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Original article

Value of complex evoked auditory brainstem response in patients with post-stroke aphasia (prospective study)

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ABSTRACT

Objective: To evaluate the perception of complex ABR (C-ABR) in aphasic patients and to compare it before and 3 months after management of stroke.

Methodology: A prospective study was conducted on 30 aphasic patients using C-ABR. The results were compared within 2 weeks post-stroke and 3 months after management. The results of aphasic patients were compared with normal subjects.

Results: The seven C-ABR waves regarding the onset (wave V and A), offset (peak O), transition (peak C) and frequency following responses (peak D, E and F) were identified in all participants. There was a statistically significant difference in C-ABR latencies between control and study group in the waves D, E, F and O, this means that aphasic patients exhibited abnormal neural synchrony affecting the source elements (fundamental frequency) (waves D, E, F and O) however there was no effect on the filter elements (transients).

Conclusion: Aphasic patients exhibited abnormal neural synchrony affecting the source elements (waves D, E, F and O) however there was no effect on the filter elements (transients).

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1. Introduction

Aphasia is an acquired language disorder in which there is an impairment of a language modality, it is not a result of sensory or motor deficit, a general intellectual deficit, confusion or psychiatric disorder. The disorder impairs the expression and understanding of language as well as reading and writing.⁵

According to **NIH stroke score**, post stroke language is classified into four grades. Grade 0: no aphasia; normal. Grade 1: mild to moderate aphasia, at which there is loss of fluency without significant loss of expression. Grade 2: severe aphasia at which all the communication through fragmentary expression. Grade 3: mute, global aphasia, there is no usable auditory or speech comprehension.

Kolb et al.⁹ classified aphasia into three categories: fluent, non fluent and pure aphasia. Fluent aphasia (called also receptive aphasia) is an impairment related mostly to reception of language. Speech is easy and fluent but there are difficulties related to the

input of language. Fluent aphasia is sub-classified into: wernicke's aphasia, Tran cortical sensory aphasia and conduction aphasia. Non fluent aphasia (also called expressive aphasia) is characterized by difficulties in articulation. Non fluent aphasia is sub-classified into: Broca's aphasia, Anomic and Global aphasia. Lastly pure aphasia is a selective impairment in reading, writing or the recognition of words; pure aphasia is sub-classified into pure alexia and agraphia. Global aphasia is the most common type in the acute period affecting about 25–32% of aphasic patients, while other classic types are seen less frequently.⁴

Skoe and Kraus¹⁸ reported that the auditory brainstem response (ABR) has proven to be a clinically useful tool for assessing neural function at the brainstem level and is most commonly elicited by clicks or tone-bursts. However, recent research has established that complex stimuli can also elicit the response such as Music, complex tones, and speech stimuli (e.g., /da/, /ba/, and /ga/). A speech stimulus is particularly useful, as it can provide clues as to how temporal and spectral features are preserved in the brainstem.

Greenberg³ was one of the first to adopt complex stimuli for recording auditory brain stem response. The complex ABR provides discrete representations of many aspects of the acoustic structure of speech, including separate neural representations of speech

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sound onset, phase-locking to the fundamental and formant frequencies and speech sound offset.¹⁶

Many studies were performed on auditory brainstem response to speech sounds in auditory specialization (e.g., musicians, native language speakers), auditory processing disorders, language-based learning impairments such as dyslexia, specific language impairment, autism, hearing loss, and age-related hearing loss.¹⁸

2. Objectives

To evaluate the perception of complex ABR in aphasic patients, to compare complex ABR perception among normal and aphasic patients and to compare speech perception in post stroke aphasic patients before and 3 months after management of stroke.

2.1. Methodology

1-Subjects: were divided into two groups:

(A) *Study group:* includes 30 post stroke aphasic patients (recent post stroke within the first 2 weeks) age range from 20 to 55 years. No history of hearing loss, ear disease, trauma, ototoxic drug intake or ear operations. Normal middle ear functions as evidenced by otological examination, tympanometry and acoustic reflex thresholds. Hearing threshold doesn't exceed 25 dBHL in the frequencies from 250 Hz to 8000 Hz. The patients were admitted at Sohag university hospital and were examined within the first two weeks of the stroke and follow-up was done 3 months after management. Patients did not receive language therapy.

(B) *Control group:* include 30 subjects with bilateral normal peripheral hearing with no neurological deficit.

2-Method:

A) *Equipments:* Sound treated room IAC model 1602, Pure tone audiometry: Madsen Orbiter 922, Immittance: Maico MI44, Evoked potentials system SMART intelligent hearing system.

B) *Procedure:* All subjects were subjected to:

1. *Informed written consent.*
2. *Full history taking.*
3. *Otological examination.*
4. *Basic audiological evaluation:* Pure tone audiometry including air and bone conduction, speech audiometry including: Speech Recognition Threshold (S.R.T) test: using Bisyllabic words for adults Soliman et al.²⁰ Word Discrimination score (W.D) test: using Arabic Phonetically-balanced adults (PBA) words Soliman,¹⁹ WIPI test in patients who couldn't perform Speech discrimination by PBA words. Immittance including tympanometry and acoustic reflex threshold.
5. *Neurological evaluation including NIH stroke scale.*
6. *Click evoked Auditory Brainstem Response:* to confirm presence of wave V.

Stimulus parameters: type: click stimulus, intensity: 90dBnHL, polarity: alternating, Presentation rate: of 13.1p/s, mode of delivery: stimuli were presented monaurally to the right ear via an ER3A- insert phone.

Recording parameters: electrode montage: The active electrode was placed on the high frontal (Fz), the ground electrode on the low frontal (FPz), the negative electrode on the right side and the reference electrode on the left side. Number of sweeps: 1024, filter: band passes of 100–1500 Hz, analysis period: 0–12 ms,

7. *Complex Auditory Brainstem Response (C-ABR):*

Recorded recently post stroke and 3 months after management.

Stimulus parameters: Type: 40-ms /da/ syllable it consists of onset noise burst during the first 10 ms and formant transition

between the consonant and a steady-state vowel. The stimulus was generated by Intelligent Hearing System Company and included in speech auditory brain response software. Intensity: 80 dB SPL, polarity: alternating, presentation rate: of 11p/s, mode of delivery: stimuli were presented monaurally to the right ear via an ER3A-insert phone.

Recording parameters: Electrode montage: The active electrode was placed on the high frontal (Fz), the ground electrode on the low frontal (FPz), the negative electrode on the right side and the reference electrode on the left side. According to Vander and Kathy²² there are no ear differences in complex ABR so the recordings were obtained from the right ear only. All electrodes were connected to the pre-amplifier of the Smart EP equipment. Number of sweeps: 4000, filter: band passes of 100–1500 Hz, analysis period: 75 ms including 15 ms pre-stimulus recording.

Response analysis: The response was identified by the presence of seven waves (V, A, C, D, E, F, O), wave V analogous to the wave V elicited by click stimuli, followed immediately by a negative trough (wave A). Following the onset response, a series of peaks (C–F) represent FFR. Offset response is represented by wave O. The wave's absolute latency, amplitude, VA amplitude, duration, area and also V-A slope all were measured. According to Wible et al.²³ V-A slope was mathematically calculated by dividing wave V-A amplitude by its duration.

3. Results

The control group consists of 30 subjects with age ranges from 20 to 50 years with the mean of 34.47, they were 17 males (56.7%) and 13 females (43.3%). The study group consists of 30 aphasic patients with age ranges from 25 to 50 years with the mean of 41.33, they were 21 males (70.0%) and 9 females (30.0%). The duration of aphasia in days ranges from two to seven days with the mean of 4.23.

3.1. Audiological findings

Pure tone audiometry: Study group: PTA was done only on six aphasic patients representing 20% of the whole study group; these patients were of motor type. They had bilateral normal hearing. While PTA in the control group was done to the whole subjects, and they had bilateral normal hearing.

Auditory brainstem Audiometry: ABR threshold: was done to the remaining aphasic patients who PTA couldn't be obtained. ABR at 88 dBnHL: was done to whole study and control groups to identify wave V. In click ABR, the absolute latencies of wave V were within normal values. There was no significant difference between the latency of wave V of click and C-ABR.

3.2. Follow up results

There were twelve (40%) patients that come for follow-up.

4. Discussion

In the current study, the age range was between 20 and 50 years in the control group with the mean age 34.47 years while the aphasic patients aged from 25 to 50 years; which was one of the selection criteria with the mean age of 41.33 years. In our study, males were more prevalent than females in the study group with a ratio of 70%:30%. This disagrees with²¹ who studied eighty aphasic patients, they found no gender difference in aphasic patients. The discrepancy between the two results may be attributed to the difference in the number of the both groups.

In the current study, the commonest risk factors of post stroke aphasia were hypertension, diabetes mellitus (DM), history of previous heart surgery and smoking. This agrees with² who reported that the most important risk factors for post stroke aphasia are hypertension, DM, cigarette smoking and arterial fibrillation . Ischemic heart disease, Postpartum hemorrhage and rheumatic heart disease were another risk factors (Fig. 1).

The majority of our patients were of global type as they representing 73.3% of the whole group followed by motor type, representing 20% and lastly sensory aphasia 6.7% and this agree with^{4,11,13} who found that global aphasia is the most common type in the acute stage (Fig. 2).

5. ABR results

In the control group, the mean latencies of C-ABR waves are represented in (Table 1). They were compared to²² who studied C-ABR in young adults aged from 20 to 26 years. Their study was comparable to our C-ABR results.

The seven C-ABR waves regarding the onset (wave V and A), offset (peak O), transition (peak C) and frequency following responses (peak D, E and F) were identified in all participants (Table 1). The wave's detectability was compared to⁷ study who studied 88 normal hearing adults. They reported that the onset and offset responses and peak F were present in 100% of the individuals, while peak D and E were present in 95 and 98% of the individuals respectively. While our results disagree slightly to⁶ who studied C-ABR in adults aged 21–30 years and reported that the onset peaks (V and A) were 100% detectable in all subjects, wave D (87%), wave E (91%), wave F (91.6%) and wave O (83.3%) however, wave C was only detectable in two thirds of the participant. The discrepancy between the two results could be attributed to the small sample size as their study was on twelve adults only.

In the current study, there was a statistically significant difference in complex ABR latencies between control and study group in the waves D, E, F and O (Table 1). This means that aphasic patients exhibited abnormal neural synchrony affecting the source elements (fundamental frequency) (waves D, E, F and O) however there was no effect on the filter elements (transients). This dissociation between the encoding of the fundamental frequency (source) and harmonic and timing cues (filter) in the brainstem agrees with¹⁰ who observed dissociation between the encoding of the fundamental frequency and harmonic and timing cues in the brainstem . It can be explained that transient and sustained responses represent independent mechanisms.¹⁶ The transient response

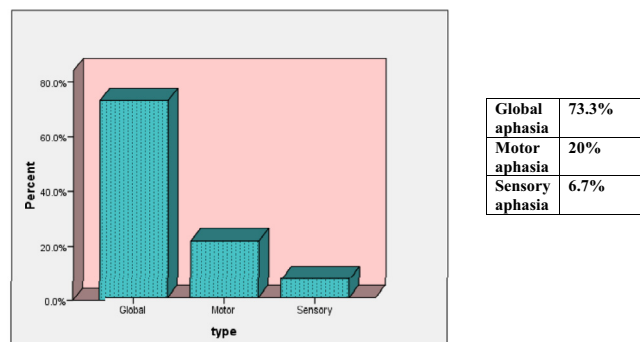
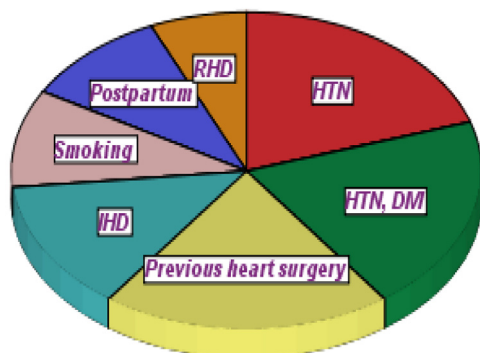


Fig. 2. Types of aphasia in the study group.

reflects the response to the onset of the sound stimulus where as the sustained response provides information about the neural encoding of the vowel.¹⁷

Significant latency delay was found in waves D, E, F & O (Table 1). These findings suggest that cortical function is closely related to the brainstem response for speech sounds. An important finding in the current data is the presence of temporal processing abnormalities across the brain stem level. Although the results reported in the current study do not prove causality between brainstem and cortical processing of speech sounds, the three following mechanisms could explain a relationship. The first mechanism is that neural deficits at a lower level of the auditory pathway (i.e., peripheral) cause abnormal cortical activation patterns. An evidence of this mechanism is that auditory brainstem responses reach maturity many years before auditory cortex,¹⁵ indicating a peripheral-to-central hierarchy in the development of this system. This interpretation would be an oversimplification of an extremely complex system that includes parallel⁸ and top-down^{25,14} processing from cortex, allowing for ongoing reciprocal brainstem/cortical interactions. Alternatively, a second mechanism is a top-down (reverse hierarchy) in which abnormal cortical function could cause poor neural synchrony in the brainstem and high cortical areas responsible for plasticity in lower cortical levels.²⁵ A third possible mechanism to explain the dynamics of abnormal brainstem–cortical function; is that abnormal function is truly systemic in nature, owing neither to aberrant brainstem or cortical function. In this mechanism, abnormal brainstem– cortical function represents a general failure of the system, attributable to asynchronous activation patterns between the two auditory regions.



HTN	20 %
HTN, DM	20 %
Previous heart surgery	20 %
IHD	13.33%
Smoking	10.00%
Postpartum	10.00%
RHD	6.67%

Hypertension (HTN), Diabetes Mellitus (DM), Ischemic heart disease (IHD), Rheumatic heart disease (RHD)

Fig. 1. Risk factors of aphasia in the study group.

Table 1
Comparison of complex ABR latencies between control and study groups.

ABR waves	Control group		Study group		t value	p value
	Mean	SD	Mean	SD		
V	5.87	0.27	5.96	0.40	−0.10	0.35
A	7.36	0.33	7.47	0.35	1.37	0.19
C	17.10	0.93	17.36	1.15	1.05	0.30
D	23.32	0.98	25.45	1.46	9.01	**0.00
E	31.21	0.80	32.00	1.74	2.27	*0.04
F	39.45	1.02	41.20	0.94	7.82	**0.00
O	47.75	0.69	49.24	0.96	6.64	**0.00

*There were highly statistically significant difference of complex ABR latencies between study and group in the waves D, F and O and a significant difference of complex ABR latencies between control and study group in wave E.

Table 2
Correlation between complex ABR latencies and degree of aphasia.

Degree	Complex ABR latencies	Mean	SD	Correlation co-efficient	p value
		V	5.96	0.40	−0.06
A	7.47	0.35	−0.01	0.97	
C	17.36	1.15	0.02	0.93	
D	25.45	1.46	−0.21	0.27	
E	32.00	1.74	−0.03	0.90	
F	41.20	0.94	−0.17	0.37	
O	49.24	0.96	0.08	0.69	

*There was no significant correlation between speech ABR latencies and degree of aphasia.

Table 3
Correlation between Complex ABR latencies and type of aphasia.

Type of aphasia	Complex ABR latencies	Mean	SD	Correlation co-efficient	p value
		V	5.96	0.40	0.27
A	7.47	0.35	0.38	0.04	
C	17.36	1.15	−0.001	0.99	
D	25.45	1.46	0.37	0.05	
E	32.00	1.74	0.15	0.42	
F	41.20	0.94	−0.23	0.22	
O	49.24	0.96	0.11	0.57	

*There was no significant correlation between speech ABR latencies and type of aphasia. *Follow up results:* There were twelve (40%) patients that come for follow-up.

The degree of aphasia was analyzed according to NIH stroke score; it was classified into three degrees: first, second and third degree. In the current study, we found that increasing the degree of aphasia had no significant effect on complex ABR latencies (Table 2). Also the type of aphasia had no significant effect on complex ABR latencies (Table 3).

6. Follow up results

Table 4 showed means of latencies of different complex ABR waves in the follow up group. Regarding comparison of complex

ABR Latencies between the follow up and the control group, there was no significant difference in the whole C-ABR waves (Table 4). This may be due to spontaneous recovery and neuroplastic changes following recovery from stroke and this agree with¹² who demonstrated that spontaneous recovery usually occurs within the first three months post stroke. The current study included also comparison of C-ABR results in recently post stroke aphasic patients and three months after management. There was a statistically significant difference between study and follow up groups in waves representing frequency following response and offset (wave D, E, F and O) (Table 5). This difference in most C-ABR waves mostly due neuroplastic changes following stroke.

Table 4
Comparison of complex ABR Latencies between control group and follow up of the study group.

ABR waves	Control group		Study group Follow up		t value	p value
	Mean	SD	Mean	SD		
V	5.87	0.27	5.99	0.26	−0.07	0.35
A	7.36	0.33	7.27	0.13	1.06	0.31
C	17.10	0.93	17.17	1.09	−0.06	0.96
D	23.32	0.98	23.53	0.53	−0.77	0.46
E	31.21	0.80	30.91	1.26	0.60	0.56
F	39.45	1.02	40.47	1.44	−2.10	0.06
O	47.75	0.69	48.06	0.83	−0.87	0.40

*There was no statistically significant difference of complex ABR Latencies between control group and follow up of the study group in all complex ABR waves.

Table 5

Comparison of complex ABR latencies between patients in study that come for follow up (twelve patients) & their follow up results.

	Study group (twelve patients)		Follow up Results		t value	p value
	Mean	SD	Mean	SD		
V	5.98	0.38	5.99	0.26	1.0	0.64
A	7.33	0.18	7.27	0.13	0.86	0.41
C	17.22	1.06	17.17	1.09	0.27	0.80
D	25.12	1.44	23.53	0.53	3.81	**0.00
E	31.62	2.13	30.91	1.26	2.57	*0.02
F	41.31	1.15	40.47	1.44	5.48	**0.00
O	49.11	0.60	48.06	0.83	4.02	**0.00

**There were highly statistically significant difference of complex ABR latencies between the study and the follow up group in the wave D, F and O and statistically significant difference of complex ABR latencies between the study and the follow up group in the wave E.

From the previous findings, we suggested that cortical processing of speech which disturbed in aphasic patients is closely related to the brainstem response of speech however the results don't prove causality between them. It can be explained by there is a strong relationship between auditory processing at the brainstem and the cortex. Because the brainstem and the cortex are linked by both ascending and descending pathways.²⁴ So abnormal cortical processing cause abnormal feedback on the brainstem and also subtle timing deficit at the brainstem adversely affects cortical processing. This manifested by the pattern of timing deficits observed in individuals with abnormal complex-ABR.¹

Conclusion: Aphasic patients exhibited abnormal neural synchrony affecting the source elements (waves D, E, F and O) however there was no effect on the filter elements (transients). Neuroplastic changes following stroke had effect on C-ABR waves; this exhibited on comparison the C-ABR in the study with the follow up groups, there was difference in most C-ABR waves (wave D, E, F and O). There was relation between the cortical processing of speech which disturbed in aphasic patients and the brainstem response of speech.

Recommendations: Using C-ABR as a prognostic tool in aphasic patients. Evaluation of post-stroke aphasic patient by C-ABR recently after stroke.

Conflict of interest

There was no conflict of interest happened when working on the paper. For this study there was no financial support or funding. Informed written consent was taken from all participants.

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