COMPARATIVE EVALUATION OF TRANSIENT EVOKED OTO-ACOUSTIC EMISSIONS AND BRAINSTEM EVOKED RESPONSE AUDIOMETRY AS SCREENING MODALITY FOR HEARING IMPAIRMENT IN NEONATES

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Abstract : Objective: *This study was designed to evaluate Transient Evoked Oto-acoustic Emission (TEOAE) as screening modality for hearing impairment in neonates. Brainstem Evoked Response Audiometry (BERA) was used as gold standard diagnostic tool in this study. The factors affecting the specificity of TEOAE were also studied.*

Methods*: The study group of 200 randomly selected neonates was subjected to TEOAE and BERA (400 ears). Oto-endoscopy was done in all TEOAE failures and a repeat test was done after suction cleaning of blocked external auditory canal (EAC).*

Results*: Otoscopic evaluation of all 52 TEOAE failures was done. EAC obstruction was noticed in 31 ears and 4 ears showed collapsible EAC. TEOAE was repeated after suction cleaning of the obstructed EAC and using long probe tips for collapsible EAC. This improved the Pass rate of TEOAE from 87% to 92%. EAC obstruction and collapsible EAC were the two factors identified in this study that significantly affected the specificity of TEOAE as a screening test. Pass rate of TEOAE in <48 hrs age group was found to be 55.5%, which was nearly half of over-all pass rate. This was because of high prevalence of obstructed EAC in this age group. TEOAE was found to be a rapid screening tool as average time taken for BERA was 35 min/neonate and for TEOAE was 17.4 min/neonate. Acceptability of TEOAE was found to be higher as compared to BERA.*

Conclusions*: TEOAE is a simple and rapid test with relatively higher acceptability. But, the low sensitivity and specificity are the main shortcomings that take away from TEOAE, the status of independent screening modality for hearing impairment in neonates. TEOAE cannot completely replace BERA as screening modality for hearing impairment in neonates, however can complement it.*

Keywords: *Screening, Hearing impairment, BERA, TEOAE*

INTRODUCTION

Prevalence estimates of childhood hearing loss are expected to differ between countries primarily due to environmental factors such as the presence of endemic or epidemic diseases and differences in the level of medical care. Several large studies evaluating children ranging in age from 0 to 6 years and choosing the hearing thresholds >50-60 dB bilaterally, give different prevalence values of hearing impairment: Feinmesser M. et al., 1982 (Israel): 1.7/1000[1], Kankkune A., 1982 (Finland): 1.3/1000[2], Martin J.A.M., 1982 (U.K.): 1.0/1000[3], Thringer K. et al., 1984 (Sweden): 0.9/1000[4] and McPherson B. et al., (West Africa): 2.2/1000[5]. The typical consequences of such impairment if left undetected will be in the form of poor language development and low academic achievement [6]. Therefore, the hearing impaired children need to be diagnosed and rehabilitated at the earliest for their proper development of speech, language and cognitive abilities (Joint Committee on Infant Hearing, National Institute of Health, 1991)[7].

Brainstem Evoked Response Audiometry (BERA) has been established as the most reliable screening tool for hearing assessment in neonates since its first use in 1978 for this purpose. However, technical expertise required and time consumed in performing BERA in a neonate or a child makes this modality fall short of being an ideal screening tool. Transient Evoked Oto-acoustic Emissions (TEOAE), a relatively newer modality for neonatal hearing screening, is a non-invasive test that can be performed in a newborn nursery, with little expertise required and in a shorter time as compared to BERA. The ever-growing number of candidates for hearing screening, especially in a country with very high birth rate like India generate a need for a screening modality for hearing assessment, which is reliable but at the same time requires less time and expertise. Present study was mainly designed to evaluate TEOAE as screening modality for hearing impairment and to compare it with BERA.

MATERIALS AND METHODS

The study was conducted between January 1, 2000 to April 15, 2002 in Lady Hardinge Medical College and associated Kalawati Saran Children's Hospital & Smt. Sucheta Kriplani Hospital, New Delhi.

SUBJECTS:

The study group constituted of 400 ears of 200 neonates (0-28 days) that were randomly selected without applying any high-risk criterion. The neonates were taken from Immunisation Clinic, Newborn Nursery, Neonatal ward and Intensive Care unit of our hospital. An informed consent for both the tests i.e. BERA and TEOAE were taken from one of the parents after explaining them the methods of testing in their own language.

METHODS:

Both TEOAE and BERA were performed in both the ears of all selected neonates (i.e. total 400 ears). The tests were carried out in quiet surroundings in the presence of their mothers, whenever

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possible. No special sound treatment of the room was done. The mother was instructed to feed the baby just prior to the testing. Most of the neonates fell asleep after getting their feed. The neonates who did not sleep after the feed were sedated using syrup Triclofos (25- 30 mg / kg). TEOAE recordings were obtained on ILOV5 System (Otodynamics Ltd. UK) using SNS TEOAE probe with a removable soft tip. The size of the probe tip was selected after visually inspecting the neonate's ear canal size, so that a snug fit of TEOAE probe is achieved. Quick-Screen TEOAE stimulus was used for recording the emissions. The stimulus was in the form of clicks.

The clicks were 80 milliseconds (msec) in duration, with 12.5 msec. interval between two clicks and all presented at 80 dB SPL for the first three clicks of four stimulus sets, with a fourth non linear balancing click of opposite polarity that is three times the amplitude of the first three. The criteria used for passing a neonate on TEOAE were (i) Reproducibility of at least 50% or ii) Response Spectrum contained 3 dB more power than the noise spectrum in three of the frequencies (1.0, 1.5, 2.0, 3.0, 4.0 kHz). BERA was recorded using Neuro-otometrie Octavus System (Hortmann, Germany) giving 2000 broadband clicks in the rarefaction phase at the rate of 30clicks/sec. Presence of wave V at 60 dB was used as the passing criteria for BERA in these neonates. The time taken to complete TEOAE and BERA for every subject was recorded using a stopwatch. Figure 1 shows clearly the division of 400 ears into four groups depending upon the test results and the further detailed study outline (Fig. 1).

RESULTS

Group I (True Negatives) True Negatives for this study were defined as the ears that passed on TEOAE as well as BERA. Total of 344 ears fell in this group that was discharged from the study (Table 1).

Group II (False Positives) False Positives of this study were the ears that failed in TEOAE but passed on BERA. There were 48 ears (12.0%) with such results (Table 1). All these ears were subjected to otoscopy/ otoendoscopy. 31 ears had blocked External auditory canals (EACs) due to vernix/ debris, 4 ears with collapsible EACs and rest were normal. The repeat recordings were taken after suction cleaning of blocked EACs and with using long tipped probe. 16 out of 31 ears with blocked EACs and all 4 ears with collapsible EACs passed in this repeat TEOAE testing. The repeat failures were subjected to pneumatic otoscopy to see the status of tympanic membrane (TM) mobility. All except two ears showed normal or partial mobility of TM. These two ears were subjected to Impedance Audiometry and found to be having normal compliance and middle ear pressure.

Group III (True Positives) True positives were the ears that failed on TEOAE as well as BERA. One neonate had bilateral and two had unilateral such outcomes i.e. 4 ears (Table 1). Otoscopy revealed no abnormality in these ears. These neonates were followed up for next 6 months. One neonate with unilateral failure was lost to the follow up. Rest 3 ears were subjected to repeat tests but they again failed in both tests.

Group IV (False Negatives) False Negatives for this study were the ears that passed on TEOAE but failed on BERA. There were 4 ears with such results (Table 1). One premature neonate had bilateral and two neonates with congenital hyperbilirubinemia had unilateral absent BERA waveforms with normal TEOAE recordings. These neonates were followed up. The premature neonate passed in both BERA and TEOAE when this was repeated after the completion of gestational age. Other two neonates with congenital hyperbilirubinemia were subjected to repeat BERA and TEOAE after 6 months of follow up. One of them passed on BERA and TEOAE but the other still failed on BERA.

DISCUSSION

Pass Rate of TEOAE and BERA Pass rate of TEOAE calculated after first testing in all 400 ears was 87.0%. After otoscopy and suction cleaning, 20 more ears from group II passed on repeat TEOAE (i.e. turned True Negative from False positive). Thus, pass rate of TEOAE, increased from 87.0% to 92.0%. Pass rate of BERA calculated after first testing in all 400 ears was 98.0%. After completion of gestational age in premature neonates or six months of follow up, 3 more ears from group IV passed on repeat BERA (i.e. turned True Negative from False Negative). Thus, Pass rate of BERA increased from 98.0% to 98.75%.

Sensitivity and Specificity of TEOAE : In the present study, sensitivity of TEOAE calculated using BERA as the gold standard was found to be 80%, which means that TEOAE will miss out 20% hearing impaired neonates when used as an independent screening tool. An ideal screening tool should be 100% sensitive, but in practice, this seldom occurs. In this study, we could not identify any factor that truly affected the sensitivity of TEOAE. However, we were able to identify two factors that falsely reduced the sensitivity of TEOAE by affecting the outcome of BERA, which in these situations did not behave as a gold standard test. These factors were prematurity[8] and congenital hyperbilirubinemia[9, 10,11]. These observations of our study made us question the status of BERA as 'gold standard' screening tool. Also, we were able to appreciate that TEOAE is directly dependent upon the cochlear outer hair cell integrity[12] so will not be able to detect hearing impairment arising from retrocochlear pathologies.

The specificity of TEOAE in this study was calculated to be 92.85% that means that 7.14 % of the neonates when screened by TEOAE will give false positive result. In the present study we were able to identify two factors that significantly reduced the specificity of TEOAE. First factor is blocked EAC and the second, collapsible EAC. No middle ear factor was found to be responsible. Similar observations were reported in various other studies[13, 14, 15, 16]. Thus, all TEOAE failures should be subjected to otoscopic evaluation. However, we feel that otoscopy preceding every TEOAE testing is rather unnecessary, as this will nullify the real advantages of TEOAE as screening tool – its rapidity and simplicity.

Time Factor : The time taken to complete TEOAE and BERA for every subject was recorded using a stopwatch. The time was

Fig. I: Basic outline of the study

TEOAE	BERA		
Group I ears (TEOAE: Pass BERA: Pass)	**Group II ears** (TEOAE: Fail BERA: Pass)	**Group III ears** (TEOAE: Fail BERA: Fail)	**Group IV ears** (TEOAE: Pass BERA: Fail)
↓	↓	↓	↓
Discharged from study (ears)	Otoscopy/ Otoendoscopy	Otoscopy/ otoendoscopy	Followed up
	↓	↓	↓
	Blocked EAC	Blocked EAC	Repeat BERA after completion of gestational age or after 6 months
	↓	↓	
	Suction Cleaning	Suction Cleaning	
	↓	↓	
	Repeat TEOAE	Repeat TEOAE	
	↓	↓	
	If still fails	If still fails	
	↓	↓	
	TM mobility/ Impedance Audiometry	followed up for next 6 months	
	↓	↓	
	Discharged	Repeat TEOAE/BERA	

calculated from receiving the baby to its discharge from the audiology room This included the time required for the preparation of baby, for probe fitting/ applying electrodes, for recordings, their interpretation and finally discharging the baby. To start with, we were taking longer time to sedate the baby, fixing the probe or applying the electrodes etc. But after doing these tests in quite a few cases, the test time was significantly decreased. In only 4% of the newborn ears did we fail to perform the test because of restlessness and a second attempt was always successful. All these cases were from our initial 50 recordings. In our study, average time taken as calculated from the point of receiving baby to its discharge from audiology room was 35 min/neonate for BERA and 17.4 min/neonate for TEOAE tests.

ACCEPTABILITY

Another interesting observation of this study was that acceptability of TEOAE was higher amongst parents as compared to BERA because of simplicity of the procedure of testing. At the time of taking consent, approximately 5% of parents perceived BERA as relatively invasive test.

TEST ENVIRONMENT

A screening modality should not have many specifications regarding the environment in which it can be used. Therefore we performed all the recordings in a non-sound proof room so that TEOAE could be truly evaluated as a screening modality of hearing impairment. The noise level was recorded for all TEOAE testing. In our study, the noise level while TEOAE testing varied from 42.0 to 48.0 dB SPL with an average of 44.5 dB SPL for the whole study. The noise was found to really affect TEOAE recordings. Test time was unduly prolonged when prevailing noise levels were high, and quite a number of times, TEOAE recordings had to be aborted. Other researchers have documented similar effects of noise on TEOAE recordings[17, 18].

Fig. II: Effect of age on pass rate of TEOAE

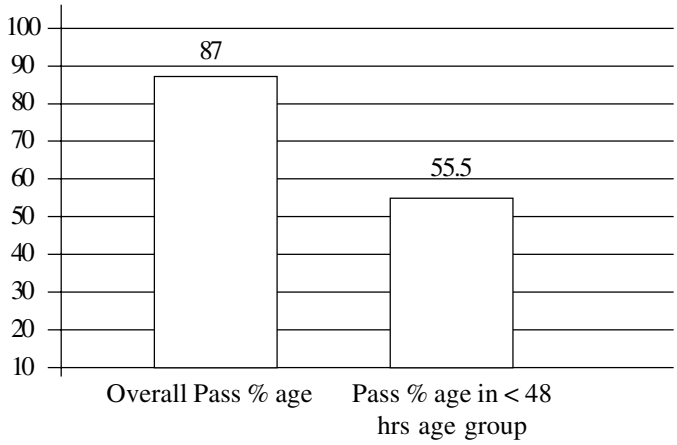

Fig. III: Pass and failure rates of BERA and TEOAE in 400 ears

	Pass BERA	Fail BERA	Total
Pass TEOAE	344 (86.0%)	04 (1.0%)	348 (87.0%)
Fail TEOAE	48 (12.0%)	04 (1.0%)	52 (13.0%)
Total	392 (98.0%)	08 (20.0%)	400

Sensitivity = 4/8 x 100 = 50%
Specificity = 344/392 x 100 = 87.75%

Effect of age on pass rate of TEOAE : In this study, pass rate of TEOAE improved significantly as the function of the age of subject. The pass rate of TEOAE in < 48 hrs age group was found to be 55.5% as compared to overall pass rate of 87.0%. (Fig.2). Out of 35 ears with blocked/ collapsible EACs, 23 were in < 48 hours age group. Thus, specificity of TEOAE is at its lowest in first 48 hours.

These observations led us to think about the ideal age when these screening tools should be applied. Though this was not a direct aim of our study, yet we found this question to be relevant. NIH consensus statement (1993) states that the screening for hearing impairment of all infants should be done within first 3 months of life and preferably before their discharge from the hospital[19]. Most of the neonates are discharged from the hospital within first 24-48 hours and it is in this duration when TEOAE gives highest number of false positive results. In our view, the screening for hearing impairment should definitely be not performed within first 48 hours, should be deferred, if possible, till the neonatal period is over. This time approach will reduce the number of false positive cases, who would otherwise require lot of unnecessary investigations and produce undue parental concern[20]. Another study was formulated to investigate the ideal

age for screening of neonates for hearing impairment, the results of which have been published elsewhere.

CONCLUSIONS

TEOAE is a simple and rapid test with relatively higher acceptability and therefore has a major role as a screening tool especially in the countries like India with very high birth rate. But, the low sensitivity and specificity are the main shortcomings that take away from TEOAE, the status of independent screening modality for hearing impairment in neonates. Therefore, TEOAE cannot completely replace BERA as screening modality for hearing impairment in neonates, however can complement it. EAC obstruction and collapsible EACs were the two factors that increased the number of false positive results of TEOAE. The prevalence of these two factors was found to be exclusively high in neonates < 48 hrs of age.

SUMMARY

- This study comprised of comparative evaluation of Transient Evoked Otoacoustic Emissions (TEOAE) and Brain Stem Evoked Response Audiometry (BERA) as screening modality for hearing impairment in neonates.
- TEOAE and BERA recordings were obtained for 400 ears of 200 randomly selected neonates in a non-sound proof room.
- TEOAE was found to be simple and rapid test with relatively higher acceptability. But, the low sensitivity and specificity are the main shortcomings which take away from TEOAE, the status of independent screening modality
- TEOAE cannot completely replace BERA as screening modality for hearing impairment in neonates, however can complement it.
- External auditory canal (EAC) obstruction and collapsible EAC were the two factors identified which increased the number of false positive results of TEOAE. The prevalence of these two factors was found to be exclusively high in neonates < 48 hrs of age.

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