Review Article

Universal Neonatal Hearing Screening: A Comprehensive Review

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ABSTRACT

Universal neonatal hearing screening test is routine test of newborn to detect hearing impairments in early stage of life. Early detection and early intervention is necessary for expected linguistic and literacy outcome. In this paper we reviewed the current state of knowledge regarding transient evoked otoacoustic emission and automated brainstem response. These tools are used as screening tools for neonatal hearing screening program. Universal newborn hearing screening is widely used than only risk factor screening. Some improvements of these tools such as automation, portability and AI integration have enhanced this program.

Keywords: Auditory Evoked Potentials, Otoacoustic Emissions, Universal Screening, Auditory Brainstem Response, Early Intervention

INTRODUCTION

Neonates are the newborn babies of below 4 weeks of age.[1] Screening involves testing asymptomatic populations to evaluate the probability of having a particular disease.[2] Neonatal screening refers to tests performed within the neonatal period. This screening is essential for early detection of congenital conditions that may not be immediately apparent, allowing for timely intervention and treatment. From metabolic disorders to hearing impairment, neonatal screening plays a crucial role in ensuring the well-being of newborns. Among thousand newborns, 1-3 are found to be suffering from severe bilateral hearing impairment.[3] This significant number of newborns demands the early screening and intervention measures to address hearing-related challenges.

Hearing impairment is defined when hearing threshold is 40dB or greater.[4] During the neonatal period hearing screening is performed for early detection of permanent childhood hearing impairment (PCHI). Early detection is necessary for the deaf child to maximize the linguistic competence and literacy development through early intervention, as normal hearing is essential for speech and language development. However, hearing impairment in early childhood is often not diagnosed until later stages, creating a challenge hence termed as hidden disability.[5] According to the joint committee on infant hearing, hearing impairment detection should be done before 3 months of age, with intervention initiated within 6 months of age.[6,7]

Screening Methods

Neonatal hearing screening method uses otoacoustic emissions (OAE) and auditory brainstem response (ABR) as screening tools. In fact, OAE is used as a screening tool and ABR is reserved only for high risk babies and ones who could not pass OAE, as ABR is costly and requirs more expertise to perform.[8] These instruments are highly sophisticated, and they undergo regular updates and enhancements. Technological advancements have revolutionized these tools like automated auditory brainstem response (aABR) devices, enhanced otoacoustic emissions (OAE) equipment.

There are two methods for screening of bilateral PCHI: risk factor screening and

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universal newborn hearing screening (UNHS).[9] Universal hearing screening means screening the all newborn babies, regardless of risk factors. Risk factors includes an admission to a neonatal intensive care unit, low birth weight prematurity, septicemia, hyperbilirubinemia, hypoxia, family history of deafness.[10,11] Universal hearing screening includes otoacoustic emissions (OAE), auditory brainstem responses (ABR).[12]

OtoAcoustic Emissions (OAE)

Outer hair cells have some active processes that produce some energy within the cochlea. These energy then transmit through middle ear into the external auditory canal which is known as otoacoustic emissions. This emissions can be recorded within the external ear canal which is a normal function of hearing. When there is absence of otoacoustic emission it indicates a loss of hearing greater than 40 dB.[14] This principle is used in neonatal hearing screening program. OAE testing is used as it is quick, simple to perform, non-invasive and can identify even mild hearing impairment. Its disadvantage is that it does not detect subtle losses such as mild losses (<35 dB) or auditory neuropathy spectrum disorder.[15] In universal neonatal hearing screening program, the OAE is used to obtain either a pass or refer test result. When a pass result is obtained, the likelihood of significant hearing loss is minimal. And when refer is obtained then it cannot be said that baby has a hearing impairment, thus no conclusions can be made. For the clarification of refer further investigations are needed. There are two types of OAE- One type of OAEs, distortion product OAEs (DPOAEs), studies passive versus active processing to identify auditory function. Transient evoked OAEs (TEOAEs) are a second type of OAE. TEOAEs are stimulated by transient clicks and are often faster and more tolerant to noise and movement than DPOAEs.[14] There are many similarities and dissimilarities between the DPOAE and TEOAE. DPOAE shows better performance above 4 kHz, whereas TEOAE performs more effectively between 0.5 to 1.5 kHz. This is more useful in diagnostic assessment rather than as a screening tool. Another thing is that TEOAE is faster than DPOAE. But recent DPOAE machine is faster than the older versions. DPOAE can perform better in noisy environments while TEOAE needs a quiet environment. Despite their differences, both types of OAEs contribute to comprehensive neonatal hearing screening programs.

In Transient Evoked Otoacoustic Emission (TEOAE), a probe is inserted into the external canal of new-born to detect hearing losses. A click stimuli of 75–85 dB is used and response is recorded. If the response wave have an acceptable amplitude in the defined spectrum then it is considered as the pass.[16] Otherwise it is considered as referred. The newborn babies usually examined after meal and in a quiet nursery room.

Auditory Brainstem Responses (ABR)

ABR is used simple stimuli such as clicks and sinusoids to tap into and maximize these transient and sustained auditory brainstem responses. While clicks and tones have been instrumental in defining these basic response patterns, they are poor approximations of the behaviorally relevant sounds we encounter outside the laboratory.[17] Advantages of the automated system include a dual artifact rejection system, attenuating ear couplers, and a battery operated design. These findings suggest that the automated ABR screener is a viable alternative to conventional ABR instrumentation for the limited purpose of neonatal auditory screening.[18] When

auditory system is evoked with sound stimulus it produces electrical responses into the brain. These electrical responses from the brainstem is recorded with surface electrode and present with time in graphs. The recorded responses have seven positive waves. Latency of these waves along with the amplitude is used for monitoring the Auditory Brainstem Response (ABR). In ABR thousands of nerve stimulations are averaged and summated. The ABR is used for estimation of hearing threshold and sometimes monitoring of brain functions in trauma and skull base surgery. ABR has seven positive waves. The latencies and amplitudes are the measures of these waves used clinically. These measurements can be done full automated form in automated ABR (aABR).[19,20,21]

Physiology of Newborn Hearing

Hearing starts in the external ear. The pinna and ear canal receives the longitudinal sound wave and direct these waves to the eardrum which vibrate the eardrum. The vibrations are then transmitted through the osscicular system of the middle ear to the fluid-filled inner ear.[22] In the inner ear the cochlea has specialized hair cells, which convert these vibrations into electrical signals. These signals are then transmitted via the auditory nerve to the brainstem and further to the auditory cortex in the brain. The brain processes these signal. During twenty fifth week of gestation, the fetus begins to respond to sound stimuli from the external environment. As the pregnancy progresses, the auditory structures, including the cochlea and auditory nerve, continue to mature, laying the foundation for auditory processing post-birth. Following birth, the auditory system enters a critical phase of development. Within the first few months, the infant's brain undergoes significant changes in response to auditory stimuli. This period, often referred to as the critical or sensitive period, is when the neural pathways responsible for processing and interpreting auditory information are being established and refined. Key milestones during this phase include the development of sound localization, discrimination of speech sounds, and the ability to differentiate between various pitches and frequencies. These milestones are crucial for language acquisition and overall cognitive development. There are some studies to address the effects of neonatal intensive care unit on hearing. High sound pressure levels in noisy hospital environment has shown in their physiological or functional changes.[23]

Neural Plasticity and Early Interventions

Early childhood intervention is essential due to the observed plasticity in neurons, presenting a window of opportunity for modifying neural functions. Processes like synaptogenesis, myelination, and the development of specific brain structures, including the medial temporal lobe and prefrontal cortex, have limited capacity during brain maturation. However, beyond a critical time period, changes occur within these processes, such as reduced synaptic activity modification ability. Neural plasticity manifests through time-bound axonal regeneration, dendritic surface expansion, alterations in neurotransmitter synthesis and post-synaptic responses, as well as changes in cortical and subcortical metabolic activities such as glucose utilization.[24] Neural plasticity can explain the neurophysiological basis of early childhood intervention, especially concerning the motor responses of the brain. Various physiological events unfold in response to experience, with linguistic development dependent on

auditory experiences, and the critical period of neural plasticity being crucial for such development.[24] Intervention tools for hearing-impaired children, such as hearing aid fitting, cochlear implantation, and audio-verbal therapies, play significant roles in this process. Early intervention facilitates the development of language skills essential for communication, as neural plasticity is most pronounced during early developmental stages.

Challenges in Screening Programs

Implementing universal screening programs in different country faces different challenges. Lack of human resources, inadequate infrastructure, equipment-related shortcomings, and low priority for hearing impairment (HI) prevention are seen in developing conunties.[25] Addressing these challenges requires a multifaceted approach. Portable machine, user-friendly, and cost-effective devices and integration of artificial intelligence may further improve the accuracy and efficiency of screenings. The implementation of hearing screening should be incorporated into the national healthcare policy.

CONCLUSION

Neonatal hearing screening is a very helpful tool for the early diagnosis of childhood permanent hearing loss. In this review, we have explored hearing screening tools such as OAE and ABR, which aid in early intervention. Early intervention contributes to better outcomes in linguistic and speech development.

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