Original Article

http://dx.doi.org/10.1590/2317-6431-2016-1712

Audiology Communication Research
ISSN 2317-6431

Auditory brainstem response in adults at rest and in movement

Potenciais evocados auditivos de tronco encefálico em adultos em posição de repouso e em movimentação

Andreia Borges de Oliveira Lot[1], Liliane Desgualdo Pereira[1]

ABSTRACT

Purpose: Recording the evoked auditory brainstem response, in resting conditions and movement for the same individual, using new equipment/system Integrity and verifying the agreement of these responses when compared to a conventional gold device/system standard in the market. **Methods:** Thirty normal-hearing adults from both genders, aged 18 to 30 years, were submitted to Auditory Brainstem Response (ABR). Two devices, a device/system Integrity, using bluetooth technology, the conditions of rest and motion and other equipment/conventional system were used to record responses in the same individual. **Results:** The comparison between the absolute and interpeak latencies observed in conditions of rest and motion, equipment Integrity are similar. The examination times observed in both devices, in the resting are the same. The acquisition time ABR, provided movement is greater than the resting condition, the Integrity equipment. **Conclusion:** Values were obtained for normal ABR in normal hearing adults in equipment/system Integrity, which are the same for the conditions of the individual at rest and in motion. The latencies in the two devices are equivalent in the resting condition, there was an agreement between the values of latencies, equipment Integrity, on the conditions of rest and motion.

Keywords: Evoked potentials, Auditory; Hearing; Brain stem; Electrophysiology; Adult

RESUMO

Objetivo: Registrar os potenciais evocados auditivos de tronco encefálico nas condições de repouso e movimento, no mesmo indivíduo, utilizando o novo equipamento/sistema *Integrity*, e verificar a concordância das respostas, quando comparadas a um equipamento/sistema convencional, padrão-ouro no mercado. **Métodos:** Trinta adultos com audição normal, de ambos os gêneros, entre 18 e 30 anos, foram submetidos ao Potencial Evocado Auditivo de Tronco Encefálico. Para registro das respostas no mesmo indivíduo, foram usados dois equipamentos, um deles (*Integrity*) com tecnologia *bluetooth*, nas condições de repouso e movimento e outro, equipamento/sistema convencional, na condição de repouso. **Resultados:** A comparação entre as latências absolutas e interpicos observada nas condições de repouso e movimento, no equipamento *Integrity,* foi de equivalência. Os tempos de exame observados nos dois equipamentos, na condição de repouso, foram iguais. O tempo de aquisição do potencial evocado auditivo, na condição de movimento, foi maior que na condição de repouso, no equipamento *Integrity*. **Conclusão:** Os valores de referência em adultos ouvintes normais no equipamento *Integrity* foram os mesmos para as condições de repouso e em movimento. As latências obtidas nos dois equipamentos foram equivalentes na condição repouso. Houve concordância entre os valores das latências no equipamento *Integrity*, nas condições de repouso e de movimento.

Descritores: Potenciais evocados auditivos; Audição; Tronco encefálico; Eletrofisiologia; Adulto

Study performed at the Speech-Language Pathology and Audiology Department, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil.
(1) Speech-Language Pathology and Audiology Department, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brazil.
Conflict of interests: No
Authors' contribution: *ABOL* principal researcher, elaboration of the research, elaboration of the schedule, literature survey, data collection and analysis, writing of the article, submission and paperwork of the article; *LDP* advisor, article reviewing and correction, approval of the final version.
Corresponding author: Andreia Borges de Oliveira Lot. E-mail: andreia.lot@hotmail.com
Received on: 27/4/2016; **Accepted on:** 6/9/2016

INTRODUCTION

Auditory Brainstem Response (ABR) examination is an objective, noninvasive, and highly sensitive procedure to evaluate the integrity of the auditory pathway[1]. Nevertheless, there are limitations in the potentials recording.

Evoked potentials are a complex, external stimulus response, representing the neural activity generated in anatomically separate locations. Auditory evoked potentials can be classified according to several criteria. The most frequent is the response latency, the most characteristic potential and the anatomical origin of the responses at the auditory system level[2].

ABR, the short-latency auditory evoked potential, consists of the recording of the electrical activity in the auditory system, in response to an acoustic stimulus[3]. The classification of bioelectrical activities is based on the time elapsed between the introduction of the acoustic stimulus and its appearance (latency), which are analyzed in a millisecond (ms) time-frame. Short-latency potentials occur within the first 10 ms after stimulation[4,5].

The relaxation level of the patient during the examination may significantly influence the auditory evoked potentials. The patient must cooperate, remaining still and relatively immobile throughout data collection, since any movement of the body, especially the head or the jaw, produces myogenic potentials and/or electrical artifacts. Sedation may be required in some children and adults who cannot or do not want to stand still[6,7].

The equipment used is another factor to be considered in the data analysis, insuring the reliability of the results and increasing the diagnostic accuracy[8].

Conventional equipment recordings for evaluating ABR are obtained by a computer, an amplifier, and electrodes connected by wires to a serial or USB port. In this context, there may be contamination of electrical noise in the amplifier, both from the computer and the power grid[9].

Among the most cited clinical applications of ABR are the evaluation of auditory pathways of the brainstem in adults and the determination of the electrophysiological auditory threshold, especially in children, making ABR an essential exam within the procedures used for audiological diagnosis, particularly in pediatric clinic[10,11,12,13,14,15,16,17,18]. There are advantages and limitations in the clinical application and correct interpretation of ABR, which can be performed in infants, young children, and in patients difficult to evaluate. However, it requires the patient to be calm and relaxed, especially in the regions of the head, neck, and shoulders. Physiological and environmental noise may interfere with the response recording.

In order to minimize possible interferences and/or artifacts in the electrophysiological auditory evaluation, a new *Integrity* equipment/system was developed, which uses *bluetooth* technology. The system records brainstem auditory evoked potentials even in environments with electrical noise interferences and in non-relaxed patients[19].

In view of the above, this study aimed to record short-latency auditory evoked potentials in listeners at rest and in movement using the new *Integrity* equipment/system, and to assess the consistency of the responses, compared to a conventional equipment/system, gold standard in the market, in the same individuals.

METHODS

The observational, analytical, cross-sectional study was performed at the Integrated Center of Assistance, Research and Teaching in Hearing (*Núcleo Integrado de Assistência, Pesquisa e Ensino em Audição* - NIAPEA), Discipline of Hearing Disorders, Speech-Language Pathology and Audiology Department, *Universidade Federal de São Paulo* (UNIFESP).

The procedures were initiated after approval by the Ethics and Research Committee of UNIFESP, under protocol number CEP 87065. All subjects included in the research were instructed on the procedures involved and signed the Free and Informed Consent Form, authorizing their volunteer participation in the study. Thirty adults of both genders and ages ranging between 18 and 30 years old were evaluated, with no otological and/or neurological complaints and auditory thresholds up to 20 dB HL.

Auditory Brainstem Response assessment was performed with the Vivosonic® equipment/system, model *Integrity*, using *bluetooth* technology and the Intelligent Hearing (IHS)® equipment/system, model *Smart EP*, considered gold standard. The evaluation was divided in two stages: 1st stage - static position, that is, without movement, or relaxed. This stage was called Rest Condition of the Individual - *Integrity* and *Smart EP* systems. The patients were instructed to remain relaxed, motionless, reclining in an armchair with eyes closed, in a dark, silent environment; 2nd stage - movement position. This stage was called Movement Condition of the Individual - *Integrity* system. The patients were instructed to sit down, move their face, open their eyes, and read a text aloud, until examination was completed.

The following parameters were used in the brainstem responses study: unfiltered click stimulus, which covers a frequency range of 2 to 4 kHz, with 100 microseconds (µs) duration, stimulation frequency of 19.3 clicks/s, intensity of 80 dB nHL, total of 2000 averages in the rarefied (negative) polarity, for each ear. The high-pass and low-pass filters frequencies were 100-3000 Hz. Duplication of each record was performed to ensure reproducibility and reliability of the waves. Insert earphones (ER-3A) were used and the stimuli were introduced monaurally and with ipsilateral recording to the afferent ear[20].

The evoked potentials evaluation was performed only when the impedance between the electrodes connected to the skin was less than 2 kΩ and the interelectrode differences was below 1 kΩ. The velocity was selected this way in order to generate more definite ABR wave morphology responses. The areas where the disposable electrodes were fixed were cleaned, prior to the placement, with NuPrep abrasive gel and gauze, in order to reduce electrical impedance. The ground electrode was positioned on the front (Fpz), below the active electrode (Fz), and the reference electrodes (M1) and (M2) were fixed on the left and right mastoids, respectively. The stimulus was introduced through disposable ear tips, placed in the auditory canal of each volunteer(21). Wave peaks were identified and marked with roman numerals I, III, and V, and those found to be reproducible were considered waves. By marking the peaks of the waves, it was possible to obtain the values of the absolute latencies I, III, and V and of the interpeak latencies I-III, III-V, and I-V.

A descriptive analysis of the absolute latencies of the waves I, III, and V, and interpeak latencies I-III, III-V, and IV in resting condition, in the IHS and *Integrity* equipment, and in rest and movement conditions in *Integrity*, as well as the time of examination, was performed. In order to evaluate the agreement between the measurements in the two equipment and under the two conditions, the intraclass correlation coefficient, or concordance correlation coefficient was calculated(22). The values of this coefficient vary from 0 to 1 and, in general, values greater than 0.75 indicate strong agreement and values lower than 0.4, indicate weak agreement.

The McNemar test(23) was used to compare the examination times in the two equipment and in the *Integrity* equipment alone under both conditions.

RESULTS

The mean values of the absolute latencies of waves I, III, and V and of the interpeak latencies I-III, III-V and I-V, obtained through the *Smart EP* and *Integrity* systems, in the resting condition, were similar. The mean values of the wave latencies I, III, and V observed in the *Smart EP* equipment were higher than those observed with the *Integrity* equipment (Table 1).

Regarding the mean values of the absolute latencies of waves I, III, and V and of the interpeak latencies I-III, III-V, and IV obtained in the *Integrity* system, at rest and in movement conditions, the intraclass correlation coefficient values indicated a strong agreement between the two conditions assessed. The mean values observed in the *Integrity* equipment, at rest and in movement conditions, were similar (Table 2).

The latency dispersion diagram, when the *Integrity* equipment was used, at rest and in movement conditions, is illustrated according to each record, in Figures 1 (Wave I), 2 (Wave III), 3 (Wave V), and 4 (interpeaks I-III, III-V, and IV). The results show a strong agreement between the measurements obtained for both conditions.

To compare the examination times in the *Integrity* equipment at rest and in movement conditions, time categories “less than or equal to 2 minutes” and “greater than 2 minutes” were defined. Twenty-nine subjects (96.7%) showed times less than or equal to 2 minutes at rest and times greater than 2 minutes in movement. In the left ear, all individuals exhibited times less than or equal to 2 minutes at rest and times greater than 2 minutes in movement. Frequency distributions and joint and marginal percentages for the aforementioned characteristic times are shown in Table 3 (right ear) and in Table 4 (left ear).

DISCUSSION

The mean values of the absolute latencies of waves I, III, and V, and of the interpeak latencies I-III, III-V, and IV obtained in the *Smart EP* and *Integrity* systems, for the patients at rest,

Table 1. Mean values of the absolute latencies and interpeaks (ms) in the *Smart EP* and *Integrity* equipment, in rest condition, for both ears

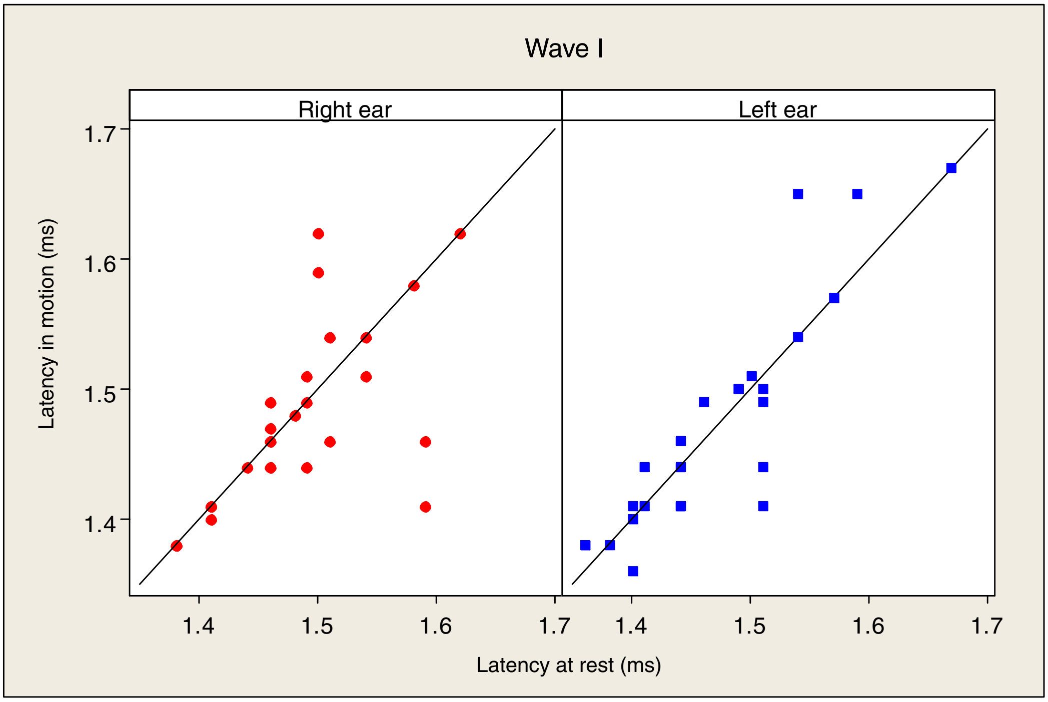
Equipment	n		I	III	V	I-III	III-V	I-V
Smart EP	60	M	1.58	3.69	5.57	2.11	1.88	3.99
		DP	0.09	0.14	0.15	0.14	0.14	0.15
Integrity	60	M	1.47	3.59	5.49	2.11	1.90	4.02
		DP	0.11	0.15	0.17	0.12	0.11	0.16

Subtitle: M = mean; SD = standard deviation; I = latency of wave I; III = latency of wave III; V = latency of wave V; I-III = interpeak latency I-III; III-V = interpeak latency III-V; I-V = interpeak latency I-V

Table 2. Mean values of the absolute latencies and interpeaks in the *Integrity* equipment and of the mean differences of latencies, in rest and movement conditions, for both ears

Equipment	n		I	III	V	I-III	III-V	I-V
Integrity rest	60	M	1.47	3.59	5.49	2.11	1.90	4.02
		DP	0.07	0.14	0.17	0.12	0.11	0.16
Integrity movement	60	M	1.47	3.58	5.48	2.11	1.90	4.01
		DP	0.08	0.10	0.16	0.13	0.11	0.16
Diference	60	M	0.00	0.01	0.01	0.00	0.00	0.01

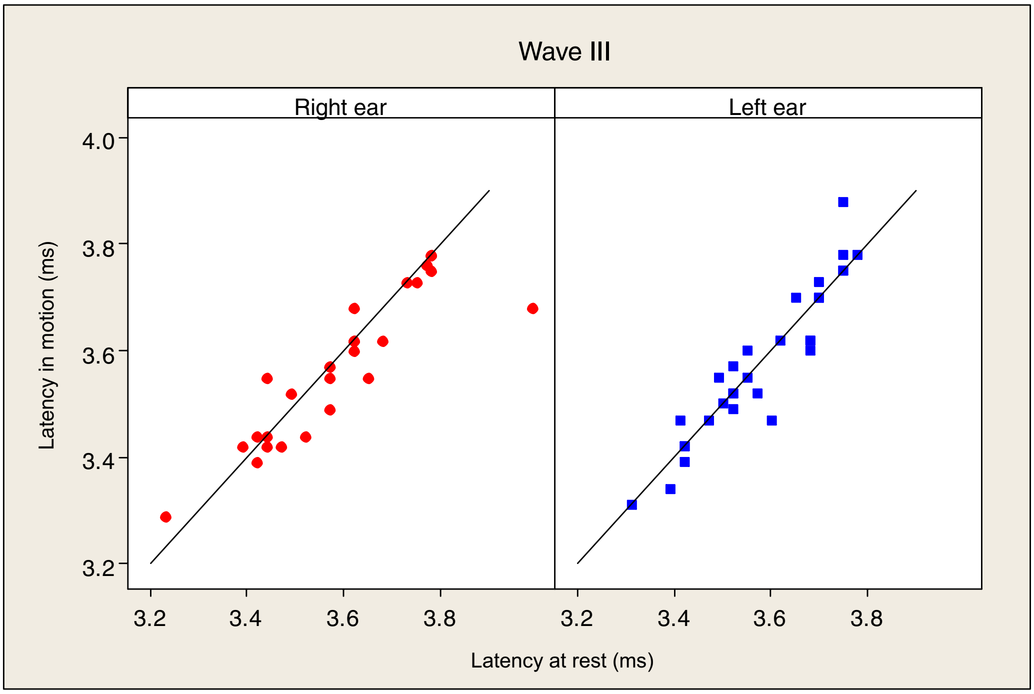
Subtitle: M = mean; SD = standard deviation; I = latency of wave I; III = latency of wave III; V = latency of wave V; I-III = interpeak latency I-III; III-V = interpeak latency III-V; I-V = interpeak latency I-V



Intraclass correlation coefficient: 0.71
95% confidence interval: [0.47; 0.85]

Intraclass correlation coefficient: 0.90
95% confidence interval: [0.79; 0.97]

Figure 1. Dispersion diagrams of latency of wave I in the Integrity equipment at rest and movement, per ear

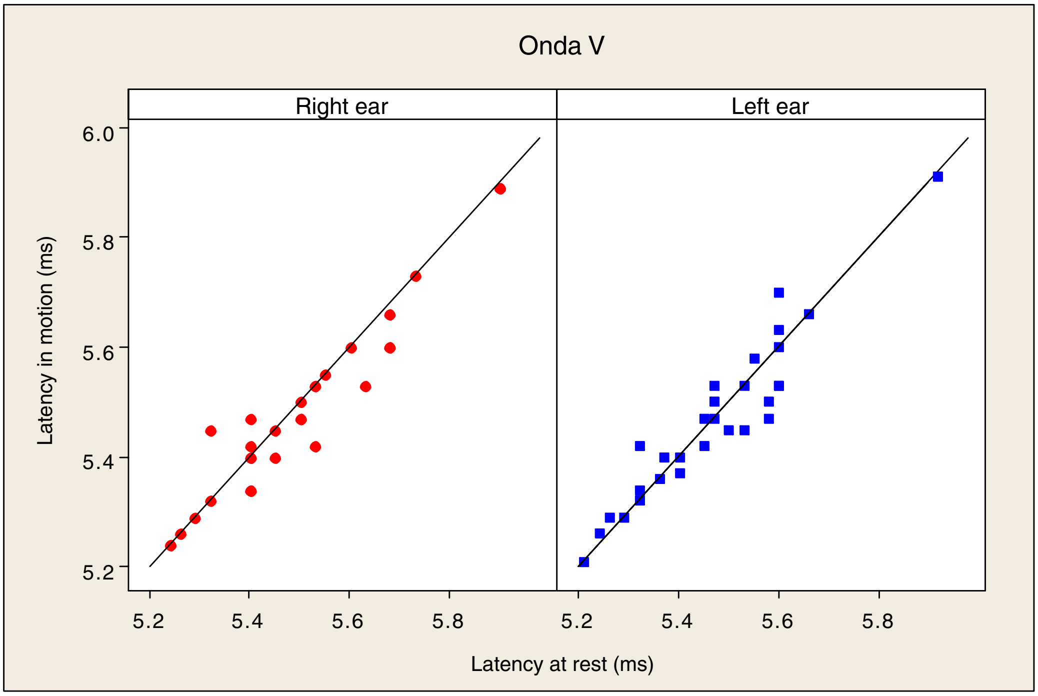


Intraclass correlation coefficient: 0.89
95% confidence interval: [0.78; 0.95]

Intraclass correlation coefficient: 0.94
95% confidence interval: [0.87; 0.97]

Figure 2. Dispersion diagrams of latency of wave III in the Integrity equipment at rest and movement, per ear

were similar (Tables 1 and 2). Although the mean values of the absolute latencies observed in the *Smart EP* system, especially in the absolute latency of wave I, were higher than those observed in the *Integrity* system in most individuals, intraclass correlation coefficient values (Figures 1 to 4) indicate the agreement between the measurements in the same individual, in the two equipment. The intraclass correlation coefficient indicates a strong agreement between the observations with both systems/equipment. Thus, the electrophysiological records in the *Integrity* system were compatible with those of a



Intraclass correlation coefficient: 0.96
95% confidence interval: [0.91; 0.98]

Intraclass correlation coefficient: 0.96
95% confidence interval: [0.92; 0.98]

Figure 3. Dispersion diagrams of latency of wave V in the Integrity equipment at rest and movement, per ear

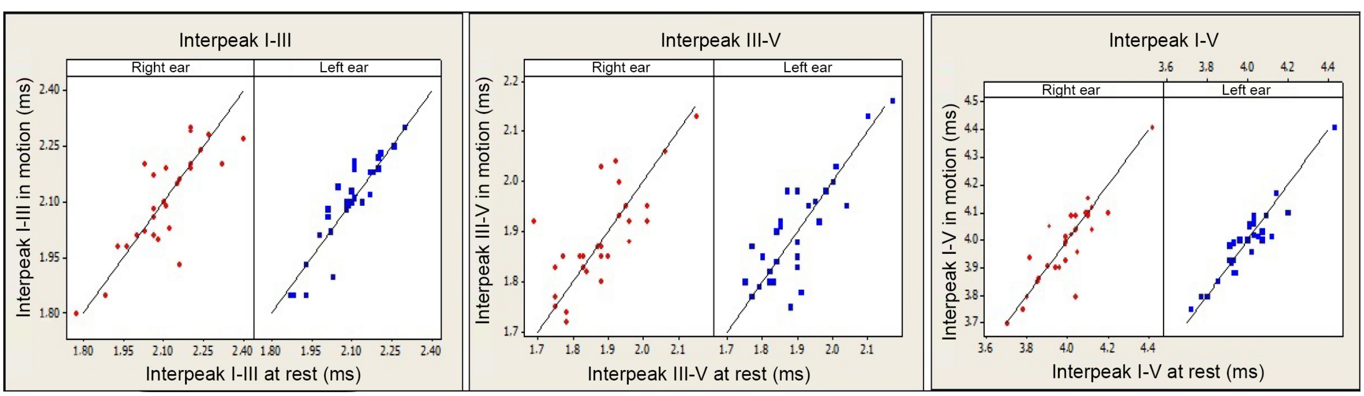


Figure 4. Dispersion diagrams of the interpeaks I-III, III-V, and I-V in the Integrity equipment at rest and in movement, by ear

Table 3. Frequency distributions and marginal and joint percentages of the examination time in the *Integrity* equipment in rest and movement conditions, in the right ear

Rest time	Time movement		Total
	≤2	>2	
≤2	1	29	30
	3.3%	96.7%	100%
>2	0	0	0
	0%	0%	0%
Total	1	29	30
	3.3%	96.7%	100%

Table 4. Frequency distributions and marginal and joint percentages of the examination time in the *Integrity* equipment in rest and movement conditions, in the left ear

Rest time	Time movement		Total
	≤2	>2	
≤2	0	30	30
	0%	100%	100%
>2	0	0	0
	0%	0%	0%
Total	0	30	30
	0%	100%	100%

The time of examination in movement is higher than at rest ($p < 0.001$), in both ears

gold standard equipment available in the market, with respect to the average variable of the absolute latencies of the I, III, and V waves and the interpeak latencies I-III, III-V, and IV. According to the literature[24,25,26] the average values of the latencies of wave I range between 1.50 and 1.68 ms, those of wave III range between 3.50 and 3.80 ms, and those of wave V range between 5.50 and 5.64.

The observations of this study, for the rest condition of the individual, agree with the data from the literature[6,9,10,11,27,28], which states that, in order to obtain reliable results in the evaluation of ABR, in conventional equipment, the patient must remain calm, relaxed, and still, because physiological and environmental noise can interfere with the response. The authors of these studies also stated that the evaluation should be performed in a room with acoustic and electric treatment and the patient should be comfortably accommodated in a stretcher or reclining chair to minimize the interference of electrical and muscular artifacts. Auditory evoked potentials may be significantly influenced by the relaxation state of the patient during examination and, therefore, he should remain still and relatively immobile during data collection. Any movement of the body, especially the head or the jaw, produces myogenic potentials and/or electrical artifacts. Contraction movements of the masseter muscle or of the cervical musculature, swallowing, and coughing can cause great background noise and make the examination unfeasible. Thus, it is often advised to perform the exam under sedation, which, following a previous study, has clinical disadvantages, such as the high cost, risk, and diagnosis delay[29].

With respect to the mean values of the absolute latencies of waves I, III, and V and of the interpeak latencies I-III, III-V, and IV obtained in the *Integrity* system, at rest and in movement, the intraclass correlation coefficients indicated a strong mutual agreement, demonstrating the effectiveness of this new system to evaluate patients in movement conditions.

These results are in keeping with previous studies which reported that the *Integrity* system was designed to be less sensitive to electrical interference, allowing movement and, consequently, the acquisition of potentials in restless patients without the need for sedation[30]. Communication between the computer and the wireless interface eliminates the occurrence of electrical noise generated from the computer and the power grid, and it is possible to record the ABR in noisy environments and in non-relaxed patients. The reduction of the effects of muscle artifacts, through the filtering technique used, allows the recording of ABR during muscle activity of the patient, such as movement or speech[30]. This new technology is designed to be less sensitive to interference than other commercially available systems/equipment, generating important benefits for patients, speech therapists, and hospitals[30].

A study of 103 children, using the *Integrity* system, evaluated ABR without sedation. No children received any sedative or anesthetic prior to data collection, 72% of the children were relaxed but not sleeping, 16% were awake and in movement, and 12% were asleep. The study concluded that the *Integrity* system reduces by up to 66% the need for sedation or anesthesia in young children. Moreover it reduces the costs of sedation and care in the administration of anesthesia, as well as the waiting time for ABR in young children who would require sedation[28].

In order to validate the *Integrity* system, another study evaluated ABR of ten adults with normal hearing and ages between 18 and 30 years, and compared the results obtained with the *Integrity* equipment and a conventional equipment, *Audera*, of the GSI brand. Two conditions were investigated in order to determine the correlation between the equipment: a noise situation where the subjects were instructed to suck lollipops and a quiet situation with the individuals in a relaxed state. The results showed that, for the conventional system, under noisy conditions, it was not possible to acquire ABR in eight of the ten evaluated subjects. In contrast, all subjects presented normal ABR under both conditions with the *Integrity* system. The authors concluded that there is a significant improvement in obtaining ABR with the *Integrity* equipment, in situations of artifacts, demonstrating the system's ability to provide a diagnosis in active children, avoiding the need for sedation and anesthesia. The authors also asserted that the validation of this new technology to estimate auditory thresholds in non-sedated small children is justified[30].

The descriptive means related to the time of examination, observed in the *Smart EP* and in the *Integrity* systems, at rest, were equal to 2 minutes in both equipments. When the time of examination in the right and left ears was analyzed with the two equipments, under the same condition, no significant difference was observed. When the descriptive means related to the examination time (Tables 3 and 4), observed in the same equipment, *Integrity*, at rest and in movement, were compared, the examination time in the movement condition was 4 minutes, that is, twice the rest condition time.

CONCLUSION

The reference values in normal hearing adults obtained with the *Integrity* equipment were the same for individuals at rest and in movement conditions. The values of the absolute latencies I, III, and V and the values of the interpeak latencies I-III, III-V, and I-V, obtained through the two equipment/systems, IHS and *Integrity*, were found to be in agreement in the resting condition.

REFERENCES

1. Jewett DL, Romano MN, Williston JS. Human auditory evoked potentials: possible brain stem components detected on the scalp. Science. 1970;167(3924):1517-8. http://dx.doi.org/10.1126/science.167.3924.1517
2. Hood L. The normal auditory brainstem response. In: Hood L. Clinical applications of the auditory brainstem response. San Diego: Singular; 1998. p. 126-44.
3. Esteves MCBN, Aringa AHBD, Arruda GV, Aringa ARD, Nardi JC. Estudo das latências das ondas dos potenciais auditivos de tronco encefálico em indivíduos normo-ouvintes. J Bras Otorrinolaringol. 2009;75(3):420-5. http://dx.doi.org/10.1590/S1808-86942009000300018
4. Lima MAMT. Potencial evocado auditivo: eletrococleografia e audiometria de tronco encefálico. In: Frota S. Fundamentos em

fonoaudiologia: audiologia. Rio de Janeiro: Guanabara Koogan; 1998. p 147-60.
5. Luccas FJC, Manzano GM, Ragazzo PC. Potencial evocado auditivo: tronco cerebral: estudo normativo. Arq Bras Neurocirurg. 1983;2(2):149-62.
6. Sokolov Y. ABR testing in children made easy. Hearing Rev. 2007 [citado 7 set 2012]; (International). Disponível em: http://www.hearingreview.com/2008/03/abr-testing-in-children-made-easy/
7. Valete CM, Decoster DMH, Lima MAMT, Torraca TSS, Tomita S. Kós AOA. Distribuição por gênero e faixa etária das aplicações clínicas da audiometria de tronco encefálico. Acta ORL. 2006:24(4):281-3.
8. Flabiano F, Leite R, Matas C. Audiometria de tronco encefálico em adultos audiologicamente normais: comparação das latências absolutas das ondas I, III, V, interpicos I-III, III-V, I-V, amplitudes das ondas I, III, V e relação da amplitude V/I, obtidas em dois equipamentos diferentes. Acta ORL. 2002 [citado 7 set 2012];21(2). Disponível em: http://www.actaawho.com.br/edicao/conteudo.aspediid=5&tpc
9. Hall JW. Analysis an interpretation. Boston: Pearson Education. 2007. New handbook for auditory evoked responses, p. 212-57.
10. Jiang ZD, Brosi DM, Li ZH, Chen C, Wilkinson A. Brainstem auditory function at term in preterm babies with and without perinatal complications. Pediatr Res. 2005;58(6):1164-9. http://dx.doi.org/10.1203/01.pdr.0000183783.99717.2b
11. Jiang ZD, Wilkson AR. Does peripheral auditory threstold correlate with brainstem auditory function at term in preterm infants? Acta Otolaryngol. 2006;126(8):824-7. http://dx.doi.org/10.1080/00016480500527177
12. Cristobal R, Oghalai JS. Hearing loss in children with very low birth weight: current review of epidemiology and pathophysiology. Arch Dis Child Fetal Neonatal. 2008;93(6):462-8. http://dx.doi.org/10.1136/adc.2007.124214
13. Rodrigues GRI, Lewis DR. Threshold prediction in children with sensorioneural hearing loss using the auditory stady-state response and tone-evoked auditory brain stem response. Int J Pediatr Otorhinolaryngol. 2010;74(5):540-6. http://dx.doi.org/10.1016/j.ijporl.2010.02.017
14. Rosa LAC, Suzuki MR, Angrisani RG, Azevedo MF. Auditory Brainstem Response: reference-values for age. CoDAS. 2014;26(2):117-21. http://dx.doi.org/10.1590/2317-1782/2014469IN
15. Casali RL, Santos MFC. Potencial evocado auditivo de tronco encefálico: padrão de respostas de lactentes termos e prematuros. Braz J Otorhinolaryngol. 2010;76(6):729-38. http://dx.doi.org/10.1590/S1808-86942010000600011
16. Marcoux AM. Maturation of auditory function related to hearing threshold estimations using the auditory brainstem response during infancy. Int J Pediatr Otorhinolaryngol. 2011;75(2):163-70. http://dx.doi.org/10.1016/j.ijporl.2010.10.027
17. Coenraad S, Hoeve LJ, Goedegebure A. Incidence and clinical value of prolonged I-V interval in NICU infants after failing neonatal hearing screening. Eur Arch Otorhinolaryngol. 2011;268(4):501-5. http://dx.doi.org/10.1007/s00405-010-1415-8
18. Amorim RB, Agostinho-Pesse RS, Alvarenga KF. The maturational process of the auditory system in the first year of life characterized by brainstem auditory evoked potentials. J Appl Oral Sci. 2009;17(n spe):57-62. http://dx.doi.org/10.1590/S1678-77572009000700010
19. Sokolov Y, Kurtz I, Isaac K, Aaron S, Long G, Sokolova O et al. Freedom from sedation: a new technology for ABRs. Hear Rev. 2007 [citado 7 set 2012].Disponível em: http://www.hearingreview.com/2007/04/freedom-from-sedation-a-new-technology-for-abrs/
20. Munhoz MSL, Silva MLG, Caovilla HH, Frazza MM, Ganança MG, Câmera JLZ. Respostas auditivas de tronco encefálico. In: Munhoz MSL, Caovilla HH, Silva MLG, Ganança MM. Audiologia clínica. São Paulo: Atheneu; 2000. p. 191-220.
21. Jasper HA. The tem-twenty system of the International Federation. Electroencephalogr Clin Neurophysiol. 1958;10:371-5.
22. Fleiss, J. L. Design and analysis of clinical experiments. New York: John Wiley & Sons; 1986.
23. Fisher, LD, Van Belle, G. Biostatistics. New York: John Wiley & Sons; 1993.
24. Anias CR, Lima MAMT, Kós AOA. Avaliação da influência da idade no potencial evocado auditivo de tronco encefálico. Rev Bras Otorrinolaringol. 2004;70(1):84-9. http://dx.doi.org/10.1590/S0034-72992004000100014
25. Lima JP, Alvarenga KF, Foelkel TP, Monteiro CZ, Agostinho RS. Os efeitos da polaridade nos potenciais evocados auditivos de tronco encefálico. Rev Bras Otorrinolaringol. 2008;74(5):725-30. http://dx.doi.org/10.1590/S0034-72992008000500014
26. Soares IA, Menezes PL, Carnaúba ATL, Pereira LD. Padronização do potencial evocado auditivo de tronco encefálico utilizando um novo equipamento. Pro Fono 2010;22(4):421-6. http://dx.doi.org/10.1590/S0104-56872010000400010
27. Widen JE, Keener SK. Diagnostic testing for hearing loss in infants and young children. MRDD Research Reviews. 2003;9(4):220-4. http://dx.doi.org/10.1002/mrdd.10083
28. Norrix LW, Trepanier S, Atlas M, Kim D. The auditory brainstem response: latencies obtained in children while under general anesthesia. J Am Acad Audiol. 2012;23(1):57-63. http://dx.doi.org/10.3766/jaaa.23.1.6
29. Assis CL, Souza FCR, Baraky LR, Bernardi AP. Estudo da audiometria de tronco encefálico em indivíduos de 20 a 30 anos com audição normal. Rev CEFAC. 2005;7(1):87-92.
30. Sokolov Y, Kurtz I, Isaac K, Aaron S, Long G, Sokolova O. Integrity techology: making ABR practical; 2005 [citado 7 set 2012]. Disponível em: http://www.vivosonic.com/en/support/files/Integrity-Technology-2005.pdf