Anales Médicos

ORIGINAL ARTICLE

Standardization of reference values in short-latency auditory evoked potentials in people over 18 months of age

Estandarización de valores de referencia en potenciales provocados auditivos de latencia corta en mayores de 18 meses

Coral M. Luna-Soto and Jesús A. Silva-Rojas*

Audiology, Otoneurology and Phoniatrics Service, Unidad de Medicina Física y Rehabilitación 601, Hospital General de México Dr. Eduardo Liceaga, Secretaría de Salud, Mexico City, Mexico

Abstract

Background: *Brain stem auditory evoked potentials or short-latency auditory evoked potentials (SLAPP) are the neurophysiological test where bioelectrical responses elicited in the auditory system are obtained from the cochlear nerve to the brain stem following the presentation of a transient acoustic stimulus (click or CE-chirp).* **Objective:** *The objective of the study is to standardize reference values of SLAPP in people over 18 months of age using the eclipse equipment from the Hospital General de Mexico (HGM) for adequate interpretation for clinical diagnostic purposes and as a control group for future research.* **Material and methods:** *A cross-sectional and descriptive study was carried out. Standardization of reference values in short-latency auditory evoked potentials. 34 ears were evaluated from people aged ≥18 months and ≤ 55 years, both genders, who attended the HGM during the period March-June 2024 who agreed to participate, verifying normal hearing.* **Results:** *Based on the Gaussian probabilistic model, ± 2 standard deviations were used in relation to the mean absolute latencies, interlatency intervals, total I-V conduction time, wave V threshold, interaural difference, and wave I/V ratio.* **Conclusion:** *We suggest that the values found can be taken as a reference of normality for studies of SLAPP, when using stimulation rates 45.1, 33.1, and 11.1 stimuli per second with click-type stimulation and CE-chirp in polarity condensation, rarefaction, and alternate, with the eclipse brand interacoustics equipment, since the ranges represent 95.45% of the population of our sample with normal hearing.*

Keywords: *Short latency auditory evoked potentials. Click. CE-chirp. Latency.*

Resumen

Antecedentes: *Los Potenciales Provocados Auditivos de Tallo cerebral (PPATC) o de latencia corta (PPALC) es la prueba neurofisiológica donde se obtienen respuestas bioeléctricas provocadas en el sistema auditivo desde el nervio coclear hasta el tallo cerebral tras la presentación de un estímulo acústico transitorio (click o CE-chirp).* **Objetivo:** *Estandarizar valores de referencia de potenciales provocados auditivos de latencia corta en mayores de 18 meses utilizando el equipo Eclipse del Hospital General de México (HGM) para una adecuada interpretación para fines de diagnóstico clínico y como grupo control para futuras investigaciones.* **Material y métodos:** *Se realizó un estudio transversal y descriptivo. Estandarización de prueba diagnóstica. Se evaluaron 34 oídos de personas con edad igual y/o mayor a 18 meses y menor y/o igual a 55 años, ambos géneros, que asistieron al HGM durante el periodo marzo-junio 2024 que aceptaron participar, comprobando audición normal.* **Resultados:** *Basado en el modelo probabilístico Gaussiano, se utilizaron más menos 2 desviaciones estándar en relación con la media de latencias absolutas, intervalos interlatencia, tiempo total de conducción I-V, umbral de onda V,*

***Correspondence:**
Coral M. Luna-Soto
E-mail: coralmluna@hotmail.com

Date of reception: 10-09-2024
Date of acceptance: 21-03-2025
DOI: 10.24875/AMH.24000021

Available online: 08-09-2025
An Med ABC. 2025;70(3):178-185
www.analesmedicosabc.com

diferencia interaural y relación de onda I/V. **Conclusiones:** *Sugerimos que los valores encontrados pueden ser tomados como referencia de normalidad para estudios de potenciales provocados auditivos de latencia corta, al utilizar tasas de estimulación 45.1, 33.1 y 11.1 estímulos por segundo con estímulo tipo click y CE-chirp en polaridad condensación, rarefacción y alterna, con el equipo eclipse marca interacoustics, ya que los rangos representan al 95,45% de la población de nuestra muestra con audición normal.*

Palabras clave: *Potenciales provocados auditivos de latencia corta. Click. CE-chirp. Latencia.*

Introduction

Brainstem auditory evoked potentials or short-latency auditory evoked potentials (SLAEPs) are neurophysiological tests where bioelectrical responses provoked in the auditory system, from the cochlear nerve to the brainstem, are obtained after the presentation of a transient acoustic stimulus (click or CE-chirp)[1].

Conventionally, SLAEPs have been incorrectly named "evoked" auditory potentials; however, according to the Royal Spanish Academy, "evoke" means to remember something or someone or to bring them to mind (to call a spirit or the dead), so the correct term is "provoked" auditory potentials, meaning to produce or cause something[2].

These have been used in the evaluation of auditory sensitivity in children, in the diagnosis of hearing loss, in intraoperative monitoring, and in the detection of tumors or other retrocochlear disease affecting the conduction of the auditory pathway in the above-mentioned segments[3].

The first reported recordings of auditory action potentials were published from Japan by Yoshie, Ohashi, and Suzuki (1967) using an electrode in the external auditory canal; in France by Portmann, Le Bert, and Aran (1967) using a needle electrode inserted through the tympanic membrane onto the cochlear promontory; and in Israel by Sohmer and Feinmesser (1967) who used an electrode on the earlobe. All showed the N1 and N2 waves of the cochlear nerve action potential and the characteristic increase in latency with a decrease in amplitude at decreasing intensity. However, it was Jewett et al*.* in 1970 who finally clearly described what would become the auditory brainstem response, proposing our current nomenclature for each recorded wave using Roman numerals: I, II, III, IV, V, VI, and VII[4]. The most important being I and V, which consider structures from the auditory nerve to the lateral lemniscus and inferior colliculus.

During gestational development, the maturation of auditory evoked responses tends to proceed from the peripheral to the central auditory system and in a caudal to rostral direction inside the central nervous system. SLAEPs can be recorded in premature patients from the 25th week of gestation; however, the neurophysiological characteristics of SLAEPs change until 18 months of age, which is when the electrophysiological maturation of the auditory pathway ends, and from this age onwards, the responses are practically identical to those of an adult in all their parameters[5].

The interpretation of the results obtained from SLAEP recordings requires values that are representative of a normal population. The fact that there are no universal normal values is due to the many variables that influence the study recordings. The need to standardize SLAEPs is implicitly related to the characteristics of the studied neuroelectrical phenomenon, as it is a signal measured in very small frequency ranges, and several factors can modify these values, such as: environmental conditions under which the study is performed, type of stimulation, polarity, stimulation rate, intensity, population differences in phenotypic and biological characteristics, variability in the manufacturing of recording equipment, accessories to be used, the distance of electrode placement, as well as the patient's muscle relaxation state[6].

Due to the above-mentioned reasons, the use of institutional standards provides a series of important advantages when interpreting recordings. Various studies currently support the recommendation that the equipment of each institution should have its normative values according to the population to be studied[7].

This study established SLAEP normality standards for normo-hearing subjects older than 18 months without current or previous neurological disease or current or previous otological disease, which will be representative for adulthood (inter-latency interval values I-III, III-V, total central conduction time with the I-V interval, absolute latencies of components I, III, and V, interaural difference of I-V intervals, amplitude ratio of waves I/V). All these parameters were assessed using different stimulation rates and polarities.

It is necessary to standardize SLAE*P* values because each device can give slightly different values depending on the characteristics of the population being evaluated and inherent differences in each device[8].

Table 1. Rate 11.1 Stimuli/Sec. Condensation polarity

Variable	CLICK			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.6	1.34	1.87	1.68	1.42	1.95
Wave II	2.59	2.24	2.93	2.79	2.52	3.07
Wave III	3.68	3.40	3.95	3.76	3.48	4.03
Wave IV	4.85	4.53	5.17	-	-	-
Wave V	5.45	4.99	5.90	5.31	4.9	5.72
Interval I-III	2.07	1.84	2.30	2.07	1.77	2.36
Interval III-V	1.76	1.28	2.25	1.55	1.24	1.87
Interval I-V	3.84	3.26	4.42	3.63	3.21	4.04
Interaural difference V-V	0.1680	0	0.39	0.17	0	0.42

σ: standard deviation.

Table 2. Rate 11.1 Stimuli/Sec. Rarefaction polarity

Variable	Click			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.68	1.41	1.94	1.69	1.41	1.96
Wave II	2.63	2.21	3.06	2.78	2.52	3.04
Wave III	3.80	3.46	4.13	3.77	3.47	4.07
Wave IV	4.90	4.51	5.29	-	-	-
Wave V	5.50	4.98	6.01	5.23	4.71	5.75
Interval I-III	2.22	1.03	3.40	2.08	1.74	2.42
Interval III-V	1.69	1.30	2.09	1.45	1.08	1.82
Interval I-V	3.82	3.26	4.37	3.54	3.03	4.05
Interaural difference V-V	0.15	0	0.45	0.13	0	0.35

σ: standard deviation.

The eclipse equipment from the Interacoustics brand at the Audiology, Otoneurology, and Phoniatrics service of Hospital General de México (Mexico City, Mexico) has not been standardized in the Mexican population; the equipment has normative values obtained in Denmark in 2012 by evaluating 10 adult subjects representing a different population[9,10].

Material and methods

We conducted a cross-sectional and descriptive study. It involved the standardization of a diagnostic test. A total of 34 ears from individuals aged 18 months and older, and 55 years and younger, of both genders, who attended Hospital General de México during the March-June 2024 period and agreed to participate in the study, were evaluated. Tone audiometry was performed to verify normal hearing thresholds, and impedance audiometry was performed to rule out middle ear disease and stapedial reflex arc issues. Instructions were given for hours of wakefulness to attend a 2nd visit for the SLAPP study. This study was conducted with conventional patient preparation, lying on a stretcher in a relaxed state. Cup electrodes were placed and named according

Table 3. Rate 11.1 Stimuli/Sec. Alternating polarity

Variable	Click			CE-Chirp		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.63	1.38	1.88	1.68	1.40	1.96
Wave II	2.62	2.23	3.01	2.77	2.45	3.08
Wave III	3.72	3.38	4.06	3.74	3.44	4.05
Wave IV	4.74	4.35	5.14	4.95	4.80	5.09
Wave V	5.46	4.99	5.93	5.23	4.79	5.68
Interval I-III	2.09	1.81	2.36	2.06	1.79	2.34
Interval III-V	1.73	1.37	2.10	1.48	1.18	1.78
Interval I-V	3.83	3.38	4.28	3.55	3.13	3.96
Interaural difference V-V	0.12	0	0.34	0.14	0	0.36

σ: standard deviation.

Table 4. Rate 33.1 Stimuli/Sec. Condensation polarity

Variable	Click			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.54	1.31	1.78	1.77	1.44	2.11
Wave II	2.53	2.16	2.90	2.82	2.40	3.24
Wave III	3.81	3.50	4.12	3.92	3.61	4.24
Wave IV	4.91	4.46	5.35	5.17	4.90	5.44
Wave V	5.76	5.47	6.04	5.69	5.27	6.10
Interval I-III	2.26	1.98	2.54	2.15	1.85	2.44
Interval III-V	1.94	1.67	2.22	1.76	1.46	2.60
Interval I-V	4.21	3.96	4.46	3.91	3.58	4.24
Interaural difference V-V	0.07	0	0.23	0.14	0	0.45
Threshold	14	-	-	8	-	-

σ: standard deviation.

to the international 10-20 system for extracranial electrode placement[11], with cleaning performed in the scalp regions where they were located; points M1 (left mastoid), M2 (right mastoid), Cz (vertex of the calvarium), and Fpz (forehead), using the eclipse potentials equipment, in a sound-attenuated room through insert earphones (ER-3a), with impedances < 5kΩ, using different rates and polarities with monaural stimuli: CE-chirp and click types, in alternating, rarefaction, and condensation polarities with 2000 averages. The recording window was 20 ms. Initially, for audiological potentials, the auditory threshold of each ear was confirmed down to the identification of the Wave V threshold in decreasing 5dBnHL steps using stimulation rates of 45.1/s and 33.1/s. Subsequently, auditory evoked potentials were recorded in neurological modality at an intensity of 70 dBSL, lowering the stimulation rate to 11.1 stimuli/s with exclusively rarefaction polarity.

The values evaluated from the recording were the latency of intervals I-III, III-V, and the total central conduction time with the I-V interval, the absolute

Table 5. Rate 33.1 Stimuli/Sec. Rarefaction polarity

Variable	CLICK			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.68	1.43	1.93	1.78	1.54	2.02
Wave II	2.69	2.14	3.24	2.84	2.53	3.14
Wave III	3.86	3.33	4.38	3.92	3.58	4.25
Wave IV	5.03	4.95	5.11	5.03	4.93	5.13
Wave V	5.68	5.26	6.10	5.74	5.30	6.17
Interval I-III	2.17	1.71	2.63	2.13	1.87	2.40
Interval III-V	1.82	1.42	2.22	1.82	1.43	2.20
Interval I-V	4.00	3.53	4.46	3.80	2.71	4.90
Difference V-V	0.13	0	0.46	0.15	0	0.38
Threshold	12.5	-	-	8	-	-

σ: standard deviation.

Table 6. Rate 33.1 Stimuli/Sec. Alternating polarity

Variable	Click			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.66	1.29	2.04	1.77	1.49	2.06
Wave II	2.65	2.14	3.16	2.85	2.52	3.18
Wave III	3.89	3.53	4.26	3.91	3.62	4.21
Wave IV	5.05	4.56	5.54	5.15	4.95	5.36
Wave V	5.79	5.37	6.21	5.70	5.26	6.15
Interval I-III	2.23	1.87	2.58	2.13	1.90	2.37
Interval III-V	1.89	1.53	2.25	1.78	1.45	2.12
Interval I-V	4.12	3.76	4.48	3.92	3.66	4.19
Interaural difference V-V	0.15	0	0.48	0.07	0	0.19
Threshold	12	-	-	9.5	-	-

σ: standard deviation.

latencies of components I, III, and V, the interaural difference, and the amplitude ratio of waves I/V according to the suggestions of the American Society for Clinical Neurophysiology[12].

Results

Electrophysiological measurements were performed on a total of 34 ears at the Audiology, Otoneurology, and Phoniatrics service unit. Four of these were discarded due to various technical reasons that resulted in poor-quality auditory evoked potential recordings. Measurements were taken for absolute latencies of components I, II, III, IV, and V, inter-latency intervals I-III, III-V, and the total central conduction time with the I-V interval, Wave V threshold, amplitude ratio of waves I/V, as well as the interaural difference of V-V intervals using click and

Table 7. Rate 45.1 Stimuli/Sec. Condensation polarity

Variable	Click			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.67	1.33	2.00	1.65	1.45	1.85
Wave II	2.65	2.23	3.07	2.91	2.56	3.27
Wave III	4.00	3.48	4.52	4.05	3.70	4.39
Wave IV	4.99	4.60	5.37	5.33	-	-
Wave V	5.87	5.46	6.29	5.83	5.40	6.25
Interval I-III	2.30	1.79	2.82	2.16	1.88	2.43
Interval III-V	1.90	1.42	2.37	1.78	1.44	2.11
Interval I-V	4.21	3.65	4.76	3.94	3.58	4.30
Interaural difference V-V	0.07	0	0.18	0.18	0	0.54
Threshold	9	-	-	8	-	-

σ: standard deviation.

Table 8. Rate 45.1 Stimuli/Sec. Rarefaction polarity

Variable	CLICK			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.88	1.45	2.30	1.89	1.61	2.18
Wave II	2.73	2.26	3.19	2.96	2.55	3.37
Wave III	4.02	3.59	4.46	4.04	3.70	4.32
Wave IV	4.96	4.73	5.18	5.25	4.90	5.57
Wave V	5.88	5.38	6.38	5.87	5.51	6.23
Interval I-III	2.14	1.73	2.55	2.15	1.77	2.52
Interval III-V	1.87	1.34	2.40	1.82	1.57	2.07
Interval I-V	4.00	3.55	4.45	3.97	3.57	4.38
Interaural difference V-V	0.14	0	0.33	0.19	0	0.52
Threshold	10	-	-	8.5	-	-

σ: standard deviation.

CE-chirp stimuli in condensation, rarefaction, and alternating polarity, in patients older than 18 months. A total of 14 of the 30 ears were men's ears and 15, women's ears, with an age range from 4 to 32 years. Based on the Gaussian probabilistic model, ± 2 standard deviations (SD) were used in relation to the mean of each of the parameters to be normalized: absolute latencies, inter-latency intervals, total I-V conduction time, Wave V threshold, and the interaural difference. Where using only 1 SD would represent 68.27% of the population, while using 2 SD would represent 95.45%. Therefore, the objective was to find normal representation limits for each of the mentioned parameters (Tables 1-9) in our population and equipment, thereby avoiding erroneous diagnoses and mismanagement of our patients[7].

Table 9. Rate 45.1 Stimuli/Sec. Alternating polarity

Variable	Click			CE-CHIRP		
	Arithmetic mean (μ)	μ – 2σ	μ + 2σ	Arithmetic mean (μ)	μ – 2σ	μ + 2σ
Wave I	1.80	1.37	2.23	1.89	1.57	2.20
Wave II	2.68	2.19	3.18	2.90	2.53	3.27
Wave III	3.96	3.55	4.36	4.03	3.69	4.37
Wave IV	5.03	4.36	5.69	5.33	5.15	5.51
Wave V	5.92	5.57	6.27	5.81	5.42	6.21
Interval I-III	2.15	1.73	2.57	2.13	1.71	2.56
Interval III-V	1.96	1.61	2.31	1.78	1.41	2.15
Interval I-V	4.12	3.71	4.53	3.92	3.50	4.34
Interaural difference V-V	0.16	0	0.38	0.14	0	0.50
Threshold	10.5	-	-	7.5	-	-

σ: standard deviation.

Conclusion

We suggest that the values found should be taken as a reference for normality when performing SLAPP studies, using stimulation rates of 45.1, 33.1, and 11.1 stimuli per second with click and CE-chirp stimuli in condensation, rarefaction, and alternating polarity, with the Interacoustics Eclipse equipment. This is because the ranges represent 95.45% of our sample population with normal hearing. These values can be compared when conducting studies with patients who have different audiological conditions that may fall outside these ranges, considering these values as "not normal." A better separation of waves IV and V was also observed when using the click stimulus and a greater Wave V amplitude in recordings with CE-chirp; therefore, we recommend using the click stimulus for performing SLAPP in their neurological modality and the CE-chirp stimulus for performing SLAPP for auditory threshold search (Wave V).

It is suggested to complement the results with further studies, including a larger sample size with a population in different age ranges < 3 years, and conduct additional evaluations with the same parameters of our study in patients with different auditory pathologies to compare the results obtained from this study.

Of note, unlike the click stimulus, which produced inter-latency intervals with very similar values regardless of the stimulation rate and stimulus polarity, the CE-chirp showed great variability. Therefore, we do not suggest the use of the latter stimulus for neurological evaluation, only for the determination of electrophysiological auditory thresholds.

Acknowledgments

The authors would like to thank Dr. L. Reyes-Contreras for her support in conducting this study.

Funding

The authors declare that they have not received funding.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The study does not involve patient personal data nor requires ethical approval. The SAGER guidelines do not apply.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

References

1. Young A, Cornejo J, Spinner A. Auditory brainstem response. In: Stat Pearls. Treasure Island, FL: StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/nbk564321 [Last accessed on 2024 Jun 30].
2. Asociación De Academias De La Lengua Española (ASALE). Diccionario De La Lengua Española. Madrid: Real Academia Española; 2023. Available from: https://dle.rae.es/evocar?m=form [Last accessed on 2024 Jan 01].
3. Delgado JH, Zenker CF, Barajas JJ. Normalización de los potenciales evocados auditivos del tronco cerebral: resultados en una muestra de adultos normoyentes. Auditio Rev Electron Audiol. 2003;2:13-8.
4. Picton TW, Hillyard SA, Krausz HI, Galambos R. Human auditory evoked potentials. I. Evaluation of components. Electroencephalogr Clin Neurophysiol. 1974;36:179-90.
5. Hall JW 3rd. Handbook of Auditory Evoked Responses: Principles, Procedures and Protocols. Boston: Pearson; 2015.
6. Chiappa KH, Ropper AH. Evoked potentials in clinical medicine (first of two parts). N Engl J Med. 1982;306:1140-50.
7. Pelaquim A, Sanfins MD, Fornazieri MA. Standardization of latency and amplitude values of short, middle and long latency auditory evoked potentials in adults. Int Arch Otorhinolaryngol. 2023;27:e278-85.
8. Sanfins MD, Colella-Santos MF, Ferrazoli N, Rezende A, Donadon C, Gos E, et al. Latency and interpeak interval values of auditory brainstem response in 73 individuals with normal hearing. Med Sci Monit. 2022;28:e937847.
9. Interacoustics. Additional Information Eclipse OAE Suite. Middelfart, Denmark: Interacoustics A/S; 2022. Available from: https://www.interacoustics.com/images/files/manuals/d-0120572-e-2022-10-additional-information---eclipse-oae-suite-1-copy-1.pdf [Last accessed on 2025 Jun 30].
10. Kristensen SG, Elberling C. Auditory brainstem responses to level-specific chirps in normal-hearing adults. J Am Acad Audiol. 2012;23:712-21.
11. Novo-Olivas CA, Chacón-Gutiérrez L, Barradas-Bribiesca JA. Mapeo electroencefalográfico y neurofeedback; 2010. Available from: https://www.researchgate.net/publication/282294960-mapeo-electroencefalografico-y-neurofeedback [Last accessed on 2025 Jul 08].
12. Stone JL, Calderon-Arnulphi M, Watson KS, Patel K, Mander NS, Suss N, et al. Brainstem auditory evoked potentials: a review and modified studies in healthy subjects. J Clin Neurophysiol. 2009;26:167-75.