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RESEARCH ARTICLE

CHIRP AUDITORY STEADY -STATE RESPONSE AS A HEARING SCREENING TOOL IN HIGH-RISK INFANTS

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Abstract

Background: Newborn hearing screening with automated procedures usually uses broad band stimuli, such as click. Studies using the Auditory Steady-State Response (ASSR) that used specific frequency chirps named **narrow band CE-chirps** have shown obvious diagnostic results.

Objective: To assess the value of the binaural multi-frequency chirp ASSR as a hearing screening tool. To compare chirp ASSR and click ABR as a tool for early diagnosis of hearing loss in infants with risk factors for hearing loss.Methodology: Two groups of infants were studied, group I (28 infants with risk factors) with one or more risk factor for permanent hearing loss, group II (ten infants without risk factors). Their age ranges from one to six months. Assessment of middle ear pressure using immittancemetry, and hearing threshold estimation using Click ABR and Chirp ASSR were done.

Results: When comparing hearing threshold of [group (I) infants with risk factors], and [group (II) infants without risk factors] it was found that there was no statistically significant difference when hearing was evaluated by using click ABR or Chirp ASSR.By comparing average ASSR (Average thresholds of1000, 2000 and 4000 HZ) threshold with ABR threshold, there was no statistically significant difference. There was high positive correlation between ABR threshold and average ASSR.

Conclusion: Chirp ASSR can be used for assessment of hearing thresholds in infants with the same accuracy of Click ABR thresholds, with more advantage perceived by ASSR in the form of frequency specific threshold estimation. The binaural multi-frequency chirp ASSR can be used as a hearing screening tool.

Introduction:-

Hearing loss is very common in the general population. Accurate diagnosis and intervention before the age of six months facilitate normal development of language and speech, regardless of the severity of hearing loss[1]. The prevalence of hearing loss ranges from 0.09 to 2.3 % in neonates with no risk factors for hearing loss, and it ranges from 0.3 to 14.1 % in the high-risk infants [2].The risk factors for hearing loss in neonates according to American Joint Committee on Infant Hearing (JCIH) are: premature birth, family history of congenital sensorineural hearing loss, low birth weightless than 1500 gm, congenital perinatal infections (Syphilis,Toxoplasmosis,Varicella–zoster,

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ParovirusB19, Rubella, cytomegalovirus, and Herpes infection), Craniofacial anomalies, hyper-bilirubinemia which needs exchange transfusion, ototoxic medication used in toxic doses (e.g.: aminoglycosides, diuretics), bacterial meningitis, mechanical ventilation, syndromes associated with sensorineural hearing loss [3&4].

Neonatal hearing screening with automated procedures, usually uses broadband stimuli, such as click, that stimulate the whole basilar membrane. Therefore, hearing affection in specific regions may be underestimated or even overestimated, due to the differences in audiometric results.As click ABR approximates behavioral pure tone levels only in the mid to high frequency frequencies [5], consequently limiting detection of hearing affection in other frequencies [6].

The application of band-limited chirps or specific frequency band stimuli gives good response in Newborn Hearing Screening (NHS).The chirp-stimuli present higher frequencies with a time delay in relation to lower frequencies. Chirp-stimuli show two advantages: higher potential amplitudes and faster potentialresponses [7].

Studies using the Auditory Steady-State Response (ASSR) that used specific frequency chirps have shown obvious results with decreasing examination time [8].Accordingly, this study was conducted in an attempt to assess ASSR testing using chirp stimulus in early diagnosis of hearing loss in a group ofinfantswith age range of one to six months.Also, whether chirpASSR can be utilized to improve the efficiency of audiological test-battery, supplementing ABR data and cross-checking test results to direct early amplification and intervention decisions more precisely.

Aims of the work:

1. To assess the value of the binaural multi-frequency chirp ASSR as a hearing- screening tool.
2. To compare chirp ASSR and click ABR as a tool for early diagnosis of hearing loss in high-risk infants.

Materials and methods:

Subjects:

This study was conducted in the Audiology unit, Hearing and Speech Institute in the time period from July 2020 to March 2021. It was conducted on two groups of infants, their ageranges from one to six months:group I(28infants with risk factors), and group II(10 infants without risk factors).Any infant with impacted ear wax, debris or foreign bodies that could not be removed, ear discharge or abnormalities of tympanic membrane were excluded.

Methodology:-

All infants underwent full history taking including: Prenatal history (maternal: medical& obstetric history),perinatal history (mode of labor, gestational age and birth weight), neonatal history (hyperbilirubinemia, cyanosis, apnea, convulsions, birth trauma, admission to the NICU and ototoxic medications) and family history (Parent's consanguinity or family history of hearing loss).

1. They were examined generally focusing on head and neck examination (looking for craniofacial anomalies
2. involving the pinna, ear canal, ear tags & ear pits).Otologic examination was performed.
3. Middle ear examination was assessedby using ImmittancmeterInteracousticsAZ26.

Hearing thresholds assessment were performed using Click ABR and chirp ASSR using Eclipse Interacoustics instrument, all infants were tested asleep naturally. To accomplish this procedure, the infant’s skin was prepared with NuPrepTM abrasive skin prepping gel to minimize electrode resistance, and then electrodes were applied, four electrodes were placed as the following: a positive electrode was placed at high frontal Fz, two negative electrodes was placed over the mastoid bones (one on each side), and the ground electrode was placed on one cheek.

1. In case of ABR testing, the stimulus was monaural acoustic rarefaction click thatwasdelivered to each ear via insertearphones. A click stimulus at the rate of 21.1/s was delivered at the intensity level of 60 dBnHLand increase or decrease the level according to the response. The Analysis Time Window is 15 ms. The waves were recorded and analyzed.
2. In case of Chirp ASSR testing:The stimulus used was narrow-band CE-chirp that was presented at a rate of 90/s in four frequency bands (0.5, 1, 2 and 4 kHz). Each single stimulus was presented at a slightly different repetition rate, in order to separate the responses which are elicited by the four stimuli in the EEG spectrum, and to assign the responses to the correct ear and test frequency. High modulation rates were used to ensure that a

satisfactory signal-to-noise ratio would exist for detection of responses during sleep or sedation. The stimulus level was ranging from115dBnHLto 0dBnHL, starting by presenting the narrow-bandCE-chirp stimuli at level of 50 dBnHL, then increase or decrease the level according to the response till obtaining a threshold.In contrast to traditional multiple-stimulus ASSR recording systems, the software running on the ASSR system used in the current study allows not only for simultaneous but also for independent thresholds estimation at the four tested frequencies binaurally.

Statistical analysis:

Data were statistically described in terms of mean±standard deviation, frequencies (number of cases). Comparison of numerical variables was done. Correlation between ABR and average ASSR was done using Spearman rank correlation equation. Two-sidedp values less than 0.05 was considered statistically significant. All statistical calculations were done using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release22for Microsoft Windows.

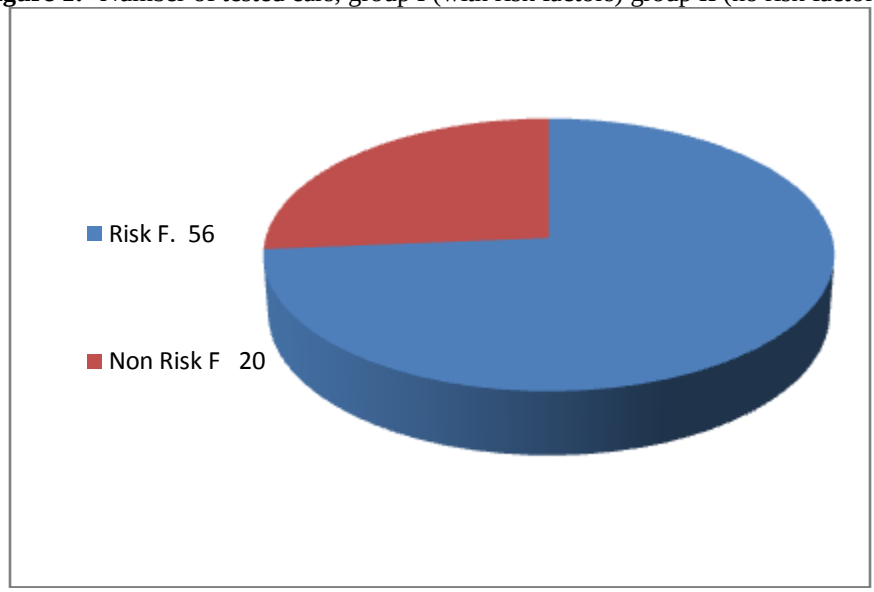
Ethical Aspects:

Informed written consent was signed by the infant's parents if accepting to share in the research.

Results:

The present study was carried out on 38 infants,20 males and 18 females, their age ranged from one to six months with mean age 4.7±1.8 months, they were divided into two groups: group I (28infants with risk factors) group II (ten infants withoutrisk factors).As there was no statistically significant difference between right and left ears as regards ABR and ASSR thresholds at different frequencies in the two study groups, the results of the right and left ears were added for further analysis with a total number of ears in group I was 56 ears, while in group II the total number of ears was 20 ears (Fig. 1).

Figure 1:- Number of tested ears; group I (with risk factors) group II (no risk factors).



It was noticed that risk factors forpermanent hearing loss detected in infants of (group I) were post-natal jaundice (six cases), prematurity of birth (five cases), followed by post-natal cyanosis (four cases), low birth weight (three cases), and positive family history of hearing loss (two cases)(Fig. 2).

Figure 2:- Distribution of risk factors in the study group I.

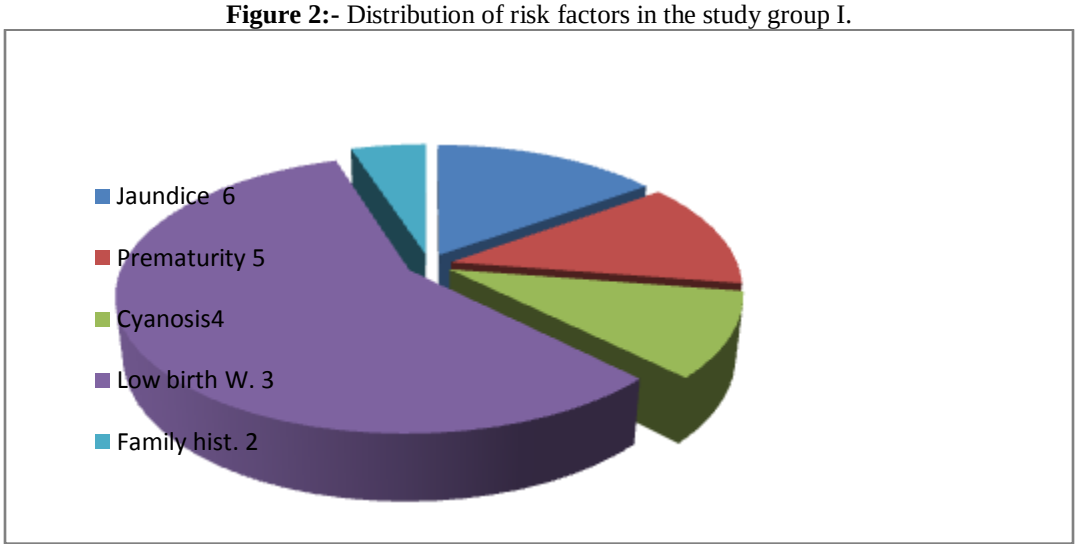


Table 1:- Mean, standard deviation (SD) and p value of ABR&ASSR (0.5,1,2,4 kHz) thresholds in group I and group II.

	Group I (With risk factors)		Group II (Without risk factors)		**P**
	Mean	SD	Mean	SD	
ABR results	50.09	43.09	45.91	27.33	0.06
ASSR 500 Hz	46.24	34.38	43.14	30.90	0.06
ASSR 1000 Hz	46.11	30.21	42.50	22.98	0.07
ASSR 2000 Hz	47.04	28.24	42.50	27.03	0.06
ASSR 4000 Hz	44.53	27.91	41.82	23.53	0.07

Table (1) shows no statistically significant difference between the two groups regarding ABR thresholds and ASSR thresholds at tested frequencies

Figure 3:- Shows difference between the two groups regarding ABR thresholds and ASSR thresholds at tested frequencies.

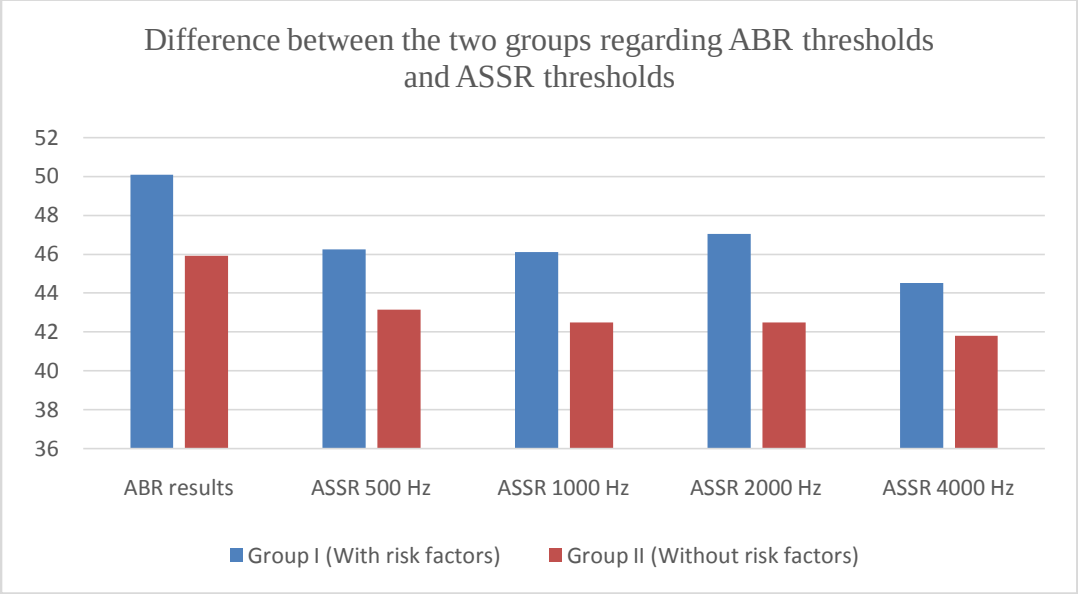


Table 2:- Mean, standard deviation (SD) and p value of average ASSR (1, 2,4 kHz) thresholds in group I and group II.

Average ASSR 1,2,4 KHz	GroupI (With risk factors)		Group II (Without risk factors)		P
	Mean	SD	Mean	SD	
	45.66	24.17	42.06	25.91	0.07

Table 2:-shows no statistically significant difference between the two groups as regard average ASSR (1, 2,4 Hz) thresholds.

Figure 4:- Shows average ASSR (1,2,4 KHz) thresholds in group I and group II.

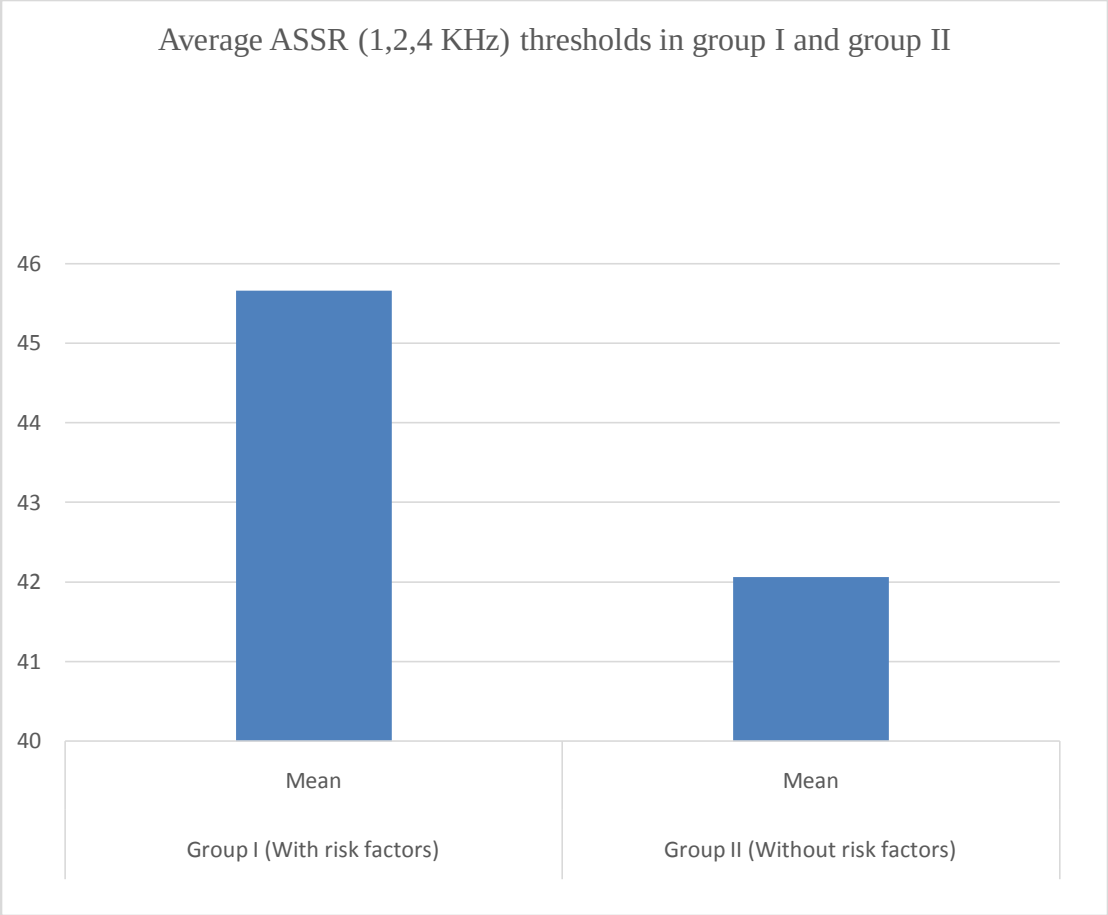


Table 3:- Mean, standard deviation (SD), p value of average ASSR (1,2&4 kHz) and ABR thresholds in group Iand group II.

GroupI	Average ASSR(1,2&4KHz)		ABR		P
	Mean	SD	Mean	SD	
	43.14	23.87	47.12	28.04	0.075
Group II	45.99	28.56	49.07	27.75	0.059

Table 3:-shows no statistically significant difference between average ASSR (1,2,3,) and ABR thresholds in group I and group II.

Figure 5:- Shows difference between average ASSR (1,2&4 kHz) and ABR thresholds in group I and group II.

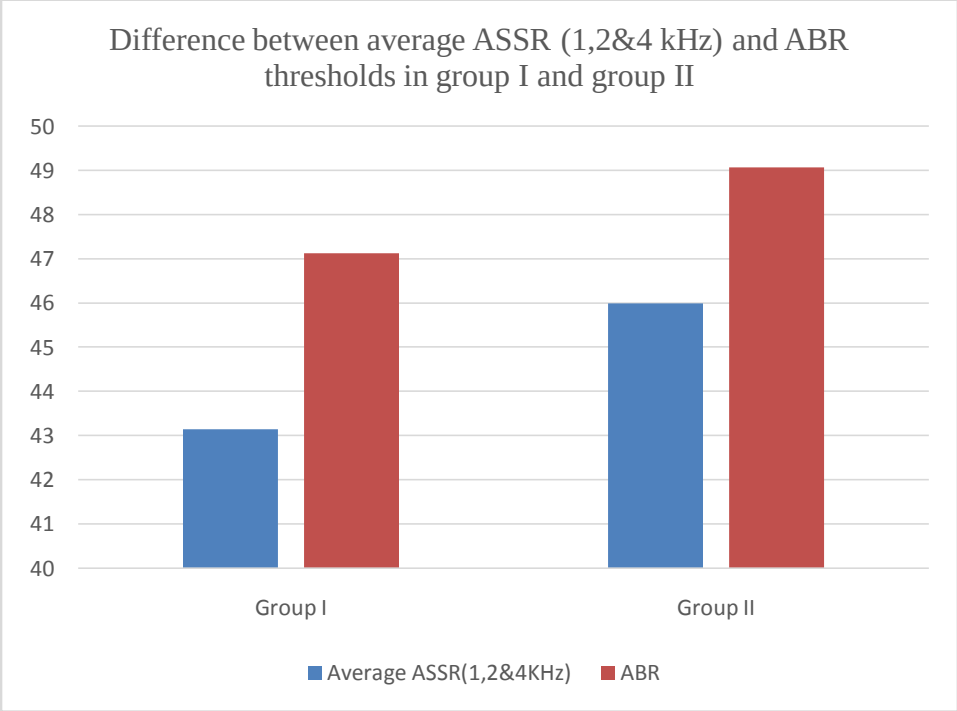
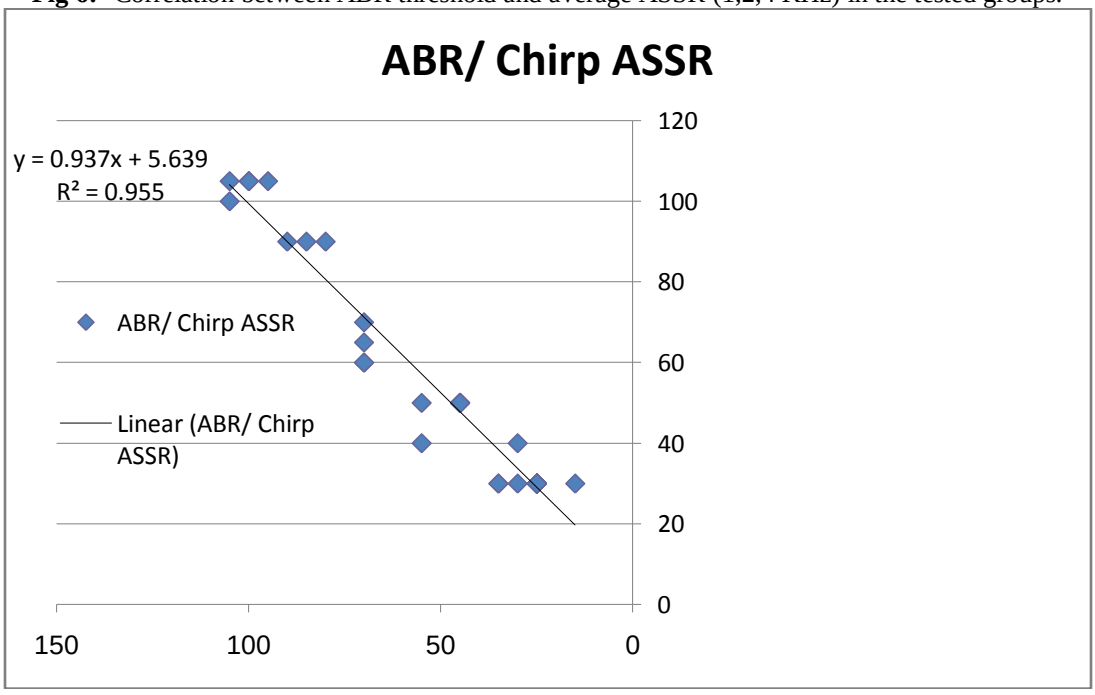


Table 4:- Correlation between ABR threshold and average ASSR (1,2,4 KHz) in both groups.

	Correlation Coefficient	P value
ABR threshold versus Chirp ASSR	0.955	0.001

Table 4:-shows a high statistically significant + vecorrelation between ABR threshold and average ASSR thresholdin both groups.

Fig 6:- Correlation between ABR threshold and average ASSR (1,2,4 KHz) in the tested groups.



Discussion:-

Objective methods become necessary to assess subjects who are either too young to respond reliably, or who are uncooperative. Auditory evoked potentials (AEP) measured from the scalp in response to acoustic stimulation have been used [9]. The most commonly used stimulus for eliciting an ABR is a broadband click stimulus [3].This stimulus is not frequency specific and used frequently in testing hearing levels in the high frequency region (2-4 kHz). The auditory steady-state response (ASSR), is another clinical test of the AEP test-battery, it is a frequency specific test [6].Aimoni et al. [10] reported that ASSR can be considered an effective procedure and a reliable test, particularly when predicting hearing threshold in very young children.Kandogan and Dalgic[11]reported that both click evoked ABR and ASSR techniques can be used to provide an estimate of hearing sensitivity in children, but ASSR is a more valuable test than click evoked ABR as click evoked ABR is not frequency-specific. They concluded that ASSR may be considered a complementary test rather than an alternative to click evoked ABR. The notion that ASSRs may be a more accurate predictor of behavioral thresholds than ABRs in certain individuals with steeply sloping hearing losses has also been supported by Johnson and Brown [12].

Subjects in this study were divided into two groups: group I;infants with risk factors for hearing loss and group II; without risk factors for hearing loss Fig. (1&2). Comparing Click ABR threshold with Chirp ASSR threshold revealed that hearing threshold for group II is better than group I. However, this difference was not statistically significant Table (1)& Figure (3).By comparing averagethresholds of Chirp ASSR (1,2, &4 KHz) with Click-evoked ABR threshold in group I and group II, there was no statistically significant difference between two groups table (2&3)& Figure (4&5). This may be attributed to early assessment of these infants before remote effects of risk factors on hearing threshold occur.Also, Swanepoel and Ebrahim [13] compared ASSR threshold and click-evoked ABR threshold for 48 infants and young children with various types and degrees of hearing loss. They found no statistically significant difference between ASSR and Click ABR thresholds.

However,Hardani et al. [14] studied prevalence of risk factors for hearing loss in neonates admitted to the Neonatal Intensive Care Unit and they found no statistically significant association between hearing loss and infants' prematurity, ventilation, sepsis, hypoglycemia, and family history of hearing loss. However, there was a statistically significant association between hearing loss and birth weight, Apgar score < 5, hyperbilirubinemia, ototoxic drug, asphyxia, and consanguinityofparents.This difference in results may be due to small number of cases in our study group and also the small number of cases in individual risk factor which is considered a limitation of this study.

In the current study, there was significant positive correlation between click evoked ABR and average ASSR thresholds Table (4) & Figure (6). This demonstrate the reliability of verifying the averaged high frequency ASSR thresholds with click evoked ABR as an important cross-check in infants and young children when behavioral audiometry is difficult to do.These results agree withSwanepoel and Ebrahim [13] who found high correlation between the ABR and average ASSR frequencies for all categories of hearing loss.Also, Cebula et al. [7]found that, the overall correlation between the multiple-ASSR and ABR was very strong (r0.97).This clearly suggests that ASSR provides reasonably accurate estimates of hearing thresholds and both tests are efficient to be replaced by each other.They concluded that the ASSR technique can be used for evaluating and managing pediatric subjects with sensorineural hearing loss ranging from severe to profound at levels which cannot be detected by high levels of click ABR test [7].Vander Werff et al. [15] investigated the degree to which ASSR thresholds correlated with ABR thresholds in a group of sedated infants and children, their age ranges from two months to three years with different ranges of hearing loss. They found strong correlations between the 2000-Hz ASSR thresholds and click evoked ABR thresholds.

Conclusion:

Chirp ASSR can be used for assessment of hearing thresholds in infants with the same accuracy of click evoked ABR thresholds, with the more advantage perceived by ASSR in the form of frequency specific threshold estimation. The binaural multi-frequency chirp ASSR can be used as a hearing screening tool in the neonates as it is rapid test.

Recommendations:

1. Further assessment of hearing threshold in neonates and infants, with chirp ASSR with large number of cases.
2. To compare the results of different risk factors on hearing thresholds in larger numbers of infants.

3. Follow up of cases after one year to detect the remote effects of risk factors on hearing thresholds which may appear later.

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