The Journal of Laryngology & Otology (2007), ***121***, *639–643.*

doi:10.1017/S0022215106004403
Printed in the United Kingdom
First published online 20 November 2006

Main Article

An alternative strategy for universal infant hearing screening in tertiary hospitals with a high delivery rate, within a developing country, using transient evoked oto-acoustic emissions and brainstem evoked response audiometry

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Abstract

Objective: To formulate an alternative strategy for universal infants hearing screening in an Indian tertiary referral hospital with a high delivery rate, which could be extended to similar situations in other developing countries. The system should be able to diagnose, in a timely fashion, all infants with severe and profound hearing losses.

Methods: One thousand newborn were randomly selected. All underwent testing with transient evoked oto-acoustic emissions (TEOAE) in the first 48 hours of life. All TEOAE failures were followed up and repeat tests were performed at three weeks, three months and six months of age. Infants with acceptable TEOAE results at any of the four ages were discharged from the study. Infants with unacceptable TEOAE results at all the four ages underwent brainstem evoked response audiometry and oto-endoscopy. The 'pass rate' for TEOAE testing was calculated for all four ages. The time taken to perform TEOAE and brainstem evoked response audiometry was recorded for all subjects. These recordings were statistically analysed to find the most suitable strategy for universal hearing screening in our hospital.

Results: The pass rate for TEOAE was 79.0 per cent at $\leq$48 hours, 85.0 per cent at three weeks, 97.0 per cent at three months and 98.0 per cent at six months. The average time taken to perform the test was 12 minutes for TEOAE and 27 minutes for brainstem evoked response audiometry. Obstructed and collapsed external auditory canals were the two factors that significantly affected the specificity of TEOAE in infants $\leq$48 hours old.

Conclusion: The concept of screening all neonates within the first 48 hours of life is impractical because the specificity of TEOAE is lowest at that age. Many false positive results are generated, such that a larger number must undergo brainstem evoked response audiometry, wasting time and resources. This can easily be avoided by delaying TEOAE screening until three months of age, when it has a substantially lower false positive outcome. We expect that implementation of this alternative strategy in our hospital will maximise the benefits of such a programme.

Key words: Deafness; Mass Screening; Audiometry, Evoked Response; Developing Countries

Introduction

Early detection, diagnosis and rehabilitation of hearing impairment are necessary for the development of appropriate speech, language and cognitive abilities in hearing impaired children.[1] The ever-growing number of candidates for such hearing screening, especially in a country with a very high birth rate such as India, generate the need for a infants screening policy for early detection of hearing impairment which is reliable but also feasible. There are certain high risk factors associated with neonatal hearing impairment, as stated in 1994 by the joint committee on infant hearing.[2] In a 1991 position statement, this same committee recommended that all neonates with even a single high risk factor should receive audiological screening and rehabilitation at the earliest possible opportunity. Similar recommendations have also been issued by the American speech language hearing association (1989).[3] However, many studies suggest that nearly half of hearing impaired children fail to be identified by the joint committee high risk register.[4,5]

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Accepted for publication: 10 August 2006.

At the National Institutes of Health 1993 development conference on early identification of hearing impairment in infants and young children, the consensus panel concluded that 'all' infants should be screened for hearing impairment and that this should be done within the first three months of life, and preferably before post-natal discharge (i.e. within the first 48 hours of life).[6] This panel also urged that further research be carried out to evaluate the validity and reliability of screening instruments and to compare screening procedures. In our study, we aimed to evaluate such a universal screening policy when applied to an Indian tertiary hospital, and subsequently formulated an alternative, more feasible strategy.

Study design

This study included 1000 infants delivered at the Smt Sucheta Kriplani Hospital, New Delhi, (2000 ears) between January 2001 and April 2003. The study sample was randomly selected without applying any high risk selection criterion. The neonates were selected from the obstetric ward, newborn nursery, neonatal ward and neonatal intensive care unit of our hospital. The transient evoked oto-acoustic emissions test (TEOAE) was used as the screening tool, and brainstem evoked response audiometry was the 'gold standard' diagnostic tool. The tests were carried out on sleeping neonates in quiet surroundings. In our study, the noise level during TEOAE testing varied from 43.5 to 47.0 dBSPL (median, 44.0 dBSPL). Informed consent was obtained before testing.

All neonates underwent TEOAE within the first 48 hours of life. These recordings were performed using ILO V5 system (Otodynamics Ltd, Hatfield, Herts, UK) using a TEOAE probe delivering quick-screen TEOAE stimuli in the form of clicks. The criteria used for 'passing' a neonate regarding TEOAE were (1) reproducibility of response by at least 50 per cent, or (2) response spectrum containing 3 dB more power than the noise spectrum in three of the frequencies (1.0, 1.5, 2.0, 3.0 or 4.0 kHz).

Brainstem evoked response audiometry was performed in all infants 'failing' the TEOAE. Brainstem evoked response audiometry was performed using Neuro-otometrie-octavus system (Hortmann, Metzingen Germany) – brainstem evoked response audiometry soft, which delivered 2000 broadband clicks. The presence of wave V at 60 dBnHL was used as the pass criteria, as we aimed to detect infants with severe and profound hearing losses who required immediate rehabilitation in the form of a hearing aid or implant.

All initial TEOAE failures (subgroup one) were followed up with repeat TEOAE at three weeks, three months and six months of age. Infants who passed their TEOAE at any of these later ages were discharged from the study. Those who failed (subgroups two, three and four) underwent brainstem evoked response audiometry (Figure 1). Although it is possible that some of the neonates discharged from the study would have failed subsequent

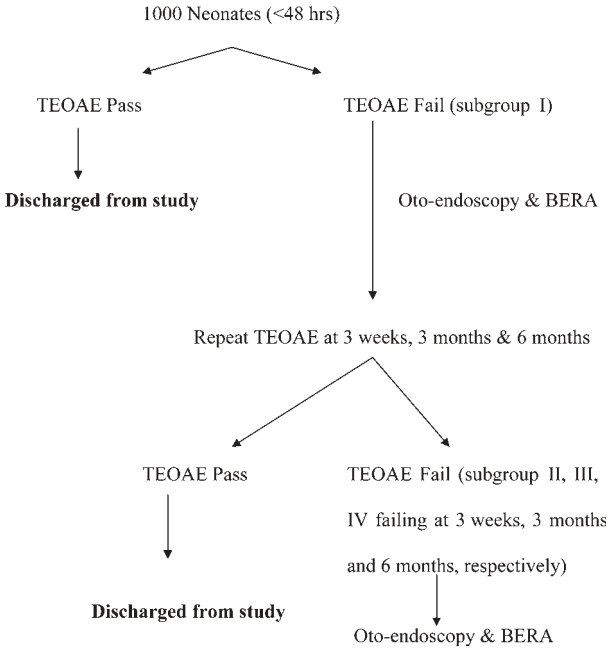

FIG. 1

Study design. TEOAE = transient evoked oto-acoustic emissions test; BERA = brainstem evoked response audiometry

TEOAE testing, further follow up with repeat TEOAE was not feasible. Oto-endoscopy was performed in TEOAE failures in all four age groups, and TEOAE was repeated after suction cleaning of obstructed canals or using a long-tipped probe in the case of collapsed canals.

The pass rate and specificity of the transient evoked oto-acoustic emissions test (TEOAE) was calculated for all four ages, using brainstem evoked response audiometry as the gold standard. The time taken to perform TEOAE and brainstem evoked response audiometry was recorded for all subjects. These recordings were then applied to the hospital statistics and analysed to determine the ideal strategy for universal infants hearing screening in a tertiary hospital with very high delivery rate, within a developing country.

The resultant strategy does not diagnose moderate sensorineural hearing loss or mild to moderate conductive losses, as seen in cases of otitis media with effusion. However, infants who failed TEOAE but who had brainstem evoked response audiometry thresholds between 60 and 40 dB were followed up and subjected to repeat brainstem evoked response audiometry and further diagnostic investigation.

Results

Following the initial TEOAE recordings in 1000 neonates $\leq$48 hours old, the pass rate was 79.0 per cent (1580/2000 ears). All the TEOAE failures (subgroup one) underwent brainstem evoked response audiometry, following which the hearing pass rate improved to 95.5 per cent (1910/2000 ears). Oto-endoscopy of this sub-group revealed external auditory canal obstruction by lanugo or vernix in 43 per cent of ears (180/420 ears). In another

https://doi.org/10.1017/S0022215106004403 Published online by Cambridge University Press

12 per cent of ears (50/420 ears), the canal was found to be collapsed. No ear cleaning was performed initially, as such treatment would disqualify the intervention from consideration as a screening tool.

Neonates in subgroup one underwent repeat TEOAE at three weeks of age, at which time the pass rate was 85.0 per cent (1700/2000 ears). The TEOAE failures at this stage (subgroup two) underwent brainstem evoked response audiometry, resulting in a hearing pass rate of 97 per cent (1940/2000 ears). The same ears underwent oto-endoscopy; 17 per cent (51/300 ears) were found to be blocked partially by debris and 3 per cent (9/300 ears) by a collapsible canal.

These subgroup two neonates were further followed up with repeat transient evoked oto-acoustic emissions tests (TEOAEs) at three months of age. There was significant improvement in the pass rate, from 85.0 per cent at three weeks (1700/2000 ears) to 97.0 per cent at three months (1940/2000 ears). The neonates who still failed this TEOAE (subgroup three) were found at otoscopy to have blocked external auditory canals in 3.3 per cent (2/60 ears) and collapsed canals in 1.6 per cent (1/60 ears). Brainstem evoked response audiometry was performed in all subgroup three neonates, and the hearing pass rate improved further to 98.5 per cent (1970/2000 ears).

The subgroup three neonates were followed up with repeat TEOAE at six months of age. The pass rate was only marginally improved, by 1 per cent, compared with that seen at three months. The TEOAE failures at this stage (subgroup four) underwent brainstem evoked response audiometry, and the hearing pass rate improved again to 99.5 per cent (1990/2000 ears). Otoscopic evaluation of this sub-group did not show any significant findings.

The average time taken to perform the tests was 12 minutes for TEOAE and 27 minutes for brainstem evoked response audiometry.

Discussion

Opinions differ on the age at which screening tools such as TEOAE and brainstem evoked response audiometry should be applied to infants. The National Institutes of Health consensus statement of 1993 recommends that screening take place preferably before the discharge of the infant from hospital.[6] However, in their 1994 study, Bess and Paradise state that most newborns are usually discharged from hospital within 24–48 hours, the age at which the specificity of TEOAE is lowest.[7] Therefore, to undertake TEOAE testing on neonates before hospital discharge is to invite an even larger number of false positive results than would otherwise occur. Kok *et al*. (1993) studied TEOAE in 1036 ears of healthy neonates and concluded that TEOAE testing should not be done before the age of four days, as the amniotic fluid present in the middle ear after birth affects the TEOAE result and takes a few days to clear.[8] Alberti *et al*. (1995) studied various aspects of early identification of hearing loss in children. They advised that, for high risk infants, a pre-discharge risk assessment along with a hearing test at the age of four months was the most acceptable method of early identification of hearing loss.[9]

In this study, the pass rate for the transient evoked oto-acoustic emissions test (TEOAE) improved significantly as the infant's age increased. The TEOAE pass rate was 79.0 per cent at ≤48 hours, 85.0 per cent at three weeks, 97.0 per cent at three months and 98.0 per cent at six months. The specificity of TEOAE for detecting hearing impairment, calculated using brainstem evoked response audiometry as the gold standard, was lowest in the first 48 hours of life. Specificity greatly improved at three months of age, but thereafter reached a plateau until six months of age.

These observations led us to consider the ideal age for application of these screening tools. The 1993 National Institutes of Health consensus statement stated that screening for hearing impairment should be performed within the first three months of life for all infants, and preferably before their discharge from hospital. Most neonates are discharged within the first 24–48 hours of life, the age at which TEOAE gives the highest number of false positive results.

In our view, screening for hearing impairment should definitely not be performed within the first 48 hours and should be deferred until three months of age. This approach will reduce the number of false positive cases, which would otherwise prompt much unnecessary investigation and undue parental concern.

Also, rehabilitative measures usually commence by the age of six months; therefore, little is achieved by diagnosing the problem earlier. A review of literature suggests that the first six months of infancy are crucial for hearing impaired children. The language scores of hearing impaired children rehabilitated in a timely fashion are significantly better than those of children diagnosed later in life.[10–12] Similar views have been expressed by other authors.[9]

- **Universal hearing screening is the ideal strategy for early detection and appropriate rehabilitation of hearing impaired children**
- **This study was primarily aimed at developing an alternative strategy for universal neonatal screening to detect severe and profound hearing loss, in a tertiary hospital with a very high delivery rate, within a developing country, using two tools: transient evoked oto-acoustic emissions and brainstem evoked response audiometry**
- **The delayed screening policy suggested makes the goal of universal hearing screening feasible in such a clinical situation**
- **This approach would maximise the benefits and cost-effectiveness of a universal neonatal hearing screening programme in developing countries with high birth rate and limited resources**

https://doi.org/10.1017/S0022215106004403 Published online by Cambridge University Press

TABLE I

EFFECT OF AGE ON UNIVERSAL HEARING SCREENING PROGRAMME IMPLEMENTATION IN 1000 SUBJECTS

	Age			
	≤48 h	3 weeks	3 months	6 months
TEOAE pass rate (%)	79	85	95	98
Infants undergoing BERA (*n*)	210	150	50	20
Subjects requiring BERA per year* (*n*)	3941	2815	938	375
Staff hours required to implement programme per year	5526	5036	4175	3921

*Based on 18 765 births in 2003. TEOAE = transient evoked oto-acoustic emissions test; BERA = brainstem evoked response audiometry

The only drawback of this approach is that some high risk infants may not be brought back for further screening. The dropout rates at the beginning of our study were around 20 per cent, and these children were not included in the study. However, in the latter part of the study, the coupling of hearing screening with a universal immunisation programme enhanced coverage to almost 100 per cent.

Neonatal hearing screening with the transient evoked oto-acoustic emissions test (TEOAE) generated an extra pool of subjects requiring brainstem evoked response audiometry (Table I). To implement a universal infants screening programme in our hospital, we would need to screen more than 18 000 infants every year (18 765 infants were delivered in our hospital in 2003). If the screening programme was implemented at ≤48 hours, 5526 staff hours would be required to test all infants. If the screening programme was applied at three months of age, the time required would decrease to 4175 staff hours. There is a great leap in the TEOAE pass rate at three months of age, and, hence, fewer infants requiring brainstem evoked response audiometry. Application of universal neonatal hearing screening within the ≤48 hours age group would represent a distant goal for our hospital because of limited staff and resources. However, the delayed screening strategy suggested above brings this distant goal well within our reach (Figure 2). This alternative strategy of delayed, but still universal, screening would maximise the benefits of such a programme in our hospital.

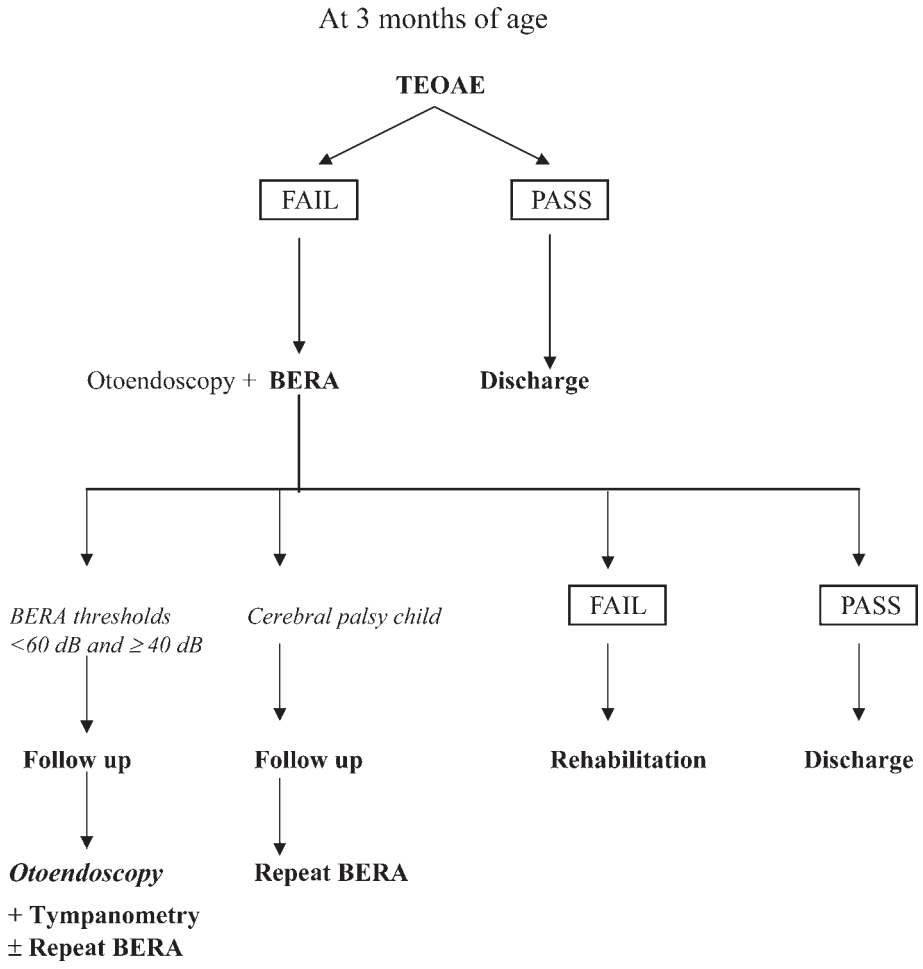

FIG. 2

Proposed universal hearing screening algorithm. TEOAE = transient evoked oto-acoustic emissions; BERA = brainstem evoked response audiometry

https://doi.org/10.1017/S0022215106004403 Published online by Cambridge University Press

Notably, we have not come across any literature suggesting that the delaying of screening for other illness modalities would be helpful.

As regards this screening protocol, two subsets of the paediatric population need special mention. Infants who fail TEOAE but who have brainstem evoked response audiometry thresholds between 60 and 40 dB need to be followed up. Their further diagnostic investigation must include tympanometry to rule out otitis media with effusion, ensuring effective management of this condition. If tympanometry findings are normal, brainstem evoked response audiometry should be repeated before six months to rule out progressive hearing loss. Secondly, the special issues related to hearing impairment in infants with neurological problems (e.g. cerebral palsy) have not been addressed by this study. However, it is reasonable to suggest that such children would require repeated hearing assessment over a long period.

We believe that such hearing screening, if coupled with administration of the third dose of the diphtheria–pertussis–tetanus vaccine and oral polio vaccine at 14 weeks, would constitute an effective universal neonatal screening strategy. However, it is essential that parents are counselled, explaining the need for hearing screening along with a suggested schedule, before the infant's discharge from hospital.

References

1 Joint Committee on Infant Hearing. Joint Committee on Infant Hearing: 1990 position statement. *American Speech Language Hearing Association* 1991;**33**(suppl 5): 3–6
2 Joint Committee on Infant Hearing. Joint Committee on Infant Hearing:1994 position statement. *American Speech Language Hearing Association* 1994;**36**:38–41
3 American Speech Language Hearing Association. Audiologic screening of newborn infants who are at risk for hearing impairment. *ASHA* NML ID: 0370563 1989;**31**: 39–92
4 Kramer SI, Vertes DR, Condon M. Auditory brainstem responses and clinical follow-up of high risk infants. *Pediatrics* 1989;**83**:385–92
5 Watkin PM, Baldwin M, McEnery G. Neonatal at-risk screening and the identification of deafness. *Arch Dis Child* 1991;**66**:1130–5
6 National Institutes of Health. *Early Identification of Hearing Impairment in Infants and Young Children. NIH consensus statement*. Bethesda MD: National Institutes of Health, PMID: 8401641 1993;**11**:1–15
7 Bess FH, Paradise JL. Universal screening for infant hearing impairment: not simple, not risk-free, not necessarily beneficial and not presently justified. *Pediatrics* 1994;**93**:330–4
8 Kok MR, van Zanten GA, Brocaar MP, Wallenburg HCS. Click evoked oto-acoustic emissions (EOAEs) in 1036 ears of healthy newborns. *Audiology* 1993;**32**:213–24
9 Alberti PW, Hyde ML, Riko K, Corbin H, Fitzhardinge PM. Issues in early identification of hearing loss. *Laryngoscope* 1985;**95**:373–81
10 Apuzzo ML, Yoshinaga-Itano C. Early identification of infants with significant hearing loss and the Minnesota Child Development Inventory. *Semin Hear* 1995; **16**:124–37
11 Robinshaw HM. Early intervention for hearing impairment: differences in the timing of communicative and linguistic development. *Br J Audiol* 1995;**29**:315–34
12 Yoshinaga-Itano C, Sedey AL, Coulter DK, Mehl AL. Language of early- and later-identified children with hearing loss. *Pediatrics* 1998;**102**:1161–71

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Dr N N Mathur takes responsibility for the integrity of the content of the paper.
Competing interests: None declared