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Hearing screening of infants in Neonatal Unit, Hospital Universiti Sains Malaysia using transient evoked otoacoustic emissions

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Abstract

The objective of this prospective study was to report on the prevalence of hearing impairment in the neonatal unit population. From 15 February 2000 to 15 March 2000 and from 15 February 2001 to 15 May 2001, 401 neonates were screened using transient evoked otoacoustic emissions (TEOAE) followed by second-stage screening of those infants who failed the initial test. Eight (2 per cent) infants failed one ear and 23 (5.74 per cent) infants failed both ears, adding up to 7.74 per cent planned for second-stage screening. Five out of 22 infants who came for the follow up failed the screening, resulting in a prevalence of hearing impairment of 1 per cent (95 per cent confidence interval [95% CI]: 0.0–2.0). Craniofacial malformations, very low birth weight, ototoxic medication, stigmata/syndromes associated with hearing loss and hyperbilirubinaemia at the level of exchange tranfusion were identified to be independent significant risk factors for hearing impairment, while poor Apgar scores and mechanical ventilation of more than five days were not. In conclusion, hearing screening in high-risk neonates revealed a total of 1 per cent with hearing loss. The changes in the risk profile indicate improved perinatal handling in a neonatal population at risk for hearing disorders.

Key words: Infant; Newborn; Hearing Loss; Mass Screening; Evoked Otoacoustic Emissions

Introduction

Many believe that language is inherent in each child's maturation, needing only the appropriate environment to trigger the process. However, the child with hearing loss does not automatically develop speech and may be confronted with a life of language difficulties and educational struggles. Because hearing loss in infants is typically a silent and hidden handicap, identification and treatment of the problem is often delayed. Undetected hearing loss can lead to delayed or impaired speech and language development, social and emotional problems, under-achievement and academic failure.

Significant hearing loss is one of the most common major abnormalities present at birth. Hearing impairment ranges from mild to profound. Even mild hearing impairment seriously affects language, speech and cognitive development.[1] Early identification and intervention lead to improved communication skills, which positively affect psychosocial, educational and vocational development.

Permanent hearing impairment occurs with a prevalence of about one to three per 1000 live births.[2–6] The occurrence of hearing loss is considerably greater in certain subpopulations, ranging from one to five per 100 in neonatal intensive care populations and in groups of infants selected by current at-risk registers.[4,7–11] Studies indicate that screening by high-risk registry alone leads to the identification of, at best, only 50–75 per cent of infants with hearing loss.[8,10,12,13]

Even though the current view is that hearing screening should be undertaken on all newborn babies, for certain developing nations and remote areas a lack of resources might limit the development of this programme. Therefore, it is recommended to start with screening at-risk infants and neonatal intensive care unit graduates.

Materials and methods

The objective of this research was to study hearing impairment among infants in the Neonatal Unit, Hospital Universiti Sains Malaysia. The study was a cross-sectional study done in the Neonatal Unit which receives almost all the Neonatal Intensive Care Unit (NICU) graduates who are stable enough

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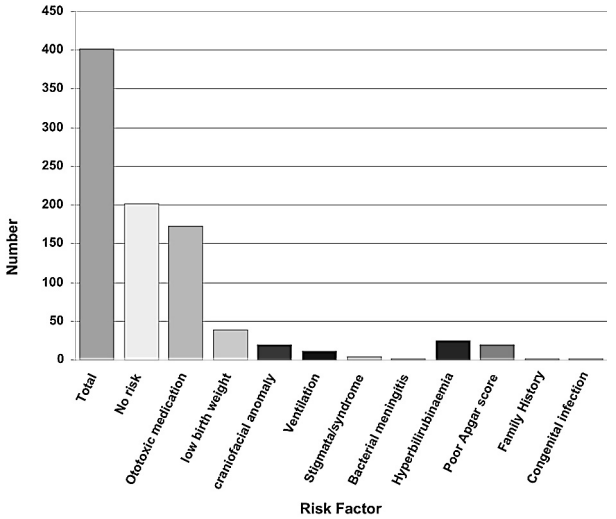

FIG. 1
Risk factors in 401 infants.

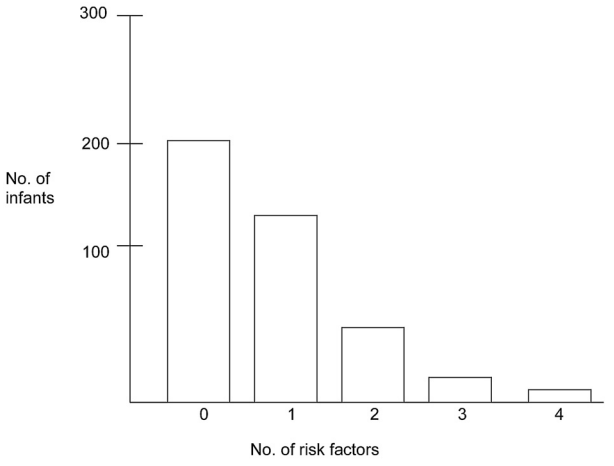

FIG. 2
Number of risk factors per child.

to be transferred out while waiting to be discharged. Apart from the NICU graduates, it also receives the problematic infants, who do not need NICU treatment but have to be admitted for conditions such as mild to moderate neonatal jaundice.

The subjects were selected using simple random sampling. The group tested were all children who had been admitted into the unit during the periods 15 February 2000 to 15 March 2000 and 15 February 2001 to 15 May 2001. Babies who were not consented and who had been admitted for less than 24 hrs were excluded from the study. The sample size was calculated using Epi info version 6. The prevalence used was 5 per cent, based on the Joint Committee on Infant Hearing 1990 Position Statement. On the basis of a 20 per cent drop out, the sample that was to be used was 365. However, during the period of data collection, the total number of admitted patients was 401. The power of study, β, was 80 per cent and the level of significance, α, was 0.05.

An echocheck otoacoustic emission (OAE) screener from Otodynamics Ltd, Hatfield, UK was used in the study. This instrument is based on the ILO88 system of transient evoked otoacoustic emissions (TEOAE) recording. It gives an automatic pass/fail test result concentrating on the main speech frequency band range of 1.6–3.6 kHz to 3 dB bandwidth. All the infants were tested as near to discharge as possible. Most were tested in their bassinets, although a few low birth weight or severely premature infants were tested while still in incubators in the Neonatal Unit itself. The background noise in this ward is not much as it is a low dependency unit, and therefore there are no noisy instruments such as ventilators. The average level of background noise in the ward was 50.9 dB.

All the children were tested on both ears. The infants who passed the screening test were considered to have normal hearing and were discharged. When those undergoing first screening failed the test in at least one ear, short-term audiological follow ups within 3–6 weeks at ORL clinics were offered. At the clinic, both of the ears were retested. The test was done by an audiologist or an audiology technician in a very quiet room. Those infants who passed the second screening were considered to have normal hearing. Tympanometry tests were done on the patients who failed the second screening. If the tympanometry test showed a normal result, the patient was considered to have sensorineural hearing loss. If the tympanometry test showed an abnormal result, the patient was determined as having either conductive deafness or mixed deafness. Both of these categories of patients were referred for further audiological assessment.

Data entry and analysis were done using SPSS Version 10.0 software. Univariate and multivariate analysis were carried out.

Results

During the study period, a total of 401 newborns were screened. Three hundred and eighty-eight (96.8 per cent) of them were Malays, 11 (2.7 per cent) were Chinese and only two (0.5 per cent) were from other races. This probably reflects the actual racial composition of the the population in Kelantan. There were 218 boys (54.4 per cent), 182 girls (45.4 per cent) and one ambiguous. The birth weight of the infants ranged from 0.75 kg to 4.58 kg, with a mean of 2.71 kg (SD = 0.65). The age at testing had a mean of 9.5 days (SD = 8.34). The ages ranged from 2 days to 67 days.

The distribution of risk factors is given in Figure 1. Potentially ototoxic drug medication was administered in 172 cases (42.9 per cent). Thirty-nine (9.7 per cent) had a birth weight of less than 1500 g, 25 had hyperbilirubinaemia at serum levels requiring exchange transfusions, 20 (5 per cent) had postnatal asphyxia (Apgar ≤ 4 at one minute or ≤ 6 at 5 min), 20 (5 per cent) had craniofacial anomalies, 11 (2.74 per cent) had undergone mechanical ventilation lasting five days or longer, and four (1 per cent) had stigmata or other findings associated with a syndrome known to include a sensorineural and/or conductional hearing loss. There were no infants with a history of bacterial meningitis, *in utero* infections or a family history of hearing loss.

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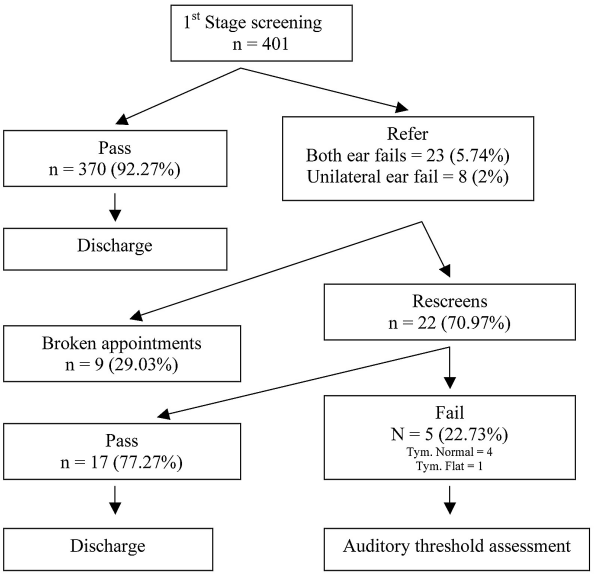

FIG. 3
Flow diagram of neonatal hearing screening and outcome.

Figure 2 shows the number of risk factors per child. Half of the babies in the Neonatal Unit (202, 50.4 per cent) did not have any risk factors for hearing impairment according to the Joint Committee on Infant Hearing. One hundred and thirty-four (33.4 per cent) of the infants had at least one risk factor, 58 (14.5 per cent) had two risk factors, seven (1.7 per cent) had three risk factors and four (1 per cent) of them had four risk factors.

The results of the hearing screening are shown in Figure 3. Of the total sample, 370 (92.27 per cent) infants passed the first-stage screening while 31 (7.73 per cent) failed it in at least one ear. Of the 31 infants that were referred for the second-stage screening, five failed the test in both ears, 17 passed the test in both ears, while nine did not turn up for the examination. One infant (case 5) had signs of middle-ear effusion. This infant might have had either a sensorineural and conductive component or only conductive hearing loss without a sensorineural component. The prevalence of hearing impairment in this study was 1 per cent (95% CI: 0.0–2.0).

Table I shows the association between high-risk infants for hearing loss with hearing impairment. The infants who had high-risk factor(s) were significantly associated with hearing impairment. In this study, all infants who failed the second test had at least two high-risk factors.

On univariate analysis (Table II), craniofacial anomalies, birth weight of less than 1500 g, hyperbilirubinaemia at the level of exchange transfusion, ototoxic medications and stigmata and/or syndromal disorders were identified as significant risk factors for hearing impairment. Mechanical ventilation and poor Apgar scores were not associated with hearing impairment. The odd ratios for ototoxic medications and stigmata/syndromal associated with hearing loss could not be calculated, and these were confirmed by using other univariate analysis (Fisher's exact). These were due to a 0 number and a very low number in one of the cells, respectively.

Simple logistic regression should be followed by multivariate analysis to confirm the validity of each significant variable. Because of a very small number of positive results, multivariate analysis cannot be employed. However, there were no confounding effects involving craniofacial anomaly, very low birth weight or hyperbilirubinaemia. Therefore, the univariate analysis for the variables can be applied. It was not appropriate to test the confounding effects of the other significant variables.

Table III lists cases that have failed the second-stage screening in a synoptical manner. All these infants had at least two high-risk factors for hearing impairment. All the cases had received ototoxic medications. Three of them had birth weights of less than 1500 g. One infant showed craniofacial malformations, one had a syndrome known to cause hearing loss, and one had a history of hyperbilirubinaemia reaching the level of exchange transfusion.

TABLE I
ASSOCIATION BETWEEN HIGH-RISK INFANTS WITH HEARING IMPAIRMENT

High risk	Hearing impaired	Normal	Total
Yes	5	187	192
No	0	200	200
Total	5	387	392

Fisher's exact test, $p = 0.027$. Odd ratios cannot be calculated due to 0 number in one of the cells.

Discussion

In cases where prevention of the underlying cause of functional abnormality is difficult, increased attempts need to be made to identify the abnormality if and when it occurs. Screening procedures form a core component of this process. Early identification, before significant handicap accrues, offers the best opportunity for initiating effective remediation and habilitation. Existing health surveillance arrangements fail to identify all cases of severe to profound hearing loss present at or near birth within the first year of life.

TABLE II
UNIVARIATE ANALYSIS OF RISK FACTORS ASSOCIATED WITH HEARING IMPAIRMENT

	Crude OR		
Variables	OR	95% CI	*P* value
Craniofacial anomalies	15.458	2.412, 99.008	0.014
Birth weight ≤ 1500 g	15.086	2.438, 93.384	0.005
Hyperbilirubinaemia at the level of exchange transfusion	10.551	1.679, 66.310	0.012
Ototoxic medication			0.003
Poor Apgar score	0.003	0.000, 2.5E+30	0.492
Mechanical ventilation ≥ 5 days	0.008	0.000, 1.4E+26	0.630
Stigmata/syndromal			0.023

Odd ratio (OR) for ototoxic medication and stigmata or syndromal baby cannot be calculated due to very low number in most of the cells. CI=confidence interval.

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TABLE III

CLINICAL SYNOPSIS OF FIVE NEONATES WITH HEARING IMPAIRMENT

Case No.	Sex	Clinical synopsis
1	Female	Born at 24 weeks of gestation with a birth weight of 750 g. Had respiratory distress and was ventilated for 25 days. Developed neonatal jaundice with highest serum bilirubin 188 mmol/l at 48 hr of life (exchange transfusion level). Had sepsis and was given multiple antibiotics – gentamicin (3 days), C. penicillin (8 days), piperacillin (5 days), netilmicin (5 days), vancomycin (12 days), amikacin (14 days), imipenam (15 days), amphotericin B (15 days). Also received i.v frusomide.
2	Male	Born at 28 weeks of gestation with a birth weight of 1.18 kg. Diagnosed to have chronic lung disease, clinical sepsis and atypical pneumonia. Received multiple antibiotics - amphotericin B (25 days), imipenam (16 days), erythromicin (12 days) and vancomycin (12 days). He also had been given i.v aminophyline (15 days) and frusomide syrup (35 days).
3	Male	Born at 27 weeks with a birth weight of 1.0 kg. Diagnosed as having congenital pneumonia and was treated with i.v amikacin for 20 days.
4	Female	Born at 36 weeks of gestation with a birth weight of 3.2 kg. Diagnosed as having congenital hydrocephalus (MRI showing hydranencephaly associated with partial Dandy Walker). Ventilated for three days. Received multiple antibiotics - C penicillin (nine days), gentamicin (seven days), piperacillin (six days), netilmicin (five days) and imipenam (five days).
5	Male	A case of Down's syndrome and Hirchprung's disease. He was born at 37 weeks of gestation. Had received i.v gentamicin and i.v C. penicillin for eight days.

Research and clinical experience show that any classification of hearing loss, simply by nature or degree, is certain to inadequately reflect its potential impact on the natural course of social, emotional, intellectual and linguistic development. Any method that improves the overall detection of hearing loss in this population must be considered to be of value.

Despite the fact that the number of babies with hearing loss is high in the NICU and low in the well-infant nursery, and that screening in the NICU yields a proportionately higher number of infants with hearing loss, approximately half of all infants with congenital hearing loss are not graduates of a NICU, nor do they have any known risk factors. This has prompted the argument that, by relying solely on an at-risk register and screening in a NICU, approximately half of all infants born with some degree of hearing loss go unidentified during the neonatal period. However, as screening capacities are limited, hearing assessment for neonates at risk should have priority.

This study tested 401 infants from the Neonatal Unit, Hospital Universiti Sains Malaysia. Five of them were confirmed as having considerable hearing impairment requiring further audiological assessment and management. The prevalence of hearing impairment in this study was 1 per cent. This rate is considerably above the newborn population estimates as a whole (0.1 per cent to 0.4 per cent)[2–6] but is below that reported in other neonatal studies (2 per cent to 5 per cent).[7–11] However, most of these studies are based on intensive care populations. The present study embraced intensive care infants, but also included infants less severely ill.

Case 5 might have either mixed type or pure conductive hearing loss due to otitis media with effusion (OME). Both of these conditions were undifferentiable since OAE can be impeded by pathology of the middle ear. To confirm the diagnosis, further audiological assessment should be done such as auditory brainstem response (ABR). Usually, OME seems to be prevalent in more than 10 per cent of newborns, requiring repeated medical monitoring and treatment.[10]

As expected, by using Fisher's exact test, there was a significant association between the infants in the high-risk group with hearing impairment ($p = 0.027$). Using univariate analysis, craniofacial anomalies, birth weights of less than 1500 g, hyperbilirubinaemia at the level of exchange tranfusion, ototoxic medications and stigmata and/or syndromal disorders were identified as significant risk factors for hearing impairment. Three out of 38 infants who had low birth weight had hearing impairment. The infant with a history of mechanical ventilation had been ventilated for 25 days. The infant who had a craniofacial anomaly was a case of congenital hydrocephalus, while the one who had syndromal disorder was a case of Down's syndrome. All the patients who failed the second stage of screening had received ototoxic medications. Poor Apgar scores and mechanical ventilation for more than five days were not found to be associated with hearing impairment in the present study population.

When compared with the non-high-risk group, infants with craniofacial anomalies and birth weight of less than 1500 g have a 15-fold increased risk, while infants who had a history of hyperbilirubinaemia at the level of exchange transfusion have a 10-fold increased risk for hearing impairment. Odd ratios cannot be measured for ototoxic medications and stigmata/syndromal associated with hearing loss, for reasons that have been mentioned above.

In the present study, out of the 18 infants who had craniofacial anomalies, one had hearing impairment. Jan et al. in their neonatal screening for hearing disorders in infants at risk found that the independent risk factors were hereditary factors, sepsis and/or meningitis and craniofacial malformations.[11] Hess *et al.* did a prospective study on 942 infants in NICU and found that four out of 13 neonates with hearing disorders suffered from craniofacial malformation.[10]

Hyperbilirubinaemia at the level of exchange transfusion has also been demonstrated by several authors in the past to be a risk factor for hearing loss. Salamy *et al.* in their study of 224 very low birth weight infants found that sensorineural hearing loss was statistically associated with higher total bilirubin

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levels ($p < 0.007$).[14] In the present study, the p value was 0.003.

A birth weight of less than 1500 g was noted to significantly increase the risk of neonatal hearing disorders in the present study ($p = 0.005$). This is consistent with the findings of many previous studies.[7,14,15] However, more recent studies done by Hess *et al*. and Jan *et al*. were somewhat contradictory to this result.[10,11] They concluded that their findings were due to improved conditions of perinatal care and overall reduced incidences of complications of prematurity.

Many studies of the factors associated with sensorineural hearing loss (SNHL) in NICU graduates have not found the use of aminoglycosides in the NICU to be a significant predictor of SNHL.[10,11,14–16] Strict monitoring of aminoglycoside serum concentrations and dose adjustments may have contributed to the avoidance of toxic side effects in study infants. In the present study, the author found that the use of aminoglycosides was statistically associated with hearing impairment ($p = 0.003$). This study was consistent with a study that had been done by Bernard[17] who reported a larger incidence of hearing loss in 26 premature infants given gentamicin or tobramycin than in an age-matched non-treated control group. In the present study, it has been noted that four out of five infants who had failed the second test had actually received multiple courses of ototoxic medications, while the fifth infant had received more than five days of intravenous gentamicin. Therefore, it might be speculated that ototoxic medications are only associated with hearing impairment if prolonged or multiple courses of the medications have been administered. However, the author agrees that if treatment with ototoxic drugs has theoretically been excluded from the risk factor catalogue, no infant with hearing loss will have been missed. The author continues to strongly recommend proper monitoring of aminoglycoside serum levels. It should also be kept in mind that aminoglycoside therapy might impair high frequency hearing, which cannot be detected by the methods used in this study.

Mechanical ventilation for more than five days and poor Apgar scores have been demonstrated to be risk factors for hearing loss by several authors in the past.[14,15] However, we were unable to confirm these findings. Both of the variables were not seen to be significant on univariate analysis.

The author found in the present trial that stigmata/syndromal disorders were associated with an increased risk of neonatal hearing disorders. However, the syndromal infant who failed the second test also had signs of middle-ear effusion, as shown by a tympanogram test. Abnormal eustachian tube function in children with Down's syndrome is a predisposing factor for otitis media effusion. Bilgin *et al.* had found that the cochlea in patients with this syndrome is slightly shortened.[18] Therefore, Down's syndrome patients may have both conductive and sensorineural hearing loss.

With the pass/fail boundary set at 30 dBHL, not only were all sensorineural losses identified, but a significant number of children with an increased risk of chronic middle-ear disease were also detected. Watson *et al.* found that 39 per cent of the surviving screen failures had evidence of middle-ear disease, compared with 11 per cent of the pass group.[9] In another study, from a cohort of 1850 infants, White *et al*. found that the prevalence of confirmed hearing loss was 5.95 per 1000 with sensorineural loss and 20.0 per 1000 with recurrent conductive loss.[19] Whatever it is, TEOAE has an advantage of being able to be used as a screening procedure if conductive hearing loss is included as a target condition. This is important because lesser degrees of hearing loss may potentiate co-existing developmental or cognitive delay or impairment.

A significant association between the infants in the high-risk group with hearing impairment shows that the babies in the group must be tested for the problem. However, the author recommends the screening of all special care babies if the centre has enough resources.

- **This study reports the results of hearing screening using transient evoked oto-emissions in a neonatal unit**
- **Out of 401 neonates tested, 1 per cent had hearing impairment confirmed after second-stage screening**
- **Craniofacial malformations, very low birth weight, ototoxic medication, syndromal abnormality and hyperbilirubinaemia are seen to be significant risk factors**

Conclusion

The present study confirms that there is a significant association between neonates who have high-risk factors for hearing impairment with hearing loss. The prevalence of hearing impairment of 1 per cent shows that it is worth doing hearing screening in the neonatal unit. The present data indicate a change in risk factors for neonatal hearing disorders. Craniofacial malformation, very low birth weight, ototoxic medications, stigmata/syndromes associated with hearing loss and hyperbilirubinaemia at the level of exchange transfusion were seen to be significant factors associated with hearing impairment. In contrast, mechanical ventilation and poor Apgar scores were not seen to be independent risk factors for pathological screening results in our study population. This change in the risk profile for neonatal hearing impairment in a high-risk population is speculated to be related to changes in perinatal and neonatal care.

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