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ORIGINAL ARTICLE

Assessment of Higher Cognitive Function Using P300 in Children with Specific Language Impairment: Data from Zagazig University Hospital

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ABSTRACT

Background: Specific language impairment (SLI) is diagnosed when a child has difficulty in producing or understanding spoken language for no apparent reason. In other words, these children present with a developmental language impairment in the absence of mental retardation, sensory disorders, serious emotional or physiological problems, or environmental deprivation. About 7% of children exhibit significant difficulties in receptive and/or expressive language.

Patients and Methods: A case-control study was conducted on 50 children with a mean age of 8.24 years, of both sexes, allocated into two groups (n=25): SLI children (study group) and healthy children (control group). The study was carried out at the Audio-Vestibular Medicine Unit in Zagazig University Hospitals. All participants underwent a language test (receptive, expressive, and total language items), an Intelligence Quotient (IQ) test, and an audiological evaluation consisting of P300 amplitude and latency evaluations.

Results: Our results showed a highly significant difference in P300 latency between both groups, with a non-significant difference concerning P300 amplitude. The study group had substantially lower mean receptive, expressive, and total language ages in comparison to control group. A significant negative correlation was found between P300 latency in both ears and IQ or language age parameters, however, a non-significant positive correlation was detected between P300 amplitude with IQ or language age (P > 0.05).

Conclusion: P300 latency is significantly higher in the SLI group, hence it may be regarded as an effectively diagnostic tool for the early assessment of auditory processing dysfunction in children suffering from SLI.

Keywords: Specific language impairment, Cognitive function, P300 potential, language age parameters, IQ.

INTRODUCTION

Specific language impairment (SLI) is a condition of a developmental language issue that affects 7-8% of children. It is defined by the failure to master spoken and written language expression and understanding while having adequate nonverbal intellect, hearing acuity, and speech motor abilities and in absence of any documented physical impairment, syndrome, or other medical conditions known to cause this linguistic difficulties [1].

Deficient language development for no apparent cause constitutes a diagnostic criterion for SLI. It was believed that SLI was caused by circumstances like as inadequate parenting, birth-related brain injury, or transitory hearing loss. It is evaluated through audiological, linguistic, and speech tests [2].

Children with SLI may have atypical cognitive processes which make them unable to acquire language normally. Cognitive processes can be measured by cortical auditory evoked potentials (CAEPs) is auditory processing [3]. CAEPs are long-latency responses to auditory stimuli recorded by using surface electrodes on the scalp (best recorded at the vertex so-called vertex potential or slow vertex response, SVR); which occur between 50 and 300 milliseconds (MS) after stimulus onset. These responses are measurable changes in the electrical activity of the brain, so can be used as a tool to evaluate the auditory pathway [4].

Cognitive Auditory Evoked Potential (P300) is one of the cortical evoked potentials that offers objective criteria of the central auditory system's functioning utilizing endogenous stimuli [5].

This potential reflects information about the electrophysiological activity at the cortical level, involved in attention, discrimination, memory, integration, and decision-making. P300 is a positive wave produced when an uncommon stimulus is distinguished from a sequence of frequent stimuli. This potential requires the completion of cognitive activity; hence, it depends on the conscious reaction of the subject. It is known that the P300 component is produced in the auditory cortex area [6].

To the best of our knowledge, this is the first research and has still not been thoroughly studied in the Zagazig University Hospitals about the evaluation of higher auditory functions in children with SLI utilizing cortical auditory evoked potential (P300 test). Hence, we conducted this study in order to improve the prognosis of these patients.

METHODS

This is a case-control study that was performed at the Audio-Vestibular Medicine unit, ENT department in Zagazig University Hospitals, , Egypt, for a period of one year from June 2020 to June 2021.

Fifty children of both genders including (16 male and 9 female) for each group, with age range from 7 to 10 years, were in the study. They were divided into 2 groups: 25 normal hearing children with no complaint regarding language and speech with an average IQ (90-110) (control group) and 25 diagnosed as SLI at phoniatric unit based on Language testing using modified preschool language scale- fourth (modified PLS-4) Arabic edition. Speech analysis was performed using the Ain Shams Assessment protocol and Arabic articulatory test for speech assessment that show a gap between receptive and expressive language age and delayed total language age with normal hearing sensitivity and with an average IQ (90-110) (study group).

Before the beginning of the study, the suggested protocols were declared to all parents, who accepted and their children met the inclusion criteria mentioned below. Full history taking regarding personal, prenatal, perinatal, postnatal, developmental, past medical history for otological and neurological diseases, and family history. Otological examination to exclude external or middle ear diseases.

Inclusion_criteria: children of both genders, matched age, ranging from 7-10 years with average intelligence quotient (90-110). Normal hearing not exceeding 20 dB in the frequency range of 250 through 8000 Hz, with normal middle ear function evidenced by otological examination, tympanometry, and acoustic reflex thresholds.

Exclusion criteria: Patient with hearing loss, mental retardation, neurological congenital malformation, history of neurological disorders or head trauma, and children with other language or speech problems were excluded from the study.

Methodology

Participants of study group were subjected to

Basic audiological evaluation that includes:

Conventional pure tone and speech audiometry using the two-channel diagnostic audiometer, [Madsen, Model, Orbiter 902].

Immitancemetry using immittancemeter [Madsen, Model, Zodiak 902].

Cortical auditory Evoked potential assessment: to perform p300 test, using Interacoustics, model Eclipse 25.

Waveform, amplitude, and latency were analysed. P300 latency was measured in the middle of a single peak or by averaging peak values if two peaks were present. If P300 amplitude peaks or broad responses were present, latency was calculated by intersecting extrapolation lines from ascending and descending slopes [7, 8].

Language and Speech assessment including:

Language testing using modified preschool language scale- fourth (modified PLS-4) Arabic edition, this test measures receptive, expressive, and total language ages [9].

Speech analysis was performed using the Ain Shams Assessment protocol which includes auditory perceptual assessment of patients, speech samples [10].

IQ using Stanford Binet 5th edition. All participants had IQs of at least 90 [11].

Arabic articulatory test for speech assessment, this test includes a set of photos with a list of their corresponding words each Arabic phoneme is presented by 3 photos for different words containing the phoneme in initial, middle or final position in the presented word [12].

Ethical consideration.

Written informed consent was obtained from all participants. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

The study design is approved by the Institutional Review Board (IRB) unit. (IRB Number: ZU-IRB#6105#28-04-2020).

STATISTICAL ANALYSIS

The collected data were tabulated and analyzed by SPSS version 20 (statistical package for the social science software). Quantitative data were expressed as mean and standard deviation (X

±SD), while qualitative data were expressed as numbers and percentages (No & %) and analyzed using the chi-square test. For comparison between the normally distributed quantitative data at the interval for the same group, a paired-samples t-test was applied. In contrast, Wilcoxon signed-rank test was applied for non-normally distributed data. Model evaluation was based on accuracy, sensitivity and specificity, as well as area under the curve (AUC) of the receiver operating characteristic (ROC). P-value≤ 0.05 was considered statistically significant.

RESULTS

50 children were included in the study divided into 2 groups, study group and control group; with an average age of 8.24 ± 1.2 and 8.40 ± 1.118, for study and control group, respectively **Table (1).**

Table (1): Children's demographic characteristics, and Audiogram of study participants

		Study group (n= 25)	Control group (n= 25)	Test -value	P-value
Age		8.24 ± 1.200	8.40 ± 1.118	0.49	0.628[1]
Gender				0	1[2]
Male		16 (64.0%)	16 (64.0%)		
Female		9 (36.0%)	9 (36.0%)		
Comparison of pure tone thresholds (dB HL) at different frequencies in both ears					
250	**Right**	8.20 ± 4.052	8.80 ± 2.986	0.60	0.554[1]
	Left	8.40 ± 3.136	9.20 ± 4.000	0.79	0.435[1]
500	**Right**	8.60 ± 3.069	8.80 ± 3.894	0.20	0.841[1]
	Left	9.00 ± 3.227	8.80 ± 3.617	0.21	0.837[1]
1000	**Right**	8.40 ± 2.784	9.20 ± 2.769	1.02	0.313[1]
	Left	9.20 ± 4.000	8.80 ± 2.986	0.40	0.690[1]
2000	**Right**	9.00 ± 2.500	9.40 ± 2.630	0.55	0.584[1]
	Left	8.40 ± 3.742	8.80 ± 2.986	0.42	0.678[1]
4000	**Right**	9.00 ± 2.887	9.20 ± 3.122	0.24	0.815[1]
	Left	9.80 ± 4.203	8.20 ± 3.500	1.46	0.150[1]
8000	**Right**	9.00 ± 3.227	9.60 ± 4.062	0.58	0.566[1]
	Left	10.20 ± 3.948	9.40 ± 4.406	0.68	0.502[1]
SRT	**Right**	8.20 ± 3.189	8.20 ± 3.189	0.00	1[1]
	Left	9.40 ± 3.629	8.00 ± 2.500	1.59	0.119[1]
WDs%	**Right**	0.99 ± 0.019	1.00 ± 0.013	1.72	0.091[1]
	Left	0.99 ± 0.019	1.00 ± 0.013	1.72	0.091[1]

1. Independent t-test. 2. Chi-square test *statistically significant as p< 0.05.

All subjects in the study and control group have type (A) tympanogram and preserved acoustic reflexes in both ears with no significant difference between both groups with respect to pure tone thresholds at all frequencies, SRT and WDs % in both ears. The two groups have normal hearing sensitivity at all frequencies, Table (1).

P300 latency show a statistically significant difference between study and control groups in right and left ears, while a non-significant difference between both groups, in both ears, was detected concerning P300 amplitude, **Table (2).**

Table (2): Comparison of P300 latency and amplitude of study versus the control group.

			Study group (n= 25)	Control group (n= 25)	Test -value	P-value
P300	**Latency**	**Right**	**345.72 ± 19.332**	**315.52 ± 12.490**	**6.56**	**< 0.001[1]***
		Left	**349.20 ± 17.856**	**316.40 ± 25.915**	**5.21**	**< 0.001[1]***
	Amplitude	**Right**	**4.40 ± 2.308**	**5.23 ± 1.702**	**1.46**	**0.151[1]**
		Left	**4.29 ± 1.822**	**4.47 ± 1.673**	**0.36**	**0.718[1]**

1. Independent t-test. *statistically significant as p< 0.05.

Also, Average IQ in study and control group was 97.12 ± 4.216 and 98.68 ± 3.602, respectively, **Table (3).**

Table (3): Intelligence Quotient (IQ) and language age parameters of study group and control group.

		Study group (n= 25)	Control group (n= 25)	Test-value	P- value
IQ		97.12 ± 4.216	98.68 ± 3.602	1.41	0.166[1]
Language age	Receptive	57.24 ± 4.294	62.00 ± 0.0001	5.54	< 0.001*[1]
	Expressive	63.48 ± 6.145	71.00 ± 0.001	6.12	< 0.001*[1]
	Total	120.72 ± 10.159	133.00 ± 0.001	6.04	< 0.001*[1]

1. Independent t-test. *statistically significant as p< 0.05.

The mean receptive, expressive, and total language age in the study group was significantly lower in comparison to control group. The mean IQ and language age tests (receptive, expressive, and total) versus P300 test results have been calculated for multiple correlations. Our findings revealed that a statically significant negative correlation were found between P300 latency in right and left ear with IQ, total language age, receptive language age or with expressive language age. Whereas a non-significant positive correlation was detected among P300 amplitude in both ear with IQ or with language age parameters (receptive, expressive, and total), **Table (4).**

Table (4): Correlation between IQ, or language age paramter (receptive, expressive and total) Versus P300 test results in the current study.

			IQ		**Total language age**		**Receptive language age**		**Expressive language age**	
			Correlation coefficient	**P- value**	**Correlation coefficient**	**P-value**	**Correlation coefficient**	**P-value**	**Correlation coefficient**	**P-value**
P300	**Latency**	**Right**	**-0.318**	**0.024**	**-0.688**	**0.0001**	**-0.662**	**0.0001**	**-0.688**	**0.0001**
		Left	**-0.243**	**0.089**	**-0.607**	**0.0001**	**-0.592**	**0.0001**	**-0.601**	**0.0001**
	Amplitude	**Right**	**0.182**	**0.207**	**0.092**	**0.525**	**0.154**	**0.284**	**0.048**	**0.742**
		Left	**0.025**	**0.865**	**0.011**	**0.940**	**0.005**	**0.973**	**0.015**	**0.920**

Multiple regression analyses of the diagnostic profile of auditory evoked potential test results in detecting presence of SLI showed that AUC of average latency was 0.903 and the best diagnostic cut-off point (threshold concentration) was 331.5 that maximized true +ve and false -ve outcomes (with 80 % sensitivity and specificity of 88 %). Additionally, concerning the right and left latency, the best diagnostic cut-off point was 324.5 (with 88 % sensitivity and specificity of 84 %) and 328.5 (with 88 % sensitivity and 76 % specificity), respectively as illustrated in Table (5) and shown in receiver operating characteristic (ROC) curve of auditory evoked potential test results, **Figure (1).**

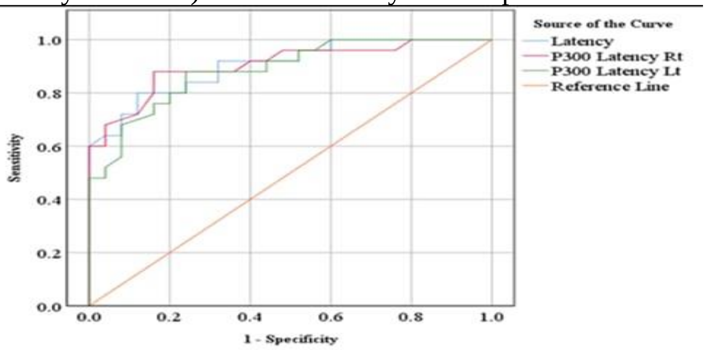

Figure (1): Receiver operating characteristic (ROC) curve of auditory evoked potential test results for detection of the presence of Specific Language Impairment.

All subjects in the study and control group have type (A) tympanogram and preserved acoustic reflexes in both ears with no significant difference between both groups with respect to pure tone thresholds at all frequencies, SRT and WDs % in both ears. The two groups have normal hearing sensitivity at all frequencies, Table (1).

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Table (5). Diagnostic profile of auditory evoked potential test results in detecting presence of Specific Language Impairment.

	Average latency	**Right latency**	**Left latency**
AUC	0.903	0.905	0.886
95% CI of ACU	0.822, 0.984	0.820, 0.989	0.798, 0.975
P-value	**< 0.001**	**< 0.001**	**< 0.001**
Cutoff point	331.5	324.5	328.5
Youden's index	0.680	0.720	0.640
Sensitivity	80.0%	88.0%	88.0%
Specificity	88.0%	84.0%	76.0%
PPV	87.0%	84.6%	78.6%
NPV	81.5%	87.5%	86.4%
Accuracy	84.0%	86.0%	82.0%

And shown in receiver operating characteristic (ROC) curve of auditory evoked potential test results, Figure (1).

DISCUSSION

Specific Language Impairment (SLI) is a term uesed by Stark and Tallal [13] to describe a group of children who have trouble acquiring and utilizing language without an apparent cause. These children have average nonverbal IQ, hearing, and social and emotional skills. A variety of language challenges are reported in these children, such as delayed onset and slower learning of lexical and grammatical forms, smaller vocabularies, trouble acquiring and employing inflectional morphology and complicated syntax [14].

Children with SLI have abnormal cognitive processes and are unable to acquire language in the normal way. Auditory processing is one of the cognitive processes involved in language acquisition, which is measured by cortical auditory evoked potentials (CAEPs) [4]. As younger children cannot undergo psychoacoustic examinations needed for any of cognitive assessment. Cortical auditory evoked potentials are routinely used to assess cognitive function as an alternative to such testing. Higher auditory functions are evaluated utilising endogenous stimuli, namely the P300 wave recording. The wave arises when an unexpected stimulus contains crucial or novel information [15].

In the current study, fifty children were involved, including 25 children diagnosed as SLI at phoniatric unit based on Language testing using modified preschool language scale- fourth (modified PLS-4) Arabic edition**,** Speech analysis was performed using the Ain Shams Assessment protocol and Arabic articulatory test for speech assessment that show a gap between receptive and expressive language age and delayed total language age with normal hearing sensitivity and with an average IQ (90-110) SLI compared to 25 healthy children, with a non-significant difference among both groups concerning the demographic characteristics (age, and gender).

Comparing P300 latency, the SLI group has longer P300 latency than the control group. Our results are consistent with early studies reported by Shaheen et al., 2011 who reported that, the SLI group has lower amplitude than the control group and P300 latency is prolonged in SLI than in the control group [16].

Silva et al., 2019 who found statistically significant differences between the SLI group and typical language development group as regards P300 latencies and amplitudes [17]. Similar findings are coincide with Ors et al., 2002 [18], Prolonged P300 latency may be a constitutional characteristic contributing to SLI children's and parents' [18] language learning problems.

The longer P300 latency and smaller amplitude in the SLI group compared to the control group imply greater cortical neurophysiological alterations indicating impairment in late auditory perceptual processing stage in these children. This indicates that language and cognitive development were impaired by a delayed processing of information and working memory deficiencies [16].

P300 reflects the updating of working memory, cognitive closure, and information transmission to awareness. The amplitude of the P300 represents the allocation of attention, whereas latency reflects the speed of perceptual processing and categorization. Latency is a considerably more reliable indication of attentional difficulty than amplitude. Similar to "optional" higher order processing, a decrease in amplitude may indicate a cessation of a later memory or attention appraisal of the disparate inputs [19].

Our finding demonstrated a substantial variation among SLI children and control groups on receptive, expressive, and total language age items, and this may be explained by the inadequate general or localized resource capacity idea of children with SLI, which is in line with the early reported findings of Shaheen et al., [16], and Ottem et al., [20]. Researchers observed that these youngsters had fewer words available for spontaneously expressing their thoughts; they created and comprehended fewer words than their typically developing classmates [21].

Numerous associations between P300 test results and all other variables were calculated to elucidate our outcomes. A strong correlation between P300 latency in both ear with receptive and expressive language age within the study group contradict Shaheen et al., [16] Who demonstrated that associations among P300 amplitude and latency, chronological age, and the language items under investigation are not significant, where agree with Shibasaki et al., [22] who gave evidence of age-related changes in P300 with decrease in latency and increase in amplitude from the age of 5 years until adult values are reached in late teens or early twenties. This can be explained by narrow age range in this study (from 4 to 6 years), thus age-related changes are difficult to be obtained, and changes start at the age of 5 years and extend until adolescence.

Concerning the ROC curve, P300 average latency within SLI group I [AUC of 0.903 and the best diagnostic cut-off point of 331.5 (with sensitivity of 80% and specificity 88%)] pointed that measuring P300 latency can be effectively used as a tool for early diagnosis of auditory processing dysfunction in children suffering from SLI [23].

CONCLUSION

We concluded that P300 latency was increased in children with SLI compared to healthy children. The presented results endorse our assumption that early diagnosis of central auditory disorder utilizing P300 test may be a valuable supplementation of diagnosis of language impairment and may contribute to an effective language therapy.

Declaration of Competing Interest:

The authors did not report any conflict of interest in competing financial or personal relations.

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