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ORIGINAL ARTICLE

Prevalence of Hearing Loss in High Risk Infants of Mediocre Socio-economic Background at Around One Year of Age and Their Correlation with Risk Factors

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Abstract The present study tried to determine the hearing threshold by brainstem evoked response audiometry (BERA) in the high-risk infants from a mediocre socio-economic background at around 1 year of age and correlate different risk factors with hearing loss. BERA was done on 127 infants of 6–18 months age of which 87 were high risk. All were given monaural acoustic stimulus using Cz-M1/M2 Montage. Based on the appearance of wave V at minimum stimulus intensity, hearing threshold in decibels (dB) of each ear was determined. To study the association of the individual risk factor with hearing loss multiple logistic regression test was applied. Taking BERA threshold for 'Pass' as ≤40 dBnHL, out of 87 high risk infants 10.34 % ($n = 9$) had bilateral severe to profound hearing loss, 17.24 % ($n = 15$) had bilateral mild to moderate hearing loss and 12.64 % ($n = 11$) had impaired hearing in one ear. All of the control group infants had normal hearing threshold of 30 dBnHL. Twenty major risk factors were identified in the whole study group at an average of 2.3 factors per infant. Twelve factors were examined for correlation using Odd's ratio (OR) with >40 dBnHL threshold as the outcome variable. Factors with very high OR were family history of deafness, Ototoxic drugs and Craniofacial abnormality followed by others. High risk infants have a persistent and definitive risk of hearing loss prompting early intervention.

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Introduction

The prevalence of newborn and infant hearing loss is estimated to range from 1.5 to 6 per 1,000 live births [1]. The prevalence of neonatal hearing disorders has been reported to be increased to 10–50 fold in infants at risk [2]. In the literature, its incidence varies widely from 1.5 to 17 % [3]. In the two Indian studies conducted in New Delhi in 1991 [4] and 1997 [5], the incidence of hearing loss in NICU babies were 19.2 and 18 % respectively.

The Position Statement [1] maintained that there was a role for the high-risk factors in sensorineural (SNHL) and/or conductive (CHL) hearing loss in newborns and infants (including delayed onset hearing loss) and once a child is identified as being at risk for hearing loss, hearing should be evaluated. With the advent of brainstem evoked response audiometry (BERA), detection and quantification of hearing impairment has been easier in pediatric patients who are unable to cooperate with routine testing [6].

The importance of early detection and early rehabilitation of prelingual childhood hearing loss is undisputed [7]. The present study was aimed to assess the hearing status of the high-risk infants at around 1 year of age by determining the hearing threshold and correlating it with the high-risk factors. Early detection of hearing loss in infants will lead to early referral for intervention and save them from a social stigma.

Material and Methods

The study is a cross-sectional comparative study. Part of the data collection was done in the Neurophysiology

Laboratory of the Department of Physiology, Jawaharlal Nehru Medical College, Sawangi (Meghe), Maharashtra and partly it was done in the Neurodevelopmental Clinic, Department of Neonatology, IPGMER, Kolkata. Data analysis, drafting of the manuscript and revision etc. were done in Nil Ratan Sircar Medical College, Kolkata.

Infants of 6 months to 1 year of age, from a mediocre socio-economic background having any of the risk-factors at birth or for delayed onset hearing loss, recognized by the Joint Committee of Infant Hearing [1] were included in the Study group. Infants of similar age having none of the risk-factors during the pre-, peri- or post-natal period were taken as control.

There was no specific exclusion criterion except the age of the infants; who fell beyond the two extremes of the age-limits, were not included in the study.

Antenatal, natal, perinatal and postnatal history as well as family and developmental history were taken from the documented evidences such as tickets from In-patient and Out-patient departments (IPD and OPD), Hospital-discharge certificate at the time of birth [from Neonatal/Paediatric intensive care unit (NICU, PICU) or Well-Baby-Nursery] and/or from discharge certificate after any type of hospital stay, any time after birth indicating the nature of illness and treatment received.

Single channel BERA was done on RMS EMG.EP MARK-II using sweep speed 1 ms/div with a sensitivity −0.2 μV/div. Highcut and Lowcut filters were kept at 3,000 and 100 Hz. respectively and input impedance was kept <5 KΩ.

Electrical activities were recorded with silver electrodes (Ag/AgCl) using Monaural montage Cz(Vertex)-M1(Mastoid) or M2. Ground electrode was placed at the nasion (Fz). In case of infants, reference electrode (Cz) is placed on the forehead at hairline [8] as the anterior fontanelle is still widely open.

Potentials were evoked during sedation by Triclofos or Promethazine, by means of monaural stimulation with clicks of alternating polarity from TDH-39 earphone at a frequency of 250–8,000 Hz. Click duration was 100 μs square wave and Envelope used was Linear.

The stimulation was first applied during a 2 min period of adaptation, preceding the recording, that progressively increased in intensity by 10 dB from 30 dBnHL until it reached 90 dBnHL. Rate of stimulation was 11.1 s.

The ear not being tested was masked with white noise 30 dB below the intensity of the stimulus.

A total of 2,000 stimulations were averaged and the process was repeated at least once to ensure reproducibility of the response.

Results were analyzed by SPSS 14.0 software and the following tests were used:

- Fisher Exact Test was used to test the association between qualitative parameters like age and sex.
- Multiple Logistic Regression Analysis was applied to test correlation of hearing loss with various risk factors.

Results

127 infants were screened for hearing impairment by BERA. Of them, 40 infants had no risk factor for hearing loss at birth or later and hence termed control group. 87 infants had at least one risk factor for hearing loss either at birth or for late onset hearing loss and hence termed study group. Mean age in the study group was 11.36 ± 4.12 months and in control group was 12.27 ± 2.83 months with no significant difference between them ($p = 0.25$). Male-female ratio in the study group was 58:29 and in control group was 25:15 with no significant difference between them ($p = 0.69$).

Taking BERA threshold for 'Pass' as ≤40 dBnHL, out of 87 high risk infants 10.34 % ($n = 9$) had bilateral severe to profound hearing loss, 17.24 % ($n = 15$) had bilateral mild to moderate hearing loss and 12.64 % ($n = 11$) had significant hearing impairment in one ear. 59.77 % ($n = 52$) of the study group had normal hearing threshold in both ears (≤40 dBnHL) (Table 1). All the control group infants had their hearing threshold at 30 dBnHL.

In all, twenty major risk factors were identified in the whole study group (Table 2). Each infant often had more than one risk factor, at an average of 2.3 factors per infant. 33.33 % ($n = 29$) of the study group had single risk factors and 66.66 % ($n = 58$) had more than one risk factors.

Table 1 Hearing status among the high risk infants (based on BERA threshold)

Hearing status	No. of patients ($n = 87$)	Percentage (%) (approximately)
A. Severe to profound deafness (bilateral threshold >80 dB)	9	10.34
B. Mild to moderate hearing loss bilaterally (bilateral threshold >40 and <80 dB)	15	17.24
C. Hearing impaired unilaterally (one ear ≥40 dB, other ear <40 dB)	11	12.64
D. Hearing present bilaterally (BERA threshold bilaterally ≤40 dB)	52	59.77
Total	87	100.00

N.B—Cut-off BERA threshold for 'Pass' is taken as ≤40 dBnHL. WHO defines and classifies hearing impairment according to the better ear hearing level (BEHL0.5–4 kHz) based on pure tone average. (15)

Table 2 Frequencies of risk factors identified in the study group ($n = 87$) (each study subject could and often did have more than one risk factor)

Risk factor	No. of infants affected	%
A. Prenatal risk factors		
Family h/o deafness	3	3.45
Parental consanguinity	5	5.75
In utero infections	2	2.30
B. Neonatal and late onset risk factors		
Developmental delay	28	32.18
Birth asphyxia	20	22.99
Low birth weight (SGA)	17	19.54
Microcephaly	17	19.54
Ototoxic medications	16	18.39
Cerebral palsy and/or mental retardation	13	14.94
Neonatal sepsis including meningitis	12	13.79
Seizure disorder	11	12.64
Prematurity	7	8.05
Cleft lip and/or palate	7	8.05
Craniofacial abnormalities	6	6.89
Congenital heart disease	4	4.6
Hydrocephalus	4	4.6
Hyperbilirubinemia	3	3.45
Mechanical ventilation ≥5 days	3	3.45
Otitis media	3	3.45
Head injury	1	1.15

Twelve factors were examined for correlation with abnormal BERA result (elevated threshold >40 dB) as the outcome variable. Odd's ratio were determined with 95 % confidence limits. Odd's Ratio (OR) signifies degree of correlation of the tested variable with outcome variable.

The factors with very high OR were Family history of deafness (OR 41.890), Ototoxic drugs (OR 21.421) and Cranio-facial abnormality (OR 20.138) followed by Microcephaly (OR 6.886), Cerebral Palsy (CP) ± Mental Retardation (MR) (OR 5.844) and Developmental delay (OR 4.334) (Table 3).

Discussion

The best predictor of permanent hearing loss is bilateral failure in auditory brainstem response (ABR) possibly because of its ability to detect both cochlear and brainstem lesions [9]. The present study has revealed a high incidence of hearing impairment in the high risk infants of mediocre socio-economic background at around 1 year of age and also shown a definite correlation of risk factors with hearing impairment.

Determination of Hearing Threshold

The aim of great majority of neonatal screening program is to identify the children that present perception (or mixed) hearing impairment with a threshold level of at least 40 dBHL in the better ear [10]. Hearing loss of 40 dB or more is defined as sensorineural deafness at any frequency in the range of 0.5–4 kHz in the better ear with or without associated conductive loss [9]. Pure-tone hearing threshold in normal adult is 0–25 dB (i.e. dBHL = hearing level) [11, 12] and BERA threshold is 5–10 dB above the pure-tone hearing threshold [11]. Again BERA threshold in

Table 3 Multiple logistic regression (estimation of OR)

Variables	B	S.E	Wald	df	Significant p value	Exp(B)/OR	95 % C.I for Exp (B)	
							Lower	Upper
LBW	0.186	1.044	0.032	1	0.858	1.205	0.156	9.323
B. Asphyxia	−0.247	0.726	0.116	1	0.734	0.781	0.188	3.242
Ototoxic drugs	3.064	1.213	6.387	1	0.011*	21.421	1.989	230.665
Sepsis	−1.950	1.491	1.711	1	0.191	0.142	0.008	2.643
In utero infection	1.541	1.996	0.596	1	0.440	4.667	0.093	233.508
Developmental delay	1.466	0.701	4.382	1	0.036*	4.334	1.098	17.107
Cranio-facial abnormality	3.003	1.370	4.804	1	0.028*	20.138	1.374	295.153
Microcephaly	1.930	0.832	5.383	1	0.020*	6.886	1.349	35.147
CP +/MR	1.765	0.782	5.091	1	0.024*	5.844	1.261	27.081
Family h/o deafness	3.735	1.367	7.461	1	0.006*	41.890	2.872	611.014
Parental consanguinity	0.555	1.238	0.201	1	0.654	1.741	0.154	19.704
Protein energy malnutrition (PEM)	9.627	68.598	0.020	1	0.888	15,172.598	0.000	3.73 E+62
Constant	−3.042	0.608	25.022	1	0.000	0.048	–	–

* Significant p value ($p < 0.05$)

infant is estimated to be about 10 dB higher than that of adult [13]. According to Shininger [14], neonatal ABR threshold for stimuli 500–8,000 Hz are elevated related to adult threshold by 5–25 dB. BERA using clicks gives the idea of hearing level in 2,000–4,000 Hz range [11]. So a perceptual sensitivity threshold in the 1,000–4,000 Hz sensitivity region is predicted to be within 20 dB less than the ABR threshold [15].

An infant is considered to have passed the ABR test if a replicable wave V response is present at 30 dB hearing level in both ears or in one ear at 30 dB hearing level and the other ear at 45 dB hearing level [16]. Different researchers have set their own criteria of 'Pass' for defining hearing impairment. Inserm (National Institute for Health and Medical Research, Paris) in their report Synthesis-2006 have recommended that while diagnosing hearing impairment using BAEP, only threshold ≥40 dB should be taken into account keeping in mind that the measured threshold depends essentially on auditory sensitivities at frequencies of 2–4 kHz [10]. Accordingly cut-off threshold in this study has been set at ≤40 dBnHL and average pure-tone threshold for 1–4 kHz is most accurately predicted by multiplying the BERA threshold by 0.6 [11].

This study identifies a good number of high-risk infants having very high incidence of hearing loss compared to zero incidence of auditory deficit in normal infants. A very high incidence of hearing loss in high risk infants is supported by other researchers also. Duara et al. [17] had detected 17 % hearing loss in high risk infants. Gupta AK [4] found hearing loss in 19.2 % of NICU population of an Indian hospital. Morales et al. [18] found 13 % hearing loss in high risk infants of Mexico. Chadha and Bais [5] found an auditory impairment of 18 % in high risk neonates of New Delhi even keeping cut-off level of 'Pass' at 46 dBHL. Meyer et al. [2] studied infants of 3 months of age by automated ABR and found an incidence of 5 % hearing loss in at-risk infants with 2 % having bilateral hearing loss. Zamani et al. [19] had found 8 % SNHL in this population.

The higher incidence of hearing impairment in this study can be explained in the following way:

Firstly, this study has included the high risk infants at 1 year of age as 50 % cases of deafness appears late in infants having normal birth history [20]; so inclusion of older high risk infants might have influenced the incidence rate.

Secondly, this study comprises of infants from a mediocre socio-economic background where there is malnourishment, poor hygiene concept, lack of proper medical facilities, low literacy rate etc.

Lack of proper medical facilities results in poor antenatal care and frequent home delivery by untrained dais [21]; This causes prolonged labour and increase in number of cases of birth asphyxia (22.99 % in this study) often resulting in hearing loss. Mishra and Kalita [22] have also said that incidence of hearing loss is higher in developing nations due to poor antenatal and neonatal care.

Lastly, as we have already discussed, the choice of auditory loss threshold or technique and the instrument used to identify deficits, influence prevalence variability [10].

In this study, all the parameters are found to be slightly higher in the right ear which may be due to failure of the transducer of the right earphone to produce the same output level as in the left ear which may be a manufacturing defect [23].

Determination of threshold is the mainstay of diagnosis of hearing impairment in children and threshold above 40 dBnHL is predictive of hearing loss (CHL or SNHL or both) as normal newborns usually have a threshold of 30 dBnHL [22]. Absent BAEP signifies severe sensorineural hearing impairment because in cases of conductive hearing loss, threshold usually does not exceed 60 dB as louder intensity stimulus is conducted through skull bones [22].

Salamy et al. [24] had said that subjects with greater threshold in nursery had a greater proportion of ABR abnormalities throughout infancy and early childhood.

Correlation of Different Risk Factors with Hearing Loss

The BERA threshold is very sensitive to arterial blood oxygen content and hypoxia-ischaemia occurring during the pre-, peri- and post-natal period [25]. In addition, middle-ear disorders, typically middle-ear effusion, neonatal meningitis, persistent pulmonary hypertension, ototoxic drugs, hyperbilirubinemia etc. may damage the peripheral auditory system, leading to threshold elevation [25].

In this study, infants showing elevated threshold had risk factors for hearing loss, either singly or in combination. Some of which can be cited here viz. six infants had birth asphyxia, six were low birth weight (LBW) or small for gestational age (SGA), four were exposed to ototoxic drugs, two had sepsis or meningitis, one baby was premature, one had severe hyperbilirubinemia requiring exchange transfusion, three had otitis media etc. One subject having profound deafness (threshold >80 dB) was? Down variant and increased thresholds were also reported in Down syndrome by Widen and associates [26].

Out of twelve factors that were examined by multiple logistic regression with raised BERA threshold, significant correlation was found with (a) Ototoxic drugs (Aminoglycosides), (b) Developmental delay, (c) Cranio-facial abnormality, (d) Microcephaly, (e) CP ± MR and (f) Family history of deafness (Table 3).

Though Gupta et al. [4] found no significant correlation of Aminoglycosides with hearing loss Zamani et al. [19] found hearing loss in infants with a history of using Aminoglycosides along with other risk factors. Aminoglycosides have a blocking action on cholinergic neurons and those present in the central auditory system might be the target of the damage.

Developmental delay, Microcephaly, CP +/MR are the sequela of mainly varying grades of hypoxic-ischaemic encephalopathy or bacterial meningitis or congenital viral infections [27] and high frequency of abnormal ABR is already reported in children with spastic cerebral palsy [22].

Cranio-facial abnormalities include ocular hypertelorism, flat nose, ear atresia etc. Zamani et al. [19] and Meyer et al. [2] also found highly significant correlation of these abnormalities with hearing loss. Because the development of the peripheral auditory system is related intimately to the differentiation of branchial clefts, auditory defects understandably often accompany defects of head and neck [27].

According to Volpe [27] hereditary forms of deafness have accounted for 25–35 % of all cases of deafness and many hereditary syndromes associated with deafness appear later in infancy and childhood.

The statistical association between the risk factors and the hearing loss found in this study establish the fact that risk factors have a definite role in development of hearing loss. But the risk factors may have a synergistic effect [18] as factors like hypoxia, bilirubin, Aminoglycosides, furosemide and hemorrhage alone are not sufficient to cause injury [27]. Volpe [27] also stated the possibility of the combined, additive effect of factors resulting in significant injury. This is more true in children of low birth weight and low gestational age at birth [18].

Factors that were not Tested for Correlation

We had only one case of severe hyperbilirubinemia in exchange zone (who had hearing loss), so this parameter was not tested though elevated bilirubin level is a risk factor for threshold [26] and severe forms of hyperbilirubinemia cause some defects in the cochlea especially in the outer hair cells [19].

We had three cases of otitis media; all three had conductive loss, so this factor was also not tested for correlation for obvious reasons and Mendelson et al. [28] had shown that hearing loss was reversible after the otitis had resolved.

We had three cases of congenital hydrocephalus and one case of acquired hydrocephalus. Of them, two had bilateral hearing loss and one had unilateral loss. Thus there was obvious correlation of hearing loss with hydrocephalus as reported in literature [22] and therefore not tested by regression analysis.

We had one case of congenital hypothyroidism with hearing loss who had an additional risk factor of birth asphyxia and one case of sickle cell trait (AS), but these parameters were not addressed due to paucity of data though they are known to cause alteration in BAEPs [26, 27, 29, 30].

Limitations of this Study

(i) We could not examine 100 % of those infants attending the high risk clinic of our hospital.
(ii) We could not follow them up at regular interval as ours is a cross-sectional and time-locked study.
(iii) Data regarding birth history was taken from the OPD or IPD tickets, much of which was based on verbal accounts of the parents, especially in cases of home-delivered babies. So the records may not be fully authentic.

Conclusion

Detecting a high prevalence of hearing impairment in high risk infants even at around 1 year of age establishes the requirement of a targeted screening of at-risk infants in India as early as possible. Obligatory screening of high risk infants is the first step towards a nationwide universal neonatal hearing screening program as prescribed by the Joint Committee on Infant Hearing [1]. This study intends to initiate public health actions so that all high risk infants in India are screened at the earliest and a national child hearing impairment register is formed.

Key Messages

High risk infants have a persistent risk of hearing loss and there is a definite need of hearing assessment of these infants even as they grow up which might help them develop normal speech by early intervention.

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