UDK 376.356
ВВК Ч452.026.23
GSNTI 14.29.01
Code VAK 13.00.03

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IMPROVEMENT OF MEDICO-PEDAGOGICAL REHABILITATION OF DEAF CHILDREN AFTER COCHLEAR IMPLANTATION BY SETTING UP SPEECH PROCESSOR

Abstract. Detection of the quality of physical hearing of children with auditory impairment subject to cochlear implantation, and setting up the cochlear implant processor are important areas of rehabilitation-pedagogical support for such children. The aim of the given research is to work out a system of pedagogical methods and techniques of diagnostics of accuracy of the setup of the cochlear implant processor. The setup quality control of the cochlear implant processor is done by the setup specialist and the pedagogue using subjective and objective methods. The authors have worked out a series of special pedagogical techniques to diagnose the adequacy of the processor setup in children after cochlear implantation which are effective and adequate for the assessment of the quality of the processor setup. The series includes six blocs: observation, discomfort test, registration of conditional reflex motor response to sound, categorization of the sounds by volume, the recruitment phenomenon, and speech legibility. Cochlear implantation and the subsequent processor setup facilitate the emergence of the child's physical hearing, and the lessons with pedagogues and the parents enhance the development of functional hearing, which stimulates the formation of the child's spontaneous oral speech and his integration and socialization. The suggested methods can be used by defectologists, surdopedagogues, logopedists, parents and setup specialists.

Keywords: hearing disorders; surdopedagogy; children with hearing loss; cochlear implantation; rehabilitation work; processor setup.

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At present, the cochlear implantation method is the only efficient method of rehabilitation of persons with severe hearing loss and deaf persons which allows them to get physical auditory sensations that serve as the basis for the development of functional hearing and spontaneous oral speech facilitating their socialization and integration in society.

Over recent years, the number of such operations at the Saint Petersburg Research Institute of Ear, Throat, Nose and Speech and other Russian clinics have considerably grown, which, to a large extent, satisfies the demand in the given kind of high-tech medical care. The growing numbers of cases of cochlear implantation bring about the need to improve the given kind of medical assistance to persons with hearing loss, first of all in the aspect of post-surgical aural rehabilitation, and especially to children, because the effectiveness of cochlear implantation is determined by the outcomes of the post-surgical rehabilitation-pedagogical assistance facilitating the development of hearing and speech in children.

The procedure of cochlear implantation is subdivided into several periods: pre-surgical period, operation and rehabilitation treatment, and post-surgical period (including initial, basic and final stages of rehabilitation-pedagogical assistance); this periodization is shown in table 1.

The post-surgical period is the leading one, obligatory for all categories of children and the longest one determining the final outcome of cochlear implantation. Apart from organization of purposive training aimed at the children’s development of hearing and speech, the initial stage includes the first switch-on and setup of the processor as the basis of physical hearing, which is a prerequisite for the formation and development of more differentiated auditory sensations and spontaneous oral speech. Regular processor setups and their quality control preserve their significance at the next (basic and final) stages of the post-surgical period.

Table 1. Rehabilitation periods and stages

Pre-Surgical Period	Operation and rehabilitation treatment	Post-surgical period		
		Initial stage	Basic stage	Final stage

The setup quality control of the cochlear implant processor is done by the setup specialist and the pedagogue using objective and subjective methods. **Objective** methods include data recording without using child response: neural response telemetry, stapedius reflex and brainstem auditory evoked potentials in response to electric stimulation recording. In a number of children, examination with the help of the given methods is impossible due to various reasons, for example: recording of brainstem auditory evoked potentials in response to electric stimulation has significant measurement error, and not all specialists can use this method. In addition, these methods are not always reliable for assessment of the setup quality taking into account child response to nonverbal sounds of the surrounding world and illegible speech, because the measurements are taken on the auditory structures situated before the cortex, and the human response to speech, and recognition of its individual peculiarities is localized in the temporal area of the cortex. It is due to all this that the processor setup quality assessment should include **subjective methods** that take into account the character of the child's response both to verbal and nonverbal sounds. The subjective methods of the setup specialists include detection of response to sound, categorization of sounds by loudness, and free sound field audiometry. In these cases, the setup specialists notes the presence of the child's response to clear tone sounds of different frequency. According to the data provided by scholars [1; 2; 4], the child's responses to clear tones and nonverbal and verbal sounds are distinctly different. Researchers report [5; 6; 12; 14] that it is only due to the joint effort of the setup specialist, pedagogue and the child's close people that it becomes possible to set the processor up in the proper way and to teach the child to hear with the help of the cochlear implant and, later, – to speak. The speech processor setup and adaptation to new auditory sensations are two inseparably connected processes: the setup specialist switches the processor on and tunes it up and uses objective and subjective methods with clear tones for diagnostics, which gives the child a chance to hear the surrounding sounds. And the pedagogue and the close people evaluate the hearing responses to verbal and nonverbal sounds and help the child in their learning to listen and to orient themselves in them. And the improvement of hearing responses makes the processor parameters setup easier, which, in its turn, stimulates the auditory potential of the child and hearing-and-speech rehabilitation.

Many authors [3; 6; 7; 8; 9; 10; 11; 13; 14] stress the need for application of various techniques and approaches to the organization of rehabilitation-pedagogical support, and note the significance of the joint work of the setup specialist and the pedagogue with parents. At the same time, inadequate attention is paid to the detailed study and design of specialized approaches and techniques of pedagogical assessment of the quality of processor setup.

We have worked out a series of special pedagogical techniques to diagnose the adequacy of the processor setup in children after cochlear implantation, including six blocks of realization. Let us dwell on each block separately.

BLOCK 1 – OBSERVATION

This stage begins with collection and analysis of information about the way the child reacts to various nonverbal sounds of the surrounding world including five sounds of various frequencies and volume more commonly heard in the surrounding world for each category: *everyday household sounds* (telephone ring, microwave oven beep, sound of an object falling to the floor, sound of a zipper on clothes/boots, sound of water running from a tap), *street sounds* (car horn hooting, train wheels clattering, wind howling, rain dropping, sound of sea waves), *voices of animals and birds* (cat meowing, dog barking, cow mooing, swine grunting, nightingale singing), *nonverbal human sounds* (steps, sneezing, coughing, laughter, whistling), *musical instruments* (piano, drums, flute, bell, rattle).

We have worked out special workbook for recording the auditory perception results in which children, together with the pedagogue and the parents, are to draw up and record the sounds of the surrounding world to which the child makes a response. The object or phenomenon producing the nonverbal sound is drawn in the workbook, an entry on the model "what? + is doing what?" is made, and the vocal imitation of the sound is fixed. Apart from the diagnostic effect, such workbook facilitates the development of auditory perception, as it allows collecting images of the surrounding sounds, expanding vocabulary, and training in understanding sound imitations. Sound imitations accompanied by the sound descriptions can be used later for diagnostics. It is easier for the child to explain their sensations to the setup specialist with the help of sound imitation.

BLOCK 2 – DISCOMFORT TEST

It is important to check up the discomfort parameters and take its results into account for better speech intelligibility, so that the child would not develop a negative attitude to the sounds perceived and the presence of the device itself. It is well known that the presence of discomfort at perception of loud sounds hampers auditory attention and perception in such a way that low sounds get masked and muffled by overamplified loud ones.

Check up of negative sensations presupposes test of possible presence of discomfortable perception of loud sounds across the whole frequency range. We used two kinds of loud high frequency and low frequency sounds: *festive trumpet* as a loud low frequency sound with the maximum frequency peak at 500 Hz; *office bell* as a loud high frequency sound with the maximum peak at 6,000 Hz.

Other sounds in other frequency ranges were not used, as it is difficult to select a very loud sound with a more limited and clear spectrum. What is more, we tried to find the most feasible everyday life stimuli for a wider translation of our method across the pedagogical environment.

BLOCK 3 – REGISTRATION OF CONDITIONAL REFLEX MOTOR RESPONSE TO SOUND

Detection of conditional reflex motor responses to the sounds of different frequencies and volume in a child after cochlear implantation takes place after discovery of the child's ability to hear loud and discern low sounds. We have used speech sounds of various frequencies and volume for pedagogical assessment of the setup adequacy of the cochlear implant. Nonverbal sounds were not presented as they are more broadband and have intensity peaks in various frequency ranges. The following speech sounds were used as stimuli: loud low-, mid- and high-frequency sounds, and soft low-, mid- and high-frequency sounds.

At this stage, we tried to get a motor response to a sound signal. The patients were asked to do the following: to throw a snowball to the floor or into a basket, to put a shell into a bowl filled with water, to press a button with a finger. We used an authored complex of rehabilitation materials "Zanimaemsya s Usharikom" to enhance motivation.

During the process of practicing the ability to hear speech sounds, we began by testing if the child after cochlear implantation had conditional reflex motor response to *visual* (waving of a little flag) and *tactile-vibrational* (knocking on the chair upon which the child sits) signals; after that – *to loud nonverbal sounds* (festive trumpet and office bell). If there was positive response to all these sounds, we asked the child first to listen to loud verbal syllables of various frequencies (PA, LA, SI) at close distance (70 cm – 1 m). After that, we presented low speech signals of various frequencies: first at the same distance, then – increasing it up to 6 m.

We recorded the child's responses to loud and low speech sounds of various frequencies at the distance of 6 m. We noted the absence of response and registered how the child heard the sound.

Table 2. Distribution of signals in volume and frequency ranges

Range	Sounds	
	Loud	Low
Low-frequency	MU Peaks: 200—700 Hz	po Peaks: 200—3000 Hz
Mid-frequency	LA Peaks: 1000—4000 Hz	sch Peaks: 3000—5000 Hz
High-frequency	SI Peaks: 5000—7000 Hz	s' Peaks: 4000—9000 Hz

Table 3. Distinction of sounds in volume and pitch

	Low-frequency	High-frequency
Loud	A	I
Low	sh	s

BLOCK 4 – CATEGORIZATION OF SOUNDS BY VOLUME

The ability to categorize (classify) sounds by volume in our diagnostics procedure allowed us to assess the adequacy of the cochlear implantation system processor setup in three modes: low, normal, and loud. The main task of this block is to teach the child to perceive the sounds correctly trough the device setup: loud sounds as loud, low ones – as low, and by frequency – in the corresponding frequency range. After pedagogical detection of the nature of the speech sounds perceived, the setup specialist can tune up the processor.

In the diagnostic mode (before carrying out pedagogical test proper) it is necessary to check up the child's ability to understand these categories. To this end, one can use tactile-vibrational sensations and schematic images of their intensity: small circle – soft sounds, low vibration, and big circle – loud sounds, strong vibration. Special exercises are presented in the complex of rehabilitation materials "Zanimaemsya s Usharikom"

When you clearly see that the child does the exercises correctly, it is possible to begin pedagogical diagnostics of volume categorization, which presupposes examination of the child's ability to classify sounds by loudness. Speech sounds of various frequencies are recommended to be used for this purpose (see table 3).

The child's task is to show low sounds of various frequencies ([sh], [s]) on a small circle, and loud sounds of various frequencies ([A], [I]) – on a big circle.

BLOCK 5 – THE RECRUITMENT PHENOMENON

It is well known that all people with impaired hearing have a narrow dynamic range, which makes intelligible auditory perception of the sounds and speech perception in general difficult. And the children can hardly hear a low sound after a loud one; in a quiet environment, an unexpected loud sound is perceived as discomfortable.

Pedagogical diagnostics is aimed at the study of adequacy of the cochlear implantation system processor setup. It is necessary to check up if the child hears a low speech sound after a loud one. For this purpose, we used reversed syllables with a low consonant at the end: *As, Osh, Usch*. The child was given isolated sounds and direct and reversed syllables in all combinations: *A, O, U, s, sh, sch, As, sA, Osh, shO, Usch, schU*. In addition, the children who could read were offered cards with letters and syllables.

The pedagogue pronounces sounds and syllables in an exaggerated way: low sounds – softly, and loud sounds – loudly behind a fabric screen which prevents reverberation. The child repeats what they hear. The given recruitment phenomenon test is considered to be positive if the child does not perceive a low consonant in the reversed syllable, but repeats the vowel only. It means that we observe a salient recruitment phenomenon.

BLOCK 6 – SPEECH INTELLIGIBILITY

Adequate processor setup in children after cochlear implantation focuses on speech intelligibility improvement. To evaluate the phonemic level of speech intelligibility, we studied the pupils' capability to discern speech sounds of various volume and frequency within each range.

The data of special literature and our own experience of many years of work with children after cochlear implantation let us argue that it is most difficult for the children to differentiate low-frequency sounds, including loud ones, and soft sounds of mid and high frequencies. That is why, it is these sounds that we used within the framework of the method of pedagogical assessment of processor setup design (table 4).

Table 4. Audio material for speech intelligibility analysis

Sound frequency	Sound intensity	List of sounds used
Low-frequency	Loud	O, U
Mid-frequency	Low	sh, sch
High-frequency	Low	s, s'

The pedagogue offered the child a pair of sounds for oral comprehension (behind a fabric screen in front of the processor microphone): low-frequency loud sounds, mid-frequency low sounds and high-frequency low sounds in various combinations. The child's task was to differentiate the pairs of sounds, and to point at the letter or the corresponding pictogram matching the sound pronounced by the pedagogue. Diagnostics by pictograms presupposed preliminary training and learning the correlation "sound – pictogram ". The answers were recorded and taken into account for processor setup.

All blocks of our method of pedagogical diagnostics of adequacy of processor setup in children after cochlear implantation are realized gradually, from the simple to the most complicated. Correction is held after each block, and second testing and subsequent setup are done according to the pedagogue's recommendations.

The advantage of our research consists in the opportunity to take into account delayed results of application of the pedagogical procedure of the processor setup quality.

CONCLUSIONS

Cochlear implantation and the subsequent processor setup facilitate the emergence of the child's physical hearing, and the lessons with pedagogues and the parents enhance the development of functional hearing, which stimulates the formation of the child's spontaneous oral speech and their integration and socialization.

The series of special pedagogical techniques of diagnostics of the processor setup adequacy in children after cochlear implantation including six realization blocks (observation, discomfort test, registration of conditional reflex motor response to sound, categorization of sounds by volume, the recruitment phenomenon, and speech intelligibility) is an efficient adequate tool of the processor setup quality assessment.

Many years of experience at the Saint Petersburg Research Institute of Ear, Throat, Nose and Speech and other rehabilitation centers on the program "Ya slyshu mir!" (I can hear the world!) allow recommending it for implementation in practical activity.

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