CORRELATION BETWEEN FREQUENCY-SPECIFIC AUDITORY BRAINSTEM RESPONSES AND BEHAVIORAL HEARING ASSESSMENT IN CHILDREN WITH HEARING LOSS

Correlação dos achados do PEATE-FE e da avaliação comportamental em crianças com deficiência auditiva

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ABSTRACT

Purpose: analyze and correlate the findings of the frequency specific auditory brainstem response and behavioral assessment by air and bone conduction in children with sensorineural hearing loss or mixed hearing loss. **Method**: the sample was composed of ten children up to three years old, diagnosed with sensorineural hearing loss. We conducted the FS-ABR in the frequencies of 0.5, 1, 2 and 4 kHz and behavioral audiometry in the same frequencies, by air and bone conduction. The results of both procedures were correlated in order to verify if the FS-ABR is able to predict auditory status of children with hearing impairment. **Results:** it was observed a strong correlation between the two procedures in the four frequencies studied by air conduction; for bone conduction, found a strong correlation was found in the frequencies of 0.5, 1 and 2 kHz and a moderate correlation at 4 kHz. **Conclusion:** FS-ABR estimated the hearing with strong accuracy when compared to behavioral audiometry. Thus, the application of FS-ABR enables the estimation of hearing status until they can be determined by behavioral hearing tests in the population studied.

KEYWORDS: Auditory, Evoked Response; Child; Hearing Loss; Hearing

INTRODUCTION

With the gradual implementation of the Universal Newborn Hearing Screening (UNHS), more and more newborns and infants demand an accurate audiological diagnosis, reliably defining the type, the degree and the configuration of the hearing loss. The electrophysiological measures of hearing, mainly the Auditory Brainstem Response (ABR), are used for this diagnosis[1].

There are few assessment procedures that accurately diagnose hearing loss in children that are still not able to respond to the behavioral evaluation with conditioned procedures. Currently, the ABR with frequency-specific stimuli (FS-ABR), also known as tone burst ABR, is the most recommended method to obtain hearing thresholds in newborns, infants, and children younger than six months[2,3]. This procedure uses a stimulus (tone burst) that has a frequency spectrum with energy centered in the stimulation frequency, allowing that specific regions of the cochlea are stimulated.

A meta-analysis study[4] presented evidence that the FS-ABR can estimate different hearing loss degrees and configurations. Other studies have shown strong correlation between the minimum response levels (MRL) obtained in FS-ABR and the

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behavioral thresholds of both children with hearing loss[4,5-8] and normal hearing[5,9-11], suggesting a clinical applicability in the diagnosis of hearing losses in young children that do not respond to the behavioral evaluation.

As in conventional audiometry, the bone conduction (BC) evaluation is also necessary in ABR, in order to verify the cochlear function, as well as to differentiate between conductive, mixed, and sensorineural hearing losses[12,13]. In this sense, the FS-ABR has been able to provide the type of hearing loss with accuracy, becoming a reliable predictor of behavioral hearing thresholds in children and adults, and an important tool in differential diagnosis, using both air conduction (AC) and bone conduction (BC) procedures[1,14-17].

International hearing assessment protocols for children[18,19] have suggested the use of bone-conduction FS-ABR in the frequencies of 500 and 2000 Hz. There are still no standardization and calibration for the other frequencies (1000 and 4000 Hz) that allow their incorporation in audiologic diagnosis; further studies and scientific evidences are needed with this objective. Moreover, BC has some restrictions, especially regarding the maximum intensity of the equipment, which registers responses between 45 and 60 dBnHL for 500 Hz and 60 dBnHL for 2000 Hz[1].

Thus, there are few studies that have used bone-conduction FS-ABR in all four frequencies in the assessment of newborns and infants with hearing loss. It is know that, with a more accurate audiologic profile, the child might benefit from the early use of appropriate electronic devices and rehabilitation procedures, with greater efficacy, allowing the minimization of damages caused by sensory deprivation due to the hearing loss.

Hence, the aim of the present study was to analyze and correlate the FS-ABR and behavioral assessment (AC and BC) findings in children with sensorineural of mixed hearing loss.

METHOD

This is characterized as a quantitative and qualitative cross-sectional descriptive study.

The research was carried out at a high-complexity reference service in hearing health in the city of São Paulo, Brazil. The study was approved by the Research Ethics Committee of PUC-SP, under protocol number 134/2010. The parents or legal guardians of the children selected for the study signed a Free and Informed Consent Form.

Subjects

Participants were tem children with ages ranging from birth to 3 years, diagnosed at the institution with sensorineural or mixed hearing loss.

The following inclusion criteria were considered:

1. To present diagnosis of sensorineural or mixed hearing loss, diagnosed by electrophysiological (AC and BC), electroacoustic and behavioral tests previously conducted at the institution;
2. To present the wave V by AC, at least in the maximum intensity of the equipment (100 dBnHL) and in at least one of the specific frequencies assessed in this study;
3. To not present other sensory disabilities, neurological or psychological/psychiatric disorders identified by the physicians of the institution;
4. To be younger than three years of age (inclusively).

The research design was blind, that is, two audiologists conducted the assessments – one always performed the FS-ABR, and the other, the behavioral evaluation – and none of them had previous access to the results obtained by the other researcher. Hence, each test was not influenced by the previous knowledge of the results of the other test.

Electrophysiological assessment

The electrophysiological assessment was carried out using the equipment Eclipse Black Box – software EP25, from Interacoustics MedPC, calibrated according to ISO-389-6 (International Organization for Standardization – ISO, 2007), in an acoustically treated room. The children were in their caregivers laps, in natural sleep.

The child's skin must be cleaned with alcohol and abrasive paste Nuprep, in order to remove the oiliness – which may interfere in the capture of responses for the test – and hence provide adequate registers of the electric responses. The electrodes were placed as it follows: reference electrodes in the right (M2) and left (M1) mastoids, and the active (Fz) and ground (Fpz) electrodes, needed both for AC and BC testing, in the forehead[20]. The impedance of electrodes was equal to or lower than 3 kΩ.

We considered the MRL as the lower intensity in which wave V was observed, recorded, and reproduced. The wave V was defined as the higher positive vertex, followed by a long negative deflection[4]. The recording was carried out twice in each intensity level, in order to verify the reproducibility of the responses. At least 800 stimuli with residual noise below 0.04 μV were used. The initial intensity level was gradually decreased by 20 dBnHL steps, while the responses were present, and gradually increased by 10 dBnHL steps when they became absent. The wave V threshold was searched until the intensity of 20 dBnHL, which is considered a normal hearing level in all FS-ABR frequencies[4,18,19].

For each child, responses were recorded for the frequencies of 500, 1000, 2000 and 4000 Hz in both ears, by AC and BC, with tone pip stimulus.

Air-conduction FS-ABR

To record the air-conduction FS-ABR, insert earphones EARTONE 3A were placed in the child's external auditory canal. The assessment was initiated at 80 dBnHL. When there was no response at this intensity, the intensity of 100 dBnHL was assessed.

Bone-conduction FS-ABR

To record the bone-conduction FS-ABR, the bone conduction transducer Radioear B-71 was placed in the skull above the M1 electrode (when the left ear was tested) and the M2 electrode (when the right ear was tested). The vibrator was fixed with a self-adherent elastic wrap (Coban, model 1582, from 3M) with 5 cm width, and force of 400±25 g, measured by a Ohaus-Spring scale, model 8264-M.

The BC assessment was initiated at the intensity of 40 or 50 dBnHL, depending on the availability of the equipment for each frequency.

Figure 1 shows the description of stimuli characteristics for the FS-ABR assessement, both by AC and BC.

	Frequence			
	500 Hz	**1000 Hz**	**2000 Hz**	**4000 Hz**
Polarity	Alternate	Alternate	Alternate	Alternate
Analysis window	24 ms	24 ms	24 ms	24 ms
Stimulus duration	6 ms	5 ms	2.5 ms	1.25 ms
Cycles	3	5	5	5
Envelope	Blackman	Blackman	Blackman	Blackman
Repetition rates	27.1/s	27.1/s	27.1/s	27.1/s
Filters	100-3000Hz	100-3000Hz	100-3000 Hz	100-3000Hz

Figure 1 – Characteristics of the stimuli used in the FS-ABR recording

Behavioral hearing assessment

The behavioral hearing assessment was conducted after the electrophysiological evaluation, using the audiometer AC-33, from Interacoustics, insert earphones ER-3A for AC, and bone conduction transducer B-17 for BC.

The MRL was assessed for the same frequencies tested in FS-ABR (500, 1000, 2000 and 4000 Hz). The warble tone stimulus, calibrated according to ISO-389-1 (International Organization for Standardization – ISO, 1994), was used. The thresholds were tested in 10-dB steps, and confirmed in 5-dB steps. The MRL was considered the lowest intensity in which consistent responses were obtained and confirmed.

Depending on the age and the responsiveness of the child, the assessment was conducted using either Visual Reinforcement Audiometry (VRA) or Conditioned Play Audiometry (CPA). The VRA followed an application protocol based on an international study[21], adapted by a national study[22].

The data obtained were organized in an Excel spreadsheet and statistically analyzed. For the FS-ABR, it was used the (corrected) threshold in dBnHL obtained from the equipment. The corrected threshold value was used to facilitate the correlation with the behavioral audiometry findings. To correlate electrophysiological and behavioral values, 5 dB were added to the maximum intensity of the equipment when the threshold values were absent, both in the FS-ABR and the behavioral audiometry.

It was calculated the Pearson linear correlation coefficients and the corresponding p-values associated to the hypothesis test of inexistence of linear association between the variables FS-ABR and behavioral audiometry, by frequency, for the AC and BC conditions. Scatterplots were also obtained for all the variables pairs with significant linear association (considering a significance level of 5%)[23]. Correlation values can vary from -1 to 1. Values lower than or equal to 0.4 indicate weak correlation; between 0.41 and 0.80, moderate correlation; between 0.81 and 1, strong correlation.

RESULTS

The sample comprised tem children with hearing loss, who were submitted to air-conduction and bone-conduction FS-ABR, and behavioral hearing assessment. Each child was evaluated in all four frequencies studied (500, 1000, 2000 and 4000 Hz), in a total of 20 ears (ten right ears and ten left ears) for each frequency.

Tables 1 and 2 present the Pearson linear correlation coefficients and the corresponding p-values associated to the hypothesis tests of inexistence of linear association between the variables FS-ABR and behavioral audiometry, by frequency, for the AC and BC conditions, respectively.

Significant correlations were observed for all frequencies. However, unlike in the AC, the linear correlation of the BC condition was strong in the frequencies of 500, 1000 and 2000 Hz. In the frequency of 4000 Hz, the correlation was only moderate.

Figures 2 and 3 present scatterplots for all variables pairs (FS-ABR x behavioral audiometry, in AC and in BC, respectively). There was strong linear correlation between the pair of variables in the AC condition. It is worth emphasizing that the analysis was conducted for ten children (20 ears), however, due to the occurrence of similar results between ears, it was possible to verify a superposition in the representation of the results presented below.

Table 1 – Pearson linear correlation coefficients between the variables air-conduction FS-ABR and behavioral audiometry for each frequency (n=20 ears for each frequency)

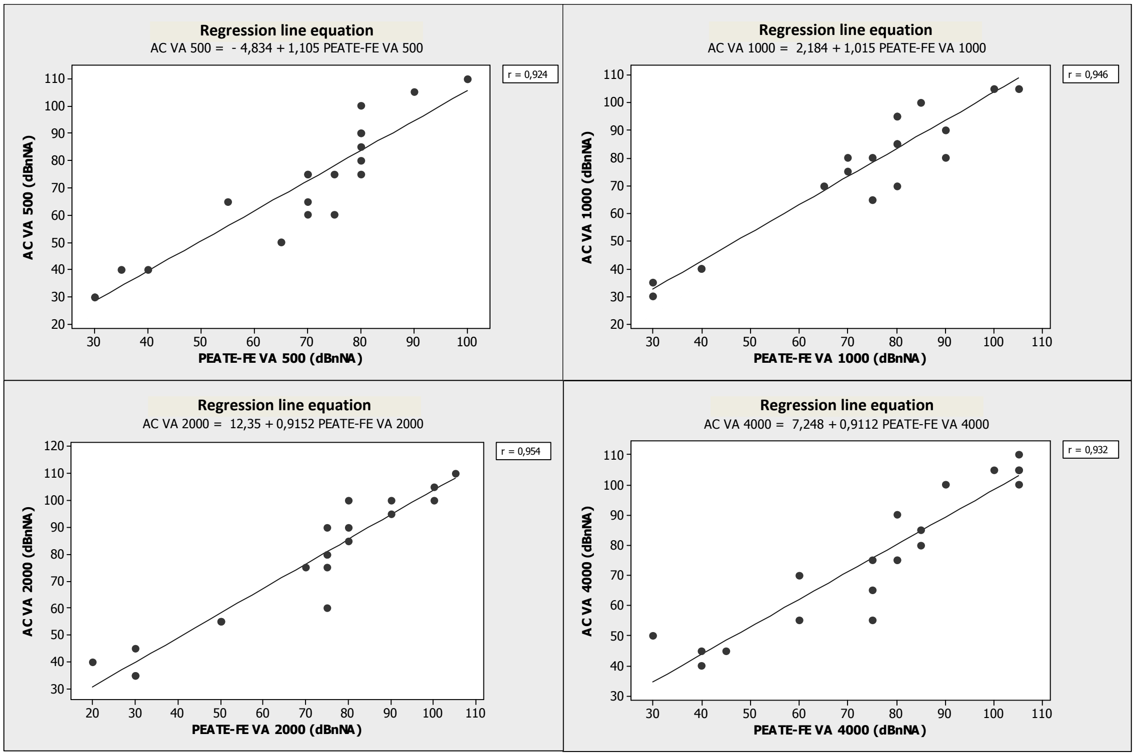
Variables	Frequency Hz	Coefficient	p-value
AC FS-ABR x AC BA	500	0.924	**<0.001**
	1000	0.946	**<0.001**
	2000	0.954	**<0.001**
	4000	0.932	**<0.001**

Note: AC = air conduction; FS-ABR = frequency-specific auditory brainstem response; BA = behavioral audiometry

Table 2 – Pearson linear correlation coefficients between the variables bone-conduction FS-ABR and behavioral audiometry for each frequency (n=20 ears for each frequency)

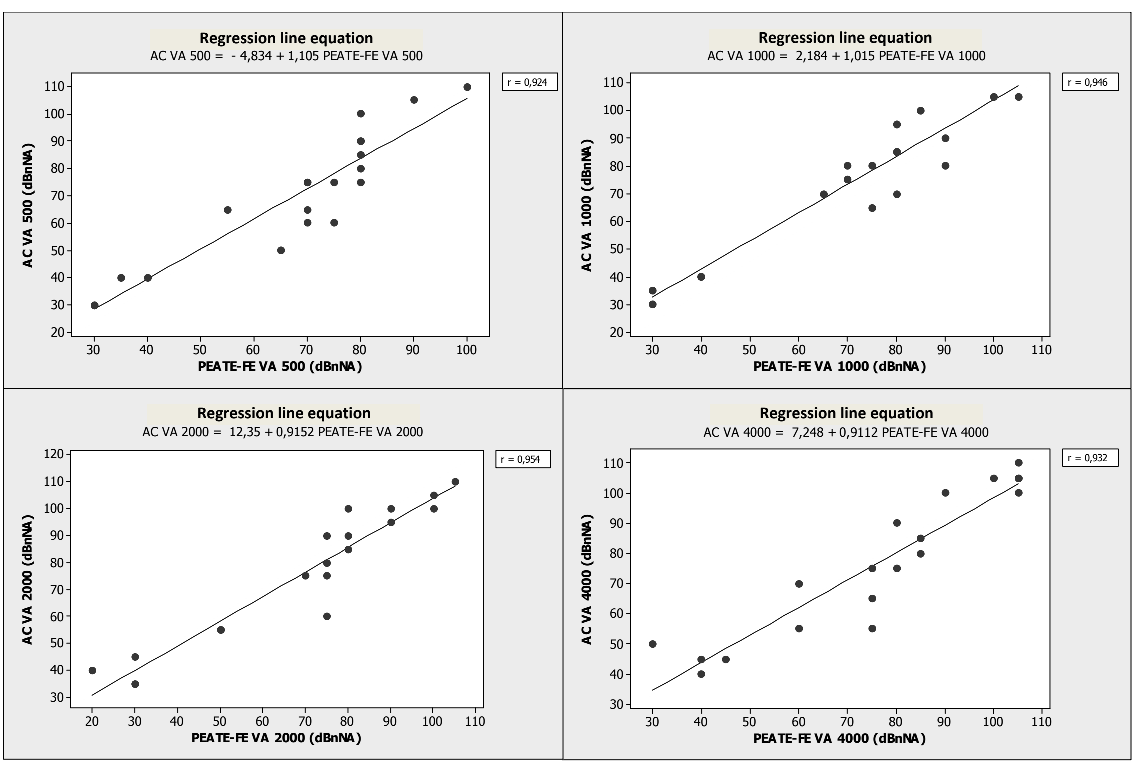
Variables	Frequency Hz	Coefficient	p-value
BC FS-ABR x BC BA	500	0.891	**<0.001**
	1000	0.901	**<0.001**
	2000	0.821	**<0.001**
	4000	0.672	**0.001**

Note: BC = bone conduction; FS-ABR = frequency-specific auditory brainstem response; BA = behavioral audiometry



Note: FS-ABR = frequency-specific auditory brainstem response; BA = behavioral audiometry; AC = air conduction

Figure 2 – Scatterbox, regression line and correlation coefficient for the variables air-conduction FS-ABR and behavioral audiometry for each frequency (20 ears for each frequency)



Note: FS-ABR = frequency-specific auditory brainstem response; BA = behavioral audiometry; BC = bone conduction

Figure 3 – Scatterbox, regression line and correlation coefficient for the variables bone-conduction FS-ABR and behavioral audiometry for each frequency (20 ears for each frequency)

DISCUSSION

The FS-ABR findings were compared to the results of the behavioral hearing assessment. There was a strong correlation between these procedures in the AC condition, in all frequencies: 0.924, 0.946, 0.954, 0.932, respectively for 500, 1000, 2000 and 4000 Hz.

These findings corroborate previous studies[6,8,11], which found similar correlations. Another study[4] pointed out differences of 5.5, 4.9, 0.6 and -8.1 dB between FS-ABR and behavioral audiometry for the frequencies of 500, 1000, 2000 and 4000 Hz, respectively. A difference of ±10 dB between these procedures was shown in another study[9], however, this difference was considered acceptable, and the FS-ABR was able to infer the degree and the configuration of hearing loss. Nevertheless, moderate correlations were found in a study conducted in California (USA)[7], which assessed children with hearing loss and found a correlation of only 0.60.

In the BC condition, strong correlations were found between FS-ABR and behavioral audiometry for the frequencies of 500 (r=0.891), 1000 (r=0.901) and 2000 (r=0.821); for the frequency of 4000 Hz, there was a moderate correlation (r=0.672). The frequencies of 1000, 2000 and 4000 Hz were assessed by BC in a study with adults, and strong correlations were also found (0.82, 0.72 e 0.85 for 1000, 2000 and 4000 Hz, respectively).

These information allow the inference that FS-ABR, both by AC and BC, may be used in audiology practice when it is not possible to obtain reliable responses in the behavioral hearing assessment. Thus, it is possible to give a fair estimate of the audiogram, helping to determine the sound amplification needed for the adaptation of electronic hearing devices before six months of life.

CONCLUSION

The FS-ABR precisely estimated subjects' hearing, since there was strong correlation between the results obtained in this assessment procedure and those from the behavioral audiometry. Hence, the application of FS-ABR allows an estimate of the hearing of children between birth and 3 years of age, until the hearing thresholds can be determined by conventional hearing evaluation.

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RESUMO

Objetivo: analisar e correlacionar os achados dos Potenciais Evocados Auditivos de Tronco Encefáico por Frequência Específica e da avaliação comportamental, por Via aérea e Via óssea, em crianças com perda auditiva sensorioneural ou mista. **Método**: a casuística foi composta por dez crianças com até três anos de idade, diagnosticadas com perda auditiva sensorioneural. Foram realizados os PEATE-FE nas frequências de 0.5, 1, 2 e 4 kHz e a audiometria comportamental nas mesmas frequências, tanto por via aérea como por via óssea. Os resultados dos dois procedimentos foram correlacionados afim de verificar se o PEATE-FE é capaz de predizer o *status* auditivo de crianças com deficiência auditiva. **Resultados:** os resultados mostraram forte correlação entre os dois procedimento nas quatro frequências estudadas por via aérea; já na via óssea, foi encontrada forte correlação nas frequências de 0.5, 1 e 2 kHz e moderada em 4 kHz. **Conclusão:** os PEATE-FE estimaram a audição com forte precisão quando comparados à audiometria comportamental. Desta forma, a aplicação dos PEATE-FE possibilita a estimativa da audição até que possam ser determinados, com segurança, os limiares comportamentais na população estudada.

DESCRITORES: Audiometria de Resposta Evocada; Criança; Perda Auditiva; Audição

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