Research Article

Neonatal Hearing Screening and Prevalence of Hearing Impairment in the Time Period of COVID-19 Epidemic in the North of Iran

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Highlights

- The "refer" results of UNHS was increased during COVID-19 epidemic
- There were more reports of neonatal hearing loss during COVID-19 epidemic

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ABSTRACT

Background and Aim: COVID-19 is an acute respiratory disease, caused by a coronavirus named SARS-CoV-2. Previous reports suggest an association between COVID-19 infection and Hearing Loss (HL). We have investigated the Universal Newborn Hearing Screening (UNHS) results in the time period of COVID-19 epidemic in Guilan Province, north of Iran.

Methods: We analyzed UNHS results from10 major obstetrics hospitals from 20th Mar 2020 to 19th Mar 2021, and compared the total UNHS positive/"refer" and total neonatal HL reports with the same time periods of recent three years. The prevalence of risk factors for HL were analyzed during the same period.

Results: The total number of childbirth was decreased significantly from 27735 birth cases in Mar 2017-2018 to 18216 births in Mar 2020-2021 ($p<0.001$), but the total "refer" rate was significantly increased from 63.0 per 1,000 births in Mar 2019-2020 to 79.8 in Mar 2020-2021 (OR=1.29, 95% CI: 1.19-1.39, $p<0.001$), and also increased from 74.7 per 1,000 births in Mar 2017-2020 to 79.8 in Mar 2020-2021 (OR=1.07, 95% CI: 1.01-1.14, $p=0.020$). The HL rate increased from 10.3 per 10,000 births in Mar 2019-2020 and from 11.4 per 10,000 births in Mar 2017-2020 to 18.7 in Mar 2020-2021 (OR=1.81 and 1.63, 95% CI: 1.06-3.09 and 1.10-2.44, $p=0.028$ and 0.015, respectively). The prevalence of preterm birth ($p=0.039$) and neonatal intensive care unit stay ($p=0.016$) was increased significantly during Mar 2020-2021.

Conclusion: The chance of "refer" results and neonatal HL, found in the UNHS program, increased during the COVID-19 epidemic in comparison to the past years.

Keywords: Newborn; hearing screening; hearing loss; COVID-19

Introduction

COVID-19 is an acute respiratory disease, caused by a coronavirus named SARS-CoV-2. The viral infection mainly affects the upper part of the respiratory system, but the symptoms are diverse and range from asymptomatic in some cases [1] to fever, cough, sore throat, headache, muscle pain, nonspecific taste and smell disturbances, diarrhea, and dyspnea in many others [2]. According to World Health Organization (WHO), COVID-19 becomes a public health emergency of international concern on 30 January 2020. The COVID-19 epidemic state was officially declared in Iran on 19th February 2020.

Neonatal hearing loss is one of the most important and prevalent disorders in neonatal care [3]. It can impede or cause a delay in speech and language development and lead to difficulties with educational and social achievements [4]. Universal Newborn Hearing Screening (UNHS) programs have been developed to implement early detection of infant hearing impairment. UNHS has been carried out in Iran since 2005 with a reported total coverage rate of about 83.5% in 2012 [5], although, unpublished reports suggest that the UNHS coverage rate is higher than 90% in Guilan province (in north Iran) since 2015. According to the newborn hearing screening program in Iran, hearing screening is done using a combination of Transient Evoked Otoacoustic Emission (TEOAE) and Automated Auditory Brainstem Response (AABR) tests [5].

A variety of risk factors are related with prevalence of congenital hearing loss, including preterm labor, familial history of congenital hearing loss, ototoxic medication, Neonatal Intensive Care Unit (NICU) stay, assisted ventilation and TORCH and other viral diseases during pregnancy, and etc. [6]. Also, a variety of viruses, including cytomegalovirus, herpes, measles, rubella, and mumps, can cause direct damage to the structure of the inner ear or cause autoimmune reactions in the inner ear, causing hearing loss [7]. Coronaviruses are neurotropic viruses that can affect the nervous system [8]. Therefore, SARS-CoV-2 infection may affect inner ear structures, theoretically. Munro et al. reported persistent changes in hearing and tinnitus in 13.2% of post-hospitalization COVID-19 cases [9]. Mustafa has reported that dysfunction of cochlear outer hair cells that is evident in the reduced amplitude of TEOAE response might be the only disease symptom in asymptomatic Covid-19 cases [10].

Congenital hearing loss is an important health problem for infants. COVID-19 outbreak can affect the UNHS results and increase the hearing test failure results. To date, there are a few studies that have investigated the impact of maternal COVID-19 and neonatal hearing loss on NHS results [11, 12] but there is no consensus. To the best of our knowledge, no study has previously reported UNHS results in the period of the COVID-19 epidemic in comparison with a recent time period before the disease outbreak. The questions we had addressed were: a) if the rate of UNHS positive results that labeled as "refer" results has been increased during the COVID-19 epidemic in comparison to the same period of the last three years? b) if the rate of neonatal hearing loss has been increased during COVID-19 epidemic in comparison to the same period of the last three years? c) is there a difference in the prevalence of hearing loss risk factors in the two different eras?

Methods

This was a retrospective study of the UNHS and the diagnostic follow-up hearing evaluation results of 10 major obstetrics hospitals in Guilan province in the north of Iran. The hospitals were selected because they were referral hospitals and had a good distribution throughout the province and they included the most complete and reliable screening information available.

In the Iranian UNHS program, the TEOAE and AABR are measured in the first month of a baby's life [5] and the State Welfare Organization of Iran is responsible for UNHS program. All infants are first tested for TEOAEs before discharge from the hospital. In infants with a fail result, the TEOAE are tested again after one week. Infants with at least one risk factor for hearing loss, such as positive family history for hearing loss, preterm labor, severe hyperbilirubinemia, etc., are tested using Automated Auditory Brainstem Responses (AABRs) up to one month after the TEOAEs test. Infants with positive screening results (i.e. "refer" response) in TEOAE and/or AABR will undergo a complete diagnostic ABR for threshold estimation within a time period of 3 months after birth. If the diagnostic ABR results verified hearing screening tests of the child, then congenital "hearing loss" would be confirmed.

In every obstetrics hospital studied here, hearing screening was consistently conducted by a specific audiologist during the last four years. The hearing screening audiologists were equipped to protective equipment including gloves, face masks, disinfectant and disposable medical gowns in the first days of the epidemic,

provided by the welfare organization of Iran. Thereby they could perform hearing screening test with the least concern about COVID-19 epidemic condition. We analyzed the UNHS and the diagnostic hearing test results from 20th Mar 2020 to 19th Mar 2021, where there were three peak periods of COVID-19 epidemic condition, and compared the total UNHS refer rates and total neonatal hearing loss reports of those neonates born in these hospitals with the same time periods of the last year and also with the recent three years from 20th March 2017 to 19th March 2020.

Considering the effect of risk factors for hearing loss on the UNHS results, we also compared the prevalence of hearing loss risk factors in the time period of COVID-19 epidemic and the last three years.

Statistical analysis

In this study, the total birth rate, the total refer rate, the total number of newborns diagnosed with hearing impairment during 4 years from Mar 2017-2018 to Mar 2020-2021 and the risk factors for hearing impairment were analyzed. The total refer rate and hearing loss rate were presented as per 1,000 and 10,000 births, respectively. Differences in the rates between the two periods were compared using a chi-square test. Moreover, the Odds Ratio (OR) and 95% Confidence Interval (CI) for total refer and hearing loss were calculated. Data analysis was carried out using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA) and the level of significance was set at 0.05.

Results

In general, there were 91742 newborns from Mar 2017-2018 to Mar 2020-2021. About 350 women who gave birth in Mar 2020-2021 had manifestations of upper respiratory infection. Because of a lack of diagnostic kit or some cultural reasons, not all of these women did a Polymerase Chain Reaction (PCR) test to confirm COVID-19 disease, but among those who did the test, COVID-19 infection was confirmed only in 27 women. There was no infant with confirmed COVID-19 disease.

The childbirth was continuously decreased from 27735 cases in Mar 2017-2018 to 24512 cases in Mar 2018-2019, 21281 cases in Mar 2019-2020, and 18216 cases in Mar 2020-2021. The total number of childbirths was decreased significantly from 27735 birth cases in Mar 2017-2018 to 18216 birth cases in Mar 2020-2021 ($p<0.001$). As the total number of childbirths, the total number of referred newborns also decreased from 5491 to 1453 cases, however, the statistical analysis revealed that the "refer" rate was significantly increased from 63.0 per 1,000 births in Mar 2019-2020 to 79.8 in Mar 2020-2021 (OR=1.29, 95% CI: 1.19-1.39, $p<0.001$). When compared to the past three years, the total refer rate was increased from 74.7 per 1,000 births in Mar 2017-2020 to 79.8 in Mar 2020-2021 (OR=1.07, 95% CI: 1.01-1.14, $p=0.020$) (Table 1).

Total refer and hearing loss rates in different years is presented in Figure 1. Similar to the finding of increased refer rate, the hearing loss rate increased from 10.3 per 10,000 births in Mar 2019-2020 to 18.7 in Mar 2020-2021 (OR=1.81, 95% CI: 1.06-3.09, $p=0.028$). The hearing loss rate was 11.4 per 10,000 births in Mar 2017-2020 that significantly increased to 18.7 in Mar 2020-2021 (OR=1.63, 95% CI: 1.10-2.44, $p=0.015$). Newborns of 27 mothers with confirmed COVID-19 infection, did not have confirmed hearing impairment at UNHS, but 2 of the mothers who had upper respiratory tract infections had positive/"refer" results that were not confirmed with diagnostic ABR. The details of the total birth and hearing loss rate are presented in Table 1.

Risk factors for hearing loss in the study population are presented in Table 2. The total number of neonates who had at least one risk factor was increased in Mar 2020-2021 compared to Mar 2017-2020 ($p=0.05$). The number of neonates with risk factors were also increased in Mar 2020-2021 compared to Mar 2019-2020, but it was not significant at the level of 0.05 ($p=0.076$). Among different risk factors, the prevalence of preterm birth ($p=0.039$) and Neonatal Intensive Care Unit (NICU) stay ($p=0.016$) was increased significantly during Mar 2020-2021 in comparison to Mar 2019-2020. When compared to Mar 2017-2020, the prevalence of preterm birth showed a considerable increase ($p=0.003$). On the other hand, the prevalence of hyperbilirubinemia (serum bilirubin levels of >17 mg/dL) was decreased ($p=0.004$) significantly in Mar 2020-2021. The prevalence of low birth weight (≤1500 g) was also increased ($p=0.062$) but was not significant at the level of 0.05.

Discussion

COVID-19 outbreak has had a deep effect on health care systems in many countries [13]. Coronavirus has infected a large number of people worldwide including men, women, and children. To date, there have been reports of hearing problems in COVID-19 patients [9, 10, 14, 15]. Also, it has been speculated that COVID-19 in pregnant women can be a risk factor for neonatal hearing loss [16]. Considering the literature, in the present

Table 1. Total "refer" rate and hearing loss rate by year in Guilan, north of Iran

		Year		Year	
		Mar 2017-2020	Mar 2020-2021	Mar 2019-2020	Mar 2020-2021
Total birth		73528	18216	21281	18216
Total "refer" results	Number of total refer	5491	1453	1341	1453
	Total refer rate (per 1,000 births)	74.7	79.8	63.0	79.8
	OR(95% CI)	1(Ref.*)	1.07(1.01-1.14)	1(Ref.*)	1.29(1.19-1.39)
	p		0.020		<0.001
Hearing loss	Number of hearing loss	84	34	22	34
	Hearing loss rate (per 10,000 births)	11.4	18.7	10.3	18.7
	OR(95% CI)	1(Ref.*)	1.63(1.10-2.44)	1(Ref.*)	1.81(1.06-3.09)
	p		0.015		0.028

OR; odds ratio, CI; confidence interval

* Reference period

study, it was hypothesized that increased risk of hearing impairment in newborns due to COVID-19 will be evident in the UNHS results. We compared the UNHS results of four consecutive years leading to 19th March 2021. The results of the present study showed a significant decrease in the total childbirth rate in Mar 2020-2021 in comparison with previous years. As it was mentioned, decreased childbirth rate was a continuous trend from Mar 2017-2018 to Mar 2020-2021 and may not be related to the COVID-19 epidemic in Mar 2020-2021. As the total number of hearing screened newborns was decreased, a significant decrease in the total number of "refer" results of UNHS would be expected. However, when the "refer" rate was accounted for, a significant increase was observed in "refer" results.

Our results showed that there was a significant increase in the refer results from UNHS and the prevalence of neonatal hearing impairment during the first year of the COVID-19 epidemic in comparison to the last years. This increased rate was also significant when compared to the mean results of the last three years. Similar to the results of the present study, Alan reported that maternal COVID-19 infection can increase a "refer" result in auditory brainstem responses in comparison with a control group [12]. Although in a second evaluation, the ABR test results did not differ significantly between the groups, the authors believed that COVID-19 infection during pregnancy can significantly be associated with an increased risk of abnormal UNHS results [12]. The increased refer rate reported in the present study can be explained, to some extent, by the increased prevalence of hearing loss risk factors. The rate of newborns with risk factor(s) for hearing loss was increased from 7.00% and 6.92% in Mar 2017-2020 and Mar 2019-2020 respectively, to 7.41% in Mar 2020-2021. Since in the Iranian UNHS program, newborns with a risk factor for hearing loss must return for AABR test within one month of the TEOAEs [5], they often get a refer result in hearing test on the first day of birth. Therefore, it is important to note that increased risk factors for hearing impairment can increase the refer rate of UNHS. There might be some other factors related to increased refer results. The audiologists performing the hearing screening test were equipped to protective equipment against COVID-19 virus. Besides, the hearing screening is a rather quick and easy to perform procedure. However, we cannot completely rule out the effect of reduced accuracy of the examiner on increased "refer" results. They might want to perform the tests as quickly as possible for each case during the pandemic.

In the Iranian UNHS program a combination of TEOAE and AABR is used to find any hearing problem in newborns. Here, Infants were first tested for TEOAEs. Newborns with a TEOAE "refer" result were tested for AABRs. If there were also a "refer" result with AABR, then a diagnostic ABR was implemented to predict the

Table 2. Risk factors for hearing loss in neonates by year

	Year		p	Year		p
	Mar 2017-2020	Mar 2020-2021		Mar 2019-2020	Mar 2020-2021	
	No.(%)			No.(%)		
No. of birth	73528	18216		21281	18216	
Total	5127(7.00)	1351(7.41)	0.050	1473(6.92)	1351(7.41)	0.076
Low birth weight	319(0.43)	98(0.53)	0.062	105(0.49)	98(0.53)	0.538
Preterm birth	1108(1.50)	331(1.81)	0.003	329(1.54)	331(1.81)	0.039
IV infection	421(0.57)	107(0.58)	0.813	109(0.51)	107(0.58)	0.315
Positive familial history	1041(1.4)	276(1.52)	0.319	327(1.53)	276(1.52)	0.864
NICU stay	842(1.14)	235(2.39)	0.108	219(1.9)	235(2.39)	0.016
Hyperbilirubinemia	685(0.93)	129(0.70)	0.004	154(0.72)	129(0.70)	0.856
Ototoxic medicine	501(0.68)	145(0.79)	0.100	152(0.71)	145(0.79)	0.352
Ventilation	326(0.44)	89(0.48)	0.417	92(0.43)	89(0.48)	0.411
Other	1136(1.54)	299(1.64)	0.355	337(1.58)	299(1.64)	0.654

IV; intravenous, NICU; neonatal intensive care unit

Total: total children having risk factors

hearing thresholds. Regardless of the increased "refer" results in the present study, the prevalence of neonatal hearing impairment was increased significantly from Mar 2017-2020 to Mar 2020-2021. Previous reports suggest an association between COVID-19 infection and hearing loss. Koumpa et al. has reported Sudden-onset Sensorineural Hearing Loss (SSNHL) following COVID-19 [15]. In a systematic review of the literature concerning the coronavirus and audio-vestibular symptoms, Almufarrij and Munro estimated that the prevalence of hearing impairment due to COVID-19 infection was 7.6 % [17]. In Iran, the COVID-19 epidemic started in the last month of Mar 2019-2020 and continued to date with this writing. Accordingly, we expected to find an increased rate of refer results and/or hearing-impaired neonates in Mar 2020-2021.

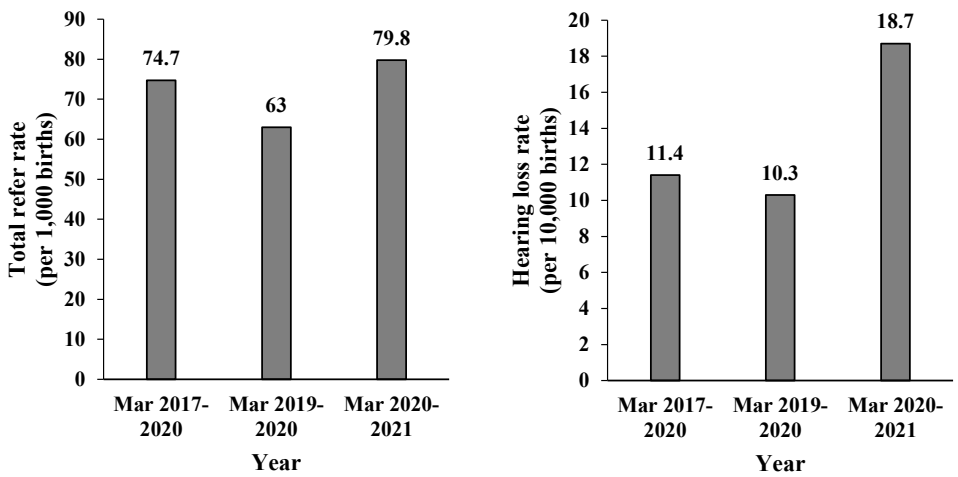

Figure 1. Total refer rate and hearing loss rate by year in Guilan, north of Iran

A few previous studies have investigated NHS results of newborns born from mothers who had COVID-19 disease during pregnancy. Oskovi-Kaplan et al. compared neonatal hearing test results of 458 newborns from mothers with a history of COVID-19 infection during pregnancy with 339 women who gave birth before the pandemic [18]. The hearing screening was performed using TEOAE or AABR. Patients who failed the first screening were reevaluated after at least 2 weeks. They found no significant difference in the incidence of failed screening results between the groups neither in the first nor in the second screening session. Schwartz has investigated the transmissibility of the virus from mother to fetus and has found no evidence of intrauterine or transplacental transmission of the SARS-CoV-2 virus [19]. Yıldız et al. have studied the results of hearing screening tests of 199 newborns from women who had coronavirus infection during pregnancy. They did not confirm a hearing loss in any of the screened newborns [16].

In the present study, although there was a limited number of confirmed COVID-19 infected mothers in the present study, we did not find a hearing impairment in any of newborns of COVID-19 mothers. However, it should be noted that the absence of hearing loss in these study populations does not completely rule out the argument that coronavirus infection can cause congenital hearing loss and it needs to be studied in larger populations.

Some of the risk factors for hearing loss were increased in Mar 2020-2021 that can have a role in increased hearing loss reports. The prevalence of preterm birth, NICU stay and low birth weight was increased in comparison to previous years. Studies have shown that Covid-19 disease itself and elevated depression and anxiety symptoms among pregnant individuals during the COVID-19 pandemic are two important factors that are involved in increased rate of preterm birth [20, 21]. Preterm birth and increased length of hospital stay can have adverse effects on auditory system [22]. Therefore, it seems that Covid-19 epidemic can increase rate of hearing loss indirectly by increasing risk factors for hearing loss. As well as there can be direct effects of COVID-19 on hearing health that has been reported in some previous studies [15, 17].

The present study found some evidence on the effect of the COVID-19 epidemic on UNHS results. Based on these findings, it seems that the COVID-19 epidemic increased the "refer" results of UNHS and the hearing loss rate in neonates. In the present study, the prevalence of hearing impairment in Mar 2020-2021, defined through diagnostic ABR testing, was found to be significantly increased in comparison to previous years. This increase in the prevalence of congenital hearing impairment found in an almost large study population can be a warning for health care services. The prevalence of hearing loss may increase even more in the next few years. As it was reported by Holzinger et al., as high as 50% of children who passed NHS at birth may develop significant bilateral hearing loss at school age [23]. Therefore, the effect of the COVID-19 epidemic on late-onset hearing impairment during childhood needs to be investigated in future studies.

The present study had some limitations. Due to lack of diagnostic tests for COVID-19 infection in the first months of epidemic, there might be a considerable number of undiagnosed COVID-19 infected mothers and/or newborns. The other limitation was that the number of hospitals with a complete and reliable screening information was limited. Although these covered about 70 percent of child birth in Guilan, it might not fully represent the hearing results of the whole neonates.

Conclusion

Our results showed that the chance of "refer" results of UNHS and the rate of neonatal hearing loss increased significantly during the COVID-19 epidemic in comparison to the past years. However, it should be kept in mind that a considerable part of hearing impairment in children can occur at later ages. Parents and hearing professionals should be aware of hearing loss in little children specifically during and a few years after the COVID-19 epidemic.

Ethical Considerations

Compliance with ethical guidelines

The study was approved by the Ethics Committees at the Guilan University of Medical Sciences (IR.GUMS.REC.1400.441).

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Authors' contributions

RP: Study design, interpretation of the results, and drafting the manuscript; SN: Study design, interpretation of the results, and drafting the manuscript; MA: Study

design; SN: Study design; SM: Statistical analysis; AH: Acquisition of data.

Conflict of interest

The authors have no conflicts of interest relevant to this article to disclose.

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