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REVIEW

ОБЗОРНАЯ СТАТЬЯ

Techniques for assessing hearing loss in infants

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Abstract. The ability to hear is one of the five major senses that allows us to communicate effectively with others. Unfortunately, individuals frequently take their sense of hearing for granted, and they do not know how important it is until it is lost or compromised. Hearing loss was not a top concern for the Indian government until recently. Prevention, early diagnosis, and care can prevent half of all occurrences of deafness and hearing impairment. The auditory sense is critical for a child's brain development. This will also reduce the strain of hearing loss, preventing the loss of many potentially productive years. The most cost-effective strategy to lessen the burden of hearing loss is to screen new-borns and babies. Hearing loss is the most frequent sensory deficiency in people all over the world. The severity of hearing loss can range from mild to severe. Kapoor Set al. suggested that by screening, the condition is detected earlier than it would otherwise be diagnosed. Because of the urgent need to prevent infectious causes of mortality, neonates and new-borns are not regularly checked for any specific disease in India. The Department of Prevention of Communication Disorders of All India Institute of Speech and Hearing (AIISH) located in the Southern India, conducts infant screening for hearing disorder on regular basis in different hospitals attached to it using Behavioural Observational Audiometry, Otoacoustic Emissions (OAE) screening, and administering High Risk Register (HRR). In the year 2009–2010, a total of 12416 new-borns in 10 hospitals associated with AIISH were screened for hearing disorder. The following paragraphs deals with various issues related to the hearing screening of infants in India. Methodology of study was as we searched PubMed Central and Google Scholar for relevant articles with key words «hearing, screening, hearing loss and infants». Full-text articles were downloaded dated July 2022 to September 19, 2022. Relevance was judged according to articles describing theories of hearing screening of infants India. **Conclusion.** Hearing screening for new-borns is critical for detecting congenital hearing loss and providing early management. Every person has the right to live a healthy lifestyle. Hearing impairment, like communication disorders, begins early in life. Infants with hearing loss will only be able to reach their full potential as fully active, contributing, and integrated members of society if systematic early screening programmes are implemented. Hearing screening for new-borns is critical for detecting congenital hearing loss. The AABR is considered necessary for HRNHS in high-risk new-borns (prematurity, anoxia, hyperbilirubinemia) who are at risk of auditory neuropathy that cannot be detected using the OAE test. The OAE test is faster and easier to conduct, but it has a larger false positive rate than the AABR. The ideal hearing procedure is still being developed. As a result, the hearing screening technique should be adapted to the specific demands of each centre.

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Introduction

The ability to hear is one of the five major senses that allows us to communicate effectively with others. Unfortunately, individuals frequently take their sense of hearing for granted, and they do not know how important it is until it is lost or compromised. Hearing loss was not a top concern for the Indian government until recently. With the establishment of the National Program for the Prevention and Control of Deafness (NPPCD), there is a renewed focus on this massive public health issue. Age, excessive noise exposure, head and ear injuries, use of ototoxic medicines, infectious disorders such as meningitis, measles, mumps, and chronic ear infections, and congenital anomalies are all common causes of hearing loss. Prevention, early diagnosis, and care can prevent half of all occurrences of deafness and hearing impairment. The auditory sense is critical for a child's brain development. Early detection of hearing loss will prevent the problem from becoming out of hand. This will also reduce the strain of hearing loss, preventing the loss of many potentially productive years. The most cost-effective strategy to lessen the burden of hearing loss is to screen new-borns and babies.

Hearing loss is the most frequent sensory deficiency in people all over the world. The severity of hearing loss

can range from mild to severe [1]. According to World Health Organization estimates from 2012, moderate to profound hearing loss is a debilitating illness that affects 360 million individuals globally [2]. Hearing loss is the second most prevalent cause of years lived with disability (YLD), accounting for 4.7 percent of overall YLD, according to Mathers C et al [3]. According to the widely cited prevalence figures for India, 6.3 percent of Indians have significant hearing loss [4]. Garg S. et al. suggested that Hearing loss is more common in rural settings than in urban areas [5]. According to the 58th round of the National Sample Survey Organization survey in 2002, there are 291 people per 100,000 who have severe to profound hearing loss. Children aged 0–14 years make up a large portion of this group. According to the report, around 7 % of persons have a congenital hearing loss [6]. Deafness acquired as a youngster has a significant influence on an individual's social, economic, and productive life. Simultaneously, there is a significant human resource shortage in health care to tackle this issue. The Indian government has chosen primary health care (PHC) as the preferred option for providing and implementing deafness prevention.

The term «hearing impairment» (synonyms: «hardness of hearing,» «hypoacusis») refers to a loss

of hearing capacity in the broadest sense, ranging from barely perceptible abnormalities to complete deafness. An interruption of sound conduction to the inner ear, sound perception by the sensory cells of the cochlea, or sound processing in the cochlear nerves, auditory pathway, or cortical auditory centres causes hearing impairment. As a result, hearing loss is a sign of a variety of disorders that damage the auditory organs. It differs from other hearing problems such hyperacusis (sound sensitivity), fluctuating hearing, and tinnitus.

Hearing loss in world and India Kapoor S. et al. suggested that by screening, the condition is detected earlier than it would otherwise be diagnosed. Because of the urgent need to prevent infectious causes of mortality, neonates and new-borns are not regularly checked for any specific disease in India. Though India has succeeded in decreasing death rates, the burden of disability has not decreased; in fact, it has increased over time [7]. Many disabilities can be avoided if we have a proper screening program. Nagapoornima P. et al. suggested that out of every 1000 children born in India, there may be 5–6 such children who cannot hear properly [8]. Cunningham M. et al. suggested the overall estimates prevalence of hearing loss in new-born are between 1 and 6 per 1,000 new-borns [9]. Mukherjee SS et al. suggested that the prevalence of hearing impairment in high-risk infants. Taking BERA out of 87 high risk infants 10.34 % had bilateral severe to profound hearing loss, 17.24 % had bilateral mild to moderate hearing loss and 12.64 % had impaired hearing in one ear [10]. Because there are no visible clues, most hearing-impaired children who are not examined at birth are not detected until they are between the ages of 1.5 and 3, far after the key period for normal speech and language development has passed. A hearing challenged infant can be discovered and treated early with the help of neonatal hearing screening. In this instance, the infant will most likely develop language, communication, and social skills on level with his or her normal hearing peers, avoiding hearing loss-related problems for the rest of his or her life [11]. In India, there has never been a large-scale initiative to test new-borns or babies for hearing abnormalities. The Department of Prevention

of Communication Disorders of All India Institute of Speech and Hearing (AIISH) located in the Southern India, conducts infant screening for hearing disorder on regular basis in different hospitals attached to it using Behavioural Observational Audiometry, Otoacoustic Emissions (OAE) screening, and administering High Risk Register (HRR). In the year 2009–2010, a total of 12416 new-borns in 10 hospitals associated with AIISH were screened for hearing disorder. Of them, 1010 infants were referred for further checkup [12]. The following paragraphs deals with various issues related to the hearing screening of infants in India.

Time of screening. The Joint Committee on Infant Hearing has recommended universal hearing screening by in month of age, diagnosis of hearing loss by 3 months of age, and enrolment in early intervention by 6 months of age [13]. Similar formula can be followed in India with best screening of every child delivered in a health centre before discharging the mother and child.

The aim of this review was to make clear picture of which screening technique will be helpful in hearing loss screening.

Screening techniques

Historical context

Sir Alexander and Lady Ewing in Great Britain were among the first to investigate systematically infant responses to auditory stimuli for purposes of hearing screening. Their technique involved observation of the infant's response to common sounds such as noisemakers, toys, crumpled paper, and the human voice. Ewing and Ewing observed and described a classic unconditioned orienting response to sound including eye-shifts and head turns in the direction of the stimulus [14].

Froeschels and Beebe provided early investigations of hearing in new-born infants. They reported that new-born infants responded to whistles but not to tuning forks. The most commonly observed response was the «acoustopalpebral reflex» (blinking). These investigators encouraged use of hearing tests during the new-born period and at monthly intervals thereafter to detect hearing loss early in life [15].

Hardy et al. also evaluated new-born responses to a «clacker,» a doorbell, and a «tonette,» each producing a moderately-loud (e.g., 61–80 dB SPL) sound at a distance of three feet from the infant's ear. Their criterion response was a complete or partial Moro response. These investigators reported that new-born infants responded best to the «clacker,» a custom-made device that produced a broad-spectrum signal [16].

Early «objective» techniques for UNHS

Observing the behaviour of new-borns in reaction to sound is susceptible to observer bias.

To eliminate observer bias and enhance test reliability Simmons and Russ described the crib-o-gram, a new-born hearing screening device that automated detection of new-born reaction to sound, to minimise observer bias and improve test reliability. In the crib-o-gram, a motion detector was placed beneath the infant's mattress. The detector was connected to a strip-chart recorder or, in later models, an electronic chip that compared the infant's movement in response to a sound stimulus to movement during silent intervals [17]. Durieux-Smith et al. suggested that the crib-o-gram contributed fundamental ideas of unbiased observation and automated reaction detection to UNHS, while being unreliable in neonatal intensive care unit population and unworkable for short-stay well-baby populations [18]. The auditory response cradle (ARC) included physiologic response detection in the study of new-born infants' behavioural responses. The ARC was developed in the 1970s in the United Kingdom and it examined motor response to sound as well as detection of changes in the infant's heart rate and breathing [18–20].

Current universal neonatal hearing screening methods practice

According to Narendra Rai et al., the significant prevalence of hearing loss necessitates the establishment of universal neonatal hearing screening (UNHS). In light of our country's economic constraints, we may begin by screening «at risk» populations [21].

Newborn hearing screening (NHS) is the process of diagnosing hearing loss in newborns using

electrophysiological methods such as brainstem evoked response audiometry (BERA) and/or otoacoustic emission (OAE) [22, 23].

Both the ABR and OAEs have benefits and limitations, and the team of specialists in charge of implementing UNHS in any given setting should choose the best approach based on the population to be tested and the testing environment

Auditory brainstem response

Both Israeli and American scientists first characterised the ABR in the late 1960s and early. The origins of the numerous response components, the effects of maturation and gender on the response, and therapeutic applications for audiologic and neurologic objectives were all investigated in the beginning [24, 25].

Schulman-Galambos and Galambos, introduced its application in newborn hearing screening [26].

The auditory brainstem response, also known as an auditory evoked potential, is an electrophysiologic response to an acoustic stimulus recorded from the auditory and central nervous systems. Surface electrodes placed to the subject's scalp can capture a series of auditory evoked potentials. The latency of these potentials, or the time it takes for them to appear after auditory stimulation, is usually used to classify them. The auditory brainstem response (ABR) is one of the first auditory evoked potentials, occurring within 20 milliseconds of sound stimulation. To detect any auditory evoked potential, including the ABR, certain stimulus and recording settings are required.

The ABR is derived from components in the eighth nerve and the brainstem auditory system. Within the first 20 milliseconds following stimulation by a short-duration, broad-spectrum auditory stimulus, often a click, this modest amplitude (less than 1.0 microvolt) response is recorded. Because the reaction is time-locked to the stimulus, automated signal-averaging algorithms may extract it from the subject's continuing electroencephalogram (EEG). Responses to more than 1,500 stimuli provided at rapid click rates (e.g., 10 to 30 clicks/second) are averaged at close-to-threshold

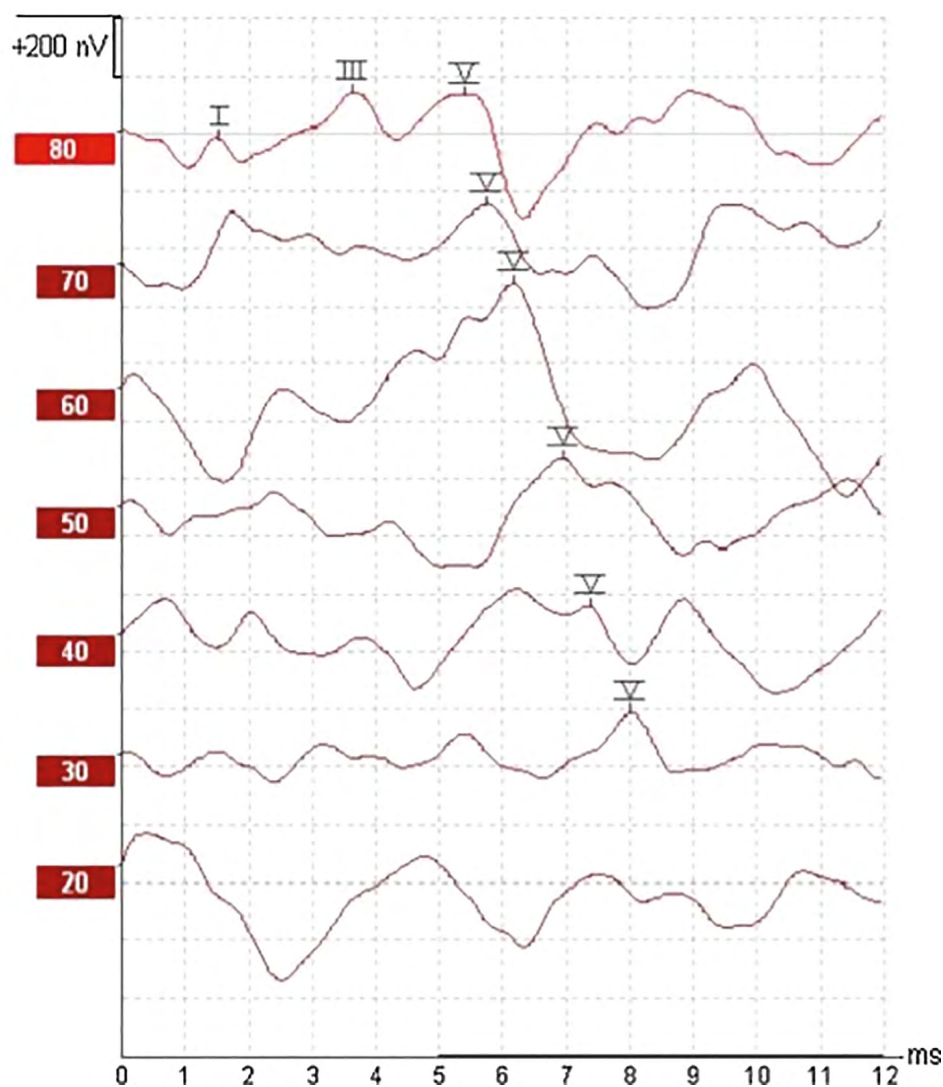


Fig. 1. Objective hearing threshold determination. Wave V remains visible up to 30 dB HL, defining this patient's threshold. ABRs reliably explore only between 2000 and 4000 Hz [30]

intensities to produce a clearly recognisable waveform (Fig. 1).

As a technique for UNHS, A-ABR provides a number of advantages. It's a well-established procedure with well-defined response characteristics. In newborn and preterm neonates, the reaction is consistently present. Specific elements such as maturation, peripheral and central auditory abnormalities, subject condition, and physiologic variables have well-defined effects on response.

According to Herrmann et al and Sininger et al. the ABR is obtained by automatic response detection

technologies such as template matching or calculation of the noise vs. noise plus signal variance ratio, which eliminates observer bias and allows the test to be conducted by nonprofessional screening personnel [27, 28].

Finally, because the response is generated by both sensory (cochlea) and neural (eighth nerve and brainstem structures and path ways) components of the auditory system, A-ABR screening will detect infants with auditory neuropathy, a relatively uncommon but important disorder [29].

The use of A-ABR for UNHS has a few drawbacks

Gorga et al. and Vohr et al. suggested that there are just a few drawbacks to adopting A-ABR for UNHS. Some manufacturers' disposable supplies are quite expensive, increasing the overall cost of screening per baby [31, 32]. Norton et al., 2001c suggested that the Test time is longer by several minutes than test time for OAE screening; longer test time is largely related to preparation for electrode application [33].

Gorga M. et al and Kileny P.R. et al suggested that the ABR response generated by a click corresponds well with hearing sensitivity in the 2k-4k Hz frequency range, but only moderately with hearing sensitivity below 1k Hz [34, 35]. So low-frequency hearing loss, an atypical audiometric configuration, may thus be missed by A-ABR screening.

Otoacoustic emissions

Acoustic signals generated by the cochlea either spontaneously or in response to sound stimulation are known as otoacoustic emissions. As part of the

natural hearing process, movement of the outer hair cells (OHC) creates OAEs. As a result, OAEs may be thought of as «cochlear energy» that travels via the middle ear and external ear canal. This cochlear energy might be detected using a sensitive tiny microphone sealed inside the subject's external ear canal. OAEs are produced both spontaneously and in response to auditory stimulus. Because spontaneous OAEs are not consistently present in all people with normal hearing, they are not currently employed in clinical audiology.

European scientists were reporting the presence of highly distinct OAEs in infants [36]. Early studies found that OAEs are consistently present in premature and newborn infant, infant OAEs are typically larger in amplitude than adult or even child OAEs and OAEs in new-borns are best obtained 48 hours or longer after birth [37–41].

The type of auditory signal used to elicit a response is usually used to classify evoked otoacoustic emissions (Fig.2).

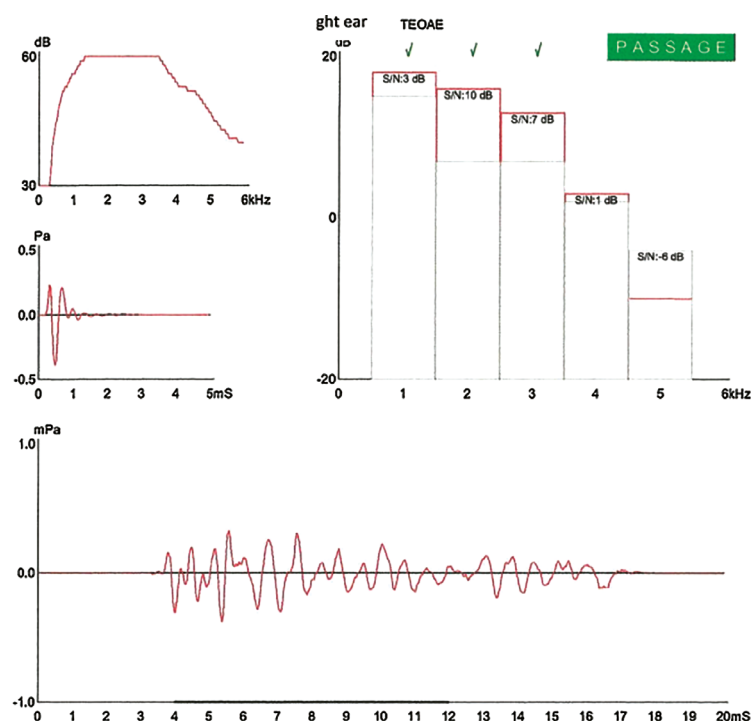


Fig. 2. Right-side transient evoked otoacoustic emissions, indicating normal right-ear hearing [30]

Transient evoked OAEs (TEOAEs), which are stimulated by a short duration acoustic transient such as a click or tone burst, and distortion product OAEs (DPOAEs), which are stimulated by two continuous pure tones delivered to the ear at the same time, have both proven therapeutic uses. DPOAEs are the result of the inner ear's natural asymmetrical amplification process. Similar to A-ABR, using OAEs in UNHS provides various advantages. It's a tried-and-true approach with well-understood response characteristics. The response is always present in new-borns and preterm new-borns. Specific factors affecting response include maturation, peripheral auditory abnormalities, subject condition, and physiologic variables. OAEs may be obtained using automated methods, which eliminate observer bias and allow nonprofessional screening employees to do the test.

Using OAEs in UNHS provides a number of benefits. It's a tried-and-true approach with well-understood response characteristics. The test is non-invasive, requires no special subject preparation (e.g., electrode attachment), and provides low risk to the new-born.

There are few disadvantages in using OAEs for UNHS. According to Vohr et al., there is a higher refer rates in the first 24 hours of life result in higher follow-up costs and unnecessary parental anxiety [42]. Because these refer rates are frequently associated with transient external or middle ear conditions that do not produce significant hearing loss, detection of infants with these conditions does not contribute to the goal of UNHS.

The discovery of new-borns with these disorders does not contribute to the UNHS target since these refer rates are commonly linked with temporary external or middle ear diseases that do not cause severe hearing loss. Another issue with OAEs for UNHS is false negative findings in new-borns with auditory neuropathy. Because OAEs are a preneural phenomenon, they do not identify issues at the sensory cell—neural element synapse, the eighth nerve, or higher auditory structures.

According to Sininger, infants with auditory neuropathy and severe hearing impairment usually display intense and recurrent OAEs [43].

Comparison

The AABR pass rate (67.9 %) was greater than the DPOAE pass rate (50.1 percent). With increasing age, both DPOAE and AABR pass rates improved dramatically (p-value 0.001). Between the ages of 36 and 48 hours, the highest pass rate for both DPOAE and AABR was 73.1 percent and 84.2 percent, respectively. With a p-value of 0.001, the mean testing duration for AABR (13.54 min 7.47) was substantially longer than DPOAE (3.52 min 1.87) [44].

The OAE is an automated hearing test that records sounds released by the cochlea in people with normal hearing, whereas the AABR is an automated hearing test that evaluates the auditory nerve system. According to previous studies by B.R. Vohr et al., N.K. Apostolopoulos et al, J.T. Jacobson et al., and B.S. Hermmann et al., OAE has a sensitivity of 90 percent-95 percent and a specificity of 89 percent-91 percent, while AABR has a sensitivity of 100 percent and a specificity of 96 percent-98 percent [45–48].

The AABR is judged required for HRNHS in high-risk new-borns (prematurity, anoxia, hyperbilirubinemia), who are at risk of auditory neuropathy that cannot be diagnosed by OAE, according to I. Rapin, J. et al. [49].

According to Benito-Orejas, AABR is more expensive and time demanding than OAE, but it has less false positives and referral rates [50].

According to Gabbard and Akinpelu AABR is less impacted by temporary circumstances in the middle ear (presence of amniotic fluid) and external auditory canal (presence of debris and vernix) than OAE at 24–48 hours after birth [51, 52].

Conclusion

Hearing screening for new-borns is critical for detecting congenital hearing loss and providing early management. Every person has the right to live a healthy lifestyle. Hearing impairment, like communication disorders, begins early in life. Infants with hearing loss will only be able to reach their full potential as fully active, contributing, and integrated members of society if systematic early screening programmes

are implemented. Hearing screening for new-borns is critical for detecting congenital hearing loss.

The AABR is considered necessary for HRNHS in high-risk new-borns (prematurity, anoxia, hyperbilirubinemia) who are at risk of auditory neuropathy that cannot be detected using the OAE test. The OAE test is faster and easier to conduct, but it has a larger false positive rate than the AABR. The ideal hearing procedure is still being developed. As a result, the hearing screening technique should be adapted to the specific demands of each centre.


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Способы оценки потери слуха у младенцев

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Аннотация. *Актуальность.* Способность слышать — одно из пяти основных чувств, позволяющих нам эффективно общаться с другими. К сожалению, люди часто воспринимают свой слух как нечто само собой разумеющееся и не осознают, насколько он важен, пока он не утрачен или не нарушен. Потеря слуха до недавнего времени не была главной проблемой индийского правительства. Профилактика, ранняя диагностика и уход могут предотвратить половину всех случаев глухоты и нарушений слуха. Слух имеет решающее значение для развития мозга ребенка. Раннее выявление потери слуха не позволит проблеме выйти из-под контроля. Наиболее экономически эффективной стратегией снижения бремени потери слуха является обследование новорожденных и младенцев. Потеря слуха является наиболее частым сенсорным дефицитом у людей во всем мире. Тяжесть потери слуха может варьироваться от легкой до тяжелой. Капур Сет др. предположили, что с помощью скрининга заболевание выявляется раньше, чем в противном случае оно было бы диагностировано. Из-за острой необходимости предотвращения инфекционных причин смертности новорожденные в Индии не проверяются регулярно на наличие каких-либо конкретных заболеваний. Отдел профилактики коммуникативных расстройств Всеиндийского института речи и слуха (AIISH), расположенный на юге Индии, регулярно проводит скрининг младенцев на нарушение слуха в различных больницах, связанных с ним, с использованием поведенческой обзорной аудиометрии и скрининга отоакустической эмиссии (ОАЭ) и ведение Регистра высокого риска (HRR). В 2009–2010 годах в общей сложности 12 416 новорожденных в 10 больницах, связанных с AIISH, были обследованы на предмет нарушений слуха. В обзоре проанализированы различные вопросы, связанные с проверкой слуха младенцев в Индии. Методология исследования заключалась в поиске соответствующих статей в PubMed Central и Google Scholar по ключевым словам «слух, скрининг, потеря слуха и младенцы». Полнотекстовые статьи были загружены с июля 2022 г. по 19 сентября 2022 г. Релевантность оценивалась по статьям, описывающим теории скрининга слуха младенцев в Индии. Вывод. Проверка слуха у новорожденных имеет решающее значение для выявления врожденной тугоухости и обеспечения раннего лечения. Каждый человек имеет право на здоровый образ жизни. Нарушение слуха, как и расстройства общения, начинается в раннем возрасте. Младенцы с потерей слуха смогут полностью реализовать свой потенциал как полноценные, активные и интегрированные члены общества только в том случае, если будут реализованы систематические программы раннего скрининга. Скрининг слуха новорожденных имеет решающее значение для выявления врожденной тугоухости. AABR считается необходимым для HRNHS у новорожденных с высоким риском (недоношенность, аноксия, гипербилирубинемия), которые подвержены риску слуховой нейропатии, которую невозможно обнаружить с помощью теста ОАЭ. Тест ОАЭ проводится быстрее и проще, но у него более высокий уровень ложноположительных результатов, чем у AABR. Идеальная процедура проверки слуха еще находится в стадии разработки. В результате методика проверки слуха должна быть адаптирована к конкретным требованиям каждого центра.

Ключевые слова: слух, скрининг, потеря слуха, дети раннего возраста

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