

Review Article

International experience and recommendations on audiological screening of schoolchildren: review.

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Abstract: Permanent childhood hearing loss is crucial for speech development and restricts learning abilities. Universal newborn hearing screening programs are well established to detect congenital hearing loss and address the need of hearing-impaired babies. Progressive or acquired permanent hearing loss can manifest later due to genetic causes, intrauterine or postnatal infections, middle ear diseases and excessive exposure to noise when listening the personal audio devices. The hearing loss prevalence in the population of 9 year-olds three times higher compared with newborns. School hearing screening is a part of hearing across the lifespan conception. The article presents international experience and recommendations for the organization of school hearing screening programs. A school-entry hearing test is mandatory, other grades might be screened also. The basic method is pure tone audiometry at frequencies of 500, 1 000, 2 000, 4 000 Hz at 20 dB. Otoscopy and tympanometry can be performed also, while whisper voice speech test is of low sensitivity. The main hearing screening issue is low follow-up of referrals to ascertain audiological assessment. Modern approaches to the prevention of hearing loss in schoolchildren and management of hearing impairments are described. Planning of hearing screening programs requires sufficient human and logistical resources, monitoring of results and quality improvement, all stakeholders engagement.

Keywords: hearing impairment, hearing loss, school hearing screening, screening protocol, pure tone audiometry, guidelines, international experience.

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1. Introduction

Universal audiological screening of newborns makes it possible to detect congenital hearing loss and compensate for impaired auditory function in the first months of a child's life. However, progressive or acquired hearing disorders may develop at a later age. In the absence of complaints of pain and discomfort in the ears, hearing impairment, as well as the attention of parents, doctors and teachers, hearing disorders often remain unrecognized. Children do not receive the necessary treatment to prevent persistent hearing impairment or rehabilitation measures in the case of already formed persistent hearing loss. Hearing impairment hinders speech development and learning, is an obstacle to the assimilation of material in the classroom and academic performance, as well as to full communication and socialization. Accessible education, including for people with disabilities, is one of the Sustainable Development Goals declared by the United Nations. According to global estimates of the World Health Organization, 34 million children in the world have socially significant hearing impairments, while about 60% of cases of hearing loss are preventable [1]. The prevalence of persistent hearing impairment among 9-year-old children increases almost threefold compared to congenital forms [2]. Therefore, screening of hearing disorders in school-age children is included in the concept of detecting hearing loss throughout life [3].

2. Etiology of hearing disorders in school-age children



The causes of hearing impairment can be classified depending on the level of localization of the pathological condition. Conductive hearing loss occurs when sound conduction is disrupted by mechanical obturation of the external auditory canal by sulfur plugs, foreign bodies or Sensorineural hearing loss, detected at preschool and school age in the absence of a well-established acquired cause, is most likely due to pathological mutations in genes, encoding the synthesis of structural proteins of the inner ear, while hearing impairment may be congenital or manifest in the post-natal period. Among children with confirmed hereditary sensorineural hearing loss, from 13 to 26% were not detected by the audiological screening program of newborns [4, 5]. A systematic review of studies on combined audiological and genetic screening showed that genetic mutations are detected in 1.4% of newborns with a negative result of audiological screening [6]. The late onset is characteristic of half of the cases of hearing loss caused by intrauterine cytomegalovirus infection [7]. Acquired sensorineural hearing loss can occur due to infectious diseases (measles, mumps, rubella, flu), the use of ototoxic drugs (aminoglycosides, platinum preparations), traumatic brain injuries. In rare cases, the cause of hearing impairment is neurodegenerative diseases involving the auditory nerves and central auditory pathways (neurofibromatosis). These diseases are classified as risk factors for hearing loss with the requirement of referral for an audiological examination [8]. Recently, special importance has been attached to the risk of irreversible damage to the auditory receptors with excessive noise exposure associated with prolonged listening by schoolchildren to personal audio devices [9].

3. Recommendations for conducting audiological screening of schoolchildren

The first study to evaluate the medical technology of audiological screening of schoolchildren is considered to be a 2007 review by J. Bamford et al. At that time, about 90% of schools in England, Scotland and Wales provided hearing testing for children before entering school, however, there was an insufficient amount of evidence-based research on this issue, as well as the need for uniform national recommendations [10]. The results of this review were used to form recommendations for audiological screening in childhood by the American Academy of Audiologists pathological secretions. Violation of sound conduction in the middle ear can be caused by inflammatory purulent or non-purulent processes in the tympanic cavity (acute and chronic purulent otitis media, exudative otitis media, adhesive otitis media), acute inflammation or persistent dysfunction of the auditory tube, perforation of the eardrum, post-traumatic or congenital pathology of the auditory ossicles. In 2011, at the Congress of the European Federation of Audiological Societies, the European Consensus on hearing screening of preschool and school-age children was approved [11]. In order to implement school screening programs for the early detection, treatment and rehabilitation of children with hearing impairments, it is necessary to raise awareness of the authorities and society, exchange knowledge and experience between countries, use information technologies and telemedicine capabilities in the provision of sign language assistance. The experience of Polish audiologists using the developed platform for the examination of sensory functions in children is presented [12]. In 2021, the program for the prevention of hearing loss and deafness of the World Organization The results of existing practices in the field of audiological screening in different age groups, including among schoolchildren, were systematized.4 When forming the program protocol, it is necessary to clearly define the main screening parameters: the target population (all students, high-risk children, age groups); target condition (degree of hearing impairment, one- or two-sided), conditions (at school, in a medical organization). Taking into account the large scale of the target population, a preliminary assessment of the costs of implementing screening and its economic efficiency is necessary [13]. In accordance with this, a method of screening hearing testing (one or a combination of methods) is chosen, criteria for a positive screening result are established, in which a referral to confirming diagnostics. Also, when implementing a screening program, quality criteria are determined that are necessary for monitoring the results and making changes to the protocol to measure effectiveness (coverage of the target population, the proportion of children identified by screening, the proportion of children who have passed a confirmatory diagnosis). The degree of hearing impairment. It is recommended to identify hearing thresholds at the level of 20 dB, since even a slight degree of hearing impairment limits the ability to learn. However, in the absence of a soundproof room with background noise above 40 dB, the number of positive screening results increases, including false positives, which increases the workload of specialists at the stage of confirmatory diagnosis. Age and frequency of the event. A hearing test is considered mandatory before entering school. In countries where kindergarten is a stage of school education, hearing testing of children aged 3-7 years also refers to audiological screening of schoolchildren. If possible, it is recommended to conduct a hearing test in the learning process (for example, in grades 1, 3, 5, 7 and 9). The venue. To ensure full coverage of audiological screening, the place of its conduct should be as close as possible to the students, i.e. the organization of screening in the conditions of school. It is also possible to conduct screening in medical organizations when organizing comprehensive medical examinations or visits for the purpose of vaccination. Staff.



Teachers, secondary medical staff of schools, and other personnel who have received appropriate training can participate in conducting audiological screening of schoolchildren. Repeated screening and diagnostic examination are carried out by specialists of surdologists, audiologists, otorhinolaryngologists. Diagnostic significance it is an objective indicator of the effectiveness of an individual method or the entire screening program. Depending on the combination of screening data and confirmatory diagnostics, the final results are divided into true positive (TP – true positive), false positive (FP – false positive), false negative (FN – false negative) and true negative (TN – true negative). Based on the ratio of the results, the main indicators of the diagnostic value of the method are calculated:

■ sensitivity – the probability of a positive screening result in a child with hearing impairment $TP/(TP + FN) \times 100\%$;

■ specificity – the probability of receiving a negative screening result in a child without hearing pathology $TN/(TN + FP) \times 100\%$.

The criteria for a positive/negative screening result should be chosen in such a way as to ensure the greatest sensitivity and specificity both in relation to a particular method and the audiological screening program as a whole. To increase the diagnostic significance, screening may include several stages with repeated immediate or delayed testing of children with a positive result [14].

4. Research methods

Tonal audiometry is used as the main method for audiological screening of schoolchildren, including preschoolers starting from the age of 3. It is mandatory to conduct a test at frequencies of 500, 1,000, 2,000 Hz, while the range of the studied frequencies can be 250-8000 Hz. In high school, it is desirable to be examined at high frequencies, taking into account the increased risk of exposure to excessive noise and personal audio devices. The intensity of a test stimulus of 20 dB with a single or multiple presentation is recommended for screening. When conducting a study in the absence of noise insulation at a frequency of 500 Hz, the intensity can be set to a higher level. The study can be carried out using stimuli of several intensities, starting from a higher level, which helps to increase the specificity of the test and reduce the number of children in need of confirmatory diagnosis, but increases the duration of testing. It is possible to use the method of recording otoacoustic emission in children under 3 years of age or at the level of mental development corresponding to the age of three. Otoscopy and tympanometry can be performed for children with a positive result of screening tonal audiometry in the presence of equipment and specially trained personnel or with the participation of a specialist doctor to exclude pathology of the outer and middle ear. Criteria A positive screening for tympanometry is a tympanogram of type B and type C (in which different levels of intratympanic pressure can be taken into account as critical – from -150 to -200 daPa). Tympanometry is recommended for children of preschool and primary school age, taking into account the high prevalence of exudative otitis media in this age group. To screen the hearing of children over 9 years old, a test of speech intelligibility in noise (digit triplet test) can be used. It is a fairly effective alternative to tonal audiometry in countries with limited health resources or in remote areas, since applications specially designed for smartphones (for example, hearWHO) can be used for its implementation [15, 16]. It is not recommended as a screening method to study the hearing of schoolchildren with whispered speech due to low sensitivity.

5. The world experience of audiological screening of schoolchildren

Despite the existing recommendations, audiological screening of schoolchildren is not a widespread practice. According to the EUSCREEN project implemented in 2018-2020, during which existing audiological screening programs were studied in 47 countries, universal (mass) audiological screening of schoolchildren is being implemented in 17 countries, screening is carried out selectively or irregularly in 8 more countries [17]. The intensity used as a criterion for passing tonal audiometry is in the range of 20-40 dB, in most cases – 30 dB in children 3-4 years old and 25 dB in children over 4 years old. In most programs, testing is carried out at frequencies of 500–4000 Hz. Screening coverage is 92-99%, the proportion of children identified by screening is 7.6–7.9%, the proportion of children who have undergone confirmatory diagnostics, – 58-77%. A systematic review of 65 studies on audiological screening of schoolchildren, published by M. Yong et al. in 2020, it also indicates an insufficiently wide implementation of screening programs, a variety of protocols and criteria [18]. In the USA, screening is implemented in 66% of states. Pilot programs have



been implemented in other countries, according to the results of which widespread implementation is recommended, but there is no information about its results. Most studies are based on conducting tonal audiometry in school conditions, the criterion of direction is the absence of a response at one frequency (most often 500, 1 000, 2 000, 4 000 Hz, with a range of 500-8000 Hz) at an intensity of 20 dB. As additional research methods otoscopy, tympanometry, registration of otoacoustic emission are used. The proportion of children identified with suspected hearing impairment varies from 0.16 to 15%. As in the EUSCREEN project, the problem of continuity of screening is noted: the proportion of children with known results of a complete audiological examination is 10-65%. In the Republic of Yemen, where universal audiological screening of newborns is not carried out, a pilot study of auditory function was conducted among 2,200 primary school students, average age 7.5 years. The protocol of audiological screening included otoscopy, audiometry with tones of 20 dB intensity at frequencies 500, 1 000, 2 000, 4 000 Hz. The criterion of the direction was the absence of a response on at least one frequency from one or two sides. According to the results of screening, 11.6% of children had hearing impairment. Conductive hearing loss of I-II degree was detected in 86% of children, the most common cause was acute and exudative otitis media. Sensorineural hearing loss was diagnosed in 14% of children [19]. Several pilot studies of audiological screening of schoolchildren have been implemented in Russia. A.V. Pashkov et al. automatic audiometry was used in 112 schoolchildren (average age 12 years) with the help of a special hardware and software complex at frequencies 500, 1 000, 2 000, 4 000 Hz, the accuracy of the study was compared with the results of standard tonal threshold audiometry. Hearing disorders were detected in 20 (18%) patients, of which 5 had sensorineural hearing loss [20]. Another Russian study included a sample of 216 children in grades 1-11 [21]. The screening protocol differs from the recommended one and includes otoscopy, tympanometry, registration of otoacoustic emission, examination whispered and spoken speech. As a result, 44% of children did not have otoacoustic emission from one or both sides. According to the results of the extended diagnosis, 13 (6%) children had a hearing impairment of I-II degree. Despite the absence of regular audiological screening programs that comply with international recommendations, medical examinations of schoolchildren have been carried out in Russia for many years. In accordance with the procedure for monitoring minors, an examination by an otorhinolaryngologist in a polyclinic is mandatory for children aged 1, 3, 6, 7, 15, 16, 17 years (Order of the Ministry of Health of the Russian Federation No. 514n dated 10.08.2017). During otoscopy, pathology of the outer and middle ear can be detected, hearing is checked by whispering speech, followed by referral to a surdologist for audiological diagnostics. If appropriate equipment is available, tympanometry can be performed. Thus, hearing screening is carried out before entering school and in high school, however, hearing impairment may be missed in elementary and secondary school students, which requires changes to existing regulations.

6. Possibilities of prevention, treatment and rehabilitation of hearing disorders identified as a result of audiological screening of schoolchildren

Prevention of hearing disorders in schoolchildren consists primarily in informing children, parents and teachers about risk factors for hearing loss, the formation of proper ear hygiene skills and safe listening. Vaccination against measles, rubella, mumps, and influenza, which can cause complications in the form of sensorineural hearing loss, plays an important role [22]. Vaccination against pneumococcus has shown high effectiveness in preventing the development of severe hearing loss and deafness due to meningitis [23]. Conductive hearing loss associated with obturation of the external auditory canal by sulfur masses and various foreign bodies is successfully resolved through appropriate manipulations. Hearing impairment due to inflammatory diseases of the middle ear is corrected by drug therapy or surgical interventions. In acute, up to 1 month, pathology of the cochlea receptor apparatus, systemic therapy with glucocorticoids is sufficiently effective, but it is often difficult to establish the period of hearing impairment, especially in the case of unilateral hearing loss [24, 25]. The main means of helping children with sensorineural hearing loss is medical rehabilitation, including hearing replacement for hearing impairment of II-IV degree, including unilateral losses [24, 25]. With mild hearing loss, it is necessary to provide the child with the correct placement in the classroom (the first desks, with a better hearing ear to the teacher), the opportunity to relax from the noise at recess. For any hearing loss, sign language correction is indicated. Cochlear implantation is indicated for children with grade IV sensorineural hearing loss and deafness [24-26]. Cases of severe bilateral hearing loss of this type are usually detected in a timely manner due to the presence of relevant complaints. Audiological screening of schoolchildren is effective in detecting unilateral sensorineural deafness, in which cochlear implantation from extra-budgetary funds can also be recommended.

7. Conclusions



Audiological screening of schoolchildren is the most effective way to timely identify and assist children with hearing impairment. Despite the developed recommendations and conciliatory documents, there are significant differences in protocols, used audiological tests and referral criteria for confirmatory diagnosis and treatment. To increase the reliability and effectiveness of audiological screening programs for schoolchildren, as well as the possibility of comparing screening results in different countries, studying the epidemiology of hearing disorders in this age group, it is necessary to form standardized protocols. On the other hand, the different capabilities of health systems in different countries require more flexible approaches to the development and implementation of audiological screening programs for schoolchildren, taking into account available resources. When forming audiological screening programs for schoolchildren, it is necessary to take into account the following aspects: provision of the surdological and otorhinolaryngological service with appropriate human and material resources for timely and full-fledged assistance to children identified as a result of screening; approval of procedures for referral and observation of children with identified hearing disorders and ear diseases; availability of medical and surgical methods of treatment of ear diseases, technologies for rehabilitation of children with hearing impairment. Audiological screening of students should be part of routine medical examinations, along with a general medical examination, a check of vision, teeth, etc. When planning an audiological screening program for schoolchildren, the responsibility of stakeholders should be determined, issues of data collection and monitoring, quality control and efficiency improvement should be worked out. Like any screening program aimed at identifying various pathological conditions, the hearing test of schoolchildren should not be limited to the use of screening techniques. In the absence of a confirmatory diagnosis, treatment and medical rehabilitation, all screening efforts result in an inefficient expenditure of resources

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