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Hearing Threshold Evaluation in Children Using Narrow Band Chirp Auditory Brainstem Response and Tone Burst Auditory Brainstem Response

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Abstract

Objectives: Correlation between Narrow Band Chirp Auditory Brainstem Response (NB-CE chirp ABR) as a frequency specific method for hearing threshold detection in children and Tone burst Auditory Brainstem Response (Tb-ABR) in reference to behavioral hearing threshold audiometry. **Material and Methods:** This study was conducted on 100 patients at audiology unit, Menoufia University hospital, in the period from Oct. 2015 to Feb. 2017. Patients enrolled within this study were classified into four groups: Group I: included 40 patients diagnosed with normal hearing, Group II: included 48 patients with mild to moderate sensorineural hearing loss (SNHL), Group III: included 56 patients with moderate to moderately severe SNHL and Group IV: included 56 patients with severe to profound SNHL. All patients' enrolled NB-CE chirp ABR, Tb-ABR as well as pure tone audiogram (PTA). **Results:** there was a significant correlation between NB-CE chirp ABR and PTA hearing threshold. The use of a chirp-ABR testing ensures higher sensitivity and accuracy than that of Tb-ABR for measuring frequency-specific thresholds in young children. **Conclusion:** NB-CE Chirp ABR is more efficient than Tb-ABR as a frequency specific tool for hearing threshold estimation in children.

Keywords

Chirp-ABR, Tb-ABR, PTA, SNHL

1. Introduction

Hearing assessment of children is a major audiological concern, so as to early detect and manage hearing impairment, thus avoiding delayed speech development and its social, emotional, cognitive and academic hazards [1]. Substantial progress has been made in the technology used and in the implementation of newborn hearing screening (NHS) programs worldwide [2]. Evoked-potential audiometry (evoked with either click or tone burst stimuli) is used to measure hearing thresholds in young children and other individuals who cannot complete behavioral audiometric tests. Click Auditory Brainstem Response (ABR) thresholds correlate with behavioral thresholds at (2 - 4) kHz range (but cannot be used to reliably estimate low-frequency hearing thresholds) [3]. The tone burst ABR (Tb-ABR), therefore, is used to evaluate frequency specific hearing threshold. More recently, Narrow Band Chirp Auditory Brainstem Response (NB-CE chirp ABR) has been available for providing hearing threshold information as a function of frequency. The chirp concept was first used in auditory electrophysiology by Shore and Nuttal [4]. It has been studied intensively to be used in the auditory field by Elberling *et al.* [5]. The CE-Chirp is a family of stimuli designed to compensate for the cochlear travel delay and provide enhanced neural synchronicity [6]. This was done through equations based on Brainstem Auditory Evoked Potentials (BAEP) latencies recorded in humans [7]. The broadband CE-Chirp is decomposed into four filtered narrow band chirps (NB CE-Chirp) with center frequencies 500, 1000, 2000 and 4000 Hz [4]. This study was performed to correlate between (NB-CE chirp ABR) as a frequency specific method for hearing threshold detection in children and (Tb-ABR) in reference to behavioural hearing threshold audiometry.

2. Material and Methods

The study was carried out at audiology unit, Menoufia University hospital, from Oct. 2015 to Feb. 2017 after obtaining ethics committee approval in 2015 and informed written consent from all subjects. One hundred subjects aged 8 - 12 years of both sex with normal middle ear function were included in the study. Subjects were classified into four groups according to behavioral methods (play-conventional audiometry) as group I includes 40 subjects diagnosed as normal hearing sensitivity. Group II: included 48 subjects diagnosed as mild to moderate SNHL. Group III included 56 subjects diagnosed as moderate to moderately severe SNHL. Group IV: included 56 subjects diagnosed as severe to profound SNHL. Exclusion criteria include any neurological, mental abnormality or any other ENT problem.

All subjects in the four groups underwent pure tone audiometry using Madsen Orbiter 922 in a sound treated room amplisilence and ABR testing using (NB-CE chirp and tone burst) stimuli using interacoustic, Eclipse 25 for hearing threshold evaluation. Both narrow band Chirp stimuli and tone bursts stimuli at frequencies 500, 1000, 2000 and 4000 Hz were used with intensity 90 dBnHL down to the threshold with alternating polarity at a repetition rate 19.1 for both NB-CE-Chirp stimuli and TB stimuli. The stimuli were presented to each ear via ER3A insert phone.

2.1. Statistical Analysis

Statistical analysis was performed using SPSS version 20. One sample t-test, chi-square test and ANOVA test with post Hoc test for detection of the statistical significance between different parameters of the ABR results. P-value was considered significant when ≤ 0.05.

2.2. Results

The age of patients ranged from 8 to 12 years. There were no statistically significant differences among the groups as regards age or sex (**Table 1**). Results of the study will be presented as follows; detectability of wave V till hearing threshold and comparison of wave V latency and amplitude between TB-ABR and NB-Chirp stimuli of all tested groups (**Table 2** and **Table 3**) (**Figures 1-4**).

3. Discussion

1) *As regard threshold differences*:

In NB CE-chirp ABR and Tb-ABR hearing thresholds were significantly overestimating behavioral thresholds. The differences were higher at 500 Hz and lower at 4000 Hz. In NB CE-chirp ABR, the difference at 500 Hz was 23.72 dB and 5.64 dB at 4000 Hz. In Tb-ABR, hearing thresholds differ by about 18.2 dB at 500 and 2.7 dB at 4000 Hz. These differences in the hearing threshold decreased with increased degree of hearing loss (**Table 3**) (**Figures 1-4**). These results agree with Federico *et al*. [8] and Almeida *et al*. [9]. This may be explained by the difference in temporal integration between normal listeners and those with hearing loss. Temporal integration refers to the dependence of behavioral threshold on stimulus duration, as short-duration sounds require higher levels for detection, compared to sounds of longer duration [10]. There were significant differences of hearing threshold levels between chirp ABR and Tb ABR at 500, 4000 Hz. No significance was shown at 1000, 2000 Hz in all groups. Rodrigues *et al*. have compared ABR responses evoked by NB-CE chirp and tone burst in normal hearing infants. They stated that data from hearing impaired infants can

Table 1. Age and gender distribution.

	Group 1 (n = 40) Mean ± SD		Group 2 (n = 48) Mean ± SD		Group 3 (n = 56) Mean ± SD		Group 4 (n = 56) Mean ± SD		P-value
Age	8.32 ± 1.74		9.27 ± 1.52		9.1 ± 2.08		8.82 ± 1.72		0.059
	No.	%	No.	%	No.	%	No.	%	
Gender:									
Male	16	40.0	28	58.3	36	64.3	32	57.1	0.11
Female	24	60.0	20	41.7	20	35.7	24	42.9	

Table 2. Amplitude and latency correlation between chirp ABR and Tb ABR.

Frequency	Variants	Group	NB CHIRP	Tb ABR	P-value
			Mean ± SD	Mean ± SD	
0.5 KHz	Amplitude	G1	797.5 ± 26.9	692 ± 29.97	<0.001
		GII	779.2 ± 52.9	675.8 ± 54.02	<0.001
		GII	717.85 ± 65.4	579.28 ± 60.8	<0.001
	Latency	GI	7 ± 0.43	12.75 ± 0.76	<0.001
		GII	7.03 ± 0.57	14.61 ± 1.34	<0.001
		GIII	8.5 ± 1.06	13.00 ± 0.79	<0.001
	Time	GI	13.25 ± 2.52	17.11 ± 2.58	<0.001
		GII	12.15 ± 2.04	14.76 ± 1.46	<0.001
		GIII	15.95 ± 1.36	18.23 ± 2.54	<0.001
1 KHz	Amplitude	GI	880 ± 65.31	772 ± 49.57	<0.001
		GII	843.8 ± 38.32	707.5 ± 18.04	<0.001
		GIII	962.9 ± 99.11	688.57 ± 27.98	<0.001
	Latency	G I	7.07 ± 0.34	13.20 ± 1.30	<0.001
		GII	7.54 ± 0.33	14.42 ± 1.05	<0.001
		GIII	7.96 ± 0.57	13.73 ± 1.12	<0.001
	Time	GI	12.63 ± 1.42	15.24 ± 1.91	<0.001
		GII	13.32 ± 1.86	17.79 ± 0.42	<0.001
		GIII	13.60 ± 2. 15	19.40 ± 2.39	<0.001
2 KHz	Amplitude	GI	859 ± 71.67	743 ± 87.82	<0.001
		GII	826.7 ± 52.1	727.50 ± 43.88	<0.001
		GIII	861.5 ± 133.5	680.71 ± 38.79	<0.001
	Latency	GI	7.25 ± 0.44	11.84 ± 1.99	<0.001
		GII	7.36 ± 0.50	13.79 ± 1.88	<0.001
		GIII	9.12 ± 0.91	12.94 ± 0.98	<0.001
	Time	GI	12.99 ± 1.35	16.08 ± 1.44	<0.001
		GII	13.19 ± 1.51	16.31 ± 1.87	<0.001
		GIII	14.85 ± 2.56	17.05 ± 1.69	<0.001
4 KHz	Amplitude	GI	897 ± 62.3	775 ± 56.25	<0.001
		GII	844.2 ± 34.4	739.2 ± 30.2	<0.001
		GIII	887.9 ± 102.3	697.85 ± 46.89	<0.001
	Latency	GI	7.30 ± 0.64	11.05 ± 3.50	<0.001
		GII	7.81 ± 0.53	13.07 ± 2.62	<0.001
		GIII	9.50 ± 0.55	11.51 ± 3.46	<0.001
	Time	GI	13.05 ± 2.10	15.92 ± 1.62	<0.001
		GII	12.84 ± 1.51	15.50 ± 1.74	<0.001
		GIII	17.62 ± 2.58	15.18 ± 3.88	<0.001

Table 3. Post HOC test between PTA, chirp ABR, Tb-ABR among 4 groups.

		P1	P2	P3
GI	500	P1 < 0.001	P1 < 0.001	P3 < 0.001
	1000	P1 < 0.001	P2 < 0.001	P3 = 0.43
	2000	P1 < 0.001	P2 < 0.001	P3 = 1.00
	4000	P1 = 0.25	P2 < 0.001	P3 = 0.24
GII	500	P1 < 0.001	P2 < 0.001	P3 < 0.001
	1000	P1 < 0.001	P2 < 0.001	P3 = 0.04
	2000	P1 < 0.001	P2 < 0.001	P3 = 0.01
	4000	P1 < 0.001	P2 = 0.86	P3 < 0.001
GIII	500	P1 < 0.001	P2 < 0.001	P3 = 0.02
	1000	P1 < 0.001	P2 < 0.001	P3 = 0.18
	2000	P1 < 0.001	P2 < 0.001	P3 = 0.09
	4000	P1 < 0.001	P2 = 0.02	P3 < 0.001
GIV	500	P1 < 0.001	P2 < 0.001	P3 = 0.68
	1000	P1 = 0.12	P2 < 0.001	P3 = 0.18
	2000		No significant differences	
	4000	P1 = 0.11	P2 = 0.01	P3 = 0.78

(p1): Comparison between PTA and CHIRP ABR. (p2): Comparison between PTA and TB ABR. (p3): Comparison between CHIRP ABR and TB ABR.

contribute to better understanding of narrow band CE-chirp stimuli in the cochlea [11].

2) *As regards amplitude and latency difference between Tb ABR and chirp ABR*:

The ABR wave responses in NB chirp ABR showed statistically higher amplitudes than Tb ABR in all frequencies (0.5, 1, 2 and 4 kHz) (**Table 2**). This agreed with Don *et al.* [12] and Mùhler *et al.* [13] who found that the chirp-stimulus evoked ABR showed significantly larger amplitudes than that of click-ABR. The ABR wave latencies were significantly shorter in CE-Chirp octave bands ABR than tone bursts ABR at all four frequencies. This agreed with Musiek *et al.* [14] who demonstrated wave V latencies to 60 dB nHL CE-Chirp octave band stimuli in normal-hearing young adults. These latency differences have been attributed to the input compensation technique applied to chirp stimuli in some AEP software.

3) *As regards time needed to complete each test*:

NB chirp ABR has less test time than Tb ABR. Also, behavioral PTA has smaller time than Chirp ABR and Tb ABR (**Table 2**). This agreed with Dau *et al.* [15]. As chirp stimuli have short test time by aligning the arrival time of each frequency component in the stimulus to its place of maximum excitation along the basilar membrane. Such compensation will make the stimulus more efficient by achieving higher temporal synchronization between the evoked activities from the different neural elements that contribute to the formation of not only

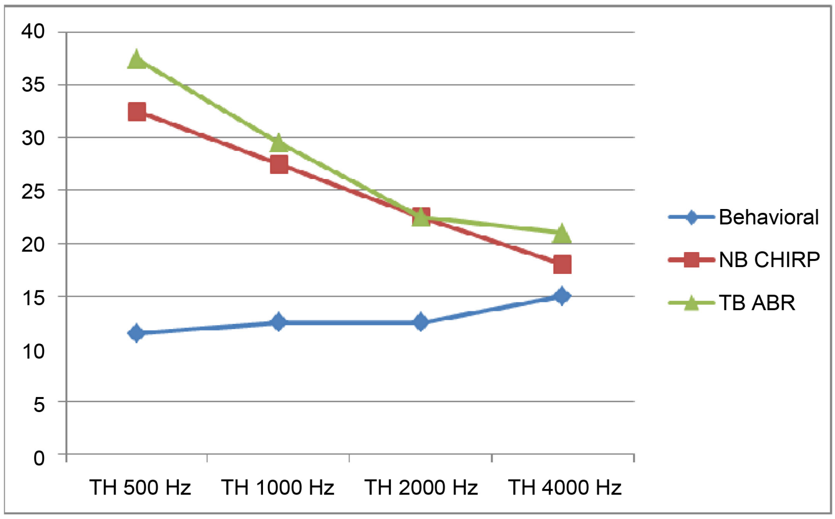

Figure 1. Threshold difference between chirp ABR and Tb-ABR and PTA in GI.

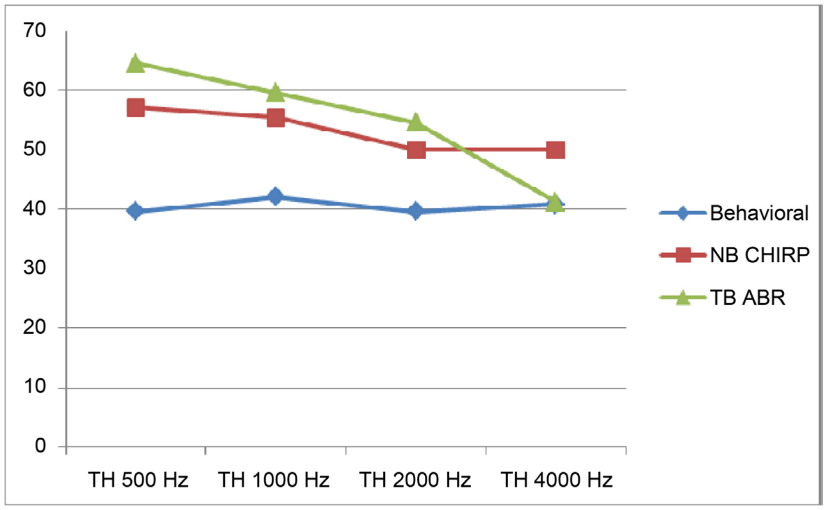

Figure 2. Threshold difference between chirp ABR and Tb-ABR and PTA in GII.

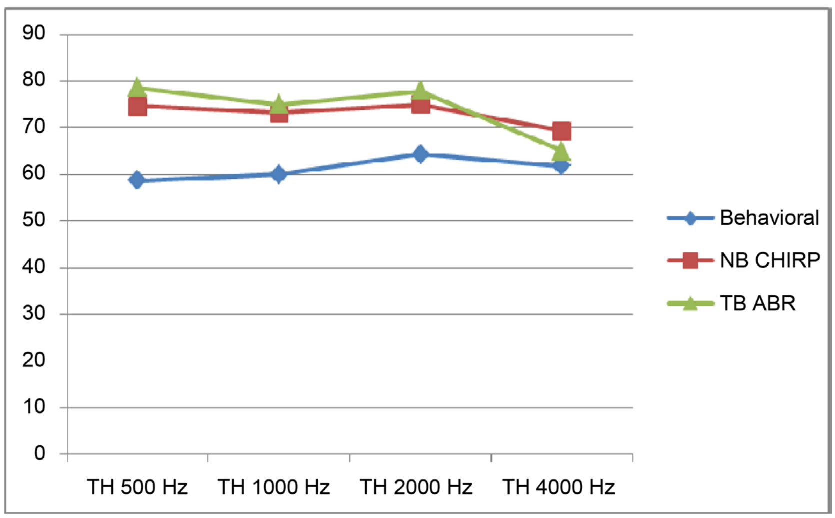

Figure 3. Threshold difference between chirp ABR and Tb-ABR and PTA in GIII.

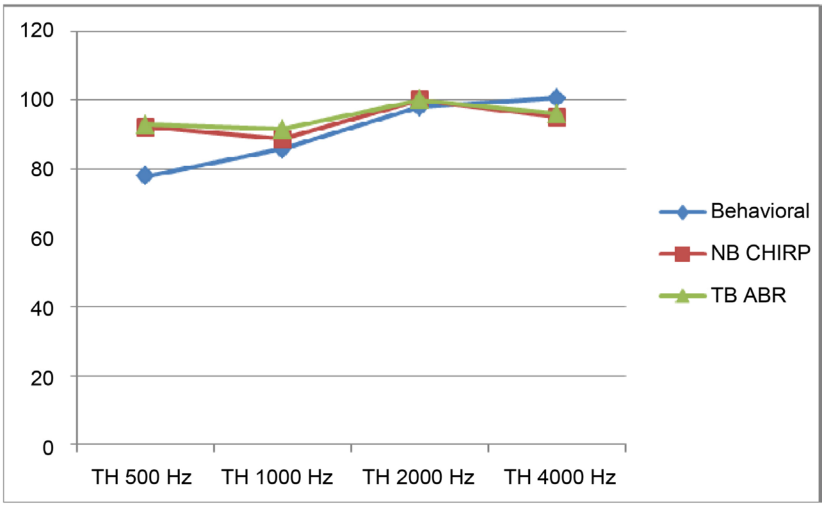

Figure 4. Threshold difference between chirp ABR and Tb-ABR and PTA in GIV.

ACAP but also the ABR and ASSR.

4. Conclusion

The use of a chirp-ABR testing ensures higher sensitivity and accuracy than that of Tb-ABR for measuring frequency-specific thresholds in young children. Chirp ABR consumes less time than tone burst ABR. CE-chirp ABR has larger responses than Tb-ABR responses in normal and hearing impaired children at all presentation levels. Regarding pure tone threshold prediction values of Tb-ABR stimuli, the best prediction was at 4000 Hz in normal hearing and hearing impaired children respectively, while the poorest prediction was at 500 Hz in all groups.

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Conflicts of Interest

The authors declare no financial or other conflicts of interest related to this work.

Ethical Approval

All procedures performed in the study were in accordance with the ethical standards of the institutional research committee.

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