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ORIGINAL ARTICLE

A Study of JCIH (Joint Commission on Infant Hearing) Risk Factors for Hearing Loss in Babies of NICU and Well Baby Nursery at a Tertiary Care Center

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Abstract Babies in Neonatal Intensive Care Units (NICU) have an additional risk for hearing loss due to various risk factors like, prematurity, low birth weight, mechanical ventilation, hyperbillirubinemia, ototoxic drugs, low APGAR score etc. as compared to the babies from well baby nursery (WBN) who, poses risk factors mostly family history, syndromic deafness. So the present study was aimed know the risk factors responsible for hearing loss in NICU and WBN babies and to assess the incidence of deafness. A total of 800 babies from NICU (n = 402) and WBN (n = 398) underwent hearing screening from a tertiary care center. Hearing screening was done using two staged screening protocol as per JCIH guidelines with Distortion product Evoked Otoacoustic Emissions (DPOAE) and Automated Auditory Brainstem Responses (A-ABR). According to DPOAE test, 311 from NICU and 383 from WBN passed the test and during second screening, 80 out of 91 from NICU and 11 out of 13 from WBN passed the DPOAE test. Further BERA was done at the 3rd month of corrected age where 6 out of 11 showed positive responses from NICU and 3 babies from WBN had profound hearing loss. Data analysis revealed that family history of deafness, anemia and hypertension in ANC, TORCH in mother, low Apgar score and hyperbillirubinemia in newborns were a major risk factor for hearing impairment. We conclude that the diagnoses of auditory disorders at early stage due to various risk factors are important since appropriate therapeutic intervention and rehabilitation would help in better development of children.

Keywords JCIH risk factors · Hearing loss · Neonatal intensive care unit · DPOAE test · Universal newborn hearing screening (UNHS)

Introduction

As per World health organization (WHO), 0.5 to 5 per 1000 newborn and infants have congenital or early childhood onset sensorineural deafness or severe-to-profound hearing impairment [18]. Genetic factors contribute to 50% with no other risk factors and this may go unnoticed in the normal newborn population. NICU babies are a subset of the general newborn population displaying characteristically high incidence of risk factors for hearing loss.

In the year 2000, Joint Commission on infant hearing (JCIH) proposed several perinatal risk factors which increase the incidence of deafness by up to 14.1% [22]. Hearing loss being an invisible disability, early detection of deafness has been a long standing priority in the field of otology. Currently the mean age of identification of pediatric deafness is 24 to 30 months. This results in loss of precious duration of Cerebral plasticity. In India, hearing disability has a higher prevalence in children aged 0–4 years (0.60%) and 5–9 years (0.28%) than all other disabilities (0.32%). Also with limited resources and population burden there are no established universal newborn hearing screening (UNHS) programs as it is masked by other life-threatening public health diseases [11] JCIH strongly recommends all neonates should undergo hearing screening by the first month of life and diagnosis should be

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made by 3 months of age, so that it can benefit patients by timely fitting of hearing aids or cochlear implants [1, 19].

Clinically, it is difficult to detect the early hearing loss in newborns. There are two widely used tests for the hearing screening. OAE an objective test which determine the cochlear status, especially the outer hair cells function, and BERA tests the functional integrity of the auditory pathway from the eighth nerve to brainstem. As OAE is simple, quick, and inexpensive, it is usually more preferred than BERA for screening as a first step in newborns [27]. The JCIH has set separate test protocols for NICUs and well-baby nurseries, recommending a two-step screening procedure for all healthy low-risk newborns, with OAEs followed by a-ABRs if there is no response at the original screening test. In 2007, JCIH set out revised guidelines, with specific mention of ANSD(Auditory Neuropathy Spectrum Disorders) detection and listing indicators which point to high-risk of developing permanent childhood hearing impairment [1].OAEs are not enough and ABRs should be the basis of the screening in order not to misdiagnose ANSD cases.

The genetic factors contribute 50–70% of either syndromic (30%) or non-syndromic (70%) profound hearing loss [24]. Over 400 syndromes presenting audiological disorders among other clinical manifestations have been identified, [25]. Non-syndromic deafness is related to mutations of genes that regulate the production of the gap junction protein connexin 26, which causes abnormal cochlear hair cell function. Overall, only 50% of hearing impaired infants have known risk factors, as given by JCIH, a fact that underlines the necessity for UNHS [26]. Several studies have tried to identify and re-evaluate the role and relative importance of certain risk factors in the development of hearing loss.We have done this study to find the incidence of hearing loss in newborns and also risk factors associated among well baby nursery and high-risk newborn from NICU at tertiary care hospital and also to develop a protocol and methodology for regular screening programme.

Materials and Methodology

Study Design

This is a clinical, prospective cross sectional study conducted at a tertiary care hospital of North Karnataka. A total of 402 babies from NICU and 398 normal newborn babies from well baby nursery (WBN) formed the study group. Ethical clearance for the study was obtained from the institutional ethics committee. Informed consent taken from the parents. A detailed history taken and documented in preformed proforma. Detailed history regarding prenatal, natal, demographic details, family history of deafness and consanguinity, gestational history of the mother, intra-natal and postnatal events, and complications and postnatal period were recorded from the mother. High-risk factors as per JCIH category were defined.. Low birth weight baby, preterm baby, delivery by cesarean section, birth asphyxia, congenital anomalies, neonatal jaundice, newborns with a history of convulsions, and infection were categorized into high-risk group. Positive antenatal history of drug intake, hypertension, diabetes, hypothyroidism, and Rh incompatibility were also considered as risk factors.

A two-stage screening protocol was made as per JCIH guidelines, in which newborn babies were screened first with Distortion product otoacoustic emissions (DPOAE). Infants who fail the OAE were screened for auditory brainstem response (ABR). In this two tier screening program, the second tier being ABR (which is more expensive) was done only for a select few, making the program more practical and viable.

Portable OAE machine is completely automated analysis systems that gives Result.as PASS (normal functioning) or REFER (poor functioning). Parents of babies who failed (REFER) the screening test were asked for follow up after counseling. Those who passed on the second DPOAE screening were discharged from the study while those who failed second time were referred for further BERA testing, which was performed at 3 month of corrected age after all diagnostic evaluation. Recording of waveforms in BERA was done at different intensities starting at 90 dB. Two replications were obtained at each intensity and peaks I,III, V were marked wherever present. Phone calls and letters were used to contact parents who failed to return for follow up.

Statistical Analysis

Data from the proforma questionnaire and the results of the testing were tabulated in Microsoft excel and subjected to analysis using Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 IBM Corp. was used to perform statistical analyses. The level of significance was set at $P < 0.05$.

Results

During the study period there were a total of 798 (NICU baby ($n = 402$), Well baby Nursery (WBN, $n = 396$) babies who underwent OAE for hearing assessment. NICU babies were assessed as per the JCIH RISK factors and 398 babies from WBN had few environmental risk factors as per JCIH. In the first DPOAE test screening, 311 from NICU and 383 from WBN passed the test and monitoring

after 4–6 weeks on second DPOAE, 80 out of 91 from NICU and 11 out of 13 passed the test. Further BERA was done at the 3rd month of corrected age where 6 out of 11 showed positive responses for 50 db from NICU babies and 5 babies showed profound hearing loss. From WBN out of 3 babies, one baby had moderate to severe and two babies had profound hearing loss. Flow chart of children/patient grouping is shown in Fig. 1.

The demographics of NICU baby that includes frequency and percentile of male: female ratio, education level, consanguineous marriage family history of deafness and associated JCIH risk factors is given in Table 1 and the risk factors associated with the babies from well-baby nursing (WBN) is represented in Table 2. Age parameter was significant to the deafness ($p = 0.048$) between babies of WBN but insignificantly associated with babies from NICU. Consanguineous marriage was a significant risk factor noted in both NICU and WBN groups with $p = 0.003$ and 0.452 respectively. Mode of delivery including normal ($p = 0.096$) and assisted delivery ($p = 0.033$) were noted to be significant in NICU babies whereas LSCS caesarean section was insignificant in both the groups (NICU, $p = 0.428$ and WBN, $p = 0.946$). Family history was also assessed for the cause of deafness in both the groups and was found to be extremely significant ($p = 0.003$) in NICU babies and ($p = 0.013$) in well-baby nursing.

WHO [10] lists a number of factors that contribute to hearing loss including hereditary and non hereditary genetical factors or the intrauterine infections such as rubella and cytomegalovirus infection during the prenatal period. In the perinatal period, birth asphyxia, hyperbilirubinemia, low-birth weight and other perinatal morbidities and their management are shown to be risk factors of hearing loss. The current study analyses the torch infection, amino injection and application of mechanical ventilators for its association with hearing loss. Torch infections which are causative pathogens of congenital infections ($p = 0.022$) and hyper-bilirubinaemia > 10 ($p = 0.001$) was noted to be associated with deafness in NICU babies. Interestingly use of routine medication was not a valid factor associated with hearing loss ($p = 0.220$) in NICU babies. Other factors including gestational age, birth weight (very low birth weight, $p = 0.188$), (low birth weight, $p = 0.149$), (normal weight, $p = 0.670$) were not significant. Similarly, APGAR score of low ($p = 0.698$), intermediate ($p = 0.444$) and normal ($p = 0.407$) in NICU babies were not significant. Maternal illness in HT ($p = 0.997$) and No (Apparently healthy) ($p = 0.004$) was significant in well baby nursing. The use of mechanical ventilator ($p = 0.730$), craniofacial anomaly, neurological factors and other associated syndromes ($p = 0.534$) were not associated with respect to the deafness.

The Receiver Operating Characteristic Curve (Fig. 2) with a probability cut off at 0.5 suggests that the maximum area under the curve was seen at a sensitivity of 0.769 and specificity of 0.775. Hence all the above-mentioned factors in Table 1 that were analysed and assessed contribute to hearing loss. RoC curve for REFER (Fig. 3) with (CI: 0.736–0.960) show that most of the parameters were associated with the deafness in NICU baby.

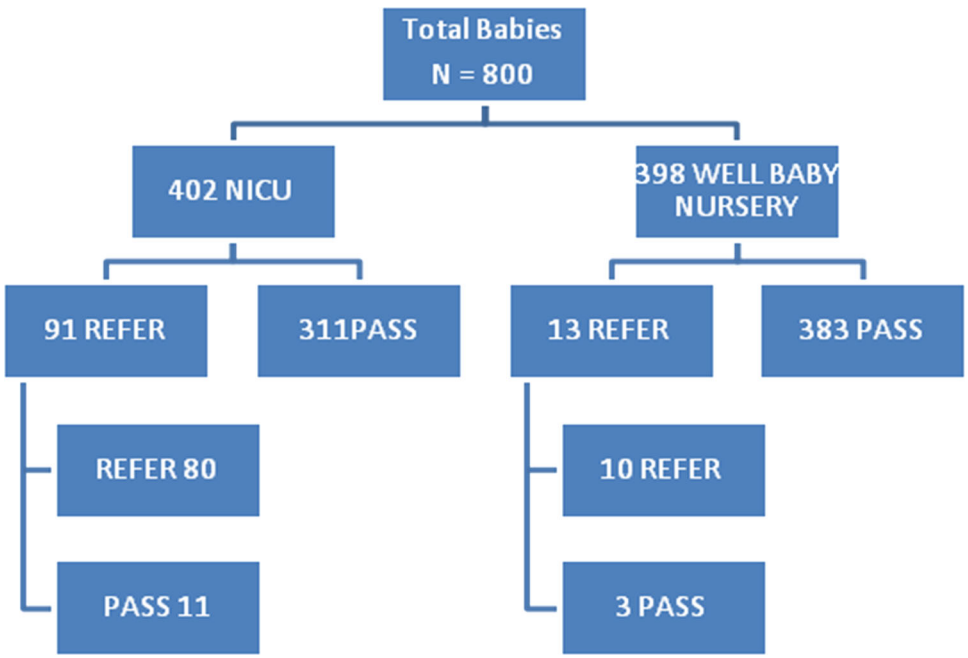

Fig. 1 Flow chart showing selection and grouping of children

Table 1 Demographic details and presentations among NICU children

Characteristics	*P* value	Exp(B)	95% C.I. for EXP(B)	
			Lower	Upper
Age	0.699	1.009	0.966	1.053
Sex				
Female	–	–	–	–
Male	0.731	1.102	0.635	1.912
Education				
H	0.514	–	–	–
I	0.468	2.55	0.203	31.987
G	0.334	1.303	0.761	2.23
Consanguos marriage				
No	–	–	–	–
Yes	0.132	1.744	0.845	3.6
ANC				
Anaemia	0.521	–	–	–
IUGR	0.117	0.266	0.051	1.395
Hypertension	0.311	1.821	0.571	5.807
Preeclampsia	0.632	0.578	0.061	5.457
Anaemia and IUGR	–	–	–	–
N	0.677	0.875	0.465	1.643
Hypertension and anaemia	0.288	2.593	0.446	15.059
Family H/O deafness				
No	–	–	–	–
Yes	0.003	12.757	2.348	69.3
Mode of delivery				
Normal	0.096	–	–	–
Assisted delivary	0.033	0.366	0.145	0.924
LSCS caeserian section	0.428	0.767	0.397	1.48
Torch infection				
No	–	–	–	–
Yes	0.022	8.242	1.35	50.318
Medication				
No	–	–	–	–
Yes	0.220	1.738	0.718	4.204
Gestational age (wks)				
Preterm	0.982	–	–	–
Early term	0.873	1.07	0.466	2.457
Full term	0.891	1.151	0.152	8.719
Birth weight (gms)				
Very low birth weight	0.188	–	–	–
Low birth weight	0.149	2.073	0.771	5.574
Normal	0.670	1.306	0.382	4.463
Apgar score				
Low	0.698	–	–	–
Intrmediate	0.444	1.42	0.579	3.478
Normal	0.407	1.496	0.578	3.874
Hyperbillirubinemia				
$< = 10$	–	–	–	–
> 10 (Significant)	0.000	5.903	2.863	12.171

Table 1 continued

Characteristics	*P* value	Exp(B)	95% C.I. for EXP(B)	
			Lower	Upper
Craniofacial aomal				
No	–	–	–	–
Yes	0.400	2.63	0.277	24.955
Neurological factors				
Normal	0.165	–	–	–
Other conditions	0.222	0.532	0.194	1.463
Intraventricular haemorrhage	0.152	4.979	0.553	44.859
Infection				
No	–	–	–	–
Yes	0.178	0.685	0.395	1.188
Amino. Inj				
No	–	–	–	–
Yes	0.401	1.272	0.726	2.231
Mech venti				
No	–	–	–	–
Yes	0.730	1.106	0.623	1.964
Asso. Synd				
No	–	–	–	–
Yes	0.534	0.443	0.034	5.763

Table 2 Demographic details and presentations among Well Baby Nursery

	P Value	Exp(B)	95% C.I.for EXP(B)	
			Lower	Upper
Age (Days)	0.05	1.412	1.003	1.986
Sex				
Male	–	–	–	–
Female	0.234	2.109	0.618	7.206
Family history				
No	–	–	–	–
Yes	0.013	12.317	1.702	89.114
Consanguineous marriage				
No	–	–	–	–
Yes	0.452	2.056	0.314	13.461
Mode of delivery				
ND	–	–	–	–
LSCS	0.946	1.065	0.169	6.725
Maternal illness				
AN	–	–	–	–
HT	0.997	–	–	–
No	0.004	0.139	0.036	0.532
Gestational age (weeks) recoded				
Preterm	–	–	–	–
Early term	0.588	1.961	0.171	22.504
Full term	0.820	0.713	0.039	13.056
Late term	–	–	–	–

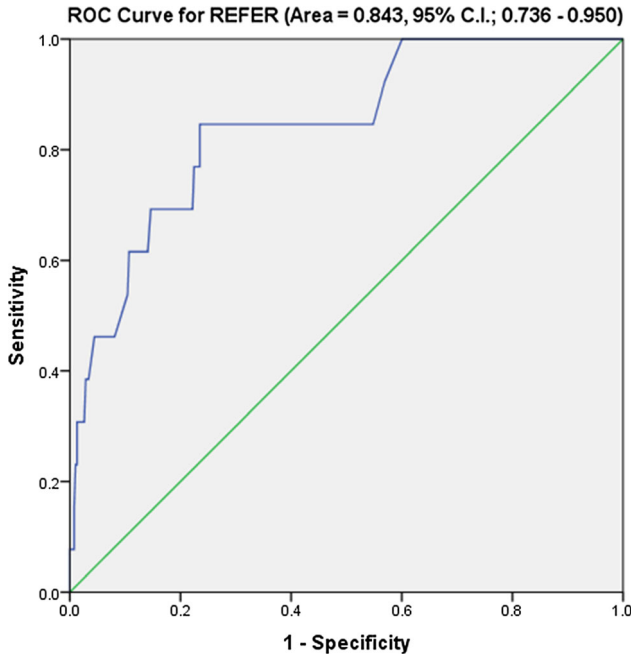

Fig. 2 ROC curve analysis for NICU children. The RoC Curve with a probability cut off at 0.5 suggests that the maximum area under the curve was seen at a sensitivity of 0.692 and specificity of 0.688. This RoC curve is for REFER with (CI: 0.736–0.960). Most of the parameters were associated with the deafness in NICU baby

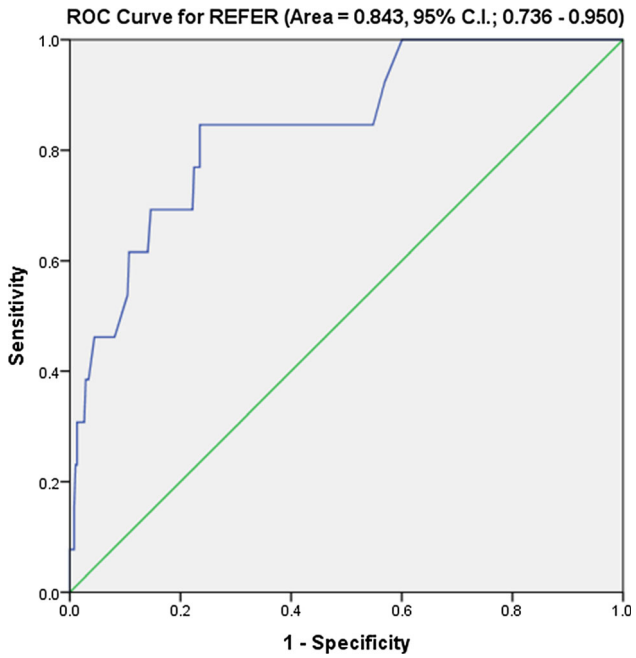

Fig. 3 ROC curve analysis for apparently healthy children. The Receiver Operating Characteristic Curve with a probability cut off at 0.5 suggests that the maximum area under the curve was seen at a sensitivity of 0.769 and specificity of 0.775. Hence all the above-mentioned factors in Table 2 that were analysed and assessed contribute to hearing loss

Discussion

Sense of hearing has been recently considered as a severe health problem by National Program for the prevention and Control of Deafness (NPPCD). Auditory sense if undetected at an early stage lead to speech impairment, developmental issues and loss of productive years of the child. Therefore detection of hearing loss at the neonatal stage decreases the burden, where intervention therapies can help the children. A two stage screening test involving otacoustic emission (OAE) and Auditory Brainstem response Audiometry (BERA) screening have been recommended [23]. When a Child develops hearing loss with no risk factors involved, first tier genetic screening for the role of the GJB2 gene encoding protein connexin-26 is also recommended since this gene accounts for 20% of sensorineural hearing impairment [6].

Early hearing detection and intervention (EHDI) states that screening infants at 1, 3 and 6 months of age, help in early prognosis and treatment procedures. In a study involving 303 childern, the age of suspicion, diagnosis and intervention was observed to be 18, 72, 84 months respectively. Parent's literacy, father's occupation, consangiuos marriage, socioeconomic status and geographical location of the family determined the age of diagnosis [7]. A prior study by Chary et al. [8] in rural Karnataka, India showed the age of hearing loss recognition between 24 and 36 months.

The current study aims to understand the incidence of deafness in newborn for NICU and WBN nursery groups with various risk factors as proposed by JCIH using DPOAE and BERA. Various studies show the incidence of hearing loss in newborns in India. In one of pilot studies conducted Paul et al. [21] at Cochin the incidence of hearing loss were 10.3/1000 births in NICU and 0.98/1000 births in well baby nursery group. In another study by Nagapoornima, et al. [16] an incidence of hearing loss of 5.6/1000 births was demonstrated. Hearing impairment incidences were higher in the current study much larger than the national average of 4/1000. This may be because our tertiary care centre hospital has large number of high risk deliveries leading to larger caseload of at-risk group. Our finding is in contradictory to the other reports, it might be because of less sample size.

Risk factors that lead to hearing impairment are primarily due to genetic aspects, congenital infections and craniofacial abnormalities. Infectious congenital hearing loss is linked to *Toxoplasma gondii*, Rubella virus, Cytomegalovirus, herpes simplex virus and *Treponema pallidum* [14]. Besides risk factors such as positive history of hearing loss in families, consangiuos marriage, admission to NICU, decreased birth weight, increased gestational age,

medical interventions such as mechanical ventilation, ototoxic drug use, venous access and increased duration of hospital stay have been linked to increased hearing loss. Bilirubin induced neurotoxicity (BINT) also leads to auditory disorder where neonates with extreme hyperbilirubinemia (Total Serum Bilirubin $\geq$ 25 mg/dL) were associated with BINT [2]. Unbound bilirubin is shown to strongly associate with auditory toxicity in 28 out of 100 neonates [2]. Preterm and term infants are affected up to 84% by hyperbilirubinemia during the first week of life. Total serum/plasma bilirubin elevated levels can be mild, transitory or inconsequential in most of the babies [3].

The current study shows that normal and assisted delivery, family history of hearing loss, torch infections and hyperbilirubinemia greater than 10 were strongly associated with the hearing loss of NICU babies. Age and family history of hearing loss were linked with the hearing impairments of WBN babies. No significant association between hearing loss and birth weight of the babies, C-section delivery, medication, gestational age, amino injection, mechanical ventilation, associated syndromes and craniofacial abnormalities was observed. However APGAR score ($p < 0.05$) and family history ($p = 0.013$) were found to have significant association. The current study is in accordance with multiple reports on risk factors of hearing impairments. In a prospective non randomized clinical study involving 8192 babies around the rural areas of Maval, Maharastra, India, various risk factors such as low birth weight (5.9/1000 high risk births), hyperbilirubinemia (3.56/1000 high risk births) and craniofacial abnormalities in neonates (1.18/1000 high risk births) were associated with hearing impairment. There was strong association between high risk babies (10.69/1000 births) and hearing loss when compared to well babies (1.689/1000 births). Birth weight (less than 2.5 kg), hyperbilirubinemia, asphyxia and family history are the high risk factors leading to hearing loss, where five infants failed in both OAE and tympanometry screening. This study screened 2000 live neonates at a tertiary care institute around a 12 month period [4] A study involving 307 children were assessed for etiologies related to mild or severe hearing loss. Stay at NICU, mechanical ventilation, ototoxic drug (aminoglycoside exposure), oxygen need and history of deafness in the family positively correlated with the hearing loss. No significant association between hearing loss and congenital disease (cytomegalovirus), bacterial meningitis, streptococcus positivity, loop diuretic exposure and ECMO [20].

A longitudinal cohort study involving 87 babies showed that NICU (65.52%), ototoxicity (48.28%), hyperbiliirubinemia (46.55%) and mechanical ventilation (39.66%) played a major risk factor in the development of hearing loss. Preterm babies were at higher risk pertaining to the parameters when compared to full term babies. APGAR score, infections, gestational age also played a major role [22–24]. In our study, family history of deafness in NICU and WBN group has statistical significance ($p = < 0.001$). Ganapathy et al. [10] conducted study on association of family history and consanguinity that showed 18.6 and 39.5% of babies having hearing loss in India. This study was also supported by an analysis on Mumbai school children by D'Mello et al. [9]. Family history of hearing loss is seen in different studies in India, with 25% in Karnataka and in Kerala, 45% had a family history of deafness with mutations in GJB2 gene [12, 15].

Risk factors contribute to the burden of hearing impairment in developing countries. Most cases of deafness in India are preventable as per WHO report which is aimed to be reduced to 1%. Screening at younger age as early as in the prenatal and perinatal period can help in effective management of hearing impairment. But the challenges that are faced to avail the services related to diagnosis of hearing loss in rural children include cultural, educational, financial and navigational barriers [9]. Therefore proper medical and counseling regimens should be employed for early detection, intervention and minimizing the risk factors that induce congenital hearing loss.

Conclusion

To summarize, data analysis in our sample revealed that family history of deafness, anemia and hypertension in ANC, TORCH in mother, low Apgar score and hyperbillirubinemia in newborns were a major risk factor for hearing impairment. The diagnosis of auditory disorders at early stage are important since appropriate therapeutic intervention and clinical treatments would help in better development of children. We also strongly recommend Universal Newborn Hearing Screening (UNHS), especially for NICU patients who are having multiple risk factors for hearing loss. Multicenter studies incorporating large sample size should be done at different levels of health care in order to get a clearer picture of hearing status of babies in developing countries. IN India, majority of hospitals do not conduct universal or high risk screening. In such a situation, a centralized facility catering to all hospitals in a city is a practical option.

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