Normative values for binaural brainstem auditory evoked potential in adults

Valores normativos para potencial evocado auditivo de tronco encefálico binaural em adultos

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ABSTRACT

Purpose: To analyze the values of the Binaural Auditory Brainstem Response (BI–ABR) to generate normative results of amplitude and latency in normal-hearing adults. **Methods:** The clinical study involved 28 participants who underwent anamnesis and audiological evaluation. Those who met the inclusion criteria were submitted to BI–ABR with 2000 stimuli, a presentation rate of 21.1 clicks per second, an intensity of 80 dBnHL, and rarefaction polarity. **Results:** The results of the Binaural Auditory Brainstem Response (BI–ABR) were analyzed using descriptive statistics, including mean, standard deviation, and confidence interval. When compared with the literature, they show that the difference between binaural and monaural brainstem responses is not considerable. The study confirms that binaural stimulation increases response amplitude due to the independence of the auditory pathways. The results of this study can serve as a standard of normality for BIC latency and amplitude in normal-hearing adults. No significant differences were observed in wave I, III, and V latencies between the monaural and binaural responses. In contrast, a significant increase in wave V amplitude was observed under binaural stimulation compared to monaural stimulation. **Conclusion:** Reference values were established for BI–ABR in adults with normal hearing, including latency and amplitude of the Binaural Interaction Component (BIC). The latency and amplitude measurements of the BI–ABR showed similarities between the right and left ears of normal-hearing individuals.

Keywords: Auditory pathways; Latency; Evoked potential; Adults; Hearing

RESUMO

Objetivo: Analisar os valores do Potencial Evocado Auditivo de Tronco Encefálico Binaural (PEATE-BI) para gerar resultados normativos de amplitude e latência em adultos normo-ouvintes. **Métodos:** O estudo clínico envolveu 28 participantes que passaram por anamnese e avaliação audiológica. Os que atenderam aos critérios de inclusão foram submetidos ao PEATE-BI com 2000 estímulos, com 21,1 cliques por segundo, intensidade de 80 dBnNA e polaridade rarefeita. **Resultados:** Os resultados do PEATE-BI foram analisados por meio de estatísticas descritivas, incluindo média, desvio padrão e intervalo de confiança. Quando comparados com a literatura, mostraram que a diferença entre as respostas binaurais e monoaurais no tronco encefálico não foi expressiva. O estudo confirmou que a estimulação binaural aumenta a amplitude da resposta, devido à independência das vias auditivas. Os resultados deste estudo podem servir como padrão de normalidade para latência e amplitude do componente de interação binaural (*binaural interaction component*) em adultos normo-ouvintes. Não foram observadas diferenças significativas nas latências das ondas I, III e V entre as respostas monoaurais e binaurais. Em contrapartida, foi observado aumento significativo da amplitude da onda V sob estimulação binaural, em comparação à monoaural. **Conclusão:** Foram estabelecidos valores de referência para o PEATE–BI em adultos com audição normal, incluindo latência e amplitude do componente de interação binaural. As medições das latências e amplitudes do PEATE–BI mostraram semelhanças entre as orelhas direita e esquerda dos ouvintes normais.

Palavras-chave: Vias auditivas; Latência; Potencial evocado; Adultos; Audição

INTRODUCTION

Binaural hearing can be defined as the use of both ears to map sound in space, perform speech recognition or select distant sounds, perceive differences between soft sounds, and separate speech from background noise. Also known as spatial hearing, it allows human beings, among mammals, to be considered the most endowed in terms of communication. In addition, it provides individuals with the ability to perceive both the number and the location of sound sources in the environment, ensures that the characteristics and dimensions of empty or enclosed spaces can be identified, and contributes to the ability to understand speech in environments with competing voices.

What differentiates sound stimuli are the characteristics of frequency, intensity and time. Two sounds with the same characteristics, directed in front of or behind a person with normal hearing may be indistinguishable. Any change in the sound characteristics forces the auditory system to adapt and generate different responses in order to process the new information. These changes can be: Inter-aural Time Difference (ITD), Inter-aural Loudness Difference (ILD) and Head Related Transfer Function (HRTF)[1].

Evaluation of binaural hearing verifys the auditory mechanism that contributes to the central processing of the sound stimuli, acting in the mechanism of sound-sources localization as well as the process of perception and selection of sound of interest in noise[2].

Deficits in auditory perception may stem from alterations in both the peripheral and central auditory systems. Studies on impaired binaural hearing include conditions such as autism spectrum disorders (ASD)[3], peripheral hearing loss[4], unilateral hearing loss[5], aging[6] and central pathologies such as amyotrophic lateral sclerosis, tumors and brain lesions[7].

The Auditory Brainstem Response (ABR) is the most widely used diagnoses tool in short-latency evoked potentials in clinical settings. It is specially vital in neonatal hearing program and pediatric audiology, as it does not require a patient response. The acoustic stimuli typically used, consists of a series of clicks or short-durations tones. The ABR includes seven neural components, but in clinical practice only waves I, III and V are analyzed.

Regarding their neural generators, wave I originates from the distal portion of the auditory nerve, wave III arises from the coclear nucleus, and wave V is generated in the lateral lemniscus[8].

The electrophysiological responses obtained are used to investigate thresholds, the integrity and maturation of the auditory pathway and the topodiagnosis of the cochlear and retrocochlear alterations[9]. Due to the maturational state of auditory pathways latency values are inversely proportional to age, typically being shorter in adults compared to the pediatric population.

The Binaural Interaction Component (BIC) of the click-evoked ABR has the potential to serve as a biomarker for auditory processing disorders[10]. However, its application remains infrequent in clinical routine. The BIC is derived by subtracting the sum While this residual response should theoretically be null in the absence of noise or artifacts, clinical practice reveals a distinct positive deflection occurring near the latency of wave V. This suggests that the simultaneous activation of auditory pathways during binaural stimulation yields a non-linear response compared to monaural activation[11].

Despite advances in research, normative data for the BIC variability in adults are still lacking. Therefore, this study aims to analyze Binaural Auditory Brainstem Response (ABR-BI) values to establish normative amplitude and latency parameters for normal-hearing adults. Consequently, provide results of improved analysis of binaural hearing related to auditory processing and hearing skills development.

METHODS

This clinical, evaluative, and quantitative investigation was carried out between September 2023 and August 2024. Data were obtained through Auditory Brainstem Response (ABR) assessments. The study followed ethical principles and was approved by the Research Ethics Committee of the Federal University of Paraíba - CEP/UFPB, Opinion nº 6.213.632, Certificate of Ethical Review (CAAE): 70626223.3.0000.5188, issued on September 2, 2023.

Population

The populations comprised 28 participants (four male and 24 female), with mean age of 25 years and 8 months (range from 20 years to 55 years and 7 months). The sample was non-probabilistic, based on the availability of volunteers who met the inclusion criteria. The results showed relatively narrow confidence intervals (95%), indicating good precision of the estimate, supporting sample adequacy for this stage. All participants assigned the informed consent form.

Inclusion and exclusion criteria

The inclusion criteria required participants to exhibit auditory thresholds within normal limits[12] (≤ 20 dB nHL) and normal middle ear function, characterized by Type A or Ad tympanometric curves and the presence of ipsilateral and contralateral acoustic reflexes. Additionally, participants were required to be free of any subjective auditory complaints.

Conversely, individuals were excluded if they presented with external auditory canal obstruction, abnormal audiological findings, specific learning disabilities, central auditory processing disorders, or any diagnosed neurological conditions.

Instruments and evaluated examinations

Data collection was conducted using KaWe® otoscope; Apololabs acoustic booth; Inventis (Flute) immittance meter; Interacoustics (AD629) audiometer; two-channel equipment for ABR-BI (Smart EP USB Jr system - Intelligent Hearing System, Miami, USA), in an acoustically treated booth with proper electrical grounding.

Participants completed an anamnesis including identification data, auditory complaints, audiological history, previous examinations, diseases, medication use, and hospitalizations.

They then underwent otoscopy to identify any obstruction and to verify tympanic membrane integrity. Tympanometry was then conducted to evaluate middle-ear integrity.

Pure tone audiometry was performed to obtain the auditory thresholds (500-8000Hz).

Participants who met the inclusion criteria were underwent the Binaural Auditory Brainstem Response examination (ABR-BI).

Skin was cleaned with gauze and NuPrep abrasive paste.

For ABR-BI, four electrodes were placed: two on the mastoids (M1, M2), one non- inverting at Cz, and one ground at the Fz. Insert phones and click stimuli were used. Two repetitions were collected for each ear and one binaural repetition (two binaural waves, one for each channel). Rest-intervals of 15-30 minutes were provided if needed.

Signal acquisition followed an adapted protocol: 2000 stimuli (0.1 ms duration), up to 10% rejected stimuli, 21.1 stimuli/s, 80dBnHL, rarefaction polarity, 12ms window, 30-3000Hz filter, 100 µV gain, electrode impedance 1-3 kΩ. Specifications appear in Chart 1.

Waves I, III and V were identified independently by two experienced researchers blinded to experimental conditions. Disagreements were resolved by consensus. Normative values used by the equipment appear in Table 1.

After collecting the ABR waves, the BIC was analyzed by summing monaural responses (right + left) and subtracting the sum of binaural response B(A) + B(B), as shown n Figure 1.

Procedures

The procedural flowchart is shown in Figure 2.

Analysis

A descriptive statistical analysis was conducted to determine the minimum, maximum, mean, standard deviation, and 95% confidence intervals. Shapiro-Wilk tests indicated a non-normal distribution for binaural wave III and monaural and binaural wave V ($p < 0.05$). Therefore, Wilcoxon non-parametric tests were used. Statistical power analysis was conducted using G*Power.

RESULTS

Reference values for ABR-BI in normal hearing adults were established, with mean, standard deviation, and confidence intervals shown in Table 2.

Wilcoxon tests showed no significant differences between binaural and monaural latencies for Waves I (Z = - 0.324, p = 0.746), III (Z= - 0.832, p = 0.406), or V (Z= - 0.350, p = 0.726). Effect sizes were small ($r \leq 0.16$), and statistical power ranged from 0.07 to 0.19, indicating low likelihood of detecting subtle differences.

A significant difference was found between binaural and monaural amplitudes of wave V (Z= - 3.672, p < 0.001). Effect size was large (r = 0.69), with post hoc power near 1.00.

Table 3 presents normative values based on mean ± 2 SD.

Figure 3 displays latency and amplitude values for the sum of monaural responses, binaural responses and the BIC.

Table 4 presents normative ranges for BIC latency and amplitude.

Figure 4 shows latencies of waves I, III, and V for monaural and binaural conditions.

DISCUSSION

The ABR–BI results (Table 1, Figure 3) indicated that binaural stimulation produced significantly greater amplitude compared to monaural stimulation, approximating the sum of monaural responses. The difference between the binaural response and the sum of monaural responses corresponds to the binaural interaction component Binaural Interaction Component (BIC, Figure 1)[14,15], showing that central auditory pathways enhance neural responses. This aligns with previous studies showing that binaural ABR provides additional information on central auditory integrity not captured by monaural assessment[6,14].

Chart 1. Adapted protocol for click-evoked Auditory Brainstem Response acquisition

Parameter	Settings
Transducer	ER-3A insert earphones
Electrode impedance	1 – 3 kΩ (kilo-ohms)
Stimulus	Click
Acquisition window	12 ms
Stimulus duration	0,1 ms
Gain	100 µV (microvolts)
Mode of presentation	Monoaural and binaural air conduction
Polarity	Rarefaction
Rate	21.1 /seconds
Intensity	80 dBnNHL
Filter	30-3000 Hz
Number of stimuli	2000
Percentage of rejected stimuli	< 10%

Subtitle: ms = milliseconds; dBnHL = decibels referenced to normal hearing level; < = less than; % = percentage. Source: Hall[19]

Table 1. Normative values for latencies of peaks I, III, and V and interpeak intervals III–I, III–V, and V–I of monaural responses

Intensity	I	III	V	I – III	III – V	I – V
80 dB	1.51-1.94	3.66-4.32	5.32-6.04	2.00-2.48	1.48-1.92	3.71-4.19

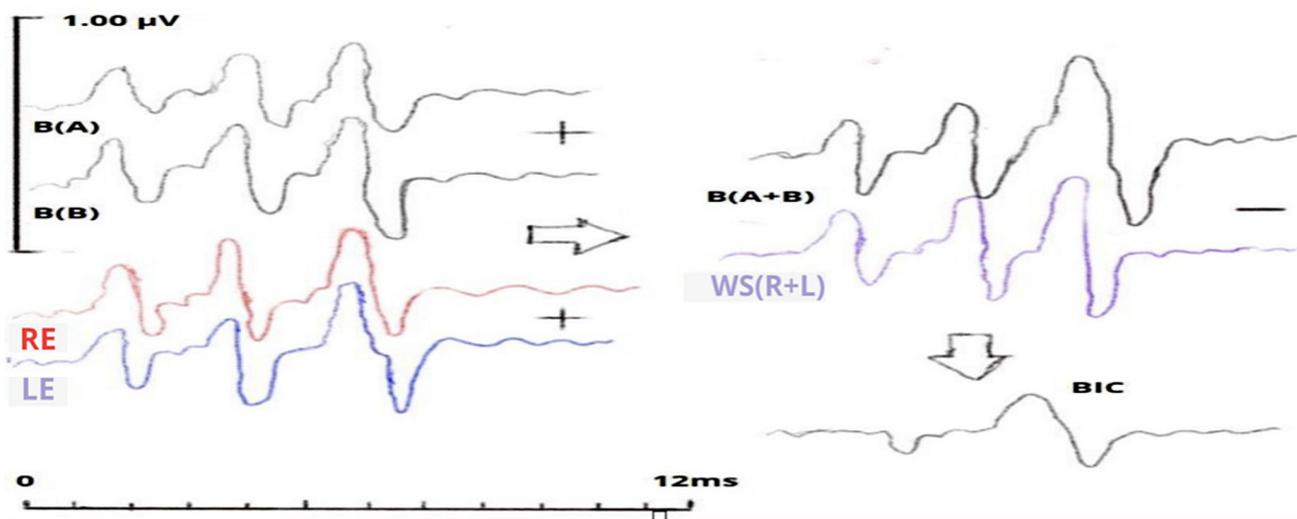**Subtitle:** dB = decibels. Source: Krishnan et al.[13]

Figure 1. Example of the calculation of the binaural interaction component
Subtitle: BIC = binaural interaction component; B(A) = binaural wave, right channel; B(B) = binaural wave, left channel; RE = right ear monaural wave; LE = left ear monaural wave; B(A+B) = wave resulting from the sum of binaural responses from the right (A) and left (B) channels; WS(R+L) = wave resulting from the sum of monaural responses from the right and left ears; BIC = positive peak resulting from the subtraction of WS(R+L) from B(A+B); ms = milliseconds; μV = microvolts
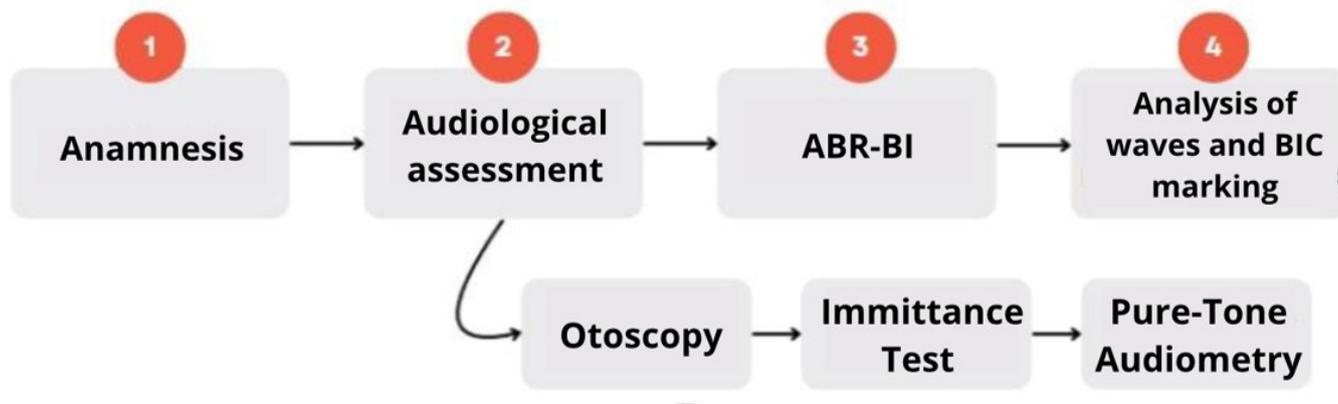

Figure 2. Flowchart of the procedures
Subtitle: ABR-BI = Binaural Auditory Brainstem Response; BIC = binaural interaction component

Table 2. Minimum and maximum latencies of binaural peaks I, III, and V and interpeak intervals III–I, V–III, and V–I, with mean, standard deviation, and confidence interval

B(A+B) Latency/ms	n	Minimum	Maximum	Mean	SD	CI (95%)	p Value
	28						
I		1.53	2.05	1.71	0.12	1.66 - 1.75	0.06
III		3.50	4.35	3.81	0.18	3.74 - 3.87	0.03
V		5.25	6.40	5.64	0.27	5.54 - 5.74	0.01
Amp V		0.32	1.95	0.78	0.38	0.63 - 0.93	< 0.001
I - III		1.85	2.35	2.10	0.12	2.05 - 2.14	
III - V		1.50	2.27	1.83	0.16	1.77 - 1.88	
I - V		3.48	4.35	3.93	0.21	3.85 - 4.00	

p = significance for the Wilcoxon test; < = less than

Subtitle: B(A+B) = wave resulting from the sum of binaural responses from the right (A) and left (B) channels; n = sample size; SD = standard deviation; CI = confidence interval; Amp V = wave V amplitude; % = percentage
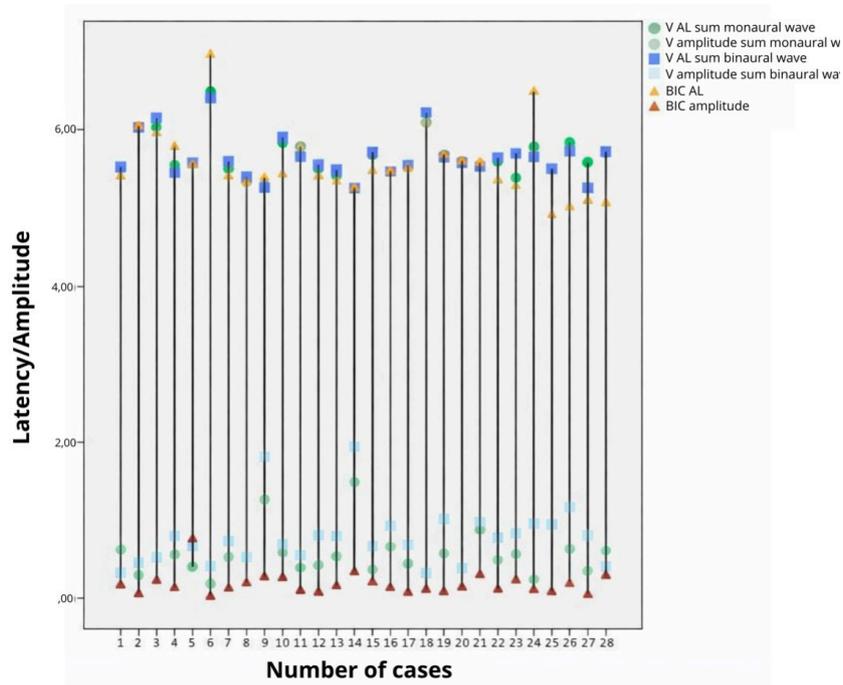
Figure 3. Comparison of minimum and maximum latencies and amplitude of wave V peaks for the sum of monaural responses, the sum of binaural responses, and the binaural interaction component
Subtitle: BIC = binaural interaction component; AL= absolute latency
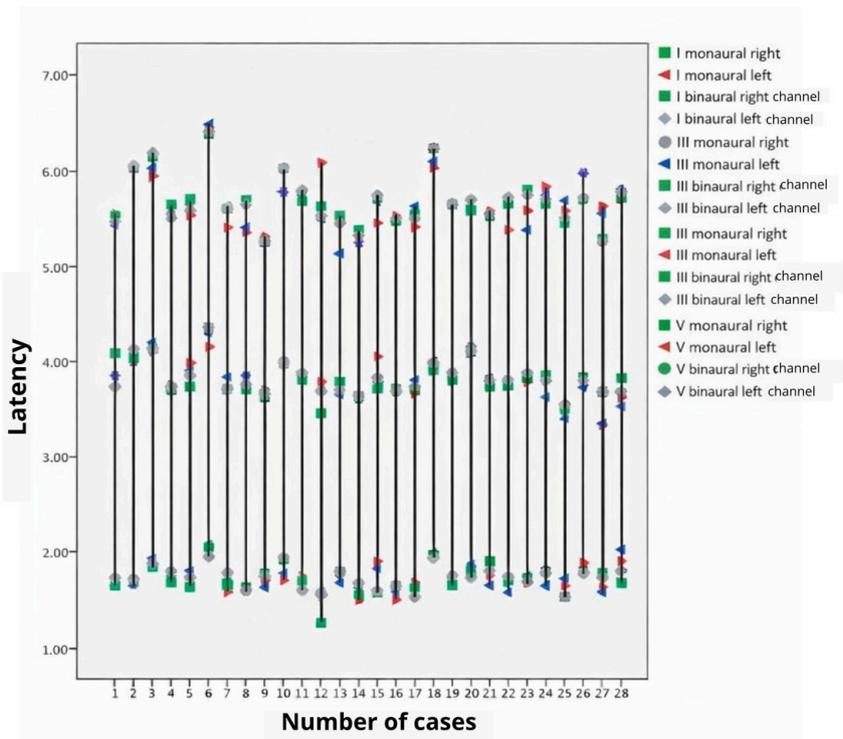

Figure 4. Latencies of waves I, III, and V of monaural responses (right ear and left ear) and binaural responses (B(A) and B(B))

Table 3. Normative values for latencies of peaks I, III, and V and interpeak intervals III–I, III–V, and V–I for the Binaural Auditory Brainstem Response

Intensity	I	III	V	I – III	III – V	I – V
80 dB	1.47 - 1.95	3.45 - 4.17	5.10 - 6.18	1.86 - 2.34	1.51 - 2.15	3.51 - 4.35

Subtitle: dB = decibels

Table 4. Normative values for latency and amplitude of the binaural interaction component

	BIC
Latency (ms)	4.67 - 6.43
Amplitude	0.16 - 0.72

Subtitle: BIC = binaural interaction component

Latency analysis of waves I, III, and V revealed no significant differences between conditions, suggesting that binaural stimulation does not alter brainstem activation timing and that early responses remain highly synchronous regardless of stimulation mode[16]. However, the low statistical power indicates that subtle effects may have gone undetected.

Amplitude analysis revealed significant differences between binaural and monaural wave V responses, reflecting neural summation when both ears are stimulated[16].

Although latencies did not differ significantly, the presence of the BIC reinforces the importance of binaural tests for detailed evaluation of central auditory processing. Physiologically, increased amplitude in binaural stimulation reflects the independence and summation of central auditory responses, with binaural ABR amplitude being approximately double the monaural response[14].

Clinically, ABR–BI offers practical advantages by reducing test time, enabling faster evaluations, particularly for screening and multicenter studies[17]. It is also useful when behavioral testing is not possible, such as during cochlear implant procedures[18].

Study limitations include small sample size, which reduced power for detecting small effects, and lack of inter-examiner reliability analysis. Future studies should include larger samples and reliability metrics.

CONCLUSION

Normative reference values for ABR–BI, specifically the latency and amplitude of the BIC, were successfully established for normal-hearing adults. The measured components demonstrated consistency across ears, suggesting the clinical promise of this electrophysiological measure.

These findings provide objective parameters that enhance clinical practice by making ABR–BI fa more time efficient tool. These normative values can be used in normal-hearing adults to reduce acquisition time and enhance the assessment of auditory pathway integrity. Future studies should aim to validate these findings across different age groups and with various types of hearing loss to establish ABR–BI as a robust tool for research and clinical evaluation.

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