Original Article

Comparison of click and CE-chirp® stimuli on Brainstem Auditory Evoked Potential recording

Comparação dos estímulos clique e CE-chirp® no registro do Potencial Evocado Auditivo de Tronco Encefálico

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ABSTRACT

Purpose: To compare the latencies and amplitudes of wave V on the Brainstem Auditory Evoked Potential (BAEP) recording obtained with click and CE-chirp® stimuli and the presence or absence of waves I, III and V in high intensities. **Methods:** Cross-sectional study with 12 adults with audiometric thresholds ≤15 dBHL (24 ears) and mean age of 27 years. The parameters used for the recording with both stimuli in intensities of 80, 60, 40, 20 dBnHL were alternate polarity and repetition rate of 27.1 Hz. **Results:** The CE-chirp® latencies for wave V were longer than click latencies at low intensity levels (20 and 40 dBnHL). At high intensity levels (60 and 80 dBnHL), the opposite occurred. Larger wave V amplitudes were observed with CE-chirp® in all intensity levels, except at 80 dBnHL. **Conclusion:** The CE-chirp® showed shorter latencies than those observed with clicks at high intensity levels and larger amplitudes at all intensity levels, except at 80 dBnHL. The waves I and III tended to disappear with CE-chirp® stimulation.

Keywords: Evoked potentials, auditory; Evoked potentials, auditory, brain stem; Electrophysiology; Hearing; Hearing tests

INTRODUCTION

The Brainstem Auditory Evoked Potentials (BAEP) are historically recorded using clicks that, due to their sudden start and broadband composition, supposedly activate synchronically a wide region of the cochlea[1].

However, studies have shown that the response to the click is not totally synchronized. When a click reaches the basilar membrane, the resulting sound wave takes a considerable amount of time to reach the apex of the cochlea, from the base. The response peak occurs milliseconds later in the low frequency regions than in the higher frequency regions. For this reason, the basilar membrane cells are not stimulated at the same time, resulting in an asynchronous depolarization of neurons. More time is needed for the low frequency region to attain the maximum dislocation reached at the base of the cochlea, in such a way that all neurons along the basilar membrane are depolarized simultaneously[1-4].

These observations evidenced negative points of the click stimulus in registering the BAEP, but also suggested points that could be modified in the elaboration of new stimuli. An alternative to the click have been developed aiming at a simultaneous neuronal activation along the basilar membrane, and, consequently, the recording of responses with larger amplitudes[1-4]. This stimulus, named *chirp*, was initially developed based on equations that consider the cochlea's mechanic properties[4] and, lately, on equations based in bands derived from the BAEP latency registered in humans[5].

Claus Elberling and a group of researchers have been developing several studies with the aim to elaborate a chirp model that compensates the temporal dispersion of the sound wave in the cochlea from equations based on BAEP latencies recorded in humans. Patented as CE-chirp® in honor of Claus Elberling, this stimulus was elaborated based on real models of the travel time of the sound wave in the human cochlea[3,5,6].

The CE-chirp® has the same frequency spectrum of a click. The difference is the presentation time of the low, medium and high frequencies components, with the aim to stimulate all frequency regions of the cochlea at the same time. This simultaneous depolarization of all frequency regions allows larger response amplitudes in the BAEP recording[7].

Study conducted at the Centro Audição na Criança, Divisão de Educação e Reabilitação dos Distúrbios da Comunicação, Pontifícia Universidade Católica de São Paulo – CeAC/DERDIC/PUC-SP – São Paulo (SP), Brasil.
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Larger amplitudes might be interesting to clinical application, because they may facilitate the evaluator's visualization of responses, making it easier to identify the waves. This may be especially interesting in the research of electrophysiological thresholds, since BAEP amplitudes are shorter when they are close to the hearing threshold.

Although the use of chirp stimulus might be promising, before considering its application on clinical practice, it is important to document the results in this new stimulus in comparison to the stimulus traditionally used. In the present study, the wave V latency and amplitude of BAEP recorded using click and CE-chirp® stimuli were compared, as well as the presence and absence of waves I, III and V in high intensities.

METHODS

This study was conducted at the Child Hearing Center (*Centro Audição na Criança* – CeAC), a service from the Division of Studies and Rehabilitation of Communication Disorders (*Divisão de Estudos e Reabilitação dos Distúrbios da Comunicação* – DERDIC) of the Pontifícia Universidade Católica de São Paulo (PUC-SP), and was approved by the Research Ethics Committee of the institution (protocol number 316/2008). All subjects signed the Free and Informed Consent Term, thus allowing the use of data and dissemination of the results obtained, according to Resolution 196/96 (Brazil, National Health Council).

Participants were 12 adults (six men and six women) with normal hearing and ages between 21 and 30 years (mean=27 years), totalizing 24 ears. Inclusion criteria were the presence of type A tympanometric curve and pure-tone hearing thresholds ≤15 dBHL before the electrophysiological hearing assessment.

The BAEP recording with click and CE-chirp® stimuli was conducted using the equipment Eclipse EP25 ABR system, from Interacoustics®. The tests were carried out with the subjects in natural sleep or in relaxed state. Reference electrodes were placed on the right (A2) and left (A1) mastoids, and the active (Fz) and ground (Fpz) electrodes, on the front. The recording was conducted only with impedance below 3 kΩ. Filters of 100 Hz to 3 kHz were used during the recording, and the equipment constantly estimated the residual noise. The recording stopped when, after 800 stimuli, the residual noise was below 40 nV[8].

Click and CE-chirp® stimuli have the same frequency spectrum (350 Hz – 11.3 kHz), and were both presented at 27.1 stimuli per second in alternate polarity using insert earphones ER3A. The BAEP recording started with click stimulus in the intensity of 80 dBnHL, followed by the intensities of 60, 40, and 20 dBnHL. After the click stimulus, the BAEP recording with CE-Chirp® stimulus was initiated on the same ear. Then the same recording order was conducted on the opposite ear.

Responses were recorded in both ears for all researched intensities (n=24). The amplitude and latency of recordings were determined by visual identification of the wave V by an experienced evaluator. Amplitude values were obtained by the marking difference between positive and negative peaks of wave V, as identified by the evaluator. The presence/absence of waves I, III and V for both stimuli was analyzed in high intensities (80 and 60 dBnHL).

Statistical analysis of data used the Wilcoxon test. It was adopted a significance level of 0.05 (5%), and confidence intervals considered a statistical confidence of 95%.

RESULTS

The Wilcoxon test compared wave V latency and amplitude results between right and left ears. The differences found between ears were not significant (CE-chirp® stimulus – latency: p=0.106, p=0.141, p=0.262 and p=0.720, respectively for the intensity levels of 80, 60, 40 and 20 dBnHL; amplitude: p=0.583, p=0.272, p=0.126 and p=0.433; click stimulus – latency: p=0.154, p=0.329, p=0.141 and p=0.140, for the intensity levels of 80, 60, 40 and 20 dBnHL, respectively; amplitude: p=0.695, p=0.388, p=0.367 e p=0.754). For this reason, the following data analysis always considered the values of both ears. Hence, the sample size was doubled and, consequently, data reliability was improved, maintaining the initial data variability.

For each intensity, the mean, median, standard deviation, quartiles and confidence interval were calculated for both latency (Table 1) and amplitude (Table 2) of wave V with click and CE-chirp® stimuli.

The Wilcoxon test was performed to compare the mean wave V latency values between both stimuli. Figure 1 shows the latencies observed between click and CE-Chirp® stimuli for the different intensities studied.

In higher intensities (80 and 60 dBnHL), the CE-Chirp® stimulus presented lower latencies than those observed with click stimulus. In lower intensities (40 and 20 dBnHL), how-

Table 1. Descriptive statistics for wave V latency on the BAEP recording with click and CE-chirp® stimuli

Latency	80 dBnHL		60 dBnHL		40 dBnHL		20 dBnHL	
	CE-chirp®	Click	*CE-chirp®*	Click	*CE-chirp®*	Click	*CE-chirp®*	Click
Mean	4.57	5.29	5.56	5.83	6.79	6.63	7.99	7.68
Median	4.53	5.20	5.53	5.80	6.80	6.57	7.97	7.74
SD	0.47	0.23	0.42	0.26	0.38	0.26	0.38	0.30
Q1	4.32	5.13	5.30	5.65	6.58	6.47	7.72	7.40
Q3	4.90	5.47	5.83	6.00	6.95	6.80	8.27	7.89
n	24	24	24	24	24	24	24	24
CI	0.19	0.09	0.17	0.10	0.15	0.11	0.15	0.12

Note: BAEP = brainstem auditory-evoked potentials; dBnHL = decibel normal hearing level; SD = standard deviation; Q1 = quartile 1; Q3 = quartile 3; CI = confidence interva

Table 2. Descriptive statistics for wave V amplitude on the BAEP recording with click and CE-chirp® stimuli

Amplitude	80 dBnHL		60 dBnHL		40 dBnHL		20 dBnHL	
	CE-chirp®	Click	*CE-chirp®*	Click	*CE-chirp®*	Click	*CE-chirp®*	Click
Mean	0.537	0.515	0.593	0.340	0.575	0.290	0.304	0.180
Median	0.510	0.461	0.601	0.323	0.607	0.308	0.325	0.177
SD	0.154	0.187	0.139	0.128	0.165	0.079	0.116	0.077
Q1	0.441	0.383	0.517	0.254	0.440	0.229	0.204	0.111
Q3	0.628	0.649	0.650	0.404	0.676	0.345	0.393	0.237
n	24	24	24	24	24	24	24	24
CI	0.061	0.075	0.056	0.051	0.066	0.032	0.046	0.031

Note: BAEP = brainstem auditory-evoked potentials; dBnHL = decibel normal hearing level; SD = standard deviation; Q1 = quartile 1; Q3 = quartile 3; CI = confidence interva

ever, the opposite occurred; click latencies were lower than those obtained with CE-Chirp® stimulus.

Figure 2 shows the wave V amplitude differences obtained on the BAEP recordings using click and CE-Chirp® stimuli, as analyzed by the Wilcoxon test.

In the intensity levels researched, the wave V amplitude on the BAEP recordings with the CE-Chirp® stimulus was larger than the amplitude obtained with clicks. This difference was significant for the intensity levels of 60, 40 and 20 dBnHL, but not for 80 dBnHL.

When the presence/absence of waves I, III and V was analyzed for high intensities with both stimuli, waves I and III tended to disappear with the CE-Chirp® stimulus (Table 3).

Figure 3 presents the BAEP tracings recorded with click and CE-Chip® stimuli from one of the subjects in this study.

DISCUSSION

In the present study, the differences obtained in the comparison between wave V latency and amplitude on the BAEP recording with click and CE-Chirp® stimuli were analyzed in normal hearing adults. For both stimuli, the mean wave V latencies were longer as intensity decreased. This result was expected, and corresponds to the BAEP latency behavior.

At high intensity levels (80 and 60 dBnHL), the CE-Chirp® stimulus presented wave V latencies lower than those observed with clicks. Similar results were reported by other authors[9], who found lower latencies in the BAEP recordings with CE-Chirp® stimulus at 50 dBnHL than with clicks.

Considering the CE-Chirp® design, it is expected that the latencies obtained with this stimulus are lower than those ob-

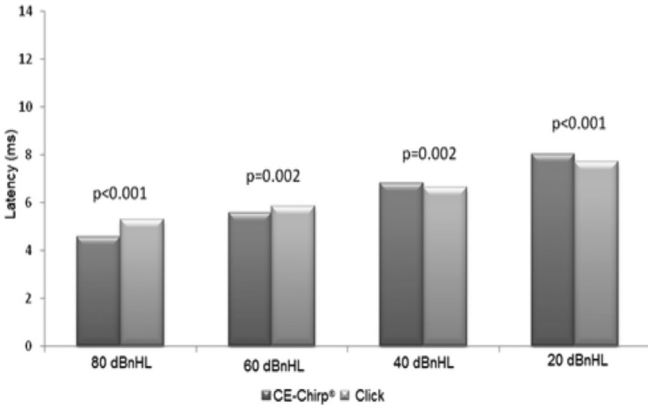

Figure 1. Comparison between wave V latencies in BAEP with clicks and CE-chirp® stimuli

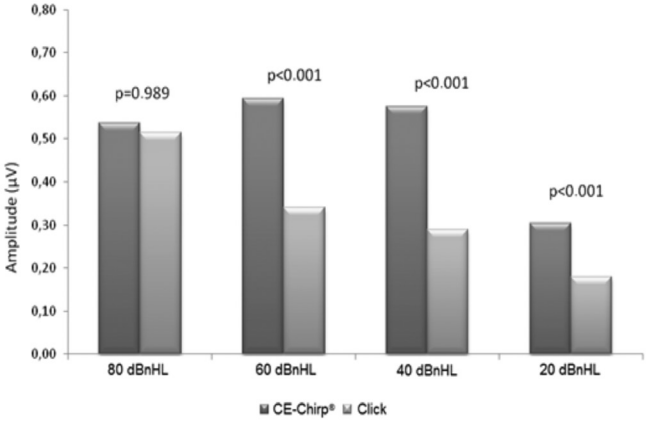

Figure 2. Comparison between wave V amplitudes in BAEP with clicks and CE-chirp® stimuli

Table 3. Presence of waves I, III and V at high intensity levels on the BAEP recording with click and CE-chirp® stimuli

Intensity	Stimulus	Wave					
		I		III		V	
		n	%	n	%	n	%
80 dBnHL	Click	24/24	100	24/24	100	24/24	100
	CE-chirp®	9/24	37.5	15/24	62.5	24/24	100
60 dBnHL	Click	20/24	83.8	22/24	91.7	24/24	100
	CE-chirp®	5/24	20.8	8/24	33.3	24/24	100

Note: dBnHL = decibel normal hearing level

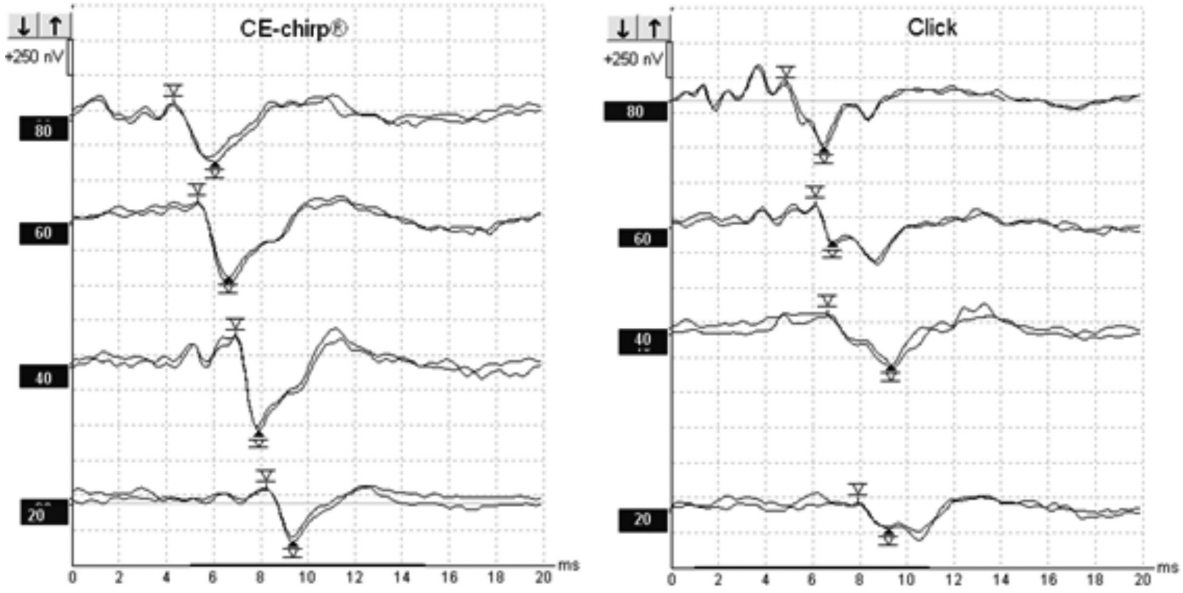

Figure 3. Example of BAEP recording with click and CE-chirp® stimuli in one of the subjects in the study

tained in the BAEP with clicks. The CE-Chirp® was developed to simultaneously stimulate the different regions of the basilar membrane, compensating the sound travel time in the cochlea. Hence, low frequency components are presented before the high frequency components, that is, before the zero latency reference, in such a way that lower latencies in response to this stimulus are really expected[9].

The amplitudes observed with the CE-Chirp® stimulus were significantly larger than those observed with clicks for all intensities, except 80 dBnHL. These results are expected and similar to previous studies that compared chirp and click stimuli in the BAEP recording[3,5,6].

In general, as the intensity level of the stimulus decreased, the wave V amplitudes in the BAEP recording also decreased. However, when the CE-Chirp® stimulus was used, the amplitude increased between 80 and 60 dB, before decreasing and presenting a behavior similar to that of the amplitude obtained with click stimulus.

Similar results were presented by other authors[2,5]. A study[5] showed that the amplitude obtained with chirp stimulus was shorter at 60 dB than at 50 dB. Although the 50 dB intensity level was not tested in this study, it was possible to observe that the wave V amplitude increases with the CE-Chirp® stimulus and decreases with the click stimulus when the intensity level decreases from 80 to 60 dB.

Studies have suggested that these findings are due to the fact that, with the CE-Chirp® stimulus, there is a broader propagation of the sound wave in the cochlea at high intensities, so that regions that would not respond are stimulated. This results in an overstimulation, which reduces the response amplitude[2,5,7].

In this study, when the presence/absence of waves I, III and V was analyzed at high intensities, both waves I and III tended to disappear with the CE-chirp® stimulation. It is worth mentioning that waves I and III have great diagnostic value in the BAEP recording.

The absence of waves I and III and the fact that intensity is directly related to the amplitude of wave V when chirps are used led Claus Elberling and his research group to improve the CE-chirp® stimulus design. When they observed that short-duration chirps were more effective at high intensities and long-duration chirps were more effective at low intensities, these authors(7) concluded that the travel time of the sound in the cochlea was not the only variable to be considered in the elaboration of a chirp. To develop a more efficient chirp for BAEP recording in humans, they proposed a new model called "direct approach"[9]. This model was based on BAEP latencies with CE-chirps® and narrow-band CE-chirps® in the frequencies of 500 Hz, 1, 2, and 4 kHz, registered at different intensity levels in several normal-hearing adults. These data were gathered in three outpatient clinics in different parts of the world (South America, North America, and Scandinavia).

The direct approach considered not only the travel time of the sound wave in the cochlea, but also the different intensity levels, allowing the development of a new model. This new model was named "level specific CE-chirp®" and is being tested[10], with the promise to overcome the limitations of the CE-chirp®.

The quick evolution of different chirp models is evident in literature. This is positive, since the final result is to reach improvements that can be used in clinical practice. On the other hand, the availability of little tested stimuli still in development in commercialized equipments is a worrying factor. The rapid and constant modernization of equipments used to record the auditory-evoked potentials, commercialized before scientific evidence, may bring disastrous consequences for clinical practice.

The results of the present research, along with the results of other international studies, have contributed for the improvement of the CE-chirp® stimulus. On the other hand, considering clinical practice, while the amplitude increase of wave V, facilitating its identification, is a positive point for the clinical use of the CE-chirp®, the absence of waves I and III is an important limitation. The use of the CE-chirp® may be particularly interesting in neonatal hearing screening equip-

ment, since larger amplitudes might facilitate the automatic detection of responses, reducing the testing time. Satisfactory results for this end have already been reported[11,12].

The professional responsible for the BAEP recording must have in mind the potential and limitations of new technologies available for this task. Thus, based on clinical findings and scientific evidence, he/she must be prepared to use all the technological resources available.

CONCLUSION

The CE-chirp® stimulus presented shorter latencies than those observed with click stimulation at high intensity levels (80 and 60 dBnHL). The BAEP recording using CE-chirp® stimulus showed larger amplitudes than with clicks, except at 80 dBnHL. The waves I and III tended to disappear when the CE-chirp® was used.

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RESUMO

Objetivo: Comparar as latências e as amplitudes da onda V no registro do Potencial Evocado Auditivo de Tronco Encefálico (PEATE) com os estímulos clique e *CE-chirp®* e a presença ou ausência das ondas I, III e V em fortes intensidades. **Métodos:** Estudo transversal com 12 adultos com limiares audiométricos ≤15 dBNA (24 orelhas) e idade média de 27 anos. Os parâmetros utilizados para o registro com os dois estímulos nas intensidades de 80, 60, 40, 20 dBnNA foram polaridade alternada e taxa de repetição de 27,1 Hz. **Resultados:** As latências da onda V observadas com *CE-chirp®* foram maiores que as observadas com o clique nas intensidades fracas (20 e 40 dBnNA). Já nas intensidades fortes (60 e 80 dBnNA), o oposto ocorreu. Maiores amplitudes foram observadas com o *CE-chirp®* em todas as intensidades, exceto em 80 dBnNA. **Conclusão:** O *CE-chirp®* apresentou latências mais curtas que as observadas com o clique em fortes intensidades e maiores amplitudes em todas as intensidades, exceto em 80 dBnNA. As ondas I e III tenderam a desaparecer quando o estímulo *CE-chirp®* foi utilizado.

Descritores: Potenciais evocados auditivos; Potenciais evocados auditivos do tronco encefálico; Eletrofisiologia; Audição; Testes auditivos

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