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Original Research Article

HEARING SCREENING OUTCOMES AND RISK INDICATORS IN HIGH-RISK NEWBORNS: A HOSPITAL-BASED OBSERVATIONAL STUDY FROM NORTH KERALA

Nasna C P[1], Shahla Vadakkethil[1], Ashna Kallingal Akbar[2]

[1]*Assistant Professor, Department of Physiology, MES Medical College, Perinthalmanna, Kerala, India.*
[2]*Associate Professor, Department of Physiology, MES Medical College, Perinthalmanna, Kerala, India*

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Corresponding Author:
Dr. Nasna C P,
Assistant Professor, Department of Physiology, MES Medical College, Perinthalmanna, Malappuram District, Kerala, India.
Email: nasnashafi2014@gmail.com

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ABSTRACT

Background: Newborn hearing screening only works if infants who fail the screen reach diagnostic testing in time. Data from Kerala's public tertiary hospitals are limited. The aim is to describe hearing screening outcomes and the pattern of recorded risk indicators among high-risk newborns at a government tertiary care centre in North Kerala.

Materials and Methods: We enrolled 556 high-risk newborns at Government Medical College, Kozhikode, between February and December 2021. Eligibility was based on an 11-item checklist adapted from the high-risk register of the All India Institute of Speech and Hearing. Each ear was screened with distortion product otoacoustic emissions (DPOAE) before discharge. Infants who were referred were rescreened at 6 weeks, 3 months and 6 months, and those referred at all four screens underwent diagnostic auditory brainstem response (ABR) testing.

Results: Referral fell from 115 infants (20.7%) at the first screen to 24, 8 and 5 at successive rescreens. All five infants referred at the final screen had abnormal ABR: three had bilateral moderate sensorineural hearing loss, one had unilateral mild sensorineural loss and one had auditory neuropathy spectrum disorder after exchange transfusion for hyperbilirubinaemia. This gives a detection yield of at least 9 per 1,000 enrolled infants (5/556; 0.90%). Prematurity was the commonest risk indicator (369/556; 66.4%).

Conclusion: An OAE-based screening pathway identified five infants with hearing disorders, but it cannot detect neural hearing loss in infants who pass. Adding automated ABR for NICU graduates, referring infants for diagnostic testing earlier, and keeping infant-level follow-up records would bring the programme closer to the 1-3-6 benchmark.

Keywords: Auditory brainstem response; Auditory neuropathy; Hearing loss; Neonatal screening; Otoacoustic emissions; Premature infant.

INTRODUCTION

A child learns to speak by hearing speech. This is something we repeat to every batch of first-year students when teaching the special senses, and it remains the simplest argument for screening newborn hearing. The central auditory pathway is not fully formed at birth; its connections are refined over the first few months by the sound that actually reaches it. When the cochlea or the eighth nerve does not deliver that input, the consequences are usually noticed late (delayed speech at two, poor school performance at five) by which time the best period for intervention has passed. WHO has placed ear and hearing care among the essential services of a health system.[1] Evidence that timing matters is old. In the cohort described by Yoshinaga-Itano et al., children identified before six months of age had better language scores than those identified afterwards.[2] JCIH (the Joint Committee on Infant Hearing) puts the targets as 1-3-6, meaning screening by one month, diagnosis by three months and intervention by

six, and asks programmes that already meet these to try for 1-2-3.[3]

Which test is used matters more than is sometimes appreciated, because OAE and ABR do not examine the same structures [Figure 1]. An otoacoustic emission is generated by the outer hair cells, whose electromotility amplifies the travelling wave in the cochlea. If an emission is recorded, the external ear, middle ear and outer hair cells are working. That is all it says. ABR is a far-field record of synchronous neural discharge from the auditory nerve (wave I) up to the lateral lemniscus and inferior colliculus (wave V). In auditory neuropathy the outer hair cells are spared and the defect is beyond them, so the emission is normal while the ABR is not. JCIH accordingly recommends automated ABR, not OAE alone, for babies discharged from a neonatal intensive care unit (NICU).[3]

Congenital deafness is one of the conditions screened for under India's Rashtriya Bal Swasthya Karyakram (RBSK).[4] How hospitals actually go about it varies a good deal from place to place.[5] Indian hospital-based studies have reported hearing impairment, or persistently abnormal ABR, in about 2% to 6% of high-risk infants, the figure depending on the selection criteria and tests used.[6,7] From Kerala, Paul's account of the Cochin centralised facility showed that OAE screening linked to ABR could be organised at scale.[8] There is comparatively little published from the government medical colleges in the Malabar region, although these hospitals look after a large number of the region's preterm and sick newborns.

Our aim was to describe the hearing screening outcomes of high-risk newborns at Government Medical College, Kozhikode, and the risk indicators recorded in them.

MATERIALS AND METHODS

Study design and setting: This was a hospital-based observational study with serial screening. It was done at the Institute of Maternal and Child Health, Government Medical College, Kozhikode, and the regional hearing screening centre attached to it. Most high-risk deliveries from the northern districts of Kerala are referred to this institute. Babies were recruited between February and December 2021 (that is, after ethics clearance); those recruited in the last months of 2021 were followed up into 2022.

Participants: Newborns delivered in the institute were eligible if they had one or more indicators from an 11-item checklist, which we adapted from the AIISH (All India Institute of Speech and Hearing, Mysuru) high-risk register.[9] Its items were family history of permanent childhood hearing loss; parental consanguinity; maternal infections and medications during pregnancy; prolonged maternal hospitalisation before delivery; prematurity (below 37 completed weeks); delayed birth cry; birth weight below 1,500 g; hyperbilirubinemia severe enough to need exchange transfusion; a low Apgar score (0-4 at one minute or 0-6 at five minutes); and craniofacial anomalies [Table 2]. Several indicators frequently coexisted in the same baby.

Babies were not enrolled if a parent declined written consent, if there were signs of active ear infection, if they had been referred in from another hospital, or if they were too unwell to be shifted for screening.

Sample size: Sample size was estimated for a single proportion using $n = Z2pq/d2$, taking Z as 2 (approximating 1.96 for 95% confidence), which reduces to $n = 4pq/d2$. Indian hospital studies of high-risk neonates have reported hearing impairment, or persistently abnormal screening and ABR results, in roughly 2% to 6% of infants.[6,7] We set the expected proportion (p) at 5.9%, close to the upper end of this range. This was a deliberate choice. For proportions well below 50%, the product pq, and hence the required sample, increases as p rises; an estimate taken from the upper end of the published range therefore errs on the side of a larger sample. With q = 94.1% and an absolute precision (d) of 2 percentage points, the calculation gave $4 \times 5.9 \times 94.1 / 22 = 555.2$, which was rounded up to 556 infants.

Hearing screening and diagnostic assessment: Both ears of each infant were screened with an Interacoustics Titan DPOAE screener before discharge. Testing was done during natural sleep or quiet rest, with the baby held on the parent's or guardian's lap. Infants who were referred in either ear were recalled for repeat screening at 6 weeks, 3 months and 6 months. Infants who were still referred at the fourth screen underwent diagnostic ABR. Under the study protocol, infants who passed DPOAE, including NICU graduates, did not have automated or diagnostic ABR.

Type and severity of hearing loss were classified from the diagnostic audiological findings. Auditory neuropathy spectrum disorder (ANSD) was diagnosed when ABR showed absent or markedly dyssynchronous neural responses at high stimulus levels together with a cochlear microphonic that reversed with stimulus polarity (condensation versus rarefaction). This pattern shows that outer hair cells are working but neural transmission is not.

Outcomes and statistical analysis: The infant was the unit of analysis. An infant with hearing loss in one or both ears was counted once. The main outcome was the number of infants with a hearing disorder confirmed on ABR. We expressed it as a detection yield over all 556 enrolled infants. Because infants who passed DPOAE did not have ABR, and some infants did not complete follow-up, this yield is a minimum figure and not a prevalence.

Categorical data are presented as counts and percentages, with 556 as the denominator for risk indicators. These percentages add up to more than 100% because infants could have more than one indicator. With only five affected infants, we did not test associations between individual risk indicators and hearing loss, and we did not estimate sensitivity or specificity.

Ethics: The Institutional Ethics Committee, Government Medical College, Kozhikode, approved the study (IEC-GMCKKD/RP2021/IEC/26, dated 16 February 2021). Written informed consent was obtained from a parent or guardian of every infant.

RESULTS

Participants and screening flow: Of the 556 high-risk infants enrolled, 284 (51.1%) were boys and 272 (48.9%) were girls (Table 1). At the first pre-discharge screen, 115 infants (20.7%) were referred. The number still referred fell to 24 at six weeks, 8 at three months and 5 at six months. All five infants who were referred at the six-month screen had abnormal results on diagnostic ABR [Figure 2].

Our follow-up records did not consistently track, for every infant, whether a later screen was a pass or a missed visit. We were therefore unable to build a complete-case denominator for the infants who were rescreened.

Risk indicators: Prematurity was the commonest risk indicator, recorded in 369 infants (66.4%). The next most frequent were delayed birth cry in 128 (23.0%), birth weight below 1,500 g in 125 (22.5%) and a low Apgar score in 77 (13.8%) [Table 2]. In total, 794 risk indicators were recorded among the 556 infants. Many infants had more than one.

Hearing outcomes: Five infants had a hearing disorder confirmed on ABR, giving a detection yield of 0.90% (9.0 per 1,000 enrolled infants). Four were girls and one was a boy. Three had bilateral moderate sensorineural hearing loss, one had unilateral mild sensorineural hearing loss and one had ANSD [Table 3]. The infant with ANSD had undergone exchange transfusion for neonatal hyperbilirubinemia.

Two of the five affected infants were preterm. One of them also had a birth weight below 1,500 g and a delayed birth cry. Of the remaining infants, one had parental consanguinity and one had a craniofacial anomaly.

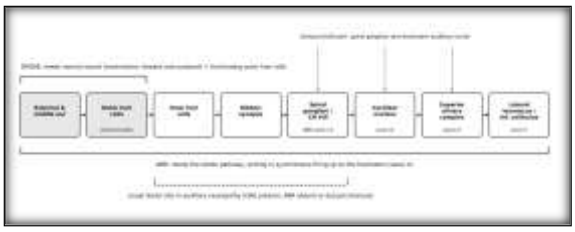

Figure 1: What each screening test examines along the auditory pathway.

Table 1: Enrolment and documented hearing outcomes (N = 556)

Characteristic	n	%
High-risk infants enrolled	556	100.0
Boys	284	51.1
Girls	272	48.9
Referred at first (pre-discharge) DPOAE	115	20.7
Referred at 6-week rescreen	24	4.3
Referred at 3-month rescreen	8	1.4
Referred at 6-month rescreen	5	0.9
Hearing disorder confirmed on ABR	5	0.9

Percentages use all 556 enrolled infants as the denominator. The detection yield is a minimum figure and not a prevalence, because infants who passed DPOAE did not have ABR and follow-up was incomplete. DPOAE, distortion product otoacoustic emissions; ABR, auditory brainstem response.

Table 2: Recorded risk indicators among enrolled infants (N = 556)

Risk indicator	n	%
Prematurity (<37 completed weeks)	369	66.4
Delayed birth cry	128	23.0
Birth weight <1,500 g	125	22.5
Apgar 0-4 at 1 min or 0-6 at 5 min	77	13.8
Maternal infection during pregnancy*	30	5.4
Family history of permanent childhood sensorineural hearing loss	16	2.9
Prolonged maternal hospitalisation before delivery	16	2.9
Parental consanguinity	14	2.5
Craniofacial anomaly, including pinna or ear-canal abnormality	7	1.3
Maternal ototoxic medication during pregnancy	6	1.1
Hyperbilirubinaemia requiring exchange transfusion	6	1.1

Indicators overlap: there were 794 indicators among 556 infants. *Measles, mumps, varicella, herpes, syphilis, cytomegalovirus, rubella or toxoplasmosis.

Table 3: Diagnoses in the five affected infants

Diagnosis	n	% of cases
Bilateral moderate sensorineural hearing loss	3	60.0
Unilateral mild sensorineural hearing loss	1	20.0
Auditory neuropathy spectrum disorder*	1	20.0
Total	5	100.0

*Infant had undergone exchange transfusion for hyperbilirubinaemia. ABR showed dyssynchronous neural responses with a polarity-reversing cochlear microphonic. Laterality was not recorded.

A DPOAE response depends on normal sound transmission through the external and middle ear in both directions and on functioning outer hair cells (shaded). The ABR needs the whole pathway, with synchronous neural firing up to the lateral lemniscus and inferior colliculus (wave V). In auditory neuropathy the lesion usually lies between the inner hair cells and the auditory nerve, so OAE may be normal while the ABR is absent or dyssynchronous. Unbound bilirubin tends to injure the spiral ganglion and the brainstem auditory nuclei. CN VIII, vestibulocochlear nerve; DPOAE, distortion product otoacoustic emissions; ABR, auditory brainstem response.



Figure 2: Flow of the 556 enrolled high-risk infants through serial DPOAE screening and diagnostic ABR.

DISCUSSION

In this cohort of 556 high-risk newborns from a government tertiary hospital in North Kerala, serial DPOAE screening followed by diagnostic ABR identified five infants with hearing disorders: four with sensorineural loss and one with auditory neuropathy. This yield of about 9 per 1,000 is a minimum figure. Infants who passed OAE were never tested with ABR, and some infants did not complete follow-up. Neither a pass nor a missed visit tells us that an infant's hearing is normal.

Why did so many infants fail the first screen?

One in five infants (20.7%) was referred at the first screen, but very few were still referred at later visits. This pattern is typical of pre-discharge OAE screening. Vignesh and colleagues found a similar DPOAE referral rate of 22.1% in Chennai.[10] The explanation is physiological. A DPOAE has to travel twice through the middle ear: the stimulus tones go inward to the cochlea, and the emission produced by the outer hair cells comes back out to the probe microphone. In the first days of life, vernix and debris in the ear canal and residual fluid and mesenchyme in the middle ear damp this two-way transmission. The emission may then be too weak to record even though the cochlea is normal. As the middle ear clears over the following weeks, most of these infants pass. A high initial referral rate therefore mostly reflects transient conductive factors and not cochlear disease. Even so, each extra rescreen visit is one more opportunity for a family to drop out. Where automated ABR has been added as a second step before discharge, referral rates have come down considerably.[10]

Comparison with other Indian studies

Our yield is lower than most Indian reports, though comparisons need care because no two centres select or test babies the same way. Nagapoornima et al. (Bengaluru) found about 10.8 per 1,000 at-risk infants to be hearing impaired.[11] In Kalaburagi, Siddique et al. used TEOAE together with automated ABR in 327 high-risk neonates; 2% had bilateral severe sensorineural loss.[6] Gulati et al. in Delhi did diagnostic ABR on all preterm babies of 34 weeks or less irrespective of OAE (a design we could not follow) and found sensorineural loss in 18.6%. Over half of those had an auditory neuropathy profile.[12] Hille et al. reported 3.2% in Dutch NICU infants who were very preterm or of extremely low birth weight, screened by automated ABR.[13]

We think two things explain the difference. One is our checklist, which admitted every baby below 37 weeks; many were late preterm and not at particularly high risk. The other is the OAE-first pathway. A baby with a neural hearing loss who passed OAE had no way of being picked up. What we report, then, is the number of cases that this particular pathway can confirm. The true burden in high-risk newborns is likely higher.

Auditory neuropathy: what OAE cannot see

The baby with ANSD is worth discussing at some length, because the case shows exactly where OAE screening fails [Figure 1]. In ANSD, outer hair cell function is generally preserved; so the emissions are present, and so is the cochlear microphonic. The lesion is further along: at the inner hair cell, its ribbon synapse, the spiral ganglion or the nerve. Firing becomes desynchronised. Since every wave of the ABR depends on many fibres firing together, the response is lost or grossly distorted. Our patient fitted this description well (dyssynchronous neural responses, with a cochlear microphonic that inverted when stimulus polarity was reversed).

Bilirubin is a known culprit. Unbound bilirubin crosses the neonatal blood-brain barrier, which is still immature, and the auditory brainstem nuclei and spiral ganglion cells are among the structures it tends to damage. Amin et al. showed that peak unbound bilirubin predicted auditory toxicity in jaundiced newborns better than total serum bilirubin did.[14] Xu et al. found ANSD in nearly 12% of neonates with severe hyperbilirubinaemia.[15]

Here is the difficulty. This child was detected only because his or her DPOAE also happened to be absent. Had the emissions been normal, as they often are in ANSD, the baby would have been discharged as having passed the screen. Gulati et al. found OAE to have a sensitivity of 46% against diagnostic ABR in preterm babies,[12] which is the reason JCIH asks for automated ABR in NICU graduates.[3] We have to accept that our cohort probably contains neural hearing losses that were never found.

Risk indicators

The three most frequent indicators were prematurity, delayed birth cry and very low birth weight. This is more a description of a tertiary NICU population than a list of predictors, and we would not interpret it as one. A biological link can certainly be argued. The outer hair cells and stria vascularis consume a great deal of energy and are among the first cochlear structures to suffer in perinatal hypoxia; and in the preterm baby, myelination of the auditory nerve and brainstem tracts is incomplete. But only two of the five affected babies were preterm. One affected baby was born of a consanguineous marriage. That deserves a mention, since most non-syndromic congenital deafness is autosomal recessive and consanguinity is not rare in parts of South India. With only five cases and so much overlap between indicators, we did not attempt any formal test of association.

Timing and record-keeping

Diagnostic ABR was done only after the six-month rescreen. With that sequence, the JCIH three-month diagnostic target cannot be met, and intervention will usually begin well beyond six months.[3] Sending the baby for diagnostic ABR after the second failed screen, or bringing in automated ABR before discharge, would shorten the gap considerably. The study also taught us something less glamorous. Programme evaluation depends on basic data discipline: one infant-level register, with the result for each ear at every visit, and a clear distinction between a pass, a refer, an invalid test and a missed appointment. Final outcomes ought to reconcile with the number enrolled. Without that, coverage, loss to follow-up and true yield cannot be reported.

Limitations

This was a single-centre study confined to selected high-risk infants. Babies too sick to be moved for screening, and those referred in from elsewhere, were excluded, so the results should not be extended to newborns in general. Since infants who passed DPOAE were not tested with ABR, sensitivity, specificity and the number of missed disorders, especially neural ones, could not be estimated. Incomplete follow-up records ruled out a complete-case proportion. Ear-specific thresholds, age at diagnosis and intervention outcomes were unavailable. Finally, follow-up stopped at six months; late-onset or progressive loss, of the kind often seen after congenital cytomegalovirus infection, would have been missed.

CONCLUSION

Among 556 high-risk newborns screened serially with DPOAE at a government tertiary centre in North Kerala, five had a confirmed hearing disorder, a minimum yield of roughly 9 per 1,000. One of them had auditory neuropathy, which OAE screening can easily overlook. Three changes follow from our experience: automated ABR for every NICU graduate, earlier referral for diagnostic ABR, and a reconciled infant-level follow-up register.

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