Research Article

The risk of hearing threshold estimation by click stimuli auditory brainstem response in children

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Abbreviations:
ABR: Auditory brainstem response, PTA: Pure tone audiogram, OAEs: Otoacoustic emissions, TEOAEs: Transient evoked OAEs, DPOAEs: Distortion product OAEs, ECochG: Electrocochleography, ASSR: Auditory steady state response, SVR: Slow vertex response or cortical auditory evoked potential (CAEP), NR: No response, RR: Recordable response

Abstract

Background: click stimuli auditory brainstem response (ABR) test is commonly used in the audiology centers for confirmation of hearing loss as well as hearing threshold estimation for hearing aid fitting in children.
Aim: To compare hearing threshold evaluation by behavioral pure tone audiometry with that by click stimuli auditory brainstem response audiometry.
Patients & Methods: The study includes 82 children with bilateral hearing loss and no ABR or behavioral responses (164 ears), ranged in ages between 1 and 8 years. These children were referred for hearing threshold estimation as a pre requisite of hearing aid fitting. 16 children (32 ears), aged 4 years and greater, which forms about 20 % of cases were selected for comparison of the results of pure tone audiograms with their auditory brainstem response results, because by the age of 4 years and greater, the pure tone audiometry with headphones can be measured reliably.
Results: The mean age of auditory brainstem response testing was 2.81 years (SD 1.56) and most of the children`s hearing is diagnosed in the 2nd, 3rd and 4th year of age with percentages of 38, 18 and 24 respectively, males (48) more than females (34). Whereas the mean age of ABR for those 4 years and greater is 2.9 (SD 1.3) and ranged in ages between 1.5 and 6 years. The mean age of pure tone audiogram tests was 5.4 (SD 1.1), and ranged between 4 and 8 years. The pure tone audiograms of the 31 ears with no click ABR responses revealed a wide range of dynamic hearing in the frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz with figures of 40-100 (mean 65), 50-100 (mean 75), 70-115 (mean80), 75-120 (mean100), 75-120 (mean105), and 80-120(mean110) respectively.
Conclusion: the study indicated that the Clicks stimuli auditory brainstem response is not a good predictor of behavioral hearing threshold in children, and there is great delay in the age of hearing loss estimation and that will results in delay and inappropriate hearing aid fitting and its consequences on speech development. This raises more attention to be paid on proper behavioral testing, and reliance more on battery of tests by combining click stimuli ABR with other frequency specific tests such as tone pips auditory brainstem response and auditory steady state response for hearing aid fitting and confirmation of hearing loss, and the use of single hearing test for assessing children`s hearing should be discouraged.

Key words: Click and tone pips ABR test, behavioral pure tone audiometry

INTRODUCTION

The estimation of hearing threshold in children is challenging most audiologists. The most young the child is, the more difficult to assess and more reliance will be on electrophysiological rather than behavioral hearing tests for confirmation of hearing threshold, particularly before the age of 6 months[1-3]. The joint committee on Infant Hearing (JCIH) recommends universal neonatal hearing screening, and that hearing impaired infants should be detected & diagnosed before the first 3 months of age and treatment initiated by the age of 6 months [4]. One of the powerful hearing screening tests in neonates is otoacoustic emissions (OAEs), including transient evoked OAEs (TEOAEs) and distortion product OAEs (DPOAEs), but they are only demonstrable in hearing loss no greater than 40 dB[5, 6]. By the age of 6 months, the behavioral hearing threshold must be obtained, and the types of behavioral hearing tests in preschool children vary from 6 months to 5 years old, which should be performed as developmentally appropriate depending on the mental age (not the chronological age) of the child, and hearing threshold can be estimated reliably if undertaken properly by skilled personals [1]. The failure to pass the OAEs in the first 3 months or later by behavioral hearing tests, is an indication for further electrophysiological tests to diagnose hearing loss and predict audiometric threshold, including, from periphery of auditory pathway to cortex, acoustic immittance measures (tympanometry and acoustic reflexes), auditory brainstem responses (ABR), electrocochleography (ECochG) as in cases with absent wave I in ABR test, the auditory steady state response (ASSR), and the slow vertex response (SVR) (or cortical auditory evoked potential (CAEP)); combination of these tests may be indicated[1-2, 7-10].

The most widely used electrophysiologic procedure for estimating hearing thresholds is ABR [2]. ABR was discovered in 1971, which is non-invasive, far field electrical hearing activity, Where, in response to acoustic stimuli a series of electrical neural potentials can be detected and recorded from surface scalp electrodes according to site of origin in the auditory pathways, and five clear waves can be recorded and used to assess the hearing threshold by wave V latency, and the integrity of auditory pathways by waves I, III, and V (figure 1) [11-12]. The sound stimuli which are used to evoke these waves are either click or tone pips (or tone bursts) [13-14]. The advantage of tone pips ABR is that it mirrors the audiometric configuration of hearing loss, which makes it more suitable for hearing aid fitting [14]. The click ABR test is not frequency specific, because it represents mainly the frequencies 2000 to 4000 Hz, and if the hearing is good in the low frequencies, it cannot be detected by this test [15]. Both click and tone pips ABR tests are limited in the assessment of severe to profound hearing losses due to the transient nature of the stimuli used [16-17]. The purpose of this study is to highlight the disadvantage of click ABR in the prediction of behavioral audiometric threshold as well as its limitation in severe to profound hearing loss, because the click stimuli ABR is the tool of choice nearly in all of audiology centers for confirmation of hearing loss, estimation of hearing threshold, hearing aid fitting, and for determination of candidacy of cochlear implants.

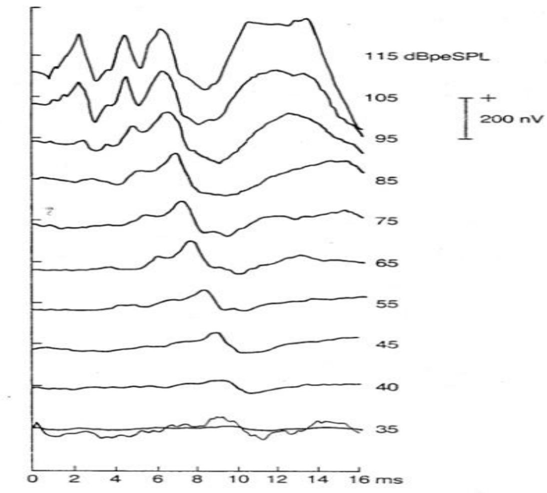

Figure 1 Normal ABR responses at different dB sound pressure levels [11-12].

PATIENTS AND METHODS

The study includes 82 children (i.e. 164 ears), 48 males and 34 females, ranged in ages between 1 and 8 years. The hearing evaluation of these children indicated no responses in click stimuli ABR and behavioral hearing tests. These cases were referred, during the year 2013, from a private hearing aid dealer in Baghdad for hearing threshold evaluation as a prerequisite of hearing aid fitting. Those children aged 4 years or greater were selected and subjected for further analysis, because at this age and greater, the pure tone audiometry with headphones can be measured reliably. These cases included 16 children (i.e. 32 ears), 10 males and 6 females, aged between 4 and 8 years, which constitute about 20 per cent of the cases referred. History from children`s parents have indicated that the hearing loss was present since birth. The hearing of these children is estimated using the updated recommended procedure of the British society of audiology, by starting hearing measurement in the frequency 1000 then 2000, 4000, 8000, 500, and lastly 250 Hz for air conduction and 500 to 4000 Hz for bone conduction [18]. Tympanomerty test was normal in all children which rules out the presence of middle ear fluid, and the TEOAEs were absent which indicate that these children have more than a mild hearing loss.

RESULT

Table 1 and figure 2 shows the age and sex distribution of children in the study, with more males (48) affected by hearing loss than females (34), and indicates that the hearing loss of most children (about 80%) was first diagnosed and confirmed by click ABR in 2nd, 3rd and 4th year of age with percents of about 38%, 18% and 24% respectively. Whereas, the rest of children which constitute about one fifth of children were first diagnosed by ABR in the 5th to 9th year of age, with only females in the 8th and 9th year of age. The mean and standard deviation (SD) of the age of diagnosis by ABR test for the 82 cases are shown in Table 2 with figures of 2.81 and 1.56 respectively, as well as the range and median.

Table 3 shows the hearing levels of pure tone audiogram (PTA) in the frequency range 250-8000 Hz, the age of PTA test, and the age of ABR test (and its result) of the 16 children, aged 4 years and greater. 31 ears of these children revealed no response (NR) or no clear reproducible wave V by click ABR test, and only one ear was with recordable response (RR) (noted as having moderate hearing loss, but without specifying the hearing level for any frequency). The ABR test was repeated twice (with same NR result) in ages 4, 4.5, 4, and 3.5 years for child 1, 8, 9, and 16 respectively. Figure 3 shows the age distribution of ABR and PTA test which reveals a wide difference in dates between the two tests & within tests (years) in most of children. Table 4 shows the mean and SD of the age of ABR and PTA tests, with figures of 2.9 (SD 1.3) and 5.4 (1.1) respectively in addition to the range and median, and as regards the age of ABR the numbers nearly coincide with that of all children in table 2. Table 5 show the mean (and SD) of audiometric pure tone thresholds for the frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz for 31 ears with NR ABR which revealed hearing levels of 65.9 (13.4), 74.7 (13.8), 84.4 (15.6), 95.6 (14.9), 101.6 (16), and 104.4 dB (16.9) respectively. Also, the range and median of hearing level in these frequencies were 40 to 100, 50 to 100, 60 to 115, 70 to 120, 75 to 120, and 80 to 120 dB respectively. Figure 4 shows the scatter of pure tone audiograms for 31 ears with NR ABR which revealed a wide dynamic range of hearing as indicated in table 5, and these levels can benefit from hearing aid fitting.

Table 1. The age & sex distribution of 82 children with no ABR or behavioral responses.

Age Range	F		M		Grand Total	
	No.	**%**	**No.**	**%**	**No.**	**%**
1 – 1.11	**13**	**15.9**	**18**	**22**	**31**	37.8
2 – 2.11	**6**	**7.3**	**9**	**11**	**15**	18.3
3 – 3.11	**9**	**11**	**11**	**13.4**	**20**	24.4
4 – 4.11	**2**	**2.4**	**3**	**3.7**	**5**	6.2
5 – 5.11	**1**	**1.2**	**6**	**7.3**	**7**	8.5
6 – 6.11	**1**	**1.2**	**1**	**1.2**	**2**	2.4
7 – 7.11	**1**	**1.2**	**0**	**0**	**1**	1.2
8 – 8.11	**1**	**1.2**	**0**	**0**	**1**	1.2
Grand Total	**34**	**41.4**	**48**	**58.6**	**82**	100

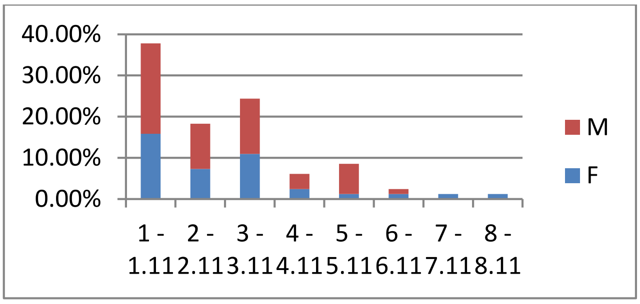

Figure 2. The age & sex distribution of 82 children with ABR or behavioral responses.

Table 2. The Mean, SD, Range and Median of age of ABR of 82 children.

	Age of ABR test
Mean	2.81
SD	1.56
Range	1-6
Median	2.5

DISCUSSION

As indicated in the results of this study from age of ABR test, there is great delay in hearing loss diagnosis, with a minimum and higher age were 1 year and 6 year respectively, and this delay in diagnosis does not comply with the JCIH recommendations which suggest that the hearing loss in children must be diagnosed in the first 3 months of age [4]. Also there is great delay in the age of estimation of behavioral hearing threshold which ranged between 4 and 8 years, and that is far away from the recommended measurement of behavioral audiometric thresholds, when become practicable, by the age of 6 months in proper audiometric set up [2]. Moeller have pointed out the importance of early detection of hearing loss before the age of 6 months followed by (within 2 months) immediate appropriate intervention services, because of the impact of hearing loss on speech language, social-emotional, cognitive, and academic achievement (19). The author think that the main causes of delay in diagnosis of hearing loss are, firstly is the lack of neonatal screening of hearing loss programs, whether universal or for the high risk children, secondly is the lack of parents `s education and their denial of hearing loss, and they seek help only when there is delay in speech production, thirdly is the lack of expertise in this field as regards trained personals, equipments, and proper audiological set up for behavioral testing of children. As revealed in this study in figure 4 there is measurable audiometric hearing thresholds in frequencies 250 to 8000 Hz with a wide range of dynamic hearing particularly in the low and mid frequencies, that can benefit from hearing aid fitting in most of children, and not only in the frequencies 2000 to 4000 Hz represented by click ABR

[15].]. Therefore, the click ABR test is not a reliable predictor of audiometric threshold, and for that reason Gorga et al suggested the use of 500 or 250 Hz tone pips (or tone bursts) in combination with click ABR to assess hearing thresholds [20].

Table 3. The age of PTA & ABR testing for 16 children (32 ears) with hearing loss

Child	Age Yrs	Sex	Ear	Pure tone hearing thresholds (dB HL)						Click ABR	
			R/L	250	500	1000	2000	4000	8000	age	Result
1	4.8	M	R	90	90	100	105	110	110	1.8;4	NR
			L	100	100	110	115	115	120		NR
2	4.2	M	R	55	70	70	80	75	80	2.2	NR
			L	50	70	75	80	100	105		NR
3	4.2	F	R	65	95	110	120	120	120	2.2	NR
			L	60	90	110	120	120	120		NR
4	5	M	R	50	60	80	100	115	120	3	NR
			L	65	70	80	100	115	120		NR
5	8	F	R	75	85	90	105	105	110	3.1	NR
			L	75	80	85	105	105	110		NR
6	4	F	R	60	65	75	75	80	85	1.6	NR
			L	75	75	80	85	85	90		NR
7	6.2	F	R	55	60	65	65	55	45	6	RR
			L	75	85	85	85	85	80		NR
8	5.8	M	R	40	50	65	80	110	115	2.6;4.5	NR
			L	45	55	60	75	100	105		NR
9	5.8	M	R	60	65	60	75	75	85	3.5;4	NR
			L	55	55	70	70	75	80		NR
10	5	M	R	60	65	70	80	85	95	2	NR
			L	55	60	75	85	90	95		NR
11	6.5	M	R	80	80	95	105	105	90	5	NR
			L	75	80	85	100	105	110		NR
12	5.4	M	R	70	90	105	110	115	110	2	NR
			L	80	95	115	115	120	120		NR
13	5	F	R	55	55	75	105	110	115	2.3	NR
			L	50	55	65	95	100	105		NR
14	4.7	M	R	60	75	80	95	110	110	3	NR
			L	65	70	75	90	105	110		NR
15	7	F	R	75	95	100	105	110	115	5	NR
			L	75	90	95	100	95	100		NR
16	5.5	M	R	80	85	95	110	120	120	1.5;3.5	NR
			L	80	85	100	115	120	120		NR

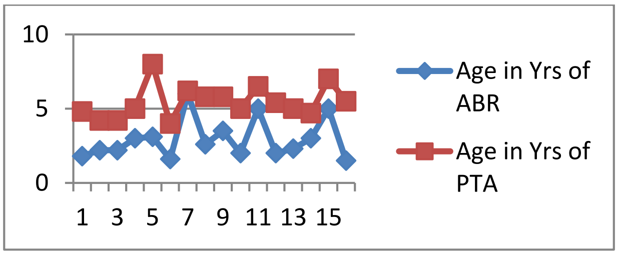

Figure 3. Age of ABR tests and Age of PTA tests

Table 4.The Mean, SD, Range and Median of age of ABR and PTA tests.

	Age of ABR test	Age of PTA test
Mean	**2.9**	**5.4**
SD	**1.3**	**1.1**
Range	**1.5 – 6**	**4 – 8**
Median	**2.45**	**5.2**

Table 5 the Mean, SD, Median, and Range of hearing levels for each frequency of the PTAs of the 31 ears with NR ABR.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Mean dB HL	65.9	74.7	84.4	95.6	101.6	104.4
SD	13.4	13.8	15.6	14.9	16	16.9
Median dB HL	65	75	80	100	105	110
Range dB HL	40-100	50-100	70-115	75-120	75-120	80-120

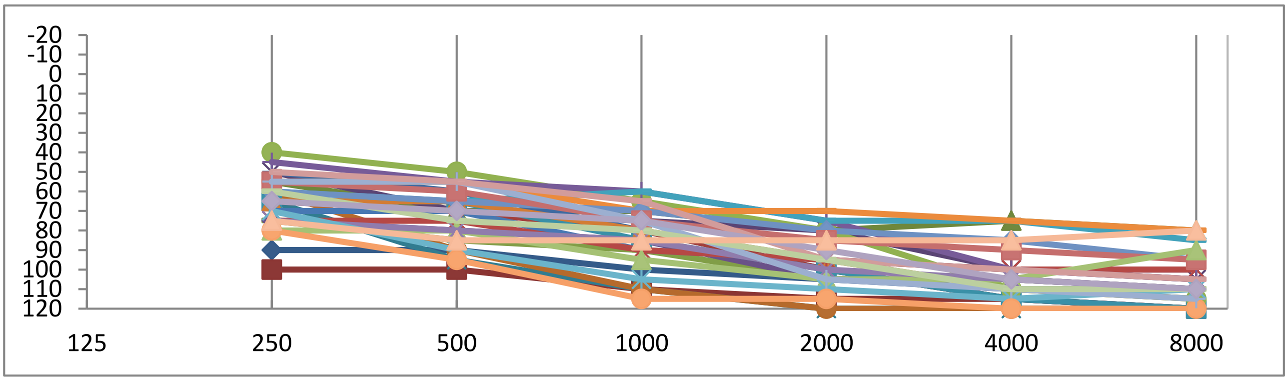

Figure 4 PTAs of 31 ears with no NR ABR

Also, other studies have reported that the use of tone burst stimuli ABR in the frequencies 500 Hz to 4 kHz provide accurate predictors of audiometric thresholds [14, 21]. Alternative frequency specific tools to tone bursts ABR are the ASSR and SVR tests [2, 10].The ASSR is used to quantify severe to profound hearing losses which are beyond the limits of ABR, and the ASSR, like the ABR, can be done in sedated infants and children. Rance et al. have found that 58 % of cases with absent click ABR have ASSR response [16]. whereas, other study by Vander Werff et al. have reported that 33% of cases with absent tone pips ABR, when stimuli are presented at the highest available intensity levels, have ASSR response, and that is due to the continuous nature of the modulated tones in ASSR which allows for increased levels of stimulation to 120dB HL [22]. But in other study by Small and Stapells, the ASSR responses have been reported in subjects with no residual hearing and it is possibly mediated by the vestibular system[23]. Adding to that, the study by Cone-Wesson et al. reported equal hearing thresholds by tone bursts ABR and ASSR in normal hearing subjects [24]. The SVR (or CAEP) is used only in old children and adults who are awake (i.e. the responses are altered by sedation) and passively cooperative, and its evoked responses, unlike ABR, are more close to behavioral hearing levels, and it test hearing ability high up to the cortical level, representing the true, perceptive behavioral hearing (2, 10, 25).

In conclusion, click stimuli ABR alone is not a good predictor of pure tone threshold, although it provide important information about neural synchrony and the integrity of brainstem which is not available from phase measurements of ASSRs. A recordable OAEs and absent or abnormal ABR waves by high level click stimuli is an indication of auditory neuropathy, but OAEs may be absent in minor middle ear problems and may still have auditory neuropathy, adding to that in auditory neuropathy the audiometric threshold may be better than the ABR results. Tympanometry and acoustic reflex test will help in the interpretation of elevated ASSR hearing threshold due to conductive hearing loss, and the acoustic reflexes are also absent in auditory neuropathy. Therefore click ABR must be combined with other frequency specific tests [3, 26-28].

It has been advised a battery of tests for children before the age of 6 months, when behavioral tests are not practicable, that includes OAEs (TEOAEs and DPOAEs), acoustic immittance (tympanometry and acoustic reflexes), click & tone- pips ABR, the ASSR to supplement ABR findings, but by the age of 6 months and older, behavioral tests must be added to these electrophysiological test to confirm the results, which include conditioned behavioral audiometry such as reinforcement audiometry (VRA) or conditioned play audiometry(CPA) according to the mental age of the child [2, 4].

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