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CLINICAL METHODS OF HEARING (SOUND) TESTING

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Abstract.

Methods of assessing the auditory (hearing) system used in clinical otorhinolaryngology and audiology are an important component of modern medicine. This article provides a detailed review of the main hearing assessment methods widely used in clinical practice — otoscopy, pure-tone audiometry, bone conduction testing, speech audiometry, tympanometry (impedance audiometry), acoustic reflex testing, otoacoustic emissions (OAE), and auditory brainstem response (ABR). The principle, technique, indications, limitations, and clinical significance of each method are described. The research results section presents data on the effectiveness of these methods in combination for determining the type of hearing loss (conductive, sensorineural, mixed), newborn hearing screening, and diagnostic outcomes in children and adults. The article aims to improve strategies for early detection and treatment of hearing disorders.

Keywords: audiometry, tympanometry, otoacoustic emissions, ABR, hearing test, pure-tone audiometry, speech audiometry, middle ear function, diagnosis of hearing loss.

Introduction. Perception of sound and speech plays a vital role in human life for social relationships, education, and professional activities. Hearing disorders affect millions of people worldwide, and their causes may be related to damage to the outer ear, middle ear, inner ear, or central nervous system. Clinical hearing assessment methods allow evaluation of every segment of the auditory system — from mechanical conduction to neural integration. With the development of modern audiology, numerous methods have emerged, ranging from simple tuning fork tests to objective electrophysiological techniques. These methods not only determine the degree of hearing loss but also accurately identify its type (conductive, sensorineural, or mixed) and location. Objective tests that do not require subjective responses (OAE and ABR) are particularly important in newborns and young children, as early screening can prevent delays in speech and language development. This article provides a systematic analysis of the most commonly used hearing assessment methods in clinical practice. The aim is to reveal the advantages, disadvantages, and principles of combined application of each method for physicians and specialists. The "cross-check" principle — comparing results from several methods — plays a key role in hearing loss diagnostics, significantly reducing the probability of error.

Main Part. Clinical hearing assessment methods are divided into several groups: subjective (based on the patient's responses) and objective (based on electrophysiological and acoustic measurements). Each method evaluates a specific part of the auditory system. Otoscopy is always performed in the first stage. This is a simple but very important method consisting of visual examination of the external auditory canal and tympanic membrane using an otoscope. Otoscopy can detect inflammation of the tympanic membrane, perforation, serous otitis, cerumen impaction, or other abnormalities. It serves as the basis for subsequent tests, as impacted wax, for example, can distort OAE or tympanometry results. Otoscopy is mandatory for every patient in the clinic and provides only visual assessment without measuring hearing levels. Pure-Tone Audiometry is considered the "gold standard" of hearing testing. This method uses an audiometer to present pure tones at various frequencies (usually 125 Hz to 8000 Hz) to the

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patient and determine their hearing thresholds. The test is conducted via air conduction and bone conduction. In air conduction testing, the patient listens to sounds through headphones, and the lowest intensity (dB HL) at which each frequency is heard is recorded. In bone conduction testing, a vibrator is placed on the mastoid bone, delivering sound directly to the inner ear and bypassing the middle ear. An audiogram is then plotted: the difference between the air and bone conduction curves (air-bone gap) indicates conductive hearing loss. If there is no gap and the hearing threshold is elevated, sensorineural damage is indicated. The advantage of this method is precise frequency-specific mapping and determination of the configuration of hearing loss (low-frequency, high-frequency, or flat). Its limitations are dependence on the patient's subjective responses and difficulty in children or patients with altered mental status. Pure-tone audiometry is usually performed in a soundproof room, and results are evaluated according to international standards (ISO, ANSI).

Speech Audiometry is an important method that complements pure-tone testing. The patient is presented with words or numbers at different intensities and asked to repeat them. Key indicators are the Speech Reception Threshold (SRT) and Speech Discrimination Score (SDS). SRT is the lowest intensity required for 50% correct word repetition. SDS measures the percentage of speech understood at the most comfortable level. This test provides important information in sensorineural hearing loss, especially in inner ear and auditory nerve damage, where pure tones may be heard well but speech understanding is difficult (e.g., in retrocochlear pathologies). Speech-in-noise testing also helps assess everyday difficulties. In clinical practice, this method is crucial for selecting hearing aids and cochlear implants. Tympanometry (Impedance/Immittance Audiometry) is an objective method for assessing middle ear function. A special probe is placed in the ear canal, and tympanic membrane mobility is measured while changing pressure (usually from -400 to +200 daPa). A tympanogram is produced: Type A — normal, As — stiff (otosclerosis), Ad — flaccid (tympanic membrane atrophy), Type B — flat (fluid or blockage, e.g., serous otitis), Type C — negative pressure (Eustachian tube dysfunction). Acoustic reflex testing is performed together with tympanometry. A loud sound is presented, and the contraction of the stapedius muscle and change in impedance are measured.

Absence or elevated threshold of the reflex may indicate middle ear, inner ear, or nerve damage. These methods do not require subjective responses and are very convenient for children and patients simulating hearing loss. Otoacoustic Emissions (OAE) are an objective method for assessing the activity of outer hair cells in the inner ear. When sound stimuli (clicks or tone bursts) are presented, the hair cells produce characteristic "echo" sounds that are recorded by the probe. The most common types are Transient Evoked OAE (TEOAE) and Distortion Product OAE (DPOAE). The presence of OAE indicates healthy outer hair cells. This method is fundamental in newborn hearing screening because it is fast (several minutes), inexpensive, and painless. Its limitation is that middle ear problems (e.g., fluid) can produce a "fail" result even if the inner ear is normal. Auditory Brainstem Response (ABR) is the most important objective method for assessing neural conduction in the auditory pathways. Electrodes are placed on the scalp, and electrical responses (waves I–V) at the brainstem level are recorded in response to click or tone stimuli. Wave I is associated with the auditory nerve, and Wave V with the upper brainstem. Analysis of ABR latency and amplitude helps identify retrocochlear pathologies (acoustic neuroma), auditory neuropathy, or central disorders.

ABR is also used to estimate hearing thresholds in children and sleeping infants (tone-burst ABR). Its advantages are objectivity and deep diagnostic value; disadvantages include time consumption (30–60 minutes) and occasional need for sedation. Automated ABR (AABR) is used for screening in modern clinics. Other methods include electronystagmography (related to balance), higher-level auditory evoked potentials (cortical potentials), and vestibular tests, but they are mainly used in special cases. The combined use of all methods — the "test battery" principle — leads to the most accurate diagnosis in clinical practice.

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Research Results. Numerous clinical studies show that the combined use of pure-tone and speech audiometry determines the type of hearing loss with 90–95% accuracy. For example, an air-bone gap greater than 15 dB indicates a high probability of middle ear pathology. In sensorineural cases, SDS may be low even when pure-tone thresholds are moderate. Studies on OAE and ABR screening in newborns (e.g., Kennedy et al., 1991) have proven the high sensitivity of automated OAE for early detection of confirmed hearing loss. When OAE and ABR are used sequentially, specificity exceeds 99%. OAE often “fails” in the presence of middle ear fluid, but ABR can still provide useful information. The clinical value of tympanometry and acoustic reflex testing is high in otitis media cases: Type B tympanogram indicates fluid with 85–90% accuracy. In children, tympanometry helps explain delays in speech development. In adults, ABR combined with MRI shows high sensitivity in the diagnosis of retrocochlear tumors (acoustic neuroma). OAE is effective for monitoring the effects of ototoxic drugs (aminoglycosides, chemotherapy), as they primarily damage outer hair cells. Multicenter studies have shown that combining subjective and objective methods improves outcomes in hearing aid selection and cochlear implantation. Speech-in-noise tests better predict functional hearing in daily life. Overall, a complete audiological battery (otoscopy + tympanometry + OAE + pure-tone and speech audiometry + ABR when needed) in modern clinics enables accurate diagnosis of hearing disorders up to 98%. These results form the basis for individualizing patient rehabilitation programs.

Conclusion.

Hearing assessment methods used in clinical practice enable comprehensive evaluation of the auditory system. Subjective methods (pure-tone and speech audiometry) assess functional hearing, while objective methods (tympanometry, OAE, ABR) precisely show mechanical and neural levels. Combined use of these methods minimizes errors and improves patients’ quality of life through early diagnosis. In the future, wider dissemination of automated and portable devices is expected, making screening more widespread. Physicians must thoroughly master these methods to provide individualized patient care. Early detection and treatment of hearing disorders remains an important strategy for public health.

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