Auditory Brainstem Response in children with Attention Deficit Hyperactive Disorder

Original Article

Ahmed Elsayed Gelaney[1], Eman Mohammed Mostafa[x], Salwa Mourad Abdelmawgoud[2], Maha Ahmed Ahmed Ibrahim[1]

Department of [1]Phoniatrics Unit, Otolaryngology, [2]Audiovestibular Unit, Otolaryngology, Faculty of Medicine, Sohag University, Sohag, Egypt

ABSTRACT

Background: Problems with attention, hyperactivity, and impulsivity are the main features of attention deficit-hyperactivity disorder. Among children with ADHD, delayed language development is a very common co-morbidity.

Objectives: To study if there were deficits in auditory brain stem response to speech stimuli in children with attention deficit hyperactive disorder.

Methodology: This study was conducted on 22 children diagnosed as having ADHD by fulfilling the criteria of DSM-V and 10 children (as control group) with DLD not fulfilling criteria of ADHD by of DSM-V. All patients were evaluated using Intelligent Quotient (IQ), Attention Deficit Hyperactivity Disorder Test. Participants in the study who had hearing impairments were excluded. Ear examination was done. Audiological examination was done, Tympanometry, Click evoked Auditory Brainstem Response and Speech Evoked Auditory Brainstem Response (S-ABR) were done in the Sohag audiology unit for all the children.

Results: There was high statistically significant difference between the two groups in the latencies of wave V, A. A significant shift in the latency of wave D was observed. Also, there was high statistically significant correlation between the degree of ADHD and the latency of wave V. A significant correlation between the degree and latency of wave A, C and O.

Conclusion: Children with ADHD showed abnormal speech processing at the level of the brain stem. The more the degree of ADHD the more affection occurs on the latency of S-ABR.

Key Words: ADHD, S ABR.

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Corresponding Author: Ahmed Elsayed Gelaney, Department of Phoniatrics Unit, Otolaryngology, Faculty of Medicine, Sohag University, Sohag, Egypt, **Tel.:** +201008475526, **E-mail:** ahmedgelaney70@gmail.com

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INTRODUCTION

Severe defects in attention control, hyperactivity and impulsivity are main features of attention deficit-hyperactivity disorder (ADHD). ADHD is primarily seen in children, but it can also have long-lasting impacts on adults[1].

In the United States the prevalence of ADHD ranges from 3 % to 7 % in children at school age. However, when estimating the prevalence of ADHD in a psychiatric setting, the figures showed that the most prevalent psychiatric illness was attention deficit hyperactivity disorder[2]. Boys have higher incidence of ADHD than girls, but the ratio ranges greatly from 2:1 to 9:1. For the inattentive type of ADHD; males show more aggressiveness and behavioral problems than girls[3].

There are three types of ADHD: The inattentive-type (The inattention is the main symptom), the hyperactive/impulsive-type (hyperactivity/impulsivity are the predominate symptom) and the combined-type. Symptoms of ADHD appear in children before the age 12 years. The duration of the symptoms must exceed six months. The symptoms should be widespread and present in two or more contexts, usually home and school. Lastly, the symptoms of ADHD causes social problems, also it affects academic performance and occupational problems[4].

One of the most common co-morbidities in children with behavioral problems and psychiatric disorders is delayed language development[5] and Conversely, children with ADHD frequently co-morbid with delayed language development[6]. There are few studies that particularly study the language abilities of patients with ADHD, in

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spite of the fact that these two frequent diseases frequently co-occur[7].

Language delay is the commonest developmental problem in early childhood[8], occurring in 48.6 % of ADHD children. The difficulty in paying continuous attention to the speech can be the reason for the delay, as language development is closely linked to hearing and listening, which are ongoing processes[9].

Patients with ADHD are typically referred to phoniatricans because these children frequently display functional area problems that are linked to language ability deficiencies. For instance, they have difficulties in sequencing and deficits in problem solving. Most of these patients struggle with following instructions and using pragmatic language. The phoniatrician/ speech-language pathologist is responsible to examine children who such problems and to make suggestions regarding diagnosis and treatment[10].

Clicks or tone bursts are the most popular ways to elicit the auditory brainstem response (ABR), that has proven to be a useful clinical method for assessing brainstem neural activity. However, Skoe *et al.*, (2015)[11] have shown that complex stimuli—including complex tones, music and speech stimuli like /da/, /ba/ and /ga/—can also elicit the response. A speech stimulus is especially helpful since it can give indications about the brainstem's preservation of temporal and spectral properties.

Speech-ABR is a relatively new unique method for measuring brainstem response since it can measure speech's subcortical encoding and reveal the characteristics of the stimulus's acoustic cues. Researchers are presently using it to evaluate the subcortical identification of vowels and consonants (CVs) and to compare the behavioral outcomes of speech detection in noise in persons with average hearing to the subcortical storage of speech in noise[12].

The speech-evoked ABR gives distinct demonstrations of several characteristics of the acoustic construction of speech, including phase-locking to the fundamental and formant frequencies, separate neural representations of speech sound onset and speech sound offset[13]. Numerous studies on the auditory brainstem response to speech sounds in auditory specialization have been conducted (e.g., musicians), specific language impairment, autism, language-based learning disabilities like dyslexia, auditory processing disorders and hearing impairment[11].

OBJECTIVES

To study if there were deficits in auditory brain stem response to speech stimuli in children with attention deficit hyperactive disorder.

METHODOLOGY

The study was carried out after being approved by Sohag Faculty of Medicine Research Ethics Committee. The participants' parents or legal guardians provided informed written consent (IRB Registration number: Soh-Med-24-05-07PD).

1-Subjects: Two groups:

(A) Study group: include 22 children, inclusion criteria Delayed language Development (DLD), diagnosed as having ADHD by fulfilling the criteria of DSM-V, age range 3-7 years. Exclusion criteria: mental retardation, hearing loss, middle ear effusion and any neurological disorder.

(B) Control group: include 10 normal hearing children with DLD, age range from 3 to 7 years and not fulfilling criteria of ADHD by ADHDT.

2- Method:

A) Equipments: The study was conducted in a sound treated room type IAC model 1602, Audiometry (Pure tone): Madsen Orbiter 922, Immittancemetry: Maico MI44 and Evoked potentials system SMART intelligent hearing system.

B) Procedure:

1- A written informed consent from the parents.

2- Intelligent Quotient (I.Q): using Stanford Binet test (IV version)[14].

3- Diagnosis and Statical manual of mental health (DSM_V) was used for diagnosis of ADHD[4].

4- ADHDT (Gilliam test)[15]: to obtain scores for hyperactivity, impulsivity, inattention and ADHD Quotient. With the assistance of the parents, the psychometric had administered the test.

5- Otological examination.

6- Basic audiological evaluation: consist of Tympanometry evaluation and acoustic reflex threshold, audiometry play or conventional according to age and cooperation of children, speech audiometry; speech reception threshold (SRT) by use of bisyllabic words for children[16] and word discrimination scores using age-appropriate test[16, 17].

7- Speech auditory brainstem response:

The first click evoked ABR was used to confirm that wave V was present and then speech evoked auditory brain stem response is done according to following stimulus parameters and recording parameters.

Stimulus parameters: Speech stimulus is a 40 ms /da/ syllable that is delivered at an intensity of 80 dBSPL, alternating polarity and 11 p /sec presentation rate. The right ear receives the stimulus monaurally through ER3A-insert phone. The stimulus consists of a first 10 ms onset noise burst and formant transition among consonant and a steady-state vowel. The stimulus created by IHS Company and comprised in speech auditory brain stem response.

Recording parameters:

Reference electrode on left side, negative electrode on right side, active electrode on high frontal (Fz), ground electrode on low frontal (FPz) and so on. According to Vander Werraf and Burns[18], there is no ear difference in speech ABR recordings, hence we solely use the right ear's recording. electrodes linked to the preamplifier of the intelligent HIS EP apparatus, with 4000 sweeps, a band pass filter ranging from 100 to 1500 Hz, a 75 ms analysis duration and a 15 ms pre-stimulus recording.

Response analysis:

Seven waves make up the response (V, A, C, D, E, F and O); wave V is the same as wave V elicited by the click stimulus and wave A is the negative trough wave A. after the initial response a series of the waves occurs (wave C, D, E, F) represent the FFR. Then (wave O) represent the offset of the response.

Statistical analysis: Quantitative data represented in mean and standard deviation (SD). Qualitative data were presented in frequencies and percentages and compared by cross tabulation. Preoperative compared to postoperative data by Friedman test as non-parametric related data. In all analyses *P* value < 0.05 indicated statistical significance.

RESULTS

The number of children in the control group was 10 children, they were 8 boys (80 %) and 2 girls (20 %) and their age ranges from 36 to 68 months with the mean of 47.1. Within the study group, there were 22 ADHD children in the study group. Their age ranges from 35 to 84 months with the mean of 59.64, they were 18 boys (81.82 %) and 4 girls (18.18 %).

Table 1: Mean and SD of IQ, ADHD Quitent, Hyperactivity, Impulsivity and Inattention score in the study and control groups:

	Control group		**Study group**		**t-value**	***P* value**
	mean	**SD**	**mean**	**SD**		
IQ	90.25	5.522	87.714	28.21	1.16	0.13
ADHD Quitent	83.14	16.79	94.25	9.91	2.12	0.02*
Hyperactivity	10.29	3.15	10	1.59	0.31	0.38
Impulsivity	7.57	3.46	9.10	2.27	1.34	0.097
Inattention	5.78	2.33	8.50	2.40	2.52	0.009*

There was high statistically significant difference between the two groups in the inattention score. A significant difference in the ADHD Quitent was observed.

Table 2: Number and % of ADHD children according to the degree of ADHDQ:

	Study		**Control**	
	No	**%**	**No**	**%**
Very high	1	4.55	0	0
High	1	4.55	0	0
Above average	2	9.09	0	0
Average	12	54.55	0	0
Below average	6	27.27	0	0
Low	0	0	7	70
Very low	0	0	3	30

Play audiometry was applied to the all children and their hearing was normal on both sides. Bilateral type A tympanograms with bilateral preserved ipsilateral and contralateral acoustic reflexes. ABR at 88 dBnHL: was carried out to identify wave V on the entire study and control groups.

Speech ABR:

Table 3: Mean and SD of S-ABR latency in control and study groups:

	Control group		**Study group**		**t-value**	***P* value**
	Mean	**SD**	**Mean**	**SD**		
V	6.30	0.18	6.54	0.27	- 3.42	0.001**
A	7.20	0.25	7.66	0.29	- 5.41	0**
C	18.72	0.70	18.9	0.59	- 0.96	0.30
D	22.10	0.40	22.56	0.60	- 2.73	0.01*
E	31.05	1.40	31.33	0.80	- 0.73	0.47
F	39.40	0.80	39.7	0.90	- 1.20	0.20
O	48.49	1.20	48.43	1	1.60	0.86

Table 3 showed high statistically significant difference between the two groups in the latencies of wave V, A. A significant shift in the latency of wave D was observed.

Table 4: Correlation between speech ABR latencies and degree of ADHD:

	Speech ABR latencies	Mean	SD	Correlation co-efficient	*p* value
Degree	V	6.54	0.27	0.046	0.002**
	A	7.66	0.29	- 0.207	0.043*
	C	18.9	0.59	0.239	0.057*
	D	22.56	0.60	- 0.507	0.257
	E	31.33	0.80	- 0.294	0.087
	F	39.7	0.90	0.402	0.162
	O	48.43	1	0.105	0.011*

Table (4) showed high statistically significant correlation between the degree of ADHD and the latency of wave V. A significant correlation between the degree and latency of wave A, C and O.

DISCUSSION

In child and adolescent psychiatry, attention deficit hyperactivity disorder (ADHD) is one of the most prevalent conditions, occurring at a frequency of more than 5 %[19].

In this study, the boys were more prevalent than girls with the percentage of 81.82 %. This matches the results of Curran et al. (2000)[20], who discovered that males are affected two to three times more often than females. This has been proven by Tahir et al. (2000)[21] in a Turkish study and Fayyad *et al.,*(2018)[22], who discovered that males had a 3:1 ADHD ratio compared to females. Boys with ADHD diagnoses usually come to clinics since they have conduct behaviors, aggression and opposition. They tend to have very disruptive behavior in the classroom that draws their teacher's attention. The male predominance most likely reflects an actual sex difference in prevalence as well as referral bias because males tend to exhibit more disruptive conduct than females. There are many other developmental abnormalities (autism, stuttering and SLI) have a sex ratio that is consistent with the excess boys to girl's ratio like ADHD[23].

There was a significant difference in the ADHD Quitent between control and study groups also there was high statistically significant difference between the two groups in the inattention score. This finding agrees with Douglas (1983)[24] who theorized that children with ADHD struggle most to maintain their attention when responding to tasks (vigilance).

There were shift of wave V and wave A to the right. ADHD children were differed in the brainstem responses to the source cues, as reflected by the distance between the peaks of FFR (C, D and E). Significant latency delay was essentially found when wave D was considered (22.56 msec.) compared to the normal children (22.1 msec.) Table 3. These results show a close relationship between brainstem response to speech sounds and cerebral function. The existence of anomalies in temporal processing at the brain stem level is an important factor to take into account with the existing data. The correlation between speech sound processing at the brainstem and cortical processing may be explained by the three next basic mechanisms, even though the facts presented here do not prove association. The first mechanism is that abnormal cortical activation patterns are caused by neuronal abnormalities at a lower (more peripheral) level of the auditory pathway; this theory is supported by signal flow in the auditory system's afferent pathway. The fact that auditory brainstem responses mature several years before auditory cortex does is evidence in favor of this hypothesis[25], suggesting a hierarchy of peripheral to central growth for this system. This interpretation would be detrimental because it oversimplifies a very complex system that incorporates top-down[26] and parallel[27] processing from the cortex, allowing ongoing interactions between the brainstem and cortex. A second mechanism, known as a reverse hierarchy mechanism, posits that aberrant cortical function may result in defective neuronal synchronization in the brainstem and high-level cortical areas that govern plasticity at lower cortical levels[26], is also a possibility. The following is a third theory that could explain the dynamics of aberrant brainstem–cortical function: The nature of the defective function is truly systemic, not specifically caused by improper brainstem or cortical activity. According to this mechanism, asynchronous activity patterns between the two auditory regions may be the cause of the system's overall failure, which is represented by aberrant brainstem–cortical function. There was a highly statistically significant correlation between the degree of ADHD and the latency of wave V, a significant correlation between the degree and latency of wave A, C and O. This means that the ADHD children exhibited pan-auditory neural deficits (abnormal overall neural synchrony) affecting both the filter elements (transients) and also the source elements (fundamental frequency).

The pattern of affection of the evoked brainstem response to speech stimulus among ADHD children was different than obtained with other clinical population such as autistic patients and learning-disabled children. This study contradicts the findings of Kraus and Nicol (2005)[28], who found dissociation between the brainstem's encoding of the fundamental frequency (source) and harmonic and timing cues (filter) for every aspect of the response (filter and source cues). Brainstem responses to these acoustic streams have also been discovered to vary between clinical and normal populations.

CONCLUSIONS

ADHD children exhibited abnormal speech processing at the level of the brain stem affecting both the transient and sustained components. The more the degree of ADHD the more affection occurs on the latency of S-ABR.

CONFLICTS OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Banaschewski T , Becker K, Döpfner M, Holtmann M, Rösler M and Romanos M (2017): Attention-Deficit/Hyperactivity Disorder, A Current Overview. Deutsches Ärzteblatt International doi: 10.3238/arztebl.2017.0149.

2. Thomas R, Sanders S, Doust J and Beller E (2015): Prevalence of attention-deficit/hyperactivity disorder: a systematic review and meta-analysis Pediatrics, - publications.aap.org.

3. Davies W (2014): Sex differences in attention deficit hyperactivity disorder: candidate genetic and endocrine mechanisms. Frontiers in neuroendocrinology, - Elsevier.

4. American psychiatric Association (APA) Diagnostic and Statistical Manual of Mental disorders. 5th ed. Washington, DC: American Psychiatric Association. pp. (2013) 77-78.

5. Beitchman J, Wilson B, Johnson C, Atkinson L, Young A and Adlaf E. (2001): Fourteen-year follow-up of speech/language-impaired and control children: psychiatric outcome. J Am Acad Child Adolescent Psychiat; 40:75–82.

6. Dyck M and Piek J (2014): Developmental Delays in Children With ADHD. Journal of Attention Disorders. Volume 18, Issue 5.

7. Cohen N, Menna R, Vallance D, Barwick M, Im N and Horodezky N (2000): Language, Social Cognitive Processing and Behavioral Characteristics of Psychiatrically Disturbed Children with Previously Identified and Unsuspected Language Impairments. The Journal of Child Psychology and Psychiatry and Allied Disciplines.

8. El Sady S, Nabeih S, Mostafa E and Sadek A (2013): Language impairment in attention deficit hyperactivity disorder in preschool children. Egyptian Journal of Medical Human Genetics.

9. Gupta R and Ahmed R (2003): Attention deficit hyperactivity disorder – can we do better? Int Pediat;18(2):84–6.

10. Heyer L (1995): Responsibilities of speech pathologists toward children with ADHD. Semin Speech Lang;16(4):275–88.

11. Skoe, E., Krizman, J., Anderson, S. and Kraus, N. (2015); Stability and plasticity of auditory brainstem function across the lifespan. Cerebral Cortex, 25(6), 1415–1426.

12. Elsayed H, Nada E, Galhoum D and Elnabtity N (2024): Speech auditory brainstem responses (s-ABRs) as a new approach for the assessment of speech sounds coding. The Egyptian Journal of Otolaryngology. 40:10 https://doi.org/10.1186/s43163-024-00562-z.

13. Russo, N., Nicol, T., Trommer, B., Zecker, S. and Kraus, N. (2009); Brainstem transcription of speech is disrupted in children with autism spectrum disorders. Developmental Science, 12(4), 557–567.

14. Faraj, S. (2010): Stanford-binet intelligence scales (SB5) fifth edition. Cairo; the anglo Egyptian Bookshop.

15. Gilliam (1995): Attention-Deficit Hyperactivity Test. A method for identifying individuals with ADHD. Austin. Texas: PRO-ED.

16. Elmahallawi T and Soliman, S. (1984): Simple speech test material as a predictor for speech recognition threshold in preschool children Ain Shams University, Cairo - Unpuplished thesis 1984.

17. Soliman, S. (1976): speech discrimination audiometry using Arabic Phonetically balanced words. Ain Shams Med. J. (27):27-30.

18. Vander, W, Kathy R Brain stem response to speech in younger and older adults. EAR and HEARING (2011) 32(2):168-180.

19. Drechsler R, Brem S, Brandeis D, Grünblatt E, Berger G and Walitza S. (2020): ADHD: Current Concepts and Treatments in Children and Adolescents. Neuropediatrics; 51:315–335.

20. Curran S, Newman S, Taylor E, Asheron P. and Hyperscheme (2000): an operational criteria checklist and minimum data set for molecular genetic studies of attention deficit hyperactivity disorders. Am J Med Genetics; 96:244–50.

21. Tahir E, Yazgan Y, Ozbay F, Waldman I, Asheron P. (2000): Association and linkage of DRD4 and DRD5 with ADHD in a sample of Turkish children. Mol Psychiat; 5:396–404.

22. Fayyad J, Graaf R, Kessler R , Alonso J , Angermeyer M, Demyttenaere K, Girolamo G, Haro J , Karam E and Lara C (2018): Cross-national prevalence and correlates of adult attention-deficit hyperactivity disorder. Published online by Cambridge University Press.

23. Verloove-Vanhorick SP, Veen S, Ens-Dokkum MH (1994): Sex difference in disability and handicap at five years of age in children born at very short duration. Pediatrics; 93:576–9.

24. Douglas V. and Parry P (1983): Effects of reward on delayed reaction time task performance of hyperactive children. Journal of abnormal Child Psychology 11; 313- 326.

25. Ponton CW, Eggermont JJ, Kwong B and Don M (2000): Maturation of human central auditory system activity: evidence from multi-channel evoked potentials - Clinical neurophysiology, - Elsevier.

26. Xiao Z and Suga N (2002): Modulation of cochlear hair cells by the auditory cortex in the mustached bat Nature Neuroscience volume 5, pages57–63.

27. Kaas JH and Hackett TA (2000): Subdivisions of auditory cortex and processing streams in primates. Proceedings of the National Academy of Sciences, National Acad Sciences.

28. Kraus N and Nicol T (2005): Brainstem origins for cortical 'what' and 'where' pathways in the auditory system. Trends Neurosci; 28(4): 176–181.