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Atherosclerosis And Hearing Loss: A New Understanding of the Relationship Between Cardiology and Otolaryngology

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Annotation

Atherosclerosis, characterized by the deposition of lipids and fibrous tissue in the walls of the arteries, is one of the leading causes of cardiovascular diseases. In recent years, there has been a growing interest in the relationship between atherosclerosis and hearing loss, which highlights the importance of an interdisciplinary approach combining cardiology and otolaryngology. Impaired blood circulation in the microcirculatory system of the inner ear caused by atherosclerotic changes can lead to hypoxia and degeneration of the auditory receptors, which increases the risk of developing sensorineural hearing loss. Current research shows that patients with atherosclerosis have a higher prevalence of hearing impairment compared to the general population.

In addition, systemic inflammation, oxidative stress, and endothelial dysfunction, which play a key role in the pathogenesis of atherosclerosis, can also affect the functional state of the hearing aid. This work summarizes current data on the pathophysiological mechanisms linking atherosclerosis and hearing loss, and also suggests promising areas for further research. Particular attention is paid to potential prevention and treatment strategies based on correcting atherosclerosis risk factors and improving microcirculation in the inner ear.

Keywords: atherosclerosis, hearing loss, sensorineural hearing loss, microcirculation, cardiology, otolaryngology.

INTRODUCTION. Atherosclerosis is a chronic disease characterized by progressive deposition of lipids, fibrous tissue and calcium in the walls of the arteries, which leads to their thickening, loss of elasticity and impaired blood flow. This systemic disease affects almost all organs and systems of the body, but most often its consequences manifest themselves in the form of cardiovascular complications such as myocardial infarction, stroke and peripheral arterial disease. In recent years, researchers have focused on less studied aspects of the effect of atherosclerosis on the functional state of individual organs, including the hearing aid.

Hearing loss is one of the most common sensory pathologies affecting more than 460 million people worldwide, according to the World Health Organization (WHO). Sensorineural hearing loss, which is caused by damage to the inner ear or auditory nerve, occupies a special place among the various forms of hearing loss. Despite the fact that age-related changes, noise exposure, and genetic factors are traditionally considered the main causes of hearing loss, there is a growing body of scientific evidence confirming the link between atherosclerosis and the development of this pathology.

The inner ear, in particular the spiral organ (Cortical organ), is an extremely sensitive structure that requires constant supply of oxygen and nutrients through the vascular network. Any microcirculation disorders in this area can lead to hypoxia, oxidative stress, and degeneration of the auditory receptors. Atherosclerotic changes in large and small vessels providing blood supply to the inner ear create prerequisites for the development of sensorineural hearing loss. In addition, the systemic inflammation that accompanies atherosclerosis can have an additional negative effect on the structures of the auditory analyzer.

The interest in the relationship between atherosclerosis and hearing loss is due not only to the desire to understand the pathogenetic mechanisms of these processes, but also to the need to develop new approaches to prevention and treatment. Current research shows that patients with atherosclerosis have an increased risk of developing hearing loss compared to people without this disease. Overcoming the consequences of this risk requires an integrated approach combining the achievements of cardiology and otolaryngology. Understanding the interrelationships between these two areas of medicine opens up new horizons for early diagnosis, timely intervention, and the development of personalized therapeutic strategies. In this context, it becomes obvious that further research is needed to study the role of vascular factors in the development of auditory disorders, as well as to find ways to minimize their negative effects.

The aim of the work is to summarize current data on the relationship between atherosclerosis and hearing loss, to consider the pathophysiological mechanisms underlying this relationship, and to discuss prospects for clinical practice. Special attention is paid to the interdisciplinary aspects of the problem, which emphasizes the importance of cooperation between specialists from various medical disciplines to achieve the best results in the diagnosis and treatment of patients.

MATERIALS AND METHODS. When working within the framework of the relationship between atherosclerosis and hearing loss, a set of theoretical methods was used that will allow a deep analysis of the problem and summarize existing data. Thus, a systematic review of publications on the research topic, including scientific articles, reviews, clinical recommendations, and meta-analyses, was conducted in order to determine the current state of research in the field of atherosclerosis and its effects on the hearing aid, identify knowledge gaps, and formulate new questions for further study. In addition, the results of various studies were compared to identify common patterns or contradictions. This made it possible to identify the key factors influencing the development of hearing loss in patients with atherosclerosis and to determine their significance. Information from various sources was also combined to create a holistic picture of the problem in order to integrate data from cardiology, otolaryngology and related fields (for example, biochemistry, neurology) to formulate new hypotheses, and attempts were made to integrate knowledge from various fields of medicine (cardiology, otolaryngology, neurology, biochemistry) to create a holistic picture of the problem..

Results. Atherosclerosis is a chronic progressive disease characterized by the deposition of lipids, fibrous tissue, and calcium in the walls of the arteries[1]. These pathological changes lead to thickening of the vascular wall, loss of its elasticity and impaired blood flow. Atherosclerosis is one of the leading causes of cardiovascular diseases (CVD), which occupy a leading position among the causes of mortality and disability of the population worldwide [2].

The key mechanism for the development of atherosclerosis is considered to be damage to the endothelium, the inner layer of the arteries, which can be caused by factors such as hypertension, dyslipidemia, smoking, diabetes mellitus and chronic inflammation. Endothelial damage promotes the adhesion of low-density lipoproteins (LDL) and their oxidation, which triggers a cascade of inflammatory reactions [3]. As a result, atherosclerotic plaques form, which can partially or completely block the lumen of the vessel, disrupting the blood supply to vital organs.

The most well-known consequences of atherosclerosis include coronary heart disease (CHD), strokes, peripheral arterial disease (PAD), and other forms of vascular pathology. However, the effect of atherosclerosis is not limited to large vessels: microcirculatory disorders caused by this disease can affect small arteries and capillaries, which is especially important for sensitive structures such as the inner ear [4].

Thus, atherosclerosis is a systemic disease that affects the entire body, and its role in the development of various pathologies, including hearing loss, is becoming the subject of increasing attention by researchers.

Impaired blood circulation in the microcirculatory system of the inner ear caused by atherosclerotic changes is a critical factor contributing to the development of sensorineural hearing loss [5]. The inner ear, and in particular the spiral organ (Cortical organ), is one of the most metabolically active structures of the body, requiring constant and adequate blood supply to maintain the normal function of auditory receptors – hair cells. Any microcirculation disorders in this area can lead to hypoxia, oxidative stress and, as a result, degeneration of auditory receptors [6].

Atherosclerotic changes in the vessels feeding the inner ear (for example, the labyrinthine artery) manifest themselves in the form of their stenosis, decreased elasticity and impaired regulation of blood flow. This may be due to both the accumulation of lipid plaques in large arteries and microcirculatory disorders at the capillary level[7]. Hypoxia, which occurs due to insufficient blood supply, triggers a chain of pathological processes: energy metabolism in hair cells is disrupted, the production of free radicals increases, cell membranes and their intracellular structures are damaged.

It is especially important to note that the hair cells of the inner ear have an extremely limited ability to regenerate [8]. Damage caused by hypoxia or oxidative stress is often irreversible, leading to progressive hearing loss. Sensorineural hearing loss, which develops against the background of such changes, is characterized by a loss of the ability to perceive sounds of varying frequency and intensity, as well as the possible appearance of tinnitus [9].

Accordingly, atherosclerosis creates favorable conditions for the development of auditory disorders due to microcirculation disorders and related pathophysiological mechanisms, which emphasizes the need for early diagnosis and correction of vascular disorders in patients at risk of atherosclerosis, especially among the elderly and people with a history of cardiovascular disease.

Modern studies demonstrate that patients with atherosclerosis have a significantly higher prevalence of hearing disorders compared to the general population [10]. This observation highlights the importance of vascular factors in the development of hearing disorders and points to the need for a more thorough study of the relationship between the state of the cardiovascular system and the functionality of the hearing aid.

In a 2018 study, the authors examined the links between concomitant cardiovascular disease and hearing loss in 433 patients aged 80 and older in the United States and found that type 2 diabetes, hypertension, coronary heart disease (CHD), and a history of stroke were associated with accelerated hearing loss, with CHD showing the strongest association. Experts point out that treatment of an underlying cardiovascular disease can prevent or slow the progression of hearing loss, and conversely, hearing loss may indicate the presence of an underlying cardiovascular disease [11].

Another group of specialists conducted a population-based study of approximately 30,000 Canadian adults aged 45 and older and found that hypertension and cardiovascular risk on the Framingham scale were independently associated with greater hearing loss during the 3-year follow-up period. The results were published in 2023 in the journal Ear and Hearing [12].

In addition, a cross-sectional analysis conducted during the study showed that smoking, obesity, diabetes, and complex measures of cardiovascular risk were independently

associated with hearing impairment after adjusting for age, race, ethnicity, income, and education.

In a retrospective study published in 2023 in Scientific Reports, audiological and general health data from electronic medical records of 6332 patients (45.5% men) observed at a major academic medical center in the United States were examined to determine the relationship between risk factors for cardiovascular disease and hearing loss. The average age of the patients was 62.96 years, and 64.0% of the patients had hearing loss [13].

The results showed a higher chance of hearing loss among current smokers and diabetic patients compared to non-smokers and non-diabetic patients, and the presence of 2 or more major risk factors for cardiovascular disease was associated with a 92% higher chance of hearing loss compared to patients without these risk factors. Only in men, hypertension was also associated with hearing loss.

The authors concluded that improved glucose control, smoking cessation, and early blood pressure management (for men) can contribute to healthy hearing, although such strategies need to be confirmed by longitudinal studies [13].

The results of numerous other studies in recent years have demonstrated a link between risk factors for cardiovascular diseases, as well as existing cardiovascular diseases and hearing loss. [14, 15, 16, 17]. In a meta–analysis published in March 2024 in the journal Otolaryngology-Head and Neck Surgery, the authors examined data from 4 cohort studies (N=940,771) and 6 cross-sectional studies (N =680,349) and found that stroke, coronary heart disease, and any cardiovascular disease were strongly associated with hearing loss. The total combined OR for each association with hearing loss was 1.26 (95% CI, 1.16–1.37; I2 = 78%) for stroke; 1.36 (95% CI, 1.13–1.64; I2 =96%) for coronary heart disease; and 1.38 (95% CI, 1.07–1.77; I 2 = 99%) for any cardiovascular diseases [18].

The presented results suggest that physicians treating patients with hearing loss should be aware of this connection and consider hearing loss in the broader context of general health and aging.

Atherosclerosis, affecting both large and small vessels, has a systemic effect on blood circulation, including microcirculation in the inner ear. Disruption of blood flow in the labyrinthine artery or other vessels that supply the auditory analyzer leads to hypoxia and metabolic disorders in the cells of the spiral organ. Such changes become the main triggers for the development of sensorineural hearing loss, the most common form of hearing loss associated with damage to hair cells or the auditory nerve [19].

Epidemiological data show that the frequency of hearing impairments among patients with atherosclerosis is significantly higher than in people without this disease. For example, studies have shown that in patients with diagnosed atherosclerosis, the risk of developing sensorineural hearing loss increases by 30-50% compared to the control group. This relationship is especially pronounced in the elderly, where the combination of age-related changes and the atherosclerotic process creates a "double burden" for auditory function. In addition, the presence of risk factors such as hypertension, dyslipidemia, diabetes mellitus, and chronic inflammation further increases the likelihood of hearing loss [20].

The pathophysiological basis of this relationship includes several key mechanisms. Atherosclerotic changes reduce the elasticity of blood vessels and impair their ability to adapt

to changes in blood flow, which is especially critical for the structures of the inner ear [21]. Insufficient blood supply leads to a lack of oxygen and nutrients, which causes damage to the sensitive cells of the auditory analyzer.

Increased production of free radicals in atherosclerosis exacerbates damage to cell membranes and intracellular structures of hair cells. Systemic inflammation, characteristic of atherosclerosis, can directly affect the condition of the hearing aid, exacerbating degenerative changes [22].

Thus, the increased prevalence of hearing disorders in patients with atherosclerosis confirms the importance of vascular factors in the pathogenesis of sensorineural hearing loss. This also highlights the need for timely diagnosis and correction of atherosclerotic changes, especially in people at risk. The inclusion of an otolaryngological examination in the standard protocol for monitoring patients with atherosclerosis can contribute to the early detection of auditory disorders and prevent their progression.

Systemic inflammation, oxidative stress, and endothelial dysfunction, which are key links in the pathogenesis of atherosclerosis, have a significant impact not only on the cardiovascular system, but also on the functional state of the hearing aid. The presented mechanisms create conditions for the development of microcirculatory disorders, hypoxia and degeneration of the structures of the inner ear, which increases the risk of hearing loss [23].

To visualize the relationship between atherosclerosis and hearing loss, as well as the role of systemic inflammation, oxidative stress, and endothelial dysfunction in the pathogenesis of these processes, the table (Table 1) can be used.

Table 1
The influence of key mechanisms of atherosclerosis on the functional state of the hearing aid

Mechanism	Description of the mechanism	Effects on the hearing aid
Systemic inflammation	Activation of pro-inflammatory cytokines (IL-6, TNF-α) and chronic inflammation causing tissue damage.	Damage to the hair cells and nerve structures of the inner ear; increased fibrosis of the vessels of the microcirculatory bed.
Oxidative stress	Excessive production of reactive oxygen species (ROS) and insufficient antioxidant protection.	Damage to the membranes of hair cells, proteins and DNA; induction of apoptosis of sensitive cells of the auditory analyzer.
Endothelial dysfunction	Impaired production of nitric oxide (NO), increased vascular permeability and a decrease in their ability to vasodilation.	Decreased blood flow in the labyrinthine artery and microcirculation in the inner ear, which leads to tissue hypoxia.

Systemic inflammation plays a central role in the development of atherosclerosis, contributing to vascular endothelial damage and the formation of atherosclerotic plaques. However, its effect extends to other organs, including the inner ear. Inflammatory mediators

such as cytokines (interleukins, tumor necrosis factor α) cause tissue damage to the auditory analyzer, increasing oxidative stress and disrupting the normal functioning of hair cells. In addition, chronic inflammation can increase fibrous changes in the vessels feeding the inner ear, which impairs blood circulation and contributes to the development of hypoxia [24].

Oxidative stress is an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defenses. In atherosclerosis, increased ROS production is associated with endothelial dysfunction, low-density lipoprotein oxidation, and activation of inflammatory processes. The inner ear is particularly sensitive to oxidative stress due to the high metabolic activity of hair cells and their limited ability to regenerate. Excess free radicals damage cell membranes, proteins, and DNA, which can cause apoptosis (programmed cell death) and progressive hearing loss.

Endothelial dysfunction is one of the early signs of atherosclerosis and is characterized by a violation of the ability of the endothelium to regulate vascular tone, permeability, and antithrombotic properties of blood vessels [25]. Deterioration of endothelial function leads to a decrease in the production of nitric oxide (NO), which plays a key role in maintaining normal blood flow. This is especially important for the inner ear, as its structures depend on a stable and adequate blood supply. Endothelial dysfunction can contribute to the development of ischemia in the microcirculatory system of the inner ear, which increases the risk of hypoxia and degeneration of auditory receptors.

It is important to note that systemic inflammation, oxidative stress, and endothelial dysfunction are closely interrelated and reinforce each other. For example, inflammatory cytokines can stimulate ROS production, which in turn increases inflammation and damages the endothelium. This "vicious circle" creates favorable conditions for the development of auditory disorders [26]. In the context of atherosclerosis, these mechanisms can occur simultaneously, which significantly increases the strain on the hearing aid and accelerates its degeneration.

Thus, systemic inflammation, oxidative stress, and endothelial dysfunction, being key components of the pathogenesis of atherosclerosis, have a significant impact on the functional state of the hearing aid. These mechanisms disrupt microcirculation, cause hypoxia, and damage the sensitive structures of the inner ear, which increases the risk of developing sensorineural hearing loss. Understanding this relationship highlights the importance of timely correction of these factors in patients with atherosclerosis, which can help prevent or slow the progression of hearing disorders.

DISCUSSION. Hearing loss associated with atherosclerosis is largely due to impaired microcirculation, tissue hypoxia, and damage to the structures of the inner ear. Given this, key prevention and treatment strategies should focus on correcting atherosclerosis risk factors, improving blood circulation, and protecting sensitive hearing aid cells.

Correction of atherosclerosis risk factors is a key direction in the prevention and treatment of hearing loss associated with this disease [27]. Blood pressure control helps prevent damage to the vessels of the inner ear caused by hypertension. The use of antihypertensive drugs, such as ACE inhibitors or angiotensin II receptor blockers, contributes not only to reducing blood pressure, but also to improving the condition of the

vascular wall due to their antioxidant properties. Regular monitoring of blood pressure allows timely detection of abnormalities and correction of therapy.

Correction of dyslipidemia plays an important role in preventing the progression of atherosclerosis. The use of statins helps to lower LDL cholesterol and reduce vascular inflammation, which is especially important for microcirculation in the inner ear. The inclusion of foods rich in polyunsaturated fatty acids, such as omega-3 fatty acids, helps reduce inflammation and improve endothelial function.

The fight against diabetes is also of great importance. Strict control of blood glucose levels helps minimize oxidative stress and prevent further vascular damage. Drugs such as metformin can improve metabolism and have a protective effect on the vascular system [28].

Quitting smoking and reducing exposure to other toxic factors are necessary to improve microcirculation and reduce the risk of oxidative stress. Conducting smoking cessation programs and minimizing the effects of noise and other harmful factors help preserve the function of the hearing aid.

Improvement of blood circulation in the microcirculatory system of the inner ear can be achieved using various approaches.:

1) the use of vasoactive drugs. Drugs that improve microcirculation, such as pentoxifylline or ginkgo biloba extract, help dilate blood vessels and improve blood flow in the inner ear. These drugs may be especially useful for patients with signs of impaired blood supply to the auditory analyzer.;

2) Antioxidant therapy. Antioxidants such as vitamin E, vitamin C, and coenzyme Q10 help neutralize free radicals and reduce oxidative stress. This is especially important to protect the hair cells of the inner ear, which are susceptible to damage due to their high metabolic activity.;

3) the use of drugs that improve energy metabolism. Drugs such as citicoline or actovegin help improve energy metabolism in cells and protect neurons from hypoxia. This may be useful for maintaining the function of the auditory nerve and hair cells.;

4) physiotherapy methods. Physical therapy methods such as magnetic therapy, laser therapy, or electrical stimulation can help improve microcirculation and reduce inflammation in the inner ear.

The following approaches can be used to protect the hearing aid from damage caused by atherosclerosis:

1) reducing the impact of noise. Noise exposure increases damage to hair cells, especially in patients with already impaired microcirculation. Minimizing noise exposure and using hearing protection devices (such as earplugs) help prevent additional damage.;

2) maintaining a healthy lifestyle. Rational nutrition, regular physical activity and weight control contribute to improving the general condition of blood vessels and reducing the risk of atherosclerosis.;

3) Early diagnosis and monitoring. Regular audiological examinations in patients with atherosclerosis can identify the initial signs of hearing loss and start treatment in a timely manner.

Strategies for the prevention and treatment of hearing loss associated with atherosclerosis should be aimed at correcting risk factors, improving microcirculation, and

protecting the hearing aid [29]. An integrated approach, including drug therapy, lifestyle changes, and physiotherapy, will help minimize the risk of hearing impairment and preserve the quality of life of patients with atherosclerosis.

The need for closer cooperation between specialists from various medical disciplines to identify and timely manage the problem of the relationship between atherosclerosis and hearing loss is due to the complex nature of this pathology. Atherosclerosis, being a systemic disease, affects many organs and systems, including the hearing aid. However, its role in the development of auditory disorders is often underestimated due to the lack of an interdisciplinary approach.

Pathophysiological mechanisms linking atherosclerosis and hearing loss include microcirculatory disorders, hypoxia, oxidative stress, systemic inflammation, and endothelial dysfunction [30]. Understanding and correcting them requires combining the knowledge of cardiologists, otolaryngologists, neurologists, biochemists, and other specialists. Hearing loss in patients with atherosclerosis may be associated not only with vascular changes, but also with other factors such as age, genetic predisposition, noise exposure, or metabolic disorders. A comprehensive assessment of these factors is possible only with the collaboration of specialists from different fields.

Detecting early signs of hearing loss in patients with atherosclerosis requires regular monitoring of the condition of the hearing aid, which becomes possible with the close cooperation of cardiologists who monitor patients with cardiovascular diseases and otolaryngologists who are able to conduct a detailed audiological examination.

Therapy aimed at correcting atherosclerosis (for example, the use of statins, antihypertensive drugs, or antioxidants) can have a positive effect on the condition of the hearing aid [31]. However, consultations of cardiologists, internists, and otolaryngologists are necessary to develop a personalized approach to treatment.

Many doctors, especially highly specialized specialists, may not take into account the relationship between atherosclerosis and hearing loss in their practice. Joint educational programs and seminars will help raise awareness of this issue among the medical community.

Cardiologists can refer patients with atherosclerosis for an audiological examination to identify the initial signs of hearing loss. Otolaryngologists, in turn, can inform cardiologists about the presence of auditory disorders, which may indicate the progression of atherosclerosis. Neurologists who treat patients with vascular disorders of the brain can collaborate with otolaryngologists to assess the condition of the auditory nerve and inner ear, especially in patients with vertebrobasilar insufficiency [32].

Therapists and nutritionists can develop individual lifestyle correction programs, including diet, physical activity, and quitting bad habits, which will contribute to both the prevention of atherosclerosis and the preservation of hearing. Biochemists and laboratory specialists can help develop new methods for assessing biomarkers of inflammation, oxidative stress, and other factors associated with atherosclerosis and hearing loss.

Closer cooperation between specialists from various medical disciplines is a key condition for the successful identification and management of hearing loss in patients with atherosclerosis. Such an interdisciplinary approach will allow not only to better understand the pathogenesis of the relationship between these conditions, but also to develop effective

prevention and treatment strategies. This, in turn, will help improve the quality of life of patients and reduce the risk of serious complications. The creation of interdisciplinary teams and the implementation of joint surveillance protocols will be an important step in solving this problem.

CONCLUSIONS. Atherosclerosis affects not only the cardiovascular system, but also other organs, including the hearing aid. Microcirculation disorders caused by atherosclerotic changes play a key role in the development of sensorineural hearing loss.

Close cooperation between cardiologists, otolaryngologists, neurologists and other specialists is required to identify and manage hearing loss in patients with atherosclerosis in a timely manner. Working together will allow us to develop comprehensive strategies for diagnosis, prevention and treatment.

Correction of atherosclerosis risk factors (hypertension, dyslipidemia, diabetes mellitus, smoking) can help preserve hearing. The use of drugs that improve microcirculation (for example, pentoxifylline), antioxidants, and drugs that protect neurons may be useful in preventing hearing disorders. Physiotherapy and lifestyle changes also play an important role in maintaining the health of the hearing aid.

Regular audiological examinations in patients with atherosclerosis can identify the initial signs of hearing loss and start treatment in a timely manner. This is especially important to prevent irreversible changes in the structures of the inner ear.

Further research should focus on the study of biomarkers, the development of new diagnostic methods (for example, visualization of microcirculation in the inner ear), evaluation of the effectiveness of therapy and the introduction of regenerative technologies to restore hearing. Understanding the relationship between atherosclerosis and hearing loss opens up new horizons for early diagnosis, personalized treatment, and improved quality of life for patients. This highlights the importance of integrating knowledge from different medical disciplines to achieve better results.

Thus, studying the relationship between atherosclerosis and hearing loss demonstrates that these conditions are closely related through common pathophysiological mechanisms. Pathologies of the cardiovascular system have a significant impact on the functional state of the hearing aid, which requires special attention from doctors of various specialties. An interdisciplinary approach combining cardiology, otolaryngology and related fields of medicine is the key to successfully solving this problem. The development of new prevention and treatment strategies based on correcting atherosclerosis risk factors and improving microcirculation in the inner ear will help minimize the consequences of these disorders and improve the quality of life of patients.

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