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Original Article

Normative auditory brainstem response values to chirp stimulus in adults with normal hearing

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ABSTRACT

Objectives: This study aimed to establish normative values for our clinic by determining Wave V latency and amplitudes with chirp stimulus in adults with normal hearing.

Patients and Methods: A total of 62 (31 males, 31 females; range, 18-60 years) individuals who had no complaints related to hearing and normal otoscopic examinations participated in the study. The participants were divided into two groups, of those age 18-39 years and 40-60 years. In the auditory brainstem response (ABR) recording parameters, CE-Chirp stimuli were used in repeated frequency rarefaction polarity at the rate of 33.1/sec. For the recording window, a setting of 15 milliseconds was selected and a frequency range of 50-1500 Hz for the recording filter. At each level of intensity, 1500 samples were collected and averaged.

Results: At 90 dB nHL, Wave I could not be obtained in 17 subjects and Wave III in 14 subjects. In Wave V values obtained from all of the subjects, the highest amplitude (0.41±0.12 microvolt) was determined as 70 dB nHL and the lowest latency (4.62±0.34 millisecond) 90 dB nHL. In the evaluation according to gender, the Wave V latencies were more delayed in males than in females. In the age-group evaluation, Wave V latencies were more delayed in the 40-60 years age group than in the younger age group.

Conclusion: With CE-Chirp ABR over 70 dB nHL, as there was upward spread of excitation, the wave formations obtained were distorted and amplitudes decreased. Therefore, the determination of the threshold at sound levels of 70 dB nHL and below was considered appropriate for use as a diagnostic method.

Keywords: Auditory brainstem response; auditory brainstem response; CE-Chirp.

Click, tonal, or chirp type stimulus can be used in auditory brainstem response (ABR) measurements.[1] Click stimulus is widely used in ABR measurements. However, the responses obtained using click stimulus are not from the whole cochlea, but are rather thought to originate from basal regions (2-4 kHz).[2]

Therefore, the chirp stimulus was developed to stimulate the entire cochlea simultaneously and provide effective neural synchronisation. Studies report that, since chirp stimulus has a specific sequence from low frequency to high, larger amplitude ABR waves can be formed than with click sounds and the whole cochlea can be stimulated at the same time.[3-5]

Although an objective method, application of well-defined technical regulations and well determined clinical standards are necessary to accurately interpret and benefit from ABR results. The responses obtained from ABR differ

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according to measurement techniques and conditions. Even if appropriate environmental conditions are provided, some factors such as testing environment, the electrical response stimuli, and the age and gender of the patient can affect the ABR wave norms.[6-8] Therefore, every clinic should establish its own standards according to the recording conditions and device.

This study aimed to determine Wave V latencies with CE (Claus Elberling)-Chirp stimulus in adults with normal hearing and to establish normative data for our clinic.

PATIENTS AND METHODS

This prospective study was conducted in the Ear, Nose and Throat Clinic and Head and Neck Surgery Department of Başkent University Medical Faculty Hospital. The study group consisted of a total of 62 individuals, aged 18-60 years, with no hearing complaints and normal results of an otoscopic examination. Evaluation of 124 ears, as 62 ears of 31 females, and 62 ears of 31 males, was performed. To determine age-related differences, the subjects were divided into two groups as those aged 18-39 years and 40-60 years. The inclusion criteria were:

- Normal otoscopic examination of both outer ear canals and tympanic membranes

- In electroacoustic immittance evaluation, middle ear pressure within ±50 daPa of the limits, Type A tympanogram, and normal levels of ipsilateral and contralateral acoustic reflexes between 500-4000 Hz.

- In the audiometric evaluation, a pure tone average (PTA) with maximum of 15 dB nHL for those aged 18-39 years, maximum 20 dB nHL for those aged 40-60 years.

With participation in the study on a voluntary basis, all subjects read and signed the "Voluntary Subject Information and Consent Form".

Before the ABR tests, all subjects underwent a routine ear examination and those whose ear membranes were evaluated to have normal appearance were included in the next stage. For the audiometric examinations, the threshold was determined with an "Interacoustics AC-40" (Interacoustics AS, Assens, Denmark) clinical audiometer in silent rooms of the "Industrial Acoustics Company" standard. Using standard earphones (TDH-39) (Telephonics Co. Farmingdale, NY, USA), the air-conduction thresholds were measured. The bone-conduction measurements were performed using a bone vibrator (Radioear B-71) (RadioEar Co. Middelfart, Denmark). Acoustic immittance measurements were evaluated using an immittance device (Interacoustic AZ 26, Interacoustics AS. Assens, Denmark). Evaluations were made at 226 Hz probe tone.

Approval for the study was granted by the Clinical Research Ethics Committee of Başkent University Medical Faculty (Project no: KA/13 /98).

ABR test

The "Interacoustics Eclipse EP15'' (Interacoustics AS. Assens, Denmark) device was used for ABR recordings. In the recording parameters, CE-Chirp stimuli were used in repeated frequency rarefaction polarity at the rate of 33.1/sec. For the recording window, 15 milliseconds (ms) was selected and a frequency range of 50-1500 Hz for the recording filter. At each level of intensity, 1,500 samples were collected and averaged. Before placement of the electrode, the skin was cleaned with peeling gel and alcohol. For each recording, 4 single-use Ag/AgCl electrodes were used.

The electrodes were placed with the ground lead on the cheekbone, the positive lead on the mid-upper section of the forehead, and the negative electrodes, one on the left ear mastoid and the other on the right ear mastoid. Throughout the test, care was taken to keep the cables as far away from the device as possible, to prevent them from overlapping during the recording to maintain electrode impedance <5 kiloOhms (k). ER-3A insert earphones (Sanibel Supply, Middelfart, Denmark) were used (Etymotic Research). It was evaluated whether Wave I and III could be obtained with CE-Chirp stimulus sent at 90 dB nHL and the Wave V latencies and amplitude values were measured at 20, 40, 50, 70, 90 dB nHL intensity levels. Peak amplitudes were automatically calculated by the device. The Wave V latencies obtained at every level of intensity were grouped and compared according to age and gender.

Table 1. Reference latency measurements of all of the cases according to the intensity levels (n=62)

Intensity (dB nHL)	Mean±SD (ms)	Min-Max
90	4.62±0.34	4.00-5.51
70	5.54±0.36	4.71-6.15
50	6.58±0.38	5.65-7.20
40	7.19±0.42	6.37-8.23
20	8.34±0.42	7.44-9.15

dB nHL: Decibel normal hearing level; SD: Standard deviation; ms: Millisecond; Min: Minimum; Max: Maximum.

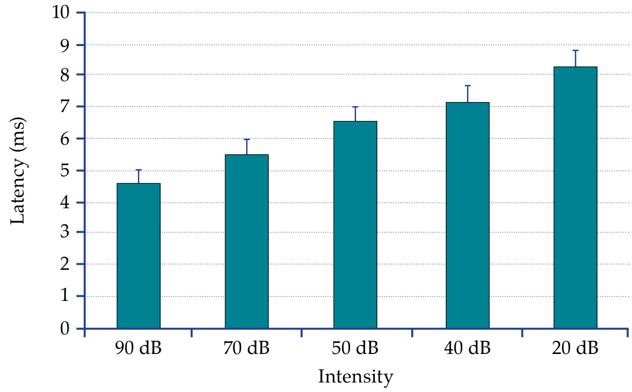

Figure 1. *Mean wave V latency values of all the subjects.*

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, NY, USA). Conformity of continuous numerical variables to normal distribution was assessed with the Kolmogorov-Smirnov test. Descriptive statistics for continuous numerical variables were stated as mean, standard deviation, minimum and maximum values.

The Bonferroni Corrected Wilcoxon Signed Rank test was used to determine any statistical significance a between the measurements of latencies and amplitudes at 90, 70, 50, 40, and 20 dB nHL intensities.

According to the Bonferroni Correction, the values accepted as statistically significant were p<0.010 for the whole group, p<0.05 for male and female groups regardless of age, p<0.005 within the 18-39 years age group and the 40-60 years group regardless of gender, and p<0.0025 for the comparisons within the male and female groups of each age group.

Table 2. Reference latency measurements of the male and female cases at all intensity levels

Intensity (dB nHL)	Mean±SD (ms)	Min-Max	p value*
90			
Male	4.68±0.29	4.27-5.20	0.045
Female	4.56±0.38	4.00-5.51	
70			
Male	5.64±0.32	5.03-6.15	0.042
Female	5.45±0.38	4.71-6.04	
50			
Male	6.74±0.25	6.04-7.20	0.002
Female	6.41±0.42	5.65-7.04	
40			
Male	7.34±0.34	6.75-8.23	0.018
Female	7.05±0.44	6.37-7.88	
20			
Male	8.51±0.33	8.00-9.15	<0.001
Female	8.18±0.45	7.44-9.05	

dB nHL: Decibel normal hearing level; SD: Standard deviation; ms: Millisecond; Min: Minimum; Max: Maximum; * Mann Whitney U test, p<0.010 accepted as statistically significant according to the Bonferroni Correction.

The Bonferroni Correction was applied to be able to obtain Type 1 error control in all the possible multiple comparisons.

RESULTS

Latency data

This study was conducted with the aim of obtaining standard data for ABR chirp stimulus, and a total of 62 individuals, 17 males and 17 females in the 18-39 years age group, and 14 males and 14 females in the 40-60 years age group, were evaluated.

In the entire group of individuals with normal hearing, regardless of age and gender, the Wave V mean latency values for both ears were 8.34, 7.19, 6.58, 5.54, and 4.62 ms at 20, 40, 50, 70, and 90 dB nHL respectively (Table 1). The Wave V latency values of all the subjects were observed to shorten with an increase in dB (Figure 1).

In the statistical evaluation of all of the cases, no statistically significant difference was determined between the Wave V latency values of the right and left ears at all the intensity levels. When the values were evaluated according to gender, no statistically significant difference was determined between the Wave V latency values of the right and left ears at all the intensity levels. In the evaluation of the mean Wave V latency values of both ears, the latencies were determined to be longer in the males than in the females at all intensity levels, with statistical significance at 50 and 20 dB nHL (Table 2).

When the Wave V mean latency values were evaluated according to age groups, the values obtained from the 18-39 years age group were shorter at all intensity levels than those from the 40-60 years age group, with statistical significance determined at 50, 40, and 20 dB nHL (Table 3).

Within the male and female groups, the Wave V mean latency values were shorter at all intensity levels in the 18-39 years age group but not enough to be of statistical significance (Figure 2).

Within each separate age group, the Wave V latency values of the females were shorter than those of the males at all intensity levels. The difference was determined to be statistically significant at 50 and 20 dB nHL in the 18-39 years age group. No statistically significant difference

Table 3. Reference latency measurements at different intensities according to the age groups

Intensity (dB nHL)	Mean±SD (ms)	Min-Max	p value*
90			
18-39 years	4.53±0.28	4.04-5.20	0.030
40-60 years	4.73±0.39	4.00-5.51	
70			
18-39 years	5.44±0.34	4.71-5.97	0.017
40-60 years	5.67±0.35	4.89-6.15	
50			
18-39 years	6.47±0.36	5.65-7.10	**0.006**
40-60 years	6.70±0.38	5.73-7.20	
40			
18-39 years	7.07±0.33	6.37-7.73	**0.004**
40-60 years	7.34±0.47	6.37-8.23	
20			
18-39 years	8.24±0.36	7.47-8.97	**0.007**
40-60 years	8.48±0.46	7.44-9.15	

dB nHL: Decibel normal hearing level; SD: Standard deviation; ms: Millisecond; Min: Minimum; Max: Maximum; * Mann Whitney U test, $p<0.010$ accepted as statistically significant according to the Bonferroni Correction.

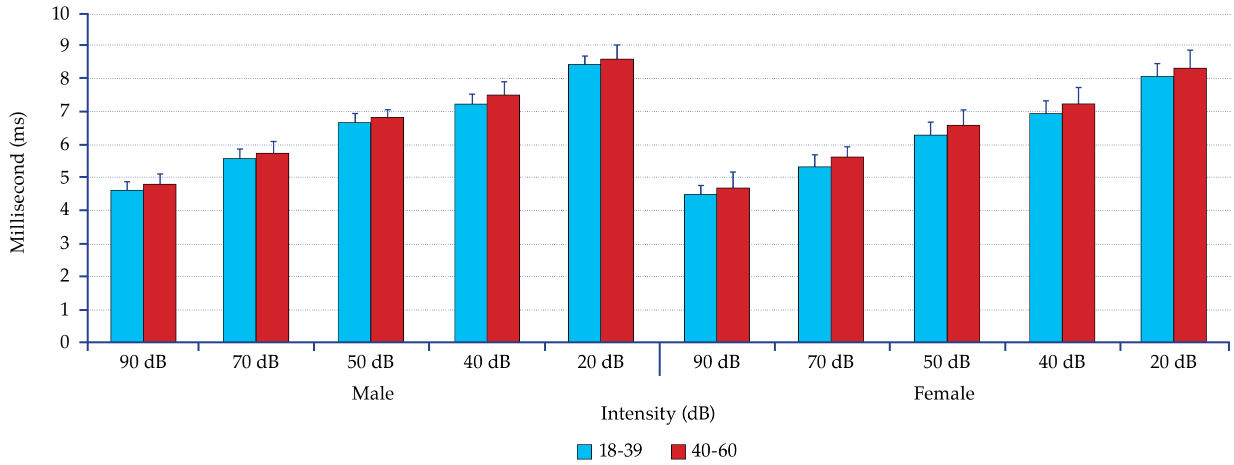

Figure 2. Latency values of the males and females according to intensity level and age groups.

was determined between the genders in the 40-60 years age group.

Amplitude data

No statistically significant difference was determined between the Wave V amplitude values of the right and left ears of the whole group at all sound intensity levels.

The Wave V amplitude data is presented in Table 4 and Figure 3. Waves of greater amplitude were obtained at 70 dB nHL than at other levels. In the statistical analysis of the differences, the amplitude values at 50, 40, and 20 dB nHL intensity were significantly lower than those obtained at 70 dB nHL (p<0.001). No statistically significant difference was determined between the reference amplitude values obtained at 90 and 70 dB nHL or between the values at 90 and 50 dB nHL (p<0.001).

Table 4. Reference amplitude measurements of all subjects at different intensities (n=62)

Intensity (dB nHL)	Mean±SD (µV)	Min-Max
90	0.38±0.10	0.19-0.65
70	0.41±0.12	0.19-0.77
50	0.35±0.13	0.15-0.76
40	0.29±0.10	0.10-0.50
20	0.21±0.09	0.07-049

dB nHL: Decibel normal hearing level; SD: Standard deviation; µV: Microvolt; Min: Minimum; Max: Maximum.

Gender was not observed to have any effect on amplitudes in any of the evaluations of all intensity levels. Differences that were observed were not statistically significant.

The reference amplitude values obtained within the age and gender groups at all of the intensity levels are shown in Table 5.

Wave evaluation

The study also evaluated whether or not Waves I, III, and V could be obtained at high stimulus intensity. At 90 dB nHL, Wave I could not be obtained in 17 (27.4%) of the total 62 subjects and Wave III could not be obtained in 14 (22.6%).

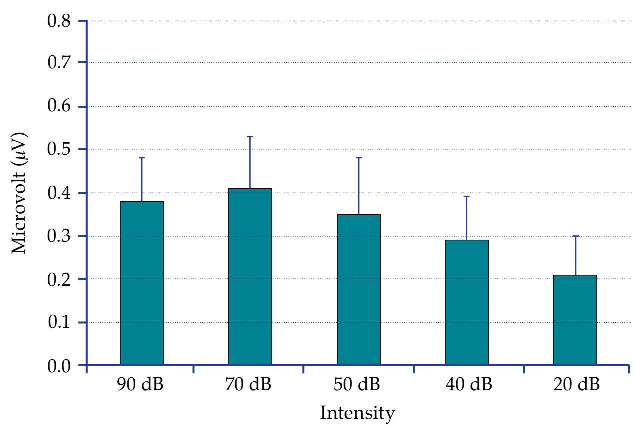

Figure 3. Wave V amplitude distribution of all subjects.

Table 5. Reference amplitude measurements of age and gender groups according to different intensities

Intensity (dB nHL)	Mean±SD (μV)	Min-Max
18-39 years male		
90	0.39±0.13	0.19-0.65
70	0.42±0.18	0.19-0.77
50	0.38±0.18	0.15-0.76
40	0.29±0.10	0.16-0.43
20	0.21±0.13	0.07-0.49
18-39 years female		
90	0.37±0.09	0.22-0.53
70	0.41±0.12	0.25-0.66
50	0.35±0.14	0.15-0.73
40	0.29±0.11	0.13-0.50
20	0.21±0.09	0.11-0.48
18-39 years general		
90	0.38±0.11	0.19-0.65
70	0.41±0.15	0.19-0.77
50	0.36±0.16	0.15-0.76
40	0.29±0.10	0.13-0.50
20	0.21±0.11	0.07-0.49
40-60 years male		
90	0.37±0.11	0.19-0.53
70	0.37±0.09	0.25-0.56
50	0.33±0.09	0.20-0.48
40	0.30±0.09	0.17-0.45
20	0.18±0.07	0.09-0.29
40-60 years female		
90	0.38±0.07	0.26-0.53
70	0.42±0.08	0.33-0.57
50	0.36±0.09	0.19-0.48
40	0.29±0.09	0.10-0.45
20	0.23±0.06	0.11-0.31
40-60 years general		
90	0.37±0.09	0.19-0.53
70	0.40±0.09	0.25-0.57
50	0.34±0.09	0.19-0.48
40	0.29±0.09	0.10-0.45
20	0.20±0.07	0.09-0.31

dB nHL: Decibel normal hearing level; SD: Standard deviation; μV: Microvolt; Min: M inimum; Max: Maximum.

Reference latency and amplitude values

The mean latency reference values obtained for the entire group of 62 subjects were found to be 4.62±0.34, 5.54±0.36, 6.58±0.38, 7.19±0.42, and 8.34±0.42 ms at 90, 70, 50, 40, and 20 dB nHL respectively.

The mean amplitude reference values obtained for the whole group of 62 subjects were found to be 0.38±0.10, 0.41±0.12, 0.35±0.13, 0.29±0.10, and 0.21±0.09 μV at 90, 70, 50, 40, and 20 dB nHL respectively.

DISCUSSION

Auditory brainstem response wave latencies, between-wave latencies, and amplitudes can differ between clinics. This is because of the effect of the type of stimulus used, the recording parameters, and the patient age and gender.[6-8]

The ABR waves obtained with chirp stimulus have been shown to be twice the amplitude and more reliable than those obtained with click stimulus.[3,9-11] This is because the stimulation of all of the cochlear frequencies is shown simultaneously.[3,9] However, the short latency in CE-Chirp ABR is unrelated to this synchronised stimulus, but is more related to the setting of a starting and finishing time of the stimulus.[3,9,11,12]

Almost all of the studies in the literature that have been conducted with chirp stimulus have set the upper limit of stimulus levels as 80 dB nHL or lower. However, for evaluation of hearing status in clinics, a level of 90 -100 dB nHL is used. In the current study, tests were applied at 20, 40, 50, 70, and 90 dB nHL levels. CE-Chirp ABR results obtained with high level sound stimulation require careful interpretation. While CE-Chirp ABR provide better results at lower sound levels, stimulations >60 dB nHL cause desynchronization in wider areas with the upward spread of neural excitation and create waves of weak morphology.[13]

There is no study in literature that has evaluated chirp stimulus with supra aural earphones. Studies using click stimulus have reported that the absolute latency of waves obtained from insert earphones are longer than when obtained with supra aural earphones.[14] However, since type ER-3A insert earphones were available in our clinic and are widely used in clinics, these earphones were used in the study.

According to the literature, wave latencies are shorter in adult females than in males.[15,16]

It has been suggested that differences in ABR waves and between-wave latencies may be due to hormonal factors or shorter neural pathways in the physical structures of females.[17] There is no study on the association between gender and chirp stimulus. In the current study, male subjects had longer latencies than females in all intensity levels. However, in the statistical analyses made at the level of p<0.010, the delay in the males was determined to be statistically significant only at 50 and 20 dB nHL. These results were consistent with the findings of studies in literature obtained with click stimulus.[18]

In the current study, the Wave V latencies of the 18-39 years age group were shorter than those of the 40-60 years age group at all intensity levels. In a study by Lotfi and Abdollah[18] that used click stimulus, the subjects were separated into three age groups of 18-30 years, 31-50 years, and 51-70 years, and the Wave V latencies of the 51-70 years age group were determined to be significantly delayed. The effect of age on latency determined in the current study showed a similarity to results obtained with chirp stimulus. The lengthening of latency that occurs with aging may be due to losses in cochlear capacity over the years and neurodegenerative processes.

Kristensen and Elberling[13] evaluated Wave V latencies and amplitudes at 20, 40, 60, and 80 dB nHL in 10 adults using CE-chirp, click, and LS-chirp stimuli. Wave V latencies with CE-chirp stimulus were found to be 7.99, 6.75, 5.42, and 4.29 ms respectively. Furthermore, in comparison with the other two methods, the shortest latencies were obtained with CE-chirp. In the current study, the Wave V latency values at 20, 40, 50, 70, and 90 dB nHL were determined as 8.34, 7.19, 6.58, 5.54, and 4.62 ms (Tables 4, 5). In the comparison of the results related to the two different age ranges, the values were observed to be close. These small differences may be due to the recording parameters and regional differences.

In the comparison of the amplitude values according to gender and age groups in the current study, no significant differences were determined. Previous studies in literature that used click stimulus have shown that as the intensity decreases, so does the amplitude. However, in the current study that used chirp stimulus, the highest amplitude waves were obtained at 70 dB nHL and when the intensity of the stimulus was reduced from 90 to 70 dB nHL, no increase in Wave V amplitude was observed. Similar results have been reported in various studies.[13,19,20]

In a study by Rodrigues and Lewis[21] conducted with CE-chirp at 80, 60, 40, and 20 dB nHL, the Wave V amplitudes were found to be 0.537, 0.593, 0.575, and 0.304 μV respectively. With the exception of 80 dB, the values at all the other intensity levels were found to be higher than those obtained with click stimulus.

The Wave V amplitude data obtained in the current study were determined to be lower than data reported in literature, especially at high intensity levels (0.38, 0.41, 0.35, 0.29, and 0.21 μV for 90, 70, 50, 40, and 20 dB nHL respectively). CE-chirp ABR results at high intensity levels (>60 dB nHL) require careful interpretation. While CE-Chirp ABR give better results at low sound levels, stimulations >60 dB nHL cause desynchronization in wider areas with the upward spread of neural excitation and create waves of weak morphology.[8]

To overcome this problem, level-specific chirp ABR (LS-Chirp) has been developed and applied. Kristensen and Elberling[13] reported that the waves formed with LS-Chirp and CE-Chirp at low levels such as 20, 40, and 60 dB nHL were of a similar size and these waves were of greater amplitude compared to click ABR. At a level of 80 dB nHL, the wave morphology with CE-chirp stimulus was distorted and the amplitude was observed to decrease, while at the same sound level, the wave morphology with LS-chirp was more regular and was of a significantly greater amplitude.

One limitation of the current study was that when taking the CE-chirp ABR measurements, measurement at 60 dB nHL together with 70 dB nHL could not be taken. If a measurement had been taken at 60 dB nHL, it would have been easier to determine from which exact level the upward spread of excitation started. Therefore, it is difficult to determine whether the distortion of wave morphology began at 60 dB nHL, as stated in literature, or at 70 dB nHL, as found in this study.

In the current study, Wave I could not be obtained in 17 of the 62 patients and Wave III in 14 patients at the level of 90 dB nHL. It is thought that the absence of these waves at high rates could originate from the clearing of Waves I and III by giving the CE-chirp stimulus at 90 dB nHL. As stated above, as the upward spread of excitation occurs at a level over 60 dB nHL, the wave morphology is distorted and amplitude is reduced.

In a study by Pushpalatha and Konadath,[12] the absence of Waves I and III at a high rate was explained by the upward spread of excitation. When clinical applications are taken into consideration, the fact that Waves I and III could not be obtained in several patients is a significant limitation for diagnosis and seems to be a disadvantage of the CE-chirp stimulus. If Waves I and III could be detected with CE-chirp stimulus, the application of this at a level of maximum 70 dB nHL would be appropriate. It could also be considered appropriate to provide the LS-chirp stimulus at higher sound levels if possible to obtain greater wave amplitudes.

Conclusion

In this study, latency and amplitude data were obtained with CE-chirp ABR for our clinic and was applied as normative data. As there was upward spread of excitation with CE-chirp ABR applied at over 70 dB nHL, the wave formations were distorted and the amplitudes decreased. However, the thresholds determined at 70 dB nHL and below are suitable for use as a diagnostic method. In the 18-39 years age group, the latency values obtained from females with CE-chirp ABR at 50 and 20 dB nHL were significantly shorter than those of males. As the waves obtained with CE-chirp ABR at frequencies below 70 dB nHL were of higher amplitude than click stimulus ABR, they can be considered suitable for the threshold determination and use for diagnostic purposes.

Declaration of conflicting interests

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REFERENCES

1. Purdy SC, Abbas PJ. ABR thresholds to tonebursts gated with Blackman and linear windows in adults with high-frequency sensorineural hearing loss. Ear Hear 2002;23:358-68.
2. Gorga MP, Johnson TA, Kaminski JR, Beauchaine KL, Garner CA, Neely ST. Using a combination of click- and tone burst-evoked auditory brain stem response measurements to estimate pure-tone thresholds. Ear Hear 2006;27:60-74.
3. Dau T, Wegner O, Mellert V, Kollmeier B. Auditory brainstem responses with optimized chirp signals compensating basilar-membrane dispersion. J Acoust Soc Am 2000;107:1530-40.
4. Wegner O, Dau T. Frequency specificity of chirp-evoked auditory brainstem responses. J Acoust Soc Am 2002;111:1318-29.
5. Bell SL, Allen R, Lutman ME. An investigation of the use of band-limited chirp stimuli to obtain the auditory brainstem response. Int J Audiol 2002;41:271-8.
6. Hatanaka T, Shuto H, Yasuhara A, Kobayashi Y. Ipsilateral and contralateral recordings of auditory brainstem responses to monaural stimulation. Pediatr Neurol 1988;4:354-7.
7. Gorga MP, Kaminski JR, Beauchaine KL, Jesteadt W, Neely ST. Auditory brainstem responses from children three months to three years of age: normal patterns of response. II. J Speech Hear Res 1989;32:281-8.
8. Sininger YS. Auditory brain stem response for objective measures of hearing. Ear Hear 1993;14:23-30.
9. Neely ST, Norton SJ, Gorga MP, Jesteadt W. Latency of auditory brain-stem responses and otoacoustic emissions using tone-burst stimuli. J Acoust Soc Am 1988;83:652-6.
10. Elberling C, Don M, Cebulla M, Stürzebecher E. Auditory steady-state responses to chirp stimuli based on cochlear traveling wave delay. J Acoust Soc Am 2007;122:2772-85.
11. Elberling C, Don M. A direct approach for the design of chirp stimuli used for the recording of auditory brainstem responses. J Acoust Soc Am 2010;128:2955-64.
12. Pushpalatha ZV, Konadath S. Auditory brainstem responses for click and CE-chirp stimuli in individuals with and without occupational noise exposure. Noise Health 2016;18:260-5.
13. Kristensen SG, Elberling C. Auditory brainstem responses to level-specific chirps in normal-hearing adults. J Am Acad Audiol 2012;23:712-21.
14. Yoshiko K, Fujita Y. Auditory brainstem responses by click stimuli via an earphone--comparison with a headphone. Rinsho Byori 1994;42:1287-93. [Abstract]
15. Costa Neto TT, Ito YI, Fukuda Y, Gananca MM, Caovilla HH. Effects of gender and head size on the auditory brainstem response. Rev Laryngol Otol Rhinol (Bord) 1991;112:17-9.

16. Muş N, Karamanyol M, Dündar A. Investigation of sex effect on hearing function in human by using electric response audiometry. Turkiye Klinikleri J Med Res 1989;7:53-7.
17. Picton TW, Stapells DR, Campbell KB. Auditory evoked potentials from the human cochlea and brainstem. J Otolaryngol Suppl 1981;9:1-41.
18. Lofti Y, Abdollah FZ. Age and gender effects on auditory brain stem response. Iranian Rehabilitation Journal 2012;10:16.
19. Elberling C, Don M. Auditory brainstem responses to a chirp stimulus designed from derived-band latencies in normal-hearing subjects. J Acoust Soc Am 2008;124:3022-37.
20. Elberling C, Callø J, Don M. Evaluating auditory brainstem responses to different chirp stimuli at three levels of stimulation. J Acoust Soc Am 2010;128:215-23.
21. Rodrigues I, Lewis R. Comparison of click and CE-chirp stimuli on Brainstem Auditory Evoked Potential recording. Rev Soc Bras Fonoaudiol 2012;17:412-6.