

## Original articles

# Visual Reinforcement Audiometry and Steady-State Auditory Evoked Potential in infants with and without conductive impairment

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## ABSTRACT

**Purpose:** to compare the findings of minimum levels of answers through air and bone conductions between the Visual Reinforcement Audiometry and the Steady-State Auditory Evoked Potential in infants from six to twelve months, with and without conductive disorder.

**Methods:** sixty children aged six to twelve months were evaluated, 30 presenting conductive disorder, and 30 not presenting it. Children with malformation in the external auditory meatus with neurological alteration and / or genetic syndrome were excluded, as well as patients with sensorineural or mixed hearing loss. The infants were subjected to Visual Reinforcement Audiometry and Steady-State Auditory Evoked Potential evaluation through air and bone conduction on the same day. The results of both assessments were compared and correlated.

**Results:** in the comparison through air conduction, for the group without conductive disorder of the medium ear, the minimum levels of response for 500 and 1000Hz were lower (better thresholds) for Steady-State Auditory Evoked Potential in both ears, and through bone conduction were very similar in all frequencies. Concerning the infants that present conductive disorder, the responses through air conduction were better in all frequencies evaluated when obtained via Steady-State Auditory Evoked Potential test. Through bone conduction, the results were very similar for both groups.

**Conclusion:** it was possible to compare the findings to the minimum levels of response through air and bone conductions between the Visual Reinforcement Audiometry and the Steady-State Auditory Evoked Potential, being that the comparison for bone conduction in both groups presents an equivalence in the results, being very similar. In addition, for the air conduction, in the control group, there was proximity of responses of some frequencies, while the values for the Steady-State Auditory Evoked Potential test were better than the behavioral responses in the conductive disorder group.

**Keywords:** Evoked Potentials, Auditory; Auditory Perception; Early Diagnosis; Middle Ear; Hearing

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## INTRODUCTION

During the last years the advances in the audiological diagnosis of children have allowed the early identification of the auditory alterations of young children and of difficult behavioral testing. In these evaluations it is necessary to verify if there is auditory alteration, the type of alteration and the degree of the same, being indispensable to differentiate conductive hearing losses of sensorineural and to determine the thresholds by air and bone pathways.

Conductive hearing loss is common in infants, otitis media being one of the most common of the childhood diseases, which consists of infection of the middle ear caused by infection, depression of the immune state, dysfunctions in the auditory tube, allergies and environmental problems<sup>1</sup>. Acoustic immittance measurements are fundamental in the identification of these alterations, however they do not quantify the degree of hearing loss<sup>2</sup>. Thus, the audiological evaluation with behavioral, electrophysiological and electroacoustic methods added to the otorhinolaryngological evaluation must be precise in the identification of such pathology, in order to avoid damages in the linguistic and auditory development of the child.

Visual Reinforcement Audiometry (VRA)<sup>3</sup> is one of the main behavioral techniques for evaluating auditory sensitivity in young children. This procedure has as principle the conditioning of the child with sound stimulus associated to a light signal, and at the moment the child searches for the sound source, the examiner offers a visual stimulus as reinforcement<sup>4</sup>. When performed by air pathway (with earphones) and by bone pathway (with vibrator), this method assists in the identification of conductive alterations (in the presence of air - bone gap), however its performance, both by air and by bone is only reliable after six months of life<sup>5</sup>, requiring the principle of cross-check with other methods of evaluation such as Auditory Evoked Potentials (AEP) by specific frequency to complete the audiological diagnosis.

Electrophysiological methods are fundamental as complementary measures being the main choice in obtaining auditory thresholds in children less than six months of age. Stable State Auditory Evoked Potential (ASSR) has been described as a promising technique in obtaining auditory electrophysiological thresholds, providing greater ease and efficiency to obtain answers, objectivity in the analysis of the records, with frequency specificity, and greater possibility of detection of auditory responses than other methods, such as pure

tone audiometry<sup>6</sup>. Some authors<sup>7</sup> describe a correlation between the minimum levels of responses obtained in the ASSR with behavioral thresholds, benefiting young children who do not cooperate in the behavioral assessment.

The ASSR can be searched by air and bone pathways, and it is possible to determine the presence and magnitude of conductive impairment by means of the difference between the minimum levels of air-bone response, which makes it a useful tool in the assessment of conductive impairment, one of the main pathologies in infants<sup>5</sup>.

The ASSR becomes an important instrument of audiological investigation because it is one of the main evaluation techniques in the identification of hearing loss, being conductive, mixed or sensorineural, of children under six months of age. Comparison of the minimum levels of air pathway and bone pathway responses with behavioral assessment also in children older than six months with and without conductive impairment, whose behavioral evaluation is feasible, is necessary in order to obtain parameters for comparison of both evaluations.

Thus, the ASSR can be used reliably in the audiological diagnosis of young children who do not cooperate in the behavioral evaluation, facilitating the identification and quantification of auditory alterations, as in the case of otitis media.

Based on the above, the objective of this study was to compare the findings for the minimum levels of air and bone pathways response between Visual Enhancement Audiometry and ASSR in children aged six to 12 months, with and without conductive impairment.

## METHODS

This study was approved by the Research Ethics Committee of the Universidade Federal de São Paulo - UNIFESP, Research protocol number 1191/10. All the parents of the children involved allowed the participation of their children in the research and results divulgation by means of signature of a free and informed consent term.

Sixty children from the Children's Audiology outpatient clinic of the research institution, of both genders, aged between 6 and 12 months, with and without middle ear alteration, were part of the sample. The groups were distributed as follows: Control group (CG): 30 children with no middle ear alteration; Study group (SG): 30 children with middle ear alteration.

Initially, the children underwent otorhinolaryngological evaluation, acoustic immittance measurements (tympanometry) and transient stimulus evoked otoacoustic emissions (TEOAE).

Otoscopy was performed by an experienced otolaryngologist and was classified as normal (no change) or altered (retracted, hyperemic, opaque, perforated, bulging).

The tympanometry was performed using the Mean Ear Analyzer Impedance Audiometer- AT235h-Interacoustics, with a test tone of 226Hz. The tympanometric curves were classified according to Jerger (1970)<sup>8</sup> and Carvallo (1992)<sup>9</sup> in: Curve Type A - single admittance peak between -150 and + 100 daPa and volume of 0.2 to 1.8 ml; Curve type D- double peak curve; Asymmetric curve - peak at high positive pressure; Curve Type C-peak admittance shifted to negative pressure; Inverted curve (I) - with inverted configuration in relation to the normal curve; Curve type B-flat curve without admittance peak.

The TEOAEs were searched using the ILO 96-Otoacoustic Emission Analyzer, using the "Quickscreen" program. TEOAEs were considered to be present when the signal to noise ratio per frequency band was  $\geq 3$  dB for 1500Hz and  $\geq 6$  dB for 2000Hz, 3000Hz and 4000Hz with general reproducibility  $\geq 50\%$  and probe stability  $\geq 70\%$ .

Only children whose otorhinolaryngological evaluation was compatible with tympanometry were included in the study. That is, when there was normal tympanometry (tympanometric curve type A) and normality according to the evaluation of the ORL or alteration of the middle ear (type B tympanometric curve) and alteration according to the evaluation of the ORL.

Also, for the inclusion of children in the group with conductive impairment, they should have type B tympanometric curve and altered Otorhinolaryngological evaluation, and for inclusion of children in the group without conductive impairment, they should have type A tympanometric curve and normal Otorhinolaryngological evaluation. Bilateral conductive hearing loss was considered as moderate to moderate. For the children in the control group, TEOAEs should be present, that is, the response that the child passed should be observed in the equipment.

Children with malformation in the external auditory meatus, with neurological alteration and / or genetic syndrome, as well as those with sensorineural or mixed hearing loss were excluded. The exclusion of children with sensorineural or mixed hearing loss was

made through the analysis of the medical record, which included information from other audiological assessments performed with the child, such as the Auditory Evoked Potential of Brainstem by specific frequency (BAEP-FE). In addition, bone values greater than 30 dBNA in VRA and ASSR were also considered suspected of cochlear alteration, with children being excluded from the study.

In addition to the otorhinolaryngological evaluation procedures, acoustic immittance measures and TEOAE, all children were submitted to the investigation of the electrophysiological thresholds by air and bone pathways through the ASSR and the minimum levels of responses by air and bone pathways via VRA. The order of the procedures was random, according to the behavioral state of the child, whether in sleep or alert.

The ASSR was searched through the Intelligent Hearing System's Smart EP equipment by air (with EAR Tone 3A insertion earphones) and by bone route (bone vibrator model B71). Such procedure was performed with the child in natural sleep in the lap of the parents or guardians. The electrodes were fixed at positions M1, Fz and M2: (-) ear tested, (+) forehead, and (ear) ear not tested. The impedance of the electrodes remained below 3 kHz. To test the bone pathway, the researcher held the bone vibrator in the mastoid holding it pressed. This method was recommended by Small and Stapells (2007) and it was the most stable method to keep the vibrator in the same position throughout the evaluation.

The carrier frequencies evaluated were 500, 1000, 2000 and 4000Hz, and the modulator frequencies were 77, 85, 93 and 101 Hz for the left ear and 79, 87, 95, 103 Hz for the right ear. The type of modulation used was modulated by amplitude (AM) at 100%. A 100,000-fold amplification was used with 30Hz high pass filters and 300Hz low pass filters. The presentation of the stimuli was ipsilateral, with 400 stimuli for each intensity, being presented in descending mode, with an initial intensity of 60 dB NPS by air and 50 dB NPS for a bone path with a variation of 10 dB NPS, in order to detect the minimum level of electrophysiological response. The responses were considered as present when the signal-to-noise ratio was greater or equal to 6.13dB for each frequency and in each intensity investigated, p-value being considered statistically significant when  $p \leq 0.05$ . Signal-to-noise ratios below 6.13 dB did not show present responses because the noise interfered in the responses.

In these cases, the children were retested and in the cases where the noise remained, they were excluded.

The noise level was controlled throughout the evaluation, considering below  $0.06\mu\text{V}$  for the responses considered present.

By air the responses of the ASSR were searched in both ears simultaneously and by bone route was captured only of the left ear (choice of side was random). It is important to note that the minimum response levels were performed in dBNPS, and the results were converted to dBNA, according to the equipment conversion table. The conversion table was performed biologically, using tests of adult individuals. NPS to NA by air: from 26dB to 500Hz, 11dB to 1000Hz, 13dB to 2000Hz and 19dB to 4000Hz. The bone conversion values were: 65dB for 500Hz, 45dB for 1000Hz, 35dB for 2000Hz and 40dB for 4000Hz. The mean time for performing the simultaneous and one-way bone pathway was one and a half hours.

Visual enhancement audiometry by air was performed only in the left ear (with supra-aural earphones model TDH39) and bone pathway (vibrator in the left mastoid model B71). The choice of the side evaluated for VRA was random, in order to avoid fatigue and compromise of responses. The children were placed in the lap of the parents or guardians, remaining in a state of alert during the evaluation. Pure tones were modulated in frequency (warble), in 500, 1000, 2000 and 4000Hz. The assessment was performed with the visual reinforcement positioned at approximately  $90^\circ$  azimuth, to the child's left, at a distance of approximately 50 cm.

The stimuli were presented in descending order of intensity and using the stimulus-response-visual reinforcement conditioning. The procedure was performed only in one ear, to avoid the fatigue of the children and reliability of the answers. It was considered as a response to the lowest intensity in which the child, after the conditioning period, turned his head towards the sound stimulus, presenting as a reinforcement a visual stimulus of a luminous clown. The bone marrow parameters were the same as those used by air.

The masking was not used considering the time of evaluation of the children, becoming the result of tympanometry the confirmation of the existence of conductive factor in both ears.

The minimum levels of ASSR and VRA responses by air and bone pathways were compared to each other in each group using the Mann-Whitney U-Test and confidence interval for the mean. In addition, the Spearman correlation test was performed. In all statistical tests, the null hypothesis was rejected when the confidence interval was equal to or less than 5%, being significant  $p \leq 0.05$ .

## RESULTS

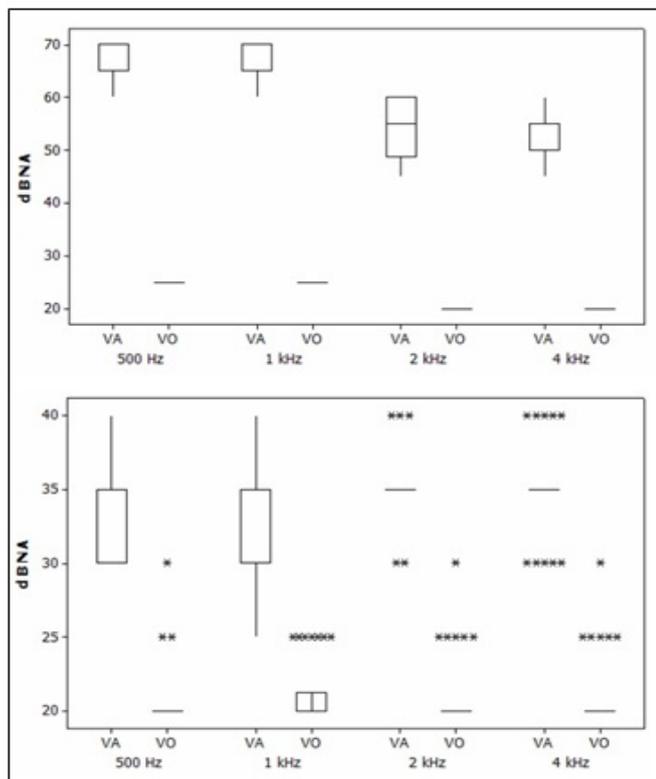
Sixty children of both genders participated in the study, 30 of the control group and 30 of the study group. The groups presented a similar distribution in relation to gender and age, with no statistically significant differences (Table 1).

**Table 1.** Characterization of the studied sample

Variables	Group				Value of $p^*$
	Control (n=30)		Study (n=30)		
	n	%	N	%	
Gender					
Females	16	53.3	14	46.7	0.606
Males	14	46.7	16	53.3	
Age average	9.3		9.2		0.674
Standard deviation	$\pm 1.8$		$\pm 1.5$		

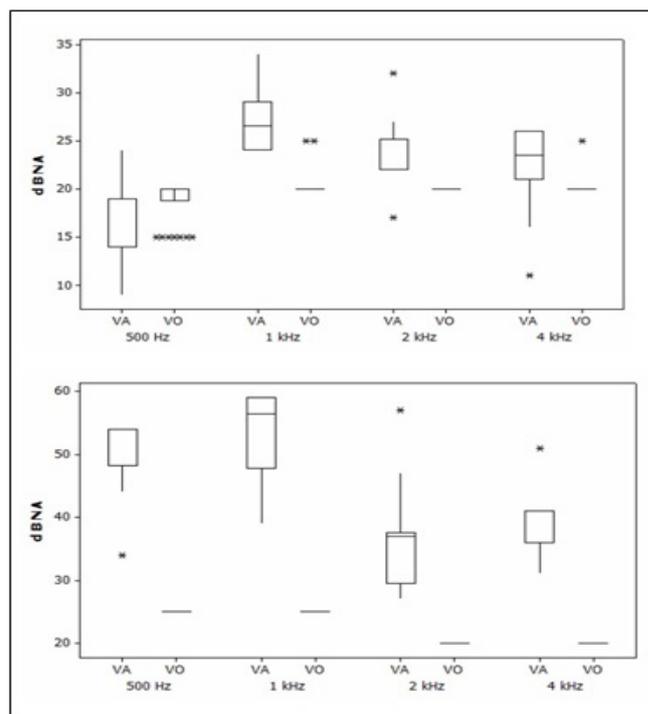
Caption: \*: Chi-square test: significant p-value  $< 0.05$  (5%); mean age: mean age of subjects in months

Figure 1 shows the minimum levels of air and bone pathways ASSR responses in both groups and Figure 2 shows the minimum levels of air and bone pathways responses in both groups.



Subtitle: VA = AP = (Air Pathway); VO = BP (Bone Pathway)

**Figure 1.** Minimum levels of airway / bone visual auditory audiometry responses in the control and study groups, respectively



Subtitle: VA = AP = (Air Pathway); VO = BP (Bone Pathway)

**Figure 2.** Minimum levels of airway / bone steady state auditory evoked potential responses in the control and study groups, respectively

Table 2 shows the comparison between the AP values for the left ear VRA and the ARPA of the left ear in both groups. The p-value refers to the comparison between the value of the left ear ASSR and the VRA.

**Table 2.** Comparison between the results of the minimum response levels of visual reinforcement audiometry and airway steady state auditory evoked potential in both groups

		VRA AP LE				ASSR AP LE (dBNA)			
		Mean	Median	ST	p-value	Mean	Median	ST	p-value
Study Group n= (30)	500 Hz	66.5	65	3.3	- x -	51.1	54	5.2	<0.001
	1 kHz	66	65	3.1	- x -	53	57	7.5	<0.001
	2 kHz	53.2	55	5.9	- x -	35.5	37	8	<0.001
	4 kHz	53	55	4.1	- x -	38.7	41	4.1	<0.001
Control Group n= (30)	500 Hz	33.3	35	3.3	- x -	16.2	14	3.1	<0.001
	1 kHz	32.5	35	3.9	- x -	26.5	24	2.9	<0.001
	2 kHz	35.2	35	2.1	- x -	23.3	22	2.9	- x -
	4 kHz	35	35	2.9	- x -	24	26	3.9	- x -

Subtitles – VRA: Visual Reinforcement Audiometry; AP – Air Pathway; ASSR –Stable State Auditory Evoked Potential ; ST- Standard deviation; LE – Left ear; dBNA- decibel level of hearing; - x –statistical analysis not performed; significant p-value < 0.05 (5%) Test *U de Mann- Whitney* and confidence interval for the mean.

In Table 3, the results of the VRA and the AEPS by bone route are described in both groups. The values of BP in the study group were not compared between

VRA and ASSR, since there were equal between them, and it was not possible to analyze statistically.

**Table 3.** Results of minimum bone-level response levels of visual reinforcement audiometry and steady state auditory evoked potential of both groups

		Study Group (n=30)			Control Group (n=30)		
		Mean	Median	Standard Deviation	Mean	Median	Standard Deviation
ARVVO LE	500 Hz	25	25	0	20.7	20	2.2
	1 kHz	25	25	0	21.2	20	2.2
	2 kHz	20	20	0	21.2	20	2.5
	4 kHz	20	20	0	21.2	20	2.5
ASSR BP dBNA – LE	500 Hz	25	25	0	18.8	10	2.2
	1 kHz	25	25	0	20	20	0
	2 kHz	20	20	0	20	20	0
	4 kHz	20	20	0	20.2	20	0.9

Subtitles – VRA: Visual Reinforcement Audiometry; BP – Bone Pathway; LE: Left Ear; ASSR –Stable State Auditory Evoked Potential; dBNA- decibel level of hearing. NOTE: VO values were not statistically compared between VRA and ASSR, since there is equivalence between them, and it is not possible to analyze statistically.

Table 4 describes the correlation between the minimum levels of responses obtained in the VRA with the ASSR by air in both groups. A correlation was observed between the minimum response levels of the ASSR and VRA in the study group. It is noteworthy that the correlation test was performed only by air, and in

some frequencies by bone in the control group, due to the distribution of the values, i.e., the minimum levels of bone pathway responses were similar for VRA and ASSR in the study group, preventing statistical analysis.

**Table 4.** Correlation of the minimum levels of responses obtained between the steady-state auditory evoked potential and the air/bone-assisted visual audiometry in both groups

ASSR vs. VRA		PA		BP	
		Corr	p-value	Corr	p-value
Control Group	500 Hz	0.6%	0.964	18.4%	0.331
	1 kHz	24.3%	0.062	-14.7%	0.437
	2 kHz	12.0%	0.359	- x -	- x -
	4 kHz	4.0%	0.760	-9.3%	0.627
Study Group	500 Hz	35.3%	0.006	- x -	- x -
	1 kHz	45.7%	<0.001	- x -	- x -
	2 kHz	38.0%	0.003	- x -	- x -
	4 kHz	-42.2%	0.001	- x -	- x -

Subtitles – VRA: Visual Reinforcement Audiometry; BP: Bone Pathway; PA: Path of air; ASSR –Stable State Auditory Evoked Potential; - x –statistical analysis not performed ; significant p-value < 0,05 (5%)Spearman’s correlation test

## DISCUSSION

In the present study, it was observed that in the group of children without conductive impairment, the difference of the minimum levels of responses between the behavioral and electrophysiological tests by air was 17.1; 6; 13.2; 11dB for 500, 1000, 2000 and 4000Hz respectively. The VRA values were higher than the ASSR, with a statistically significant difference for 500 and 1000Hz (Table 2). The findings of this study agree with those of another author<sup>10</sup> who evaluated air pathway hearing in adults and found a difference between electrophysiological and behavioral assessment of  $14 \pm 11$ ,  $12 \pm 11$ ,  $11 \pm 8$  and  $13 \pm 11$  dB for 500, 1000, 2000 and 4000Hz, respectively, and with another study<sup>11</sup>, where the differences were approximately 7.2dB for normal-hearing adult.

The statistically significant difference for the 500 and 1000Hz frequencies in the current study can be justified by the greater difficulty of obtaining these responses in the VRA, due to the greater probability of influence of environmental noise, even though this situation was controlled during every procedure, and by the subjectivity of such evaluation, which may make it difficult to obtain the results in the evaluated age group.

In the comparison of VRA and ASSR by bone of the control group (Tables 3 and 4), the differences were smaller than the same frequencies evaluated by air, being  $\pm 1.9$ ;  $\pm 1.2$ ;  $\pm 1.2$ ;  $\pm 1$ , and with higher values in the behavioral evaluation. These results disagree with a study<sup>10</sup> that found differences of  $11 \pm 5$ ,  $14 \pm 8$ ,  $9 \pm 8$  and  $10 \pm 10$  for 500, 1000, 2000 and 4000 Hz in adult individuals. Also, these results disagree with some researchers<sup>12</sup>, who describe better results in the audiometry of children and adolescents, and another study<sup>13</sup>, with children with normal hearing, where the results were 7 to 16 dB worse for the ASSR. These differences in the results of the studies may be justified by the age group evaluated, as older children and adult individuals respond better in behavioral assessments<sup>14,15</sup> when compared to infants.

Regarding the ASSR thresholds in the group of children without conductive alteration (Table 3), mean values were 18.8dB for 500Hz, 20dB for 1000Hz, 20dB for 2000Hz and 20.2dB for 4000Hz. These results corroborate with another study<sup>16</sup> with SSBB in children with normal hearing, where the average thresholds were 14, 20, 26 and 22 dB for the frequencies of 500 to 4000 Hz, respectively, with better results for the lower frequencies. Another study<sup>13</sup>, in children with normal auditory thresholds, described bone AEPS values from

20 to 500Hz and 1000Hz and from 30 to 2000Hz and 4000Hz. The predominance of the best thresholds of the most severe frequencies found in the present study in the control group corroborate with the theory of frequency maturation, with the lowest frequencies being the first ones to be perceived<sup>16</sup>.

For the group of children with conductive alteration, the minimum response levels for the ASSR were lower than those found in the behavioral evaluation in the four frequencies evaluated by air, with the differences between electrophysiological and behavioral around 15.4; 13; 17.7 and 14.3 dB for the frequencies of 500, 1000, 2000 and 4000 Hz, respectively (Table 2). Such results are in line with expectations, since children with conductive disorders respond poorly to behavioral assessment and fluctuate at minimum levels of response<sup>5</sup>. In the evaluation by bone, the differences diminish being practically nonexistent for the four frequencies. We did not find in the national and international literature studies with conductive alterations in the same age range of the present study comparing ASSR with VRA by air and bone pathways. However, the results of the present VO study agree with another research<sup>17</sup>, in which the authors compared the behavioral evaluation with the electrophysiological evaluation by air pathway with adult individuals simulating a conductive hearing loss, with the differences being found of  $20 \pm 10$ ;  $15 \pm 8$ ;  $11 \pm 7$ ;  $13 \pm 9$ , for the frequencies of 500, 1000, 2000 and 4000 Hz.

Another study<sup>7</sup> with children and adolescents with severe and profound sensorineural hearing loss and with descending hearing loss found mean differences in the ASSR threshold and the audiometry threshold between 1.4 and 7.5 dB in the group with descending loss and between -0.40 and -8.5 dB, in the group with severe and profound hearing loss. Such differences, smaller than those obtained in the present study, were expected in view of the fact that adolescents or children with hearing loss respond better in tonal audiometry<sup>15</sup> when compared to young children with conductive loss.

In the present study, in the comparison of the ASSR of the left ear, the air-bone gap of the children with conductive change was around 26.1dB for 500Hz, 28dB for 1000Hz, 15.5dB for 2000Hz and 17.2 for 4000Hz, and average for the four frequencies of 21.7 dB considering the best results of the air and bone AEPS (Tables 2 and 3). These results agree with another study<sup>5</sup>, with similar methodology, however with a younger age group, in which the authors found air-bone gap

around 20dB for children with conductive impairment. The authors highlight that the larger air-bone gap for frequencies of 500 and 1000Hz is expected due to the configuration of conductive hearing loss, a fact also observed in the present study.

When a correlation test was performed between the minimum response levels of VRA and the ASSR for the control group, it was observed that the correlation ranged from 0.6% to 24%, and it was not statistically significant. This does not show a good correlation. These findings differ from other studies mentioned in the literature that found a good correlation between air pathway exams, such as in another study<sup>18</sup>, where the correlation was higher than 0.95 for frequencies of 500 to 4KHz, for the same age group of the present study and other researchers<sup>19</sup>, who carried out a study with infants and pre-school children, finding an excellent correlation between VRA and ASSR by air, varying from 0.82, 0.90, 0.83 and 0.83 in the 500, 1000, 2000 and 4000Hz frequencies.

For the study group, there was a correlation between the ASSR and the VRA (Table 4), being statistically significant. These data corroborate with the literature. Researchers<sup>20</sup> observed a high correlation between the ASSR and behavioral thresholds throughout the study sample including children with sensorineural hearing loss. Research with children with sensorineural hearing loss demonstrated that, although the mean difference between the ASSR and the behavioral assessment was 8 to 15 dB, being higher for the ASSR, there was a strong correlation between the two procedures<sup>21</sup>. Thus, the findings of the present study disagree with the aforementioned studies, and it is believed that because the children in the studied sample presented conductive hearing loss, increasing the differences between the behavioral and electrophysiological evaluation due to the greater instability of the responses to the conductive impairment. This means that conductive impairment makes it difficult to perform by VRA.

For the bone pathway, the correlation can not be calculated in the study group because the values were the same, in the control group there was no statistically significant difference (Table 4). Few studies were performed by bone in this age group comparing the two procedures, and when performed<sup>16</sup> there was no analysis of the correlation test.

In view of the innumerable consequences that a middle ear alteration can cause, it is evident the need to carry out evaluations that identify and quantify this conductive component in order to deal with and prevent

further complications. Therefore, the indispensability of an early diagnosis and evaluation through the bone, in the identification and treatment of conductive changes is visible.

## CONCLUSION

It was possible to compare the findings for the minimum levels of air and bone pathways response between Visual Enhancement Audiometry and ASSR, and the comparison for BP in both groups brings an equivalence in the values, which are very similar. Also, for the air pathway, in the control group, there was a greater proximity between the responses, while in the group with conductive impairment the ASSR values were better than the behavioral responses for all the frequencies surveyed.

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