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Role of High Frequency Tympanometry in Neonatal Hearing Screening Program

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ABSTRACT

Background: Hearing loss (HL) is a common congenital disease present at birth, happening in approximately one to three of every 1000 healthy newborns. Evoked otoacoustic emission (OAE) is extremely useful in infant hearing screening. Tympanometry is a test that measures the changes of the acoustic impedance (AI) of the tympanic ossicular system (TOS). **Objective:** This study aimed to evaluate the role of high-frequency tympanometry (HFT) in neonatal hearing screening (NHS), and to study the prevalence of HL in a sample of newborns.

Patients and methods: This Cross-sectional study included 100 neonates who were tested in three stages, first stage was screening by transient evoked otoacouastic emissions (TEOAE) and HFT at primary health care centers, second and third stages was audiological diagnosis at the Audiology Unit of Mansoura New General Hospital.

Results: Tympanometry (1000Hz) was with type A in 152 ears and type B in 48 ears. Ipsilateral acoustic reflexes were present in 146 ears and absent in 54 ears. In 2nd step, tympanometry (1000Hz) was type A in 29 right ears and 29 in left ears and type B in 8 right ears and 8 left ears. In 3rd step, tympanometry (1000Hz) with type A was in 22 ears and type B in 4 ears. Normal click auditory brainstem response (ABR) threshold was found in 17 ears and abnormal click ABR threshold was found in 9 ears. **Conclusion:** 1000 Hz tympanometry has to be a component of the NHS test battery. The HFT has to be considered for NHS programs to detect the middle ear pathological conditions in infants.

Keywords: Hearing Loss, Tympanometry, Transient evoked otoacouastic emissions, Diagnostic auditory brainstem response.

INTRODUCTION

Hearing loss (HL) is a frequent congenital disease that presents at birth, happening in approximately two of every 1000 healthy neonates and two to four of every 100 neonates in the neonatal intensive care unit [1]. Several causal factors might cause HL in newborns. Genetic predisposition accounts for 55% or more of childhood HL, such as congenital anomalies and family history of hearing impairment. Environmental causes of HL include, for instance, rubella infection, prematurity, hyperbilirubinemia, asphyxia, and head traumas [2].

The manifestations of neonatal hearing loss (NHL) are frequently mild, making systematic NHS a critical modality for early detection. This method is not only effective but also necessary to mitigate the potential impact of hearing affection on a baby's future communication skills [3]. Neonatal hearing screening (NHS) is a process that involves the application of rapid and simple tests, examinations, or other procedures to many individuals. Its aim is to identify those individuals with a high probability of the disorder. This method has now become a standard of care in several countries and is gaining more recognition worldwide [4].

As regards Egypt, there is a comparatively high prevalence of consanguineous marriage, in association with inadequate antenatal care and a lack of public awareness as regards the significance of NHS. As a result, in spite of reliable screening approaches [Transient evoked otoacoustic emissions (TEOAEs), auditory brainstem response (ABR)] and effective management methods, UNHS programs are still unavailable. Evoked otoacoustic emissions are extremely useful in infant hearing screening. They are accurate, economical, easy to procedure, and time-efficient [5].

In addition, OAEs are utilized to evaluate cochlear integrity and are physiological measurements of the response of the outer hair cells to acoustic stimuli. They act as a fast screening test for normal perineural cochlear functions by using the probe in the ear canal [6]. One of the evaluation modalities utilized in traditional audiology of the ME is the measurement of AI, a general term related to the transfer of acoustic energy, either by facilitation (admittance) of or opposition (impedance) to the passage of sound energy. The amount of influence of sound energy absorbed and reflected by the tympanic membrane (TM), when it is more compliant, the TM absorbs more energy, allowing greater system admittance. In contrast, the more rigid the TM, the more energy will be reflected, resulting in higher system impedance [7]. Tympanometry could measure the change of the AI of the TOS produced by pressure changes introduced into the external auditory canal (EAC) [8].

This work aimed to evaluate the role of HFT in neonatal hearing screening, and to study the prevalence of HL in a sample of newborns.

MATERIALS AND METHODS

This Cross-sectional study was conducted at Mansoura New General Hospital and included 100 neonates with ages varied from one day to 3 months, full-term infants, (38-42 weeks gestation) and free from any congenital hearing loss risk factors based on American Speech-Language-Hearing Association (ASHA), but we excluded patients with infections, such as rubella or herpes simplex virus, premature birth, small for gestational age infants, infants with birth injuries, infants with jaundice and Rh factor problems, infants with maternal diabetes, infants with maternal preeclampsia and infants with genetic problem.

METHODS

Equipment used for basic audiological evaluation was Immittancemetry (interacoustics-Titan) and Otoacoustic emission (Biologic scout OAE, Natus hearing diagnosis version 4.0 USA), ABR (Ep 15) with headphone TDH-39P and computer software for documentation.

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All neonates were subjected to full history taking, including prenatal history (maternal co- morbidities as diabetes, hypertension, and chronic liver diseases), pregnancy related complications (as gestational diabetes, hypertension, and oligohydramnios/polyhydramnios), maternal history of drug intake during pregnancy or alcohol, perinatal history including method of delivery, birth weight, pre-term or full term, congenital infections and birth asphyxia, neonatal history including incubation (duration –indication), neonatal jaundice (either physiological on the 2nd or 3rd day of life or pathological on the first day of life), convulsions, cyanosis, assisted ventilation, antibiotic injections, family history including history of hearing loss or delayed language development, history of similar conditions in the family and consanguinity of the parents. The general examination was done to pick up facial features of syndromic hearing loss that included examination of ear (pre-auricular pits & tags, accessory auricles, any deformities in E.A.C & auricles), head (over-riding sutures and low set ears), eyes (epicanthic folds, dystopia canthorum, and heterochromia iridis), mouth (abnormalities of hard and soft palate), hair (pigmentary disorder of hair), face (mid face hypoplasia and maldevelopment of maxilla) and neck (bronchial cyst or fistula). Otological examination included otoscopic examination for any congenital malformations, cerumen or debris impaction in E.A.C. It was done by selecting the proper ear speculum size for proper seal and comfort.

Audiological assessment included immitancemetry, both tympanometry & acoustic reflex tests were conducted to all neonates. Tympanometry was done with probe tone (1 KHz), the test was conducted while the infant naturally sleeping in the arms of the caregiver to have the infant as calm as possible. When the tympanometric curve wasn't adequately acquired, due to infant motion causing pressure escape, the test was repeated, removing the probe and reinserting it in the same ear to get novel reliable values.

TEOAEs test was conducted to all neonates. The TEOAEs was recorded in a soundproof room (single room double walled cabin). Testing was done while infants were sleeping or were alert and calm in the lap of caregivers. In cases when during the test infants were alert active or crying, the test couldn't be completed, and retesting was conducted on the next day. Diagnostic ABR test was conducted to neonates who had abnormal findings by immitancemetry/OAE tests of both tests.

Ethical approval: Mansoura Medical Ethics Committee of Mansoura Faculty of Medicine has approved this study. After obtaining all of the information, all participants gave their signed approvals. The Helsinki Declaration was followed throughout the study's operations.

Statistical analysis

All data were tabulated in SPSS sheet version 29.0. Categorical data were expressed in numbers and percentages. Qualitative data were presented as number and percentage; whereas quantitative parametric data (normal distribution) was presented as mean and standard deviation and quantitative non-parametric data (abnormal distribution) was presented as median (minimum, maximum).

RESULTS

In this study, males and females were equally distributed and the mean age of completion of diagnosis in months was 1.5 months ± 0.866 (range 1day to 3 months). In 1st step, Table **(1)** showed that the Otoscopic examination showed normal T.M in 152 ears, abnormal T.M in 28 ears and plug and vernix caseosa in 20 ears. Tympanometry (1000Hz) was with type A in 152 ears and type B in 48 ears. Ipsilateral acoustic reflexes were present in 146 ears and absent in 54 ears, only (30 %) had "refer" results of (OAE) test.

Table (1): Otoscopic examination, tympanometry (1000Hz), ipsilateral acoustic reflexes and OAE test among studied neonates

		Total ears	**Right ear**	**Left ear**
		No. =200	**No. =100**	**No. = 100**
Otoscopic examination	Normal T.M	152 (76%)	74 (74%)	78(78%)
	Abnormal T.M	28(14%)	16(16%)	12(12%)
	Plug and Vernix caseosa	20(10%)	10(10%)	10(10%)
Tympanometry (1000Hz) Peak pressure	Type A	152 (76%)	74 (74%)	78 (78%)
	Type B	48(24 %)	26 (26%)	22(22%)
Ipsilateral acoustic reflexes	Present	146(73%)	71(71%)	75(75%)
	Absent	54(27%)	29(29%)	25(25%)
Result of OAE test	Pass	140 (70%)	68(68%)	72 (72%)
	Refer	60(30%)	32(32%)	28(28%)

Table (2) showed acoustic reflexes thresholds among studied neonates who had normal tympanograms where 1000 Hz threshold was 90.54 ± 5.51 dBHL in 71 right ears and 92.46 ± 5.01 dBHL in 75 left ears.

Table (2): Acoustic reflexes thresholds among studied neonates who had normal tympanograms

Acoustic reflexes thresholds		Total ears	Right ear	Left ear
		No=146	No=71	No=75
1000 Hz threshold	Mean ± SD	92.50 dBHL ± 6.95	90.54 dBHL ± 5.51	92.46 dBHL ± 5.01
	Range	80 – 100dBHL	80 – 100dBHL	80 – 95dBHL

Table (3) showed that regarding relation of OAE test results in both ears with tympanometry (1000 Hz) pressure, almost all neonates with type (A) tympanogram gave "Pass" results by OAE test & all neonates with type (B) tympanogram gave "Refer" results by OAE test. Regarding relation of OAE test results in both ears with presence of acoustic reflexes, 12 neonates who had acoustic reflexes by tympanometry (1000 Hz), had "refer" results.

Table (3): Relation of (OAE) test results in both ears with tympanometry (1000 Hz) pressure and presence of acoustic reflexes

		OAE test results	
		Pass	**Refer**
		No. =140 ears	**No. = 60 ears**
Tympanometry (1000 Hz) pressure	Type(A)	140(100%)	12(20%)
	Type(B)	0(0.0%)	48(80%)
Acoustic reflexes	Present	134(95.7%)	12(20%)
	Absent	6(4.3)	48(80%)

In 2nd step, the neonates who had no ability to pass from the first step assessed by TEOAE and high-frequency tympanometry 2 week after the first step (37 neonates), 26 neonates were with refer bilaterally by TEOAE, 8 neonates were with refer unilaterally, 6 neonates right ear referred and 2 neonates left ear referred and 3 neonates absent ipsilateral acoustic stapedial reflex with type A tympanogram. Table **(4)** showed that tympanometry (1000Hz) was type A in 29 right ears and 29 in left ears an dtype B in 8 right ears and 8 left ears. Ipsilateral acoustic reflexes were present in 26 right and 26 left ears, and absent in 11 right and 11 left ears. Results of OAE test showed that 56 ears passed, and 18 ears referred.

Table (4): Tympanometry (1000Hz) parameters and ipsilateral acoustic reflexes results among studied 37 neonates

		Total ears	Right ear	Left ear
		No. =74	No. = 37	No. = 37
Tympanometry (1000Hz) Peak pressure	Type A	58 (78.38%	29(78.38%)	29 (78.38%
	Type B	16 (21.62%	8 (21.62%)	8(21.62%)
Ipsilateral acoustic reflexes	Present	52(70.27%)	26(70.27%)	26(70.27%)
	Absent	22(29.73%)	11(29.73%)	11(29.73%)
Results of OAE test	Pass	56(75.68%)	27(73%)	29(78.38 %
	Refer	18(24.32%)	10 (27%)	8(21.62%)

In 3rd step, the neonates who had no ability to pass from the second step were assessed by TEOAE's, high frequency tympanometries and ABR's at age of three months, 8 neonates refer bilaterally by TEOAE and 2 neonates did not pass unilaterally (rt ear refer), and 3 neonates absent ipsilateral acoustic stapedial reflex with type A tympanogram. Table **(5)** showed that among studied 13 neonates, tympanometry (1000Hz) with type A was in 22 ears and type B in 4 ears. Ipsilateral acoustic reflexes were present in 18 ears and absent in 8 ears, and result of OAE test was passed in 16 ears and referred in 10 ears. Normal click ABR threshold was found in 17 ears and abnormal click ABR threshold was found in 9 ears.

Table (5): Tympanometry (1000Hz) parameters, ipsilateral acoustic reflexes and results of OAE test among studied neonates

		Total ears	**Right ear**	**Left ear**
		No. =26	**No. = 13**	**No. = 13**
Tympanometry (1000Hz) Peak pressure	Type A	22(84.6%)	11 (84.6%)	11(84.6%)
	Type B	4 (15.4%)	2(15.4%)	2(15.4%)
Ipsilateral acoustic reflexes	Present	18(69%)	9(69%)	9(69%)
	Absent	8(31%)	4(31%)	4(31%)
Result of OAE test	Pass	16(61.5%)	7(53.8%)	9(69.2%)
	Refer	10(38.5)	6 (46.2%)	4(30.8%)
Click ABR threshold	Normal	17(65.4)	8(61.5%)	9(69%)
	Abnormal	9(34.6%)	5(38.5%)	4(31%)

Table **(6)** showed that among neonates with normal hearing & hearing loss (8 neonates), tympanometry test type A was in 17 ears with normal hearing and 5 in hearing loss. Type B was in 4 ears in hearing loss. Acoustic reflexes was present in 17 ears in normal hearing and 3 in hearing loss and absent in 6 ears in hearing loss. Results of OAE test was passed in 10 ears in normal hearing and 2 in hearing loss and referred in 7 ears in normal hearing and 7 in hearing loss.

Table (6): Distribution of tympanometry types, acoustic reflexes, and results of OAE Test among neonates with normal hearing & hearing loss

		Total ears no.=26 ears	
		Normal hearing	**Hearing loss**
		No. =17 ears	**No. = 9 ears**
Tympanometry Test (1000 Hz)	Type A	17 (100%)	5 (55.6%)
	Type B	0 (0.0%%)	4 (44.4%)
Acoustic reflexes	Present	17(100.0%)	3 (33.3%)
	Absent	0 (0.0%)	6 (66.7%)
Results of OAE Test	Pass	10(59%)	2 (22%)
	Refer	7 (41%)	7(78%)

Table **(7)** showed that all neonate passed TEOAE had normal hearing except one of two neonates with absent IASR (this neonate with absent waves at 90 dBHL). There was 1 neonate had right unilateral moderate hearing loss by click ABR (wave V could be traced down to 60 dBHL). There was one neonate with type A tympanometry, preserved IASR and absent OAE had moderate severe Hl (wave V could be traced down to 70 dBHL). The 2 neonates with type B tympanometry, one of them had mild HL (wave V could be traced down to 40dBHL) and the other had moderate HL (wave V traced down to 60dBHL). By using the Chi-square statistic, the p-value between the 1000 Hz and ABR tests

was greater than 0.05, suggesting no statistically significant difference between the results of these two tests.

Table (7): Result of tympanometry, TEOAE and ABR of neonates not pass from 1ST and 2nd step

3rd Step	1000Hz and ASR	TEOAE	ABR
Pass	18(9%)	14 (7%)	17 (8.5)
Refer	8 (4%)	12 (6%)	9 (4.5)

DISCUSSION

The National Health Service (NHS) program emphasizes the significance of early diagnosis of HL in neonates to facilitate timely intervention. The presence of undetected bilateral hearing loss in a child can result in a significant delay in both speech and cognitive development. In some cases, the child may not develop normal speech and language abilities at all [9]. The early diagnosis of HL in neonates and the recognition of predisposing factors for late–onset HL are of great significance to evaluate a therapeutic program to reach proper linguistic competences [10].

Early hearing detection and intervention programs commonly referred to as EHDI, have been developed with the primary objective of ensuring timely access to language stimulation and intervention services. In order to further enhance the effectiveness of these programs, it is proposed that a revised target timeline be established, known as the 1-2-3 months approach. This approach entails completing hearing screenings within the first month of a child's life, followed by the completion of an audiologic diagnosis by the second month, and initiating early intervention no later than the third month of age. By adhering to this proposed timeline, EHDI programs can maximize their impact and provide crucial support to infants with hearing impairments at the earliest possible stage [11].

In this study conducted at El Mansoura New General hospital on 100 neonates, the mean age of the studied neonates was 45 ± 20.7 (2-220 hours old) with equal gender distribution. In this investigation, three steps were performed, in 1st step, the infants were assessed by otolaryngological examination TEOAE and HFT 1000 Hz, in 2nd step the infants who had no ability to pass from the first step assessed by TEOAE and HFT 1000 Hz two weeks after the first step and in 3rd step, the infants were assessed by TEOAE's, HFT and ABR's at age of three months.

Otological examination of examined neonates revealed that most of neonates had normal TMs (152/200 ears). Abnormal TM was seen in 28 /200 (14%) of examined ears in the form of retracted & congested TM. Vernix caseosa and ear plug were detected in 20/200 (10%) of neonate. The otoscopic examinations in recent study revealed a large majority (71%) neonates have normal TM except for vernix caseosa in their EACs, and 39 (32%) were considered to have narrow ear canals. The value of otoscopy is to confirm that there are no contraindications to placing an earphone or probe in the EAC, verify that the AUC is free of obstruction and that there is no drainage from the middle ear in addition to the examination of the TM properties concerning colour, position, and anatomic changes [12].

OAE test result in the current study revealed that only 60/200 ears (30%) had referred result in first step compared 12\200 (6%) ears in third step, so false positive for the results of the primary screening stage. **Raghuwanshi *et al.*** [13] reported similar results where 78.4% of the newborns passed with normal OAE after 1 month of newborn screening.

Based on several literatures, the primary cause for false-positive outcomes with OAE testing are temporary situations in the EAC (such as collapse of the ear canal), middle ear [such as existence of amniotic fluid (AF) and mucus], and high ambient noise level. Such conditions often resolve within the initial hours of life [12, 13]. Another cause for false-positive outcomes with OAE testing is the use of lower frequencies. Sounds of various frequencies are transmitted in a different way across the middle ear. The presence of AF and mesenchyme in the middle ear in the initial days of life decreases the volume of middle-ear air space and raises its stiffness, with subsequent affection for the transmission of lower-frequency sounds. Additionally, screening comprising greater frequencies (2–5 kHz) has lower referral rates to detect permanent congenital sensorineural hearing loss (PCHL), as it isn't much affected by the existence of liquid and debris [9]. Unlike the current study, **Escobar-Ipuz *et al.*** [14] reported that 87.3% passed the screening test, while 12.6% failing retest on examination.

Refer results by TEOAE test in third step in the current study were seen in 10/26 (38.5%) ears, 4 ears type B tympanograms and 6 ears type A tympanograms. It is worth to be mentioned that not all of them (6 ears with type A tympanograms appeared to have SNHL by ABR test & 3 ears had normal ABR). Tympanometric (1000 Hz) result in first step showed that most of examined ears (76%) neonates had type (A) tympanograms, while 24% ears had type B. In 2nd step, tympanometric data showed 78.38% of referred neonates to second step had type (A) tympanograms and 21.62% had type (B) tympanograms. In 3rd step, tympanometry showed 84.6% type (A) tympanogram and 15.4% type b tympanograms. **Garcia *et al.*** [15] showed that there was an association between 1000 Hz tympanometry and otoscopic outcomes, which come in accordance with the present study.

Rhodes *et al.* [16] performed TEOAE, ABR, and multifrequency tympanometry. They demonstrated that the infants failing with 226 Hz and 678 Hz tympanometries (30% to 67%) passed the other hearing tests and the ears failing from 1000 Hz failed from the other tests too. Additionally, they demonstrated that the otoscopically abnormal ears passed from the hearing tests recommending that the otoscopic assessment findings criteria mightn't be applied to neonates. On the other hand, **Garcia *et al.*** [15] displayed an association between otoscopic outcomes and 1000 Hz tympanometry, similarly in the current study.

In the current study diagnostic ABR test was done for the neonates who had refer response by OAE test and absent ipsilateral acoustic stapedial reflex, click ABR test

at (2-4 KHz) was done using headphone TDH-39P. The results of click ABR test showed that a total of 17/26 ears (65.4%) had normal hearing table. The mean click ABR threshold for neonates with normal hearing was around 25 dBHL. Among the 9 ears diagnosed as HL tested by ABR test, 5/9 ears had type (A) by tympanometry (1000 Hz) & they were diagnosed as SNHL. As expected, all neonates with normal hearing by ABR (17 ears) had preserved acoustic reflexes and 9 ears with hearing loss had absent acoustic reflex who had refer result by OAE test. Among 17 (65.4%) ears with normal hearing by ABR test, 3 ears (11.5%) had "Refer" results by OAE test. **Chawla *et al.*** [17] reported that 11 (22.0%) referred ears (with RFs of HL) by OAE test in 2ry newborn screening, 16.0% of ears had normal hearing by BERA test. Also, 2 ears with hearing loss by ABR test were passed by TEOAE.

Recent study by **Acke *et al.*** [18] about the audiological and etiological results of NHS reported that the primary causes of HL included middle ear diseases mostly otitis media with effusion, genetic disorders (12%), congenital cytomegalovirus (CMV) infection (5%) and atresia/stenosis of the EAC (5%).

Concerning the degree ranged from mild to severe HL, the current study revealed one neonate with absent IASR with absent waves at 90 dBHL (severe to profound HL). There was 1 neonate had right unilateral moderate hearing loss by click ABR (wave V could be traced down to 60dBHL). There was one neonate with type A tympanogram, preserved IASR and absent OAE had moderate severe HL (wave V could be traced down to 70 dBHL). The 2 neonates with type b tympanogram, one of them had mild HL (wave V could be traced down to 40dBHL) and the other had moderate HL (wave V traced down to 60dBHL). The results of clinical ABR in the study of **Kilic *et al.*** [19] showed that 2/50 neonates had hearing loss.

Given a PCHL prevalence of 1-3 per 1000 live births, a referral rate of 4% indicates that around ten neonates are referred for each actual case detected. [20]. Considering this notion, the current newborn study is not good but fair. Our study showed that hearing loss was diagnosed within three months of age, which is in line with guidelines.

CONCLUSIONS

The HFT demonstrated a significant correlation between both otolaryngological evaluation and the TEOAE test and the ABR test. It could be recommended that the 1000 Hz tympanometry should be a part of the NHS test battery. The HFT has to be considered for NHS programs to detect middle ear diseases in infants. The diagnosis of NHL was done by OAE, immitancemetry, and ABR tests.

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Conflicts of interest: None.

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