Auditory brainstem response to chirp stimulus in children with moderate and severe sensorineural hearing loss

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Background
Click auditory brainstem response (ABR), is abrupt and rapid onset, have broad spectrum nonfrequency-specific response. ABR needs good neural synchrony, the greater number of neurons that fire results in a larger response amplitude. The application of chirp stimuli aims to produce a synchronized response from a large portion of hair cells in the basilar membrane. The chirp was designed to produce simultaneous displacement maxima along the cochlear partition by compensating for frequency-dependent traveling-time differences.

Objectives
The aim of this study was to correlate between pure-tone audiometry (PTA) threshold and click and chirp-ABR thresholds in children with moderate and severe sensory neural hearing loss.

Patients and methods
This study included two groups: control group (G1), which consisted of 30 children with normal peripheral hearing and study group (G2), which consisted of 60 children with moderately severe sensorineural hearing loss (SNHL).

Results
Results showed that significant correlation between chirp and behavioral PTA and between click and behavioral PTA in normal hearing and hearing-impaired children, except in severe steeping SNHL. In steeping SNHL, there was a reduced correlation between behavioral PTA and click ABR stimuli. In addition, there was a significant correlation between narrow band-chirp at 500, 1000, and 4000 Hz and behavioral PTA in normal hearing and sensory neural hearing loss in children, otherwise in severe steeping SNHL. In this category, there was a reduced the correlation between behavioral PTA and narrow band-chirp-ABR stimuli.

Keywords:
auditory brainstem response, chirp auditory brainstem response, sensorineural hearing loss

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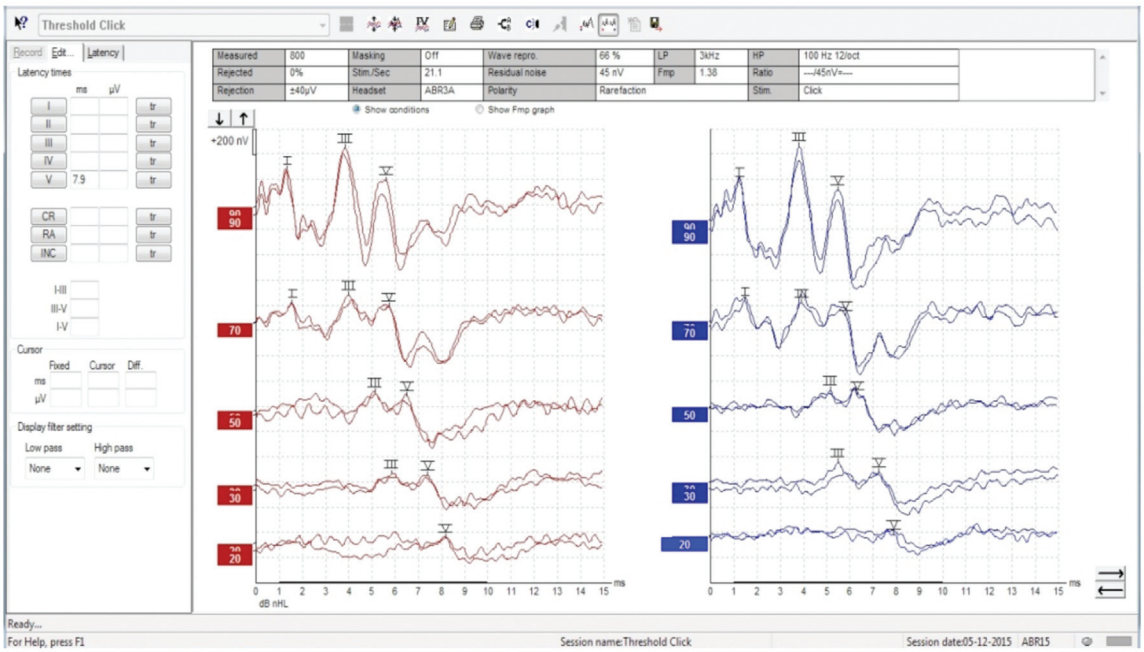
Introduction

In click auditory brainstem response (ABR), the cochlear traveling wave takes some time to reach from the base of the cochlea to its apical end [1]. Therefore, the different neural units' activity along the cochlear partition will not be stimulated at the same time, and the neural activity across all nerve fibers will be smeared [2]. In an attempt to compensate for the dispersion in the human cochlea, a chirp has previously been designed from the cochlear delay on the basis of derived-band ABR latencies. It depends on the cochlear filter build up time and on the unit response waveform; this implies that the lack of the temporal synchrony can be partly neutralized by an upward chirp stimulus [3].

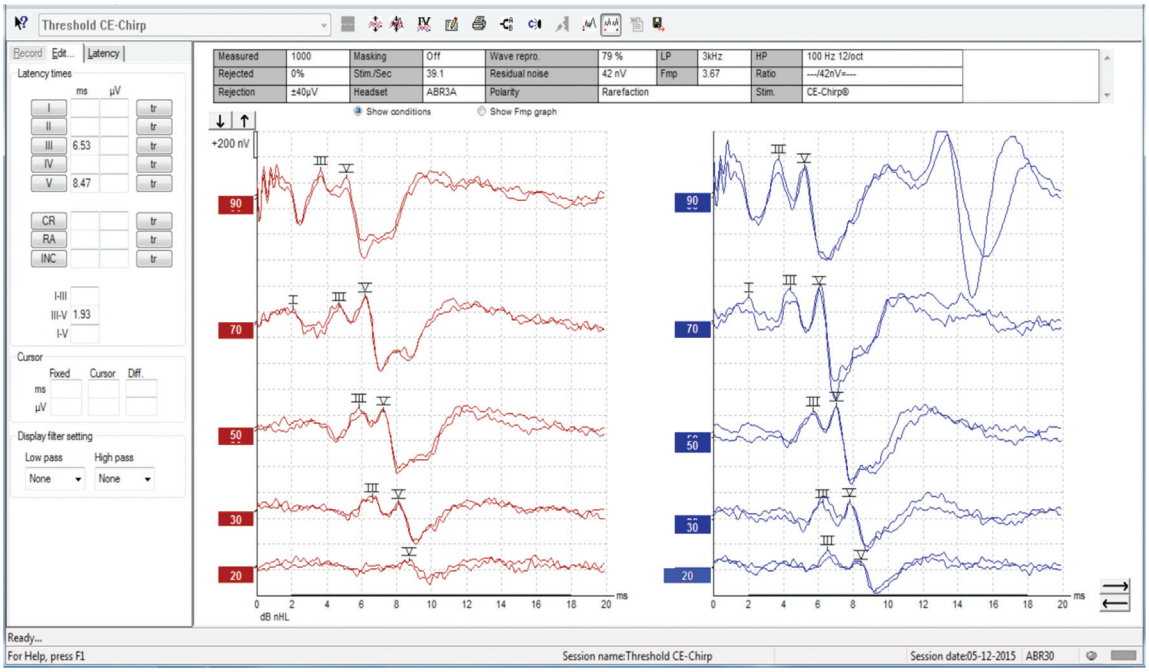
Patients and methods

The study included a total number of 90 children with an age range of 6–12 years. The control group (G1) consisted of 30 patients with bilateral normal peripheral hearing. Informed consent and ethics committee approval in medical research: Guidance on informed consent and ethical approval requirements based on the study type, Study design. The study group consisted of 60 patients; they were divided in to two subgroups:30 patients with moderate sensorineural hearing loss (SNHL) (G2-M) and 30 patients with severe SNHL (G2-S). This subgroup (G2-S) was divided into two subgroups: 20 patients with flat audiometric (G2-Sf) configuration pattern and 10 patients with steeping audiometric configuration pattern (G2-Ss). All children were tested in a sound-treated room model no RE. 24, acoustic immettancemeter model Interacoustics AZ26 (Interacoustics, USA) with a probe tone 220 Hz, pure-tone audiometer Interacoustics model AC40 with headphones TDH39 and bone vibrator B71 and auditory-evoked potentials model Interacoustics Eclips

Figure 1



Click



Chirp

Click and chirp-evoked ABR responses for a normal hearing child (right and left ears). ABR, auditory brainstem response.

25. All of them were subjected to careful history taking, full audiological history, basic audiological evaluation including in the form of pure-tone audiometry for both air conduction (for the frequency range 250–8000 Hz) and bone conduction (for the frequency range 500–4000 Hz), speech audiometry, including immittancemetry and ABR (click and chirp stimulus was used and tested at 0.5, 1, 4 kHz). Stimuli were presented monaurally to each ear via an ER-3A insert phone, with repetition rate (RR) 21.1/s for click and 44/s, 35/s for chirp. Alternating polarity, 1000 sweeps for both stimuli, the recording window is 1–14 ms, and the filtering system was 150–3000 Hz for both click ABR and chirp-ABR.

Results

Results of the study will be presented as follows: detectability of wave V at 90, 70, 50, and 30 dBnHL in G1 and comparison of wave I, III at 90 dBnHL and V latency and amplitude between click ABR and chirp stimuli (44 and 35 RR) of all tested groups (Fig. 1).

Discussion

Waveform detectability in all study groups

Detectability of wave V (Table 1)

Wave V was 100% detectable at all tested ears in G1. This occurred when the presence/absence of waves V was analyzed at 90, 70, 50 and 30 dBnHL on using either CE-chirp or click. In both G2-M and G2-S, wave V was detectable in all tested ears; wave V detectability was better when using CE-chirp stimulation than with click stimuli. This agrees with Cebulla *et al.* [4]. They demonstrated that wave V was always identifiable when using 60 dBnHL stimulus level (100%). At 40 dBnHL wave V was reliably recognizable in 95% of the click-evoked ABR and in 100% of the chirp-evoked ABR in neonates.

G2-Sf showed detectable wave V in 82.5% when using click stimuli 90 dBnHL. This percentage improved to 100% upon using chirp stimuli at the same level. When reducing intensity levels until obtaining the threshold, wave V detectability was better for CE-chirp stimuli at 70 dBnHL than click stimuli (41.5% with chirp 44 RR and 39% with chirp 35 RR, and only 5% with click). However, there was no identifiable wave V at 60 dBnHL for all stimuli. This result emphasized that the absence of ABR waves at high intensity levels with click does not necessarily imply total deafness. It is well known that click ABR threshold represents hearing in the 2–4 kHz and is dependent on the mean threshold of both latencies [5].

Detectability of waves I and III (Table 2)

Waves I and III were analyzed at 90 dBnHL. The percentage of detectability for those waves tended to decrease with the CE-chirp than with click stimuli.

Table 1 Detectability of wave V in all tested groups

	Click (%)	Chirp 44 RR (%)	Chirp 35 RR (%)
G2-M			
Detectability of wave V at 90 dBnHL	100	100	100
Detectability of wave V at 70 dBnHL	100	100	100
Detectability of wave V at 60 dBnHL	66	95	90
Detectability of wave V at 50 dBnHL	8	31	28
G2-Sf			
Detectability of wave V at 90 dBnHL	82.5	100	100
Detectability of wave V at 80 dBnHL	65	100	97.5
Detectability of wave V at 70 dBnHL	5	41.5	39
Detectability of wave V at 60 dBnHL	0	0	0
G2-Ss			
Detectability of wave V at 90 dBnHL	100	100	100
Detectability of wave V at 80 dBnHL	70	100	95
Detectability of wave V at 70 dBnHL	0	85	80
Detectability of wave V at 60 dBnHL	0	65	55

RR, repetition rate.

Table 2 Detectability of waveform I and III in all tested groups at 90 dBnHL

	Click (%)	Chirp 44 RR (%)	Chirp 35 RR (%)
G1			
Detectability of wave I	96	55	50
Detectability of wave III	100	78	73
G2-M			
Detectability of wave I	73	65	43
Detectability of wave III	88	73	58
G2-Sf			
Detectability of wave I	57.5	30	25
Detectability of wave III	67.5	60	35
G2-Ss			
Detectability of wave I	60	65	55
Detectability of wave III	60	75	65

The finding agrees with Rodrigues and Lewis [6]. They reported that detection of early waves achieved better with click stimulation when tested at 80, 60, 40 and 20 dBnHL than with chirp stimuli.

In contrast, Cebulla *et al.* [4] came to the conclusion that chirp stimulus was superior to the click with regard to wave III detection. They reported that wave III was clearly identifiable in all chirp-evoked ABR at 60 dBnHL (100%) and at 40 dBnHL (98%). In contrast, in click-evoked ABR, wave III could only be detected in 92% of the 60 dBnHL responses and 74% of the 40 dBnHL responses. They reported in the same study that wave I analysis showed a significant detectability reduction at both intensity levels using the chirp stimulus.

Correlation between pure-tone audiometry and chirp and click auditory brainstem response thresholds

Correlation between CE-chirp, click stimuli and pure-tone audiometry (Table 3)

ABR threshold was determined as the lowest intensity at which significant repeatable response was detected. In the current study, there was a high degree of correlation between CE-chirp, click and behavioral pure-tone audiometry (PTA) in all tested groups. The only reduced correlation between behavioral PTA and click ABR threshold was obtained in G2-Ss with severe steeping SNHL. In the current study, the correlation between both objective stimuli and behavioral threshold was consistent with that obtained by Maloff and Hood [7]. They found that ABR thresholds to chirps were closer to overall behavioral thresholds, and this continues to occur in severe SNHL for chirp but not for click. The strongest correlations were observed between click-evoked ABR thresholds and pure-tone thresholds at 2 and 4 kHz [5].

In contrast, the reduced correlation between click and behavioral PTA in severe steeping SNHL (G2-Ss) could be explained on the basis of mode of cochlear excitation of the cochlea by click stimuli. In persons with impairment of auditory sensitivity in the higher frequency region, ABR generation may not necessarily follow this pattern with chirp stimuli [8].

In contrast to the above studies, Stapells *et al.* [9] have reported less agreement between click-evoked responses: behavioral thresholds at the same frequencies. They concluded that the result has been attributed to the click's broad spectrum. In their circumstance, the click-evoked threshold was related to the frequency (ies) for which hearing was best.

Table 3 Correlation between threshold of wave V (dBnHL) on using CE-chirp 44 repetition rate versus average of pure-tone audiometry threshold through frequency range 250 Hz and 8 kHz of all tested patient: correlation between threshold of wave V (dBnHL) on using click stimuli with average pure-tone audiometry through frequency range 2000and 4000 Hz of all tested patients

G1	CE-chirp 44 RR at frequency 0.5–4 kHz	Click ABR at frequency 24 kHz	NB-chirp threshold at 500 Hz	NB-chirp threshold at 1000 Hz	NB-chirp threshold at 4000 Hz
	PTA at frequency 0.5–4 kHz	PTA at frequency 2–4 kHz	PTA at 500 Hz	PTA at 1000 Hz	PTA at 4000 Hz
r	0.666	0.681	0.877	0.581	0.751
P value	0.000**	0.000**	0.000**	0.000**	0.000**
G2-M	CE-chirp 44 RR at frequency 0.5–4 kHz	Click ABR at frequency 2 4 kHz	NB-chirp threshold at 500 Hz	NB-chirp threshold at 1000 Hz	NB-chirp threshold at 4000 Hz
	PTA at frequency 0.5–4 kHz	PTA at frequency 2–4 kHz	PTA at 500 Hz	PTA at 1000 Hz	PTA at 4000 Hz
r	0.837	0.692	0.779	0.247	0.703
P value	0.000**	0.000**	0.000**	0.021*	0.000**
G2-Sf	CE-chirp 44 RR at frequency 0.5–4 kHz	Click ABR at frequency 2–4 kHz	NB-chirp threshold at 500 Hz	NB-chirp threshold at 1000 Hz	NB-chirp threshold at 4000 Hz
	PTA at frequency. 0.5–4 kHz	PTA at frequency 2–4 kHz	PTA at 500 Hz	PTA at 1000 Hz	PTA at 4000 Hz
r	0.784	0.778	0.269	0.434	0.840
P value	0.000**	0.000**	0.112	0.001**	0.000**
G2-Ss	CE-chirp 44 RR at frequency 0.5–4 kHz	Click ABR at frequency 2–4 kHz	NB-chirp at 500 Hz	NB-chirp at 1000 Hz	NB-chirp at 4000 Hz
	PTA at frequency 0.5–4 kHz	PTA at frequency 2–4 kHz	PTA at 500 Hz	PTA at 1000 Hz	PTA at 4000 Hz
r	0.858	0.425	0.631	0.553	0.808
P value	0.000**	0.100	0.003**	0.011*	0.000**

Moreover, it showed a correlation between the threshold of wave V (dBnHL) by using NB-chirp 44 RR at 500, 1000, and 4000 Hz versus threshold of PTA at 500, 1000, and 4000 Hz of all tested patients. ABR, auditory brainstem response; NB, narrow band; PTA, pure-tone audiometry; RR, repetition rate. *Mean

Correlation between narrow band-chirp and pure-tone audiometry

In the current study, there was a higher degree of correlation between narrow band (NB)-chirp-ABR and behavioral PTA at the corresponding frequency in all tested groups, except in the G2-Sf subgroup at 500 Hz. This finding agrees with Xu *et al.* [10]. They reported that there was a high degree of correlation between chirp-ABR thresholds in both low-frequency

and high-frequency audiometric bands in young patients with severe hearing loss. They concluded that increased sensitivity of the chirp-ABR to more severe degrees of hearing loss may be attributed to the recruitment associated with cochlear hearing impairment [10].

The reduced correlation between NB-chirp and behavioral PTA in severe flat SNHL (G2-Sf) at 500 Hz, agrees with Elberling and Don [11]. They reported that in the objective frequency-specific assessment of hearing threshold using auditory-evoked potentials, there are greater differences at 500 Hz between the objective and the subjective threshold. This applies to simple tone burst ABR, to notched-noise ABR, and to the threshold assessed by means of auditory steady state response (ASSR). In contrast, in severe steeping SNHL (G2-Ss) our results showed a high correlation between NB-chirp and behavioral PTA at 500 Hz. This could be attributed to the better synchronized activity in the better hearing low frequency rejoin that contributes to the frequency-specific chirp response.

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Conflicts of interest
There are no conflicts of interest.

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