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Objective hearing disorder diagnostic methods in younger children

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Objective: *comparative analysis of objective hearing function examination methods in children and identification of the factors affecting examination results.* ***Patients and methods.*** *We studied hearing in 473 children of 3 months – 5 years of age with sensorineural hearing loss and surdity. The control group was comprised of 30 children with normal hearing. Along with the standard clinical examination of ENT-organs, we performed tympanometry and reflexometry, examination of delayed evoked otoacoustic emission and reflection-source frequency otoacoustic emission, registered short-latency auditory evoked potentials and auditory steady state response (ASSR) in all children. We also conducted behavioral audiometry in children of 2-3 years of age and play audiometry in older children.* ***Results.*** *Various hearing loss risk factors are revealed in anamneses of most children (77%) with sensorineural hearing loss and surdity. The most sensitive (Se = 100%) and specific (Sp = 98.3%) method of diagnosing hearing level in children is the registration of short-latency brainstem auditory evoked potentials.* ***Conclusions.*** *The most reliable results of hearing thresholds identification are obtained when classic psychoacoustic hearing function examination methods are combined with modern electrophysiological examination method and hearing loss grade verification using surdopedagogic tests.*
Keywords: *hearing examination, sensorineural hearing loss, surdity, children.*

The first years of a child's life are important for speech, cognitive and intellectual development. Hearing disorders in children result in disturbed speech development. Speech development delay leads to the secondary intellectual development delay [1]. However, hearing disorders appear at the age of 0-2 years in 82% of the children, i.e. in the preverbal period or in the speech formation period [1]. Timely and correct diagnosis allows starting audiologic rehabilitation and integration of the child into the speech environment as early as possible. Introduction of the modern diagnostic equipment into practice, development and improvement of the newest electroacoustic hearing correction and cochlear implantation technologies provides new solutions for diagnosis and treatment of diseases of the organ of hearing.

Despite the progress of the modern otorhinolaryngology and audiology, hearing diagnosis in small children poses a lot of difficult tasks. It is difficult to diagnose the hearing level and select electroacoustic hearing correction parameters in children under 3 years of age; it is rather difficult to objectively assess the specific hearing thresholds in small children under 2-3 years of age when determining whether cochlear implantation is necessary or not.

Peculiarities of hearing examination in children under 2 years of age are caused by impossibility of audiometry, which requires a certain level of development and the child's cooperation. Objective audiometric techniques, which do not require the patient's cooperation, are widely used in children under 3-4 years of age [2]. Play audiometry may be an option for most children over 3-4 years of age. Moreover, there are play audiometric techniques, which help to quickly and reliably examine hearing in the intellectually safe children over 2 years of age, such as the "Pilot Test" (play speech audiometry) [3]. Objective techniques are required if this method reveals hearing disorders. Moreover, L.V. Neyman draws attention to the absence of listening skills in the children with hearing disorders; thus, they react only to the stimuli, the intensity of which considerably exceeds the threshold intensity; this results in overdiagnosis of hearing disorders [4, 5]. Objective techniques are considered to be the most reliable methods of hearing examination in children [2].

D.I. Tarasov and G.D. Tarasova divide all the causes and factors of hearing pathology or contributing to the development thereof into 3 groups [6]. The first group includes hereditary causes and factors. They result in structural alterations of the acoustic apparatus and development of hereditary hearing loss (30-50% of cases of congenital hearing loss and surdity) [6]. The second group includes endogenous and exogenous factors affecting a fetus's organ of hearing when hereditary background is not compromised. They result in congenital hearing loss [6]. Mutations in gene *GJB2*, which encodes protein connexin 26 (Cx26) are considered the primary cause of congenital and preverbal nonsyndromic hearing loss [7]. The third group includes the factors affecting a born healthy child's organ of hearing in one of the critical periods of child development. These factors result in acquired hearing loss. A child's acoustic apparatus is especially vulnerable to pathogenic factors from the 4^{th} gestational week to 4-5 years of age [6]. Risk factors establish a favorable background for hearing loss development. If such factors are detected, the neonate should be classified as a risk group child and undergo audiologic examination as early as possible – before 3 months of age [6]. Such factors include the mother's prenatal infectious diseases, intrauterine fetal hypoxia, birth trauma and asphyxia, hyperbilirubinemia (more than 200 mcmol/l) resulting in bilirubin encephalopathy, low birth weight (less than 1,500 g), low Apgar score etc. Moreover, many authors refer to prematurity as one of the risk factors of hearing loss and surdity [6, 8]. Thus, D.I. Tarasova et al. state that sensorineural hearing loss is more often detected in premature children (15%) than in term infants (0.5%) [6]. The aforementioned risk factors contribute to the increase in the number of children with sensorineural hearing loss and surdity and poly-pathology; this requires a complex approach and early rehabilitation actions.

Thus, diagnosis of hearing in children is one of the most difficult and relevant issues of the present audiology.

Subjective (use of audiometers, play audiometry, visually reinforced audiometry, behavioral orientation audiometry) and objective techniques (tympanometry [for middle ear condition assessment], acoustic reflexometry, registration of short-latency auditory evoked potentials [SAEPs] and steady state response [ASSR]) are widely used to determine audibility thresholds in children [9]. Short-latency auditory (acoustic brainstem) evoked potentials reflect the condition of cochlear brainstem nuclei of various levels and of the cochlear nerve [10].

The study is aimed at the comparative analysis of objective techniques of hearing examination in children and determination of the factors affecting study results.

PATIENTS AND METHODS

We examined hearing in 473 children from 3 months to 5 years of age with sensorineural hearing loss or surdity. The control group was comprised of 30 children with normal hearing. The study was conducted in 2008-2011. Along with the standard clinical examination of the ENT organs, all the children underwent tympanometry and reflexometry, examination of the delayed evoked otoacoustic emission (OAE) and otoacoustic emission on a frequency of the distortion product, registration of SAEPs and ASSRs. Moreover, children under 2-3 years of age underwent behavioral audiometry, children over 2-3 years of age – play audiometry. All the children visited a teacher of persons who are hearing impaired, a neurologist and a psychologist. All the children underwent electroacoustic hearing correction and, if the former proved ineffective, cochlear implantation.

RESULTS AND DISCUSSION

The most often observed risk factors in medical histories of children with sensorineural hearing loss or surdity were as follows: gestational age less than 37 weeks (17.3%); birth weight less than 1,500 g (3.4%); birth trauma or asphyxia (7.8%); hyperbilirubinemia over 200 mcmol/l in neonatality (2.1%); early use of ototoxic drugs (5.5%); mother's prenatal diseases, which could result in loss of hearing, e.g. rubella, scarlet fever, measles, herpes (7.4%); acute pediatric meningitis (2.5%); craniocerebral injury (0.6%); compromised hereditary background (surdity or hearing loss in parents) (12.3%). It ought to be mentioned that risk factors of hearing loss were not present only in 23% of the study group children; only one risk factor was revealed in 46% of the children; 2-3 risk factors were revealed in 25% of the children; more than 3 risk factors were revealed in 5% of the children.

Advantages and disadvantages of various objective techniques of examining organ of hearing were analyzed.

1. Registration of the delayed evoked otoacoustic emission (DEOAE) and OAE on a frequency of the distortion product (DP-gram) are used as a screening method. Both techniques are objective, easy to perform and take no more than 10-15 minutes.

Delayed evoked otoacoustic emission was registered in 56 cases in the control group (children with normal hearing, 60 ears). False positive results were yielded in 4 cases. These were children without hearing loss, who did not undergo neonatal screening. DEOAE was not registered due to Eustachian tube dysfunction in 3 cases, due to the non-standard organization of the external auditory meatus – in 1 case.

Thus, dependence of methods of registering various types of auditory evoked potentials on the state of the external auditory meatus and the middle ear is a relative disadvantage thereof; this is why preliminary cleaning of the auditory meatus off cerumen and epidermis is required; these methods also yield little information in the event of middle ear pathology (acute otitis media and exudative otitis).

Delayed evoked otoacoustic emission was not registered in 941 cases in the group of children with sensorineural hearing loss and surdity (946 cases). Despite hearing disorders, DEOAE was registered in 5 cases on the basis of behavioral thresholds, play audiometry data and results of an examination conducted by a teacher of persons who are hearing impaired. Later, retrocochlear pathology was diagnosed in 3 of these children (in 2 – binaurally, in 1 – monaurally) after the registration of SAEPs and an ASSR test; auditory neuropathy – in 2; central hearing loss – in 1 (due to cerebral organic lesion, encephalopathy and multiples cysts on temporal lobes).

DEOAE was registered in 57 cases in the control group as a result of OAE registration on a frequency of the distortion product (DP-gram). False positive (mistakenly observed) results were yielded in 3 cases. OAE registration methods reflect the condition of hair cells of the organ of Corti; however, they are not capable of detecting retrocochlear pathology. Audiologic hearing screening based on the registration of various OAE types only may yield erroneous results in children with retrocochlear (central) pathology of the auditory analyzer.

DEOAE registration method sensitivity (Se) in our study was 99.5%, specificity (Sp) – 93.3%. Sensitivity and specificity of the method of OAE registration on a frequency of the distortion product (DP-gram) was 99.6 and 95.0%, respectively.

2. Tympanometry is used to rule out the middle ear pathology. This method does not provide any insight into the child's hearing level; however, it helps to rule out a latent otitis media (e.g., exudative otitis media).

3. Acoustic reflexometry helps to assess the child's hearing thresholds indirectly, as reflex thresholds become worse with time up to the absence of reflexes (in case of grade III-VI hearing loss) in case of hearing loss.

4. Brainstem SAEP registration. This method is used both for in-depth audiologic examination and screening (if one stimulation level is used – 40 dB [normal audibility thresholds]). SAEP registration reflects activity of the auditory meatus and depends on the state of the sound-conducting system to a lesser extent.

Hearing examination using the SAEP registration method confirmed normal function of the organ of hearing in 59 cases out of 60 in the control group with registration of all the SAEP components in the children over 2 years of age and a well visualized SAEP V-peak in the children under 2 years of age. False positive result (absence of V-peak registration at normal hearing) was observed in only one case (due to peculiarities of the child's outer ear organization [narrow external auditory meatus with a rather wide angle between the chondral and the osseous parts, which resulted in the auditory meatus's "angulation" by the testing signal]).

SAEP registration yielded positive results (detected hearing loss at the existing hearing pathology) in 946 cases (100%) in the group of children with hearing disorders. No false positive results (mistakenly not detected at the loss of hearing) were registered.

Thus, SAEP registration method is highly sensitive (Se = 100%) and specific (Sp = 98.3%) and allows indirectly assessing hearing thresholds in the range of 2-4 kHz (pic. 1). The disadvantages of the method are long duration and the need in the child's immobility, the latter often achieved by drug sedation.

5. Auditory Steady-State Response (ASSR) to modulated tones. This technique provides the frequency-specific information required for implanting hearing aids, i.e. it helps to plot an "objective audiogram" of the child (pic. 2).

ASSR test confirmed normal function of the organ of hearing in 58 cases out of 60 in the control group. False positive results were yielded in 2 cases (ASSR test alteration at normal hearing). ASSR test yielded positive results (correspondence of the detected hearing thresholds with behavioral and play audiometry data) in 941 cases out of 946 in the group of children with hearing disorders. False positive results (absence of correspondence of the detected hearing thresholds with behavioral and play audiometry data) were yielded in 5 cases. ASSR test specificity and sensitivity were 96.7 and 99.5%, respectively. Audibility threshold fluctuations were observed in 12.3%; these results require comparison of our data with the results yielded by the other methods. An important advantage of this technique is the possibility to apply maximum intensity stimuli and assess hearing thresholds up to 120 dB.

The study and the observation of the group of small children allowed revealing factors, which may lead to inaccurate results of the child's hearing examination:

1) child's restlessness;
2) underestimation of the middle ear's condition (otitis media);
3) obstruction of the external auditory meatus with cerumen or epidermis;
4) presence of equipment or physical artifacts, external or electrical interference;
5) wrong selection of stimulation parameters;
6) no revalidation of the detected thresholds with the repeated application of the used stimulation level and the sufficient build-up;
7) no comparison of the detected audibility thresholds with the data of psychoacoustic hearing examination techniques (play and behavioral audiometry).

The most reliable results of hearing thresholds identification were observed when the classic psychoacoustic hearing function examination techniques were combined with the modern electrophysiological test with hearing loss grade verification using surdopedagogic tests.

CONCLUSION

Various hearing loss risk factors are revealed in medical histories of most children (77%) with sensorineural hearing loss and surdity. The most sensitive (Se = 100%) and specific (Sp = 98.3%) method of diagnosing hearing level in children is the registration of short-latency brainstem auditory evoked potentials.

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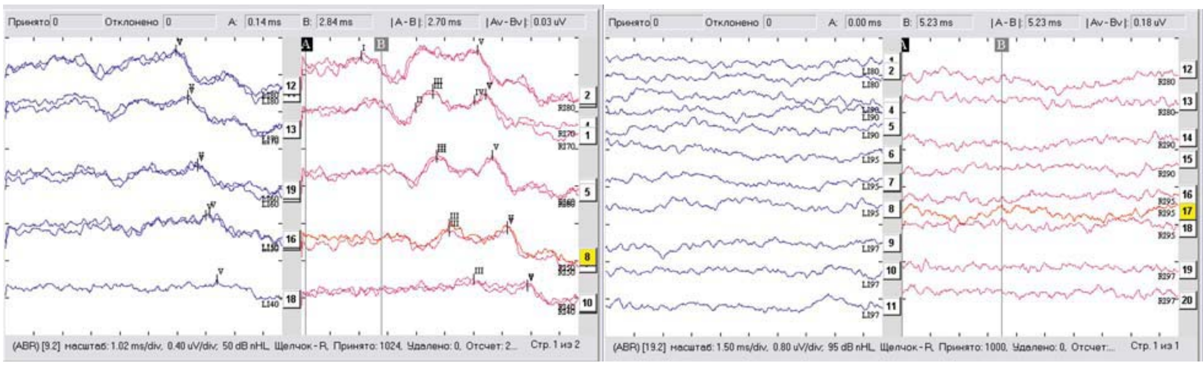
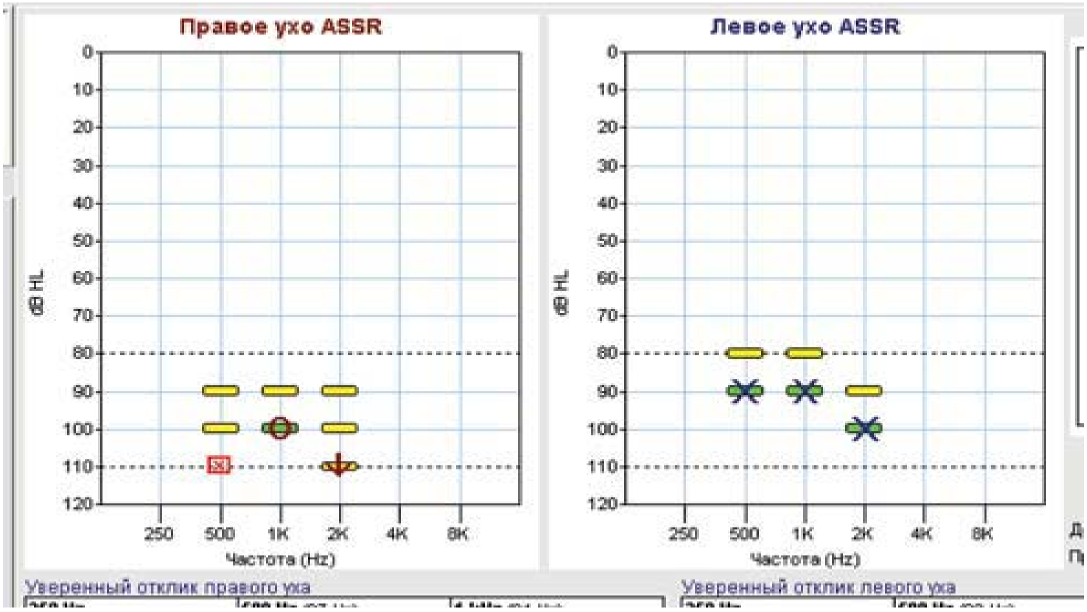
Pic. 1. Short-latency auditory evoked potentials of an 8-month-old healthy child (A) and a 9-month-old child with sensorineural hearing loss (B)

A B



Pic. 2. Steady state response (ASSR) of a 6-month-old child with grade IV sensorineural hearing loss; the response detection threshold is indicated with green color

A B



Note. A – right ear: detected ASSR threshold on a frequency of 1,000 Hz – 100 dB;
B – left ear: ASSR threshold on a frequency of 500 Hz – 90 dB; 1,000 Hz – 90 dB; 2,000 Hz – 100 dB.