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Standardization of latency and amplitude parameters on brainstem auditory evoked potential recording with narrow band Ichirp stimulus in normal hearing adults

Padronização dos parâmetros latência e amplitude no registro dos potenciais evocados auditivos de tronco encefálico com o estímulo *Ichirp* de banda estreita em adultos audiologicamente normais

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ABSTRACT

Purpose: Standardize the latency and amplitude parameters using the narrow band *Ichirp* stimulus on Brainstem Auditory Evoked Potential (BAEP) at frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz. **Methods**: The study was performed at the Hospital for Rehabilitation of Craniofacial Anomalies (HRAC), Auditory Health Division, University of São Paulo (USP). Twenty normal hearing adults, aged between 18 and 35 years, were submitted to pure tone audiometry, speech audiometry, immittance and to BAEP with narrow band *Ichirp* stimulus at 500 Hz, 1 kHz, 2 kHz and 4 kHz frequencies. **Results**: In all frequencies evaluated, the latency-intensity function was observed, that is, the increase in the latency of the V wave as the stimulus intensity was decreased, as well as the decrease in the latency of the V wave with the increase of the frequency. In addition, the reduction in the amplitude of the wave V was verified with the decrease of the intensity of the stimulus. The minimum response level, in all frequencies, was found to be lower than the values suggested in the literature as a criterion of normality in frequency - specific BAEP, with the highest values at frequencies of 500 Hz and 1 kHz. **Conclusion**: Normal reference values to BAEP were obtained in normal hearing adults with the narrow band *Ichirp* stimulus, which may contribute to its improvement in clinical practice.

Keywords: Brainstem Auditory Evoked Potentials; Electrophysiology; Adult; Hearing; Parameters

RESUMO

Objetivo: Padronizar os parâmetros de latência e amplitude obtidos com o estímulo *Ichirp* de banda estreita, na pesquisa dos potenciais evocados auditivos de tronco encefálico nas frequências de 500 Hz, 1 kHz, 2 kHz e 4 kHz. **Métodos:** O estudo foi realizado na Divisão de Saúde Auditiva do Hospital de Reabilitação de Anomalias Craniofaciais, da Universidade de São Paulo. Participaram 20 adultos ouvintes normais, na faixa etária de 18 a 35 anos. Todos os participantes foram submetidos à audiometria tonal limiar, logoaudiometria, imitanciometria e aos potenciais evocados auditivos de tronco encefálico, pesquisados com o estímulo *Ichirp* de banda estreita, nas frequências de 500 Hz, 1 kHz, 2 kHz e 4 kHz. **Resultados:** Em todas as frequências avaliadas foi observada a função latência-intensidade, ou seja, o aumento na latência da onda V, na medida em que a intensidade do estímulo foi diminuída, bem como a diminuição na latência da onda V com o aumento da frequência avaliada. Além disso, verificou-se a redução na amplitude da onda V com a diminuição da intensidade do estímulo. Constatou-se o nível mínimo de resposta, em todas as frequências, em níveis inferiores aos valores sugeridos pela literatura como critério de normalidade no registro dos potenciais evocados auditivos de tronco encefálico de frequência específica, sendo os maiores valores nas frequências de 500 Hz e 1 kHz. **Conclusão:** Foram obtidos os valores de referência de normalidade para os potenciais evocados auditivos de tronco encefálico em adultos ouvintes normais com o estímulo *Ichirp*, valores estes que podem contribuir para o aprimoramento do exame, na prática clínica.

Descritores: Potenciais evocados auditivos do tronco encefálico; Eletrofisiologia; Adulto; Audição; Parâmetros

Study carried out at setor de Divisão de Saúde Auditiva, Hospital de Reabilitação de Anomalias Craniofaciais, Universidade de São Paulo – HRAC/USP - Bauru (SP), Brasil.

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INTRODUCTION

The great interest in the investigation of different stimuli for the capture of Auditory Brainstem Evoked Potentials (BAEP) occurred when observing that the cochlear response to the stimuli commonly used as click and *tone burst*, may it is not fully synchronized, since this stimulation occurs initially in the basal region of the cochlea and, later, in the apical region, which can result in an asynchronous pattern of nerve fiber firing along the cochlea[1-4].

The click is characterized as an abrupt onset stimulus with a broad spectrum, however, devoid of frequency selectivity, being insufficient to configure hearing loss. *Tone burst*, in turn, is a tonal stimulus presented by a sinusoidal wave, with a short duration, capable of evaluating specific frequencies[5-8].

Although these stimuli were extremely important to define the basic BAEP response patterns, researchers have pointed out negative aspects in relation to their application in clinical practice, such as difficulties in identifying wave V to determine the Minimum Response Level (MRL), especially at low frequencies[9,10].

In this context, the development of the *chirp* stimulus has, as main objective, to compensate the time of sound travel in the cochlea before the BAEP record, so that all cells along the basilar membrane depolarize at the same time[11].

Following this idea, the creation of a stimulus based on the temporal dispersion of sound wave travel in the cochlea, aims to increase the synchrony of the action potential composed of the auditory nerve, which may reflect in responses with greater amplitudes in the BAEP[12].

Thus, different types of *chirp* were developed, both broadband and narrowband. The *Ichirp* stimulus, in turn, available on the platform *SmartEP* of *Intelligent Hearing Systems* (IHS), it is considered a version of a linear model derived from the stimulus better known as *CE-Chirp*. However, although the proposal for this stimulus is promising, the evidence regarding its use is still poorly known, which makes it essential to validate its results[2].

In the specialized literature, studies using narrow band *Ichirp* stimulus in the BAEP record are restricted. Therefore, the objective of the study was to standardize the latency and amplitude parameters and determine the MRL obtained with the narrow band *Ichirp* stimulus, in the BAEP research.

METHODS

The study was carried out at the Hearing Health Division of the Hospital for Rehabilitation of Craniofacial Anomalies, University of São Paulo (HRAC-USP), in the city of Bauru (SP).

Ethical aspects were considered in research involving human beings, being approved by the Ethics Committee of HRAC-USP, under protocol No. 1,425,385. All study participants read and signed the Free and Informed Consent Form, consenting to the realization and dissemination of this research and its results, as recommended by Resolution 466/12.

The study sample consisted of 20 adults, aged 18 to 35 years, totaling 40 ears.

The study inclusion criteria were: age between 18 and 35 years; good health status and normal hearing, according to criteria established in 1997 for the classification of hearing impairment, by the World Health Organization (WHO)[13]. Exclusion criteria were considered: individuals with middle ear alteration, who gave them conductive or mixed hearing loss; individuals with neurological disorders and alcoholics and / or drug users.

All participants underwent auditory evaluation, consisting of pure tone audiometry, logoaudiometry and conventional immittance testing, to prove normal hearing, and electrophysiological evaluation with BAEP. It must be noted that all participants underwent meatoscopy before the audiological evaluation, in order to observe the possibility of performing the exam.

The materials and equipment used in the audiological evaluation were: AD 229e audiometer, from the brand *Interacoustics*, calibrated to the ANSI-69 standard and TDH39 supra-aural headphones *Telephonics*, for pure tone audiometry and logoaudiometry, in an acoustic booth of the brand *Vibrasom* and the AT235h equipment, from the brand *Intercoustics*, to perform immittance testing.

In the electrophysiological evaluation, it was used: SMART - EP equipment, from the brand IHS, abrasive paste Nuprep, brand *Weaver and Company*, for cleaning the skin on the forehead and on the right and left mastoids, surface electrodes, 3M brand and Ten 20 electrolytic paste, *Weaver and Company* brand, used in the electrodes to provide better electrical conductivity. The individuals were comfortably accommodated in a reclining chair, inside a cabin with acoustic and electric treatment.

The assembly of the electrodes followed the standards established by the *International Electrode System* (IES) 10 – 20[14]. The active (positive) electrode was positioned in the frontal region (Fz); the reference electrode (negative) and the ground electrode, alternately positioned on the right (M2) and left (M1) mastoids. The impedance of the electrodes was kept below 5 kOhms and the difference between the electrodes, less than 2 kOhms.

The presentation of the stimuli was made by means of insertion headphones ER - 3A, from the brand IHS and used the stimulus *Ichirp* of specific frequency, developed by the same company. To obtain the PEATE-*Ichirp* narrowband, the following parameters were used: presentation rate; polarity; duration; mediation; high-pass filter; low-pass filter; gain and analysis time (Chart 1).

The mean and standard deviation for latency and amplitude of wave V, in four levels of intensity, in ten ears, established by the company IHS, are represented in Tables 1 and 2, respectively.

The BAEPs were initially researched at an intensity of 80 dBnNA and, after obtaining a response, the level of presentation of the stimulus was reduced to 60, 40 and 20 dBnNA, until there was no response. Then, the intensity was increased by 5 dB, in order to detect the electrophysiological MRL at frequencies of500 Hz, 1 kHz, 2 kHz and 4 kHz. All BAEP records were analyzed by an experienced appraiser and the amplitude measure was calculated by the *software*.

It is noteworthy that the control conditions, regarding the appearance of electrical artifacts in the record, were guidance to the patient, regarding muscle positioning and relaxation, changing electrical cables and changing electrodes.

Descriptive statistical analyzes of wave V latency and amplitude values were performed for the frequencies studied (mean and standard deviation), as well as the mean, minimum and maximum values for MRL. For statistical analysis, the *software Statistica*, version 12, was used.

Chart 1. Parameters for obtaining auditory brainstem evoked potentials with narrow band chirp

Parameters	*Ichirp*-500 Hz	*Ichirp*-1000 Hz	*Ichirp*-2000 Hz	*Ichirp*-4000 Hz
Submission fee	27.1	27.1	27.1	27.1
Polarity	Alternated	Alternated	Alternated	Alternated
Duration	5000 µs	5000 µs	3000 µs	2000 µs
Promediation	2048	2048	2048	2048
High-pass filter	100	100	100	100
Low-pass filter	3000	3000	3000	3000
Gain	100 k	100 k	100 k	100 k
Analysis time	24 ms	24 ms	24 ms	24 ms

Legend: Hz = hertz; µs = microvolt; k = kilo; ms = milliseconds

Table 1. Average value and standard deviation of latency (in milliseconds) of wave V of the brainstem auditory evoked potential, in four levels of intensity (in dBnHL), in ten normal ears

Stimuli	*Response Thresholds*	Lat (ms)			
		80 dB	60 dB	40 dB	20 dB
BroadBand	20 ± 6	8.2 ± 0.2	8.7 ± 0.2	9.8 ± 0.3	10.9 ± 0.5
500 Hz	20 ± 4.7	7.3±0.1	8.1±0.2	9.3±0.3	11.3±0.4
1000 Hz	20±8.1	7±0.1	7.7±0.2	8.6±0.2	10.4±0.1
2000 Hz	18±7.8	6.2±0.1	6.7±0.1	7.4±0.1	8.7±0.3
4000 Hz	21±8.7	6±0.1	6.4±0.07	7.1±0.1	8±0.2

Source: *Intelligent Hearing Systems* (IHS)
Legend: dBnHL = *decibel normal hearing level*; Hz= hertz;dB = decibel

Table 2. Average value and standard deviation of the amplitude (in microvolts) of wave V of the brainstem auditory evoked potential, in four levels of intensity (in decibels), in ten normal ears

Stimuli	Amp (µV)			
	80 dB	60 dB	40 dB	20 dB
BroadBand	0.37 ± 0.1	0.37 ± 0.07	0.37 ± 0.08	0.29 ± 0.06
500 Hz	0.46 ± 0.09	0.30 ± 0.05	0.20 ± 0.05	0.16 ± 0.04
1000 Hz	0.49 ± 0.08	0.34 ± 0.05	0.22 ± 0.09	0.15 ± 0.03
2000 Hz	0.50 ± 0.09	0.37 ± 0.11	0.23 ± 0.06	0.18 ± 0.04
4000 Hz	0.41 ± 0.08	0.29 ± 0.05	0.21 ± 0.05	0.13 ± 0.05

Source: *Intelligent Hearing Systems* (IHS)
Legend: Hz= hertz; µV = microvolts (amplitude); dB = decibel

Table 3. Average value and standard deviation for V wave latency of auditory brainstem evoked potential with narrow band *Ichirp* stimulus at four intensity levels (in decibels), at frequencies of 500 Hz, 1 kHz, 2 kHz and 4k Hz

Intensity	n	500 Hz Average (SD)	n	1 kHz Average (SD)	n	2 kHz Average (SD)	n	4 kHz Average (SD)
80 dBnNA	40	7.75 (0.35)	40	7.36 (0.54)	40	6.37 (0.28)	40	6.11 (0.25)
60 dBnNA	40	8.60 (0.50)	40	7.97 (0.37)	40	6.89 (0.29)	40	6.43 (0.27)
40 dBnNA	39	10.24 (0.77)	39	9.12 (0.62)	40	7.67 (0.33)	40	7.04 (0.36)
20 dBnNA	32	11.90 (0.86)	37	10.90 (0.75)	40	8.77 (0.54)	40	8.05 (0.58)

Legend: n = number of individuals; SD = standard deviation; Hz = hertz; kHz = kilohertz; dBnNA = *normal hearing level decibel*

RESULTS

For each intensity and frequency evaluated, latency and amplitude, mean and standard deviation were calculated, respectively (Tables 3 and 4).

In all frequencies evaluated, it was possible to observe the latency-intensity function, that is, the increase in wave V latency, as the stimulus intensity was decreased, as well as the decrease in wave V latency, with the increase in the assessed frequency. It was also observed a reduction in the amplitude of wave V, with a decrease in the intensity of the stimulus.

In addition, mean values, standard deviation, minimum and maximum MRL values were obtained at frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz (Table 5).

The descriptive analysis of the results, regarding the MRL, showed higher values in the frequencies of 500 Hz and 1 kHz, being observed that, in some individuals, the MRL was superior to 20 dBnNA.

Figure 1 illustrates the BAEP record with *Ichirp* stimulus of specific frequency at different frequencies and intensities, in one of the study participants, in which it was possible to observe the occurrence of the latency-intensity function.

Table 4. Mean value and standard deviation for the V wave amplitude of the brainstem auditory evoked potential with narrow band *Ichirp* stimulus at four intensity levels (in decibels) at the frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz

Intensity	n	500 Hz Average (SD)	n	1 kHz Average (SD)	n	2 kHz Average (SD)	n	4 kHz Average (SD)
80 dBnNA	40	0.43 (0.12)	40	0.44 (0.13)	40	0.49 (0.16)	40	0.46 (0.15)
60 dBnNA	40	0.28 (0.09)	40	0.31 (0.11)	40	0.36 (0.11)	40	0.36 (0.12)
40 dBnNA	39	0.15 (0.06)	39	0.18 (0.06)	40	0.25 (0.11)	40	0.23 (0.07)
20 dBnNA	32	0.12 (0.05)	38	0.13 (0.05)	40	0.18 (0.08)	40	0.17 (0.06)

Legend: n= individuals number; SD = standard deviation; Hz = Hertz; kHz = kilohertz; dBnNA = *normal hearing level decibel*

Table 5. Average, standard deviation, minimum and maximum values for the minimum response level at frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz with the narrow band *Ichirp* stimulus

Frequency	N	Average	SD	Minimum	Maximum
500 Hz	40	20.37	8.27	5.00	50.00
1000 Hz	40	14.00	8.63	0.00	45.00
2000 Hz	40	8.00	5.75	0.00	20.00
4000 Hz	40	8.37	5.81	0.00	20.00

Source: Elaborated by the authors
Legend: N= individuals number; Hz = hertz; SD = *standard deviation*

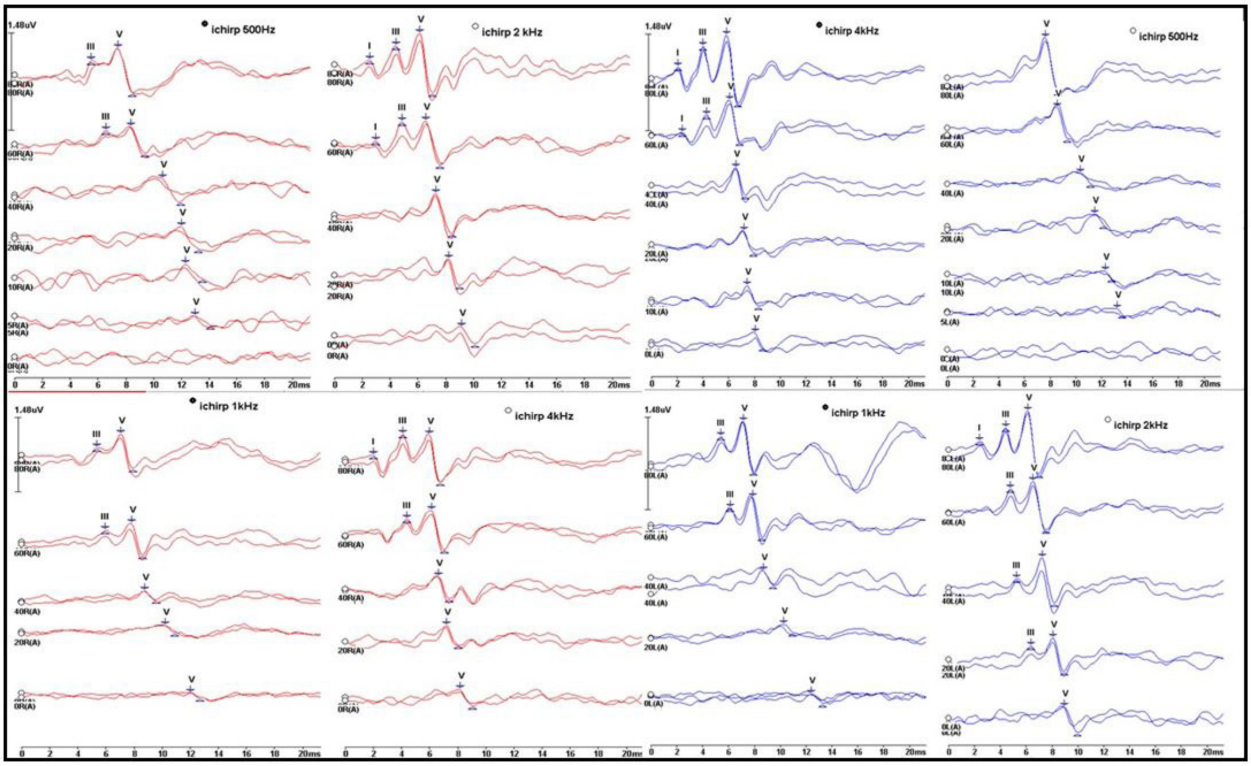

Figure 1. Latency-intensity function in the recording of the auditory brainstem evoked potential with narrow band *Ichirp* stimulation in the right and left ear in a study participant
Source: Elaborated by the authors

DISCUSSION

The BAEPs have been extensively studied and scientific articles portray aspects related to the procedures used during the performance of this exam, such as the systems for recording potentials, as well as the characteristics of stimuli to elicit such evoked potentials[15].

Regarding the type of stimulus, the literature shows that it must activate a large number of neuronal fibers simultaneously, so that it is possible to capture electrical activity[16].

Frequency-specific BAEPs, elicited by short-term stimuli, stimulate limited regions of the cochlea, which generate specific frequency responses, thus making it possible to estimate hearing sensitivity, both in children and in adults with normal hearing or with hearing loss[9].

The *Ichirp* stimulus has no direct comparison with other types of *chirp*, as, for example, CE-Chirp, already described in the literature. According to the company IHS, the narrow band *Ichirp* stimulus was built taking into account the Boer model, which gives the cochlea great frequency selectivity, involving a range of audible frequencies of more than nine octaves[17].

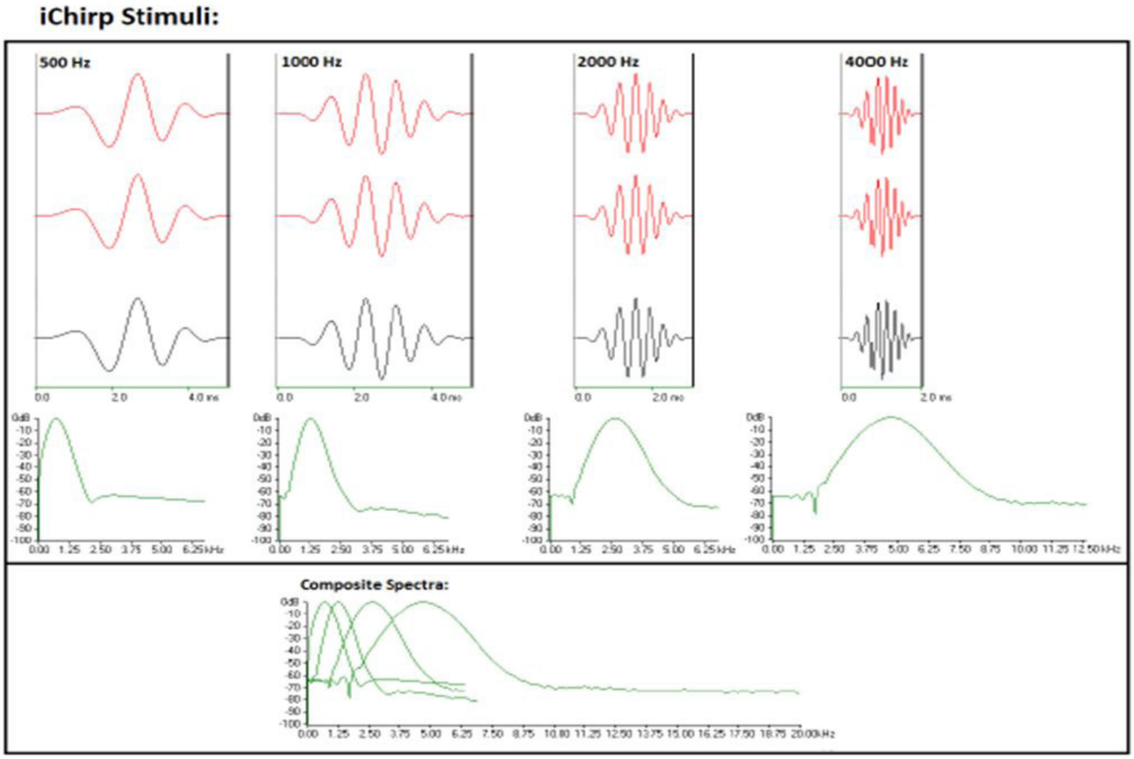

Figure 2. Narrow band *Ichirp* time and signal spectrum
Source*: Intelligent Hearing Systems* (IHS)

Thus, each frequency region was approximated by a linear and expanded function, in order to allow better frequency specificity (Figure 2).

The results in relation to latency, in the four evaluated frequencies, agree with previous investigations using other stimuli, such as click an *tone burst*[18-20], which showed an increase in latency with a decrease in the level of intensity used to provoke the response, as well as a decrease in latency with an increase in the assessed frequency. According to the literature, these characteristics show cochlear tonotopy, as well as the specificity of the stimulus used to capture BAEP. The increase in latency at lower frequencies represents the activity of hair cells, located in the apical region of the cochlea, which, when elicited, show a response with greater latency. However, when hair cells in the basal region of the cochlea are stimulated, they respond with a shorter latency[9].

The findings mentioned differ from the study by Rodrigues[2], who, when using the narrow band CE-chirp stimulus, observed that latencies increased proportionally to the increase in frequency.

In the present study, it was possible to observe more expressive wave V amplitudes in the BAEP records, which allowed the determination of the MRL at levels lower than the values suggested as a normality criterion in the BAEP record of specific frequency in children[21], in all evaluated frequencies. The literature emphasized that this is expected, since chirp stimuli were developed to activate different regions of the cochlea simultaneously, resulting in V waves with greater amplitudes[1,22,23].

Rodrigues[2] showed that greater amplitudes can be interesting for clinical applications, as they can facilitate the visualization of responses, mainly in the research of electrophysiological MRL, since the BAEP amplitudes are smaller when they are close to the MRL.

It is important to note that, despite more significant amplitude values for the determination of MRL at levels considered normal[21], there was still some difficulty in determining wave V at low intensities, mainly at 500 Hz and 1 kHz, requiring greater reproducibility of the waves. These findings are similar to the studies carried out with the *tone burst* stimulus, in which smaller amplitudes and more bulged morphology of wave V were observed, often making it difficult to identify them[24].

It must be noted that another factor that can interfere with the amplitude of the waves in the BAEP record is the artifact. The presence of artifact in the BAEP record, at lower frequencies, is a factor that makes it difficult to identify wave V, even leading to an increase in research time[9]. The appraiser must be aware of interferences that could compromise the BAEP record, such as, for example, the *Post-Auricular Muscle Artifact* (PAM), that occurs in 10 to 14 milliseconds, is caused by muscle tension in the neck or jaw and can affect both latency and amplitude. In these cases, moving the electrodes of the mastoids or lobes can decrease the artifact, however, it is important to make sure that the patient remains relaxed and with his/her eyes closed, keeping his/her teeth loosened[25].

Although in the present study higher MRL was observed at frequencies of 500 Hz and 1 kHz (mean of 20.37 and 14.00 respectively), in relation to the other frequencies, the mean values were lower than those considered normal in clinical practice (35 dBnHL for 500 Hz and 1 kHz, 30 dBnNA for 2 kHz and 25 dBnNA for 4 kHz), in all evaluated frequencies (21). According to some authors[19,24,25], who used the *tone burst* stimulus, this result is due to the limited neural synchrony in the apical region of the cochlea, in addition to noise contamination for low frequencies, which cause worse responses in the BAEP for that region.

In view of this, the present study allowed to obtain normal reference values for BAEP in normal hearing adults, using the narrow-band *Ichirp* stimulus, values that can contribute to the improvement of the exam. The importance of the investigation, by the professional, of technological advances in this area is emphasized, based on clinical findings and scientific evidence, in order to provide better patient care.

CONCLUSION

The narrow band *Ichirp* stimulus presented the latency-intensity function in all evaluated frequencies, as well as records with more expressive amplitudes, allowing the identification of MRL at levels below the normality criteria suggested in the researched literature, in all evaluated frequencies.

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