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Auditory brainstem response thresholds difference using Click and CE-Chirp in auditory brainstem response

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Abstract

Introduction: *Auditory Brainstem Response, also known as short-latency auditory evoked potentials (SLAEP) is a useful tool for performing auditory evaluations in children and difficult to test patients. Different types of stimuli have been described to elicit the auditory response including Click and CE-chirps among others.* **Objective:** *The objective the study is to compare the auditory brainstem response thresholds obtained with Click and CE-Chirp stimuli and to describe if there is a difference in the correction factor for the auditory brainstem hearing threshold between the two stimuli.* **Material and methods:** *A retrospective, cross-sectional, observational, comparative, and descriptive study was carried out. The patients' records who, as a diagnostic protocol, had been evaluated with auditory brainstem response with both Click and CE-Chirp, were analyzed. 38 ears were reviewed with both CE-Chirp and Click recordings. The mean and standard deviations between the electrophysiological hearing thresholds of both stimuli were calculated. A student's t-test was performed between the means of the hearing threshold. The correction factor for CE-Chirp was calculated.* **Results:** *The means of the electrophysiological hearing threshold obtained with Click stimulus were of 30.26 dBnHL and with CE-Chirp of 23.21 dBnHL. There is a significant difference between the hearing thresholds obtained with both stimuli with p = 0.000.* **Conclusions:** *The threshold difference between CE-Chirp and Click was 6.57 dB, and the thresholds obtained with CE-Chirp are lower than with Click. Therefore, thresholds between 20 dBnHL and 25 dBNHL with CE Chirp should be considered normal, unlike the Click that is universally accepted as normal with 30 dBnHL or less.*

Keywords: *Auditory brainstem response. CE-Chirp stimuli. Click stimuli. Hearing threshold.*

Introduction

Short-latency auditory evoked potentials (SLAEP) are defined as the bioelectrical response recorded in the scalp after the activation of the fibers of the auditory pathway (from the auditory nerve to the inferior colliculus), and this response consists of a sequence of up to seven positive waves toward the vertex recorded by specialized electrophysiological equipment. The waves are usually labeled with Roman numerals of which waves I, III, and V are the most important and specifically, the V wave is used to determine the electrophysiological auditory threshold[1,2].

The study can identify the presence of hearing loss in subjects who cannot cooperate for audiometry, either because of their age, such as neonates, or adults with inability to participate, such as dementia. The test itself is a fairly objective measure of the measurement of electrophysiological auditory thresholds and is considered to be a reliable and very approximate estimate of behavioral thresholds at frequencies from 2000 to 4000 Hz[2].

The auditory threshold of the SLAEP obtained with Click stimulus is obtained with the lowest stimulus intensity at which the V-wave can be identified in a clear

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and reproducible way. It provides a fairly close estimate of the behavioral hearing threshold and is considered the gold standard for determining the hearing threshold in non-cooperative patients. However, for decades, it has been known that the electrophysiological auditory threshold obtained with Click is higher than the behavioral threshold obtained, for example, with tonal audiometry, with a difference between behavioral thresholds and electrophysiological thresholds with Click of approximately 10 dB[3].

The Click stimulus is a broadband stimulus, that is, it stimulates many cochlear frequencies and has been used routinely in SLAEP for more than five decades[4]. The Click is a stimulus produced by a square wave electrical pulse lasting 100 μs. It allows the stimulation of the entire cochlea; however, this Click causes a progressive stimulation from high to low frequencies, that is, it does not stimulate them simultaneously, which produces a depolarization out of phase in time of the axons of the auditory nerve. This implies a limitation when obtaining records because we only obtain responses from the base of the cochlea, more specifically frequencies between 2000 Hz and 6000 Hz, excluding frequencies below 2000 Hz that are stimulated later than those mentioned above.

Similarly, the CE-Chirp stimulus is also a broadband stimulus that also allows the activation of the entire cochlea, however, in contrast, because it is designed to avoid the lag in the high and low frequencies, a synchronized depolarization of a greater number of axonal fibers is obtained, which produces a bioelectric vector of greater amplitude and this results in larger waves, including the V wave, in addition to having a wider frequency contribution, from 250 Hz to 8000 Hz. It was designed by Klaus Elberling in 2007 due to the limitations in frequency stimulation offered by the Click stimulus[4-6]. It is assumed that a more robust bioelectrical vector produces larger SLAEP waves and at lower stimulation intensities with the CE-Chirp.

Due to the potential difference between the auditory thresholds obtained by Click and CE-Chirp, there is a need to measure the difference between the thresholds obtained with both stimuli and thus avoid diagnostic errors and the appropriate classification of hearing loss according to the degree of loss. Since it is commonly used that when viewing V wave at 30 dBnHL with Click, the study is stopped and it is considered normal hearing[7].

There are previous studies in which SLAEP are compared using Click stimulus and CE-Chirp stimulus; however, they compare other parameters other than the threshold such as the absolute latencies of waves I, III, and V, the interlatency intervals, the amplitude of the V and I waves, and the interaural difference of the V waves between the 2 stimuli finding similar values between the two stimuli; however, they do not specifically compare the difference in V-wave thresholds obtained with CE-Chirp and Click[8]. Other studies have reported differences between audiometric thresholds and SLAEP thresholds with Click[9-11].

Studies have also been carried out where auditory thresholds are compared using different stimuli in the SLAEP, such as tone burst, tone pip, NB-Chirp[12-17] which are specific frequency stimuli. Whose usefulness is restricted to determining hearing by frequency, however, the performance of SLAEP with these stimuli considerably increases the time of performance of the test and limits its use to patients with hearing loss confirmed by CE-Chirp or Click, in whom more information is necessary by frequency, for example for an adequate adaptation of hearing aids. However, the most frequently used and universally used stimuli are the CE-Chirp and the Click, which allow tests to be carried out more quickly to identify normal hearing and hearing loss in the first stage[18].

To our knowledge, there is a study with 10 adult participants (20 ears) with normal hearing, the responses of the SLAEP using the CE-Chirp stimulus and Click stimulus were compared with the auditory thresholds obtained by tonal audiometry, it was found that when the CE-Chirp stimulus was used, the V-wave thresholds are closer to the audiometric thresholds, with a difference of 2 decibels between CE-Chirp and tonal audiometry. However, the sample is very small and the sample is restricted to adults, not including pediatric patients and patients with hearing loss[19,20].

The purpose of this study is to determine what is the difference in decibels between the auditory thresholds obtained with SLAEP with CE-Chirp and the auditory thresholds obtained with Click in the same ears of patients who represent the tertiary hospital population with a spectrum of patients more representative of a specialized hospital service such as ours. Including mostly children who are the ones who are most frequently subjected to SLAEP to determine threshold[20].

Material and methods

A retrospective, cross-sectional, observational, comparative, and descriptive study was conducted. Clinical records of the Audiology, Otoneurology, and Phoniatrics service of the Hospital General de México were reviewed with a graphic report of auditory evoked potentials of short latency belonging to norm hearing or hearing-impaired patients who attended diagnostic evaluation with the interacoustic device model Eclipse EP 25 and that as a diagnostic protocol, they were evaluated with both stimuli, CE-Chirp and Click. The final sample size was 38 ears (19 patients) as explained below.

As a diagnostic protocol, clinical records were reviewed in which the SLAEP was performed on the patients according to the conventional preparation with the following methodology: patients who attended with wakefulness were positioned in the supine position, entering physiological sleep at the beginning of the study, after preparing the patient and placing electrodes, with ER-3A insertion hearing aids. Impedance measurement < 5 Ohms, the stimulation rates were preserved according to how the equipment is programmed from the factory: with Click stimulus at a stimulus presentation rate of 33.1/s and subsequently records with CE-Chirp of 45.1/s, in both cases of alternating polarity. No moving the insertion hearing aids or electrodes during the study.

A total of 300 patient records with CALAP records were reviewed, which included 572 ears, of which 534 ears were excluded because the CALP records presented different situations that influenced their exclusion, such as poor morphology and irregular replicability and patients with central auditory pathology, records with only one type of stimulus, presence of noise, etc. A total of 38 ears, 22 right ears, and 16 left ears were selected that had good quality SLAEP recordings with both Click and CE-Chirp, with replication at all intensities with threshold search up to the lowest possible intensities and that both recordings were made during the same session (Fig. 1).

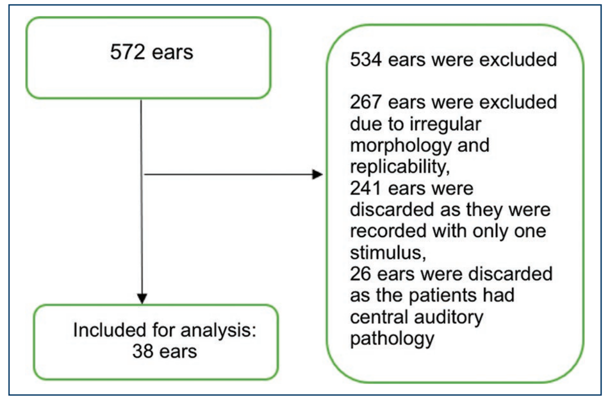

Figure 1. The total number of ears tested, the number of ears excluded for different issues (as described in the figure), and the total number of ears used for the analysis are displayed.

The electrophysiological auditory threshold was defined as the lowest audiological level at which a clear V-wave response was observed for each of the stimuli, CE-Chirp and Click. The aim was for the recordings to have a lower intensity register than the V-wave detection to ensure that at lower intensities the V-wave was no longer identified in both stimuli. The electrophysiological auditory thresholds of the CE-Chirp and Click stimuli were compared in the same ear. The data obtained were analyzed in the SPSS software version 28.0 (IBM Inc.).

Results

17 patients were male and 6 females, the average age was 2 years 8 months. The age range was from 1 month of life to 24 years (Table 1). Eight ears have the diagnosis of hearing loss and 30 ears have normal hearing. The mean electrophysiological auditory threshold obtained with Click stimulus was 30.26 dBnHL with a standard deviation of 20.5 dBnHL. The mean electrophysiological auditory threshold obtained with CE-Chirp stimulus was 23.21 dBnHL with a standard deviation of 19.7 dBnHL. The standard deviations of the electrophysiological auditory thresholds obtained were wide since normal hearing patients and those with hearing loss were included (Table 2 and Fig. 2). The fact that the standard deviations are so wide is to be expected, since patients with normal hearing and with different degrees of hearing loss were included so that the sample of patients was representative of the patients in our department. It was decided to include real patients from a broader spectrum since there is, as mentioned, only one study in normal adults. One objective is to see the behavior of the test with real patients[20].

A t-test of paired samples was performed comparing the means of the electrophysiological auditory thresholds of both stimuli to determine the existence of statistical differences in the means of the thresholds obtained by CE-Chirp and Click in each ear, finding $p = 0.000$ in all cases (total and per ear), which allows us to conclude that the difference between the means is reliable. The results in the right ears were 5682 dB, in the left ears were 7813 dB and the total of 6579 dB always with higher thresholds for the Click. Figure 3 shows the comparison of recordings in one ear of the same patient with normal hearing using Click and CE-Chirp in which a difference of 10 dB nHL between both recordings can be observed.

Table 1. The age range, sex, and hearing of the subjects used for analysis are displayed

Age range (months)	No. patients	Male	Female	Hearing hearing loss	Norm-hearing
1-6	13	11	2	2	11
7-12	4	4	0	1	3
13-24	1	1	0	0	1
2-24 years	5	1	4	3	2
Total	23	17	6	6	17

Table 2. Electrophysiological auditory thresholds obtained with Click stimulus and CE-Chirp stimulus by ear and total. Means of electrophysiological auditory thresholds obtained per ear with standard deviation

Stimulus	Minimum hearing threshold (dB)	Maximum hearing threshold (dB)	Media (dB)	Standard deviation (dB)
Click right ear	10	65	26.82	14.355
Click left ear	15	90	35.00	26.646
Total Click	10	90	30.26	20.532
CE-Chirp right ear	10	60	21.14	14.387
CE-Chirp left ear	5	85	25.50	24.597
Total CE-Chirp	5	85	23.21	19.780

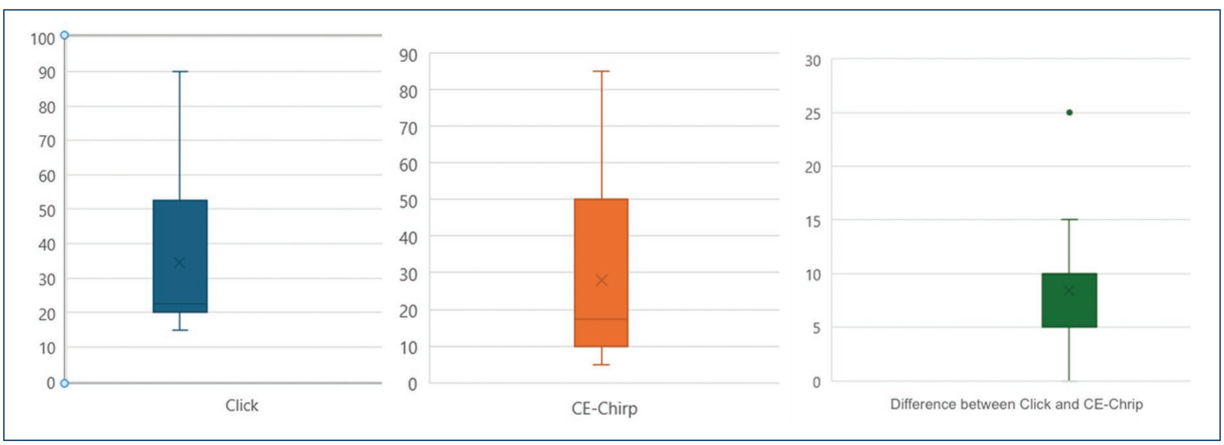

Figure 2. Auditory threshold with Click in blue, with CE-Chirp in orange, difference between the auditory threshold using both stimuli in green, all of the above in dB.

Due to the non-normal distribution and the sample is relatively small, a Wilcoxon test was also performed, since it is a paired sample, also finding a p = 0.

Discussion

According to the results obtained, the difference in the thresholds of SLAEP obtained with CE-Chirp and Click is 6.57 dB, which clearly indicates that the thresholds obtained with CE-Chirp are better than the thresholds obtained with Click; therefore, we propose that to consider the normal threshold of V-wave with CE-Chirp, they should be obtained in a limit between 20 dBnHL and 25 dbNHL. We preferably suggest 20 dBnHL to have a little more specificity and thus avoid false negatives. As mentioned with the Click universally, and for

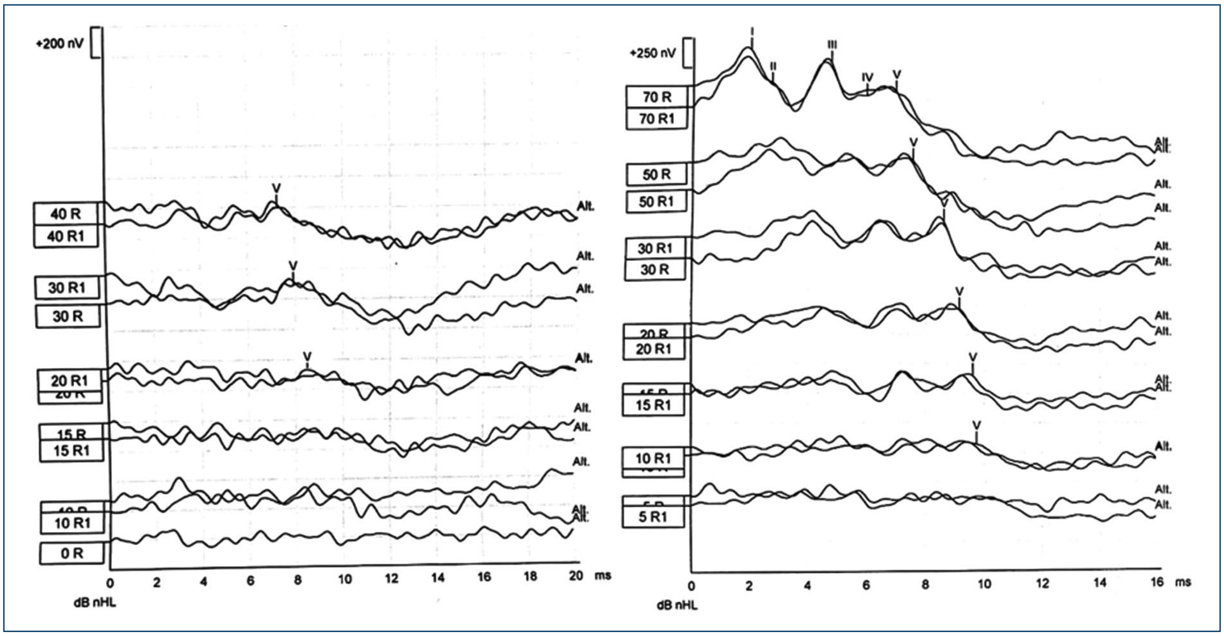

Figure 3. Short-latency auditory evoked potentials of the right ear of a patient with normal hearing using CE-Chirp stimulus on the right side and Click on the left side. A better threshold is observed with CE-Chirp by 10 dBnHL.

decades, the limit of the normal threshold has been considered equal to 30 dBnHL. In our case, we suggest that with CE-Chirp, it is 20 dBnHL. With this correction, we will prevent patients with superficial hearing loss from being misdiagnosed as normal when using CE-Chirp.

The Click stimulus has been used for at least 5 decades or more and there is extensive knowledge of its behavior in SLAEP. However, because the CE-Chirp is more recent (2007), there is less evidence of its electrophysiological performance both for the measurement of auditory thresholds and evaluation of neurophysiological dysfunction. As mentioned, the CE-Chirp will cause a more robust V-wave response to lower the hearing threshold, which is what this study has intended to answer. Moreover, in this way, we would avoid misclassifying the degrees of hearing loss and/or normal hearing and consequently the subsequent management. The results are consistent with the only study in normal adults mentioned above[19].

There are limitations for this study. The number of ears included in the sample is reduced. Moreover, the characteristics of the patients are heterogeneous. Ears with normal hearing, and ears with different degrees of hearing loss were included in the sample. Although most of them were pediatric, there were also X adults. It is necessary to mention that despite this, the behavior of the test was very similar to that obtained in normal adult patients[19]; however, we know that different types and degrees of hearing loss could influence the results. Therefore, we suggest continuing this line of research to evaluate in prospective studies the performance of SLAEP with EC-Chirp in different degrees and types of hearing loss, stratified by age group, as was done in the past with the Click.

Conclusion

This study found different electrophysiological auditory thresholds in the same ears of the same patients with 2 different broadband stimuli, Click and CE-Chirp, which are by far the most universally used. Based on our findings, it is recommended that when determining the hearing threshold in SLAEP with CE-Chirp, a threshold of 20 dBnHL should be considered normal and not 30 dBnHL used with the Click. In this way, errors in the diagnosis, follow-up and management of patients are avoided.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of human and animal subjects. The authors state that no experiments were conducted on humans or animals for this study.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from patients, and received approval from the Ethics Committee. The SAGER guidelines were followed according to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript.

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