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Auditory brainstem response: study of the air and bone conduction in infants with middle ear changes

Potencial evocado auditivo de tronco encefálico: estudo da via aérea e da via óssea em lactentes com alterações de orelha média

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ABSTRACT

Purpose: To compare the electrophysiological thresholds of the FS- ABR by air and bone conduction in infants with and without middle ear alterations, verifying the applicability of the air-bone gap in the differential diagnosis of the types of hearing loss and its relationship with the results of tympanometry and of the ABR click. **Methods:** The sample was composed of 73 infants: study group (52 ears) with conductive alteration, absence of emissions, otoscopy and altered tympanometric curve, and the control group (82 normal ears). Click ABR was performed at 80 dB nHL and threshold research (click, 500 and 2000 Hz) was recorded by air and bone conduction. Tympanometry was obtained with a 1000 Hz probe (children up to six months of age) and a 226 Hz probe (older than six months). **Results:** The control group had normal thresholds in air and bone conduction without gap. In both groups, air thresholds at 500 Hz were higher and in bone conduction thresholds at 500 Hz lower than at 2000 Hz. There was an association between gap, tympanometric curve and increased latency of wave I. **Conclusion:** The FS-ABR BC can be considered a viable in the clinical practice of a public health service, which does not always have sedation. The associations of altered tympanometry and prolonged latency of wave I with air bone gap reinforce the clinical importance of the combination of AC and BC ABR by specific frequency as a viable and effective alternative in the diagnosis of conductive hearing loss in infants.

Keywords: Brainstem auditory evoked potentials; Infant; Bone conduction; Auditory tests; Conductive hearing loss

RESUMO

Objetivo: Comparar os limiares eletrofisiológicos do potencial evocado auditivo de tronco encefálico por frequência específica (PEATE-FE) por via aérea (VA) e via óssea (VO), em lactentes com e sem alteração condutiva, verificando a aplicabilidade do *gap* aéreo-ósseo no diagnóstico diferencial dos tipos de perda auditiva e sua correlação com os resultados da timpanometria e do PEATE clique. **Método:** Amostra de 73 lactentes: grupo estudo (52 orelhas), com alteração condutiva, emissões ausentes, otoscopia e curva timpanométrica alteradas, e grupo controle (82 orelhas normais). O PEATE clique foi realizado a 80 dBNA e a pesquisa do limiar (clique, 500 e 2 000 Hz) foi registrada por condução aérea e óssea. A timpanometria foi obtida com sonda de 1000 Hz (crianças até 6 meses) e de 226 Hz (maiores de 6 meses). **Resultados:** O grupo estudo apresentou limiares por via aérea aumentados e via óssea normal com *gap* aéreo-ósseo. O grupo controle apresentou limiares normais na condução aérea e óssea sem *gap*. Em ambos os grupos, os limiares por via aérea em 500 Hz foram mais elevados e, na condução óssea, os limiares em 500 Hz inferiores aos de 2000 Hz. Houve associação entre *gap*, curva timpanométrica e aumento da latência da onda I. **Conclusão:** O PEATE-FE VO pode ser considerado viável na prática clínica de um serviço público de saúde, que nem sempre dispõe de sedação. As associações da timpanometria alterada e da latência prolongada da onda I com *gap* aéreo ósseo reforçam a importância clínica da combinação do PEATE VA e VO por frequência específica como uma alternativa viável e eficaz no diagnóstico das perdas auditivas condutivas em lactentes.

Palavras-chave: Potenciais evocados auditivos do tronco encefálico; Lactente; Condução óssea; Testes auditivos; Perda auditiva condutiva

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INTRODUCTION

In newborn hearing screening programs, little importance has been attributed to middle ear alterations, as they are transitory. However, changes resulting from conductive impairment may compromise speech perception and make understanding difficult, especially in a noisy environment, which impairs the child's language development.

Hearing fluctuation caused by conductive alterations in the first years of life may impair auditory processing, interfering with school learning[1]. In recent decades, studies have been dedicated to discuss the selection of the most appropriate procedures to assess newborns and infants[2,3].

Otoacoustic emissions and acoustic immittance measures are objective measures that contribute to obtaining important information to assess the conditions of the cochlea and middle ear, however, they do not detect the degree of hearing loss.

The brainstem auditory evoked potential (BAEP) is recommended[4] as gold standard to aid in the early diagnosis of hearing disorders in children, as it allows detecting the type and degree of hearing loss.

The study of BAEP by specific frequency (BAEP-SF) is recommended to determine the electrophysiological thresholds at the different frequencies, establishing the degree and configuration of the hearing loss to better adjust the process of hearing enablement[3].

In cases of middle ear alterations, BAEP performed with the click stimulus may not present delay in wave latencies which, associated with high electrophysiological thresholds, causes the misinterpretation of sensorineural hearing loss[2]. In these cases, obtaining the threshold through bone conduction (BC) is the most indicated procedure to perform the differential diagnosis of the hearing loss type[5], since, in middle ear alterations, bone-conducted BAEP will present wave V at normal intensities, characterizing the air-bone gap[2].

In the literature, there is still controversy about protocols for BAEP-SF through the bone, which makes it difficult to make a differential diagnosis between conductive and sensorineural loss[2] and to estimate the degree of loss and, consequently, the clinical applicability of this method. In Canadian protocols[6,7], the bone route is recommended when the thresholds are high through air conduction (AC), being performed in the frequencies of 500 Hz and 2000 Hz. The British protocol[8] recommends research in 1000 Hz and 4000 Hz.

Besides, bone-conducted BAEP is used due to interfering factors, such as the presence of artifacts[9], the need or not for masking, the use of one- or two-channel equipment to interpret the tracings, as well as on how the bone vibrator is fixed and positioned on the child.

However, there is a consensus that its use in the topodiagnosis of hearing loss in infants is essential[10,11].

The current study intended to contribute to obtaining a more accurate diagnosis of conductive hearing loss in infants, besides adding data on the importance and feasibility of using BAEP-SF through bone conduction in this population.

This study aims to compare the electrophysiological thresholds of BAEP-SF through air conduction and bone conduction in infants with and without middle ear alterations, and to check the applicability of the air-bone gap in the differential diagnosis of the types of hearing loss and its correlation with the results of tympanometry and BAEP click.

METHODS

A cross-sectional observational study was developed at “Universidade Federal de São Paulo” after approval by the Research Ethics Committee (process nr. 51497). Those responsible for the participants consented to the performance of this research and the dissemination of the results, by authorizing and signing the Informed Consent Form. The sample consisted of 73 infants aged 1 to 12 months, from neonatal hearing screening programs and the institution's audiological diagnosis clinic. All infants underwent neonatal hearing screening with less than 1 month of life, and those who failed the retest returned to the clinic, on average, at 3 months of age. Infants approved in the hearing screening were invited to participate in the study and appointments were made according to their parents' availability. The babies were divided into two groups, in a total of 134 ears assessed, considering that some of them woke up during the test and did not conclude the assessment. In the study group, the results obtained in 52 ears of children with a medical diagnosis of conductive impairment were included, characterized by altered otoscopy, tympanometric curve B or C[12], absence of transient-evoked otoacoustic emissions and click BAEP at 80 dBnHL, no central change. In the control group, 82 ears with the presence of otoacoustic emissions, type A tympanometric curve, normal otoscopy, normal click BAEP at 80 dBnHL and the presence of wave V at 30 dBnHL were included. Children with cochlear and retrocochlear alterations and/or the presence of syndromes and malformations were excluded.

Children were evaluated in natural sleep, in a room with electrical and acoustic isolation. For the recording of click BAEP and BAEP-SF, Smart EP equipment, with one channel, available at the institution, was used. Skin preparation was carried out with an abrasive paste. Conductive Adhesive Medi-Trace ECG electrodes were used, positioned in Fpz (active), M1/M2 – ipsilateral (reference) and contralateral (ground) mastoids to the stimulated ear, with impedances below 5 Ω and inter-electrode differences below 3 Ω.

To verify the neurophysiological integrity of the auditory pathway, BAEP with click stimulus at 80 dBnHL was used, and the recording of waves I, III and V with absolute latencies and values of the interpeak intervals I-III, III-V and IV was considered normal within the normal range for the chronological age. On the other hand, when the absolute latencies of waves I, III and V increased with values of interpeak latencies I-III, III-V and I-V within the normal range, the test was considered suggestive of conductive alteration.

In the click BAEP, a presentation rate of 27.7/s, rarefied polarity, a 25 ms analysis window and a 30 - 1 500 Hz band-pass filter were used.

The search for thresholds with click was obtained by decreasing the intensity progressively until finding the lowest intensity in which wave V could be observed, as recommended in the literature[13]. Thresholds were searched with tone burst at frequencies of 500 Hz and 2000 Hz, using ER 3A earphones for air conduction research and a bone vibrator B71 for bone conduction recording[14]. The vibrator was positioned in the temporal bone region in the auricular super-posterior position, close to the stimulated ear, and kept in that position without the use of an elastic band, with manual fixation performed by the examiner[15]. For bone conduction research, masking (white noise) of 60 dBNPS[16] was used, contralateral to the stimulated ear, because the equipment used has only one channel, making it impossible to compare the ipsi and contralateral recordings to confirm the side of the response in which wave V would present greater amplitude and lower latency in the channel ipsilateral to the stimulated cochlea[6].

Stimulus polarity was alternated with a stimulation rate of 39.1/s, window of 25.6 ms, blackman envelope, filter of 30 to 1500 Hz and 1000 to 3000 stimuli. The stimulus duration time at the 2000 Hz frequency was 4 ms and at the 500 Hz frequency, it was 8 ms, with two ascending cycles, 0 plateau and two descending cycles. Biological calibration was performed in ten young adults with audiometric thresholds equal to or lower than 20 dBnHL at 500 and 2000 Hz bone conduction, as recommended in the literature[6]. The reference value of 0 dBnHL was 36.2 dBpNPS for 500 Hz, and 28.2 dBpNPS for 2000 Hz.

To reduce electroacoustic interference in the examination, the child was placed on its mother's lap and evaluated after breastfeeding, during natural sleep.

Response detection was based on subjective analysis, with manual wave detection and reference standards: latency/intensity function, visual reproducibility, residual noise less than 0.08 μV and signal-to-noise ratio greater than 1.0[6].

In the study group, air stimuli were presented in a decreasing fashion, starting at 70 dBnHL. In the control group, both by air and by bone, the examination was started with standardized intensities as a criterion for normality, according to the literature[6]: for the area, 30 dBnHL at 2000 Hz and 35 dBnHL at 500 Hz and, for bone conduction, 30 dBnHL at 2000 Hz and 20 dBnHL at 500 Hz, in order to reduce the time of the examination. In the absence of response at 10 dBnHL (minimum investigated intensity), the intensity was increased by 5 dBnHL. The electrophysiological threshold with the lowest intensity was considered, in which wave V could be identified and reproduced, with no response at an intensity 5 dB below the identified threshold[2].

The examination time was calculated by the microcomputer clock, in absolute time, not considering the breaks to control the examination conditions and/or the infant's state.

To assess the mobility of the tympanic-ossicular joint, tympanometry was performed with the Impedance Audiometer AT235h-Interacoustics equipment, with a 1000 Hz probe (for children up to 6 months of age) and 226 Hz (for children older than 6 months). Tympanometric curves were recorded with pressure variation from +200 daPa to -200 daPa. Tympanometric curves were classified as: normal – type A (peak admittance between 0.3 and 1.65 ml and pressure between -100 and +100 daPa), with single peak or double peak – and altered – type B (flat curve no admittance peak) and type C (peak shifted to negative pressure beyond -100daPa)[12]. Children who were not recommended by an ear-nose-and-throat doctor (ENT) and who had an abnormal test were referred to an ENT to confirm the conductive change and treatment.

Data analysis was inferential using the following tests: Chi-square, Kruskal-Wallis, Z-Test, Mann-Whitney, Fisher's Exact Test and Spearman's Correlation Coefficient. The level of significance adopted was 5%.

RESULTS

The age range of the infants ranged from 1 to 12 months, with a mean age of 3.2 months, and mean time to perform the test of 131.7 minutes, with no difference between the medians of age and time of the test between the two groups. This means that the age variation in this study did not influence the examination time. The analysis of electrophysiological thresholds, as a result of sound frequency, showed that the threshold at the frequency of 500 Hz was greater than 2000 Hz by air and lower by bone, with a significant difference in both groups (Table 1).

Regarding the comparison between groups, air-conducted thresholds were higher in the study group, and at 500 Hz, this difference was greater. Bone thresholds were within normal limits in both groups, with a slight increase in the study group (Table 2).

In Figures 1 and 2, examples of the results of AC and BC recording thresholds obtained in infants from the control and study groups are presented.

An analysis of the presence of an air-bone gap between groups was performed. Therefore, the mean values of the gap at the frequencies of 500 Hz and 2000 Hz were considered. There was a gap only in the study group at 500 Hz and 2000 Hz

Table 1. Mean values of electrophysiological thresholds in dB nHL by air and bone at frequencies of 500 Hz and 2000 Hz in the study group and control group

Variable	N	Average	Median	Standard deviation	Minimum	Maximum	p-value
Control group							Z-Test
AC Threshold – 500 Hz	82	26.6	30	5.8	5	35	-
AC Threshold – 2000 Hz	82	21.5	20	7	5	35	
500 X 2000 difference (Hz)	82	5.2	5	7.4	-20	25	**<0.001***
BC Threshold - 500 Hz	82	16.3	20	5.1	5	25	
BC Threshold - 2000 Hz	82	21.3	20	7.1	5	30	
500 X 2000 difference (Hz)	82	-5	-5	6.5	-20	10	**<0.001***
Study group							Z-Test
AC Threshold - 500 Hz	52	46.6	47.5	13.1	20	75	-
AC Threshold - 2000 Hz	52	38.2	35	15.8	20	70	
500 -2000 difference (Hz)	52	8.5	10	13.1	-30	35	**<0.001***
BC Threshold - 500 Hz	52	18.5	20	4.1	10	30	
BC Threshold - 2000 Hz	52	23.8	25	6.5	10	30	
500 X 2000 difference (Hz)	52	-5.4	-5	6.5	-20	10	**<0.001***

Subtitle: N = number of ears; AC = air conduction; BC = bone conduction; *significant difference

Table 2. Comparison of mean values of electrophysiological thresholds at 500 Hz and 2000 Hz (dBnNA) by air and bone between groups

Variable	Group	N	Average	Median	Standard deviation	Minimum	Maximum	p-value Z-Test
Threshold at 500 Hz (AC)	**CG**	82	26.6	30.0	5.8	5	35	**<0.001***
	SG	52	46.6	47.5	13.1	20	75	CI (16.14;23.84)
Threshold at 2000 Hz (AC)	**CG**	82	21.5	20.0	7.0	5	35	**<0.001***
	SG	52	38.2	35.0	15.8	10	70	CI (12.07;21.35)
Threshold at 500 Hz (BC)	**CG**	82	16.3	20.0	5.1	5	25	**0.008***
	SG	52	18.5	20.0	4.1	10	30	CI (0.58;3.78)
Threshold at 2000 Hz (BC)	**CG**	82	21.3	20.0	7.1	5	25	**0.038***
	SG	52	23.8	25.0	6.5	10	30	CI (0.15;4.98)

Subtitle: N = number of ears; AC = air conduction; BC = bone conduction; CG = control group; SG = study group; CI = Confidence Interval; *significant difference

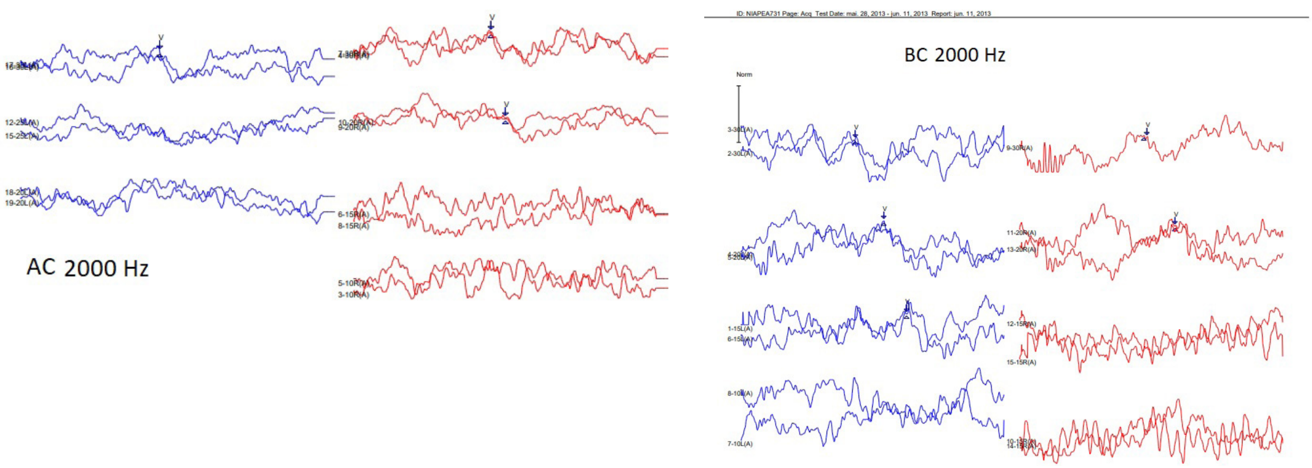

Figure 1. AC and BC BAEP recording at 2000 Hz in an infant with normal hearing
Subtitle: AC = air conduction; BC = bone conduction

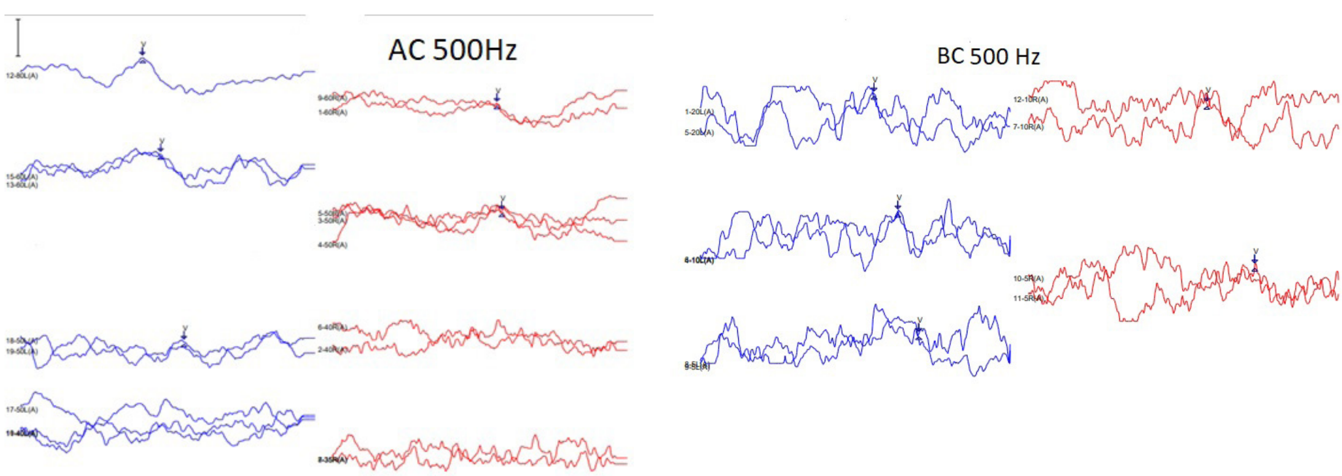

Figure 2. Recording of AC and BC BAEP at the frequency of 500 Hz in an infant with conductive alteration
Subtitle: AC = air conduction; BC = bone conduction

frequencies, with a significant difference when compared to the control, which did not present an air-bone gap (Table 3).

It is noteworthy that the presence of a negative air-bone gap, observed in some cases in the control group, occurred because the recording of electrophysiological thresholds via air was above the thresholds via bone, characterizing the absence of a gap.

In the general population studied (study group + control group), the relationship between the tympanometric curve and two variables was analyzed: air-bone gap and wave I latency (Table 4). There was a higher occurrence of type A curves in ears with a normal wave I latency (95.3%) and without air-bone gap (90.7% at 500 Hz and 72.6% at 2000 Hz), while in ears with type B tympanometric curve, there was a higher occurrence of air-bone gap and prolongation of wave I (85.4%). Type C curves were present in 14.5% of the ears with an increased wave I latency and only 4.7% of them with a normal wave I latency.

Table 3. Mean values of air-bone gap at 500 Hz and 2000 Hz per group and comparative analysis

Variable	Group	N	Average	Median	Standard deviation	Minimum	Maximum	p-value Z-Test
gap at 500 Hz	CG	82	10.4	10	6.1	-10	25	<0.001*
	SG	52	28.3	30	13.2	0	60	CI (14.02; 21.79)
gap at 2000 Hz	CG	82	0.2	0	8.3	-20	20	<0.001*
	SG	52	14.3	10	15.7	-10	50	CI (9.42; 18.8)

Subtitle: N = number of ears; CG = control group; SG = study group; CI = Confidence Interval; *significant difference

Table 4. Comparison of the types of tympanometric curve and presence of air-bone gap and wave I latency for the click stimulus at 80 dBnHL (n=134 ears)

	Tympanometric curve type				
Gap	A	B	C	Total	p-value Z-Test
With *gap* at 500 Hz	23 (33.3%)	37 (53.6%)	9 (13%)	69 (100%)	**<0.001**
Without *gap* at 500 Hz	59 (90.7%)	4 (6.1%)	2 (3.0%)	65 (100%)	
Total	82	41	11	134	
With *gap* at 2000 Hz	4 (14.8%)	19 (70.3%)	4 (14.8%)	27 (100%)	**< 0.001**
Without *gap* at 2000 Hz	78 (72.8%)	22 (20.5%)	7 (6.5%)	107 (100%)	
Total	82	41	11	134	

Table 5. Association between presence and absence of air-bone gap and wave I latency for the click stimulus at 80 dBnHL

	Latency wave I		Total
	Altered	Normal	
With *gap* 500 Hz (≥ 15)	43 (62.32%)	26 (37.68%)	69 (100%)
Without *gap* 500 Hz (< 15)	5 (7.69%)	60 (92.31%)	65 (100%)
Total P value < 0,001	48 (35.82%)	86 (64.18%)	134 (100%)
With *gap* 2000 Hz (>15)	21 (75%)	7 (25%)	28 (100%)
Without *gap* 2000 Hz (<15)	27 (25.48%)	79 (74.52%)	106 (100%)
Total P value < 0,001	48 (35.82%)	86 (64.17%)	134 (100%)

Z-Test

A significant association was observed between the air-bone gap and click BAEP wave I latency. Increased wave I latency was associated with the presence of a gap, and normal latency was associated with the absence of a gap (Table 5).

DISCUSSION

One of the important factors to be considered when evaluating infants is the time taken to perform the exam, especially when it is performed during natural sleep. In this study, the mean time for researching the electrophysiological threshold of click-BAEP and BAEP-SF (AC and BC), in both ears, was two hours and twelve minutes, and, in 68% of the sample, the evaluation was performed in a single session, regardless of the group. The duration of the exam was similar to a study in the literature[17], however, slightly higher than the average obtained in another study[18]. Probably, the longest duration of the exam occurred due to the absence of anesthesia, due to the recording of the absolute time, without considering the necessary pauses to guarantee the neonate's condition and the investigation of the electrophysiological threshold, instead of the minimum response level. Studies[19,20] that performed BAEP in a shorter time, in general, considered the minimum response level, that is, the last response without decreasing to visualize the absence of response, or were performed using anesthesia. Despite a long time, the complete assessment was carried out in all children and, in 68% of the sample, in a single session. These results allow considering the recording of BAEP-SF by air and bone as a viable procedure in the clinical practice of public health service, which does not always have sedation available. In clinical practice, an alternative to reducing the evaluation time is to consider the minimum response level instead of the electrophysiological threshold.

The study group had increased air conduction electrophysiological thresholds and normal bone conduction thresholds, with an air-bone gap. The control group showed normal electrophysiological thresholds in air and bone conduction without a gap.

In this study, the mean air-conducted thresholds obtained in infants with conductive impairment were 46.6 dB (500 Hz) and 38.2 dB (2000 Hz). This is similar to a study in the literature[21] which found mean thresholds of 48 dBnHL at 500 Hz and 42.2 dBnHL for 2000 Hz. It is noteworthy that the thresholds in children with conductive loss vary according to the degree of loss and the cause of middle ear alteration.

The elevation of air-conducted thresholds in conductive impairment was already expected, since 80% of the ears in the study group had a type B tympanometric curve with higher protein content (glue-ear)[22]. In 20% of the ears, the tympanometric curve obtained was type C, characterizing negative pressure in the middle ear, with retraction of the tympanic membrane and increased rigidity of the tympanic-ossicular system[12].

In the investigation of bone electrophysiological thresholds, the use of masking was necessary, as the equipment available at the institution did not have two channels. In two-channel equipment, the laterality of the origin of responses (which cochlea is responding) may be determined by observing the latency asymmetries and amplitude of the ipsilateral and contralateral wave V recordings. Recordings of ipsilateral responses may be confirmed by the presence of wave V, with greater amplitude and lower latency in infants, due to interaural attenuation of up to 25 dB in this age group[6]. This infers that BAEP-BC responses resulted from cochlear stimulation on the same side. Thresholds by bone conduction remained within the normal range in both groups evaluated. This data is relevant, as it indicates a diagnostic accuracy, identifying both the degree and the type of loss in infants who do not respond to conventional audiometry. With newborn hearing screening, a significant number of newborns and infants are referred for diagnosis, and the results of this study confirm the effectiveness of using these procedures in this population.

In the control group, the mean thresholds obtained by air at 500 Hz (26.6 dBnHL) and 2000 Hz (21.5 dBnHL) were similar to those obtained in studies in the literature[21,23] and slightly higher than those reached in another study[18]. At 2000 Hz, the thresholds were better than those obtained in Brazilian studies[20,24] carried out with the same equipment. These differences are due to the fact that the studies establish the minimum response level, concluding the exam when reached 30 dBnHL. In this study, there was a precise investigation of the electrophysiological threshold, with a decrease until the absence of response. On the other hand, an international study[21] found even better air conduction electrophysiological thresholds, probably due to the use of sedation that reduces unwanted artifacts and noise.

In both groups, air-conducted thresholds at 500 Hz were higher compared to 2000 Hz. The reason for this finding is the absence of sedation, which impairs threshold capture, especially at the 500 Hz frequency, which is more affected by the presence of noise.

In infants with conductive impairment, the frequency of 500 Hz was the most affected, both in this study and in the literature[21]. Probably, this fact also occurred because of the stiffness alterations suffered in the middle ear[1,22]. Effectively, higher electrophysiological thresholds at 500 Hz by air in children with and without conductive alterations have already been found in the literature[2,20,21,24]. This result can also be explained by the difficulty in obtaining and visualizing wave V at 500 Hz, at low intensities, since low frequencies are more contaminated by noise and need a longer time to reach the apex of the cochlea and produce responses[25]. Thus, the latency of wave V is longer and its peak is wider, which makes it difficult to mark it. One way to improve the signal/noise ratio and enable the recording of electrophysiological thresholds at weaker intensities is to increase the number of stimuli per scan to 3000[2]. In this study, even using 3000 stimuli, thresholds at 500 Hz were higher in both groups. This fact was expected, since correction values suggested by the Canadian protocol in 2012 consider decreases of 15 dB at 500 Hz, 10 dB at 1000 Hz, 5 dB at 2000 and 0 at 4000 Hz. Therefore, the estimated thresholds for the control group are between 10 and 15 dBeNA (estimated tonal thresholds), characterizing normality. In the study group, after correction, the values remained altered around 30 dB at 500 Hz and 25 dB at 2000 Hz, confirming the ascending hearing loss.

The mean bone electrophysiological thresholds were within normal limits in both groups, with better thresholds at 500 Hz compared to the 2000 Hz frequency. This difference may be related to the response of each frequency by the bone vibrator in the skull and its transmission characteristics[26]. Thus, it is suggested that the response of cochlear activity at a frequency of 500 Hz is better than at a frequency of 2000 Hz.

At 500 Hz, the mean bone conduction threshold was 16.3 dBnHL in the control group and 18.5 dBnHL in the study group, similar to those obtained in the literature[21,27]. With the correction of –5 dB(6), the estimated bone conduction thresholds would be between 10 dB in the control group and 15 dB in the study group, which indicates normality in both groups.

For the 2000 Hz frequency, the mean bone conduction threshold was 21.3 dBnHL in the control group and 23.8 dBnHL in the study group, close to that found in the literature[2]. Similar studies[21,27] presented lower threshold values, around 15 dBnHL. This difference is legitimated by the type of equipment used in the literature, which is programmed to facilitate the capture of responses by an algorithm in which it is possible to capture responses[27], even with children agitated and in movement, and by attaching the vibrator with an elastic band, factors that contribute to the identification of better thresholds[21].

In this study, the outstanding factor was the identification of the presence of an air-bone gap, which facilitates the diagnosis of the type of hearing loss. In the group of children with conductive loss, air-bone gap was present at frequencies 500 and 2000 Hz, with a significant difference compared to the control group (Table 3). In the consulted literature, there was only one work[21] containing the analysis of the air-bone gap between children with normal hearing and conductive hearing loss, in which there was no gap at 500 Hz and 2000 Hz in children with normal hearing, with differences of 15 dB and 5 dB. These data are similar to those obtained in this study (differences of 10.4 and 0.2). On the other hand, in children with conductive loss, there was a gap (37 dB at 500 Hz and 26 dB at 2000 Hz), slightly higher than that obtained in this study (28.3 dB at 500 Hz and 14.3 dB at 2000 Hz). In that same study[21], negative gaps were also found, as were in this study, which is justified by the presence of thresholds through the air, which is better than through the bone, especially in the control group, characterizing the absence of a gap.

It is important to emphasize that the largest occurrence of gaps was obtained at frequency 500 Hz, as well as the largest gaps. Thus, in order to optimize the examination time in neonates, the frequency of 500 Hz should be chosen for researching bone pathway. In fact, in clinical practice, the ascending configuration of conductive losses, due to increased stiffness, provides a greater gap at low frequencies.

In this study, the investigation of tympanometric curves, using a 1000 Hz probe in infants aged less than 6 months, identified the presence of conductive alteration, as there was an association between the altered curve and the presence of air-bone gap (Table 4). In fact, studies[28,29] have shown that infants younger than 6 or 9 months without response to emissions may have a normal tympanogram, with a 226 Hz test tone, even when there is conductive change, characterizing low sensitivity in the identification of mild middle ear problems. While this study was underway, the recommendation to use the 1000 Hz probe was for infants younger than 6 months. The most recent literature recommends the 1000 Hz probe in children up to 9 months of age, an age group that presents a greater correlation with the ear-nose-and-throat evaluation and with the result of otoacoustic emissions and greater sensitivity to identify middle ear alterations[4,28,29].

In light of the argumentation above, the study considers the findings in the literature, since, in the group of infants with no gap, 90.7% and 72.6%, respectively for the frequencies of 500 and 2000 Hz, presented a type A tympanometric curve. Besides, there was a predominance of type A curves (95.3%) in ears with a normal wave I latency, and a greater occurrence of type B curve (85.4%) in ears with a prolonged wave I latency, with evidence of association between the type of curve and wave I latency (Table 4).

Thus, the presence of air-bone gap in the BAEP at frequencies of 500 and 2000 Hz may be considered a strong indication of conductive impairment. Furthermore, the significant association between the presence of air-bone gap and the increase in wave I latency, observed in this study (Table 5), was also reported in the literature[23].

However, in this study, among the 86 ears with a normal wave I latency, four (4.6%) presented conductive alteration, that is, wave I latency was not enough to identify 100% of the conductive losses (Table 5). In fact, some studies report that wave I may not be a good predictor for identifying conductive losses[2,30], as well as revealing the gap size[21]. On the other hand, some infants with conductive loss had an increase in wave I latency without the presence of a gap, in one of the studied frequencies (500 or 2000 Hz), as the child could present an absence of gap at 2000 Hz with a gap at 500 Hz (Table 5). Furthermore, the increased latency of wave I in some infants may be associated with conductive impairment resulting from the C curve, which is not always accompanied by the presence of an air-bone gap.

The associations of altered tympanometry and prolonged latency of wave I, with the presence of air-bone gap in the BAEP, reinforce the clinical importance of using the combination of AC and BC BAEP by specific frequency as a viable and effective alternative in the diagnosis of hearing loss conductive in infants.

CONCLUSION

The results of this study allow us to consider the registration of BAEP-SF via bone a viable procedure in the clinical practice of a public health service, which does not always have sedation availability.

The associations of altered tympanometry and prolonged latency of wave I, with the presence of air-bone gap in BAEP, reinforce the clinical importance of using the combination of AC and BC BAEP by specific frequency as a viable and effective alternative in the diagnosis of losses conductive hearing aids in infants.

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