



Childhood Hearing Impairment in India: A Call for Preventive and Strategic Actions

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Abstract

Hearing is one of the most important sensory ability endowed to the humankind that serves as a primary human communication channel on which most of the human civilization is established. Hearing impairment even of mild degree has been associated with breakdown in communication, reduced civility and poor quality of life. Hearing impairment impacts about 34 million children worldwide and majority (80%) of them are in south Asian countries. Untreated sensorineural hearing impairment in the first year of life has profound consequences that transverse almost all developmental domains, manifesting in significant and often lifelong deficits in gross and fine motor skills, cognitive performance, speech and language development, and psychosocial development. However, it is unnecessary for a child to suffer from the negative consequences of hearing impairment, despite there is technological advancement in identification of hearing impairment, and current rehabilitation strategies in the 21st century are effective and efficient to significantly minimize the negative consequences of hearing impairment. Therefore, this working paper attempts to advocate primary and secondary prevention strategies to reduce the prevalence of hearing impairment and minimize the negative consequences of hearing impairment through introducing the best approaches for screening of hearing impairment and implementing the established protocols for early intervention of hearing impairment.

Keywords: Hearing impairment; Prevention; Hearing screening; Early identification; Intervention

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Introduction

Hearing or auditory sense is the organism's ability to perceive sounds by detecting vibratory changes in the sound pressure of the surrounding through an organ such as the ear. Hearing is an essential means of acquisition of communication and speech-language skills on which human developments and civilizations are largely instituted. Hearing takes place by a complex mechanism involving the transformation of sound waves by the combined operation of different parts of auditory system viz. peripheral and central auditory system [1]. Hearing loss is the impairment of auditory system to hear environmental sounds. Thus, hearing impairment is the result of impaired auditory system causing loss of sensitivity and/or diminished speech intelligibility of varying magnitude and degree [2].

The degree of hearing impairment is primary data to determine impact on hearing related human functions including communication and education. Hearing impairment in neonates of mild to profound degree, bilaterally or unilaterally, hearing loss of varying degree above 1000 Hz or auditory deprivation, probably for few days, due to recurrent otitis media not only results in significant and long-term effect, although less well documented, reduced auditory input also adversely affects the developing central auditory nervous system which has harmful impact on acquisition of speech-language skills and speech perception abilities [1].

The magnitude or degree of hearing impairment in children also has significant impact on learning, reading and writing in educational settings. Educationally significant hearing loss has been defined as "any hearing loss that potentially interferes with access to classroom instruction and impacts a child's ability to communicate, learn and develop peer relationships [3]. Table 1 below shows commonly used classification systems of degree of hearing impairment (threshold average at 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz).

Children with hearing impairment struggled with communication, speech-language difficulties and overall developmental deficits that places severe limitations on their educational and vocational

Table 1: Classification of hearing loss range and its impact on communication.

Degree of Hearing Loss [4]	Hearing Threshold (dBHL)	Perceived Communication Difficulties [5,6]
Normal	-10 to 15	May miss instructions and conversation depending upon configuration of hearing loss.
Slight	16 to 25	Child can miss up to 10% of speech when speaker is at >3 feet distance or in background noise.
Mild	26 to 40	May have difficulty in hearing some quieter conversations in presence of noise.
		May miss 50% of conversation/discussion when speaker face is not visible or speaker is unknown.
Moderate	41 to 55	Conversations may be hard to hear even at close distance and in presence of background noise.
		May not respond to speech in presence noise and behave like severely hearing impaired.
Moderately severe	56 to 70	Can hear and understand about 50% of loud conversation from 3 feet distance.
		Requires full time amplification and speech reading skills to enhance speech perception.
Severe	71 to 90	Can hear only few loud syllable or word. May have difficulty hearing louder sounds – siren, bell.
		Requires high power fulltime amplification along with speech reading training.
Profound	91+	May not hear even very loud speech & environmental sounds without amplification.
		May require specialize speech reading training and sign language for communication.

attainments and may continue to impact the child for lifetime. Hearing impairment not only has substantial impact for the affected child but also the family, and the community [7]. If remain unattended. For instance, the estimated lifetime educational cost of hearing loss is \$115,600 per child [8]. Further, persons with speech disabilities are more often found to be unemployed or belong to a lower economic stratum, and the income for the hearing-impaired population is 40% to 45% lower than for the hearing population [9].

Burden of Hearing Loss

According to the World Health Organization (2018), around 466 million people worldwide have disabling hearing loss, and 34 million of these are children. The disabling hearing loss refers to hearing loss of 41 decibels (dB) or greater in the better hearing ear in adults and a hearing loss greater than 30 dB in the better hearing ear in children. The majority (at least 80%) of people with disabling hearing loss live in low - and middle-income countries [10]. In LMICs countries approximately million children in the first 5 year of life have disabling sensorineural hearing impairment [11-13] (Olusanya BO, 2012; UNCF, 2013) Census of India (2011) reports that hearing impairment affects about 5.07 million and 1.98 million of the populations with various types of speech problems almost uniformly distributed around the country [14]. Population-based survey (2016) using WHO protocol (2012) estimated the prevalence of hearing loss to be 10.5% in Indian population [15]. Pascolini & Smith reported that bilateral severe to profound hearing loss affect more than 10 infants in every 1,000 live births in developing countries [16]. Niskar et al. found 14.9% of children with either low frequency or high frequency hearing loss in a hospital-based survey [17]. As per the Census of India (2011), 20.42 lakhs children aged 0 to 6 years are disabled, among them 23% children have hearing disability, 20% children aged 0 to 19 years have hearing disability and 9% multiple disabilities. Thus, one in every 100 children in the age group 0 to 6 years suffered from some type of disability and 69% of them live in rural India [18]. Further, according to recent data from the sample registration survey of India (SRS: 2018) children between ages 0 to 14 years made up 25.9% of Indian population which is one fifth of world’s child population [19].

The estimated population with hearing impairment data is not only very high but also growing exponentially. According to

Census of India 2001, 21.9 million people were disabled which has increased to 26.8 million in Census 2011. This growth accounts for 22.4% increase in disable population in 2011. Census of India, 2001 had counted 1,261,722 (1.26 million) people in whom hearing disability existed. This population had grown to 5,071,007 (5.07 million) in Census of India 2011. There is a rise of 24.8% hearing disability which is greater by 2.4% to the national rise in disable population [19]. Additionally, there are 1,998,535 (1.9 million) people with speech disability [14]. Thus, considering the trend of previous data and demographic, health and poverty in India, the numbers of people with hearing and speech disability are expected to rise in due national population census 2021. Hence, it can be held that India is and will be the home to the largest child population with hearing disability in the world.

This gigantic child population with hearing impairment, no matter what, best identification and intervention approach one may apply, a hindsight suggest that it is highly difficult to screen and to provide them hearing devices, individualized speech & language therapy, special education, vocational training and employment in India where there is limited infrastructure, shortage of health care personnel and unequally distributed manpower and disable population in the country. There are about 8,000 ENT specialists & 2,500 audiologists available. The audiologist vs. population ratio was found to be 1:500,000 and the ratio of speech therapists or special educator to the deaf population are 1:200 [20].

Most recently, Times of India reported that there are about 50 million people who need the services of Speech Pathologist & Audiologist (SLPAs). However, currently, India has only around 5,000 SLPAs [21]. Further, there is also a misdistribution of personnel with more hearing health care professionals are located in urban than rural areas. Human resource analysis also revealed that there is a need to enhance the skills and working capacity of doctors, hearing health care professionals and other health care personnel [20]. Furthermore, it is also very important to note that the hearing disability is exponentially increasing in India.

These are not mere numbers but part of human development component and if left unaddressed have potential to negatively impact human productivity, sustainable development of national economy and mainstream developmental initiatives, programs & strategies that

are targeted to illiteracy and poverty eradication programs embodied in the Millennium Development Goals of United Nations. In spite prevalence rate are important for planning and implementation of policies, program and schemes. Unfortunately, nation does not have prevalence of hearing disable population as per RPWD Act-2016 [22].

Hence, it can be concluded that, at this point of time even if national program for early identification & intervention is implemented to detect hearing impairment in the line of standard practice of universal neonatal hearing screening, it would not be able to achieve similar success. The enormity of the problem can only be tackled if primary preventive strategies are thoughtfully employed & secondary preventive strategies such as early identification & interventions are judiciously implemented. Under this background, the purpose of this paper is,

- Firstly, to emphasize the necessity of primary prevention to eradicate hearing & speech impairment, and to reduce the prevalence of hearing impairment,
- Secondly, to accentuate importance of secondary prevention i.e., early identification & intervention to minimize the negative consequences of hearing impairment and
- Thirdly, to highlight the current standard procedures practiced for primary prevention and secondary prevention strategies worldwide.

Prevention of childhood hearing impairment

There is myriad of genetic & environmental causes that disturb the hearing system and its functions. At least 50% of childhood hearing loss is genetic, 25% are environmental which includes infectious disease, developmental syndromes, physical trauma, noise exposure, ototoxic drugs, and chemicals etc. and remaining 25% are idiopathic in nature resulting in varying characteristics of hearing impairment. Fortunately, 50% to 60% of all cases of hearing loss can be prevented through public health measures (WHO, 2015) [23]. The public health prevention measures are all about avoiding disease or injury before it starts impacting human health fulfilling the famous dictum "prevention is better than the cure". There are three distinct levels of prevention.

Primary prevention- Primary prevention refers to actions aimed at avoiding the manifestation of a disease i.e., intervening before adverse health effect occurs. Primary prevention services and activities include:

- Immunization and vaccination against infectious diseases
- Provision of information on behavioral and medical health risks, and measures to reduce risks at the individual and population levels;

Secondary prevention - Those measures that lead to early diagnosis and prompt treatment of a disease, illness or injury to prevent developing more severe problems i.e., aims to reduce the impact of a disease or injury that has already occurred. Secondary prevention includes activities such as:

- Implementing provision of maternal and child health programs, including screening & prevention of congenital malformations and early detection of diseases.
- To provide intervention to the disease or injury timely

to halt or slow its progress and the strategies to prevent future complications, and

- To offer intervention measures with proven effectiveness at an early stage of the disease to attain the normal ability to function and to prevent long-term impact.

Tertiary Prevention - Managing disease post diagnosis to stop disease progression often long-term-complex complications or to soften the impact of an ongoing illness that has lasting effects through measures such as rehabilitation & remedial measures. Tertiary prevention includes:

- To provide with special teaching/remedial measures who have already developed a permanent hearing impairments or disability.
- To deliver technological devices, special intervention measures, and to support groups that allow members to share strategies for quality living.
- Vocational rehabilitation programs and to provide special employment in order to improve as much as possible one's ability to function and, quality of life.

Primary prevention of childhood hearing impairment

The primary prevention of a disease has major importance to both professionals and health policy makers. The effective primary prevention policies can significantly reduce the burden of disability. As per WHO (2015) about 60% hearing loss in children under 15 years of age in low-and middle-income countries are attributable to preventable causes. These preventable causes of childhood hearing loss include [22]:

- Infections such as mumps, measles, rubella, meningitis, cytomegalovirus infections, and chronic otitis media (31%).
- Complications at the time of birth, such as birth asphyxia, low birth weight, prematurity, and jaundice (17%).
- Use of ototoxic medicines in expecting mothers and babies (4%); and Others (8%).

The preventable causes such as infectious diseases, poor antenatal and perinatal health services and other environmental factors are widespread in India. Way back in 1980, World Health Organization summarized the main causes of hearing impairment in developing countries including India as: Infections, Neglect and Ignorance during prenatal, perinatal and post-natally which remains relevant even today are listed in Table 2 [24]. The prevention of hearing disability has to deal with overcoming these three basic causes of hearing impairment. Therefore, addressing these preventable causes of childhood hearing loss is of significant importance to avoid and to reduce the prevalence of hearing loss in our country.

Further, WHO (2018) reported that about 30% of hearing losses, though not preventable, are treatable or can be managed with amplification devices. Thus, about 90% of all hearing impairment conditions are avoidable. However, as per the report of 76th round of the National Sample Survey 2019 [25], 76.4% of persons with disabilities have not receive any kind of aid and appliances and only 28.8% have a disability certificate essential for availing subsidized hearing aid and cochlear implant and other facilities provided under various schemes. Further, about 89.8% children with disabilities do not have access or could not receive pre-school intervention

Table 2: Major causes of hearing impairment in developing countries: Infections, Neglect & Ignorance (WHO -1980).

	Prenatal	Perinatal	Postnatal
Infections	<ul style="list-style-type: none"> T - Toxoplasmosis, O - Other bacterial infections like syphilis, R - Rubella, C - Cytomegalovirus, H - Herpes simplex. 	<ul style="list-style-type: none"> Bacterial meningitis, Neonatal jaundice. 	<ul style="list-style-type: none"> Measles, Mumps, Meningitis, Encephalitis, Diphtheria, Tetanus, Whooping cough, Pneumonia, Middle ear infections.
Negligence	<ul style="list-style-type: none"> Neglecting vaccination of preventable diseases to post pubertal females. Malnutrition and non-immunization of the pregnant mother. Ignorant of presence of Rh-incompatibility factor, Less satisfactory managed diseases during pregnancy e.g., T.B, Malaria, Epilepsy etc. requiring administration of ototoxic drug. 	<ul style="list-style-type: none"> Deliveries in less satisfactory and poor hygienic conditions inviting trauma & infections. Deliveries with poor technique, unsafe & complicated deliveries by non-professionals resulting in prolonged asphyxia/trauma and/or infections. Non-immunization of children for vaccine preventable diseases, 	<ul style="list-style-type: none"> Neglect or poorly managed Ear, Throat and Nose infections. Less satisfactorily managed diseases (such as malaria, pneumonia & typhoid) resulting in possible ototoxicity during the treatment with drugs like aminoglycosides e.g., Streptomycin, Gentamycin, Kanamycin, Quinine preparations & loop diuretics etc. Persistent URT infection, Barotraumas, head trauma due to swimming in Bawdies & Ponds Excessive exposure to loud noise at work place & festivals. Neglect of head and ear tumors
Ignorance	<ul style="list-style-type: none"> There is a general public ignorance regarding clean drinking water, eating nutritious food & breathing fresh air. Consanguineous marriages - risk of hereditary impairment. Immunization & health care of pregnant women. 	<ul style="list-style-type: none"> The importance of nutrition, health and immunization of the pregnant mother Hygienic and safe deliveries, Insufficient care for premature & low birth weight babies. 	<ul style="list-style-type: none"> The ignorance of nutrition and immunization of the newborn, infants and children. Ignorance of ear infection & otitis media, ear wax, improper care of post-surgical cases. Insufficient follow up of medical cases, method & doses of drug administration Noise pollution and ignorance towards its ill effects.
	1. General Public: General ignorance of health, hygiene, nutrition and not seeking early help for disease/trauma/condition. 2. Government and private sector administration ignorance could be		
	<ul style="list-style-type: none"> The cost effectiveness of undertaking preventive measures compared to the cost involved in instituting rehabilitative measures. The cost effectiveness of promotion of manpower development to undertake effective preventive measures. Ineffective implementation of rules and regulations to control noise in public places/industries. 		
	3. The medical/paramedical Fraternity		
	<ul style="list-style-type: none"> Several preventable causes of hearing impairment (such as, the nature and dosage of drugs used, the method of administration of the drug, the effective follow up to control the disease/condition) which can be controlled by medical professionals go beyond their control, at times. This may be due to: Non-inclusion of these aspects in their curriculum at undergraduate/post graduate levels. Lack of opportunities to attend Continuing Education Programme and lack of other facilities (such as books & journals etc.) to up-date themselves regarding these issues. 		

services. NSSO (2003) reported that people are unable to utilize their amplification devices to their maximum benefit [26].

This indicates that there is inadequate procurement of assistive technologies & learning materials, lack of timely detection & certification of disability, and intervention services are inaccessible to majority of disable population in India. This is due to the severe shortage of audiologists to offer informational counseling, troubleshooting & minor repairs of malfunctioning amplification devices; speech language pathologists to provide speech & language therapy, and non-availability of intervention centers are the major hurdles in addressing the issues of hearing impairment. This stresses a point here that not only public awareness & prevention strategies but also effective audiological intervention and service delivery i.e., secondary prevention should be the considered as important goal to deal with deleterious consequences of hearing impairment in India.

Strategies for primary prevention of hearing impairment

WHO (2015) has suggested primary prevention strategies for hearing impairment. Some simple strategies for primary prevention may include [23]:

- Immunizing children against childhood diseases, including measles, meningitis, rubella and mumps;

- Immunizing adolescent girls and women of reproductive age against rubella before pregnancy;
- Preventing cytomegalovirus infections in expectant mothers through good hygiene; screening for and treating syphilis and other infections in pregnant women;
- Strengthening maternal and child health programs, improving antenatal and perinatal care, including promotion of safe childbirth;
- Reducing exposure (both occupational and recreational) to loud sounds by raising awareness about the risks; developing and enforcing relevant legislation; and encouraging individuals to use personal protective devices such as earplugs and noise-cancelling earphones and headphones.
- Avoiding the use of particular ototoxic drug which may be harmful to hearing, unless prescribed and monitored by a qualified physician;
- Referring infants at high risk, such as those with a family history of deafness or those born with low birth weight, birth asphyxia, jaundice or meningitis, for early assessment of hearing, to ensure prompt diagnosis and appropriate management, as required;

Table 3: Hearing and Speech & Language Development Milestones [31].

Developmental Age	Hearing and Speech & Language Skills
Birth to 3 months	Reacts to loud sounds with startle reflex Is soothed and quieted by soft sounds Turns head to you when you speak Is awakened by loud voices and sounds Smiles in response to voices when spoken to Seems to know your voice and quiets down if crying
4 to 6 months	Looks or turns toward a strange/new sound Responds to "no" and changes in tone of voice Imitates his or her own voice Enjoys rattles and other toys that make sounds Begins to repeat sounds (such as, "ooh," "aah," and "ba- ba") Becomes scared by a loud voice or noise
7 to 12 months	Responds to his or her own name, telephone ringing, someone's voice, even when not loud Knows words for common things (such as, cup or shoe) and sayings (such as, "bye-bye") Makes babbling sounds, even when alone Starts to respond to requests (such as, "come here") Looks at things or pictures when someone talks about them Enjoys games like peek-a-boo and pat-a-cake Imitates simple words and sounds; may use a few single words meaningfully
1 to 2 years	Follows one-step commands when shown by a gesture Uses words he or she has learned often Uses two to three-word sentences to talk about things Says more words as each month passes Points to some body parts when asked Understands simple "yes-no" questions (such as, "Are you hungry?") Understands simple phrases (such as, in the cup, or on the table) Understands "not now" and "no more" Chooses things by size (such as, big or little) Follows two-step commands (such as, "Get your shoes or come here.") Understands many action words (such as, run or jump)

- Hearing loss due to otitis media can be prevented by following healthy ear and hearing care practices. It can be suitably dealt with through early detection, followed by appropriate medical or surgical interventions.

Secondary prevention of hearing impairment

About 50% of all hearing losses are unrelated to environmental risks and results from genetic conditions [20,23]. Therefore, it is necessary that secondary prevention strategies should be implemented to identify infants & children with hearing impairment at early age through systematic hearing screening programs, otherwise hearing loss will only be detected after exhausting the critical language development periods of the child resulting in severely restricted prospects for communication, psychosocial, literacy, academic and vocational outcomes. To accentuate the importance of timely intervention, very recently WHO (2021) said that “effective and timely interventions can benefit all those at risk of, or living with, hearing loss” [27].

However, until now, detection of infant hearing loss in India remains a passive process in spite there is legislative mandate under right to persons with disabilities Act 2016 for primary prevention and early identification and intervention of disabilities [28]. The average age of identification of children with severe to profound hearing loss is 5 years in India (RCI, 2000). Recently, reported average age of suspicion, diagnosis, fitting of amplification and initiation of early intervention for hearing loss are found to be 16.5, 24.3, 31.7 and 33.4 months respectively in Mumbai and detection of infant hearing loss primarily occurred as a result of concerns regarding observed speech and language delays or unusual behavior in children by parents and family members [29].

In contrast age at which such children are identified in Israel, Britain and United States is 7 to 12 months. These countries could alleviate the ages of identification of hearing impairment only after the

implementation of Universal Newborn Hearing Screening Program. In recent years, secondary prevention services have been an important strategy to alleviate the ages of early detection & intervention, to reduce the burden of hearing impairment and to maximize therapeutic benefits. Thus, secondary prevention approaches such as detecting hearing loss at an early age and instituting otologic, audiologic-habitation and parent’s support programs at right time may be helpful to avoid and to minimize the negative consequences of hearing impairment.

Strategies for secondary prevention - early identification and intervention of hearing impairment

Universal Newborn Hearing Screening Program is currently a standard practice across the world. The early identification of a hearing loss is the first step towards the intervention and reversing the negative consequences of hearing loss. The identification of hearing loss can be conducted into two steps:

- Hearing screening
- Comprehensive Diagnostic Assessment

Hearing screening: Screening is a process of applying certain rapid, accurate, valid, simple tests and procedures to generally a large population to identify individual with high probability of having target condition from the individuals who probably don’t have the disorder, with less commitment of time, cost and inconvenience, who are than given diagnostic test and if necessary, treatment. Hearing screening is a tool to tell if individuals might have hearing loss. Hearing screening is easy, simple and painless procedure [30].

Screening methods: Depending on the circumstances and based on evidence from well conducted studies, different methods can be used to decide which neonates and infants should be referred for a complete diagnostic audiological evaluation. There are basically three measures of hearing screening *viz.* family questionnaire or High-

Table 4: Summarizes hearing screening approaches and their rationale.

Screening Approaches	Screening Rationales
1. Auditory Brain Response	<ul style="list-style-type: none"> • It is objective measurement of auditory system. • It provides ear specific information. • It is independent of subject's state (sleeping, awake). • It doesn't require sound booth for evaluation. • ABR is independent of cerebral status. • It has a valuable contribution to cross check principle. • AABR is cost effective.
2. Otoacoustic Emission	<ul style="list-style-type: none"> • Normal OAE is recorded in normal cochlea. • OAE can be recorded reliably from new-borns. • OAE is abnormal even in mild hearing loss cases. • It can be performed by non-audiological person. • OAE recording require relatively brief time. • It provides frequency specific information. • Identifies auditory neuropathy along with ABR.

Risk Registry (HRR), behavioral and electro-physiological measures [1,30].

Family questionnaires & high-risk register (HRR)

Hearing develops early in fetal development and is fully functional at birth. Hearing is linked with future biological development like oral language and cognition. These behaviors grow hierarchically and time bound manner. These developmental schedules can be used to assess the child's development. Parents or caregivers may be asked about the auditory responses of their neonate or infant to environmental sounds and their use of language, including early indicators of language development such as vocalizations and babbling etc.

Hearing problems may be suspected in children who are not responding to sounds or who are not developing their language skills appropriately. The following are some age-related developmental guidelines that may help to decide if child is experiencing hearing problems. The parents and hearing care professionals can use these developmental milestones for screening purposes. The pediatrician or pediatric audiologist consultation is suggested if suspicion about child's hearing is found or observed. This may also help to tap the children who are at risk for acquired, progressive, or delayed-onset hearing loss.

Hearing and speech & language development checklist

The rationale of using check list of developmental milestones is that the development of various biological functions is time bound, orderly and sequential phenomenon. The delayed, deviated or deficient development of biological function in infants & children may indicate disorder. Hence, it can be used as effective tool to screen and identify the children with various speeches and hearing disorder. The National Institute on Deafness and Other Communication Disorders (USA) and other experts list the following age-appropriate hearing milestones for babies and toddlers (Table 3) [31]. The developmental milestone check list can be used by hearing health care professionals, parents, caregivers, social workers health workers, anganwadi workers and significant others.

It is also important to note that not every child is the same, and children reach or acquire developmental milestones of biological functions at slightly variable ages. Therefore, caution is suggested in making an opinion about the child's developmental status negatively. However, infants performing poorly on such measures can be referred for more-comprehensive audiological assessment. One can also use self-administered tests as an initial screen for babies/children or himself to find out if an (hearing) evaluation is needed or not.

These self-administered tests contain certain warning signs of

hearing, speech & language behaviors in infants, older children & adults. Such tools are advantageous that they can be employed at any time and at any place.

However, ideally, such family questionnaires [32] or checklist should be validated before its widespread application so that excessive false negative & false positive results are minimized.

Babies, infants & children

- Child is inconsistently responding to sound.
- Child's speech and language development is delayed.
- Turned up high volume on electronic equipment (radio, TV, CD player).
- Child does not follow directions/commands.
- Child often says, "Huh"
- Child does not respond when called.
- Infant doesn't move or jump when a loud sound is made
- No babbling by the time the infant is 9 months old
- No words spoken by age 18 to 24 months
- Doesn't follow simple commands by age
- Speech is unclear & voice quality is poor at any age

Older children/adults

- Problem hearing over the telephone
- Better through one ear than the other when you are on the telephone
- Trouble in following the conversation with two or more people at the same time
- Turn the TV volume up too high and strain to understand conversation
- Trouble hearing in a noisy background like in restaurants
- Dizziness, pain, or ringing in your ears?
- Asks people to repeat the words, phrases or sentences

If answers are yes to more than two of the above questions, then child may likely to have hearing difficulty; in such condition he should be given the formal hearing test. It is recommended that the children should have at least one hearing test by 2 to 2 1/2 years of age [32]. The babies performing poorly on such measures can then be referred

for more comprehensive audiological assessment.

High risk register

High Risk Registry is another potential tool to screen or to detect hearing impairment in infants and children. The Position Statement of Joint Committee on Infant Hearing-2019 (JCIH-2019) has recommended following disease conditions with highest risk of hearing impairment [33].

A. For use with NEONATE (from embryonic age to 29 days post-natally)

1. Family history of hereditary childhood sensorineural hearing loss
2. In-utero infection-cytomegalovirus, rubella, syphilis, herpes & toxoplasmosis
3. Craniofacial anomalies including those with morphological abnormalities of the pinna and ear canal
4. Birth weight less than 1,500 grams (1.5 kg)
5. Hyperbilirubinemia at a serum level requiring exchange transfusion
6. Ototoxic medications, including but not limited to the amino glycosides, used in multiple courses or in combination with loop diuretics
7. Bacterial meningitis
8. APGAR scores of 0 to 4 at 1 min or 0 to 6 at 5 min
9. Mechanical ventilation lasting 5 days or longer
10. Stigmata or other findings associated with a syndrome known to include a sensorineural and/or conductive hearing loss

B. For use with BABIES (age 29 days through 2 years)

Following are the certain health conditions which require re-screening even after child has passed initial screening.

1. Parents or caregiver concerns regarding hearing, speech, language, or developmental delay
2. Bacterial meningitis and other infections associated with sensorineural hearing loss
3. Head trauma associated with loss of consciousness or skull fracture
4. Stigmata or other findings associated with a syndrome known to include a sensorineural and/or conductive hearing loss
5. Ototoxic medications, including but not limited to chemotherapeutic agent or amino-glycosides, used in multiple courses or in combination with loop diuretics
6. Recurrent or persistent otitis media with effusion for at least 3 months

C. For use with BABIES who pass the initial hearing screening (age 29 days through 3 years)

Some newborns & infants may pass initial hearing screening but require periodic monitoring of hearing to detect delayed-onset sensorineural and/or conductive hearing loss. Babies with these indicators require hearing evaluation at least every 6 months until 3 years and at appropriate intervals thereafter.

Indicators associated with delayed onset sensorineural hearing loss include:

1. Family history of hereditary childhood hearing loss.
2. In utero infection, such as cytomegalovirus, rubella, syphilis, herpes and toxoplasmosis.
3. Neurofibromatosis Type II and neurodegenerative disorders.

Indicators associated with conductive hearing loss include:

1. Recurrent or persistent otitis media with effusion.
2. Anatomic deformities and other disorders that affect Eustachian tube function.
3. Neurodegenerative disorders.

Children found with above HRR should be given initial hearing screening (usually OAE & AABR approach is implemented) and comprehensive diagnostic audiological assessment thereupon, if hearing impairment is suspected. The high-risk babies with hearing loss are estimated at 2 to 4 per 100 infants in the intensive care unit. Thus HRR & Neonatal Intensive Care Unit (NICU) approach is very compelling and found to be effective in identifying children with hearing impairment at an early age. However, the effectiveness of above techniques raise queries as literature reveals that more than 50% of children with hearing impairment are likely to be missed out in H.R.R and N.I.C.U. approaches [1,30]. Moreover, many of them may develop hearing impairment later in life. Further, its application requires a team of specialized professionals & consumes lot of time to record/review/interview for risk indicators. These issues and limitation make these approaches expensive & less time efficient.

Behavioral Measures

The responses of babies and infants to behavioral measuring devices (ranging from simple noisemakers to more sophisticated audiological equipment) and procedures such as Behavioral Observation Audiometry (BOA) or Visual Reinforcement Audiometry (VRA) can also be used to identify hearing loss. However, such methods produce high levels of both false negatives and false positives with babies less than 12 months old [1]. Further, these tests are time consuming and responses are less reliable especially for difficult to test population. The effectiveness of above techniques also raises query as literature reveals, the behavioral approaches can miss unilateral & milder hearing losses. However, reliable screening tests that minimize referral rates and maximize sensitivity and specificity are now readily available.

Physiological Measures

The two common screening methods used with newborns, infants and difficult to test population are Otoacoustic Emissions (OAE) and Auditory Brainstem Response (ABR). These tools can detect hearing loss averaging 30 to 40 decibels (dB) or more in the frequency region important for speech recognition, e.g., approximately 500 Hz to 4000 Hz. The ABR measurements are obtained from surface electrodes that record neural activity generated in the auditory nerve and brainstem in response to acoustic stimuli delivered *via* an earphone. Screening ABR measurements are usually automated (AABR) and reflect the status of the peripheral auditory system, the eighth nerve, and the brainstem auditory pathway. Many researchers have reported specificity & sensitivity in excess of 96% for ABR screening

in newborns [34]. Automated ABR screener ALGO-2 innovative technology has high sensitivity and low failure rate making screening more time and cost effective [35].

Otoacoustic emission represents another promising, quick, cost effective and valid method of testing cochlear function. OAE measures are obtained from the ear canal by using a sensitive microphone within a probe assembly that records cochlear responses to acoustic stimuli. OAEs measure the status of the peripheral auditory system extending to the cochlear outer hair cells. The limitation of OAEs include its sensitivity to conductive hearing loss, which may occur within the first few days of life due to a vernix plug in an infant's ear canal, does not detect auditory neuropathy, and DPOAEs may miss mild hearing loss. In spite these limitations; Vohr et al. reported sensitivity of 100% and specificity of 82% of OAE screening [36]. Thus, the OAE and ABR test procedures are considered as well-suited test for hearing screening in infants and children. Joint Committee on Infant Hearing JCIH-2007 has recommended two steps or two stages universal newborns hearing screening program using OAE and AABR [30]. Table 4 summarizes the hearing screening approaches and their rationales. Most of the universal newborn hearing screening program involves two step physiological hearing screening measures at birth. However, wherever these instruments are not available, time valued behavioral observation, validated checklist, questionnaire or pure tone audiometry can be used to detect hearing loss. Those who fail the screening procedures must be given comprehensive audiologic assessment and specialty medical evaluation to confirm the presence of hearing loss and to determine type, nature, options for treatment, and (whenever possible) etiology of the hearing loss (Joint Committee on Infant Hearing Screening: Position Statement, 2007; 2019) [30,33]. The recommended diagnostic audiological assessment protocol for infants/children is given below.

Recommended diagnostic audiological assessment protocol for infants/children [30,33]

- The audiological test procedures indicated below are age specific and are recommended for use with infants/children and are consistent with protocols recommended by the Joint Committee on Infant Hearing.
- A battery of audiological tests is suggested as no single procedure has sufficient reliability to stand alone.
- Parents/primary caretaker(s) should be present and participate in the administration of all assessment procedures.

Audiological Procedures According to Age of Child

To determine the type, degree and configuration of hearing impairment following audiological procedures are commonly employed across world which can be used in India.

Months

- Child and family case history/Parent observation report.
- Otoscope examination.
- Acoustic Immittance: Tympanometry, physical volume, and acoustic reflexes (Using a higher probe tone, i.e., 1000 Hz)
- Otoacoustic emissions–distortion product and/or transient evoked emissions.
- Auditory brainstem response–click and tone bursts (500

Hz and 4000 Hz) stimuli by air and bone conduction.

- Behavioral observation audiometry (BOA)/Visual Reinforcement Audiometry (VRA) depending on the child's developmental age.

6 Months to 2 Years

- Child and family case history/Parent observation report.
- Otoscope examination.
- Acoustic Immittance: Tympanometry, physical volume, and acoustic reflexes.
- Otoacoustic emissions-distortion product and/or transient evoked emissions-for continued monitoring of cochlear function.
- Auditory brainstem response-click and tone bursts (500 Hz and 4000 Hz) stimuli by air and bone conduction-may still need to be used to monitor individual ear thresholds if reliable individual ear results cannot be obtained, especially in the presence of an asymmetric hearing loss.
- Behavioral Observation Audiometry (BOA)/Visual Reinforcement Audiometry (VRA) depending on the child's developmental age.

2 Years to 5 years

- Child and family case history/Parent observation report.
- Otoscope examination.
- Acoustic Immittance: Tympanometry, physical volume, and acoustic reflexes.
- Conditioned Play Audiometry-to include pure tones from 250 Hz to 8000 Hz by air conduction and 250 Hz to 4000 Hz by bone conduction, speech awareness reception thresholds if possible.
- Otoacoustic emissions-distortion product and/or transient evoked emissions-for continued monitoring of cochlear function.

5+ Years

- Child and family case history/Parent observation report.
- Otoscope examination.
- Acoustic Immittance: Tympanometry, physical volume, and acoustic reflexes.
- Standard audiometry-to include air and bone conduction, speech reception thresholds and speech/word recognition.
- Otoacoustic emissions-for continued monitoring of cochlear function.

If a child or individual does not pass a hearing screening, it's important to get a full hearing test done as soon as possible. The implementation of comprehensive diagnostic audiological assessment protocol for infants/children or adults will help us to identify and profile the hearing loss. This will help us to implement the effective intervention/rehabilitation program [37-40].

Conclusions

Unaddressed hearing impairment poses a significant challenge on a child's development and well-being of families. There are significant costs associated with unaddressed hearing impairment involving health, education and employment as well as lost productivity. India

has sizable about 10% disabling hearing impairment of its total population and the prevalence of hearing impairment is on rising trend in official records. The Census 2011 recorded proportionate increase in hearing impairment population by about 2.4% as compared to Census of India 2001. Census 2021 is pending due to COVID-19 pandemic but it is expected to rise due to demographic, hygiene & health, and development factors.

Unless appropriate action is taken, hearing impairment will continue to impact human dignity, quality of life and national productivity. Thus, to avoid and to reduce the prevalence and increasingly rising population of hearing impairment, to minimize the burden on limited infrastructure and manpower to identify and intervene hearing impairment serious attention of community, policy makers, public health experts and administrators are warranted. The good news is that about half of, about 60% of all cases of hearing impairment can be prevented through public health measures such as immunization, improved maternal and neonatal care, and screening for, and early management of, otitis media in children under 15 years of age and several others can be benefited from secondary prevention i.e., early identification of hearing loss followed by prompt and suitable interventions.

Unfortunately, we are not doing well in both the directions; neither India has universal public health measures or any universal hearing screening program. Till date national average identification age of children with severe hearing loss is not available. As per the estimation, the average identification age is 5 years whereas Joint Committee on Infant Hearing (2007, 2019) endorses that diagnosis of hearing loss before 3 months with appropriate intervention no later than 6 months is advantageous to take full advantage of the auditory plasticity of the developing sensory system. The studies have indicated that use of hearing aids, cochlear implants and other assistive devices; captioning & sign language; and other forms of educational & social support can benefit to hearing impaired to achieve fullest potential to become inclusive member of the society. These intervention modalities are cost effective as compared to the cost of untreated hearing loss.

India has launched the National Program for Prevention and Control of Deafness in 2006 with aims to identify babies with bilateral severe-profound hearing loss by 6 months of age and intervene or initiate rehabilitation by 9 months of age and currently operational in over 60 districts across country. Under this scheme, the pediatric population has a provision of subsidized Behind the Ear (BTE) hearing aids. There is also provision for subsidized digital Behind the Ear (BTE) hearing aids and cochlear implant along with batteries for three years to persons with hearing impairment through the scheme 'Assistance to Disabled Persons for Purchase-Revised 2014 funded by the Ministry of Social Justice and Empowerment. Similar facilities are also available under Rashtriya Bal Swasthya Karyakram (RBSK-2013) launched by ministry of health and family welfare. It is an initiative aimed at screening over 27 Crore children from 0 to 18 years for 4 Ds: Defects at birth, Diseases, Deficiencies and Development Delays including Disabilities. Child Health Screening and Early Intervention Services under NRHM plan to cover 30 identified health conditions for early detection and free treatment and management. Children diagnosed with illnesses shall receive follow up including surgeries at tertiary level, free of cost under National Rural Health Mission (NRHM).

If these programs are implemented through the systematic

approach and in right spirit, it would yield rich dividends in protecting and promoting the health and improving quality of life of children with hearing impairment. However, it is difficult to believe that every child with hearing impairment will benefit with early detection program. It is not because, these measures are inefficient or ineffective but the fact that global production of hearing aids meets less than 10% of global need (WHO 2021). Further, the lack of availability of services for fitting and maintaining digital hearing aid & cochlear implant, and the lack of batteries are also barrier in effective use of these amplification devices (NSSO, 2003).

Under these conditions, it is necessary that primary prevention and secondary prevention i.e., early identification & intervention services must be simultaneously implemented with primary focus on prevention of disease and health promotion rather than the diagnosis and treatment of diseases. UNCRPD-2006 envisions a world in which no individual experiences leading to hearing impairment hearing loss due to preventable causes, and those with hearing loss can achieve their full potential through rehabilitation, education and empowerment (WHO, 2021) and India is signatory of UNCRPD-2006 and promulgated the RPWD Act 2016 to ensure primary & secondary prevention of hearing impairment in Indian population. Thus, we must strive firstly for primary prevention. World Health Organization, way back in 1995, has recommended very robust roadmap for the prevention of hearing impairment to its member states to implement prevention strategy, which remains pertinent even today includes.

- Prepare national plans for the prevention and control of major causes of avoidable hearing loss and for early detection of such loss in neonates, infants, children, and the elderly, within the framework of primary health care.
- Take advantage of existing guidelines and regulations or introduce appropriate legislation for the proper management of particularly important causes of deafness and hearing impairment, such as otitis media, use of ototoxic drugs and harmful exposure to noise, including noise in the work environment and loud music.
- Ensure the highest possible coverage of childhood immunization against the target diseases of the Expanded Program on Immunization, and against mumps, rubella, and meningococcal meningitis whenever possible.
- Consider setting up mechanisms for collaboration with nongovernmental or other organizations for support to-and coordination of-action to prevent hearing impairment at the country level, including the detection of hereditary factors and genetic counseling; and
- Ensure appropriate public information and education for hearing protection and conservation in particularly vulnerable or exposed population groups.

The primary intervention efforts can reduce the infectious disease burden associated with congenital and early-onset hearing loss along with other environmental risks and those who inflict with hearing impairment can be helped with secondary intervention through early detection. Thus, primary and secondary prevention together can reduce substantial number of children with hearing impairment can minimize the long-term effects of hearing impairment.

Final Comments and Recommendations

Hearing impairment is second most frequent sensory deficit in

Indian children imposing serious health concern and impairs speech, language and cognitive development. The primary prevention efforts can reduce the infectious disease burden associated with congenital and early-onset hearing loss along with other environmental risks and early identification and intervention program can substantially reverse the impact of hearing loss. India has envisaged substantial scheme, mission, campaign, and programs to manage the hearing impairment through modern technology like digital hearing aid, cochlear implant and speech & language therapy to enhance communication abilities, special educational facilities to improve the quality of life of children with hearing impairment.

However, the lack of availability of services for fitting and maintaining digital hearing aid and cochlear implant, and the lack of batteries are also barrier for its effective use.

Moreover, causes of hearing loss such as infection, negligence and ignorance with underlying reasons of low socioeconomics and poor hygienic conditions, still remains relevant even today. Thus, it can be assumed that early identification and intervention will not fit the bill. If we are to reduce unnecessary sufferings, poor educational performance of children and well-being of the families, we have to employ community, primary, secondary and tertiary health measures to reduce the prevalence and to identify hearing loss at birth and to provide the timely intervention. Certainly, we must begin with Head Start Program in these directions. Therefore, whether one does or doesn't embrace the strategies of prevention of hearing loss and expert may differ in their professional opinion, how best to achieve the goals of early identification & intervention. However, it is believed that until health care services can be guaranteed for all, prevention and hearing screening appears to be right plan.

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