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Newborns' Hearing Health Associated with Infectious Diseases in Primary Healthcare Infectious Diseases and Neonatal Hearing Screening

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Introduction

According to the World Health Organization [1], hearing loss is unevenly distributed worldwide and importantly associated with each region's per capita income. Hearing is one of the most important human senses [2], and a healthy auditory system is a prerequisite to language and auditory skill development [3]. Hence, it is a serious matter for patients when their auditory health is affected.

Hearing loss is defined as an important decrease in the capacity to perceive speech and environmental sounds. However, if detected early, patients may be less impaired by this dysfunction [4]. To this end, Federal Law no. 12.303 made the universal neonatal hearing screening (UNHS) mandatory in Brazil in 2010 [5]. It is performed with evoked otoacoustic emissions (EOAE) and automated auditory brainstem response (A-ABR) [4], following scientific institution protocols by the Joint Committee on Infant Hearing (JCIH) (2007, 2019) [6,7] and restated by the Multiprofessional Committee on Hearing Health (COMUSA, in Portuguese) [8] and the NHS Attention Guidelines [4].

Studies point out that congenital infections are risk indicators for hearing loss (RIHL). The JCIH began defining RIHL in the 1970s (2007) [6] to identify newborns more susceptible to having hearing loss. In Santa Catarina, Brazil, 277 cases of congenital syphilis were reported in 2014, and 700, in 2017, indicating a 153% increase between those years [9]. In Florianópolis (the capital of Santa Catarina), 129 cases were reported between 2016 and 2017 [10].

Given the above, the main objective of his research was to construct association models employing logistic regression and Cochran–Mantel–Haenszel odds ratio (OR) calculation to assess the strength of association between infectious diseases in newborns and NHS, minimizing interferences from confounding variables (mother's age, year of birth, ICU stay, and prematurity) in primary healthcare at an NHS reference service of the Unified Health System (SUS, in Portuguese) in the state of Santa Catarina.

Methods

Study design and setting

This is a historic (retrospective) cohort study analyzing data from newborns submitted to UNHS at two maternity hospitals in Santa Catarina between January 2017 and December 2021. Secondary data furnished by a reference hearing health service were surveyed and analyzed.

Screening procedure and data collection

UNHS was conducted while newborns were in maternity ward stay or intermediate care. They were assessed with transient evoked otoacoustic emissions (TEOAE) in both ears, recorded separately; when necessary, A-ABR was performed.

If, however, the result was unsatisfactory, the auditory monitoring referral protocol of the state of Santa Catarina was followed [11].

Outcome variable

NHS, categorized into "pass" or "fail", was addressed as a variable. Newborns who failed the TEOAE and/or A-ABR in one or both ears were considered "fail".

Main exposure variables and covariables

The main investigation variable was the presence of infectious diseases (no; yes). The covariables were the year of birth (2017; 2018; 2019; 2020; 2021), mother's age (≤ 19; 20-29; ≥ 30 years), ICU stay (no; yes), and prematurity (no; yes).

Data analysis

The data were organized in Microsoft Excel® spreadsheets and then exported to and analyzed in MedCalc® Statistical Software, version 20.027 [12]. The categorical variables were described in absolute and relative frequencies, with their respective 95% confidence intervals (95% CI). An association analysis was made with the chi-square test between the outcome (NHS) and the main exposure variable (congenital syphilis) and covariables. Whenever possible, the chi-square was also used to assess trends (mother's age and year of birth). In raw (bivariate) and adjusted analyses, the OR was used as an association measure; it was estimated with logistic regression analysis and 2x2 table analysis (raw OR), or with the Cochran–Mantel–Haenszel test. The main exposure variable was adjusted for all study variables, regardless of the p-value. The variables were simultaneously included in the adjusted analysis, following the statistical method of a previous study [13]. Statistically significant associations were admitted only when their odds of occurrence were equal to or lower than 0.05 (i.e., $p \leq 5\%$).

Ethical aspects

This study was approved by the Research Ethics Committee of the Federal University of Santa Catarina under CAAE no. 39562720.8.0000.0121. All parents/guardians signed an informed consent form.

Results

Altogether, 34,801 newborns who had been submitted to NHS between January 2017 and December 2021 participated

Table 1: Sample description with the year of birth, mother's age, neonatal hearing screening, and risk indicators for hearing loss. Florianópolis, SC, 2017 to 2021 (n = 34,801).

Variable	n	%	95% CI
Year of birth (n = 34,801)			
2017	6,956	19.99	19.52-20.46
2018	7,584	21.79	21.3-22.29
2019	6,894	19.81	19.34-20.28
2020	6,443	18.51	18.06-18.97
2021	6,924	19.90	19.43-20.37
Mother's age (n = 34,097)			
≤ 19 years	4,302	12.62%	12.24-13.00
20 to 29 years	18,134	53.18%	52.41-53.96
≥ 30 years	11,661	34.20%	33.58-34.83
NHS (n = 34,738)			
Pass	34,346	98.89	97.83-99.92
Fail	392	1.13	1.02-1.25
ICU stay (n = 34,715)			
No	33,387	96.17	95.15-97.21
Yes	1,328	3.83	3.62-4.04

Prematurity (n = 34,715)			
No	33,443	96.34	95.31-97.37
Yes	1,272	3.66	3.47-3.87
Infectious diseases (n = 34,737)			
No	33,781	97.25	96.21-98.29
Yes	956	2.75	2.58-2.93
95% CI: 95% confidence interval.			

in this study; 392 (1.13%) of them failed the screening. Most mothers in the sample were 20 to 29 years old (53.18%). Infectious diseases were present in 2.75% of the newborns, while prematurity and ICU stay were higher than 3.65% (Table 1).

NHS failures occurred more frequently in newborns whose mothers were ≤ 19 years old than in the other categories, with a statistically significant difference ($p < 0.0001$). Also, there was a greater proportion of failures in newborns with infectious diseases than without them ($p < 0.0001$) (Table 2).

Table 2: Relative frequencies of failures in the neonatal hearing screening per mother's age and risk indicators for hearing loss. Florianópolis, SC, 2017 to 2021 (n = 34,801).

Variable	**Neonatal Hearing Screening**			
	% Failure	95% CI	p-value*	p-value**
Mother's age			P<0.0001	P=0.0016
≤ 19	1.79	1.42-2.24		
20 to 29	1.01	0.87-1.17		
≥ 30	1.02	0.85-1.22		
Year of birth			P<0.0001	P<0.0001
2017	1.19	0.95-1.48		
2018	1.47	1.21-1.77		
2019	2.28	1.94-2.66		
2020	0.5	0.34-0.71		
2021	0.13	0.06-0.25		
Infectious diseases			P<0.0001	NA
No	1.03	0.93-1.15		
Yes	4.49	3.24-6.07		
ICU stay			P<0.0001	NA
No	1.07	0.96-1.19		
Yes	2.49	1.71-3.50		
Prematurity			P<0.0001	NA
No	1.03	0.92-1.15		
Yes	3.58	2.61-4.79		
95% CI: 95% confidence interval; NA: not applicable. *Pearson chi-square test; **Chi-square test for trend.				

The association analysis between infectious diseases and NHS failures is presented in Table 3. In the adjusted analysis, newborns with infectious diseases were 4.73 times more likely to fail NHS than those without syphilis (95% CI: 3.02-7.41). The same analysis was made excluding newborns who were premature and/or stayed in ICU, and the adjusted OR was 4.88.

The adjusted OR obtained with Cochran–Mantel-Haenszel test considering the confounding variables are shown in Table 4. Their values ranged from 3.58 to 4.15, with overlapping values in all their 95% CI, indicating a clear and robust association between the newborns' NHS failure and congenital syphilis. The OR for the various situations is presented in Figure 1.

Table 3: Adjusted association analysis between NHS failures and congenital syphilis. Florianópolis, SC, 2017 to 2021.

Variable	Neonatal Hearing Screening			
	Raw OR (95% CI)	p-value	Adjusted OR* (95% CI)	p-value
Infectious disease (model 1)		P<0.0001		P<0.0001
No	1		1	
Yes	4.50 (3.25-6.24)		4.73 (3.02-7.41)	
Infectious disease (model 2)		P<0.0001		P<0.0001
No	1		1	
Yes	5.04 (3.55-7.16)		4.88 (3.43-6.96)	

95% CI: 95% confidence interval. *Obtained with logistic regression and adjusted with all study variables; model 1: including all newborns, model 2: excluding all newborns who stayed in ICU and/or were premature.

Table 4: Cochran–Mantel–Haenszel odds ratio of the association between NHS failure and Infectious diseases adjusted for possible confounding variables. Florianópolis, SC, 2017 to 2021.

Variable	Neonatal Hearing Screening		
	Cochran–Mantel–Haenszel Test		OR Homogeneity Test (Breslow-Day-Tarone)
	Adjusted OR (95% CI)	p-value	p-value
Infectious diseases (Confounding variable = year of birth)		<0.00001	0.4659
No	1		
Yes	4.39 (3.15-6.10)		
Infectious diseases (Confounding variable = categorized mother's age)		<0.00001	0.76629
No	1		
Yes	4.17 (2.96-5.87)		
Infectious diseases (Confounding variable = ICU stay)		<0.00001	0.66703
No	1		
Yes	4.59(3.31-6.37)		
Infectious diseases (Confounding variable = prematurity)		P<0.0001	ND
No	1		
Yes	4.73 (3.41-6.55)		

OR: odds ratio; 95% CI: 95% confidence interval; ND: not designated.

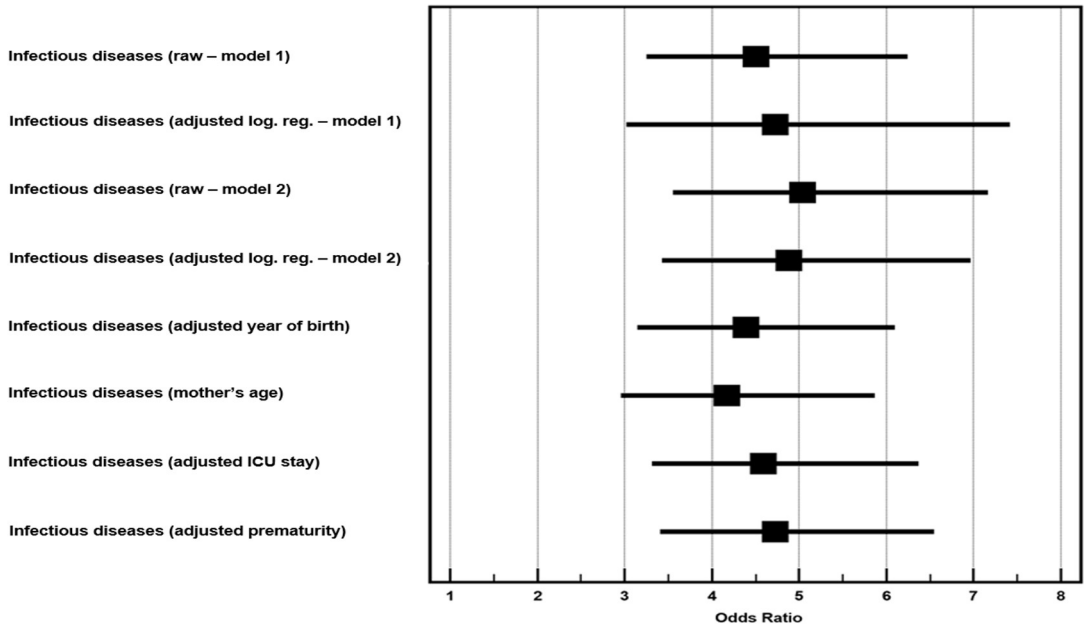

Figure 1: Forest plot of the odds ratios (raw, adjusted with logistic regression, and adjusted Cochran–Mantel–Haenszel odds ratio) of the association between failures in the neonatal hearing screening and infectious diseases adjusted for possible confounding variables. Florianópolis, SC, 2017 to 2021.

Discussion

A total of 392 (1.13%) newborns failed the NHS, while 552 (1.6%) were diagnosed with congenital syphilis. In the final adjusted analysis, newborns with congenital syphilis were 3.7 times more likely to fail the NHS than those without syphilis (95% CI: 2.01; 5.26). Before the Unified Health System was established, the Brazilian epidemiological profile was characterized by a high incidence of mortality from communicable diseases and rural endemics, with limited surveillance, prevention, and control measures. After the 1980s, such measures were reorganized and universalized through the National Health Surveillance System in cooperation with the other fields of the healthcare network. Thus, vaccines and treatment were universally provided free of charge to the population [14].

The National Program for Humanized Prenatal Care and Birth (PHPN, in Portuguese), launched in 2000 by the Ministry of Health, proposes indicator criteria for prenatal care performance and quality and financial incentives to the municipalities that adhered to the program [15]. In 2011, the Ministry of Health implemented the Stork Network to complement PHPN and provide a new healthcare model for mothers and children, from birth to 24 months old, ensuring accessibility, support, and solutions and decreasing mother and child mortality rates [16]. Worldwide estimates indicate that approximately one million pregnant women are infected with syphilis per year. In Brazil, congenital syphilis remains a major public health problem [17] – in 2009, its incidence rate was 2.1:1000 live births, which increasingly progressed to 9:1000 live births in 2018, decreasing back to 8.2:1000 live births in 2019 [9].

Communicable diseases, even if asymptomatic, may cause early or late sensorineural hearing loss in newborns [18]. Such losses interfere with their social and emotional life and impair their linguistic and cognitive development. Auditory monitoring follows up on behavioral and linguistic development inherent to auditory skills and auditory pathway maturation. Thus, it minimizes the impact on auditory and linguistic development, benefitting from the period of neuronal plasticity when adequate treatment is conducted [19].

Moreover, the Hearing Healthcare Policy determined that hearing healthcare should be provided along with primary healthcare measures, either individually or collectively, aiming at the promotion, prevention, and early identification of hearing loss. Therefore, it is expected to include informative, educational, and family instruction initiatives; secondary healthcare measures, with diagnosis, follow-up, and therapy for patients with hearing loss; and tertiary healthcare measures [20]. Regulations (SAS no. 587, of October 7, 2004, and SAS no. 589, of October 8, 2004) also accredited the Hearing Healthcare Services. They specify the measures that should be carried out on the three healthcare levels and standardize the organization and implementation of the State Hearing Healthcare Networks, which are responsible for establishing

and organizing the reference and counter-reference flow [20,21].

The absence of race, educational attainment, and family background as variables in this research may be considered limitations. However, these data were not available in the newborns' medical records. Therefore, associations between these variables and possible NHS failures could not be verified. It is suggested that services include these and other data in the medical records to ensure that health professionals have access to more comprehensive information.

Early hearing loss identification and detection with NHS is a key tool for child follow-up, encompassing all healthcare levels. Therefore, the Family Health Strategy must incorporate the initial flow for longitudinal follow-up [22].

Conclusion

Knowing the multidimensional aspects of health in the various life cycles is a comprehensive care strategy. The aim is to learn the population's health profile, needs, and vulnerability issues, especially regarding the existing policies and services. Some elements must be considered when interpreting the results of this study. The logistic regression design in this research directly estimates the odds of the occurrence of an event. However, it is not possible to infer changes that occurred over time or ensure the causality of actions. Unavailable information on the mother's educational attainment and race can be considered a limitation, as these could have provided a more in-depth data analysis.

In conclusion, infectious diseases were associated with NHS failure. To reach an early diagnosis and intervention, there must be investments in public policies for primary healthcare, aiming to strengthen and give greater importance to prenatal care and hearing screening.

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