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Brief Report

Auditory Brainstem Response Wave Amplitude Characteristics as a Diagnostic Tool in Children with Speech Delay with Unknown Causes

Susan Abdi[1], PhD;
Ghamartaj Khanbabaee[2], MD;
Kourosh Sheibani[3], MD

[1]Arash Hospital, Tehran University of Medical Sciences, Tehran, Iran;

[2]Mofid Children's Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran;

[3]Imam Hossein Medical Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Correspondence:
Susan Abdi, PhD;
3rd Floor, No. 37, Bahareshiraz Street, Shariati Avenue,
Postal Code: 15657-74419,
Tehran, Iran
Tel: +98 912 1499920
Email: susanabdi2000@gmail.com
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Abstract

Speech delay with an unknown cause is a problem among children. This diagnosis is the last differential diagnosis after observing normal findings in routine hearing tests. The present study was undertaken to determine whether auditory brainstem responses to click stimuli are different between normally developing children and children suffering from delayed speech with unknown causes. In this cross-sectional study, we compared click auditory brainstem responses between 261 children who were clinically diagnosed with delayed speech with unknown causes based on normal routine auditory test findings and neurological examinations and had >12 months of speech delay (case group) and 261 age- and sex-matched normally developing children (control group). Our results indicated that the case group exhibited significantly higher wave amplitude responses to click stimuli (waves I, III, and V) than did the control group (P=0.001). These amplitudes were significantly reduced after 1 year (P=0.001); however, they were still significantly higher than those of the control group (P=0.001). The significant differences were seen regardless of the age and the sex of the participants. There were no statistically significant differences between the 2 groups considering the latency of waves I, III, and V. In conclusion, the higher amplitudes of waves I, III, and V, which were observed in the auditory brainstem responses to click stimuli among the patients with speech delay with unknown causes, might be used as a diagnostic tool to track patients' improvement after treatment.

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Keywords ● Language development disorders ● Diagnosis ● Differential ● Evoked potentials ● Auditory ● Brain stem

What's Known

- Auditory brainstem response has a wide range of clinical applications, including intraoperative monitoring, retrocochlear pathology screening, and newborn hearing screening.
- In most of these applications, wave V latency has been the center of attention; however, there are also a few investigations considering the wave amplitude as a diagnostic factor.

What's New

- We observed higher amplitudes of waves I, III, and V in auditory brainstem responses to click stimuli in patients with speech delay with unknown origins.

Introduction

Language and speech problems, which affect 5% to 8% of preschool children, are the most common types of developmental childhood disabilities.[1] Speech refers to verbal expression, including the way words are formed, while language is a broader system of expressing and receiving information.[2] A number of problems may cause these language and speech deficits, including exposure to more than a single language, a learning disability, hearing loss, psychosocial deprivation, elective mutism, receptive aphasia, cerebral palsy, and autism and similar disorders, which impair social interactions and development.[1,3] It

is important to identify these problems early so that the child can begin treatment.[1]

Speech delay is known as a relatively late start of speech which has a typical pattern of development.[2] Speech delay with an unknown cause is a problem in children. These children exhibit normal findings in routine auditory tests and also show no findings in their test by a neurologist, indicating autism and similar disorders.[2] Treatment should begin as soon as possible, but the dilemma in the diagnosis and treatment of speech delay with an unknown cause is the fact that this diagnosis is a last differential diagnosis after observing normal findings in routine hearing tests among this group of patients and also the absence of any neurological causes of speech delay.

The auditory brainstem response (ABR) is a neurological test used to evaluate the auditory brainstem function in response to clicks as an auditory stimulus.[4] This method was described by Jewett and Williston for the first time in 1971 and is the most common application of auditory evoked responses.[5] The test yields information about the inner ear and the brain pathways of hearing.[6] During this test, the patient rests quietly or sleeps and no response by the patient is necessary. The result of the test is shown as a series of vertex-positive waves, with waves I through V being evaluated by the examiner.[7] These waves, labeled with roman numerals, occur in the first 10 ms after the onset of an auditory stimulus.[7] Considering the fact that the ABR is dependent on external factors, it is considered an exogenous response.[8]

To interpret the ABR, the examiner considers the wave amplitude, which indicates the number of neurons firing; latency of the wave, which indicates the speed of transmission; interpeak latency, which shows the time between peaks; and finally the interaural latency, which shows the difference in wave latency between the 2 ears.[9]

The ABR has a wide range of clinical applications, including intraoperative monitoring,[10] screening for retrocochlear pathology,[11] and universal newborn hearing screening.[12] Additional applications include ICU monitoring,[13] frequency-specific estimation of auditory sensitivity,[14] and diagnostic information regarding suspected demyelinating disorders (e.g. multiple sclerosis).[15] In most of these applications, the wave V latency has been the center of attention, although there are also a few investigations considering the wave amplitude as a diagnostic factor.[16-18]

The objective of this research was to conduct an investigation of the ABR among children with delayed speech disorder with unknown causes and to compare the findings with those in age- and gender-matched children with normal speech ability. To our knowledge, there are very few previous studies evaluating the use of the ABR wave amplitudes as a diagnostic factor, which makes the present study worthwhile.

Patients and Methods

Participants

This prospective, cross-sectional study was performed from May 2006 to April 2013 in a private audiology clinic in Tehran, Iran, and the Neurology Department of Mofid Children's Hospital.

The inclusion criteria were age >10 months and <72 months with a speech delay based on the early language milestone criteria (ELM) for children <3 years old and the Peabody Picture Vocabulary Test–Revised criteria for children >3 years old and normal routine auditory tests like behavioral auditory, impedance audiometry, and distortion-product otoacoustic emission (DPOAE) tests as well as normal neurological examinations by a neurologist.

The control group consisted of children with normal speech development for their age based on the same tests as those in the case group. These children were also matched with the case group based on their sex and age. The control group comprised children from a preliminary school volunteering to enter the study by their parents' consent. The sample size calculation was performed to have a 95% power to detect a difference of 0.1 in the amplitude of wave V when the standard deviation of each group was assumed to be 0.31. Only 250 subjects in each group were required; however, we included 261 cases and 261 controls in our study. The study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran, and all the participants' parents gave a written consent before the children's inclusion in the study. All the findings, including the demographics and the ABR findings as well as the findings of routine hearing examinations and neurological examinations, were recorded in a predesigned questionnaire by the investigators. Out of the 261 participants in the case group, 243 patients were evaluated after 1 year, and the rest of the patients (18 patients) were lost to follow-up.

Instrumentation

In the present study, for pure tone testing and speech audiometry, we utilized an OB922 dual channel clinical audiometer (Version 2).

The Madsen OTOflex 100 OTOdiagnostics suite was used for tympanometry and acoustic reflex measurement and recording.

The ABR was recorded using the Intelligent ICS CHARTR EP 200 (GN Otometrics, Illinois, U.S.A.). DPOAE was recorded using the Capella Cochlear Emissions Analyzer (GN Otometrics).

Test Procedure

Each subject was evaluated using the tools listed above. Also, otoscopy was performed on all the subjects to ensure that no visible external or middle ear abnormalities were present on the day of the test. Speech audiometry was carried out using live voice at 40 dB HL. As was indicated above, tympanometry and acoustic reflexes were recorded to rule out middle-ear pathology.

ABR Recording

An ICS CHARTR EP 200 (GN Otometrics, Illinois, U.S.A.) Auditory Evoked Potentials system was used for the ABR testing. The test was performed while the patients were seated in a reclining chair inside a room that was electrically and acoustically shielded. Acoustic click stimuli with 15-ms durations were individually applied to each ear at 80 dB nHL. The stimulus presentation rate was 21.1 Hz, and EEG samples following 2,000 clicks were averaged to produce each test run. At least 2 runs were obtained in each stimulus condition and compared to determine waveform repeatability. The post hoc analysis of the recordings was carried out by an experienced clinician, blinded to the subjects' identity. For amplitude, the difference between the highest and the lowest points of a wave was calculated. For absolute latency, the time between the sound stimuli and a wave peak of a positive wave was calculated. Interpeak latency was defined as the peak-to-peak time between the waves. We measured the peak latencies of waves I, III, and V at their highest peak. If there was a clearly recognizable wave IV, the peak latency for wave V was measured at its highest peak. If waves IV and V were a complex, wave V was measured at the farthest excursion before the trough of the complex.

Statistical Analysis

To represent the data, we employed mean, standard deviation, median, range, frequency, and percentage. To evaluate the differences between the 2 groups, we used the *t*-test and the chi-square test. Within-group changes were evaluated using the paired *t*-test. All the statistical analyses were performed using SPSS (Version 21.0 Armonk, NY: IBM Corp.). P<0.05 was considered statistically significant.

Results

We recorded the click ABR in 261 children who were clinically diagnosed with delayed speech with unknown causes (case group) and 261 age- and sex-matched normally developing children (control group). There were no significant differences regarding sex and age between the case and control groups (table 1).

When comparing the ABR findings, we did not see any statistically significant differences in the latencies of waves I, III, and V (table 2).

The main difference found between the 2 groups was related to the amplitudes of waves I, III, and V. The mean amplitude of wave V was 0.53±0.2 μV among the cases and 0.21±0.14 μV among the controls (P<0.001) (table 3). This amplitude was significantly reduced after 1 year to 0.45±0.12 μV (P<0.001), but it was still significantly higher than that of the control group (P=0.001) (table 4). The significant difference was seen regardless of the age and sex of the participants. There were also statistically significant differences between the 2 groups considering the amplitudes of waves I and III (table 3); the differences were still significant after 1 year (table 4).

Discussion

The development of normal speech and language functions is closely related to normal hearing.[19]

Table 1: Demographic findings in the case and control groups

	Total	Group		P value
		Case	Control	
Age				
Mean±SD	39.2±13.8	39.4±13.9	39±13.7	0.733‡
Median (range)	36 (10 to 72)	37 (10 to 72)	36 (10 to 72)	
Gender				
M (%)	358 (68.6)	182 (69.7)	176 (67.4)	0.572*
F (%)	164 (31.4)	79 (30.3)	85 (32.6)	

‡Based on the *t* test; *Based on the Chi-square test

Table 2: Wave latencies for waves I, III, and V in the case and control groups

Latency	Total	Group		Diff	95% CI		P value‡
		Case	Control		Lower	Upper	
Absolute latency wave I							
Mean±SD	1.54±0.09	1.53±0.09	1.54±0.09	-0.01	-0.02	0.01	0.464
Median (range)	1.55 (1.14 to 1.73)	1.53 (1.39 to 1.73)	1.56 (1.14 to 1.73)				
Absolute latency wave III							
Mean±SD	3.65±0.16	3.65±0.16	3.64±0.16	0.00	-0.02	0.03	0.807
Median (range)	3.68 (3.3 to 3.83)	3.68 (3.3 to 3.83)	3.68 (3.3 to 3.83)				
Absolute latency wave V							
Mean±SD	5.71±0.42	5.7±0.42	5.72±0.41	-0.02	-0.09	0.05	0.550
Median (range)	5.87 (4.66 to 6.45)	5.87 (4.66 to 6.45)	5.87 (4.66 to 6.45)				
Interpeak latency I-V							
Mean±SD	4.12±0.32	4.12±0.32	4.12±0.32	0.00	-0.05	0.05	1.000
Median (range)	4.1 (3.55 to 4.6)	4.1 (3.55 to 4.6)	4.1 (3.55 to 4.6)				

‡Based on the *t* test

Table 3: Differences in the amplitudes of waves I, III, and V between the case and control groups

Amplitude	Total	Group		Diff	95% CI		P value‡
		Case	Control		Lower	Upper	
Wave I							
Mean±SD	0.18±0.1	0.2±0.08	0.17±0.11	0.03	0.01	0.05	<0.001
Median (range)	0.17 (0.02 to 0.9)	0.2 (0.07 to 0.46)	0.16 (0.02 to 0.9)				
Wave III							
Mean±SD	0.42±0.17	0.55±0.14	0.29±0.1	0.25	0.23	0.27	<0.001
Median (range)	0.37 (0 to 0.87)	0.55 (0 to 0.87)	0.32 (0.1 to 0.45)				
Wave V							
Mean±SD	0.37±0.24	0.53±0.2	0.21±0.14	0.32	0.29	0.35	<0.001
Median (range)	0.23 (0 to 0.9)	0.53 (0 to 0.89)	0.18 (0.08 to 0.9)				

‡Based on the *t* test

Table 4: Differences in the amplitudes of waves I, III, and V between the case group after 1 year and the case group at the start of the experiment and the control group

Amplitude	Post	Pre			P value‡
	Case	Case	P value†	Control	
Wave I					
Mean±SD	0.19±0.04	0.2±0.08	0.006	0.17±0.11	0.013
Median (range)	0.16 (0.05 to 0.38)	0.2 (0.07 to 0.46)		0.16 (0.02 to 0.9)	
Wave III					
Mean±SD	0.49±0.13	0.55±0.14	<0.001	0.29±0.1	<0.001
Median (range)	0.47 (0 to 0.83)	0.55 (0 to 0.87)		0.32 (0.1 to 0.45)	
Wave V					
Mean±SD	0.45±0.12	0.53±0.2	<0.001	0.21±0.14	<0.001
Median (range)	0.45 (0 to 0.89)	0.53 (0 to 0.89)		0.18 (0.08 to 0.9)	

†Based on the paired *t* test; ‡Based on the *t* test

However, most children with delayed speech development show normal tone thresholds, so the investigation of the probable cause should include higher levels in the auditory system.[20] There is evidence suggesting a connection between language impairments and a central auditory processing disorder; nonetheless, the underlying mechanisms are not well known.[20] On the other hand, an objective diagnostic method of central auditory function is needed.

In the present study, we compared the ABR findings between patients with speech delay with unknown causes and age- and sex-matched normal controls. Although our patients did not

show any significant differences in their routine auditory tests such as behavioral auditory, impedance audiometry, and DPOAE tests and also had normal neurological examinations findings, there were statistically significant differences considering the amplitudes of waves I, III, and V between the 2 groups.

Since the advent of the ABR in the early 1970s, much emphasis has been placed on wave latency in utilizing the ABR for studying the different kinds of hearing loss and speech disorders mostly focusing on the wave V latency.[21] Nevertheless, there are a few other studies which have indicated a significant change in amplitude in the ABR readings caused by different diseases. Mason et al.[17] compared the topography of the brain-stem (ABR), middle latency (MLR), and auditory cortical (ACR) responses between children with normal speech and language development and those with either language or motor speech disorders. The authors found that there was a significant inter-group difference when the amplitude of the different responses was considered. The ABR between both the language group and the motor speech group showed small amplitudes for waves I, III, and V when compared to those of the control group, but there was no change in latency. Two explanations were suggested by Mason et al. for this reduction in amplitude between the patients and the normal children. The first explanation was the abnormal functioning of the peripheral hearing mechanism, even though the hearing thresholds were normal (which the authors ascribed to the secondary effect of the deprivation of normal speech and language development). The second explantation was far-field recording effects due to differences in the electrical conductivity of tissue and the distance separating the generator site and the recording electrodes. Since our findings showed a high amplitude among the patients compared to that in the normal controls, our findings are in contrast with the findings by Mason et al.

Azzam et al.[21] compared 15 children with attention deficit hyperactivity disorder with matched normal controls using the ABR. The authors reported that the mean of the ABR had a significant delay in the intervals of waves III, IV, V, I-III, and I-V, with the delay being significantly high among the inattentive type patients; nevertheless, they found no statistically significant differences between the 2 groups regarding the amplitude of the ABR waves.

Gonçalves et al.[22] studied the neurophysiological ABR to clicks and repeated speech stimuli in typically developing children and children with phonological disorders. They reported that the latency of waves I, III, and V was significantly longer in the cases than in the controls. Although all the measures were within the normal range values, the authors did not report any statistically significant differences considering the wave amplitudes between the 2 groups. They also suggested that the speech-evoked ABR might have a higher sensitivity for finding phonological disorders than the click-evoked ABR.

The difference between the findings of the above-mentioned studies and our findings might be due to patient selection. Those investigations entered patients with any phonological disorder in their evaluations, while we only entered patients with speech delay with unknown causes.

Rance et al.[23] studied the ABR findings among children with Charcot-Marie-Tooth disease and observed a delayed or low amplitude ABR. The ABR amplitudes were reduced in the individuals with an axonal form of the disease. In comparison with their findings, we found a sharp increase in the wave V amplitude among our patients, which can be related to the different nature of underlying pathologies.

We also found a significant reduction in the wave V amplitude among our patients after 1 year and improvement of speech among our patients, which somehow confirms our previous findings linking high amplitudes and delayed speech. Nonetheless, even after this period, the amplitude was still significantly higher in the case group than in the normal group.

To our knowledge, the present study is the first study to indicate an increase in the ABR wave amplitudes among patients with speech delay with unknown causes compared to normal children. A more in-depth understanding of the underlying mechanism of this increased amplitude among patients requires further studies with longer follow-up periods.

Conclusion

The higher amplitudes of waves I, III, and V observed in the ABR to click stimuli in patients with speech delay with unknown origins might be used as a diagnostic tool in these patients to track their improvement after treatment. More studies emphasizing on wave amplitudes among these patients with longer follow-up periods are suggested.

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Conflict of Interest: None declared.

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