



Use of Auditory Steady State Response in infants at low risk for hearing loss

Utilização do Potencial Auditivo de Estado Estável em lactentes com baixo risco para perda auditiva

Uso del potencial auditivo de estado estacionario en bebés con bajo riesgo de pérdida auditiva

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Abstract

Introduction: Based on the need for audiological diagnosis and intervention as soon as possible in the life of a child with hearing loss, it is necessary to elaborate of hearing evaluation protocols with high efficiency, which provide the greatest amount of information. **Aim:** To analyze a pediatric hearing health program regarding their adherence to hearing screening, failure rates, and diagnostic procedures. **Method:** This is a cross-sectional, descriptive, quantitative study, and consisted of three stages: Performed in three steps: 1st step: hearing screening of rooming-in neonates; 2nd stage: retest of failures; 3rd stage: audiological diagnosis of infants who failed in the previous stages using the Steady State Response (ASSR) together with the Brainstem Evoked Response Audiometry (BERA). **Results:** In 2019, 1,898 infants were submitted to the program, of whom 287 (15.2%) failed the screening in at least one of the ears. A total of 197 (10.3%) infants attended the retest and 14 (0.73%) failed the TOAE in at least one of the ears. Ten (0.52%) infants returned for diagnosis. The sample was homogeneously full-term children. One child showed unilateral HL. The average amount of time required to collect information in the

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Authors' contributions:

MLRGD: Study design, methodology, data collection, original writing.

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ASSR was 20 minutes. **Conclusion:** For diagnosis, ASSR can be an alternative to be used in the battery of examinations in pediatric hearing assessment along with the other procedures, using the cross-check principle and adding valuable information, especially regarding the low frequencies.

Keywords: Evoked potentials; Neonatal screening; Early diagnosis; Hearing loss

Resumo

Introdução: Com base na necessidade do diagnóstico audiológico e da intervenção precoce na vida de uma criança com perda auditiva, faz-se necessário a elaboração de protocolos de avaliação auditiva que forneçam o maior número de informações. **Objetivo:** Analisar um programa de saúde auditiva infantil com relação à adesão à triagem auditiva e procedimentos de diagnóstico. **Metodologia:** Pesquisa de caráter transversal com análise quantitativa. Realizado em três etapas: 1ª etapa: triagem auditiva de neonatos de alojamento conjunto; 2ª etapa: reteste das falhas; 3ª etapa: diagnóstico audiológico dos lactentes que falharam nas etapas anteriores com a utilização do Potencial Evocado Auditivo de Estado Estável (PEAEE) em conjunto com o Potencial Evocado Auditivo de Tronco Encefálico (PEATE). **Resultados:** Em 2019, 1.898 neonatos foram triados e destes, 287 (15,2%) falharam na primeira testagem em pelo menos uma orelha. Um total de 197 (10,3%) foram retestados e 14 (0,73%) falharam em pelo menos uma orelha. Dez (0,52%) neonatos retornaram para diagnóstico compondo uma amostra homogênea de neonatos nascidos a termo. Um neonato apresentou perda auditiva unilateral. O tempo necessário para coleta de dados no PEAEE foi de 20 minutos. **Conclusão:** O PEAEE pode ser considerado uma alternativa a ser utilizado na bateria de testes na avaliação audiológica infantil, juntamente com outros procedimentos, utilizando-se do princípio de verificação cruzada e adicionando uma informação valiosa, especialmente com relação às baixas frequências.

Palavras-chave: Potenciais evocados auditivos do tronco encefálico; Triagem neonatal; Diagnóstico precoce; Perda auditiva

Resumen

Introducción: En base a la necesidad de diagnóstico audiológico e intervención lo antes posibles en la vida de un niño con pérdida auditiva, es necesario elaborar protocolos de evaluación auditiva de alta eficiencia, que proporcionan la mayor cantidad de información. **Objetivo:** Analizar un programa de salud auditiva infantil en cuanto a la adherencia al tamizaje auditivo, tasa de fracaso y procedimientos diagnósticos. **Metodología:** Investigación transversal con análisis cuantitativo, Realizado en tres pasos: 1er paso: tamizaje auditivo de los neonatos en alojamiento conjunto; 2ª etapa: retest de fallas; 3ª etapa: diagnóstico audiológico de los lactantes que fracasaron en las etapas anteriores utilizando el Potencial Evocado Auditivo de Estado Estacionario junto con el Potencial Evocado Auditivo de Tallo Cerebral. **Resultados:** Em 2019, se cribaron 1,898 neonatos y de estos, 287 (15,2%) no pasaron la primera prueba en al menos un oído. Un total de 197 (10,3) fueron reevaluados y 14 (0,73%) fallaron en al menos un oído. Diez (0,52%) neonatos regresaron para diagnóstico, conformando una muestra homogénea de neonatos a término, con una edad gestacional media de 39 semanas y dos días. Un neonato tuvo pérdida auditiva unilateral. El tiempo de recogida de los resultados en el ASSR fue de 20 min. **Conclusión:** Para el diagnóstico, la ASSR puede considerarse una alternativa para ser utilizada en la batería de pruebas en la evaluación audiológica infantil, junto con otros procedimientos, utilizando el principio de verificación cruzada y agregando información valiosa, especialmente en lo que se refiere a las bajas frecuencia.

Palabras clave: Potenciales evocados auditivos del tronco encefálico; Tamizaje neonatal; Diagnóstico temprano; Pérdida auditiva

Introduction

Hearing is crucial for the acquisition and development of oral language and for social integration through speech. Neonatal hearing screening (NHS) programs are essential in this process, encompassing the screening and diagnostic stages; in the latter case, when hearing loss is detected, appropriate intervention strategies can be developed for each child. Objective procedures are necessary to diagnose hearing loss in the first months of life, such as the electroacoustic test with otoacoustic emissions (OAE) and the electrophysiological one named auditory brainstem response (ABR) ¹.

The Joint Committee on Infant Hearing (JCIH, 2019) currently suggests that the first option for investigating a child's hearing thresholds is to perform the ABR with specific frequencies or tone burst (FS-ABR), which provides the minimum hearing levels obtained electrophysiologically for a specific frequency. The recording is performed one frequency at a time, and in each ear separately. Interpretation of results depends on the evaluator's clinical skill and experience. Thus, the FS-ABR is difficult to apply because of the time it takes and its subjective analysis ^{2,3}.

Auditory steady-state response (ASSR) has been reported as a promising alternative in the search for results with specific frequencies. The main advantages of ASSR in relation to ABR are the opportunity to detect simultaneous and frequency-specific hearing thresholds in several of them (including the lowest ones), a shorter assessment time, and the option to test both ears with a range of frequencies simultaneously ^{3,4}.

Steady-state auditory responses are short-latency evoked potentials, just like the ABR and FS-ABR, and evaluate the same generating sites. However, instead of depending on amplitude and latency like ABR and FS-ABR, ASSR uses the amplitude and phase of the frequency domain, and the detection of responses, in this case, depends on the peak of the frequency spectrum. Potentials obtained in the steady state are generated from stimulation that is sufficiently rapid for the response to stimuli to overlap with the previous stimuli, generating a periodic, stable response ^{5,6}. The possibility of simultaneous multifrequency assessment, aiming to estimate sensitivity at different frequencies, associated with the analysis of response detection by the equipment, demonstrates the importance

of studies on ASSR, especially in infants under 6 months of age, given the impossibility of behavioral audiometry in this population.

Various studies in the literature correlate ASSR findings with other audiological examinations in different populations. The correlation between hearing thresholds found in other examinations and those found in ASSR is high ^{4,7,8}. Furthermore, different stimuli can be used, such as broadband (click) or frequency-specific stimuli (frequency-limited chirps, narrowband, tone burst). The use of chirp and newer detection algorithms allows for faster data collection, approximately half the collection time compared to other stimuli ⁹ that equipment may use.

Therefore, this research aimed to analyze a Child Hearing Health Program with healthy newborns, born in a public hospital, regarding their adherence to hearing screening, failure rate, and diagnostic procedures including ASSR.

Methodology

Descriptive, quantitative, cross-sectional study, conducted at the Hospital Prof. Dr. José Aristodemo Pinotti (CAISM) and Centro de Estudos e Pesquisas em Reabilitação Prof. Dr. Gabriel Porto (CEPRE), the latter belonging to Universidade Estadual de Campinas.

The research was approved by the Research Ethics Committee from Faculdade de Ciências Médicas da UNICAMP (FCM-UNICAMP), approval number 3106714 (CAAE 02183018.4.0000.5404). All infants' parents/guardians were informed about the study procedures and signed an informed consent form before participating in the study.

This research had 3 phases. In the first one, NHS was performed at the maternity hospital before discharge; if the newborn was discharged on a Sunday and/or holiday, their parent/guardian would receive an appointment to carry out the screening at CEPRE. The second phase consisted of retesting the cases of newborns who failed the first screening, and the third phase encompassed the diagnosis of hearing changes also at the CEPRE.

The inclusion criteria for this study were as follows: being born between January 1 and December 31, 2019, at CAISM, in good health conditions, who stayed in the maternity ward and underwent the transient-evoked otoacoustic emissions test (TEOAE) in the first month of life. Infants admitted

to the Intensive Care Unit and Intermediate Care and whose parents/guardians did not authorize participation in the research were excluded.

The NHS was performed as follows: 1) Survey of the mother's data (such as age, education level, and risk factors for hearing loss [RFHL]) and the newborn's data (such as sex, birth weight, gestational age, and test results). The following RFHL were considered in this study: Family history of hearing loss and consanguinity, congenital infections (rubella, syphilis, cytomegalovirus, herpes, toxoplasmosis, HIV), craniofacial anomalies, including those of the pinna and external auditory canal, hyperbilirubinemia, ototoxic drugs, 1-minute Apgar score of 0 to 4, 5-minute Apgar score of 0 to 6, syndromes, and maternal alcohol and/or psychotropic drug consumption during pregnancy^{1,10}.

The NHS was performed with TEOAE or automated ABR (A-ABR) if the newborn had any RFHL. The equipment for testing and retesting was OTOREAD (Interacoustics) or OTOPORT (Otodynamics); the pass-fail criterion used was the same for both devices. When a newborn failed the test on the first attempt, the auricular facilitation maneuver was performed, and the device was repositioned for a new attempt, with the same device. The equipment records two possible responses: Pass (PASS) or Fail (REFER); the same criteria were used on both devices. In the Pass criterion, the presence of TEOAEs is registered automatically; in the Failure criterion, TEOAEs are not present, which can be unilateral (only one ear) or bilateral (in both ears). The test was performed twice in case of failure.

The two devices were configured with the following parameters: click stimuli, the intensity at 83 dB SPL, sweep of 260, reproducibility > 50%, and probe stability > 80%. It was considered PASS when the signal/noise ratio was present at three frequency bands, according to the criteria: signal/noise ratio > 6 dB (at 1000 and 1500 Hz) and > 5 dB (at 2000, 3000, and 4000 Hz)¹⁰. The assessments were carried out in a quiet environment, with environmental noise levels controlled and kept under 45 dB SPL.

The screening equipment used for A-ABR was Accuscreen, manufactured by GN Resound. Click stimuli were presented at 35 dB HL, preferably before hospital discharge. The newborns were prepared for the test by cleaning their skin with alcohol and attaching three self-adhesive electrodes in the positions suggested by the equipment manual – i.e.,

on the vertex (active), the zygomatic bone (ground), and the C7 vertebra (reference). The probed test plug was chosen according to the size of the newborn's external auditory canal, then positioned in one of the ears, which was selected randomly according to the position in which the newborn was in the crib or parent's/guardian's lap in natural sleep. Next, the equipment was activated, and the electrode impedance test and stimulus calibration took place. The equipment can start the test with an impedance of up to 12 ohms, but it was preferably maintained at values lower than 6 ohms.

Cases that failed the test and retest were referred for audiological diagnosis, with the following procedures: Inspection of the external auditory canal with the Welch Allyn pocket otoscope model 22840, acoustic immittance measurements, and electroacoustic and electrophysiological hearing assessment. The same evaluator performed all procedures. Electroacoustic and electrophysiological assessments were carried out in natural sleep, in a room with acoustic and electrical insulation.

Tympanometry considered normal middle ear conditions, type-A curves characterized by peaks of maximum compliance between +100 and -100 daPa and volume greater than 0.3 ml¹¹. This measurement was carried out with the AT235, Interacoustics equipment, with a 1000 Hz probe.

In the OAE test, the infant was on the mother's/guardian's lap, who was accommodated in a comfortable reclining chair. OAE was investigated with transient stimuli, using the ILO V6 (Otodynamics) equipment with the Quickscreen method, and non-linear click stimuli close to 80 dB SPL. The stability of the stimulus was checked before collection began, considering values above 75%. The criterion to interrupt the examination was the collection of 260 responses. The signal-to-noise ratio was established at 6 or more dB in at least three frequency bands, one of which must be 4000 Hz.

The infant's skin was prepared with an abrasive paste for subsequent electrophysiological examinations. While in natural sleep, the electrodes were positioned on the infant's right and left mastoids (M2 and M1, respectively) as negative reference electrodes, the forehead (Fpz), as the ground electrode, and the vertex (Cz), as active (positive) electrodes, keeping the impedance < 5 kΩ. The acoustic stimuli were presented through ER-3B insert headphones, adapted to the external auditory canal with plugs.

ABR and ASSR were researched with the Intelligent Hearing System (IHS) equipment, Smart EP module, in an acoustically and electrically treated room. They used click stimuli with rarefied polarity, at a rate of 19.3/sec, totaling 1,024 stimuli. The integrity of the auditory pathway was analyzed with acoustic stimuli at 80 dBHL, evaluating one ear at a time.

The absolute latencies and absolute interpeak intervals of waves I, III, and V were analyzed, according to the normal values of the equipment for the age group, to study the ABR, verify the integrity of the central auditory pathways, and establish the electrophysiological threshold. To investigate the latter, the intensity was gradually reduced 20 dB at a time until wave V was no longer visualized. Then, it was increased by 10 dB until obtaining the lowest intensity at which wave V was present with reproducibility.

ASSR was detected automatically by comparing the signal amplitude with the noise amplitude at the presentation rate. Frequency peaks corresponding to the modulation frequency were considered valid when statistically higher than the noise level. The software used the F statistical test, which considered the response present when the signal-to-noise ratio was greater than or equal to (\geq) 6.13 dB at the corresponding frequency. Statistical analysis was performed every 20 scans, presenting a maximum of 400, without filter. The criterion to interrupt the exam recording was the presence or absence of a response with residual noise below 0.70 μ V (a parameter suggested by the equipment's technical manual). In case the noise did not reach this threshold within 400 scans, the examination was restarted. It used tonepipe stimuli, modulated at 100% in amplitude, with carrier frequencies of 500, 1000, 2000, and 4,000 Hz at the following modulation frequencies (respectively for the carrier frequencies): 79, 87, 95, 103 Hz (in the right ear) and 77, 85, 93, and 101 Hz (in the left ear). The stimuli were presented bilaterally.

The initial intensity used for the scan was always calculated as follows: the intensity found in the ABR threshold research plus 10 dB. In case no response was present at any frequency evaluated in the initial scan, the intensity was increased by 10 dB.

ASSR responses were analyzed with the equipment's software through a sophisticated and objective detection algorithm, based on the spectral

peak of the modulation frequency. The amplitude of this response must be statistically greater than the background noise. This analysis is provided through statistical testing (Fast-Fourier Transform). The minimum values per frequency were found by subtracting the correction value (provided by the equipment) from the result, concluding the research.

It should be noted that the research on minimum response levels used dB SPL, and the results were converted to dB HL, according to the equipment conversion table. The presence or absence of a response was given by the equipment.

The time needed to complete the ASSR was calculated with the computer's stopwatch. The computer timer always started at the beginning of ASSR, after placing the electrodes and headphones and preparing the patient, and stopped at the end or if the collection needed to be interrupted, thus recording the time required to obtain ASSR information.

The values described by Van Maanen (2009) were used to establish comparative normality criteria for ASSR since the stimuli and modulation were the same in the equipment used for this research. The author mentioned above researched normal values for children using the IHS equipment, with frequency-modulated tonepipe stimuli. The correlated values were 50 dB HL at 500 Hz, 45 dB HL at 1000 Hz, and 40 dB HL at 2000 Hz and 4000 Hz⁷. The equipment furnished the values without the correction factor.

The study evaluated the correlation between ABR and ASSR exams, the effectiveness of starting ASSR at 10 dB above the electrophysiological ABR threshold, and the time taken to collect the ASSR.

Results

In 2019, 1,898 infants underwent NHS in this program, of which 287 (15.2%) failed the screening in at least one of the ears.

Altogether, 197 (10.3%) infants attended the retest, with an adherence of 68.64% of cases. Of these, 14 (0.73%) maintained TEOAE failure in at least one ear. Ten (0.52%) infants returned for diagnosis, none of which had RFHL. Adherence to diagnosis was 71.42%.

Of the 10 children evaluated at the diagnosis stage, 30% (n = 3) were male and 70% (n = 7) were female. During the audiological evaluation, the

average age was 60 days, with a minimum age of 30 days and a maximum of 108 days. The sample had homogeneous gestational ages, and they were considered full-term newborns, with a gestational age of 39 weeks and 2 days and a maximum of 41 weeks.

In tympanometry¹¹, the 10 infants had type-A curves bilaterally. TEOAE results indicated bilateral presence of emissions in 60% (n = 6), unilateral presence in 30% (n = 30), and bilateral absence in 10% (n = 10%).

The auditory pathway integrity was researched in ABR at 80 dBHL. A single infant in one ear presented the absence of waves I, III, and V. The remaining infants presented all three waves at 80 dBHL. In researching the electrophysiological threshold, 30 dBHL was observed bilaterally in 60% of children and 40 dBHL in 20% of infants. A threshold of 30 dBHL in one ear and 40 dBHL in the other was obtained in one child (10%). A threshold of 40 dBHL was also obtained in the left ear and a lack of response at 80 dBHL in the right ear in one

child (10%). ABR results were analyzed along with TEOAE results, using the cross-check principle.

After performing ABR, thresholds were searched at specific frequencies with ASSR, initially at 10 dBHL above the worst electrophysiological threshold found in ABR. In 50% of cases, all responses at specific frequencies were found in the first scan. Hence, the recorded threshold was within the normal range in 50% of cases. In three infants, two 10-dB increments to the electrophysiological threshold were necessary to find specific frequency responses. In two infants, three increments were needed.

For the infant whose electrophysiological threshold could not be researched in the click-ABR unilaterally, the increments were counted considering the result obtained in the ear in which the threshold was researched.

The mean ASSR survey time was 20.7 minutes, with a minimum of 10 minutes and a maximum of 45 minutes. The complete descriptive table (Table 1) provides an overview of the results.

Table 1. Complete description of the battery of examinations and results in the diagnostic investigation phase (N = 10)

Case	Sex	Age	TEOAE		TIMP RE/LE	ABR		ASSR 500 Hz		ASSR 1000 Hz		ASSR 2000 Hz		ASSR 4000 Hz	
			RE	LE		RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
A	F	108d	A	P	A	0	1	0	1	0	1	0	1	0	1
B	F	53d	A	A	A	1	1	1	1	1	1	1	1	1	1
C	F	41d	P	P	A	1	1	1	1	1	1	1	1	1	1
D	M	61d	P	A	A	1	1	1	1	1	1	1	0	1	1
E	F	73d	P	P	A	1	1	1	1	1	1	1	1	1	1
F	M	34d	P	P	A	1	1	1	1	1	1	1	1	1	1
G	F	62d	P	P	A	1	1	1	1	1	1	0	1	0	1
H	F	30d	P	P	A	1	1	1	1	1	1	1	1	1	0
I	F	38d	P	A	A	1	1	1	1	1	1	1	1	1	1
J	F	46d	P	P	A	1	1	1	1	1	1	1	1	1	1

Caption: TEOAE- transient-evoked otoacoustic emissions; RE- right ear; LE- left ear; Timp- Tympanometry; A- type A tympanometry; ABR- auditory brainstem response; ASSR- auditory steady-state response; F- females; M- males; d- days; P- present; A- absent; 1- within normal limits; 0- not within normal limits

Discussion

In 2019, 1,898 infants were screened, of which 287 (15.2%) failed the screening in at least one ear. In the retest, the number of failures was reduced to 14 (0.73%). The literature¹² indicates that the newborn's hours of life at the time of screening is a factor in the high rate of NHS false-positives, due to the presence of vernix in the external auditory

canal – i.e., the fewer the newborn's hours of life, the greater the chance of presence of vernix¹³.

The Brazilian Committee on Hearing Loss in Children made considerations about the technique, stating that failure rates can vary from 5% to 20% when screening is carried out with OAE in the first 24 hours, falling to 3% when carried out between 24 and 48 hours after birth¹⁴.

A total of 197 (68.6%) infants attended the retest, with a 31.4% absence rate. The fact that



NHS is carried out partly in the maternity ward and partly at an outpatient center means that some families do not return for screening after 15 days of hospital discharge. According to the Multiprofessional Committee on Hearing Health (COMUSA, in Portuguese)¹⁴, NHS should be universal – i.e., it should be performed entirely in the maternity unit, covering at least 95% of live births. However, the program of this research has many difficulties performing NHS at the maternity hospital, as it does not have a speech-language-hearing pathologist on duty; there is only one professional hired by the hospital, and the testing time is restricted. Two resident professionals assist the hired speech-language-hearing pathologist, but a screening program performed entirely at the maternity requires professionals on all days of the week, including Sundays and holidays.

An integrative review conducted in 2014¹⁵ on articles referring to NHS aimed to understand and describe the national scenario of these services in Brazil and evaluate whether the programs meet quality indicators. Only nine services had screened 95% of newborns. Most NHS programs take place in public maternity hospitals. The rates describing the lack of return for retesting ranged from 5% to 50% in public hospitals and 9% to 34% in private/mixed hospitals. Unattendance for diagnosis was high, between 5% and 66% in public hospitals and 28% and 100% in private/mixed hospitals. These numbers draw attention, as the follow-up to the diagnosis had lower adherence when compared to the retest, perhaps because it was carried out outside the maternity ward. Cities in the inland Southeast region showed clearly higher attendance rates for diagnosis, and maternity hospitals in smaller cities seem to facilitate the organization of NHS programs. The authors of this review concluded that non-adherence to audiological diagnosis compromises the quality of the service and is one of its biggest challenges¹⁵.

Researchers¹⁶ reported the following reasons for families' non-adherence to all stages of an NHS Program: parents' low educational level and lack of financial support, confusion with the various appointments scheduled after hospital discharge, mothers with several children, and lack of knowledge about the child's behavioral reactions to sounds, the rights of hearing screening, and the consequences of hearing loss for the development of oral language. Other authors cited

difficulties with the scheduling system and the lack of transportation for families to the screening site as contributors to non-adherence¹⁷. Some authors¹⁸ also cite the high dropout rate in the various stages of the program. Hence, in the event of a child with hearing loss, there must be an adequate network of referrals including identification, diagnosis, intervention, support, and guidance to the families. In a study that examined the reasons for dropout, major difficulties included families' lack of interest in learning about their child's hearing loss, lack of knowledge about the importance of hearing, and conflicting schedules¹⁹.

Of the 14 who failed the retest, 10 (71.42%) returned for diagnosis. The construction of the sample for diagnosis was circumstantial, composed of infants born between January 1 and December 31, 2019, and who failed the TEOAE or A-ABR test.

On the day of the diagnostic assessment, all infants had type-A tympanometry. Based on Jerger's classification¹¹, the author states that this type of curve indicates no changes in the middle ear, which could compromise the results of otoacoustic emissions and evoked auditory potentials. Silva (2020) highlighted the importance of performing tympanometry beforehand, since any change in the middle ear can interfere with the energy transmitted through the external auditory canal, avoiding false positives and delays in diagnosis regardless of the patient's age²⁰.

The estimated time to perform ASSR in this study ranged from 10 to 45 minutes, with a mean of 20 minutes. A study²¹ found that the mean time to obtain the minimum electrophysiological thresholds per specific frequency with FS-ABR was 1 hour and 30 minutes. Another study²² used stimulation modulated by amplitude, frequency, and the combination of both and found a 45-minute collection time. With CE-chirps, the time reported in some studies is lower, ranging from 7²³ to 22 minutes²⁴. Hence, the time was lower than with FS-ABR²¹, whose maximum time was higher than that with CE-chirp^{23,24}, although the mean time was within the values found with CE-chirp^{23,24}.

The proposed procedure of starting the ASSR research 10 dBHL higher than the threshold obtained with click-BAEP took advantage of available data to optimize the collection time. Thus, it used click-ABR threshold data to decide the initial ASSR intensity – which was sufficient to obtain ASSR responses in 50% of the infants, while for



the others, at least another increase of 10 dBHL was necessary. Thus, the procedure is believed to reduce the examination time.

Click-ABR and ASSR correlation data were analyzed through descriptive analysis (with frequency data) and statistical analysis (with ANOVA). Student's t-test was used to correlate the click-ABR electrophysiological threshold with the intensity at which an ASSR response was obtained.

The equipment reported whether a response was present, removing the subjectivity of the examiner's analysis and the patient's response by evaluating the response amplitude, which is significantly greater than the noise amplitude evaluated at adjacent frequencies with the Fast Fourier Transformation performed by the equipment.

The need for a quick, convenient, and accurate examination to evaluate hearing thresholds at 500 to 4000 Hz has encouraged the use of ASSR in clinical practice, especially in children. Previous studies with ASSR have demonstrated high correlation coefficients between ASSR thresholds and pure-tone thresholds (greater than 0.8) and between ASSR and tone-burst ABR^{25,26}. Data in this study showed a correlation (0.68) between ABR and ASSR evoked with tonepipes. Linhares et al. (2009), using the same equipment (Smart-EP, HIS) and the same stimuli as our study, in children with sensorineural hearing loss aged 1 to 7 years, obtained correlation values between ASSR and ABR ranging from 0.83 to 0.89²⁷.

A study⁷ investigated the relationship between thresholds obtained with ASSR and ABR in the IHS equipment with a population of 98 children divided into two groups, one with and the other without hearing loss. The correlation, excluding the group without hearing loss, was high, being 0.88 for 500 Hz, 0.77 for 1000 Hz, 0.85 for 2000 Hz, and 0.89 for 4000 Hz. Approximately 40% of the data belonged to the group without hearing loss, in which thresholds were estimated and not actually measured. The values found by the authors are higher than those in the present study. However, in this research, 90% of the data comes from normal hearing infants.

The 500 Hz frequency has been identified as difficult to obtain thresholds, but it is extremely important as it provides valuable information regarding low frequencies in the diagnosis of ascending losses²⁸. Given the good correlation of thresholds obtained with ASSR, ABR, and visual

reinforcement audiometry, ASSR proves to be a reliable and fast alternative for acquiring thresholds at 500 Hz^{5,24}. The 500 Hz ASSR survey in the present study provided information that the other tests had not provided. No response was found in only one ear of one out of the 10 subjects. In the others, the thresholds were equal to or lower than 50 dBnHL – the normal standard suggested by Van Maanen is 50 dBnHL at 500 Hz⁷.

Despite the strong correlations between ABR and ASSR thresholds^{5,25,26}, ABR does not identify ascending hearing losses, with a pronounced slope, and lack of responses at specific frequencies. Therefore, if ABR is absent, the existence of useful residual hearing cannot be ruled out. In cases of hearing loss, ASSR threshold estimates, especially at low and medium frequencies, can be of invaluable assistance in deciding on appropriate early intervention, amplification, and cochlear implant services.

ASSR data directly depend on the stimuli and detection algorithm, although good results were observed with the equipment used. As reported in the literature, other devices and types of ASSR stimulation prove to be even more efficient, especially regarding time^{23,29,30}. One difficulty in the clinical use of ASSR in infants is how to deal with stimulus and/or algorithm updates. Such changes must be validated through data collection, which is time-consuming when dealing with babies. Hence, further research with ASSR in the battery of audiological exams in infants is necessary for standardization.

Conclusion

ASSR assessment was feasible for diagnostic procedures in full-term infants, enabling the identification of electrophysiological auditory responses at different frequencies. Furthermore, the initial sweep intensity used was 10 dBHL above the electrophysiological threshold already researched in ABR, which proved to be promising. However, larger samples are needed for its use in clinical practice.

ASSR can be an alternative in the battery of exams for pediatric audiological assessment, together with other procedures, using the cross-check principle. It adds valuable information, especially regarding at low frequencies.

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