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Comparison of Hearing Assessment Results Using Behavioral Observation Audiometry and Brainstem Evoked Response Audiometry in Children with Speech Delay at Dr. Soetomo General Hospital, Surabaya

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ABSTRACT

Hearing impairment is one of the possible causes of speech delay in children, making hearing assessment necessary to identify potential auditory problems. Behavioral Observation Audiometry (BOA) and Brainstem Evoked Response Audiometry (BERA) are hearing assessment methods based on subjective and objective evaluation principles, respectively. This study aimed to analyze the distribution and agreement of BOA and BERA hearing assessment results in children with speech delay. An analytical observational study with a retrospective cross-sectional approach was conducted using secondary medical record data of 97 children diagnosed with speech delay at Dr. Soetomo General Hospital, Surabaya, from 2020 to 2023. Subjects were selected using total sampling. Data were analyzed using univariate analysis and Cohen's Kappa concordance analysis. Most subjects were aged ≤5 years (61 children; 62.9%), and 53 (54.6%) were male. The most frequent BOA finding was profound hearing loss in 38 children (39.2%), whereas the most frequent BERA finding was normal hearing in 57 children (58.8%). Cohen's Kappa value was 0.111 ($p < 0.001$), indicating low agreement between the two assessments. The findings indicate that BOA and BERA results showed different distributions and low agreement; therefore, results should be interpreted by considering the characteristics and limitations of each method.

Keywords: speech delay; behavioral observation audiometry; brainstem evoked response audiometry; hearing impairment; children

INTRODUCTION

Speech delay is a condition in which a child's speech abilities lag behind the expected developmental milestones for their age [1]. Language and speech development are crucial aspects of a child's growth and development because they play a role in communication skills, social interaction, and cognitive development. Delays in language and speech development in children require attention because they can affect various aspects of their future development [2,3].

There are various factors that can contribute to speech delay, one of which is hearing loss. The ability to hear plays a crucial role in language acquisition and speech development. Hearing loss can cause children to have difficulty perceiving and distinguishing sounds, thereby hindering the development of language and speech skills [4]. Previous studies demonstrate a relationship between the degree of hearing loss and the severity of speech and language development delays in children. Therefore, hearing assessment is an essential component of the evaluation of children with speech delay [5,6].

The evaluation of hearing loss is conducted in several stages, ranging from medical history and physical examination to audiological testing. Audiological testing in children can utilize either behavioral or electrophysiological methods [7]. One behavioral test is Behavioral Observation Audiometry (BOA), which assesses a child's behavioral responses to auditory stimuli, such as changes in facial expressions, body movements, or other reactions. This test is primarily used for infants

and children who are not yet able to participate in a structured behavioral audiometry test [8].

In addition to BOA, there are objective tests such as Brainstem Evoked Response Audiometry (BERA), also known as Auditory Brainstem Response (ABR) [9,10]. BERA is an electrophysiological test that records electrical activity along the auditory pathway up to the brainstem in response to auditory stimuli [11]. This test does not require an active response from the patient and can therefore be used for infants and children who have difficulty participating in behavioral hearing tests [12,13].

BOA and BERA are based on different testing principles, which may result in differences in hearing assessment findings. BOA evaluates a child's behavioral responses to auditory stimuli, whereas BERA measures electrophysiological responses along the auditory pathway [14]. Therefore, this study aimed to analyze the distribution and agreement of BOA and BERA hearing assessment results in children with speech delay at Dr. Soetomo General Hospital, Surabaya.

MATERIALS AND METHODS

This study was an analytical observational study with a retrospective cross-sectional design using secondary data from medical records. The study was conducted at the Audiology Clinic, Department of Ear, Nose, and Throat (ENT) and Head and Neck Surgery, Dr. Soetomo General Hospital, Surabaya. The data were obtained from pediatric patients diagnosed with speech delay between 2020 and 2023.

The study population comprised pediatric patients diagnosed with speech delay at Dr. Soetomo General Hospital. The study sample consisted of patients who had undergone both BOA and BERA examinations and met the inclusion and exclusion criteria. The inclusion criteria were pediatric patients diagnosed with speech delay who had undergone both examinations, while the exclusion criterion was incomplete medical records. The minimum sample size was calculated using the Lemeshow formula, resulting in 97 subjects.

A total sampling technique was applied to all medical records that met the eligibility criteria, resulting in 97 subjects.

The study variables were the results of BOA and BERA examinations. Hearing assessment results were classified into six categories: normal hearing (0–25 dB), mild hearing loss (26–40 dB), moderate hearing loss (41–54 dB), moderate-severe hearing loss (55–69 dB), severe hearing loss (70–89 dB), and profound hearing loss (≥90 dB).

BOA was performed by observing the child's behavioral responses to auditory stimuli using a small hand drum, a toy rattle, and a plastic trumpet. The results were determined based on the minimum response level. BERA was performed by recording the electrophysiological responses of the auditory system and identifying Wave V at the lowest stimulus intensity to estimate the hearing threshold. The collected data underwent editing, coding, data entry, and cleaning. Data processing was performed using Microsoft Excel, while statistical analysis was conducted using SPSS version 26.0. Univariate analysis was used to describe the characteristics of the subjects and the distribution of BOA and BERA results. Cohen's Kappa analysis was performed to evaluate the agreement between the two examination methods.

This study received approval from the Health Research Ethics Committee of Dr. Soetomo General Hospital, Surabaya. Patient confidentiality was maintained by using coded or anonymous identifiers during data processing and reporting.

RESULTS

This study used secondary data from the medical records of pediatric patients diagnosed with speech delay at Dr. Soetomo General Hospital in Surabaya from 2020 to 2023. A total of 97 patients met the inclusion and exclusion criteria and had BOA and BERA test data.

Characteristics of the Study Subjects

Based on age group, the majority of subjects were ≤5 years old, totaling 61 children (62.9%), while 36 children (37.1%) were >5 years old.

TABLE 1: Distribution of Demographic Characteristics by Age.

Age group	Frequency	Percentage (%)
≤5 years	61	62.9
>5 years	36	37.1
Total	97	100.0

By sex, there were 53 boys (54.6%) and 44 girls (45.4%).

TABLE 2: Distribution of Demographic Characteristics by Sex.

Sex	Frequency	Percentage (%)
Boys	53	54.6
Girls	44	45.4
Total	97	100.0

Results of the Behavioral Observation Audiometry (BOA) Test

The BOA results showed variations in behavioral responses to three types of auditory stimuli. For the small hand drum, 48 children (49.5%) did not respond. For the toy rattle stimulus, 41 children (42.3%) showed ambiguous responses. Meanwhile, for the plastic trumpet stimulus, 43 children (44.3%) did not respond.

TABLE 3: Distribution of Behavioral Responses Based on BOA.

BOA stimulus	Response	Frequency	Percentage (%)
Small hand drum	+	16	16.5
	–	48	49.5
	±	33	34.0
Toy rattle	+	37	38.1
	–	19	19.6
	±	41	42.3
Plastic trumpet	+	16	16.5
	–	43	44.3
	±	38	39.2

Notes: (+) responds to sound; (–) does not respond to sound; (±) ambiguous response.

Based on the results of the BOA test's minimum response level, the most common category was profound hearing loss, affecting 38 children (39.2%), followed by severe hearing loss, affecting 33 children (34.0%). No subjects were found to have normal hearing.

TABLE 4: Distribution of BOA Results.

Minimum response level at BOA	Frequency	Percentage (%)
Normal hearing	0	0.0
Mild hearing loss	3	3.1
Moderate hearing loss	12	12.4
Moderate-severe hearing loss	11	11.3
Severe hearing loss	33	34.0
Profound hearing loss	38	39.2
Total	97	100.0

Brainstem Evoked Response Audiometry (BERA) Test Results

The BERA test results show that the most common hearing category was normal hearing, with 57 children (58.8%), while profound hearing loss was found in 31 children (32.0%). The average estimated hearing threshold was 46.44 dB, with a minimum value of 20 dB and a maximum of 95 dB. The standard deviation of the BERA test results was 33.48.

TABLE 5: Distribution of BERA Test Results.

Estimated hearing threshold on BERA	Frequency	Percentage (%)
Normal hearing	57	58.8
Mild hearing loss	1	1.0
Moderate hearing loss	1	1.0
Moderate-severe hearing loss	4	4.1
Severe hearing loss	3	3.1
Profound hearing loss	31	32.0
Total	97	100.0

Comparison of BOA and BERA Test Results

A comparison of the distribution of test results shows that the most common category in BOA was profound hearing loss, with 38 children (39.2%), while in BERA, the most common category was normal hearing, with 57 children (58.8%).

A concordance analysis using Cohen's Kappa yielded a κ value of 0.111 with an Asymptotic Standard Error (ASE) of 0.031 and a p-value < 0.001. These results indicate a low level of agreement between the BOA and BERA test results.

TABLE 6: Comparison of the Distribution of BOA and BERA Test Results.

Hearing category	BOA n	BOA (%)	BERA n	BERA (%)
Normal hearing	0	0.0	57	58.8
Mild hearing loss	3	3.1	1	1.0
Moderate hearing loss	12	12.4	1	1.0
Moderate-severe hearing loss	11	11.3	4	4.1
Severe hearing loss	33	34.0	3	3.1
Profound hearing loss	38	39.2	31	32.0
Total	97	100.0	97	100.0

Cohen's Kappa = 0.111; ASE = 0.031; Approximate T = 3.608; $p < 0.001$.

DISCUSSION

Characteristics of the Study Participants

The majority of subjects in this study were aged ≤5 years (61 children; 62.9%). This finding is consistent with a previous study involving children aged 2–6 years with isolated speech and language delay [8]. Early childhood is an important period for language and communication development; therefore, delays identified during this period require appropriate evaluation [1,2].

Regarding sex distribution, male subjects were more numerous than female subjects, accounting for 53 children (54.6%) and 44 children (45.4%), respectively. This result describes the sex distribution in the present study population and should not be interpreted as evidence of a causal relationship between sex and speech delay.

Results of the Behavioral Observation Audiometry (BOA) Test

BOA is a behavioral hearing assessment that evaluates a child's responses to auditory stimuli. Observable responses may include changes in attention, body movements, searching for the sound source, and reflexive responses such as blinking or startling [5,14].

In this study, the small hand drum and plastic trumpet stimuli most frequently produced no response, observed in 48 children (49.5%) and 43 children (44.3%), respectively. In contrast, ambiguous responses were most frequent with the toy rattle stimulus, occurring in 41 children (42.3%). These differences may be related to the acoustic characteristics of each stimulus, including frequency and intensity. The small hand drum produced a frequency of 750 Hz and an intensity of 88 dB at 1 meter and 85 dB at 2 meters. The toy rattle produced a frequency of 3,150 Hz and an intensity of 75 dB at 1 meter and 73 dB at 2 meters. Meanwhile, the plastic trumpet produced a frequency of 4,000 Hz and an intensity of 103 dB at 1 meter and 99 dB at 2 meters.

Based on the minimum response level classification, profound hearing loss was the most frequent category, affecting 38 children (39.2%). No subjects were classified as having normal hearing based on BOA. These findings should be interpreted with consideration of the behavioral nature of the examination. A child's ability to attend to sounds, cooperate during testing, and provide consistent responses may influence the results of behavioral hearing assessments [13,14].

Results of the Brainstem Evoked Response Audiometry (BERA) Test

BERA is an objective electrophysiological examination that records the auditory system's response to sound stimuli. Hearing thresholds can be estimated by identifying the auditory brainstem response waves, particularly Wave V [11].

In this study, normal hearing was the most frequent BERA category, found in 57 children (58.8%), while profound hearing loss was found in 31 children (32.0%). The mean estimated hearing threshold was 46.44 dB, with a range of 20–95 dB and a standard deviation of 33.48 dB.

Although the mean estimated hearing threshold was 46.44 dB, most subjects were classified as having normal hearing. This difference reflects the variation in hearing thresholds among subjects, as a number of subjects with elevated thresholds may have influenced the overall mean. BERA does not require an active behavioral response from the patient, making it useful for assessing hearing in infants and children who cannot provide consistent behavioral responses [7,13,15].

Comparison of BOA and BERA Test Results

This study found different distributions of hearing assessment results between BOA and BERA. Profound hearing loss was the most frequent category in BOA, affecting 38 children (39.2%), whereas normal hearing was the most frequent category in BERA, affecting 57 children (58.8%).

The Cohen's Kappa analysis yielded a value of 0.111, indicating low agreement between BOA and BERA results. This finding suggests that the two methods did not demonstrate strong agreement in classifying the degree of hearing loss in the study population.

The differences may be related to the distinct principles of the two examinations. BOA evaluates behavioral responses to auditory stimuli, which may be influenced by the child's attention, cooperation, and the examiner's interpretation. In contrast, BERA measures electrophysiological responses along the

auditory pathway and does not depend on an active response from the patient [13,14].

The present study did not use a gold standard to assess the diagnostic accuracy of either method. Therefore, the differences in results and the low level of agreement cannot be interpreted as evidence that one method is more diagnostically accurate than the other. The two examinations have different characteristics and limitations, and their use should be considered in the context of the child's clinical condition and hearing assessment needs [13,14].

CONCLUSION

Based on the results of a study of 97 children with speech delay at Dr. Soetomo General Hospital in Surabaya, the BOA test results most frequently indicated profound hearing loss in 38 children (39.2%), while the BERA test results most frequently indicated normal hearing in 57 children (58.8%). A concordance analysis using Cohen's Kappa yielded a value of $\kappa = 0.111$, indicating a low level of agreement between the two tests. The two methods have different testing characteristics; therefore, the results must be interpreted in accordance with the specific method and the patient's clinical condition.

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