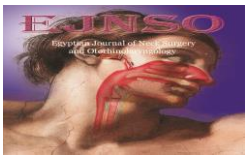
EJNSO



Overview of Newborn Hearing Screening by transient otoacoustic emissions in Aswan, Egypt: A Hospital-Based preliminary Study

Mohamed M Elmoursy [1] , Ashraf A Meabed [2], Hager S Nagdy [2], Hanan M Aly [2], Edrees H Zaki [3], Magda F Gabri [2]

1 Audio vestibular Medicine Unit, Al-Azhar University, Assuit, Egypt
2 Pediatric Departments, Aswan University, Aswan, Egypt
3 Pediatric Departments, Assuit University, Assuit, Egypt

Abstract:

Objectives: One of the most significant risk groups for hearing loss is neonates who spend time in the neonatal intensive care unit (NICU). This study aimed to estimate the prevalence of hearing loss in all neonates admitted to our hospital NICU and evaluate their risk factors. It is a prospective cross-sectional study conducted on all neonates admitted to our hospital in one year.

Patients and methods: All Neonates were subjected to history, clinical, Otoscopic examination, and Oto-acoustic emissions test. Neonates with congenital ear anomalies or ear problems that interfere with the screening test were excluded.

Results: 90.6% of cases passed the test, and 9.4% had a Refer result in the initial screening. A repeated test for the referral cases showed 6.7% passed and 2.7% had hearing affection (2% bilateral and 0.7 % unilateral).

Conclusions: The prevalence of hearing loss was 2.7%, 2 % had bilateral hearing affection, and 0.7 % had unilateral hearing affection. There was a significant correlation between exposures to certain risk factors among the affected neonates; all cases remained more than 5 days in NICU with history of exposure to ototoxic drugs, especially gentamycin, furosemide, vancomycin, and amikacin.

Keywords: NICU, hearing loss, screening, TEOAEs

Introduction

Hearing is a crucial component of a newborn's interaction with his surroundings and is essential to the development of speech and language. The first few years of life are by far the most critical period for this development. Early life hearing loss (HL) may have several adverse effects on the infant, particularly speech and language achievement. It may also have an effect on the social, mental, and academic achievement of the child. [1]

The seriousness of these hearing disabilities is relative to the duration of hearing loss that remains untreated. Therefore, the 'wait and watch' approach is not wisely adapted to hearing impairment in neonates.[2]

Early identification and intervention can prevent severe psychosocial, educational, and linguistic impacts. Infants who are not identified before 6 months of age have delays in speech and language development. Intervention at or before 6 months of age allows a child with impaired hearing to develop normal speech and language.[3]

The importance of universal early screening, diagnosis, and intervention in reducing the negative impact of congenital hearing loss has been described extensively worldwide. [4]

According to the Joint Committee on Infant Hearing (JCIH 2019), one of the greatest risk groups is neonates who spend time in a neonatal intensive care unit (NICU), prone to high-frequency ventilation, hyperbilirubinemia, low birth weight, and ototoxic medications. [5]

The present research has been conducted to estimate the incidence of neonatal hearing loss in high-risk neonates admitted to NICU in Aswan University hospital and to evaluate the different risk factors associated with HL.

Patients and Methods:

This study is a prospective cross-sectional study. It was conducted on all neonates admitted to Aswan hospital NICU in one year from January 1st, 2019, to December 31st, 2019. Neonates with congenital ear anomalies or ear problems that interfere with the screening test were excluded from the study.

Method:

All Neonates included in this study were subjected to full history taking, clinical examination, including otoscopic examination and tympanometry with high frequency probe (1 K Hz) and investigation via transient otoacoustic emissions (TEOAEs).

OAEs are physiologic measurements of the outer hair cells' response to acoustic stimuli and are used to assess cochlear integrity. They serve as a fast, objective screening test for normal perineural cochlear function. To measure TEOAEs, a probe assembly was placed in the ear canal, tonal or click stimuli were delivered, and the TEOAEs generated by the cochlea are measured with a microphone. If the patient's middle ear function is normal, these measurements can assess cochlear function for the 500-6000 Hz frequency range. [3]

The presence of TEOAEs is positively correlated with normal hearing, while the absence of TEOAEs suggests auditory dysfunction. Absent TEOAEs may indicate cochlear dysfunction, though abnormal outer or middle ear function may also affect the outcome. TEOAEs was recorded in both ears by using Eroscan Screener OAE Maico Diagnostic (Path Medical, Germering, Germany), and the results were documented as either PASS or REFER; specifically, a TEOAE SNR of $\geq$ 6 dB is often used as the criterion for the presence of TEOAEs in the frequency band.

OAE was recorded with a non-linear click-sequence stimulus at the intensity of 80 dB SPL level with a click rate of approximately 60 Hz and at frequency bands beginning at 1,000, 2,000, 3,000, 4,000, and 5,000 Hz. [6]

In the NICU, the test was conducted by the bedside or inside the incubator. The test was performed before the newborn was discharged from the NICU.

After otoscopic examination and tympanometry with 1 kHz probe frequency to exclude middle ear effusion, which is usually not detected by low-frequency tympanometry.

TEOAEs probe was inserted into the external ear canal and adjusted. If the

TEOAEs could not be recorded or gave a 'fail' result despite the absence of ambient noise in the room and the infant baby being quiet, a second attempt for TEOAEs testing was performed immediately after the first attempt. Newborns, who did not meet the pass criteria at the second attempt, were recruited for further full audiological assessment.

Statistics:

All statistics were performed using SPSS version 23. Summary of measures was reported as mean ± standard deviation (SD) for quantitative variables as age and birth weight and percentages for categorical variables such as sex and mode of delivery.

The differences in distribution were evaluated using the chi-square test for categorical variables and t-test for quantitative variables. Correlation analysis and calculation of P-value and Odd's ratio were done. P-Value ≤ 0.05 was considered statistically significant.

Results:

The current study included 317 neonates admitted to NICU. Two hundred ninety-nine of them had undergone neonatal hearing screening program by transient otoacoustic emissions. Eighteen neonates, their parents, did not perform the hearing screening for them despite the counseling about the importance of the hearing screening.

Socio-demographic characteristics of the studied cases (Table 1) showed that the mean ± S.D. of birth weight was (2.52± 0.77) grams, male represent 53 % of cases, full-term neonates was 59.2% of cases, most of the neonates (84.6 %) delivered by C.S. Respiratory distress syndrome (RDS) was the most common causes of admission among the newborn infants, followed by transient tachypnea of the newborn (TTN) then neonatal sepsis. Congenital anomalies presented in 13.7% of cases, mainly congenital heart diseases (CHD) and nervous system anomalies (hydrocephalus and meningocele).

The frequency of exposure to risk factors among the studied cases (Table 2) showed that 69 % of them stayed more than 5 days in NICU, 40 % of cases were preterm, 18 % had sepsis, and 9% had in utero infection. 73.6 % of mothers had no risk, 8.4 % had PROM, and 6.3% had Pre-eclampsia.

Regarding the frequency of administration of ototoxic drugs: gentamycin was used in all cases, vancomycin in 19.6 %. In contrast, co-administration of ototoxic drugs revealed that gentamycin was used as a mono ototoxic drug in 79 % % of studied cases, gentamycin with vancomycin was used in 16 %.

Results of screening for hearing loss among the newborn infants (Table 3) revealed that 90.6% passed the test, and 9.4% had a Refer result in the initial screening. A repeated otoacoustic emission test for the referral cases showed 20 (6.7%) neonates passed and 8 (2.7%) had hearing affection (2% bilateral and 0.7 % unilateral).

The mean age of cases at the initial first otoacoustic test was 9.61± 5.363 days. Otoscopic examination reversed 0.7% of total cases had ear wax, and 7 % had vernix caseosa.

Socio-demographic characteristics of the affected cases revealed that the mean birth weight was (1.82±0.57) kg. Females were 3 times to male, and all cases were delivered by C.S., gestational age categories showed that preterm babies were 3 times that of full term.

The frequency of exposure to risk factors among the affected neonates (Table 4) showed that all cases remained more than 5 days in NICU, no one had

meningitis, and one-third of cases had birth asphyxia. Three quarters were preterm, all cases had APGAR score of more than 4 at one min and 6 at 5 min, two-third of cases were on mechanical ventilation, half had sepsis, one quarter had an in-utero infection and severe hyperbilirubinemia (at the level of exchange transfusion), but no one had a family history of hearing loss.

Regarding maternal risk factors among the affected newborn: more than one-third of mothers had TORCH infection, one-quarter of mothers had pre-eclampsia, 12.5 % was ABO incompatibility, 12.5 % had PROM, and 12.5% of cases did not have any maternal illness.

Regarding the administration of ototoxic drugs, gentamycin was administrated in all cases, as a mono ototoxic drug in 25 % of affected cases, more than one-third of cases received furosemide, amikacin administered in 25% of cases, and 12.5 % were used vancomycin.

In comparing affected cases with normal, (Table 5) showed that there was a significant relationship regarding birth weight, congenital anomalies, and cause of admission, while there was an insignificant relationship regarding gender and mode of delivery.

Concerning risk factors, Table 6 showed a significant relationship between affected and normal newborns regarding NICU stay ≥ 5 days, birth hypoxia, maturity, mechanical ventilation, sepsis, severe hyperbilirubinemia, presence of maternal risk factors, and use of ototoxic drugs either alone or in combination. There was an insignificant relationship regarding APGAR score, meningitis, congenital infection, and family history of hearing loss.

Table 7 showed that there were significant positive predictors for hearing loss among newborn infants admitted to NICU, including the presence of congenital anomalies, severe hyperbilirubinemia, and presence of maternal risk factors. A newborn infant with congenital anomaly is 3.9 times more at risk of hearing loss than the other group (OR=3.913, 95%CI (0.001-0.367)). Moreover, newborn infants with severe hyperbilirubinemia are 4 times more likely to develop hearing loss (OR=4.259, 95% CI (0.000-0.587)). The maternal risk factor is 3.5 times more likely to develop hearing loss (OR=3.585, 95 % CI (0.001-0.813).

Table (1): Socio-demographic characteristics, cause of admission, and congenital anomalies of the studied cases

Socio-demographic data	No. = 299	Cause of admission	No. =299	Congenital anomalies	No. =299
Gender					
Male	158 (52.9**%**)	RDS	112 (37.5 %)	CHD	14 (4.7**%**)
Female	141 (47.1**%**)	TTN	78 (26.1 %)	Cleft palate	3 (1**%**)
Birth weight:		MAS	18 (6 %)	Congenital ascites	1 (0.3**%**)
Range	(1- 4)	IDM	10 (3.3 %)		
Mean± SD	2.52± 0.77				
Birth weight category (gram):		HIE	7 (2.3 %)	Cystic hygroma	1 (0.3**%**)
NBW (2500 – 4000)	167 (55.8**%**)	N. Convulsion	5 (1.7 %)	Down syndrome	4 (1.3 **%**)
LBW (2500 – 1500)	105 (35.2**%**)				
VLBW (< 1500)	27 (9 **%**)			Hydrocephalus	10 (3.3**%**)
Gestational age:		N. Sepsis	35 (11.7 %)	Imperforate anus	4 (1.3**%**)
Pre-term	122 (40.8**%**)				
Full-term	177 (59.2**%**)			Meningeocele	3 (1**%**)
Mode of delivery		N. Jaundice	24 (8 %)	Vertebral anomalies	1 (0.3**%**)
Vaginal delivery	46 (15.4 **%**)				
Caesarian section	253 (84.6 **%**)	Meningitis	10 (3.3 %)	No anomalies	258 (86.3**%**)

Table (2): Frequency of exposure to risk factors among studied cases

Variable	No (=299)	Variable	No (=299)
NICU stay		**Maternal risk factors**	
Mean ± SD	7.19 ± 5.067	ABO Incompatibility	10 (3.3**%**)
Range	1- 45	Antepartum Hemorrhage	6 (2.0**%**)
NICU stay		HBV	5 (1.7**%**)
< 5 days	93 (31.1**%**)	Gestational diabetes	9 (3**%**)
≥5 days	206 (8.9**%**)	Pre-eclampsia	19 (6.3**%**)
Meningitis		PROM	25 (8.4**%**)
Yes	13 (4.3**%**)	Congenital infection	5 (1.7**%**)
No	286 (5.7**%**)	No maternal risk factor	220 (73.6**%**)
Birth hypoxia			
Yes	6(2**%**)		
No	293(98**%**)		
Gestational age		**Frequency of administration of ototoxic drugs**	
Preterm	122 (40.8**%**)	Gentamycin	299 (100) %
Full-term	177 (59.2**%**)	Vancomycin	59 (19.6**%**)
APGAR score < 4 at one min		Furosemide	7(2.6**%**)
Yes	18 (6 **%**)	Amikacin	5 (1.7**%**)
No	281 (4 **%**)		
APGAR score < 6 at 5 min		**Co-administration of variable ototoxic medications**	
Yes	4 (1.3**%**)		
No	295 (98.7**%**)		
Mechanical ventilation		Gentamycin	237 (79.3%)
Yes	32 (10.7**%**)	Gentamycin and vancomycin	49 (16.3%)
No	267 (9.3**%**)	Gentamycin and furosemide	7 (2.3 %)
Sepsis		Gentamycin and nancomycin	1 (0.3%)
Yes	56 (18.7**%**)	Gentamycin, vancomycin and amikacin	5 (1.7%)
No	243 (81.3**%**)		
In utero infection			
Yes	27 (9 **%**)		
No	272 (91 **%**)		
Severe Hyperbilirubinemia		**Family history of hearing loss**	
Yes	6 (2 **%**)	Yes	2 (0.7**%**)
No	293 (98 **%**)	No	297 (99.3**%**)

Table (3): Results of screening for hearing loss among the studied cases

Variable	No. (=299)	Variable	No. (=299)
Age at first test		**Hearing loss**	
Mean ± SD	9.61 ± 5.363	Yes	8 (2.7%)
Range	42 (3- 45)	No	291 (97.3%)
Otoacoustic test		**Type of hearing affection**	
Pass	271 (90.6%)	Bilateral hearing affection	6 (2 %)
Refer	28 (9.4%)	Unilateral hearing affection	2 (0.7%)
		Normal hearing	291 (97.3%)
Age at repeated test:		**Gender**	
Mean ± SD°	16.00± 4.61	Male	2 (25 %)
Range	10- 27	Female	6 (75 %)
Repeat test who not pass 1st		**Birth weight**	
Pass	20(6.9 %)	Mean ± SD	1.82 ± 0.57
Not pass	8 (2.7 %)	Range in kg	1.7-3
Not done *	271 (90.6 %)	**Gestational age**	
		Preterm	6 (75%)
		Full-term	2 (25%)
Otoscopic examination		**Mode of delivery**	
Ear wax	2 (0.7%)	Normal vaginal delivery	0 (0%)
Vernix caseosa	21 (7%)	Cesarean section	8 (100%)
Normal	276 (92.3%)		

Test repeated in only 28 patients who aren't passed from the first test.
*Not done as they pass from the first test.

Table (4): Frequency of exposure to risk factors among the affected newborn

Variable	No. =8	Variable	No. =8
NICU stay:		**Maternal risk factors** ABO	
Mean ± SD	8.00 ± 1.77	Incompatibility	1 (12.5%)
Range	5-9	Pre-eclampsia	2 (25.0%)
Less than 5 days	0 (0%)	PROM	1 (12.5%)
5 days or more	8 (100%)	TORCH	3 (37.5%)
Meningitis		No	1 (12.5%)
Yes	0 (0%)		
No	8 (100%)		
Birth hypoxia		**Frequency of exposure to different ototoxic drugs**	
Yes	3 (37.5%)	Gentamycin	8 (100%)
No	5 (62.5%)	Furosemide	3 (37.5%)
Gestational age		Vancomycin	1 (12.5%)
Pre-term	6 (75.0%)	Amikacin	2 (25.0%)
Full-term	2 (25.0%)		
Apgar score < 4 at 1 min		**Co-administration of variable ototoxic medications**	
Yes	0 (0%)	Gentamycin and furosemide	2 (25%)
No	8 (100%)	Gentamycin, vancomycin and amikacin	1 (12.5%)
Apgar score < 6 at 5 min		Gentamycin, vancomycin, amikacin and furosemide	3 (37.5%)
Yes	0 (0%)		
No	8 (100%)		
Mechanical ventilation			
Yes	5 (62.5%)		
No	3 (37.5%)		
Sepsis		**Severe Hyperbilirubinemia**	
Yes	4 (50.0%)	Yes	2 (25.0%)
No	4 (50.0%)	No	6 (75.0%)
In utero infection		**Family history of hearing loss**	
Yes	2 (25.0%)	Yes	0 (0%)
No	6 (75.0%)	No	8 (100%)

Table (5): Comparison of different characteristics among the normal and affected newborn

Variable	Normal (n= 291)	Hearing loss (n=8)	P-value
Gender©			
Male	156 (53.6%)	2 (25.0%)	0.107
Female	135 (46.4%)	6 (75.0%)	
Birth weight Mean ± SD	2.51±0.77	1.02±0.16	0.12
Birth weight categories			
NBW	165 (56.7%)	2 (25.0%)	0.045*
VLBW	27 (9.2%)	0 (0.0%)	
LBW	99 (34.1%)	6 (75.0%)	
Mode of delivery©			
Vaginal delivery	46 (15.4%)	0 (0.0%)	0.269
Cesarean section	245 (84.6%)	8 (100%)	
Age at first test	9.61 ± 5.363	1.03±0.16	0.51
Otoscopic examination			
Normal	268 (92.2%)	8 (100%)	0.71
Vernix caseosa	2 (0.7%)	0 (0.0%)	
Ear wax	21 (7.2%)	0 (0.0%)	
Congenital anomalies©			
Yes	35 (13%)	6 (75%)	0.000**
No	256 (87%)	2 (25%)	
Causes of admissions			
RDS	78 (7.8%)	2 (25%)	0.001**
TTN	78 (26.8%)	0 (0.0%)	
Neonatal jaundice	31 (7.6%)	2 (25%)	
Neonatal sepsis	31 (10.6%)	4 (50%)	
Others	2 (17.2%)	0 (0.0%)	

© Fisher`s Exact test were used.
***:** Statistically significant: ($p < 0.05$)
****:** High statistically significant: ($p < 0.01$).

Table (6): Risk factors association among the affected newborn

Variable	Normal (n= 291)	Hearing loss (n=8)	P-value
NICU stay© Mean ± SD	7.18±5.051	1.03±0.16	0.22
Less than 5 days	93 (31.7%)	0 (0.0%)	0.062*
5 days or more	200 (68.3%)	8 (100%)	
Meningitis©			
Yes	13 (4.4%)	0 (0.0%)	0.54
No	278 (95.6%)	8 (100%)	
Birth hypoxia©			
Yes	6 (2.0%)	3 (37.5%)	0.001**
No	285 (98.0%)	5 (62.5%)	
Maturity©			
Full-term	116 (41.0%)	2 (25.0%)	0.06*
Preterm	175 (59.0%)	6 (75.0%)	
Apgar score < 4 at 1 min©			
Yes	18 (6.1%)	0 (0.0%)	0.47
No	273 (93.9%)	8 (100%)	
Apgar score < 6 at 5 min©			
Yes	4 (1.4%)	0 (0.0%)	0.89
No	287 (98.6%)	8 (100%)	
Mechanical ventilation©			
Yes	27 (10.6%)	5 (62.5%)	0.001**
No	259 (89.4%)	3 (37.5%)	
Sepsis©			
Yes	52 (17.7%)	4 (50%)	0.042*
No	239 (82.3%)	4 (50%)	

In utero infection©			
Yes	25 (8.9%)	2 (25.0%)	0.165
No	267 (91.1%)	6 (75.0%)	
Severe Hyperbilirubinemia			
Yes	4 (2%)	2 (25.0%)	0.016*
No	287 (98%)	6 (75.0%)	
Family history of hearing loss©			
Yes	2 (0.7%)	0 (0.0%)	0.815
No	289 (99.3%)	8 (100%)	
Maternal risk factors			
ABO incompatibility	9 (3.4%)	1 (12.5%)	0.001**
Pre-eclampsia	17 (5.8%)	2 (25.0%)	
PROM	24 (8.2%)	1 (12.5%)	
Others	22 (8.5%)	2 (37.5%)	
No	219 (74.1%)	1 (12.5%)	
Ototoxic drugs			
Gentamycin	235 (80.8%)	2 (25.0%)	0.000**
Gentamycin and vancomycin	49 (16.8%)	0 (0.0%)	
Others	7 (2.4%)	6 (75.0%)	

© Fisher`s Exact test were used.
***:** Statistically significant: ($p < 0.05$)
****:** High statistically significant: ($p < 0.01$).

Table (7): Logistic regression analysis to determine risk factors for hearing loss among newborn

Variables	Ref	Adjusted OR	P-value	95.% C.I.	
				Lower	Upper
Birth weight Low birth weight	NBW	2.418	0.162	0.003	2.639
Congenital anomalies Yes	NO	3.913	0.008	0.001	0.367
Birth hypoxia Yes	NO	0.492	0.840	0.005	71.788
Mechanical ventilation Yes	NO	2.702	0.101	0.003	1.697
Sepsis Yes	NO	1.496	0.303	0.013	3.852
Severe Hyperbilirubinemia Yes	NO	4.259	0.025	0.000	0.587
Maternal risk factors Yes	NO	3.585	0.038	0.001	0.813

($R^2 = 0.695$)

Discussion:

Worldwide, hearing loss in children is a significant obstacle to optimal growth of language development and learning. In the general population, it is estimated that 0.5 to 3 of every 1000 neonates have congenital or early-onset childhood sensorineural hearing loss of variable degrees that ranged from mild to profound SNHL. This prevalence of hearing impairment can be 10–20 times higher in high-risk infants who require treatment in NICU. [7]

Despite the implementation of universal hearing screening services for newborn babies in many countries, there are substantial disparities in screening coverage, partially because participation in the program is voluntary and many underdeveloped countries do not perform hearing screening. [8]

The present study revealed that 90.6% of our cases passed the test, and 9.4% had a Refer result in the initial screening. In the second re-screening test: 97.3% of a referral case passed, and 2.7% failed. Of affected cases, 2 % had bilateral hearing affection, and 0.7 % had unilateral hearing affection. Our

findings were similar to Bener et al. [9], Helli et al. [10], Wood et al. [11], Colella-Santos et al. [12], and Gouri et al. [13] as they found the prevalence of hearing impairment in their cases was 5 %, 3.2%, 2.1%, 3%, and 5.3 % respectively.

On the other hand, Pourarian et al., [14] reported a slightly higher prevalence rate of 13.7% of hearing impairment among their cases. On otoscopic examination of our cases, 0.7% had ear wax, 7% had Vernix caseosa, and 92.3% was normal, in contrast to results revealed by Doyle et al., [15] as the prevalence of occluding vernix in their cases was 13%, the prevalence of vernix that was non occluding was 32% and 54.5% of their cases were normal.

In this study, the test was done immediately after NICU discharge to assess the hearing and to avoid the NICU noisy environment and was repeated after one week to ensure the test results; the failure rate dropped to about 5.7 %. This was in agreement with Maqbool et al., [2], as 16 % of their cases tested abnormal in the initial screening procedure, 10% on follow-up, and the failure rate dropped to about 6%.

In contrast to Farid et al., [16], as in their first screening phase, 29% of their cases were given a Refer response. In the second screening phase, 31% were given a Refer, and 41% were dropouts, as they had passed their critical stage and had been discharged.

25% of affected cases were males, which was close to Maqbool et al.,[2] where 15.25% of affected cases in their study were males. In contrast to Synnes et al.[5] where 48% of their affected cases were males.

About 75% of affected cases were preterm. These results agreed with Colella-Santos et al., [12], as they reported that preterm was a major risk factor for hearing loss by a percentage of 66.8 %.

Prematurity is considered a major risk for hearing loss due to longer periods of intubation, ventilation, oxygen treatment, acidosis, and the more frequent treatment with ototoxic drugs and more vulnerability to hyperbilirubinemia. [12] In contrast to our results, Korres et al., [17], as all cases in their study were full term. Robertson et al., [18] said that role of prematurity alone as a risk factor for the high prevalence of hearing impairment remains had multiple interacted etiologies.

No one of the affected cases in our study had a family history of hearing loss. This is in line with Maqbool et al., [2] where no one of the affected cases in their study had a family history of hearing loss, while this finding disagrees with the results of De Hoog et al., [19] where 7% of their hearing affected cases had a family history of hearing loss, he reported that family history of hearing loss is considered a risk factor of hearing loss especially for the late-onset or progressive hearing loss so monitoring is essential for those with positive family history even when they passes the hearing screening.

Three-quarters of affected cases were low birth weight (LBW). This data was similar to the results of De Capua et al. [20], john et al. [21], and Sun et al. [22], as they concluded that low birth weight was a significant risk factor for hearing impairment as the prevalence of LBW in their studies was 95%, 56.5%, and 75%.

While this slightly disagrees with Beswick et al. [23] and Gouri et al. [13] as they reported that the prevalence of LBW infants with hearing loss in their studies were 2.7% and 5.2%, respectively and Synnes et al., [5] where all their cases were LBW.

All affected cases in our study were delivered by C.S. This agrees with Smolkin et al., [4] as they found that birth by C.S. was associated with significantly higher rates of failure on first hearing screening in neonates up to

47 hours of age. Our results disagree with Xiao et al. [25] where they found that only 28.9% of their affected cases delivered by C.S. this can be explained on the basis that delivery by C.S. may be accompanied by retained fluids in the middle ear and hence impaired neonatal hearing screening. [25]

There was insignificant relation between normal and affected newborn regarding sex, age, and mode of delivery, while the low birth weight infant was a significant risk factor. Male was three-time times to female in affected neonates, three-quarters of cases were preterm, all affected newborns were delivered by C.S. Half of them had neonatal sepsis, one quarter had RDS 37.5% had birth asphyxia, and one quarter had severe hyperbilirubinemia. 13.7% of our cases had congenital anomalies, mainly CHD. However, no one had meningitis nor a family history of hearing loss. All cases stayed more than 5 days in NICU, 62.5 % of cases were on mechanical ventilation,

Our results are similar to Vohr et al. [26] as they found that the most frequent risk factors in the NICU were ototoxic drugs, low birth weight, connection to mechanical ventilation for more than 5 days. Korres et al. [17] found that toxic levels of ototoxic drugs, mechanical ventilation for more than 24 h, prematurity, and low birth weight were the four frequent risk factors.

In contrast to our result, Farid et al. [16] as they encountered the major risk factor in the NICU was ototoxicity (100%), followed by hyperbilirubinemia (55%) then low birth weight (14.5%) and mechanical ventilation for more than 5 days (11.5%).

In the present study, only 25% of the affected cases had hyperbilirubinemia. Our results are similar to Dantas et al. [27] and Recchia et al. [28] as they found that 3.9% and 13.6% of their cases had hyperbilirubinemia. In addition, they said that despite an association between hyperbilirubinemia and "failed" results in tests and retests, brain stem auditory evoked potential in cases with hyperbilirubinemia is essential with TEOAEs results to exclude the possibility of Auditory Neuropathy Spectrum Disorder. In contrast to the results of our study, hyperbilirubinemia was the most frequent factor encountered in Farid et al. [16] study; he reported that hyperbilirubinemia alone is risk factor for hearing loss, and the incidence of hearing loss increase a lot with the coexistence of other factors such as prematurity, NICU admission, LBW, family history of hearing loss and craniofacial malformations.

NICU staying for more than 5 days was recorded as a major risk factor for hearing impairment. Our results are similar to de Oliveira et al. 29, and Colella-Santos et al. 12, as 100% and 70.6% of their cases reported NICU staying > 5 days.

In contrast to Dantas et al. [27] as they found that NICU staying >7 days had 8.2 % of neonatal hearing impairment, and this was the fifth risk factor in their study. JCIH 2007 guidelines conclude that any illness or condition requiring admission of 24 hours or more to NICU is a risk factor for hearing impairment.

In the current study, mechanical ventilation for more than five days showed a 62.5% significant association with hearing impairment. That was in agreement with Lima et al. [30] and Poonual et al. [31] as 20% and 16.4% of their cases connected to mechanical ventilation. Various aspects have been related to the more significant occurrence of deafness in neonates submitted to assisted ventilation, including the noise level of the appliances, duration of mechanical ventilation, and the pulmonary pathologies involved.

In the present study, sepsis was identified as one of the risk factors and

was observed in 50% of our cases. These results were slightly close to Coenraad et al. [32] as they found that 39.7 of their cases had sepsis and the hearing loss may contribute to the sepsis itself as it affects the inner ear or the brain or as a side effect of ototoxic medication used to treat the sepsis.

Meyer et al. [33] and Al-Harbi et al. [34] concluded that bacterial meningitis is a significant factor associated with failed hearing screening and subsequent hearing loss, usually of severe or profound degrees. [35]

Maternal risk factors revealed that one-third of affected cases had a maternal history of congenital infection, one-fourth of their mothers had pre-eclampsia, 12.5 % had ABO, PROM. De Hoog et al. [19] and Maqbool et al. [2] found that only 2% of the hearing-affected cases had a history of in utero infection. Ohl et al. [36] found that in utero, infection presented in 7.1% of conductive hearing loss cases, 16.7% of cases were unilateral sensorineural hearing loss, and 5.9% were bilateral SNHL.

In the present study, ototoxicity is considered a significant risk factor that affects hearing. Gentamycin was administrated in all cases of affected neonates and used as a mono ototoxic drug in 25 % of them, 37.5% received furosemide, 12.5 % used vancomycin and amikacin administered in 25% of cases.

Our results in agreement with de Oliveira et al. [29], where they found that the ototoxic drugs use was in all of their cases, and so they concluded that the ototoxic drugs use is the most frequent risk indicator among newborns admitted to the NICU.

Coenraad et al. [32] found that gentamycin was the most frequent drug administrated, followed by vancomycin, furosemide, and tobramycin. On the other hand, Bielecki et al. [37] and Colella-Santos et al. [12] found that about one-third of their cases had hearing impairment due to exposure to ototoxic medications, and it was the fifth risk factor of neonatal hearing loss in their results. De Hoog et al. [19] found that vancomycin is the most frequent drug administrated, followed by tobramycin and furosemide.

Before reaching a conclusion, it should be noted that there are some limitations to this study. The limited sample size is one of the limitations of our research which is attributed to the small numbers of NICU nurseries, and hence our findings need to be confirmed by more studies to emphasize the importance of hearing assessment in all newborn babies and more attention should be paid to the NICU babies and to increase the awareness of the pediatrician towards the importance of hearing screening.

Another limitation is the use of the TEOAEs without the ABR; hence the auditory neuropathy spectrum disorders can be missed. Finally, this work is considered the first to be done in Aswan Governorate and is considered as a part of the efforts made to make the dream of universal hearing screening in Egypt comes true.

Conclusion:

This study is considered the first step towards implementing universal hearing screening in the hospital and could help in the meta-analysis of studies on hearing screening in Egypt.

The prevalence of hearing loss was 2.7 %, 2 % had bilateral hearing affection, and 0.7 % had unilateral hearing affection. The diagnosis is confirmed after a full audiological evaluation. There was a significant correlation between exposures to certain risk factors among the affected neonates; all cases remained more than 5 days in NICU with a history of exposure to ototoxic drugs, especially gentamycin, furosemide, vancomycin,

and amikacin. Other risk factors included prematurity, low birth weight, mechanical ventilation, neonatal sepsis, birth asphyxia, and severe hyperbilirubinemia.

This preliminary study in one hospital in Aswan Governate, and we recommend generalized in all hospitals to obtain valid and reliable data about the prevalence of hearing loss among neonates in the whole Governorate.

Funding: This research received no external funding, and there were no sponsor companies.

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Ethics Committee of Aswan University. The committee's reference code is Aswu /350/3/19.

Informed Consent and Statement: Informed consent was obtained from all parents of infants involved in the study. Written informed consent has been obtained from the infant's parents or caregivers to publish this paper.

Acknowledgments: the authors acknowledge ministry of health due to their help providing us with TEOAEs device.

Conflicts of Interest: The authors declare no conflict of interest.

Reference:

1. Haddad, J.; Dodhia, S.N.; Spitzer, J.B. Hearing Loss. Nelson Textbook of Paediatrics. 21thed; Kliegman RM, Behrman RE, Jenson HB, Stanton BF. Institute: Elsevier, USA. 2020. pp.2620-26.
2. Maqbool, M.; Najar, B.A.; Gattoo, I.; Chowdhary, J. Screening for Hearing Impairment in High Risk Neonates: A Hospital Based Study. J of Clinical and Diagnostic Research. 2015, 9(6): 18-21.
3. Delaney, A.; Meyers, A.; Talavera, F.; Roland, P.; Meyers, A.; Faust, R.; Ruth, R. Newborn Hearing Screening. Journal of Hearing Science. 2016, 5(4): 55-55.
4. Lin, H.; Yang, C.; Chiang, Y.; Hung, P.; Yang, E.Y.; Wang, L.; Lin, G. Effect of identification and intervention age on language development for Mandarin-speaking deaf children with high family involvement. International Journal of Pediatric Otorhinolaryngology. 2011, 75 (3): 409–14.
5. The Joint Committee on Infant Hearing: Principles and Guidelines for Early Hearing Detection and Intervention Programs: year 2019 Position Statement: The Journal of Early Hearing Detection and Intervention 2019; 4(2): 1-44.
6. Di Stadio, A.; Molini, E.; Gambacorta, V.; Giommetti, G.; Della Volpe, A.; Ralli, M.; Ricci, G. Sensorineural hearing loss in newborns hospitalized in Neonatal Intensive Care Unit: An observational study. International Tinnitus Journal. 2019, 23(1): 31–36.
7. WHO. Newborn and infant hearing screening: current issues and guiding principles for action. Geneva, Switzerland: WHO, 2010.
8. Matulat, P.; Fabian, S.; Kohn, A.; Spormann- Lagodziski, M.; Lang- Roth, R.; Rissmann. A.; et al. Quality of universal newborn hearing screening results: multicenter analysis of data recorded between 2009 and 2012 in four German states. HNO. 2014; 62: 171– 9.
9. Bener, A.; Eihakeem, A.; Abdulhadi K. Is there any association between consanguinity and hearing loss. Int J Pediatr Otorhinolaryngol. 2005, 69:327–333
10. Hille, E.T.; Van Straaten, H.L.M.; Verkerk, P.H. Dutch NICU Neonatal Hearing Screening Working Group. Prevalence and independent risk factors for hearing loss in NICU infants. Acta paediatrica. 2007, 96(8): 1155-1158.
11. Wood, S.A.; Davis, A.C.; Sutton, G.J. Effectiveness of targeted surveillance to identify moderate to profound permanent childhood hearing impairment in babies with risk factors

who pass newborn screening. International Journal of Audiology. 2013, 52(6): 394–399.
12. Colella-Santos, M.F.; Hein, T.A.D.; de Souza, G.L.; do Amaral, M.I.R.; Casali, R.L. Newborn Hearing Screening and Early Diagnostic in the NICU. BioMed Research International. 2014, 1–11.
13. Gouri, Z.U.H.; Sharma, D.; Berwal, PK.; Pandita, A.; Pawar, S. Hearing impairment and its risk factors by newborn screening in north-western India. Maternal health, neonatology and perinatology. 2015, 1(1): 17.
14. Pourarian, S.; Khademi, B.; Pishva, N.; Jamali, A. Prevalence of Hearing Loss in Newborns Admitted to Neonatal Intensive Care Unit .Iran J Otorhinolaryngol. 2012, 24 (68): 129–134.
15. Doyle, K.J.; Burggraaff, B.; Fujikawa, S.; Kim, J.; Macarthur, C. J. Neonatal Hearing Screening with Otoscopy, Auditory Brain Stem Response, and Otoacoustic Emissions. Otolaryngology-Head and Neck Surgery. 1997, 116(6), 597–603.
16. Farid, A.S.; Seoud, I.A.; El Dessouky, T.M.; El Shabrawy, M.M.; Mounir, Z.M. Newborn hearing screening: Importance and characteristics of a high-risk register in a neonatal intensive care unit. The Egyptian Journal of Otolaryngology. 2012, 28(1): 17.
17. Korres, S.; Nikolopoulos, T.P.; Komkotou, V.; Balatsouras, D.; Kandiloros, D.; Constantinou, D.; Ferekidis, E. Newborn hearing screening: effectiveness, importance of high-risk factors, and characteristics of infants in the neonatal intensive care unit and well-baby nursery. Otology & Neurotology. 2005, 26(6): 1186-1190.
18. Robertson, C.M.T.; Howarth, T.M.; Bork, D.L.R.; Dinu, IA. Permanent Bilateral Sensory and Neural Hearing Loss of Children After Neonatal Intensive Care Because of Extreme Prematurity: A Thirty-Year Study. PEDIATRICS. 2009, 123(5): e797–e807.
19. De Hoog, M.; van Zanten, BA.; Hop, WC.; Overbosch, E.; Weisglas-Kuperus, N.; van den Anker, JN. Newborn hearing screening: tobramycin and vancomycin are not risk factors for hearing loss. The Journal of pediatrics. 2003, 142(1): 41-46.
20. De Capua, B.; Costantini, D.; Martufi, C.; Latini, G.; Gentile, M.; De Felice, C. Universal neonatal hearing screening: The Siena (Italy) experience on 19,700 newborns. Early Human Development. 2007, 83(9): 601–606.
21. John, M.; Balraj, A.; Kurien, M. Neonatal screening for hearing loss: pilot study from a tertiary care centre. Indian Journal of Otolaryngology and Head & Neck Surgery. 2009, 61(1): 23-26.
22. Sun, P.; Liang, Y.; Tan, M.; Yuan, Y.; Yang, C.; Liu, Y.; Li, Q. Correlation between risk factors of hearing lose and results of initial hearing screening in 1021 neonates. Lin chuang er bi yan hou tou jing wai ke za zhi= Journal of clinical otorhinolaryngology, head, and neck surgery. 2015, 29(10): 893-898.
23. Beswick, R.; Driscoll, C.; Kei, J. Monitoring for Postnatal Hearing Loss Using Risk Factors: A Systematic Literature Review. Ear and hearing. 2012, 33 (6): 745 – 756.
24. Smolkin, T.; Mick, O.; Dabbah, M.; Blazer, S.; Grakovsky, G.; Gabay, N.; Makhoul, IR. Birth by Cesarean Delivery and Failure on First Otoacoustic Emissions Hearing Test. PEDIATRICS. 2012, 130(1): e95.
25. Xiao, T.; Li, Y.; Xiao, L.; Jiang, L.; Hu, Q. Association between mode of delivery and failure of neonatal acoustic emission test: A retrospective analysis. International Journal of Pediatric Otorhinolaryngology. 2015, 79(4): 516–519.
26. Vohr, B.R.; Widen, J.E.; Cone-Wesson, B.; Sininger, Y.S.; Gorga, M.P.; Folsom, R.C.; Norton, S.J. Identification of neonatal hearing impairment: characteristics of infants in the neonatal intensive care unit and well-baby nursery. Ear and hearing. 2000, 21(5), 373-382.
27. Dantas, M.B.D.; dos Anjos, C.A.L.; Camboim, E.D.; Pimentel, M.D.R. Results of a neonatal hearing screening

program in Maceió (Resultados de um programa de triagem auditiva neonatal em Maceió). Revista Brasileira de Otorrinolaringologia. 2009, 75(1): 58-63.
28. Rechia, I.C, Liberalesso, K.P.; Angst, O.V.M.; Mahl, F.D.; Garcia, M.V.; Biaggio, E.P.V. Intensive care unit: results of the Newborn Hearing Screening. Brazilian Journal of Otorhinolaryngology. 2016, 82 (1): 76–81.
29. de Oliveira, J.S.; Rodrigues, L.B.; Aurélio, F.S.; de Silva, V.B. Risk factors and prevalence of newborn hearing loss in a private health care system of Porto Velho, Northern Brazil. Revista Paulista de Pediatria. 2013, 31(3): 299–305.
30. Lima, G.M.; Marba, S.; Santos, M.F.C. Hearing screening in a neonatal intensive care unit. Jornal de pediatria. 2006, 82(2): 110-114.
31. Poonual, W.; Navacharoen, N.; Kangsanarak, J.; Namwongprom, S. Risk factors for hearing loss in infants under universal hearing screening program in Northern Thailand. Journal of Multidisciplinary Healthcare, 2015, 9: 1-5
32. Coenraad, S.; Goedegebure, A.; van Goudoever, J.B.; Hoeve, L.J. Risk factors for sensorineural hearing loss in NICU infants compared to normal hearing NICU controls. Int J Pediatr Otorhinolaryngol. 2010, 74(9):999-1002.
33. Meyer, C.; Witte, J.; Hildmann, A.; Hennake, K.H.; Schunck, K.U.; Maul, K.; Franke, U.; Fahnenstich, H.; Rabe, H.; Rossi, R.; Hartmann, S.; Gortner, L. Neonatal screening for hearing disorders in infants at risk: incidence, risk factors and follow-up. Paediatrics. 1999, 104: 900-4.
34. AL-Harbi, M.; Barakat, N.; AL-Khandary, M. Hearing Screening in at Risk Newborn. Journal of Medical Sciences, 2008, 8: 648-653.
35. Saunders, J.E.; Vaz, S.; Greinwald, J.H.; Lai, J.; Morin, L.; Mojica, K. Prevalence and Etiology of Hearing Loss in Rural Nicaraguan Children. The Laryngoscope. 2007, 117(3): 387–398.
36. Ohl, C.; Dornier, L.; Czajka, C.; Chobaut, J. C.; Tavernier, L. Newborn hearing screening on infants at risk. International Journal of Pediatric Otorhinolaryngology. 2009, 73 (12):1691–1695.
37. Bielecki, I.; Horbulewicz, A.; Wolan, T. Risk factors associated with hearing loss in infants: An analysis of 5282 referred neonates. Int J of Pediatric Otorhinolaryngology. 2011, 75(7):925-30