant patients. *Obstet Gynecol* 2022;139:107-109.
- Kharbanda EO, Haapala J, DeSilva M, et al. Spontaneous abortion following COVID-19 vaccination during pregnancy. *JAMA* 2021;326:1629-1631.
- Beharier O, Plitman Mayo R, Raz T, et al. Efficient maternal to neonatal transfer of antibodies against SARS-CoV-2 and BNT162b2 mRNA COVID-19 vaccine. *J Clin Invest* 2021;131:e154834.
- Mullard A. Flooded by the torrent: the COVID-19 drug pipeline. *Lancet* 2020;395:1245-1246.
- National Center for Immunization & Respiratory Diseases. COVID-19 Vaccine Safety update. Advisory Committee on Immunization Practices (ACIP) January 27, 2021. Available from: <https://www.cdc.gov>

- gov/vaccines/acip/meetings/downloads/slides-2021-01/06-COVID-Shimabukuro.pdf Accessed March 14th, 2022.
33. Lipkind HS, Vazquez-Benitez G, DeSilva M, et al. Receipt of COVID-19 vaccine during pregnancy and preterm or small-for-gestational-age at birth - eight integrated health care organizations, United States, December 15, 2020-July 22, 2021. *MMWR Morb Mortal Wkly Rep* 2022;71:26-30.
  34. Jackson LA, Anderson EJ, Roupael NG, et al. An mRNA vaccine against SARS-CoV-2 - preliminary report. *N Engl J Med* 2020;383:1920-1931.
  35. Shimabukuro TT, Kim SY, Myers TR, et al. Preliminary findings of mRNA Covid-19 vaccine safety in pregnant persons. *N Engl J Med* 2021;384:2273-2282.
  36. Zauche LH, Wallace B, Smoots AN, et al. Receipt of mRNA Covid-19 vaccines and risk of spontaneous abortion. *N Engl J Med* 2021;385:1533-1535.
  37. Hillson K, Clemens SC, Madhi SA, et al. Fertility rates and birth outcomes after ChAdOx1 nCoV-19 (AZD1222) vaccination. *Lancet* 2021;398:1683-1684.
  38. Stock SJ, Carruthers J, Calvert C, et al. SARS-CoV-2 infection and COVID-19 vaccination rates in pregnant women in Scotland. *Nat Med* 2022.
  39. Gray KJ, Bordt EA, Atyeo C, et al. Coronavirus disease 2019 vaccine response in pregnant and lactating women: a cohort study. *Am J Obstet Gynecol* 2021;225:303.e1-303.e17.
  40. BioNTech. Pfizer and Biontech commence global clinical trial to evaluate COVID-19 vaccine in pregnant women. Available online: <https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-commence-global-clinical-trial-evaluate> Accessed March 14th, 2022.
  41. Dooling K, Marin M, Wallace M, et al. The advisory committee on immunization practices' updated interim recommendation for allocation of covid-19 vaccine - United States. December 2020. *MMWR Morb Mortal Wkly Rep* 2021;69:1657-1660.
  42. Royal College of Obstetricians & Gynaecologists. COVID-19 vaccines, pregnancy, breastfeeding FAQs. Available from: <https://www.rcog.org.uk/guidance/coronavirus-covid-19-pregnancy-and-women-s-health/vaccination/covid-19-vaccines-pregnancy-and-breastfeeding-faqs/> Accessed on March 14th, 2022.
  43. Golan Y, Prah M, Cassidy A, et al. COVID-19 mRNA vaccination in lactation: assessment of adverse events and vaccine related antibodies in mother-infant dyads. *Front Immunol* 2021;12:777103.
  44. Rottenstreich A, Zarbiv G, Oiknine-Djian E, Zigron R, Wolf DG, Porat S. Efficient maternofetal transplacental transfer of anti - severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spike antibodies after antenatal SARS-CoV-2 BNT162b2 messenger RNA vaccination. *Clin Infect Dis* 2021;73:1909-1912.
  45. Jaffe E, Goldfarb IT, Lyerly AD. The costs of contradictory messages about live vaccines in pregnancy. *Am J Public Health* 2021;111:498-503.
  46. Skjette M, Ngirbabul M, Akeju O, et al. COVID-19 vaccine acceptance among pregnant women and mothers of young children: results of a survey in 16 countries. *Eur J Epidemiol* 2021;36:197-211.
  47. Ceulemans M, Foulon V, Panchaud A, et al. Vaccine willingness and impact of the covid-19 pandemic on women's perinatal experiences and practices-a multinational. Cross-sectional study covering the first wave of the pandemic. *Int J Environ Res Public Health* 2021;18:3367.
  48. Ciapponi A, Bardach A, Mazzoni A, et al. Safety of components and platforms of COVID-19 vaccines considered for use in pregnancy: A rapid review. *Vaccine* 2021;39:5891-5908.
  49. Perl SH, Uzan-Yulzari A, Klainer H, et al. SARS-CoV-2-Specific antibodies in breast milk after covid-19 vaccination of breastfeeding women. *JAMA* 2021;325:2013-2014.