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Neonatal Hearing Screening: From Biology to Policy -A Systematic Review for the Generalist Clinician.

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Abstract

Background: Hearing is the biological foundation of language. Congenital hearing loss produces irreversible deficits in speech, language, literacy, and cognitive development. India records an estimated 125,000–150,000 neonates born with hearing impairment each year, yet has no statutory mandate for universal newborn hearing screening (UNHS). ***Objectives:*** To systematically review peer-reviewed and grey literature on neonatal hearing screening in Indian and international settings, covering the aetiology and genetics of congenital hearing loss, screening technology, diagnostic workup and rehabilitation, developmental outcomes, healthcare provider and parental knowledge and attitudes, psychosocial barriers to programme participation, and national policy. ***Methods:*** Systematic review of peer-reviewed publications, government programme documents, and grey literature. Structured searches were conducted in PubMed, Scopus, and Google Scholar from 2000 to 2026 using the MeSH terms Neonatal Screening; Hearing Loss; Otoacoustic Emissions; Evoked Potentials, Auditory, Brain Stem; Cochlear Implants; India; and Infant, Newborn. Studies reporting original data on the prevalence of neonatal hearing loss, screening protocols, diagnostic workup, rehabilitation outcomes, knowledge-attitude-practice (KAP), and health economics of neonatal hearing screening were included; case reports and studies without primary outcome data were excluded. Data were extracted on study design, population, setting, screening protocol, outcomes reported, and principal findings, and synthesised narratively given the heterogeneity of study designs and outcomes. ***Results:*** Hearing loss prevalence ranges from 1–6 per 1,000 in general neonatal populations and 13–18 per 1,000 in NICU populations. Approximately 60% of severe congenital hearing loss is genetic, with GJB2 mutations - particularly the W24X founder variant in South Indian populations, accounting for the largest genetic proportion. A two-stage protocol of DPOAE (distortion product otoacoustic emission) followed by AABR (automated auditory brainstem response) confirmation is the validated standard for well-baby neonates; AABR must be used as the first-stage test in NICU neonates to detect auditory neuropathy spectrum disorder (ANSD). Cochlear implantation before 12 months produces near-normal speech outcomes when followed by auditory-verbal therapy (AVT). Loss to follow-up after a failed screen ranges from 24% to 73% across Indian programmes. Psychosocial stressors - stigma, financial insecurity, misinterpretation of referral results, and family pressure - are widely reported but systematically unmeasured drivers of non-compliance. India has NPPCD (National Programme for Prevention and Control of Deafness) infrastructure and government rehabilitation funding (ADIP -Assistance to Disabled Persons scheme) but lacks a statutory UNHS coverage mandate. ***Conclusions:*** The scientific knowledge, clinical technology, and policy infrastructure to reduce preventable disability from congenital hearing loss in India are largely in place. A statutory UNHS mandate with enforceable benchmarks, together with research that measures parental psychosocial barriers as a primary outcome rather than a confounding variable, are the two most urgent requirements.

Keywords: Neonatal Screening, Hearing Loss, Otoacoustic Emissions, Evoked Potentials, Auditory, Brain Stem, Cochlear Implants, India, Infant, Newborn.

INTRODUCTION

Hearing is not simply the reception of sound; it is the biological mechanism by which the human brain builds language. During the first three years of life, continuous auditory input drives the formation of cortical synaptic connections. A child born with hearing loss who is not identified within this critical window falls behind their peers, because the neural architecture required for spoken language and executive function develops differently, and the resulting disability compounds with every year of delay.

This matters globally, and it matters most in India. India records approximately 25 million births each year, and with a prevalence of 1–6 per 1,000, an estimated 125,000–150,000 neonates are born with hearing impairment annually. The technology to identify these children within 48 hours of birth costs about the same as a routine blood test, and cochlear implantation before 12 months of age reliably produces speech and language outcomes approaching those of hearing peers.[1] Yet India has no statutory mandate for universal newborn hearing screening (UNHS). Most of these children will not be identified until school age or later, by which point the critical period has closed and the disability is irreversible.

This systematic review synthesises the evidence on neonatal hearing screening across its full arc - from the biology of auditory development, through aetiology, screening technology, diagnostic workup, rehabilitation, parental psychosocial barriers, and national policy - for the generalist clinician who encounters these families and these decisions in practice.

Summary Points

- Neonatal hearing loss affects an estimated 1–6 per 1,000 live births in India, representing approximately 125,000–150,000 new cases annually. Around 60% of severe cases have a genetic basis, with GJB2 (connexin 26) mutations - particularly the W24X founder variant in South Indian populations - accounting for the largest single genetic cause.
- Distortion product otoacoustic emission (DPOAE) testing at 48–72 hours, followed by automated auditory brainstem response (AABR) confirmation, is the validated two-stage protocol for well-baby neonates; AABR must be the first-line test in all NICU admissions, since single-stage OAE testing will miss ANSD, which accounts for a substantial proportion of hearing loss in NICU populations.
- Cochlear implantation before 12 months of age, followed by intensive auditory-verbal therapy, produces speech and language outcomes approaching those of hearing peers. Each month of delay during the critical period represents a loss of cortical plasticity that cannot be fully recovered later.
- Loss to follow-up after a failed screen ranges from 24% to 73% across Indian programmes. Parental psychosocial stressors - including social stigma, fear of unaffordable treatment, misinterpretation of a screening referral as confirmed deafness, and family pressure - are widely reported but systematically unmeasured drivers of non-compliance.
- India has NPPCD infrastructure, government cochlear implant funding through the ADIP scheme, and the clinical knowledge needed to reduce preventable disability from congenital hearing loss, but lacks a statutory mandate for universal newborn hearing screening with enforceable coverage targets and accountability mechanisms.

MATERIALS AND METHODS

Search Strategy

A structured literature search was conducted in PubMed, Scopus, and Google Scholar covering the period January 2000 to March 2026. The following MeSH terms and free-text keywords were used in combination: ("neonatal hearing screening" OR "newborn hearing screening" OR "universal newborn hearing screening") AND ("India" OR "South Asia") AND ("otoacoustic emissions" OR "DPOAE" OR "AABR" OR "auditory brainstem response" OR "cochlear implant" OR "hearing loss" OR "GJB2" OR "connexin 26" OR "auditory neuropathy"). Reference lists of identified studies were hand-searched for additional eligible sources. Government programme documents (NPPCD, RBSK, ADIP) and grey literature (WHO reports, ICMR health technology assessments) were retrieved directly from authoritative sources.

Eligibility Criteria

Studies were eligible for inclusion if they: (1) reported original primary data or systematic evidence synthesis on neonatal or infant hearing screening; (2) described prevalence, screening protocols, diagnostic pathways, rehabilitation outcomes, healthcare provider or parental knowledge-attitude-practice (KAP), or health economics of newborn hearing screening; (3) were conducted in India or were internationally relevant to the Indian clinical or policy context; and (4) were published in peer-reviewed journals, government documents, or recognised grey-literature sources. Case reports, letters, and editorials without original data were excluded. No language restriction was applied; all eligible studies retrieved were in English.

Study Selection and Data Extraction

Titles and abstracts were screened against the eligibility criteria, and full-text review was performed for all potentially eligible studies. Data were extracted on study design, setting, population (sample size, neonatal vs NICU), screening protocol employed, primary and secondary outcomes reported, and principal findings. Where multiple publications reported overlapping datasets, the most comprehensive or most recent report was used.

Quality Assessment

Observational and descriptive studies were assessed for methodological quality using the Newcastle-Ottawa Scale adapted for cross-sectional studies. KAP survey studies were assessed for sampling representativeness, response rate, and

instrument validation. Health economic analyses were assessed for perspective, comparator, and cost inputs. Risk of bias across studies was summarised narratively, given the heterogeneity of study designs.

Synthesis

Because of the clinical and methodological heterogeneity across included studies - spanning prevalence surveys, screening programme evaluations, genetic studies, KAP surveys, and cost-effectiveness analyses - quantitative meta-analysis was not performed. Results were synthesised narratively and organised thematically. Prevalence estimates are reported as ranges across studies, alongside their original denominators and settings.

RESULTS

Study Selection

The structured search identified 24 peer-reviewed publications and grey-literature sources meeting the eligibility criteria: 9 primary observational studies from Indian settings, 3 national KAP surveys, 1 health technology assessment (ICMR), 1 international systematic review, and several government programme documents. The principal Indian studies are summarised in Table 1.

Auditory Development and the Critical Period

The otic placode, the embryological precursor of the inner ear, appears by the fourth week of gestation. By 20 weeks, the cochlea has reached its adult 2.5-turn configuration, and by 25–28 weeks the fetus responds to sound. Cochlear outer hair cells are terminally differentiated by mid-gestation and are not regenerated if damaged - the fundamental biological fact that makes prevention and early detection essential. The auditory cortex reaches its maximum plasticity in the first three years of postnatal life, the period during which acoustic experience shapes synaptic architecture in ways that later intervention cannot fully reverse.

The clinical implication of this biology is the Joint Committee on Infant Hearing (JCIH) 2007 "1-3-6" framework: screen by one month, confirm diagnosis by three months, and enrol in early intervention by six months.[2] Multiple studies confirm that cochlear implantation before 12 months produces outcomes indistinguishable from those of hearing peers, while outcomes deteriorate with each year of delay.[1] Indian outcome data from Sri Ramachandra Medical Centre, Chennai, support this relationship in the Indian population: the 0–2 year implant cohort showed superior Categorical Auditory Performance and Speech Intelligibility Rating scores at follow-up compared with all older implant groups.[3] The 1-3-6 targets are not administrative benchmarks; they reflect a biological deadline.

AETIOLOGY

Genetic Causes

Approximately 50–60% of severe congenital sensorineural hearing loss (SNHL) is attributable to genetic causes. In India this proportion may be higher given the prevalence of consanguineous marriage, estimated at 20–30% in several southern states, which increases the probability of autosomal recessive deafness.[4] The GJB2 gene, encoding connexin 26, is the largest single genetic cause of non-syndromic SNHL. The mutation spectrum in India diverges from that in Western populations: while 35delG predominates globally, the W24X variant shows a founder effect in South Indian populations, accounting for 32–73% of mutant GJB2 alleles in Kerala and Tamil Nadu.[5,6] GJB2-related deafness carries an important implication for cochlear implant candidacy, since the cochlear nerve is structurally intact.[4] Beyond GJB2, whole-exome sequencing yields a genetic diagnosis in 40–50% of cases unsolved by first-tier testing and is increasingly available in Indian academic centers.[7] OTOF gene mutations, a cause of auditory neuropathy spectrum disorder, are particularly relevant because of their implications for cochlear implant prognosis.

Syndromic Causes

Approximately 30% of genetic hearing loss occurs as part of a recognised syndrome. Clinicians should actively screen for Pendred syndrome (SLC26A4 mutations; enlarged vestibular aqueduct; thyroid dysfunction), Waardenburg syndrome (pigmentation anomalies), Usher syndrome (progressive retinitis pigmentosa), branchio-oto-renal syndrome (renal anomalies), and CHARGE syndrome (coloboma, choanal atresia). Each carries specific management implications, and missing syndromic features at the point of diagnosis is a preventable gap in comprehensive care.[4]

Acquired and Perinatal Causes

In the Indian NICU setting, hypoxic-ischaemic encephalopathy (HIE), hyperbilirubinaemia requiring exchange transfusion, ototoxic aminoglycoside exposure, and mechanical ventilation beyond five days are consistently significant risk factors.[8,9] Aminoglycosides, still the mainstay of empirical neonatal sepsis treatment, cause permanent cochlear hair cell damage that is potentiated by concurrent loop diuretics. Serum level monitoring, standard practice in high-income settings, is rarely available in Indian NICUs. Congenital cytomegalovirus (cCMV) is the leading non-genetic cause of congenital

hearing loss worldwide; CMV PCR on urine in the first three weeks of life is the only window for diagnosing congenital infection.[4]

SCREENING TECHNOLOGY AND THE OPTIMAL PROTOCOL

Otoacoustic Emissions

Distortion product otoacoustic emissions (DPOAEs) are sounds generated by cochlear outer hair cells, measurable in the sealed ear canal. Their presence confirms outer hair cell integrity and the absence of hearing loss above approximately 30–40 dB hearing level. DPOAE testing is rapid, non-invasive, and requires no electrode placement, making it a practical first-line tool for hospital-based UNHS. Its main limitation is that it cannot detect pathology beyond the outer hair cells, including ANSD, which arises at or beyond the inner hair cell–auditory nerve synapse. Testing before 48 hours of age produces high false-positive rates because of residual vernix in the canal; the validated screening window is 48–72 hours.

Auditory Neuropathy Spectrum Disorder (ANSD)

ANSD is defined by present or near-normal OAEs combined with absent, grossly abnormal, or inconsistent auditory brainstem response (ABR). It accounts for a meaningful proportion of permanent childhood hearing loss in the general population, and a substantially higher proportion in NICU populations with significant hyperbilirubinaemia or HIE. A programme relying on OAE alone will miss every case of ANSD. The site of lesion in ANSD determines cochlear implant prognosis: pre-synaptic lesions (OTOF mutations) respond well, while post-synaptic lesions with cochlear nerve deficiency require high-resolution MRI of the internal auditory canal before implant decisions.

The Validated Two-Stage Protocol

Evidence supports a differentiated approach. For well-baby neonates: DPOAE at 48–72 hours, AABR for DPOAE referrals, and diagnostic ABR for AABR referrals. For all NICU neonates: AABR as the first-stage test (not DPOAE), given the disproportionate ANSD burden in this group. The Manipal comprehensive UNHS model, which combined this protocol with a digital database and a multidisciplinary team, reduced loss to follow-up from 73% to 33% and achieved a median age of identification of six months.[8] A 2024 ICMR health technology assessment confirmed that portable AABR-based UNHS is cost-effective within existing NPPCD infrastructure, without adding substantial financial burden.[10]

Diagnostic Workup of the Screen-Positive Neonate

A screening referral is not a diagnosis; it is an instruction to evaluate further. The workup is systematic:

- Audiological confirmation: diagnostic (not automated) ABR with frequency-specific tone-burst stimuli, 1000 Hz probe tympanometry, and OAE characterisation for ANSD.
- Medical evaluation: ophthalmology (Usher, Waardenburg), renal ultrasound (branchio-oto-renal), thyroid function (Pendred), ECG if there is a family history of sudden unexplained death (Jervell and Lange-Nielsen), and CMV PCR on urine before three weeks of age.
- Imaging: high-resolution CT of the temporal bones for cochlear anatomy, and MRI of the internal auditory canals for cochlear nerve calibre - mandatory before cochlear implant candidacy evaluation, especially in ANSD.
- Genetic evaluation: GJB2 sequencing as the first-tier test; SLC26A4 if there is an enlarged vestibular aqueduct; OTOF if ANSD is present without perinatal risk factors; whole-exome sequencing for unsolved cases.[4,7] Genetic diagnosis enables recurrence-risk counselling, helps predict cochlear implant prognosis in ANSD, and identifies at-risk siblings.

REHABILITATION

Hearing Aids

For mild to severe SNHL, digital hearing aids fitted with real-ear measurement and target-based gain prescription should be started before three months of age. In India, the NPPCD and ADIP scheme provide subsidised devices through district hospitals, but programme quality is uneven. Many children receive inadequately programmed devices that provide insufficient gain - a problem as clinically damaging as no device at all, since it looks like treatment while failing the child.

Cochlear Implantation

Bilateral severe-to-profound SNHL with insufficient hearing aid benefit is the indication for cochlear implantation. Age at implantation is the single most powerful modifiable predictor of outcome.[3] The ADIP scheme and the Rashtriya Bal Swasthya Karyakram (RBSK) now fund bilateral cochlear implantation for eligible children under six years from below-poverty-line families - a policy advance that needs to be actively communicated to families and primary care clinicians, who are often unaware it exists. ANSD with intact cochlear nerve anatomy has cochlear implant outcomes broadly equivalent to conventional SNHL; MRI confirmation of nerve calibre before implantation is mandatory.

Auditory-Verbal Habilitation

Auditory-verbal habilitation (AVH) is the process by which the implant's electrical output is turned into usable language. It requires structured, intensive therapy - typically over one to five years - with active family participation as its core mechanism. Geography remains the main access barrier in India: qualified therapists are concentrated in metropolitan centres, leaving children implanted in smaller cities without adequate post-implant support. Tele-rehabilitation platforms show preliminary evidence of outcomes comparable to in-person therapy, a finding with real implications for India's geography. Indian Sign Language, recognised as a language under the Rights of Persons with Disabilities Act 2016, is an equally valid rehabilitation pathway for families who prefer it or for whom oral language is not achievable.

KNOWLEDGE, ATTITUDES, AND PSYCHOSOCIAL BARRIERS

Healthcare Providers

A national survey of Indian paediatricians found that 95% were aware of UNHS and 98.3% supported it for all neonates, but only 20.5% had a screening programme available at their institution.[11] A nursing survey found that 40% of nurses believed screening causes excessive parental anxiety.[12] The Manipal programme addressed this through structured healthcare provider sensitisation, with demonstrated improvements in knowledge and counselling practice.[8]

Parental Knowledge

A national knowledge and attitude survey of Indian mothers found reasonable awareness of environmental risk factors, but major gaps in understanding perinatal causes and, critically, the difference between a screening referral and a confirmed diagnosis.[13] A parent who interprets a DPOAE "refer" result as meaning their child is definitively deaf may understandably choose not to return for confirmation. Pre-screening counselling that explicitly frames the test as a first step, not a verdict, should be treated as a core programme requirement rather than an optional extra.

Psychosocial Barriers in the Indian Context

No published Indian study has systematically measured parental psychosocial stress as a primary, quantified outcome in the context of newborn hearing screening — the most important research gap identified by this review. Clinical experience and the wider sociological literature point to several India-specific stressors that likely drive loss to follow-up beyond what logistics alone can explain.[14] Social stigma attached to disability, and its consequences for marriage prospects, family reputation, and community standing, may lead families to delay confirming a diagnosis that, once documented, becomes harder to set aside. Financial insecurity is acute: private-sector hearing aids cost roughly Rs 20,000–200,000, and cochlear implantation Rs 6–12 lakh per device. Maternal guilt, gender dynamics that constrain autonomous health-seeking decisions, and family pressure to conceal or dismiss a diagnosis are additional stressors that likely operate within existing programme data without being captured by it.[14] Until these dimensions are measured, programme designers cannot know what proportion of loss to follow-up reflects logistics versus psychosocial causes, and cannot design interventions that target either one specifically.

National Policy: Progress, Gaps, and What is Needed

The National Programme for Prevention and Control of Deafness (NPPCD, 2006) now covers 587 of India's districts, providing OAE and ABR equipment to district hospitals and funding awareness activities.[15] The Rashtriya Bal Swasthya Karyakram (RBSK, 2013) added newborn hearing screening to its National Health Mission mandate. The Rights of Persons with Disabilities Act 2016 recognised Indian Sign Language and mandated accessible education. The ADIP scheme funds hearing aids and cochlear implantation for eligible children below the poverty line. Together, these frameworks provide the scaffolding for a national UNHS system: equipment infrastructure, district-level referral pathways, and rehabilitation funding all exist.

What is missing is a statutory mandate with enforceable coverage targets, age-of-identification benchmarks, and accountability mechanisms. Without this, UNHS in India remains what it has been for two decades: a set of strong individual institutions surrounded by a much larger population of undetected congenital hearing loss.

Roughly 75% of India's population lives outside the major cities where tertiary UNHS programmes operate, and over half of all births occur in settings without access to OAE equipment. The 2024 ICMR cost-effectiveness analysis confirmed that portable AABR-based UNHS is cost-effective within existing NPPCD infrastructure, without adding substantial financial burden.[10].

The economic case is made and the clinical case is strong; the policy infrastructure partly exists. What remains is the legislative step of mandating UNHS nationally, as the United Kingdom did in 2006 and the United States did through its Early Hearing Detection and Intervention Act, both producing near-universal screening within populations that, a decade earlier, looked much like India's does today.[16]

Table 1: Key Indian Studies on Neonatal Hearing Screening: Design, Population, and Principal Findings.

Study (Year)	Setting	Design / Population	Key Finding
Thomas et al 2018[17]	Kerala; secondary hospital	DPOAE two-stage protocol; 2,092 neonates	10.6% referred at first screening; 6.5% confirmed hearing deficit (2.6% bilateral); 24.3% lost to follow-up at confirmatory testing
Ravi et al (Manipal), 2022[8]	Karnataka; tertiary	Comprehensive UNHS model; >16,000 neonates	Loss to follow-up reduced from 73% to 33% with digital database and counselling; healthcare provider sensitisation improved KAP
Pradhan et al, 2024[9]	Mumbai; NICU	DPOAE + BERA; 226 NICU neonates	17.7% failed initial screen; asphyxia, ototoxic drugs, and hyperbilirubinaemia independently significant (all $p<0.005$)
Pehlajani et al, 2025[18]	Bhopal; full-term NICU graduates	Two-stage DPOAE–BERA; 229 neonates	Hearing loss 13 per 1,000; HIE ($p=0.004$), bilirubin encephalopathy ($p=0.022$), and oligohydramnios ($p<0.001$) significant
Sija & Gireeshan, 2022[19]	Kerala; tertiary	4-year UNHS programme; 16,625 neonates	Coverage 96.3%; 61.5% of confirmed cases had no identifiable risk factors
Joseph & Rasool, 2009[5]	Kerala; genetics	GJB2 sequencing; 86 NSHL probands	GJB2 mutations in 36% of NSHL; W24X founder mutation predominant in the Kerala population
Ravi et al (nurses), 2017[12]	India; national survey	Nursing KAP survey	40% felt screening causes excess parental anxiety; gaps in follow-up knowledge identified
Ravi et al (paediatricians), 2017[11]	India; national survey	Paediatrician KAP survey; n=112	95% awareness; 98.3% support for UNHS; only 20.5% had a programme at their institution
Sahoo et al (HTAIn), 2024[10]	India; national	Cost-effectiveness analysis	Portable AABR-based UNHS is cost-effective within existing NPPCD infrastructure

DISCUSSION

Principal Findings

This review demonstrates that the tools needed to reduce preventable disability from congenital hearing loss in India largely already exist: validated screening technology, established cochlear implant surgery, evidence-based auditory-verbal habilitation, genetic diagnostic capability, government funding mechanisms, and a policy framework awaiting activation. What has prevented these from coming together into a functioning national system is not a lack of knowledge, but a lack of decision.

The principal findings are: (1) two-stage DPOAE/AABR screening is evidence-based and cost-effective; (2) AABR should replace OAE as the primary modality in NICU populations; (3) cochlear implantation before 12 months produces near-normal outcomes in the Indian population; (4) loss to follow-up is high (24–73%) and appears to be driven substantially by unmeasured psychosocial barriers rather than logistics alone; and (5) a statutory mandate is the single structural intervention most likely to produce population-level impact.

Strengths and Limitations

This review is broad in scope, covering the full path from molecular biology to health policy, and drawing on both Indian and international evidence. Its limitations include the heterogeneity of included studies, which precluded meta-analysis; the absence of prospectively registered systematic review methodology in the original narrative article from which this review was adapted; and reliance on narrative synthesis for prevalence estimates drawn from studies with different denominators and settings. The most important limitation is not methodological but substantive: no Indian study has measured parental psychosocial stress as a primary, quantified outcome, which means the dominant driver of programme failure remains uncharacterised.

Comparison with Existing Literature

The WHO World Report on Hearing (2021) identified early detection and intervention as a top priority for addressing the global hearing loss burden.[20] A systematic review by Kuper et al of early hearing detection programmes in low- and middle-income countries in Asia confirmed the feasibility of UNHS in resource-limited settings, but identified loss to follow-up and the absence of statutory mandates as near-universal barriers.[16] The present review builds on these findings by describing the India-specific psychosocial context and identifying the measurement gap around parental barriers as the critical unanswered research question.

Implications for Practice and Policy

For the clinician: screen every neonate, use AABR in the NICU, counsel before the test about what a referral result means, tell families about the available government funding schemes, refer for genetics early, and track every case until diagnosis is confirmed or ruled out. For policymakers: the evidence summarised here does not require further study before it can be acted on. For researchers: the most important unanswered question is also the most actionable one - what specifically stops Indian families from returning after a failed screen, and what intervention brings them back.

CONCLUSION

The scientific knowledge, clinical technology, and policy infrastructure needed to reduce preventable disability from congenital hearing loss in India are largely in place. A statutory UNHS mandate with enforceable coverage targets, age-of-identification benchmarks, and accountability mechanisms, together with research that measures parental psychosocial barriers as a primary outcome rather than a confounding variable, are the two most urgent requirements. Until psychosocial barriers are measured as a primary outcome, programmes will continue to refine the technology while families walk through hospital doors and do not return.

Practical Recommendations for Clinicians and Programme Managers

- Screen all neonates: implement DPOAE at 48–72 hours for well-baby neonates; use AABR as the first-stage test for all NICU admissions. Single-stage OAE is not sufficient as a sole protocol.
- Apply the 1-3-6 framework: screen by one month, confirm diagnosis by three months, enrol in early intervention by six months. These are biologically determined deadlines, not administrative targets.
- Do not reassure on OAE alone in high-risk neonates: a neonate with hyperbilirubinaemia, HIE, or prolonged NICU admission who passes OAE but has an abnormal ABR needs urgent specialist referral. Treat this as ANSD until proven otherwise.
- Request genetics early: GJB2 sequencing should be routine for non-syndromic SNHL, with specific testing for W24X in South Indian populations. An OTOF mutation in ANSD predicts a good cochlear implant outcome.
- Counsel before and after the screen: explain that a refer result is not a diagnosis of deafness before the test begins. Address stigma, treatment costs, and family pressure explicitly, and inform families about NPPCD and ADIP funding.
- Track every referred neonate: maintain a digital register with automated follow-up reminders. An untracked referral is a missed diagnosis.
- Refer for cochlear implant candidacy at confirmation, not after years of hearing-aid trial: age at implantation is the single most powerful modifiable predictor of outcome.

REFERENCES

1. Moeller MP. Early intervention and language development in children who are deaf and hard of hearing. Pediatrics 2000;106(3):e43.
2. Joint Committee on Infant Hearing. Year 2007 position statement: principles and guidelines for early hearing detection and intervention programs. Pediatrics 2007;120(4):898-921.
3. Selvarajan HG, Bellur R, Mandke K, et al. A comprehensive outcome framework of a cochlear implant program at a university hospital in Chennai: a preliminary report. Indian J Otolaryngol Head Neck Surg 2022;74(Suppl 3):6462-7.
4. Korver AM, Smith RJ, Van Camp G, et al. Congenital hearing loss. Nat Rev Dis Primers 2017;3:16094.
5. Joseph AY, Rasool TJ. High frequency of connexin26 (GJB2) mutations associated with nonsyndromic hearing loss in the population of Kerala, India. Int J Pediatr Otorhinolaryngol 2009;73(3):437-43.
6. RamShankar M, Girirajan S, Dagan O, et al. Contribution of connexin26 (GJB2) mutations and founder effect to non-syndromic hearing loss in India. J Med Genet 2003;40(5):e68.
7. Fareed M, Sharma V, Singh I, et al. Whole-exome sequencing reveals a rare variant of OTOF gene causing congenital non-syndromic hearing loss among large Muslim families favoring consanguinity. Front Genet 2021;12:641925.
8. Ravi R, Gunjawate DR, Yerraguntla K, et al. Universal newborn hearing screening: an Indian experience of conceptualizing and testing a comprehensive model. Indian J Otolaryngol Head Neck Surg 2022;74(Suppl 1):170-7.
9. Pradhan M, Bhaisara B, Shinde SRG. Prevalence and risk factors of hearing loss in high-risk neonates at a tertiary care hospital in Mumbai. Int J Contemp Pediatr 2024;11(1):54-9.
10. Sahoo KC, Dwivedi R, Athe R, Chauhan A, Jain S, Sahoo RK, et al. Cost-effectiveness of portable-automated ABR for universal neonatal hearing screening in India. Front Public Health 2024;12:1364226.
11. Ravi R, Gunjawate DR, Yerraguntla K, et al. A national survey of knowledge, attitude and practices among pediatricians towards newborn hearing screening in India. Int J Pediatr Otorhinolaryngol 2017;95:9-14.
12. Ravi R, Gunjawate DR, Yerraguntla K, et al. Knowledge, attitude and practices among nurses towards newborn hearing screening in India. Online J Health Allied Sci 2017;16(3):5.
13. Ravi R, Yerraguntla K, Gunjawate DR, et al. Knowledge and attitude (KA) survey regarding infant hearing loss in Karnataka, India. Int J Pediatr Otorhinolaryngol 2016;85:1-4.

14. Gunjawate DR, Ravi R, Driscoll C. Stress among parents of children with hearing loss and how they deal with it: a systematic review. Int Arch Otorhinolaryngol 2023;27(1):e166-77.
15. National Programme for Prevention and Control of Deafness (NPPCD). Operational guidelines. New Delhi: Ministry of Health and Family Welfare, Government of India; 2006 (revised 2017).
16. Kuper H, Joshi BD, Ramkumar V, et al. Early hearing detection and intervention (EHDI) programmes for infants and young children in low-income and middle-income countries in Asia: a systematic review. BMJ Paediatr Open 2023;7(1):e001752.
17. Thomas G, Jacob P, Thomas T. Neonatal hearing screening, need of the hour in India, a secondary hospital experience. Int J Dent Med Sci Res 2018;2(2):57-61.
18. Pehlajani Y, Shrivastava J, Mandraha S, et al. Incidence and risk factors of hearing impairment in full-term neonatal intensive care unit (NICU) graduates: a cross-sectional observational study from central India. Cureus 2025;17(8):e90399.
19. Sija S, Gireeshan VK, Ajith Kumar VT, et al. Outcome of newborn hearing screening program at a tertiary care centre, South India. J Early Hear Detect Interv 2022;7(1):101-107.
20. World Health Organization. World report on hearing. Geneva: WHO 2021.