

Hearing changes in newborns whose mothers had been diagnosed with COVID-19 during pregnancy: A systematic review

Alterações auditivas em recém-nascidos de gestantes com diagnóstico de covid-19: uma revisão sistemática

Alteraciones auditivas en recién nacidos de mujeres embarazadas con diagnóstico de covid-19: una revisión sistemática

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Abstract

Introduction: The integrity of the auditory system is essential for children to develop auditory skills and acquire language. Considering the high prevalence of hearing loss in newborns due to congenital infections that occur during pregnancy, there is a need to investigate the effects of COVID-19 on newborns' hearing. **Objective:** To verify the association between hearing loss in newborns whose mothers had been diagnosed with COVID-19 during pregnancy. **Research Strategy:** Scientific articles were searched in the MEDLINE (PubMed), LILACS, SciELO, Scopus, Web of Science, and BIREME databases, without restrictions on the language, time, and place of study. The grey literature was also searched in Google

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Authors' contributions:

LBC: research conceptualization and development, data collection, and article writing.

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Scholar to complement the sample and avoid risk bias. **Selection Criteria:** The systematic review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and included studies that scored ≥ 6 points according to the protocol for qualitative scoring proposed by Pithon et al. (2015). **Data analysis:** It was performed using a specific form for systematic reviews prepared by two researchers in Excel®. **Results:** 29 potentially eligible articles were retrieved, six of which answered the research question. Four studies did not detect an association between maternal COVID-19 infection and congenital hearing loss. **Conclusion:** COVID-19 infection during pregnancy does not seem to be a risk factor for congenital hearing loss and there were no impacting hearing changes due to vertical infection that might affect these newborns.

Keywords: Pregnant women; Newborns; Hearing Loss; SARS-COV-2.

Resumo

Introdução: A integridade do sistema auditivo é essencial para o desenvolvimento das habilidades auditivas e aquisição da linguagem da criança. Considerando a alta prevalência de perda auditiva em recém-nascidos, devido a infecções congênitas que ocorrem durante a gestação, há a necessidade de investigar os efeitos da Covid-19 na audição do RN. **Objetivo:** Verificar a associação entre perda auditiva em neonatos de gestantes diagnosticadas com COVID-19. **Estratégia de Pesquisa:** A busca de artigos científicos foi realizada nas bases de dados Medline (Pubmed), LILACS, SciELO, Scopus, Web of Science e Bireme sem restrição de idioma, período e localização. Para complementar e evitar viés de risco foi realizada uma busca por literatura cinzenta no Google Acadêmico. **Crítérios de Seleção:** A revisão sistemática foi conduzida de acordo com as recomendações do Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) e incluiu estudos que pontuaram ≥ 6 pontos de acordo com o protocolo de pontuação qualitativa proposto por Pithon et al. (2015). **Análise dos dados:** Os artigos elegíveis foram analisados e quantificados seguindo os critérios propostos no presente estudo com juízes cegos nas etapas de recuperação. **Resultados:** foram recuperados 29 artigos com potencial de inclusão, dos quais 6 responderam à questão norteadora com potencial de elegibilidade. Quatro estudos encontrados não detectaram associação entre infecção materna por COVID-19 e perda auditiva congênita. **Conclusão:** A infecção por COVID-19 durante a gravidez não parece ser fator de risco para perda auditiva congênita e não foram verificadas alterações auditivas impactantes que comprometessem estes neonatos por infecção vertical.

Palavras-chave: Gestantes; Recém-Nascidos; Perda Auditiva; SARS-COV-2.

Resumen

Introducción: La integridad del sistema auditivo es fundamental para el desarrollo de las habilidades auditivas y la adquisición del lenguaje de los niños. Considerando la alta prevalencia de hipoacusia (HL) en recién nacidos (RN), debido a infecciones congénitas que ocurren durante el embarazo, surge la necesidad de investigar los efectos del Covid-19 en la audición del recién nacido. **Objetivo:** Verificar la asociación entre hipoacusia en neonatos de gestantes diagnosticadas con COVID-19. **Estrategia de investigación:** La búsqueda de artículos científicos se realizó en las bases de datos Medline (Pubmed), LILACS, SciELO, Scopus, Web of Science y Bireme, sin restricción de idioma, período y ubicación. Para complementar y evitar sesgos de riesgo, se realizó una búsqueda de literatura gris en Google Scholar. **Criterios de selección:** La revisión sistemática se realizó de acuerdo con las recomendaciones de los Elementos de información preferidos para revisiones sistemáticas y metanálisis (PRISMA). Los estudios que obtuvieron una puntuación ≥ 6 puntos según el protocolo de puntuación cualitativa propuesto por Pithon et al. (2015). **Análisis de datos:** Se realizó mediante un formulario específico para revisión sistemática elaborado por dos investigadores del Programa Excel®. **Resultados:** se recuperaron 29 artículos con potencial de inclusión, de los cuales 6 respondieron a la pregunta orientadora Cuatro estudios encontrados no detectaron una asociación entre la infección materna por COVID-19 y la pérdida auditiva congénita. **Conclusión:** La infección por COVID-19 durante el embarazo no parece ser un factor de riesgo para la pérdida auditiva congénita y no hubo cambios auditivos impactantes que pudieran comprometer a estos recién nacidos debido a la infección vertical.

Palabras clave: Mujeres embarazadas; Recién nacidos; Pérdida de la audición; SARS-COV-2.

Introduction

The World Health Organization (WHO) declared the new coronavirus disease 2019 (COVID-19) a pandemic¹ in March 2020. COVID-19 has similarities with common influenza, with symptoms such as fever, coughing, lower respiratory tract infection, and in some cases, severe pneumonia and acute respiratory distress syndrome. Early symptoms like anosmia (the total loss of smell) and dysgeusia (changes in taste) may also be present, while on the other hand, there are also asymptomatic cases². There is no specific treatment for the disease, which had important morbimortality indices, especially in risk groups such as newborns and pregnant and postpartum women³. Data on previous pandemics and seasonal influenza suggest that pregnant women may be at greater risk of morbidity and mortality associated with the infection⁴. Physiological changes in pregnancy without complications or metabolic or vascular changes in high-risk pregnancies may affect the pathogenesis or exacerbate the clinical presentation of COVID-19⁵.

Auditory system integrity is essential for children to develop auditory skills and acquire language. Even in asymptomatic cases, congenital infections may cause sensorineural hearing loss, which can impair inner ear structures due to lesions in the hair cells or the auditory nerve, thus decreasing sound transmission effectiveness. Consequently, the perception of sound quality and intensity decreases, importantly impacting the subject's development⁶. Given the high prevalence of hearing loss in newborns in both developed and

underdeveloped countries, the Joint Committee on Infant Hearing (JCIH)⁷ determined that universal neonatal hearing screening (UNHS) be performed with electrophysiological measures through auditory brainstem response (ABR) and/or otoacoustic emissions (OAE). In Brazil, Law no. 12.303 was approved in 2010, making UNHS obligatory in all maternities and hospitals nationwide⁸.

Given the above, this research aimed to verify the possible association of hearing loss in newborns whose mothers had been diagnosed with COVID-19 during pregnancy to answer the following research question: "Can COVID-19 infection during pregnancy be considered a risk factor for hearing loss (RFHL)?"

Research Strategy

This review was conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)⁹. Two researchers independently searched for scientific articles in the MEDLINE (PubMed), LILACS, SciELO, SCOPUS, Web of Science, and BIREME databases, with no restriction on language, time, or place of study. The research was structured and organized according to PICOS, an acronym for **P**opulation, **I**ntervention, **C**omparison, **O**utcomes, and **S**tudies, as follows: population of interest or health problem (P): newborns; intervention (I): newborns whose mothers had tested positive for COVID-19 during pregnancy; comparison (C): newborns whose mothers had tested negative for COVID-19; outcome (O): hearing changes; (S): cross-sectional studies, case-control studies, and cohort studies (Table 1).

Table 1. Description of picos components.

Acronym	Definition
P	Newborns
I	Newborns whose mothers had tested positive for COVID-19 during pregnancy
C	Newborns whose mothers had tested negative for COVID-19 during pregnancy
O	Hearing changes
S	Cross-sectional studies case-control studies Cohort studies

Source: Developed by the authors.

Descriptors were selected from controlled vocabulary in Health Science Descriptors (DeCS) and Medical Subject Heading Terms (MeSH), due to their being extensively used by the scientific community to index articles in the PubMed database. The search strategy used the following combination of descriptors and a Boolean operator: (COVID-19) and (Hearing loss) and (Neonate) and

(Pregnancy) and (SARS-CoV-2). The search took place in March 2022. The grey literature was also searched in Google Scholar to complement the sample and avoid risk bias. Studies were included with no restriction on language, time, or place of study. Table 2 presents the inclusion and exclusion criteria used in this research.

Table 2. Synthesis of the inclusion/exclusion criteria

Inclusion criteria	
Design	Cross-sectional studies case-control studies Cohort studies
Place	No restriction
Language	No restriction
Exclusion criteria	
Design	Letters to the editor Guidelines Literature reviews Systematic reviews Meta-analyses
Studies	Unclear, poorly described, or inadequate studies
Form of publication	Only abstract

Source: Developed by the authors.

Reviewers independently assessed the methodological quality of the studies included in the review, following PRISMA recommendations⁹. The assessment gave priority to clearly described information. The review was blind at this point, masking authors' and journals' names to avoid any potential bias or conflict of interest.

Selection Criteria

The eligibility reviewers were initially calibrated to conduct the systematic review. After being calibrated and having their questions answered, the eligibility reviewers (who were blind to the authors' and journals' names) examined the titles and abstracts independently. Articles whose titles were within the scope, but whose abstracts were unavailable, were also retrieved and analyzed in full text. Studies outside the scope, case reports, letters to the editor and/or editorials, literature reviews, indices, abstracts, systematic reviews, and

meta-analyses were excluded. Then, the full texts of preliminarily eligible studies were retrieved and analyzed. The review excluded studies published as letters to the editor, guidelines, literature reviews, narrative reviews, systematic reviews, meta-analyses, abstracts, and those whose full texts were unavailable (Table 2). It included quality studies, scoring ≥ 6 points in the qualitative scoring protocol proposed by Pithon et al. (2015)¹⁰.

Data Analysis

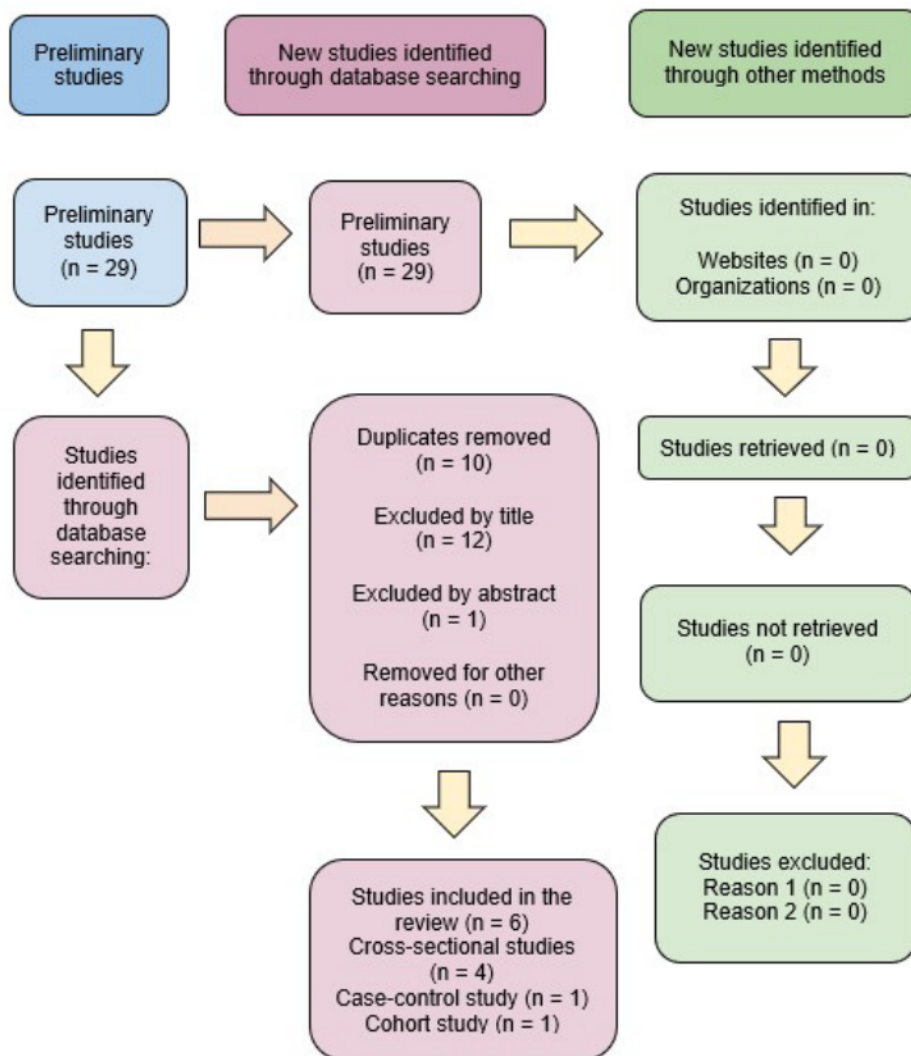
Data for the study eligibility process were extracted with an Excel[®] form developed by the researchers for systematic reviews. One of them entered the data extracted from the studies, which were then verified by another researcher. They were initially selected by their title, and then the abstracts were analyzed; only the potentially eligible ones were selected. Based on their abstracts, articles were selected for full-text reading, and those that

met all preestablished criteria were selected. After the screening, two authors reviewed the selected articles and extracted data standardly, supervised by a third judge. They identified the year of publication, place of research, language of publication, type of study, sample, method, results, and conclusion. The clinical result of interest was the verification of hearing changes in newborns whose mothers had been diagnosed with COVID-19 during pregnancy. Studies that did not have the predefined approach were not included in the sample of the systematic review.

Results

Initially, 29 articles were selected, which decreased to 19 after removing the duplicates. Then, titles and abstracts were analyzed, and 13 papers were excluded for not being within the scope of the research. Hence, six articles underwent the final analysis and were all included in the research (Figure 1). Selected studies were designed as cross-sectional, case-control, and cohort studies.

Databases were consulted with the chosen descriptors, and the results are presented in Table 3.



Source: Developed by the authors.

Figure 1. Flowchart of article identification, eligibility, and inclusion

Table 3. Classification of references obtained from the PUBMED, SCIELO, LILACS, BIREME, WEB OF SCIENCE, SCOPUS, and CAPES portal databases

Descriptors	Total no. of articles	No. of excluded references	Reason for exclusion	No. of selected articles	Database
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	4	3	Excluded by title (0) Excluded by abstract (0) Duplicates (3)	1	PUBMED
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	0	0	Excluded by title (0) Excluded by abstract (0) Duplicates (0)	0	SCIELO
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	0	0	Excluded by title (0) Excluded by abstract (0) Duplicates (0)	0	LILACS
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	2	0	Excluded by title (0) Excluded by abstract (0) Duplicates (0)	2	BIREME
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	2	1	Excluded by title (0) Excluded by abstract (0) Duplicates (1)	1	WEB OF SCIENCE
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	2	1	Excluded by title (0) Excluded by abstract (0) Duplicates (1)	1	SCOPUS
(COVID-19) and (Hearing loss) and (Neonate) and (Pregnancy) and (SARS-CoV-2)	19	18	Excluded by title (12) Excluded by abstract (1) Duplicates (5)	1	CAPES PORTAL
Total	29	23	Excluded by title (12) Excluded by abstract (1) Duplicates (10)	6	PUBMED, BIREME, WEB OF SCIENCE, SCOPUS, CAPES PORTAL

Source: Developed by the authors.

Study Design

Alan and Alan (2021)¹¹ conducted a study in newborns born between April 2020 and December 2020 whose mothers' PCR tests were positive for SARS-CoV-2 during pregnancy. The study investigated the possible association between the mothers' SARS-CoV-2 and the newborns' hearing loss. The study inclusion criteria were single pregnancies and newborns without RFHL and whose ABR results were available in the Turkish National Newborn Hearing Screening Database. Study group results were compared with those of the healthy controls. UNHS was performed with ABR bilaterally in the first 2 weeks after birth; newborns who failed the test were retested with ABR after another 2 weeks.

Celik et al. (2021)¹² researched 37 newborns whose mothers had been diagnosed with CO-

VID-19 during pregnancy. The study aimed to assess the auditory functions of these newborns, who had been exposed to vertical transmission of COVID-19. All infants were tested with transient evoked OAE (TEOAE), distortion-product OAE (DPOAE), and contralateral OAE suppression, and the results were compared with the control group, which had 36 healthy newborns. The ears, noses, and throats of all newborns included in this research were examined in detail. They were also submitted to tympanometry and acoustic reflex measurement bilaterally with a tonal probe at 226 Hz. The research inclusion criteria were type A tympanograms, no RFHL, and no other diseases.

Kaplan et al. (2021)¹³ investigated the incidence of hearing changes in newborns whose mothers had been diagnosed with COVID-19 dur-

ing pregnancy, between March 2020 and October 2020. Altogether, 797 patients were included in the research – 458 women with the diagnosis confirmed during pregnancy, and 339 women in the control group. UNHS was performed with ABR in 735 newborns and TEOAE in 62 newborns.

Yıldız et al. (2022)¹⁴ conducted a retrospective study between April 2020 and May 2021 at a reference tertiary healthcare center in Turkey. A total of 199 newborns whose mothers had been infected with coronavirus during pregnancy were assessed with ABR. The study aimed to verify whether COVID-19 infection during pregnancy can cause hearing loss in newborns.

Mostafa et al. (2021)¹⁵ conducted a retrospective cohort study including all newborns born between November 2020 and April 1, 2021, who had been submitted to UNHS. Maternal COVID-19 infection was analyzed regarding its time and severity, and the newborns' UNHS results were compared with the incidence of hearing loss in newborns in the UNHS program in the same period. The study included 984 newborns.

Ghiselli et al. (2022)¹⁶ conducted a study to investigate the possible correlation between gestational COVID-19 infection and hearing loss onset in newborns. Children were submitted to UNHS with OAE and audiological assessment (encompassing acoustic immittance, DPOAE, and A-ABR) by 4 months old. The study included 63 newborns.

Main Findings in the Studies

In the COVID-19 group in the study by Alan and Alan (2021)¹¹, 37 newborns (31.4%) failed bilaterally, 11 (9.3%) failed in the right ear, and five (4.2%) failed in the left ear in the ABR test, while 65 (55.1%) passed it bilaterally. In the control group, 16 newborns (13.6%) failed bilaterally, four (3.4%) failed in the right ear, eight (6.8%) failed in the left ear, and 90 (76.2%) passed this test bilaterally. Hence, newborns in the COVID-19 group were more likely to have negative ABR results than those in the control group in the first UNHS stage. As for the mothers' clinical conditions, none of them had to be admitted to the intensive care unit, 75 (63.6%) women were asymptomatic, and 43 (36.4%) had at least one symptom, such as coughing, myalgia, or dyspnea. ABR results had no statistically significant differences between symptomatic and asymptomatic mothers. Newborns whose mothers tested positive for SARS-CoV-2 in

the second trimester of pregnancy were more likely to have a negative ABR result (66.6%) than in the third trimester of pregnancy (38.7%)¹¹.

TEOAE results in quiet (no contralateral noise) had statistically considerable differences between groups at 3 kHz and 4 kHz. Both groups had similar results in the comparison of amplitude ratios at low frequencies, whereas at high frequencies, the amplitude ratios were smaller in the group of COVID-19 newborns. With contralateral noise, differences were found only at 4 kHz, confirming that COVID-19 can affect inner hair cells at high frequencies. DPOAE results revealed differences only at 1 kHz, which the authors did not consider a differential effect of the disease, concluding that COVID-19 does not affect this level of the auditory system. Nevertheless, the contralateral suppression examination was much more effective in the control group, with significant differences at all frequencies, especially the higher ones (3 kHz and 4 kHz). The authors suggest an insufficiency in the medial olivocochlear efferent system in newborns exposed to SARS-CoV-2¹².

In the study by Celik et al. (2021)¹², about 67.7% of mothers had COVID-19 in the third trimester of pregnancy, with no statistically significant examination differences between the trimesters when mothers were diagnosed. Their most frequent symptoms were loss of smell (78.4%) and coughing (51.4%). Kaplan et al. (2021)¹³ showed that 12.4% of the newborns in the COVID-19 group and 9.4% of those in the control group failed the first screening test. In the second screening, 1.3% of the COVID-19 group and 2.9% of the control group failed the screening. They were referred for additional assessments, but there were no statistically significant differences between them. The authors concluded that COVID-19 infection during pregnancy is not a neonatal RFHL, contrary to the findings of the other cited studies.

In the study by Yıldız et al. (2022)¹⁴, 21 newborns (10.5%) failed unilaterally in the first auditory test – 11 had hearing loss in the right ear (52.4%) and 10, in the left ear (47.6%). The mother of one (4.7%) of these patients was diagnosed with the disease in the first trimester, 10 (47.6%) had the disease in the second trimester, and 10 (47.6%) had it in the third trimester. The newborns' auditory examinations were considered normal in the retest, performed 15 days later. The authors concluded that COVID-19 infection is not a neonatal RFHL.

Mostafa et al. (2021)¹⁵ verified that the overall occurrence of failures in UNHS was 2.3%, while in the group of newborns whose mothers had tested positive for COVID-19, 2.9% failed the screening. The findings were statistically insignificant. Ghiselli et al. (2022)¹⁶ verified that 52 newborns failed UNHS bilaterally, but their hearing thresholds were normal in the audiological assessment – which found normal ABR thresholds bilaterally in 59/63 children. Four children (6.3% of the total) had abnormal ABR thresholds, though two of them had

normal thresholds in ABR retest, performed up to 1 month after the first test. The other two infants had unilateral ABR changes, but one of them had concomitant middle-ear effusion. Hence, only one child (1.6% of the sample) had an abnormal ABR result – who also had a positive swab for SARS-CoV-2, with no RFHL. The study reports not finding evidence that maternal COVID-19 infection is a congenital RFHL in newborns. The main characteristics of the studies selected for this review are shown in Table 4.

Table 4. Synthesis of articles included in the review

Author/ Year/ Place of publication	Objective	Sample	Trimester when maternal contamination occurred	Method	Results	Conclusion	Qualitative grade of the study
Mehmet Akif Alan et al, (2021) Turkey	To investigate the possible association between maternal SARS-CoV-2 and neonatal hearing loss.	118	1 st : 1 2 nd : 24 3 rd : 93	Retrospective study in newborns born between April 2020 and December 2020. Those with UNHS risk factors were excluded. Newborns included in the research were compared with healthy control groups regarding UNHS results and independent variables.	Newborns in the COVID-19 group were more likely to have negative ABR results than controls. The second ABR test results were not significantly different between the groups.	Newborns whose mothers tested positive for SARS-CoV-2 during pregnancy are highly associated with risks of abnormal UNHS results. Moreover, the time of infection (trimester) may be related to negative results.	9
Celik et al, (2021) Turkey	To assess the auditory functions of newborns who had been exposed to COVID-19 through vertical transmission.	73	2 nd : 12 3 rd : 25	Cross-sectional study conducted between March 2020 and December 2020 in newborns whose mothers had been diagnosed with COVID-19 during pregnancy. All infants were submitted to TEOAE, DPOAE, and contralateral OAE suppression tests.	There were important differences in TEOAE between the COVID-19 group and the control group at 3 kHz and 4 kHz. There were important differences in contralateral suppression at all frequencies. It was more effective in the control group.	The authors suggest changes in the olivocochlear efferent system in newborns exposed to the COVID-19 virus during pregnancy.	10
Z. Asli Oskovi-Kaplan et al., (2021) Turkey	To investigate the incidence of hearing changes in newborns whose mothers had been diagnosed with COVID-19 during pregnancy	797	1 st : 8 2 nd : 126 3 rd : 127 Positive newborns at birth: 197	Retrospective cohort study in newborns whose mothers had been diagnosed with COVID-19 during pregnancy. UNHS was performed with ABR or TEOAE. If newborns failed it, they were retested 15 days later.	There were no significant differences between the groups in the first screening – 12.4% of the COVID-19 group and 9.4% of the control group failed it. In the second screening, 1.3% of the COVID-19 group and 2.9% of the control group failed.	The authors concluded that COVID-19 infection during pregnancy is not a neonatal RFHL.	10



Author/ Year/ Place of publication	Objective	Sample	Trimester when maternal contamination occurred	Method	Results	Conclusion	Qualitative grade of the study
Mostafa et al. (2021), Egypt	To determine the possible effects of maternal SARS-CoV-2 on the newborns' hearing	984 (508 male and 476 female newborns)	1 st : 17 2 nd : 8 3 rd : 9	Retrospective cohort study conducted at two tertiary centers including all newborns born between November 2020 and April 2021 submitted to UNHS. Maternal infection was recorded, and their newborns' screening results were compared with the incidence of neonatal hearing loss in the UNHS program in the same period.	63 newborns were excluded due to RFHL. The overall incidence of UNHS failures was 2.3%. Of the 34 mothers who tested positive for COVID-19, 17 were diagnosed in the 1st, 8 in the 2nd, and 9 in the 3rd trimester. 29 newborns failed the first test, and only 1 failed the retest (2.9%)	The authors concluded that newborns whose mothers tested positive for COVID-19 are seemingly not at greater risk of hearing loss.	9
Yildiz et al, (2022) Turkey	To investigate whether COVID-19 infection during pregnancy can cause congenital hearing loss	199 newborns	1 st : 23 2 nd : 62 3 rd : 14	Unicentric retrospective study conducted between April 2020 and May 2021 at a reference tertiary healthcare center in Turkey. 422 mothers who had been infected with the coronavirus were followed up, and 203 were born at the institution where the study took place. Newborns were regarded in the risk protocol and were tested with A-ABR before hospital discharge.	199 newborns were included in the study; 4 were excluded for having RFHL. 11.6% of the pregnant women had COVID-19 in the 1st, 32.2% in the 2nd, and 57.3% in the third one. As for UNHS results, 178 passed A-ABR and 21 failed it in one ear. All these 21 newborns passed the retest.	Given the incidence of congenital hearing loss in the population, the study concluded that the absence of hearing loss in the research newborns does not confirm that coronavirus infection causes congenital hearing loss.	9
Ghiselli et al, (2022) Italy	To investigate the possible correlation between gestational COVID-19 infection and hearing loss onset in newborns	63 (36 females and 27 male newborns)	1 st : a nd 2 nd : 5 3 rd : 40	Prospective observational study in children whose mothers had been infected with COVID-19. They were submitted to UNHS with DPOAE and TEOAE before hospital discharge and audiological assessment up to 4 months old, using the acoustic immittance, TEOAE, PDOAE, and A-ABR	6.3% of newborns failed the initial screening, but only 1 of them failed the retest.	This study did not detect a significant correlation between maternal COVID-19 infection and congenital hearing loss.	9

Sources: Alan and Alan (2021); Celik et al. (2021); Kaplan et al. (2021); Mostafa et al. (2021); Yildiz et al. (2022); Ghiselli et al. (2022).

Caption: universal neonatal hearing screening (UNHS); auditory brainstem response (ABR); transient evoked otoacoustic emissions (TEOAE); distortion-product otoacoustic emissions (DPOAE); risk factors for hearing loss (RFHL).



Discussion

The effects of COVID-19 on pregnant women and their newborns have not been fully clarified yet. However, some studies report effects such as premature birth, low birth weight, and neonatal asphyxia. Moreover, exposure to different types of viruses is known to cause hearing loss. Hence, the effects of COVID-19 on the auditory system must be researched¹⁷⁻¹⁸⁻¹⁹.

The studies by Kaplan et al. (2021)¹³, Yıldız et al. (2022)¹⁴, Mostafa et al. (2021)¹⁵, and Ghiselli et al. (2022)¹⁶ analyzed the UNHS test and retest data (thus encompassing the complete screening) and concluded that newborns whose mothers had tested positive for COVID-19 do not seem to be at greater risk of hearing loss. The incidence of congenital hearing loss in the population and the absence of hearing loss in research newborns do not confirm that coronavirus infection causes congenital hearing loss. The results of these studies may be related to low vertical transmission. Current data in a comprehensive review on the management of the COVID-19 pandemic, focusing on healthcare for pregnant women and newborns, suggest a low risk of neonatal transmission²⁰⁻²¹.

Another study, conducted by Czeresnia et al. (2020)²², reports that, although pregnant women's unique characteristics make them more likely to have viral infection complications, this tendency has not yet been observed regarding the new virus. The study by Alan and Alan (2021)¹¹ verified that newborns whose mothers had tested positive for SARS-CoV-2 during pregnancy are associated with risks of abnormal UNHS results. The retest results in this study had no statistically significant differences, but the authors did not consider these definitive data, claiming there had been many absences in the retest. Since UNHS encompasses tests and retests with physiological and electrophysiological auditory measures to refer them for diagnosis, effective UNHS programs must consider the retests to confirm screening effectiveness²³.

Even though few studies have reported neonatal hearing loss due to COVID-19, developing inner ears are susceptible to the risks of infections during pregnancy and even after birth²⁴. Celik et al. (2021)¹² suggest an insufficiency in the medial olivocochlear system in newborns whose mothers had been exposed to the virus during pregnancy, which corroborates the findings by Mustafá

(2020)²⁵. The author reports that the COVID-19 virus had harmful effects on cochlear hair cells, as positive patients had smaller TEOAE amplitudes. Although four studies did not report associations between neonatal hearing loss and SARS-CoV-2 exposure, Swain et al. (2021)¹⁷ and Mostafa et al. (2021)¹⁵ emphasized the importance of continuous follow-up and detailed screening to understand this pathogenesis and detect possible late effects on the inner ear.

Conclusion

The studies that analyzed UNHS test and retest data concluded that newborns whose mothers had tested positive for COVID-19 were not at greater risk of hearing loss. The incidence of congenital hearing loss in the population and the data obtained in the studies point to the definition that coronavirus infection does not cause congenital hearing loss. The results obtained in these studies may be related to low vertical transmission. Nevertheless, the TEOAE suppression analysis identified results suggestive of insufficiency in the medial olivocochlear system in newborns whose mothers had been exposed to the virus during pregnancy.

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