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Specific Protocol for Hearing Assessment in Preterm Babies

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ABSTRACT

Hearing impairment is frequently met in preterm babies as compared to well baby population. Incidence of congenital and perinatal hearing loss in prematurely born children is 2-4% and in case of extreme prematurity (less than 32 GW) it could reach 6 %. It could be caused by extreme immaturity of the newborn baby as well as by multiple risk factors (gestational age, extremely low birth weight, hypoxia, hyperbilirubinaemia, infection, ototoxic medication, prolonged NICU stay, mechanic ventilation) Procena stanja sluha kod prevremeno rođenog deteta je izuzetno složena, a tumačenje dobijenih rezultata zahteva veliko iskustvo I poznavanje miljkaza i složenosti razvoja u ovoj populaciji. Pored kohlearnog oštećenja sluha često se mogu javiti I retrokohlearni problemi usled auditivne neuropatije i disnhronije, ali i nezrelosti centralnih auditivnih puteva. Hearing screening in prematurely born babies should not be restricted to otoacoustic emission testing (OAE), but automated auditory brainstem response (AABR) is mandatory for detection of retrocochlear pathology which is frequently seen in those babies. In case of several negative OAE tests baby should be refered for further audiology evaluation. Interpretation of audiology test results is complex and dependent on the degree of prematurity, age at the time of testing and comorbidities. Type and timing of eventual intervention is determined by the degree of the hearing impairment and other developmental disorders. It should be kept in mind that one third of babies identified as significant hearing loss in the first months of life, later on could achieve normal hearing thresholds through maturation process. It is essential to monitor development of these children closely at least during first two years of life in order to adjust type of amplification and habilitation of hearing and speech.

Keywords: preterm babies, hearing loss, hearing assessment

1 INTRODUCTION

Preterm birth

Preterm birth, before 37th week of pregnancy can occur for many reasons. Many vital functions in those babies are not mature enough requiring intensive care and support in order to provide survival and prevent further damage. According to the national health statistics in 2018, out of 63955 newborns in Serbia, 4500 were born preterm, which comprises 6.8%. The babies that were born extremely premature or with serious health problems have been referred to the Institute of neonatology in Belgrade. One thousand preterm babies are treated in that hospital each year. The percentage of premature births in Serbia is similar to UK statistics from the year 2015, with 53209 registered preterm babies (7.7%) and 3014 babies (0.4%) born before 28th gestational week or extremely premature (Cook, 2019). The percentage of prematurely born babies is on the constant rise all over the world due to better survival rates. However, there are still numerous issues regarding their morbidity and further development.

Incidence of hearing impairment

Occurring in 1-2 out of 1000 babies born at full term, hearing loss is the most frequent sensory impairment in newborn. The incidence of hearing impairment in premature babies is much higher due to their immaturity and various risk factors. The rate of hearing loss in preterm babies comprises 2-4% and in extremely premature (born before 32nd GW) it could be 6%.(Wroblevska-Seniuk K. et al, 2017). Better survival rates and improved methods in intensive care could lead to decrease in the incidence of various sequels to 1% with hearing or vision impairment (Pierrat V., 2017)

Risk factors for hearing impairment

Joint Committee on Infant Hearing (JCIH) has defined the risk factors that can contribute to the occurrence of hearing impairment in infants. Those factors are likely to induce hearing impairment 20 times more than in general population. However, one half of the infants diagnosed with hearing loss do not have any of those factors in their medical history. The list of those factors has been revisited and extended on several occasions. According to the newest revision in 2007. The list of the risk factors for hearing loss is as follows:

RISK FACTORS FOR HEARING IMPAIRMENT (JCIH, 2007)

- Familial deafness
- Extremely low birth weight <1500 g
- Intrauterine infection (toxoplasmosis, rubella, CMV, herpes, HIV,)
- Asphyxia (APGAR score 0-3)
- Extreme hyperbilirubinemia
- Head or neck congenital anomalies
- Neonatal bacterial meningitis
- Mechanical ventilation >2 days
- Neonatal intensive care >5 days
- Ototoxic medication

The longitudinal study on auditory development in preterm babies treated in the Institute of neonatology in Belgrade from 2014 to 2016 has revealed that most of those babies had 3 or more risk factors from JCIH list, but only a small number of them have been diagnosed with hearing loss eventually. The multiple risk factors imply that prematurely born babies should be referred for audiology diagnostics and their auditory development should be monitored carefully (Nikolić M, 2014).

Early hearing detection and intervention (EHDI)

Congenital or early postnatal hearing loss seriously affects speech and language development in children thus compromising their cognitive capacity and educational perspective. Early diagnosis and intervention for hearing impairment (EHDI) is essential for achieving optimal outcome, because of the plasticity of central nervous system in infants. The current timeline of EHDI considers that the neonatal hearing screening should be done before 1 month of age, complete audiology diagnostics before 3 months of age and intervention for hearing loss before age of 6 months.

According to the recent publication by C. Yoshinaga –Itano (2017) it might be not good enough. She had found that verbal score of hearing impaired children from EHDI at the age of 30 months is 82, which is still inferior to normal hearing children (VS-100), but considerably better than of VS of lately diagnosed hearing impaired children (VS-70, 10th percentile). Therefore she has suggested that EHDI timeline should be shifted to earlier age, so that the screening should be done before 1 month, diagnosis at 2 month and intervention at 3 month of age. Although it could be ideal from the maturational point of view, it might not be realistic in the majority of the countries. When premature babies are considered the EHDI timeline is not met in the majority of the cases due to multiple health issues in that population.

Regardless of the failed hearing screening, comprehensive audiology diagnostic should be postponed until baby is not well enough and in case of the diagnosed hearing impairment, planning of the intervention should be coordinated with other rehabilitation priorities.

2 DIAGNOSTIC PROCEDURES IN AUDIOLOGY

Hearing screening in newborn babies is the corner stone of every EHDI program. By this easy procedure babies with suspected hearing loss are recruited for further audiology diagnostic procedures in order to confirm the degree of hearing impairment and commence rehabilitation procedure. Early diagnosis and treatment provide for optimal outcomes, thus minimizing deleterious impact of congenital hearing loss on the development of speech and language in the affected child.

Neonatal hearing screening

Neonatal hearing screening could be organized as universal, when all the babies born in certain country are screened right after the birth or sporadic, with some of the hospitals screening the hearing in babies (hospital based) or reserved for special population of newborns, such as babies from neonatal intensive care units (NICU graduates) or prematurely born babies. Screening which does not cover at least 95% of the population is not working efficiently. It is usually performed by otoacoustic emissions, using either TEOAE or DPOAE modality. This screening method is insufficient for NICU graduates and preterm babies because of the possible retro cochlear pathology, which could be overlooked by otoacoustic emissions. Combination of OAE and automated auditory brainstem (AABR) screening is recommended for this population of newborns. Two-step screening using OAE or combination of OAE and AABR is the way to decrease the referral rate and overall number of babies who need further audiology diagnostics.

National program for universal hearing screening with proper tracking and follow-up is the best guarantee that the majority of the children should be diagnosed with hearing loss soon after birth. It is also the most economic and cost effective regarding the cost of the screening per baby (7-13 euro) or the cost per infant diagnosed with hearing loss is 8000 euro (Brockow et al 2018).

Unlike well babies, born at full term, who are screened on second or third day after birth, timing of the hearing screening in preterm babies should be determined in accordance with general health of the baby. Prematurely born babies could fail hearing screening on several occasions even if further audiology diagnosis confirms normal hearing function. However, preterm babies frequently require comprehensive audiology diagnostic due to numerous risk factors for possible hearing impairment and general immaturity of the central nervous system (Nikolić M, 2014).

Behavioral methods in pediatric audiology

The initial step of hearing assessment in babies and infants begins with conditioned orientation reflex (COR) and behavior observation audiometry (BOA), thus depicting their reaction to sounds of different pitch and intensity. In babies older than 6 months visual reinforcement audiometry (VRA). In older infants and toddlers play conditioned audiometry (PCA) could be appropriate. Pure tone audiometry requires full cooperation of child and several days of conditioning is usually needed in order to obtain precise hearing threshold. Masking of the contralateral ear could not be applied in children younger than 6 years because of the immaturity of central nervous system and hearing function. That could affect the proper measurement in case of unilateral or asymmetric hearing loss.

Objective methods in audiology

Considering the fact that infants and toddlers could not cooperate in hearing threshold measure (TEOAE) or distortion products (DPOAE). They could be registered in very young babies and it makes them convenient for neonatal hearing screening. They are the part of the comprehensive audiology test battery in fully diagnostic mode as well. In order to avoid false negative screening results OAE screening should not be performed immediately after birth, on the first day of because of the immaturity of OAE mechanism. Starting OAE screening from the second day after birth diminishes the referral rate (Mikić, 2005).

Auditory brainstem evoked potentials (ABR or BERA) measurement is an important tool for the assessment of hearing threshold in babies and infants as well as in subjects who do not cooperate in subjective audiometry tests. The stimulus used for BERA could be click or frequency specific. Accuracy of the threshold measurement is much better in high frequency range. Unstable electric activity of the brain (EEG), as well as asynchronous activity along auditory pathways (auditory neuropathy-dissynchrony) could affect the results.

Auditory steady state response (ASSR) is another objective test used in pediatric audiology, especially useful for the diagnosis of severe to profound hearing loss.

Cortical evoked potentials are no longer used for determination of hearing threshold due to poor accuracy, but they are widely used for evaluation of maturation of central auditory system.

The best way to achieve exact evaluation of hearing threshold and auditory maturation in pediatric audiology is to use the full test battery, combining subjective and objective measurements as well.

ment, audiology diagnostic requires a number of electrophysiology tests, aka objective measurements.

Acoustic impedance measurements include tympanometry and acoustic reflex. Tympanometry depicts mobility of the tympanic membrane and middle ear ossicles and the content of the tympanic cavity. It could reveal possible conductive hearing loss. Acoustic reflex threshold and decay could be helpful in diagnosing sensori-neural hearing impairment.

Otoacoustic emissions are useful for the assessment of inner ear functioning. They could be either spontaneous or evoked. Evoked otoacoustic emissions could be represented as transient

3 HEARING ASSESSMENT IN PRETERM BABIES

Considering the fact that hearing loss could be 20-30 times more frequent in preterm babies than in well baby newborns, it is of utmost importance to assess the hearing function as soon as possible. Babies born before 28th GW are at the greatest risk for developing hearing loss.

Preterm babies, especially those born extremely premature, are usually vitally endangered and critically ill, so that hearing screening could not be done immediately after birth.

General health condition, comorbidities and maturity of the prematurely born baby are the main determinants of the timing for comprehensive audiology testing.

In some cases hearing loss could be progressive and that requires prolonged audiology monitoring of prematurely born babies. Progressive or delayed onset of hearing loss could be genetically determined, caused by cytomegalovirus infection (CMV), ototoxic medication, severe hypoxia, etc. Those babies could pass initial newborn hearing screening but develop hearing loss later on. Repeated audiology testing and continuous surveillance is required at least in the first two years of life and later on if necessary.

Hearing screening methods

TEOAE screening is not always enough in the population of preterm babies, because of the high probability of retro-cochlear (or central) hearing pathology. Besides the immaturity of central nervous system, there could be intracranial bleeding or other CNS pathology as a cause of retro-cochlear hearing impairment. TEOAE could be normal in some cases and screening using only this method could lead to false positive results (Akinpelu et al, 2014). Therefore the use of automated ABR (AABR) screening is a must in this population.

On the other hand, TEOAE screening in preterm babies is frequently negative and should be repeated on several occasions, before the baby is referred to audiology department for comprehensive hearing assessment. False negative result of OAE hearing screening could be caused by a fluid in the ear canal or middle ear, as well as by negative pressure in tympanic cavity.

Behavioral assessment

Behavioral assessment of hearing function and choice of behavioral test depends of the age and maturity of an infant. In case of the preterm birth corrected age (the difference between the expected and real birth date) is always used for assessing developmental milestones and maturation of certain functions, such as hearing and speech. Corrected age should be used for at least two years after birth.

Test method should be chosen in accordance with corrected age, general health and maturity of the baby or infant. In older children cognitive level, maturity and general health affect the choice of audiometry type.

In case of developmental delay, associated neuropathology or grave illness, the degree of hearing loss could be overestimated. On the other hand, it is essential not to attribute the poor reaction to sound to kid's general delay or neuropathology and miss the diagnosis of hearing impairment. In those cases high frequency hearing loss could be easily overlooked. It is very important to define hearing threshold precisely in order to choose adequate hearing aid or hearing implant and provide speech and hearing rehabilitation thus stimulating overall development of a child.

Combination of subjective and objective measurements is necessary for the most precise diagnosis of hearing impairment.

Longitudinal follow-up is necessary because auditory function in preterm babies can improve over time due to maturation of central nervous pathways and synapses. On the other hand there is a possibility of development of acquired or progressive hearing loss in babies who initially have passed hearing screening. Continuous audiology surveillance is mandatory for at least first two years of life and longer if necessary.

Objective aka electrophysiology methods

Since preterm babies have low or extremely low birth weight the volume of the external ear canal remains extremely small for quite a long time. It is important to know that in those cases tympanometry ought to be done with high frequency probe (1000 Hz) in order to avoid faulty recordings obtained by 220 Hz probe.

Acoustic reflex measurements in prematurely born babies could be negative in the beginning due to extreme central nervous system immaturity or extensive brain lesions (intracranial hemorrhage, hypoxic-ischemic encephalopathy, etc).

Registration of auditory brainstem evoked potentials (ABR or BERA) could be affected not only by hearing impairment, but dominantly by central nervous system pathology and maturity. Synchronous propagation of the signal through auditory pathways is required for obtaining good waveform, absolute and inter-peak latencies. Pre- or postsynaptic dis-synchrony affects BERA morphology and could be mistaken for hearing loss (Silva, 2015). If normal auditory function is assumed by behavioral tests, BERA

should be performed with 40 and 70 dB click stimulus, followed by tone burst of 4 kHz at 40 dB, according to NHS protocol in UK. On the other hand, in case of suspected hearing loss based on behavioral methods, BERA should be done both click and tone burst at 0.5, 1, 2 and 4 kHz to determine hearing threshold. This is not always easy task in premature baby because of neurological comorbidities and immaturity (Hof, 2015).

Combination with auditory steady state response (ASSR) could be helpful in determining the degree of hearing impairment.

Using complete audiology test battery and cross check principle (J. Jerger, 1976) is the only way to achieve the precise diagnosis in pediatric audiology, especially when prematurely born babies are concerned.

Parent's questionnaires designed for follow up of infant's hearing are useful tool for monitoring auditory development in early years. There are several of them such as LittleEARS, CHILD or PEACH. Information gathered from parents on auditory behavior of child in everyday situations could improve comprehensive diagnostic process. (Schaefer et al, 2013)

Flaws and obstacles

Hearing assessment in babies and infants born prematurely could be very challenging because of the numerous prenatal and perinatal risk factors. Extremely preterm babies born before 28th week of gestation are especially endangered to develop hearing loss.

It is not always possible to perform complete audiology assessment due to poor general health and severe comorbidities. Neonatal hearing screening should be done as soon as possible and repeated on several occasions if necessary, but comprehensive audiology testing should be postponed until preterm baby is not well enough and capable for it.

Two types of errors could occur. Hearing impairment could be overlooked or underestimated if infant's poor reaction to sound is attributed to general developmental delay or associated neuropathology. It could unnecessarily postpone amplification and speech therapy thus affecting final outcome.

On the other hand if the degree of the hearing loss is overestimated hasty intervention, such as early cochlear implantation could possibly do a lot of harm (Coenrad et al, 2011) There have been numerous records of auditory function recovery through the maturation process of preterm babies in the first and second year of life. Hof et al. (2013) have reported that one third of 14 preterm babies diagnosed with severe to profound hearing loss in the first months has shown complete recovery of the auditory function within a year following diagnosis. We have encountered partial or full recovery of hearing in preterm babies occasionally as well.

It is therefore necessary to monitor auditory development and maturation in prematurely born children for at least two years of life and later if needed.

4 CONCLUSION


Hearing assessment in preterm neonates and infants is considerably different and quite complicated as compared to babies born at full term. Incidence of hearing impairment in premature babies is 20 to 30 times higher than in well baby population because of extreme immaturity of sensory organ and central auditory pathways. Preterm babies have elevated risk for developing hearing impairment. They usually have 3 or more risk factors from defined by Joint Committee on Infant Hearing.

Otoacoustic emissions are not sufficient for neonatal screening in preterm neonates, because retro-cochlear pathology could be easily overlooked. Combination of OAE and AABR is required for hearing screening in this population. Timing of screening depends on general health and maturity of the baby and should be postponed until baby is fit for screening. In case of repeated failure on screening procedures, baby should be referred for comprehensive audiology diagnostics. Complete test battery combining behavioral and objective measurements should be used for obtaining most accurate hearing assessment.

However, due to immaturity of all systems and multiple comorbidities hearing loss could not be always properly diagnosed. It could be overlooked or underestimated, thus leading to delayed intervention and poor outcome. On the other hand, it could be overestimated in young babies. Considerable number of preterm babies diagnosed with severe to profound hearing loss in the first months of life could restore hearing through maturation process. It is therefore important to adjust the intervention mode to such possibility and to avoid early cochlear implantation in preterm infants. Continuous audiology monitoring and repeated hearing and speech assessment is mandatory for at least first two years of life and longer if needed.

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Sleep - a Multifunctional Phenomenon: Memory Consolidation and Protective Effect with Respect to Psychosomatics

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ABSTRACT

Sleep is a universal physiological necessity whose precise mechanisms and function(s) are still unknown (Huber, 2004, Donlea, 2018). The most known attempt to describe its role by Allan Hobson “Sleep is of the brain, by the brain and for the brain” (Hobson, 2005) is slowly but inevitably extended by “...and for the organism”. On the basis of electroencephalographic and electromyographic activity sleep is defined as the approx 8 hour cyclic successive alteration of Non REM (or Quiet Sleep) and REM sleep (or Active Sleep) (Rechafen & Kales, 1968). Duration, sleep quality and harmonic alteration of Non REM and REM sleep play essential role in memory consolidation which is consequently of paramount importance for the new vocabulary learning (Batterink, 2017), motor skills learning (Cipolli, 2005) and the learning process in general. Non REM and REM sleep have specific physiology both on neurophysiological and molecular levels (Kryger, 2017) that drive restorative processes of the cardiovascular (Zoccoli, 2001, Silvani, 2003, Bojić, 2014), respiratory (Harper, 2017), immune (Opp, 2017) and endocrine system (Van Cauter, 2017) all the way to the genetic restorative processes (Fuller, 2019). Thus, healthy sleep contributes to healthy functioning of the organism and assures higher abilities like mental attention, mindfulness, insightfulness (Wagner 2004), creative (constructive), focused/unscattered and vivacious oral communication and social high quality self-regulation and cooperation. In the era of information revolution where the only limitations are the individual’s cognitive and memory capacities, the importance of healthy sleep regime must be recognized and taken as a priority with respect to short term benefits of stress-driven learning coupled with sleep deprivation. Consequently, sleep deprivation, a novel phenomenon of 24/7 society is becoming a notable circumstance of the general human psychophysical health.

Key word: sleep, memory, speech