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Auditory development of infants with risk indicators for hearing loss

Desenvolvimento auditivo de lactentes com indicadores de risco para perda auditiva

Desarrollo auditivo de lactantes con indicadores de riesgo de pérdida auditiva

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Abstract

Introduction: Audiological monitoring seeks to follow the process of hearing development and language acquisition. Hearing plays a fundamental role in the development of oral language, so early diagnosis is essential for the beginning of the intervention. **Objective:** To analyze the auditory development of infants who passed the neonatal hearing screening, but who had risk indicators for hearing loss in their neonatal history. **Methods:** A cross-sectional and longitudinal analysis was performed. In the cross-sectional analysis, infants were divided into three groups considering the corrected age: G1 at 6-9 months, G2 at 9-13 months and G3 at 13-18 months. In the longitudinal analysis, infants who attended more than once for evaluation were evaluated. These infants form the G4 group. **Results:** For assessment with non-verbal sounds, in G3 were found 18.6% (n=11) of indirect responses to lower location and 40.7% (n=24) of indirect responses to upper location. Regarding the recognition of verbal commands, in group G3, 30.5% (n= 8) answered to two commands. As for the longitudinal analysis, among the infants who were evaluated in two phases, the occurrence of 25% (n=5) with altered development of hearing skills was observed. **Conclusion:** From the analysis of the results, responses suggestive of changes in the hearing skills of infants were identified.

Keywords: Infant; Risk Index; Hearing Tests

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Resumo

Introdução: O monitoramento audiológico busca acompanhar o processo de maturação da audição e de aquisição da linguagem. Como a audição exerce um papel fundamental para o desenvolvimento da linguagem oral, o diagnóstico precoce é essencial para o início da intervenção. **Objetivo:** Analisar o desenvolvimento auditivo de lactentes que passaram na triagem auditiva neonatal, mas que possuíam em seu histórico neonatal indicadores de riscos para perda auditiva. **Método:** Foi realizada análise transversal e longitudinal. Na análise transversal os lactentes foram divididos em três grupos considerando a idade corrigida: G1 com 6-9 meses, G2 com 9-13 meses e G3 com 13-18 meses. Na análise longitudinal foram avaliados os lactentes que compareceram mais de uma vez para avaliação. Estes lactentes formam o grupo G4. **Resultados:** Para sons não verbais, em G3 encontrou-se 18,6% (n=11) de respostas indiretas para localização para baixo e 40,7% (n=24) de respostas indiretas para localização para cima. Quanto ao reconhecimento de comandos verbais, no grupo G3, 30,5% (n=18) responderam para até dois comandos. Quanto à análise longitudinal, dentre os lactentes que foram avaliados em duas fases, observou-se a ocorrência de 25% (n=5) com desenvolvimento alterado das habilidades auditivas. **Conclusão:** A partir da análise dos resultados identificaram-se respostas sugestivas de alteração nas habilidades auditivas dos lactentes.

Palavras-chave: Lactentes; Indicador de Risco; Testes Auditivos

Resumen

Introducción: El monitoreo audiológico busca seguir el proceso de maduración auditiva y adquisición del lenguaje. Dado que la audición juega un papel clave en el desarrollo del lenguaje oral, el diagnóstico temprano es esencial para el inicio de la intervención. **Objetivo:** Analice el desarrollo auditivo de los bebés que pasaron el examen de audición neonatal, pero que tenían indicadores de riesgo de pérdida auditiva en su historia neonatal. **Métodos:** Se realizó un análisis transversal y longitudinal. En el análisis transversal, los lactantes se dividieron en tres grupos considerando la edad corregida: G1 a los 6-9 meses, G2 a los 9-13 meses y G3 a los 13-18 meses. En el análisis longitudinal, se evaluó a los lactantes que asistieron más de una vez para evaluación. Estos bebés forman el grupo G4. **Resultados:** Para los sonidos no verbales en G3, encontramos un 18,6% (n=11) de respuestas indirectas a la ubicación descendente y un 40,7% (n=24) de respuestas indirectas a la ubicación ascendente. Con respecto al reconocimiento de comandos verbales, en el grupo G3, el 30.5% (n=18) respondió por hasta dos comandos. En cuanto al análisis longitudinal, entre los lactantes que fueron evaluados en dos fases, se observó la aparición del 25% (n=5) con desarrollo alterado de las habilidades auditivas. **Conclusión:** A partir del análisis de los resultados, se identificaron respuestas que sugieren cambios en las habilidades auditivas de los bebés.

Palabras clave: Lactante; Índice de Riesgo; Pruebas Auditivas

Introduction

Hearing plays a fundamental role in the development of oral language, which is one of the main forms of communication between individuals and the environment. When hearing is impaired, it may affect not only the acquisition of oral language, but may also cause social and emotional detriment[1-4]. Thus, early diagnosis is essential for the beginning of the intervention, which will minimize any difficulties related to sensory deprivation[5,6].

The first step for early diagnosis is to perform universal neonatal hearing screening (UNHS). UNHS is a simple and fast procedure, used to trace newborns (NB) who are most likely to have hearing loss and need a complete audiological diagnosis[4,7,8]. However, although some infants pass the test, there is a risk of them being susceptible to changes in the auditory function maturation stages, during the first years of life. This occurs due to the presence of risk indicators in the neonatal history of these infants[3].

The risk indicators for hearing loss (RIHL) are: family history of congenital or late onset deafness, use of prolonged mechanical ventilation, exposure to ototoxic drugs, birth weight less than 1,500 g, hyperbilirubinemia, craniofacial anomalies, apgar from 0 to 4 in the first minute or from 0 to 6 in the fifth minute, and genetic syndromes associated with hearing loss[9,10]. Infants with these indicators are at a higher risk of having a hearing disorder with a progressive characteristic and/or a late appearance[11].

The prevalence of hearing loss is approximately 3:1000 newborns. For the population without risk, the incidence is lower (1 to 2:1000) compared with those with risk indicators (20 to 50:1000)[8,12,13].

Considering the prevalence of hearing loss among infants with risk indicators and the fact that hearing loss may not manifest immediately after birth, the national and international committees (Multiprofessional Committee on Auditory Health (COMUSA) and Joint Committee of Infant Hearing (JCIH)) recommend that infants who obtain satisfactory results in UNHS but present risk indicators for hearing loss should be included in a monitoring program, in which they will be periodically evaluated[5,9,14].

Audiological monitoring aims to assess and monitor the auditory maturation and language acquisition processes[15,16]. According to Azevedo (2015), auditory skills assessment can be included in monitoring to monitor at-risk children, since behavioral assessment combined with electrophysiological assessment provides data on the maturation of the peripheral and central auditory system[15-17].

It is important to consider during monitoring that the development of auditory skills undergoes a gradual stage of complexity, in which children must be able to detect, specify, locate, memorize, recognize and understand sounds. This sequence of behaviors evolves until the age of two, and must be observed during monitoring to determine the next step in the intervention in cases of impairment[16,17].

The assessment of auditory skills involves behavioral examinations using verbal and non-verbal sounds, which produce a change in the child's behavior. Thus, reflex responses, attention to sound, search for source, lateral, upper and lower location, reaction to voice and understanding of simple commands are observed.

Stimulation and exposure to auditory experiences have a great impact on the development of auditory skills and the first years of life are critical to the consolidation of these skills.

This research aimed to analyze the auditory development in the first years of life of infants who passed the hearing screening but had in their neonatal history risk indicators for progressive and/or late appearance hearing loss or auditory processing impairment.

Method

This study was approved by the UNICAMP Research Ethics Committee under protocol no. 932,602/2015. It was a cross-sectional and longitudinal study, with a quantitative approach.

The sample consisted of infants who attended the monitoring program of the "Prof. Dr. Gabriel O. S. Porto" Research and Rehabilitation Studies Center (CEPRE), aged between 6 and 18 months. In the cross-sectional analysis, 155 infants were evaluated, of which 83 were male and 72 female. In the longitudinal analysis, there were 20 subjects, 10 male and 10 female.

The research only included infants who attended the monitoring from August 2017 to September 2018 and who were hospitalized in the Neonatal Intensive and/or Intermediate Care Unit of UNICAMP's Prof. Dr. José Aristodemo Pinotti Women's Hospital (CAISM) for more than 48 hours. These infants passed auditory screening, performed by using the Automatic Brainstem

Evoked Auditory Potential (BAEP-a) and had other risk indicators for progressive and/or late onset hearing loss in their neonatal history.

Due to the importance of the development of auditory skills to the maturation of the peripheral auditory system, we decided to use behavioral assessments, following the protocol proposed by Azevedo[17].

The evaluation protocol applied during the monitoring program was composed as follows:

- observation of behavioral responses to non-verbal sound stimuli (rattle) and verbal sound stimuli (reaction to voice and recognition of verbal commands)
- visual reinforcement audiometry.

In the evaluation with non-verbal sound stimuli, the infants' responses were tested with rattle instrument, right and left in the lateral plane and above and below the auricular pavilion[17,18].

Regarding verbal sounds, two evaluations were performed. The first evaluation tested the reaction to voice, using a familiar voice or the examiner's voice as stimulus, while the second evaluation tested the recognition of verbal commands, in which we used three levels of simple commands, as follows: level I (Blow a kiss! Wave goodbye! Clap your hands!); level II (Where's the pacifier? Where's Mom? Where are your shoes?), and level III (Where's your hair? Where's your hand? Where are your feet?)[17].

In Visual Reinforcement Audiometry (VRA), the PA-5 pediatric audiometer from INTERACOUSTICS was used, with Warble modulated tones at frequencies of 500, 1000, 2000 and 4000 Hz, at intensities of 80, 60, 40 and 20 dBHL. VRA enabled determining the minimum level of response at which the same response occurred in more than 50% of the presentations at each frequency. This test was performed bilaterally[12].

Chart 1 shows the expected responses for each behavioral assessment, considering the age group.

Chart 1. Expected responses for behavioral assessment in each age group, according to Azevedo 2015.

Age Group (Months)	Response to instrumental sound	Response to verbal sound	Minimum level of response (dBHL)
6-9*	Right and left lateral location Indirect lower and upper location	Locates the mother's and examiner's voices	40 to 60
9-13*	Right and left lateral location Direct lower and indirect upper location	Recognizes Level I verbal commands	20 to 40
13-18*	Right and left lateral location Direct lower and direct upper location	Recognizes Level II and III verbal commands	20

*meses incompletos

Regarding data analysis, the findings were organized in two ways. The first was the cross-sectional analysis, in which the subjects were separated into three groups considering the corrected age. Group 1 (G1) included 40 infants aged 6 to 9 months, Group 2 (G2) included 56 infants aged 9 to 13 months, and Group 3 (G3) included 59 infants aged 13 to 18 months. In this stage, the development of auditory skills was considered, assessed through behavioral responses to verbal and non-verbal sound stimuli and Visual Reinforcement Audiometry.

The second stage was the longitudinal analysis, in which subjects who attended more than one assessment were selected. These infants composed Group 4 (G4). The time G4 infants were aged 9 to 13 months was called Phase 1, while the time the infants were aged 13 to 18 months was called Phase 2. This analysis aimed to observe whether there was evolution in the infants' responses over time. To that end, the responses were observed as to the auditory skills, which were classified as normal or impaired according to the responses found in each age group. Infants who, in Phase 2, presented responses consistent with those expected for the age group were considered to have normal development. While infants who showed inferior responses for this phase were considered to have impaired development.

When we observed impaired development of auditory skills, parents were instructed to stimulate the child at home, since the more contact with the world of sound the better their auditory and oral language development. Regarding average ear conditions, when impaired, infants were referred for pediatric evaluation and management.

In the cross-sectional analysis, statistical analysis was performed using the chi-square and ANOVA tests. The chi-square test was applied in the analysis in relation to the sex and to the behavioral assessments with verbal and non-verbal sound stimuli. For the responses found in Visual Reinforcement Audiometry, the ANOVA technique was used. The level of significance was set at 5% and statistically significant values were highlighted in bold ($p \leq 0.05$).

Results

Table 1 shows the data for sample characterization according to sex. A homogeneous sample is observed, with no statistically significant difference (p=0.403).

Table 1. Infants in groups G1, G2 and G3, according to sex.

Sex	G1	G2	G3	TOTAL	p-value*
Male	25 (62.5%)	29 (51.8%)	29 (49.2%)	83 (53.5%)	
Female	15 (37.5%)	27 (48.2%)	30 (50.8%)	72 (46.5%)	0.403
TOTAL	40 (100%)	56 (100%)	59(100%)	155(100%)	

Caption: *chi-square test

Regarding the evaluation for non-verbal sounds, the results found are shown in Table 2. In G3, we found 18.6% (n=11) of indirect responses for lower location and 40.7% (n=24) of indirect responses for upper location. In this same group, 1.7% (n=1) did not respond to the sound in the lower and upper location.

Table 2. Infants in groups G1, G2 and G3, according to responses for evaluation with non-verbal stimulus.

Evaluation with non-verbal sound	Response	G1	G2	G3	TOTAL	p-value*
Lower location	Indirect	33(82.5%)	23(41.1%)	11(18.6%)	67(43.2%)	**<.001**
	Direct	7(17.5%)	33(58.9%)	47(79.7%)	87(56.1%)	
	Did not locate	0 (0%)	0 (0%)	1 (1.7%)	1 (0.6%)	
	TOTAL	40 (100%)	56 (100%)	59 (100%)	155(100%)	
Upper location	Indirect	40 (100%)	39(69.6%)	24(40.7%)	103(66.5%)	**<.001**
	Direct	0 (0%)	17(30.4%)	34(57.6%)	51 (32.9%)	
	Did not locate	0 (0%)	0 (0%)	1 (1.7%)	1 (0.6%)	
	TOTAL	40 (100%)	56 (100%)	59(100%)	155 (100%)	

Caption: *chi-square test

Table 3 shows the results for the evaluation with verbal sound. In the reaction to voice test, in G1, 2.5% (n=1) presented unilateral response and 2.5% (n=1) presented the search for source reaction, when called by name. As for the recognition of verbal commands, in G3, 30.5% (n=18) responded to up to two commands.

Table 3. Infants in groups G1, G2 and G3, according to responses for evaluation with verbal stimulus.

Evaluation with verbal sound	Response	G1	G2	G3	TOTAL	p-value*
Reaction to voice	Located	38(95%)	56(100%)	59(100%)	153(98.7%)	0,213
	Search for source	1(2.5%)	0 (0%)	0 (0%)	1 (0.6%)	
	Unilateral location	1(2.5%)	0 (0%)	0 (0%)	1 (0.6%)	
	TOTAL	40(100%)	56 (100%)	59 (100%)	155 (100%)	
Recognition of verbal commands	Up to 2 commands	-	46(82.1%)	18(30.5%)	64(55.7%)	**<.001**
	3 or more commands	-	10(17.9%)	41(69.5%)	51(44.3%)	
	TOTAL	-	56(100%)	59(100%)	115(100%)	

Caption: *chi-square test

As for the results found for visual reinforcement audiometry (VRA), the three groups evaluated showed a minimum level of response consistent with the values estimated for the age group. The results of this evaluation are shown in Table 4.

Table 4. Infants in groups G1, G2 and G3, according to responses for Visual Reinforcement Audiometry.

VRA	Groups	Mean	SD	Lower limit	Upper limit	p-value*
Right ear	G1	23.6	0.542	22.6	24.7	**<.001**
	G2	20.5	0.457	19.6	21.4	
	G3	20.2	0.446	19.3	21.1	
Left ear	G1	24.4	0.579	23.2	25.5	**<.001**
	G2	20.5	0.490	19.6	21.5	
	G3	20.2	0.477	19.2	21.1	

Caption: *ANOVA

As for the longitudinal analysis, among the infants who were evaluated in two phases, aged 9-13 and 13-18 months, there was the occurrence of 25% (n=5) infants with impaired development as to auditory skills. The results found for G4 are shown in Table 5.

Table 5. Infants in group G4 according to development of auditory skills

G4	Phase 1 (9-13 months)	Phase 2 (13-18 months)	FINAL
Normal	11 (55%)	15 (75%)	15 (75%)
Altered	9 (45%)	5 (25%)	5 (25%)
TOTAL	20 (100%)	20 (100%)	20(100%)

Discussion

Auditory skills develop gradually until the age of two. Observing their maturation is important due to the influence of these skills on language development and their impacts on social, emotional and educational aspects[18,19].

In the evaluation with non-verbal stimuli, the responses of infants were analyzed based on the ability to localize the sounds. We observed that in G3 there were 18.6% (n=11) lower indirect responses and 40.7% (n=24) upper indirect responses. We observed in this group the occurrence of responses that are not expected, since the normality criterion is direct responses. These results suggest a delay in the skill to localize the sound[12,18]. In this same group, there was also the occurrence of 1.7% (n=1) that did not respond to lower and upper sound, suggesting a delay in development.

In G2, in the stage of lower location, we observed 41.1% (n=23) infants with indirect responses. The normality criteria for this group is direct responses, suggesting impairment in sound location.

Regarding the statistical analysis in the evaluation with non-verbal stimulus, there was statistically relevant difference for the two stages of evaluation, in the upper location and in the lower location. In both stages, p-value was <.001 (Table 2); therefore, there was a difference in responses between the groups. Since, for this skill, changes in responses are expected over time, because the older the subject the more complex the responses to sound become, a decrease in indirect responses is common as these evolved to direct responses. However, as described above, some infants in this study showed inferior responses to those expected for the age group[17]. It is believed that these infants are still in the process of maturation and development of location, since hospitalization in ICU and presence of risk indicators may have caused a delay in their development[5,15,17].

Considering the responses to verbal stimuli (Table 3), the infants were evaluated as to the skill to locate sound with the reaction to voice test. We observed in G1 the occurrence of an infant who searched for the direction of the source but was unable to locate it and an infant who performed unilateral location of the source. Based on the responses found, we observed that the subjects detect sound, but still do not locate the sound source, a reaction that is expected for the age[17].

For the age group of G2 and G3, the pattern of responses to verbal stimuli is different from that expected for G1, which enables evaluating the recognition of verbal commands[12]. Since for the reaction to voice test G2 and G3 presented adequate responses in their entirety, the recognition of verbal commands constitutes a differential for these two groups.

Thus, G2 and G3 were evaluated as to the skill for auditory recognition of verbal stimuli. The results for recognition of commands show that in G3 there is an incidence of 30.5% (n=18) of infants with less responses than expected, since recognition of more than 3 simple commands is expected, which did not appear during the evaluation. As for the statistical analysis for this stage, we found a difference in results (p=<.001) between the groups. Due to the age group, more complex responses are expected to develop over time. Thus, it is believed that despite the results found, the recognition of at least one command indicates that the skill is maturing[17].

The recognition skill occurs when the signifier-signified association is established, enabling the subject to point to figures or body parts and to follow simple commands. This skill is very important for language development, as it will evolve to auditory comprehension, which will enable infants to answer questions and retell stories. Considering the importance of this development, parents were instructed during the assessments to foster their children's development using language as a resource, telling stories and naming body parts and objects.

Considering the auditory skills' developmental hierarchy, their evaluation in auditory monitoring becomes essential to understand in what stage the infant's auditory maturation is, as well as to hypothesize as to possible peripheral or central impairment, since each skill requires integral auditory system structures in order to consolidate.

The minimum level of response to sound in infant's can be determined through Visual Reinforcement Audiometry. Considering the responses obtained, we observed no VRA values that were inconsistent with the reference values in the literature[14] (Table 4). The mean responses ranged from 20.2 dB to 23.6 dB in the left ear and from 20.2 dB to 24.4 dB in the right ear. In both ears,

the statistical analysis determined a p-value <.001. We observed that G1 has a higher mean, compared with G2 and G3, suggesting greater variability of responses during the evaluations. Such variability may be related to the children's age, for which, according to the literature, responses of up to 60 dB are expected. Higher responses for infants aged 6-9 months are expected, as they are still in the initial process of maturation of auditory skills, needing the consolidation of the motor system to provide the responses. In addition, the presence of risk indicators makes the infant more susceptible to having a high response in the minimum level of hearing, as motor development and auditory function development may be compromised[20,21]. It should be noted that the infants in this study remained hospitalized in the ICU, a factor that can influence responses during the first months of life.

Regarding to the longitudinal analysis, infants who attended the evaluation at two different times composed G4. We analyzed the responses of these infants in relation to the behavioral assessment. Among the 20 infants who composed this group, it was found that 25% (n=5) showed responses suggestive of impaired development of auditory skills. It is expected that over time the infants' responses for auditory skills will evolve, gradually following a developmental hierarchy. However, what was expected was not observed in all infants in the longitudinal analysis, with responses inconsistent with the normality criterion[15,16,17,19]. The reduced number of subjects in this group reflects the difficulty in finding in the database infants evaluated between August 2017 and September 2018 who attended more than one evaluation.

Auditory monitoring is essential for early tracing of complications in auditory development and establishment of appropriate conducts for each case.

Conclusion

It was possible to analyze the auditory development in the first years of life of infants who passed the hearing screening, but who had in their neonatal history risk indicators for progressive and/or late onset hearing loss or impaired auditory processing.

Based on analysis of the results found in this research, we conclude that there was no occurrence of progressive and/or late onset hearing loss; however, the infants presented responses suggestive of impaired auditory skills.

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