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КАФЕДРА ОТОРИНОЛАРИНГОЛОГИИ
С КУРСОМ ПОВЫШЕНИЯ КВАЛИФИКАЦИИ И ПЕРЕПОДГОТОВКИ

МЕТОДЫ ИССЛЕДОВАНИЯ СЛУХА И ВЕСТИБУЛЯРНОГО АППАРАТА

HEARING INVESTIGATION AND VESTIBULAR FUNCTION TESTS

Учебно-методическое пособие

Минск БГМУ 2026

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Освещены основные методы диагностики слухового анализатора и вестибулярного аппарата. Приведена информация по дифференциальной диагностике слуховых и вестибулярных нарушений.

Предназначено для студентов медицинского факультета иностранных учащихся, обучающихся по специальности «Лечебное дело» на английском языке.

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MOTIVATIONAL CHARACTERISTICS OF THE TOPIC

Topic of the lesson: "Clinical Anatomy and Physiology of the ear. Methods of hearing and vestibular analyzer research. Diseases of the outer ear".

A person receives information from the environment through analyzers. The ear is the peripheral part of two analyzers: the auditory and the vestibular (statokinetic). This training manual reflects the methods of studying hearing and vestibular apparatus. The relevance of studying functional and pathological changes in the vestibular and auditory systems is determined by the high prevalence and complexity of differential diagnosis of auditory and vestibulocochlear disorders of various etiologies.

The assessment of the state of hearing and vestibular apparatus in healthy people is carried out during a professional examination in order to determine professional suitability.

The term "social adequacy of hearing" refers to a person's ability to perceive sound stimuli of varying complexity (including speech) and participate in a dialogue. Patients with a hearing level below "socially adequate" have difficulties in communication, which can contribute to the separation of a person from society. Thus, it is necessary to have a clear system for identifying people with a pathology of the sound analyzer and using the entire arsenal of hearing restoration methods as early as possible.

The vestibular function is closely related to the activity of the central nervous system and the cerebellum, ensures the position of the body in space, its balance in statics and movements, which is explained by the regulation of muscle tone, coordination of movements. The study of the vestibular analyzer in patients is performed for the differential diagnosis of various diseases. In the practice of a doctor, situations arise when it is necessary to differentiate the types of peripheral vestibular disorders that occur with inflammatory and non-inflammatory lesions of the ear, and central vestibular disorders.

Objective of the lesson: to develop the ability to diagnose hearing and vestibular disorders; to diagnose diseases of the external ear.

Lesson objectives:

1. To study methods of hearing and vestibular analyzer examination required for clinical examination of patients.
2. To acquire knowledge of the anatomical and physiological features of the vestibular system necessary for a comprehensive understanding of disease etiology, pathogenesis, clinical manifestations, diagnosis, prevention, and treatment.

Upon completion of this topic, students should study:
– the anatomy of the vestibular and auditory systems;
– the etiopathogenesis and clinical manifestations of vestibular disorders;
– the etiopathogenesis and clinical manifestations of auditory disorders;
– differential diagnosis of various vestibular system disorders;
– vestibular dysfunction associated with different inner ear pathologies;
– the routes of infection spread to the inner ear;

– differential diagnosis of labyrinthitis and non-suppurative inner ear diseases;

– the most common diseases of the external ear: furuncle, diffuse otitis externa, and auricular chondroperichondritis.

Requirements for the initial level of knowledge. To fully master this topic, students should review:

– Human Anatomy: structure and age-related features of the inner ear;

– Normal Physiology: physiology of the vestibular system;

– Histology, Cytology, and Embryology: structure of the receptor apparatus of the vestibule, semicircular canals, and the spiral organ (organ of Corti);

– Topographic Anatomy and Operative Surgery: topography of the ear; surgical techniques involving the mastoid process;

– Pathological Anatomy: morphological changes of the ear in inflammatory and neoplastic diseases;

– Radiology and Radiation Therapy: main radiological methods for diagnosing ear diseases; principal types of radiographic studies used in otolaryngological practice and their interpretation;

– Microbiology, Virology, and Immunology: microbiology of the ear; techniques for collecting microbiological specimens;

– Medical and Biological Physics: fundamental physical laws applied in otology (laws of inertia and universal gravitation, principles of resonance, lever systems, Brownian motion of fluids); principles of acoustics and mechanics including angular and linear acceleration and their measurement;

– Pharmacology: groups of ototoxic medications.

Review questions from related disciplines:

1. What are the anatomical components of the inner ear?
2. What are the anatomical components of the external ear?
3. Through which anatomical structure does the inner ear communicate with the subarachnoid space?
4. What are the differences between perilymph and endolymph?
5. Which radiological imaging methods are used in the diagnosis of ear diseases?
6. What is the structure of the peripheral receptor of the vestibular system?
7. In which planes are the semicircular canals oriented?
8. Which groups of ototoxic drugs are known?

Topic-specific review questions:

1. What types and grades of spontaneous nystagmus are distinguished?
2. How is spontaneous nystagmus detected?
3. What principles underlie the diagnosis of vestibular system disorders?
4. What mechanisms determine the fast and slow components of nystagmus?
5. What are the clinical manifestations of vestibular system disorders?
6. What are the differences between peripheral and central vestibular disorders?
7. What are the main causes of sensorineural hearing loss?
8. What are the main causes of conductive hearing loss?

9. What diagnostic methods are used to differentiate sensorineural and conductive hearing loss?
10. What are the clinical features of a furuncle of the external auditory canal?
11. With which conditions should diffuse otitis externa be differentiated?

CLASSIFICATION OF HEARING RESEARCH METHODS

Examination of auditory function is carried out by means of two groups of methods:

1. **Subjective** (psychoacoustic):

– hearing test with speech;
– hearing test with tuning forks;
– subjective audiometry.

2. **Objective:**

– objective (computer) audiometry;
– acoustic reflexometry;
– tympanometry;
– otoacoustic emission;
– unconditioned reflex
– reactions;
– conditioned reactions to sound.

SUBJECTIVE METHODS OF HEARING INVESTIGATION

With all subjective methods of hearing research, the subject himself evaluates whether he hears the sound or not and communicates this to the researcher in some other way.

With objective examination methods, the results obtained do not depend on the patient's wishes, and their registration in most cases occurs with the help of special equipment.

Subjective examination of hearing is carried out by means of the following methods:

1. Examination of hearing with speech (whispered speech, conversational speech, shouting).
2. Examination of hearing with the help of tuning forks (duration of perception of sounding tuning forks of different frequencies, experiments of Rinne, Weber, Schwabach, Gelle.
3. Audiometry (tone (threshold, suprathreshold), speech; ultrasound hearing test, auditory adaptation test).

Due to the widespread introduction of modern technologies, audiometric methods of hearing research using speech and tuning forks into clinical practice, this is currently carried out mainly for the purpose of approximate assessment of the state of auditory function.

SPEECH HEARING TEST

Two principles are used to regulate the level of stimulus intensity in the assessment of speech hearing: 1) words are pronounced with varying intensity (whispering, conversational speech, shouting); 2) words at varying distances from the subject's ear. When testing hearing with speech, words from the table are usually used V. I. Voyachek or two-digit numerals.

HEARING TEST USING WHISPERED SPEECH

The patient's head is turned so that the ear being tested faces the examiner, whom the patient should not see. To avoid errors associated with overlistening, the patient presses on the tragus of the ear not being tested, thereby closing the external auditory canal. Normally, a person should hear whispered speech at a distance of at least 6 m. If the patient does not hear, the researcher, gradually approaching, repeats the words until the patient clearly hears the spoken numerals and repeats them correctly. This distance (in meters) is recorded in the hearing passport (Table 1, 2). In case of sudden hearing loss must be examined using the same method using spoken language or shouting (for each ear separately).

Table 1

Auditory passport of a patient with acute purulent otitis media on the right (conductive hearing loss)

AD	Criteria	AS
+	Subjective noise	–
2 m	Whispered speech	6 m
5 m	Spoken speech	> 6 m
26 sec	C_{128} (air)	67 sec
32 sec	C_{128} (bone)	33 sec
21 sec	C2048	34 sec
–	R	+
←	W	–
Prolonged by 7 seconds	Sch	=

Table 2

Auditory passport of a patient with damage to the sound-receiving apparatus on the left (sensorineural hearing loss on the left)

AD	Criteria	AS
–	Subjective noise	+
6 m	Whispered speech	1 m
> 6 m	Spoken speech	3 m
68 sec	C_{128} (air)	32 sec
34 sec	C_{128} (bone)	17 sec
35 sec	C2048	18 sec
+	R	+
←	W	–
=	Sch	Shortened by 7 seconds

HEARING EXAMINATION WITH TUNING FORKS

A complete set typically includes eight tuning forks (C32, C64, C128, C256, C512, C1026, C2048, C4096). For practical, everyday work, in most cases, only two of them (C128 and C2048) are sufficient. When evaluating the results of hearing tests using tuning forks, their standards are used, i.e. the duration of time during which the sound of the tuning forks is heard by individuals with normal hearing.

Research using tuning forks allows us to roughly determine the degree of hearing loss and, in some cases, the level of damage auditory analyzer (conductive or sensorineural hearing loss).

The perception of sound by air conduction is determined using both tuning forks (C128 and C2048), and by bone conduction — only using a tuning fork with a frequency of 128 Hz (C128). Air conduction provides information about the auditory analyzer as a whole (both the sound-conducting (outer, middle ear) and sound-perceiving system (inner ear)). Bone conduction transmits sound directly to the inner ear, which makes it possible to assess the condition of the sound-perceiving apparatus.

When using a tuning fork to examine hearing, the duration is determined. perception (in seconds):

– tuning fork **C128 — in air**;

– tuning fork **C2048 — in air**;

– tuning fork **C128 — on bone**.

Measurements are carried out as follows:

1. The sounding tuning fork C128 is placed at a distance of 2–3 cm from the auricle and the duration of sound perception is determined (air conductivity) in seconds.

2. The time of perception of a tuning fork in air is determined in a similar manner C2048.

3. To study bone conduction, the C128 tuning fork is placed with its stem on the mastoid process and the time of perception is recorded. These measurements are performed for each ear separately.

Comparing the duration of perception of a sounding tuning fork by a patient with a tuning fork standard, one can roughly judge the degree of hearing loss. In diseases of the sound-conducting section (e.g. earwax plug, otitis media, etc.), only air conduction is reduced. Diseases of the sound-perceiving apparatus (sensorineural hearing loss) lead to disruption of both bone and air conduction.

To determine the localization of damage to the sound analyzer (sound-conducting or sound-perceiving parts) it is advisable to carry out a series of experiments using tuning forks.

Rinne's experiment (R) (comparison of the duration of sound perception tuning fork C128 (bone and air conduction) is a method for differential diagnosis of diseases of the sound-perceiving and sound-conducting apparatus.

The test is carried out as follows: the foot of the sounding tuning fork C128 is placed on the mastoid process, as soon as the patient stops hearing the sound, the tuning fork is brought closer to the external auditory canal. Since air conduction is normally longer than bone conduction, sound through the air will still be audible — ***Rinne's experience is positive (R+)*** (this can also be observed with damage to the sound perception apparatus, but the duration of perception decreases). If the duration of sound perception through bone is longer than through air (a condition when, after the cessation of sound perception through bone conduction, the patient does not perceive sound through the air), then this indicates damage to the sound-conducting apparatus (conductive hearing loss) **— *Rinne's experience is negative (R–)***.

The Weber test (W) (determination of sound lateralization) is a method of differential diagnosis of damage to the sound-conducting and sound-receiving apparatus of the ear, based on subjective perception localization of the sound source using a tuning fork placed in the center of the patient's crown. The stem of the sounding C128 tuning fork is placed on the crown. Since bone conduction of sound ***is normally*** equal in both ears, ***in a healthy person the sound is felt in the center of the head*** (in both ears are the same). A similar result would be obtained with bilateral sensorineural hearing loss of the same degree.

If the sound is heard louder in one of the ears, it is called lateralization. sound in this ear. In case of unilateral damage, if the lateralization of sound

If the sound lateralizes to the worse-hearing ear, it indicates damage to the sound-conducting apparatus (conductive hearing loss) in that ear. If the sound lateralizes to the better-hearing ear, it indicates damage to the sound-perceiving apparatus (sensorineural hearing loss) on the affected side. In case of bilateral hearing loss of various origins. Assessing the diagnostic value of the Weber test can be difficult.

The Schwabach Experiment (Sch) is a diagnostic method for sensorineural and constructive hearing loss. A sounding tuning fork C128 is mounted on the patient's nipple, a prominent appendage. After the patient ceases to perceive sound, the tuning fork is moved to the mastoid process of a researcher with obviously good hearing (comparison of bone conduction in a sick and healthy person). With sensorineural hearing loss, the patient's ***Sch experience is shortened*** by a certain number of seconds, with conductive hearing loss, the ***Sch experience is prolonged***, and normally it is ***the same (Sch=)***.

Gelle's experiment (G) is a method for detecting ankylosis of the foot plate of the stirrup in otosclerosis. The sounding tuning fork C128 is mounted on the coccoid process, the air pressure in the external auditory canal is increased by a Zigle funnel or by pressing the tragus, as a result of which the foot plate of the stirrup is pressed into the niche of the oval window, and the patient feels a decrease in the intensity of sound perception (***Gelle's positive experience (G+***) is the norm). In case of ankylosis of the stirrup (otosclerosis), the foot plate of the stirrup does not shift, and there is no weakening of the sound ***(Gelle's (G–)*** experience is negative).The results of hearing tests using speech and tuning forks are recorded in the hearing passport (acumetric formula) proposed by V. I. Voyachek.

Acumetric formula: SN (subjective noise): “+” — presence, “–” — absence; perception of WS (whispered speech), SS (spoken speech) is indicated in meters; at WS = 6 m SS often record > 6 m; the time of perception of sounding tuning forks is recorded in seconds; experiments R and Sch are indicated as “+” or “–”; experiment W “↔” or “↓” — in the absence of lateralization, “←” or “→” — in the presence (in the indicated direction). Figure 1 and 2 presents the examples of Auditory passport.

AUDIOMETRY

Methods of hearing research based on the use of sound generator of electronic equipment are called “audiometry”. From a psychophysiological point of view, a distinction is made between subjective and objective audiometry. In subjective audiometry, the outgoing the sound is standardized (in frequency and volume), but the subject himself evaluates whether he hears or not. There are the following varieties subjective audiometry: tonal threshold, speech, tonal suprathreshold, auditory adaptation study, hearing study ultrasound.

Tonal threshold audiometry involves the use of a special device, an audiometer, which synthesizes sounds of a specific frequency (standard range: 125, 250, 500 Hz, 1, 2, 4, 8 kHz) and intensity (in decibels (dB)). A threshold audiometer allows one to determine hearing thresholds by air and bone conduction over a wider range of frequencies and with greater accuracy than when testing hearing with tuning forks. The hearing threshold is understood as the lowest sound intensity perceived by a healthy ear. The test results are recorded on a special form called “audiogram”, which is a graphic representation of the threshold auditory sensations. Two graphs are plotted on each form: the first is the threshold of sound perception by air conduction (demonstrates sound conduction), the second is by bone conduction (demonstrates sound perception). Based on the nature of the air and bone conduction threshold curves, as well as their relationship, one can obtain a qualitative characteristic of the patient's hearing. Normally, both curves are located no more than 10 dB from the baseline and no more than 10 dB from each other (Fig. 1, *a*).

The presence of a difference between the threshold levels of air and bone conduction (bone-to-air) on the tonal threshold audiogram interval) is regarded as an audiological symptom **of conductive hearing loss** (Fig. 1, *b*).

In case of impaired sound perception **(sensorineural hearing loss)**, the threshold of perception by air and bone conduction increases, while the air-bone gap is practically absent (Fig. 1, *c*).

In **mixed (combined) lesions**, the threshold of perception for air and bone conduction increases in the presence of an air-bone gap (Fig. 3, *d*). At present, perfect designs of automatic audiometers, which are controlled by embedded microprocessors.

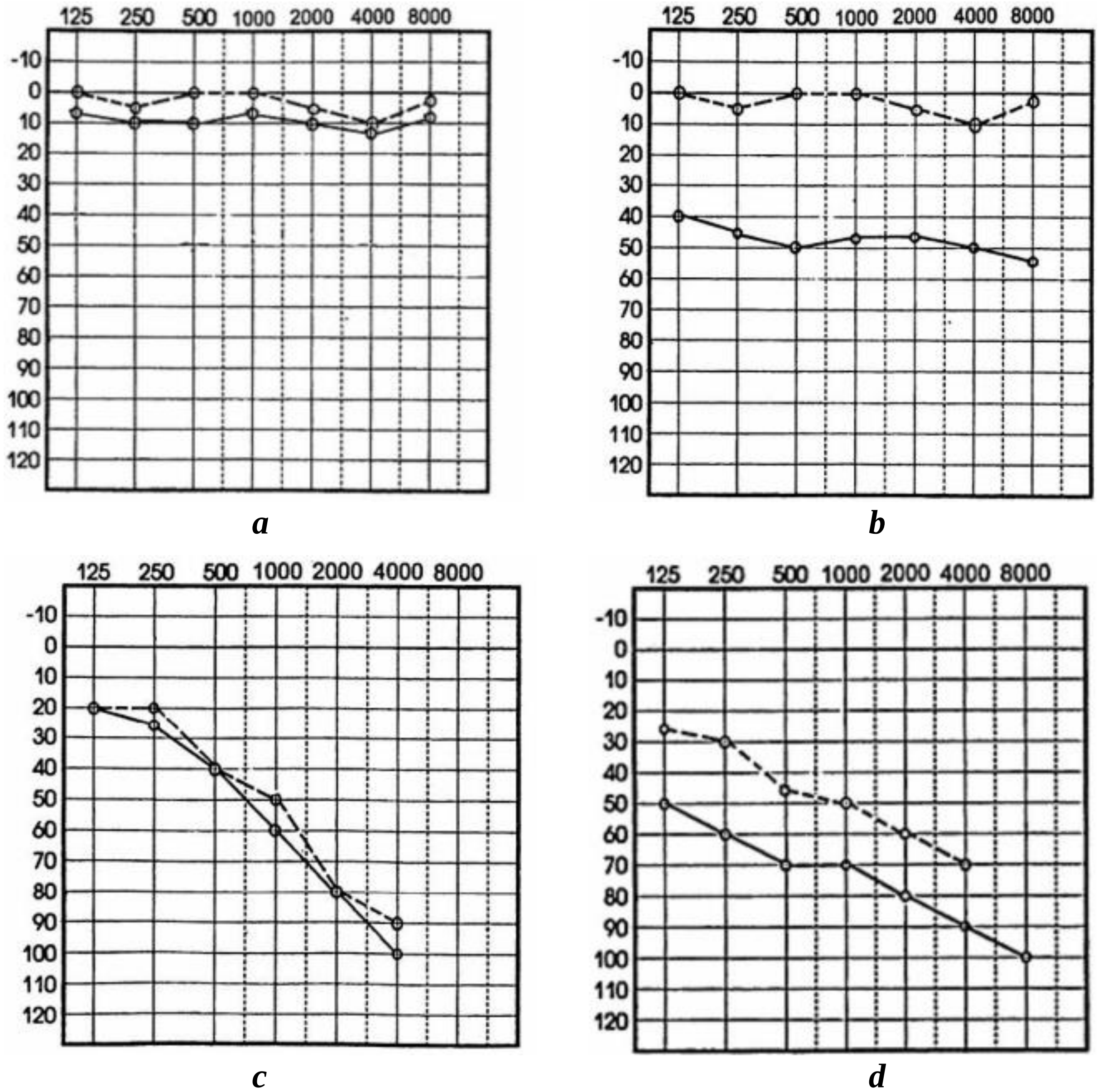


Fig. 1. Examples of audiograms:
a — normal; *b* — with conductive hearing loss; *c* — with sensorineural hearing loss; *d* — with combined hearing loss

SPEECH AUDIOMETRY

Speech audiometry allows us to identify social adequacy hearing, is based on the determination of speech intelligibility thresholds. Speech intelligibility is understood as the ratio of the number of correct responses to the total the number of listened sounds, expressed as a percentage. Speech audiograms are recorded the intensity of speech stimuli in decibels, and on the ordinate axis is speech intelligibility, i.e. the percentage of speech stimuli correctly repeated by the patient stimuli. In this way, a speech intelligibility curve is constructed (Fig. 2). Speech intelligibility graphs differ for different forms of hearing loss, which has important diagnostic value.

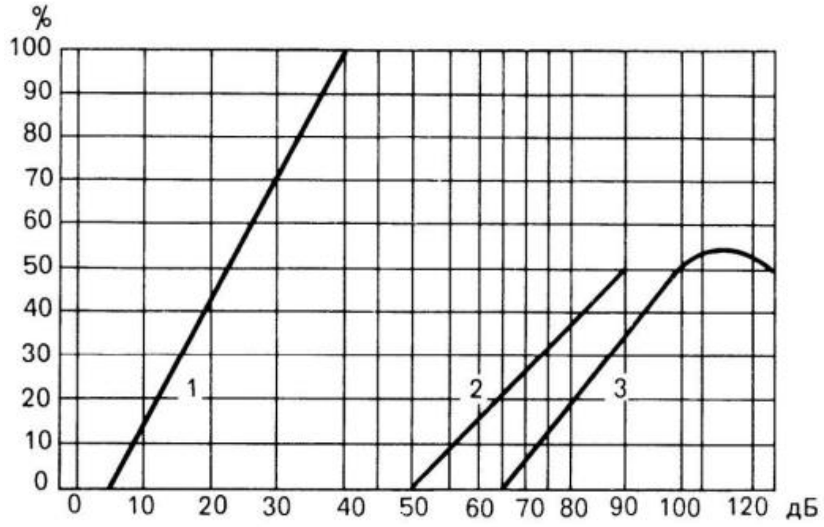


Fig. 2. Speech intelligibility curve:
1 — normal; *2, 3* — sensorineural hearing loss

OBJECTIVE METHODS OF HEARING EXAMINATION

Objective methods of hearing examination are used when there is a suspicion of a psychogenic nature of deafness, simulation, aggravation, dissimulation and disaggravation, with intense subjective tinnitus, as well as in children in the presence of risk factors (increased probability development of hearing loss or deafness).

An objective examination of hearing is carried out using the following methods:

1. Objective (computer) audiometry.
2. Acoustic reflexometry.
3. Tympanometry.
4. Otoacoustic emission.
5. Unconditioned reflex responses to sound.
6. Conditioned responses to sound.

The results obtained with the specified methods of hearing examination do not depend on the patient's wishes and are recorded in most cases using special equipment.

OBJECTIVE (COMPUTER AUDIOMETRY)

Objective (computer) audiometry is based on registration bioelectric impulses (auditory evoked potentials) propagating in the conducting pathways and the central part of the auditory analyzer. The impulses are recorded using electrodes located on the surface of the skull (electroencephalogram). In children, objective audiometry is performed in a state of drug-induced sleep, in adults — while awake. In response to sound clicks (short-duration sound stimuli — up to 1 ms), short-latency auditory evoked responses occur potentials (SLAPP/SAEPs) are impulses that provide information about the function of the conduction pathways and the subcortical part of the auditory analyzer (vestibule-cochlear nerve, cochlear nuclei, olivary nuclei, lateral lemniscus, quadrigemina). In response to longer sound stimuli with a certain frequency characteristic, long-latency auditory evoked potentials (LAEPs) arise, providing information about the state cortical part of the auditory analyzer.

Thus, objective audiometry allows not only to realistically assess the state of hearing, but also, in case of its impairment, to determine the localization of the pathological process.

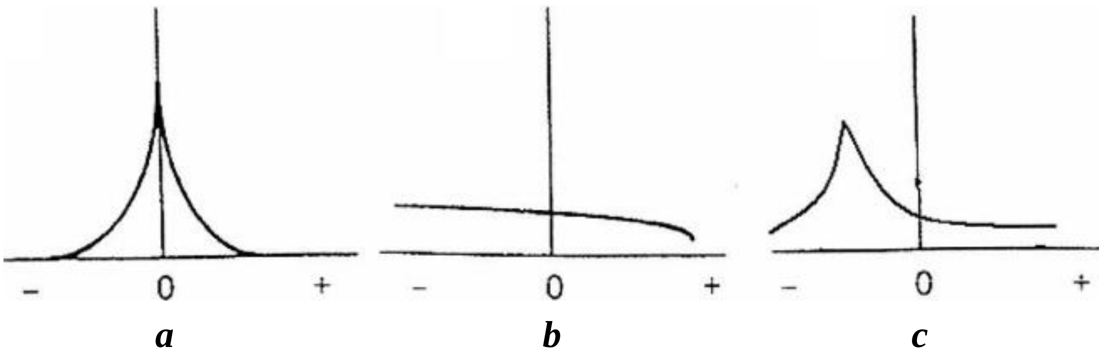
ACOUSTIC REFLEXOMETRY

The muscles located in the tympanic cavity (stapedius, tensor tympani) perform a protective function. When they are tense, the amplitude of movement of the auditory ossicles is limited, which protects the structures of the inner ear from damage. In response to intense sound stimulation, a reflex impulse occurs, which leads to contraction of the muscles of the tympanic cavity. Normally, the threshold of the acoustic reflex (the moment of contraction) stapedius muscle, recorded using special equipment) is 80 dB higher than the individual sensitivity threshold.

Thus, by determining the acoustic reflex threshold for a specific patient, one can calculate (by subtracting 80 dB) the individual sensitivity threshold. In cases of conductive hearing loss, damage to the auditory nerve, or pathology of the trunk or nuclei of the facial nerve, the acoustic reflex is absent on the affected side.

TYMPANOMETRY

Tympanometry is based on recording the acoustic resistance that sound encounters when propagating through the structures of the system outer, middle and inner ear, at different air pressures in the external auditory canal (usually with a pressure amplitude of +200 up to –400 mm H_2O). The change in acoustic impedance depending on the pressure is displayed graphically (the tympanometric curve, which is called a “tympanogram”). Different types of tympanograms indicate the condition of the middle ear (Fig. 3).



a ***b*** ***c***

Fig. 3. Tympanograms:
a — normal; *b* — exudative otitis; *c* — dysfunction of the auditory tube (tubootitis)

OTOACOUSTIC EMISSION

In addition to perception, the inner ear is capable of making sounds due to the vibration of hair cells. The recording of sounds emanating from the inner ear using special highly sensitive equipment is called “registration of otoacoustic emission”. The intensity and frequency spectrum of the outgoing signals are different in various pathological conditions of the labyrinth. Depending on the registration conditions, spontaneous and induced otoacoustic emissions are distinguished. Spontaneous otoacoustic emission is recorded without sound stimulation of the ear, it is mainly a reflection of the condition of the outer hair cells of the Corti organ. The induced otoacoustic emission is recorded after stimulation and reflects the ability of the receptive apparatus of the inner ear to respond to physiological triggers.

UNCONDITIONAL REFLECTIVE REACTIONS ON SOUNDS

The essence of the reactions consists of the contraction of muscle tissue in response to an intense sound stimulus. A distinction is made between somatic and autonomic unconditioned reactions. In a somatic reaction, striated muscle tissue (skeletal muscles) contracts: a person flinches, and the eyelids close (auro-palpebral reflex). In an autonomic reaction, smooth muscles contract, which leads to pupil dilation (auropupillary reflex). The vascular reaction consists of a change in the tone of the smooth muscles of the vascular wall in response to intense sound stimulation (recorded using plethysmography). The galvanic skin reflex is manifested in a change potential difference between areas of the skin due to sound stimulation.

CONDITIONED RESPONSES TO SOUND

Conditioned reactions to sound consist in developing a conditioned motor reaction in a child in response to sound stimuli, using the method of game audiometry. The study is carried out according to the principle of developing a conditioned reflex, when the child responds to a sound signal with a motor reaction — by pressing a button. This button is either from a projection device, when a picture appears on the screen when pressed, or from a child's audiometer. The principle of action of which is that a child, by pressing a button, “helps people, animals, etc. to free themselves from the “enchanted” house” only when their cry is heard in headphones worn on the child’s ears. When a child has a conditioned motor reaction synchronously with the perception of a sound of a certain intensity, they switch to reflecting the motor reaction to a weaker sound, determining the lowest threshold value perceived by the child.

There are also more simplified methods of gaming audiometry.

CLASSIFICATION OF THE DEGREE OF HEARING LOSS

The described methods of hearing examination allow us to recognize the degree hearing loss, nature, localization of damage to the auditory analyzer. International Classification of Hearing Loss (classification WHO) is based on average values of the threshold of sound perception at speech frequencies (500, 1000, 2000, 4000 Hz).

Classification of Hearing Loss (WHO, 1997): I degree — 26–40 dB, II degree — 41–55 dB, III degree — 56–70 dB, IV — 71–90 dB, deafness — more than 90 dB.

The 2021 update classifies hearing loss as: Mild (20–34 dB), Moderate (35–49 dB), Moderately severe (50–64 dB), Severe (65–79 dB), and Profound (80–94 dB).

VESTIBULAR FUNCTION TESTS

ASSESSMENT OF VESTIBULAR (STATOKINETIC) FUNCTION

Evaluation of vestibular function includes:

1) analysis of patient complaints and medical history;

2) physical examination and assessment of spontaneous abnormalities;

3) performance of experimental vestibular tests.

Analysis of complaints and medical history. When obtaining the medical history, attention is paid to the duration of the disease, its onset (sudden or gradual), possible causes, and the presence of vertigo, vestibular symptoms, and hearing impairment.

Vertigo is classified into:

– **labyrinthine vertigo**, associated with irritation or suppression of the peripheral vestibular system;

– **retrolabyrinthine vertigo**, caused by lesions of the vestibular pathways or central nuclei.

Peripheral (labyrinthine) vertigo is systemic and characterized by a sensation of rotation of surrounding objects or of the patient rotating around their own axis. Labyrinthine vertigo is accompanied by autonomic symptoms (nausea, vomiting, sweating, changes in heart rate and respiration) and intensifies with changes in head position. Central vertigo lacks a clear rotational component, is non-systemic, and is often accompanied by headache.

A sudden decrease in hearing (conductive or sensorineural) is characteristic of labyrinthine lesions. In retrolabyrinthine vestibular disorders, hearing is either preserved or declines gradually.

EXAMINATION AND ASSESSMENT OF SPONTANEOUS DISORDERS

Nystagmus is an involuntary, rhythmic, biphasic movement of the eyeballs consisting of slow and fast phases.

Ocular motor nerve activity is maintained by equal impulses originating from both labyrinths. When this balance is disrupted due to irritation of one labyrinth, a slow deviation of the eyes occurs toward the side opposite the stimulated labyrinth.

Two components of nystagmus are distinguished:

– The **slow component**, caused by vestibular stimulation transmitted reflexively to the ocular motor nuclei.

– The **fast component**, representing a central corrective response that returns the eye to its neutral position.

The fast component is directed toward the stimulated labyrinth. Nystagmus persists as long as asymmetrical vestibular stimulation exists.

If labyrinthine function is lost (destruction of the receptor apparatus), impulses arise only from the intact labyrinth. In this case the fast component is directed toward the healthy labyrinth and the slow component is directed toward the affected side.

Nystagmus occurs in the plane of rotation and is opposite to the direction of endolymph flow. For example, rotation of a person around the vertical axis with the head upright or slightly flexed forward predominantly stimulates the horizontal semicircular canal, producing horizontal nystagmus.

DETECTION OF NYSTAGMUS

Nystagmus is recorded according to its fast component. The patient is instructed to follow the examiner's finger positioned slightly above eye level at a distance of approximately 0.5 m, which is moved slowly from one extreme gaze position to the other.

Spontaneous nystagmus is usually observed for up to 15–20 days, gradually decreasing in intensity.

In cases of vestibular irritation, nystagmus is directed toward the affected ear.

In cases of vestibular suppression, it is directed toward the healthy ear.

Degrees of nystagmus. Three degrees are distinguished:

– ***Grade I*** — present only when gazing toward the fast component;

– ***Grade II*** — present when gazing straight ahead;

– ***Grade III*** — present when gazing toward the slow component.

By amplitude, nystagmus may be:

– fine-amplitude;

– medium-amplitude;

– large-amplitude (typically of central origin).

LAWS GOVERNING LABYRINTH FUNCTION

Ewald's laws:

1. In the horizontal semicircular canal: endolymph movement toward the ampulla produces nystagmus toward the stimulated ear; movement away from the ampulla produces nystagmus in the opposite direction.

2. In the vertical semicircular canals, the opposite relationship applies.

3. In the horizontal canal, ampullopetal flow (toward the ampulla) produces a stronger response than ampullofugal flow. In vertical canals, the reverse is true.

Voyachek's laws:

1. The plane of nystagmus corresponds to the plane of rotation.
2. The slow phase of nystagmus coincides with the direction of endolymph flow.
3. The patient falls toward the slow component of nystagmus.

Spontaneous nystagmus is one of the early signs of labyrinthine disorders.

Characteristics of labyrinthine nystagmus:

1. It is never pendular.
2. It depends on gaze direction: looking toward the fast component increases nystagmus; looking toward the slow component decreases it, potentially to disappearance.
3. It is accompanied by vertigo.

TYPES OF NYSTAGMUS

Physiological nystagmus:

1. **Optokinetic nystagmus** — occurs during rapid motion (e.g. while observing objects from a moving train).
2. **Gaze-evoked (end-position) nystagmus** — fine-amplitude nystagmus occurring at extreme gaze positions and typically fatigues within 5–10 seconds.

Pathological nystagmus:

1. **Spontaneous labyrinthine nystagmus** — caused by imbalance between the labyrinths due to irritation or suppression of one side.
2. **Rotatory nystagmus** — observed in lesions of the vestibular nuclei at the floor of the fourth ventricle.
3. **Pendular large-amplitude nystagmus** — seen in cerebellar pathology.
4. **Congenital nystagmus** — present from birth and persists throughout life.
5. **Vertical dissociated nystagmus** — observed in lesions of the optic chiasm, where one eye moves upward and the other downward.

COORDINATION TESTS

Movements and maintenance of posture are accompanied by characteristic changes in the tone of the trunk and limb muscles. The vestibular system plays a crucial role in the regulation of statokinetic functions, and its disorders lead to impaired static balance and coordination. Therefore, coordination tests are essential in the assessment of vestibular function.

ROMBERG TEST

The patient stands upright with feet together (heels and toes touching), arms extended forward, and fingers spread apart. If the patient maintains stability, they are asked to close their eyes for 5–10 seconds. The examiner observes whether postural sway increases or whether complete loss of balance occurs. If the patient immediately loses balance, the test is repeated several times to determine whether there is a consistent tendency to fall to the same side. In labyrinthine dysfunction, the patient falls toward the side of the slow component of nystagmus. A characteristic feature is a change in the direction of falling when the head position is altered.

For example:

– In right-beating nystagmus, the patient falls to the left.

– If the head is turned 90° to the left, the patient falls backward.

– If the head is turned 90° to the right, the patient falls forward.

In cerebellar lesions, imbalance occurs toward the side of the lesion. Changes in head position do not affect the direction of falling. The Romberg test may also help detect functional (psychogenic) imbalance. In such cases, the patient appears to fall backward but consistently regains balance before actually falling.

STRAIGHT-LINE WALKING TEST

The patient is instructed to take five steps forward along a straight line with eyes closed and then, without turning around, take five steps backward. In vestibular disorders, deviation occurs toward the side of the slow component of nystagmus. In cerebellar lesions, the patient demonstrates an ataxic ("drunken") gait, with deviation toward the affected side.

TANDEM SIDE-STEPPING (LATERAL WALKING TEST)

The patient steps laterally to the right by moving the right foot outward and bringing the left foot toward it, performing five side steps. The test is then repeated to the left.

In vestibular dysfunction (e.g. labyrinthitis), the test is typically performed adequately. In cerebellar lesions, the patient is unable to perform side-stepping toward the affected side.

FINGER-TO-EXAMINER TEST (POINTING TEST)

The examiner sits opposite the patient with arms extended forward. The patient's hands rest on their knees. With eyes closed, the patient attempts to touch the examiner's index fingers.

In vestibular disorders, the patient misses with both hands toward the side of the slow component of nystagmus. In cerebellar lesions, misdirection occurs in the hand on the affected side only.

FINGER-TO-NOSE TEST

With eyes closed, the patient alternately touches the tip of their nose with the index finger of each hand. In vestibular dysfunction, deviation occurs with both hands toward the side of the slow component of nystagmus.

Rapid Alternating Movements (Test for Adiadochokinesis)

The patient performs rapid alternating supination and pronation movements with both hands. Normally, these movements are rapid, symmetrical, and well coordinated.

In vestibular disorders, coordinated bilateral movement is preserved. In cerebellar lesions, adiadochokinesis is observed, characterized by impaired rapid alternating movements and lagging of the hand on the affected side.

Experimental Tests

Experimental examination of the vestibular apparatus, i.e. its stimulation to assess functional status, is performed using a series of tests.

Pressure (Fistula) Test

The pressure test consists of increasing and decreasing air pressure in the external auditory canal when a fistula of the horizontal semicircular canal is suspected (this is the part of the labyrinth closest to the entrance to the mastoid antrum of the temporal bone). The test is performed in cases of chronic suppurative otitis media. Changes in pressure in the external auditory canal are produced by pressing the tragus of the affected ear with the physician's finger or by using a Politzer balloon.

During positive pressure, if a fistula of the horizontal semicircular canal is present, endolymph moves toward the ampulla, causing horizontal nystagmus toward the affected ear. During negative pressure, the nystagmus is directed to the opposite side, since the endolymph moves away from the ampulla toward the non-ampullary end of the canal.

Rotational Test

The rotational test (an adequate stimulus for the semicircular canals) is performed by rotating a seated patient with closed eyes on a special rotating chair (Bárány chair) equipped with a backrest and arm and foot supports. Rotation of the patient about their vertical axis produces angular acceleration of the semicircular canals. Stimulation of the ampullary receptors by the movement of endolymph induces nystagmus, as well as post-rotational motor and autonomic reactions observed after cessation of rotation.

Rotation is performed first in one direction and, after a 10-minute interval, in the opposite direction. The standard rate is 10 revolutions in 20 seconds. Under normal conditions, after 10 rotations and abrupt stopping of the chair, post-rotational nystagmus appears in the direction opposite to the rotation and lasts 20–30 seconds. The test is usually performed with the patient's head inclined forward by 30° (placing the horizontal semicircular canals in the horizontal plane).

Immediately after rotation, the patient is asked to open their eyes and gaze in the direction of the expected nystagmus (at the physician's finger). After rotation to the left, right-beating horizontal nystagmus is observed.

Although post-rotational nystagmus results from stimulation of both labyrinths, the predominant stimulation after rotation to the left occurs in the right horizontal semicircular canal, where endolymph flows toward the ampulla. In the left canal, endolymph flows away from the ampulla toward the non-ampullary end, producing weaker stimulation. After rotation to the right, the left semicircular canal is predominantly stimulated, and left-beating post-rotational nystagmus occurs.

In cases of hypofunction or hyperfunction of the labyrinth, the duration of post-rotational nystagmus changes. With prolonged unilateral hypofunction, central compensation usually develops, mediated by the central nervous system. As a result, post-rotational nystagmus induced by impulses from both labyrinths becomes symmetrical but shorter than normal.

To examine the anterior (frontal) semicircular canals, the patient's head is positioned with a 90° forward or backward tilt during rotation. A torsional post-rotational nystagmus occurs. To examine the posterior (sagittal) canals, the patient's head is tilted toward one shoulder or the other, resulting in vertical nystagmus.

Disadvantages of the rotational test include relatively intense stimulation of the semicircular canals (therefore it cannot be performed during the acute phase of disease or in severely ill patients), as well as simultaneous stimulation of both labyrinths.

CALORIC TEST

The caloric test does not have the disadvantages inherent in the rotational test, since it allows separate assessment of each labyrinth. This test is based on the principle that when the walls of the semicircular canals are cooled or warmed (with the canals positioned vertically), convection currents arise: cooled endolymph moves downward and warmed endolymph upward until thermal equilibrium is achieved.

The caloric test is performed by irrigating the external auditory canal with 100 mL of cooled (18–27 °C) or warm (42–45 °C) water using an appropriately sized syringe, with the head tilted backward by 60° (so that the horizontal semicircular canals assume a vertical position). Irrigation is performed slowly along the superior wall of the external auditory canal. Under normal conditions, horizontal-torsional nystagmus appears after 25–30 seconds and lasts 60–120 seconds. With cold water irrigation, nystagmus is directed to the side opposite the tested ear; with warm water irrigation, it is directed toward the tested ear.

Although the caloric test produces a non-physiological (thermal) stimulus, its major advantage is that it can be performed in bedridden patients. In this case, to maintain the vertical position of the horizontal semicircular canals, the patient's head should be flexed forward by 30°.

THRESHOLD CALORIC TEST

There is also a method of threshold caloric stimulation. Initially, 5 mL of water heated to 27 °C is instilled. Normally, nystagmus appears after 15–20 seconds and lasts 15–30 seconds. If labyrinth excitability is reduced, the volume of water is increased or its temperature lowered. In the presence of a dry perforation of the tympanic membrane, indications for vestibular testing are more limited.

ELECTRONYSTAGMOGRAPHY

Modern vestibulometry is based on determining the ratio between the degree of irritation and the nystagmal reflex recorded by electronystagmography. Only rotatory or sinusoidal angular acceleration makes it possible to identify the actual threshold of vestibular nystagmus, characterized by the appearance of a nystagmal reflex during electronystagmography.

Electronystagmography is based on the existence of a corneoretinal potential at rest and its transfer to electrodes located in the periorbital region. This research method provides an opportunity to graphically record eye movements in the dark and with closed eyelids. This is important for the differential diagnosis of various types of non-vestibular nystagmus. Nystagmograma can be used to analyze various types of vestibular and non-vestibular nystagmus in various pathologies, such as auditory nerve neurinoma, Meniere's disease, head injury, vertebrobasilar insufficiency, multiple sclerosis.

INVESTIGATION OF THE FUNCTION OF THE OTOLITH APPARATUS

An adequate stimulus for the otolith receptor is rectilinear acceleration in the horizontal and vertical planes. This is the basis for otolith and vestibular tests on conventional swings.

Otolith sample. An otolith sample is performed for the purpose of professional selection. The subject is rotated (5 revolutions for 10 seconds) in a Barani chair with his eyes closed and his head and torso tilted forward by 90° (Voyachek–Khilov test). First they rotate in one direction, then in the other. After 5 seconds after a sudden stop, the subject is asked to open his eyes and straighten up. As a result, a person experiences defensive movements, or somatic reactions (tilting the head and torso towards rotation) of three degrees (from mild to severe with loss of balance and falling) and vegetative reactions of three degrees (Table 3).

Table 3

Reaction to the otolith sample

Degree	Reaction	
	somatic	**vegetative**
I (low)	Deviation by an angle of 0–5°	Paleness of the face, a drop in the pulse
II (medium)	Deviation by an angle of 5–30°	Cold sweat, nausea
III (strong)	The patient loses his balance and falls	Violent motor reaction, vomiting, fainting

If the patient under the influence of otolith irritation gives a very strong tilt reaction (more than 30°), then the sensitivity of the otolith apparatus is considered to be increased. With a weak tilt response (from 0 to 5°), the otolith apparatus is considered insensitive.

Investigation of the otolith apparatus on a swing (Khilov's experiment). K. L. Khilov designed a special four-bar swing that always remains parallel to the floor when swinging. The subject is swung on such a swing for 15 minutes. If specific otolith reflexes do not appear after this time, an experiment with rotation is carried out. The absence of a reaction is indicated by a zero degree of accumulation. Based on clinical and experimental data, K. L. Khilov concluded that subjects with a zero degree of reaction can be classified as individuals in whom the inhibitory function of the cerebral cortex is pronounced. Such people are recognized as fit for flight service. The appearance of vomiting after 15 minutes of swing corresponds to the first degree of cumulation. Vegetative reactions occurring after 5–15 minutes of swinging are designated as II, and after 1–5 minutes of swinging as III degree of cumulation. Persons with grade I–III cumulation are unsuitable for flight service. The results of a functional study of the vestibular apparatus are presented in the form of a vestibular passport (Table 4).

Table 4

An example of a vestibular passport

Right side	Tests	Left side
Falls to the right	Romberg position	–
Falls to the right	Walking in a straight line	–
Perfoms	Flanking gait	Perfoms
The patient misses with his right hand	Finger-to-nose test	–
Parmonious deviation of both hands to the right	Finger-to-examiner test	–
Not detected	Adiadochokinesis	Not detected
Not detected	Spontaneous nystagmus	Not detected
Report: left-sided lesion of the vestibular analyzer		

VIDEO HEAD IMPULSE TESTING

Video head impulse testing (VHIT) evaluates how well the eyes and inner ears work together at speeds more consistent with natural everyday head movement. A small set of glasses with a camera are used to monitor eye movements. The vHIT test uses very small and quick movements of the head to evaluate reflex function, as opposed to the slow or moderate speeds used in rotation testing. Not all people in the diagnosis phase will require vHIT tests.

VESTIBULAR EVOKED MYOGENIC POTENTIAL

Vestibular evoked myogenic potential (VEMP) testing is used to evaluate whether certain vestibular organs that help us detect gravity (called the otolith organs) and their associated nerves are structurally intact. Responses in this test are measured from different muscles in the neck and around the eyes. VEMP testing uses adhesive, skin surface electrodes (like ENG or some rotational tests) and earphones (like those used during a hearing test). Sound is played for a few seconds through the earphones, which stimulates the otolith organs and activates muscle responses, and electrodes record the results.

Conclusion about the type (peripheral, central, mixed), stage (compensation, subcompensation, decompensation), phase (depression, irritation), side (right-, left-sided) and localization of vestibular disorders are made based on the results of vestibulometric tests.

Peripheral vestibular disorders are characterized by the fact that all reactions (spontaneous, experimental) proceed harmoniously, i.e. they correspond to the classical Ewald laws. The harmony of peripheral vestibular reactions, for example, is manifested by the correspondence of the direction of the slow component of nystagmus to the deviation of the arms and body. Disharmony of reactions occurs in central vestibular disorders and is manifested by the absence of one or more components (sensory, vegetative, somatic) of the reaction or by a discrepancy in the severity of its various links. For example, hearing may not suffer in the presence of central vestibular dysfunctions. The second feature of central vestibular disorders is the long duration of pathological reactions and the instability of compensation processes.

SELF-ASSESSMENT OF TOPIC UNDERSTANDING

Task 1. A 37-year-old patient consulted a neurologist with complaints of dizziness attacks triggered by sudden movements, sometimes accompanied by loss of consciousness. The dizziness attacks could be accompanied by nausea, imbalance — sharp deviation to the side. Hearing is normal. Spontaneous gross nystagmus, brief. The attack lasts about 2 hours, but after that the patient’s condition remains unstable for several days. Other ENT organs show no pathological changes.

1. Diagnostic plan.
2. What disease is necessary to differentiate?
3. Make a diagnosis.

Task 2. A 42-year-old woman is admitted to the hospital with complaints of dizziness, instability when walking (pulling to the left), pain in the occipital region, and an increase in body temperature. From the anamnesis, it is known that. Has been suffering from chronic left-sided otitis since early childhood. The last exacerbation was noted 3 weeks ago. *Objectively:* in consciousness, adequate. Left ear — pus in the external auditory canal, the mastoid process is painful on palpation. Spontaneous nystagmus to the left. Adiadochokinesia on the left, finger-to-nose test — the finger misses to the left. Decreased strength in the left hand. Moves with widely spaced legs. No meningeal symptoms are present.

1. Make a diagnosis.
2. With which disease should it be differentiated?

Task 3. A 27-year-old woman visited an otolaryngologist at a polyclinic with complaints of decreased hearing in the right ear and constant noise in it. She associates the illness with childbirth 5 years ago. During the examination: whispered speech right — 2 m, left — 6 m; conversational speech right — 5 m, left — 6 m. The right ear — external auditory canal wide, skin dry, tympanic membrane thinned, a bright pink spot is visible in the posteroinferior quadrant. On the audiogram — bone conduction is normal, air conduction is reduced by 30 dB.

1. Set the diagnosis.
2. With which disease must it be differentiated?

Task 4. A 29-year-old female patient was admitted to the hospital on a stretcher with complaints of severe dizziness when turning her head to the side. She has been ill for 2 weeks. After a recent upper respiratory tract infection, she developed left otitis media, which was treated outpatient. Three days ago, she developed dizziness accompanied by nausea and vomiting. The dizziness is triggered by head movements. On examination: blood pressure is normal. There are abundant purulent discharge in the left external auditory canal. The mastoid process is painless upon palpation. Body temperature is 37.9 °C. Spontaneous horizontal nystagmus, small-amplitude, directed to the right. No meningeal signs are present.

1. Make a diagnosis.
2. With which condition should it be differentiated?

Task 5. A 26-year-old female patient was admitted to the hospital on a stretcher with complaints of severe pain in the right ear radiating to the neck, and an increase in body temperature to 38 °C. She became ill acutely 2 days ago and attributes the illness to a cold. On examination: flattening. During examination: smoothness of the right auricular sulcus. Sharp pain when pulling the auricle forward. The external auditory canal is narrowed due to infiltration of the lower wall of the cartilaginous part. Hyperemia of the lower wall of the cartilaginous part of the right external auditory canal is determined.

1. Make a diagnosis.
2. What disease should be differentiated from?

ANSWERS TO SITUATIONAL TASKS

Task 1:

1. Cervical spine radiography, carotid ultrasound, consultation with an otoneurologist, ophthalmologist.
2. Ménière’s disease, cerebellar abscess.
3. Vertebrobasilar insufficiency.

Task 2:

1. Chronic left-sided purulent epitympanitis, complicated by a cerebellar abscess.
2. Brain abscess.

Task 3:

1. Otosclerosis.
2. Adhesive middle ear.

Task 4:

1. Acute purulent middle ear with labyrinthitis.
2. Brain abscess, cerebellar abscess.

Task 5:

1. Acute external otitis.
2. Mastoiditis, furuncle of the external auditory canal.

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