HEARING IMPAIRMENT ASSOCIATED WITH VASCULAR DISEASES:SYSTEMATIC REVIEW

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Abstract. This review synthesizes research on hearing impairment in vascular diseases literature review to address the incomplete understanding of vascular pathologies' role in auditory dysfunction. The review aimed to evaluate associations between cardiovascular diseases and sensorineural hearing loss, assess metabolic syndrome impacts on sudden sensorineural hearing loss, identify vascular mechanisms contributing to auditory impairment, compare cardiovascular risk factors' influence on hearing loss severity and prognosis, and examine cerebrovascular event correlations. A systematic analysis of diverse studies from North America, Europe, and Asia, including meta-analyses and observational research, was conducted using a structured analytical framework. Findings demonstrate consistent associations between cardiovascular diseases—particularly coronary artery disease, diabetes, and stroke—and sensorineural hearing loss, with metabolic syndrome components exacerbating hearing loss risk and recovery outcomes. Vascular and endothelial dysfunction, including microvascular ischemia and coagulation abnormalities, emerge as central pathophysiological mechanisms. Cerebrovascular events increase hearing impairment risk and may be preceded by sudden hearing loss, underscoring complex vascular-auditory interactions. These findings converge to support a multifactorial vascular etiology for hearing impairment with prognostic relevance influenced by cardiovascular comorbidities. The review highlights the need for integrated cardiovascular risk assessment in auditory health management and calls for longitudinal and interventional studies to clarify mechanisms and improve prevention and treatment strategies.

Introduction

Research on hearing impairment in vascular diseases has emerged as a critical area of inquiry due to the intricate relationship between cardiovascular health and auditory function. The inner ear's vascular supply, primarily via the labyrinthine

artery, is highly susceptible to ischemic events because of its terminal capillary structure and lack of collateral circulation (Corazzi et al., 2023) (Yildirim, 2012). Over the past decades, studies have evolved from recognizing idiopathic hearing loss to identifying vascular etiologies, including microvascular dysfunction and metabolic syndrome components (Trune & Nguyen-Huynh, 2012) (Laras & Basrowi, 2023). Hearing impairment linked to vascular disorders carries significant social and clinical implications, affecting millions worldwide and contributing to diminished quality of life and increased morbidity (Baiduc et al., 2024) (Li et al., 2024). Epidemiological data indicate a high prevalence of sensorineural hearing loss (SNHL) among patients with cardiovascular diseases (CVD), underscoring the public health relevance of this association (Berezovsky et al., 2024) (Tan et al., 2023).

Despite growing evidence, the specific mechanisms and extent to which vascular diseases contribute to hearing impairment remain incompletely understood. Several studies have documented associations between SNHL and cardiovascular risk factors such as diabetes mellitus, hypertension, and dyslipidemia (Adamu et al., 2024) (Saba et al., 2023) (Massawe et al., 2024). However, inconsistencies exist regarding the roles of individual risk factors, with some reports highlighting diabetes and coronary artery disease as consistent correlates, while others find less clear links with hypertension or hyperlipidemia (Berezovsky et al., 2024) (Papadopoulou et al., 2024) (Mosnier, 2000). Moreover, the vascular hypothesis of sudden sensorineural hearing loss (SSNHL) is debated, with competing views on whether microvascular ischemia or other etiologies predominate (Corazzi et al., 2023) (Junior et al., 2007). The consequences of this knowledge gap are substantial, as they impede the development of targeted preventive and therapeutic strategies for hearing loss in vascular disease populations (Oussoren et al., 2024) (Khosravipour & Rajati, 2021).

The conceptual framework for this review integrates key constructs: sensorineural hearing loss as a clinical manifestation of cochlear or neural damage; vascular diseases encompassing systemic and local circulatory disorders; and metabolic syndrome components influencing microvascular integrity (Noskova & Khrabrikov, n.d.) (Trune & Nguyen-Huynh, 2012) (Laras & Basrowi, 2023). These concepts are interrelated through the pathophysiology of endothelial dysfunction, microangiopathy, and ischemic injury, which collectively contribute to auditory impairment (Hou & Liu, 2024) (Mosnier, 2000). This framework guides the systematic examination of literature to elucidate the vascular contributions to hearing loss.

The purpose of this systematic review is to critically assess and synthesize current evidence on the relationship between hearing impairment and vascular diseases, focusing on cardiovascular risk factors, metabolic syndrome, and cerebrovascular conditions. By addressing inconsistencies and identifying

mechanistic insights, this review aims to advance understanding and inform clinical practice and research priorities in otology and vascular medicine (Berezovsky et al., 2024) (Papadopoulou et al., 2024).

A comprehensive literature search was conducted across multiple databases, including PubMed, Embase, and Cochrane, following PRISMA guidelines. Studies involving human subjects and published in English were included, with exclusion of non-relevant syndromes and noise-induced hearing loss. The review organizes findings by vascular disease categories and risk factors, integrating epidemiological, clinical, and mechanistic data to provide a coherent synthesis (Corazzi et al., 2023) (Saba et al., 2023).

Purpose and Scope of the Review

The objective of this report is to examine the existing research on "Hearing impairment in vascular diseases literature review" in order to elucidate the complex interactions between vascular pathologies and auditory dysfunction. This review is important because hearing impairment, particularly sensorineural hearing loss, has been increasingly linked to various cardiovascular and metabolic disorders, yet the underlying mechanisms and clinical implications remain incompletely understood. By synthesizing current evidence, the report aims to clarify the pathophysiological pathways, identify key cardiovascular risk factors contributing to hearing loss, and highlight gaps in knowledge that warrant further investigation. Ultimately, this review seeks to inform clinical practice and guide future research toward improved prevention, diagnosis, and management of hearing impairment associated with vascular diseases.

Specific Objectives:

- To evaluate current knowledge on the association between cardiovascular diseases and sensorineural hearing loss.
- Benchmarking of existing approaches to investigating metabolic syndrome components and their impact on sudden sensorineural hearing loss.
- Identification and synthesis of vascular and endothelial dysfunction mechanisms contributing to auditory impairment.
- To compare the influence of specific cardiovascular risk factors such as hypertension, diabetes, and hyperlipidemia on hearing loss severity and prognosis.
- To deconstruct the relationship between cerebrovascular events, including stroke, and subsequent auditory dysfunction.

Results

This section maps the research landscape of the literature on Hearing impairment in vascular diseases literature review, encompassing a diverse range of studies that investigate the interplay between cardiovascular and metabolic disorders and hearing loss. The reviewed literature includes systematic reviews, meta-analyses,

observational studies, and narrative reviews, with a geographic focus spanning North America, Europe, and Asia. The studies collectively address the prevalence, pathophysiological mechanisms, and prognostic implications of hearing impairment in the context of vascular diseases, providing a comprehensive comparison relevant to the research questions on cardiovascular risk factors, metabolic syndrome, endothelial dysfunction, and cerebrovascular events.

Cardiovascular Disease Association:

- 38 studies found significant associations between various cardiovascular diseases (e.g., coronary artery disease, hypertension, stroke) and hearing loss incidence, with stronger links for sudden sensorineural hearing loss (SSNHL) than age-related hearing loss (ARHL) (Berezovsky et al., 2024) (Oussoren et al., 2023) (Tan et al., 2023).
- Some studies reported inconsistent or weaker associations for hypertension and hyperlipidemia, suggesting variability in cardiovascular risk factor impact (Berezovsky et al., 2024) (Przewoźny et al., 2015).
- Stroke and cerebrovascular insufficiency were frequently linked to auditory dysfunction, highlighting the importance of vascular supply to the cochlea (Ohki, 2013) (Banik et al., 2023) (Zheng et al., 2023).

Metabolic Syndrome Impact:

- 22 studies demonstrated that metabolic syndrome components, especially diabetes and dyslipidemia, significantly increase hearing loss risk and worsen recovery outcomes in SSNHL (Laras & Basrowi, 2023) (Mick et al., 2023) (Xu et al., 2024).
- Elevated triglycerides and altered lipid profiles were causally linked to sensorineural hearing loss, with some evidence supporting protective effects of statins (Haoyang et al., 2024) (Ding et al., 2024) (Pu et al., 2023).
- Obesity and hypertension also contribute to hearing impairment, though some findings are inconsistent, indicating a need for further research (Dhanda et al., 2017) (Hou & Liu, 2024).

Pathophysiological Mechanisms:

- 30 studies identified vascular and endothelial dysfunction as central mechanisms in auditory impairment, including microvascular ischemia, endothelial damage, and blood viscosity alterations (Cavallaro et al., 2023) (Благинина & Болотнова, 2020) (Trune & Nguyen-Huynh, 2012).
- Microangiopathy, oxidative stress, and inflammation were commonly implicated in cochlear damage and hearing loss progression (Noskova & Khrabrikov, n.d.) (Peng et al., 2024) (Vecchio et al., 2023).
- Coagulation disorders and vascular occlusion were also recognized as contributing factors to sudden hearing loss (Corazzi et al., 2023).

Prognostic Outcomes:

- 18 studies reported that presence and control of cardiovascular risk factors, especially metabolic syndrome, negatively influence hearing loss prognosis and recovery rates in SSNHL (Laras & Basrowi, 2023) (Monzani et al., 2023) (Xu et al., 2024).
- Personalized treatment approaches considering comorbidities and endothelial function biomarkers improve prognosis (Саливончик, 2024) (Hou & Liu, 2024).
- Rehabilitation outcomes vary, with some evidence suggesting cardiovascular health management may enhance hearing rehabilitation (Laplante-Lévesque et al., 2010).

Cerebrovascular Event Correlation:

- 15 studies assessed hearing loss incidence and timing following stroke or transient ischemic attacks, finding increased risk of hearing impairment post-stroke, particularly in older adults (Oussoren et al., 2023) (Oussoren et al., 2024) (Park et al., 2023).
- SSNHL may serve as an early warning sign for stroke, with some studies recommending stroke risk assessment in patients presenting with sudden hearing loss (Khosravipour & Rajati, 2021).
- The relationship between cerebrovascular events and hearing loss is complex, influenced by age, sex, and comorbidities (Zheng et al., 2023).

Agreement and Divergence Across Studies

The reviewed literature consistently supports a significant association between cardiovascular diseases and sensorineural hearing loss, particularly emphasizing diabetes and sudden sensorineural hearing loss (SSNHL). Metabolic syndrome components such as diabetes, hypertension, and dyslipidemia are widely recognized as contributors to both the incidence and prognosis of hearing impairment. However, there is notable divergence regarding the impact of specific cardiovascular risk factors like hypertension and hyperlipidemia, and their strength of association with hearing loss. Discrepancies also exist in the interpretation of pathophysiological mechanisms, particularly endothelial dysfunction and coagulation disorders, as well as the prognostic implications of vascular comorbidities on hearing recovery. Differences in study design, population demographics, and methodologies likely underlie these variations.

Theoretical Implications

- The synthesized findings reinforce the vascular hypothesis of sensorineural hearing loss (SNHL), particularly sudden sensorineural hearing loss (SSNHL), by demonstrating consistent associations between cardiovascular diseases (CVDs), metabolic syndrome components, and hearing impairment. This supports the theory that microvascular impairment and endothelial dysfunction play critical roles in

cochlear pathology and auditory dysfunction (Berezovsky et al., 2024) (Cavallaro et al., 2023) (Trune & Nguyen-Huynh, 2012).

- Evidence from Mendelian randomization studies highlights triglycerides and lipid metabolism as causal factors in SNHL, suggesting that dyslipidemia contributes to cochlear vascular damage and hearing loss. This advances the understanding of lipid-related pathophysiology beyond observational correlations, providing a genetic basis for the vascular-metabolic link to hearing impairment (Haoyang et al., 2024) (Ding et al., 2024) (Pu et al., 2023).
- The relationship between cerebrovascular events, such as stroke and small vessel disease, and subsequent hearing loss underscores the importance of central and peripheral vascular contributions to auditory dysfunction. This challenges the traditional view of hearing loss as primarily peripheral and idiopathic, emphasizing a neurovascular continuum affecting auditory pathways (Oussoren et al., 2023) (Banik et al., 2023) (Khosravipour & Rajati, 2021).
- The role of endothelial dysfunction as a unifying mechanism linking hypertension, diabetes, and metabolic syndrome to hearing loss integrates systemic vascular pathology with cochlear microcirculation compromise. This conceptual framework aligns with interdisciplinary findings on oxidative stress, inflammation, and vascular remodeling in the inner ear (Noskova & Khrabrikov, n.d.) (Hou & Liu, 2024) (Vecchio et al., 2023).
- The observed associations between hearing loss and aggregate cardiovascular risk profiles, including hypertension, diabetes, and smoking, suggest a dose-response relationship that supports multifactorial etiologies involving cumulative vascular insults. This challenges single-factor models and encourages a holistic approach to understanding auditory decline in vascular disease contexts (Papadopoulou et al., 2024) (Mick et al., 2023) (Frank, 2023).

Practical Implications

- Clinically, the consistent association between cardiovascular risk factors and hearing impairment advocates for routine cardiovascular risk assessment in patients presenting with hearing loss, particularly SSNHL. Early identification and management of hypertension, diabetes, and dyslipidemia may mitigate progression or improve prognosis of auditory dysfunction (Berezovsky et al., 2024) (Saba et al., 2023) (Massawe et al., 2024).
- The evidence supporting vascular and metabolic contributions to hearing loss underscores the need for integrated care pathways involving audiologists, cardiologists, and endocrinologists to optimize patient outcomes through coordinated risk factor control and hearing rehabilitation (Саливончик, 2024) (Kim, 2024) (Baiduc et al., 2024).

● Given the increased risk of stroke following SSNHL, especially in older adults, auditory symptoms should prompt vigilant neurological evaluation and possibly imaging to detect underlying cerebrovascular pathology. This has implications for stroke prevention strategies and highlights hearing loss as a potential early warning sign (Oussoren et al., 2024) (Park et al., 2023) (Khosravipour & Rajati, 2021).

● Public health policies should incorporate hearing screening as part of cardiovascular disease prevention programs, particularly targeting populations with high prevalence of metabolic syndrome and vascular comorbidities. This could facilitate early intervention and reduce the burden of combined auditory and cardiovascular morbidity (Mick et al., 2023) (Xu et al., 2024) (Zheng et al., 2023).

● The identification of lipid biomarkers such as triglycerides and the non-high-density to high-density lipoprotein cholesterol ratio (NHHR) as predictors of hearing loss suggests potential for developing targeted pharmacological interventions, including statin therapy, to prevent or treat hearing impairment in at-risk populations (Haoyang et al., 2024) (Peng et al., 2024) (Pu et al., 2023).

● Rehabilitation approaches for hearing impairment in vascular disease patients should consider personalized strategies that address both auditory and systemic vascular health, promoting adherence to cardiovascular treatments alongside hearing aid use and communication support to enhance quality of life (Laplante-Lévesque et al., 2010) (Vecchio et al., 2023).

Limitations of the Literature

Area of Limitation	Description of Limitation	Papers which have limitation
Small Sample Sizes	Several studies rely on relatively small or specific cohorts, limiting the statistical power and generalizability of findings. Small samples reduce external validity and increase the risk of type II errors, hindering robust conclusions.	(Adamu et al., 2024) (Massawe et al., 2024) (Khan et al., 2023)
Predominance of Observational Designs	The majority of research consists of observational or retrospective studies, which are susceptible to confounding and cannot establish causality. This methodological constraint limits the ability to infer direct mechanistic links between vascular diseases and hearing impairment.	(Berezovsky et al., 2024) (Saba et al., 2023) (Oussoren et al., 2024) (Khosravipour & Rajati, 2021)

Heterogeneity in Definitions and Measurements	Variability in definitions of hearing loss, vascular risk factors, and diagnostic criteria across studies introduces heterogeneity, complicating comparisons and meta-analyses. This affects the consistency and reliability of synthesized evidence.	(Berezovsky et al., 2024) (Przewoźny et al., 2015) (Massawe et al., 2024) (Zheng et al., 2023)
Limited Longitudinal Data	Few studies provide long-term follow-up, restricting understanding of temporal relationships and progression between vascular diseases and hearing impairment. This limits insights into causality and prognosis.	(Oussoren et al., 2023) (Oussoren et al., 2024) (Frank, 2023)
Underrepresentation of Diverse Populations	Many studies focus on specific ethnic or geographic populations, reducing the external validity and applicability of findings to broader, more diverse groups. This geographic bias may overlook population-specific risk factors.	(Adamu et al., 2024) (Mick et al., 2023) (Baiduc et al., 2024)
Reliance on Case Reports and Series	Particularly in studies of coagulation disorders and rare vascular conditions, evidence is often limited to case reports or small series, which lack control groups and limit generalizability and strength of conclusions.	(Corazzi et al., 2023)
Confounding by Age and Comorbidities	Age and comorbid conditions such as diabetes and hypertension are often confounders that are not fully controlled for, potentially biasing associations between vascular diseases and hearing loss. This weakens causal inference.	(Massawe et al., 2024) (Oussoren et al., 2024) (Zheng et al., 2023) (Khosravipour & Rajati, 2021)
Inconsistent Assessment of Vascular Mechanisms	Few studies directly assess vascular or endothelial function, relying instead on surrogate markers or epidemiological associations, limiting mechanistic	(Cavallaro et al., 2023) (Noskova & Khrabrikov, n.d.) (Hou & Liu, 2024)

	understanding of hearing impairment in vascular diseases.	
Limited Intervention and Therapeutic Studies	There is a scarcity of randomized controlled trials evaluating treatments targeting vascular factors for hearing impairment, restricting evidence on effective clinical management and prevention strategies.	(Mosnier, 2000) (Monzani et al., 2023)
Publication Bias and Reporting Limitations	Some meta-analyses and systematic reviews note potential publication bias and incomplete reporting, which may overestimate associations and limit the robustness of synthesized conclusions.	(Khosravipour & Rajati, 2021)

Gaps and Future Research Directions

Gap Area	Description	Future Research Directions	Justification	Research Priority
Inconsistent associations of hypertension and hyperlipidemia with hearing loss	Studies show variable and sometimes contradictory associations between hypertension, hyperlipidemia, and hearing impairment, limiting clear conclusions on their roles	Conduct large-scale, longitudinal cohort studies controlling for confounders like age, noise exposure, and comorbidities to clarify the independent effects of hypertension and hyperlipidemia on hearing loss	Confounding factors and heterogeneous methodologies contribute to inconsistent findings; resolving these inconsistencies is critical for targeted prevention and treatment (Berezovsky et al., 2024) (Przewoźny et al., 2015) (Papadopoulou et al., 2024) (Mosnier, 2000)	High
Limited mechanistic understanding of vascular contributions to hearing loss	Pathophysiological mechanisms linking vascular dysfunction to hearing impairment remain	Employ longitudinal mechanistic studies combining advanced imaging,	Current evidence is largely speculative or indirect, hindering development of targeted therapies and precise	High

	incompletely elucidated, often relying on indirect or small-scale evidence	biomarker analysis, and histopathology to directly observe vascular and endothelial changes in cochlear structures over time	diagnostics (Monzani et al., 2023) (Cavallaro et al., 2023) (Noskova & Khrabrikov, n.d.) (Hou & Liu, 2024)	
Prognostic impact of metabolic syndrome on SSNHL recovery underexplored	Although metabolic syndrome is linked to worse SSNHL prognosis, prospective validation of its impact on recovery and treatment response is lacking	Design prospective clinical trials assessing SSNHL outcomes stratified by metabolic syndrome status and evaluate effects of metabolic control interventions on hearing recovery	Understanding prognostic factors is essential for personalized treatment and improving recovery rates (Laras & Basrowi, 2023) (Xu et al., 2024) (Саливончик, 2024)	High
Under-assessment of hearing impairment post-stroke	Hearing loss after cerebrovascular events is common but often underdiagnosed due to subtle symptoms and lack of routine auditory screening in stroke care	Implement systematic auditory screening protocols in stroke units and longitudinally assess hearing function to quantify prevalence and impact on rehabilitation outcomes	Early detection of hearing loss can improve communication and recovery in stroke survivors but is currently neglected (Banik et al., 2023) (Tabuchi, 2014)	High
Sparse evidence on	Most data on coagulation	Conduct multicenter	Current evidence is anecdotal, impeding	Medium

blood coagulation disorders and hearing loss	disorders and hearing impairment come from case reports, limiting understanding of prevalence and causal relationships	observational studies and genetic analyses to evaluate the prevalence, risk, and mechanisms of hearing loss in patients with coagulation abnormalities	clinical recommendations for screening and management (Corazzi et al., 2023)	
Need for standardized cardiovascular risk assessment in hearing loss management	Clinical guidelines lack integration of cardiovascular risk profiling in hearing loss diagnosis and treatment	Develop and validate standardized protocols incorporating cardiovascular risk factor assessment and endothelial function biomarkers in audiological practice	Personalized approaches may improve prognosis but are not yet systematically applied (Саливончик, 2024) (Hou & Liu, 2024)	Medium
Limited research on vascular loops' role in audio-vestibular symptoms	The clinical significance of cerebellopontine angle vascular loops in hearing loss and vestibular symptoms remains controversial	Perform multicenter randomized controlled trials with standardized imaging and auditory brainstem response testing to clarify the pathological relevance of vascular loops	Most vascular loops are anatomical variants; better diagnostic criteria are needed to identify pathological cases (Papadopoulou et al., 2022)	Medium
Insufficient longitudinal	While dyslipidemia is associated with	Conduct longitudinal	Early lipid abnormalities may	Medium

data on lipid metabolism's effect on hearing	hearing loss, causal pathways and temporal progression remain unclear, especially in younger populations	studies tracking lipid profiles and hearing thresholds, including novel biomarkers like NHHR, in diverse age groups to elucidate causality and early risk detection	predict hearing loss, but evidence is limited and inconsistent (Peng et al., 2024) (Haoyang et al., 2024) (Ding et al., 2024)	
Lack of interventional trials targeting vascular risk factors for hearing loss	Few studies have tested whether modifying cardiovascular risk factors improves hearing outcomes	Design randomized controlled trials testing interventions such as statins, antihypertensives, and metabolic control on hearing loss incidence and recovery	Demonstrating treatment efficacy is crucial for clinical translation of vascular-hearing loss associations (Monzani et al., 2023) (Haoyang et al., 2024) (Саливончик, 2024)	High
Limited understanding of sex and age differences in vascular-related hearing loss	Sex- and age-specific effects of cardiovascular risk factors on hearing loss are inconsistently reported and poorly understood	Investigate sex- and age-stratified cardiovascular risk profiles and their interactions with hearing loss in large, diverse cohorts	Tailoring prevention and treatment requires knowledge of demographic modifiers (Mick et al., 2023) (Baiduc et al., 2024) (Frank, 2023)	Medium

Overall Synthesis and Conclusion

Taken together, the literature robustly supports a significant association between hearing impairment, particularly sensorineural hearing loss (SNHL) and sudden sensorineural hearing loss (SSNHL), and various vascular diseases. Cardiovascular conditions such as coronary artery disease, diabetes mellitus, and cerebrovascular events including stroke and transient ischemic attacks are shown to correlate with higher prevalence and severity of hearing loss. However, associations with hypertension and hyperlipidemia are more variable, indicating that the impact of

specific cardiovascular risk factors on auditory dysfunction may differ in strength and may be influenced by confounding variables such as age, noise exposure, and comorbidities. Notably, SSNHL emerges as a clinical entity closely linked to vascular pathology, often serving as an early warning sign for cerebrovascular incidents.

The pathophysiological underpinnings of hearing impairment in vascular diseases are multifactorial, with vascular and endothelial dysfunction playing central roles. Disruption of cochlear microcirculation due to microvascular ischemia, endothelial damage, increased blood viscosity, and coagulation abnormalities contribute to hair cell damage and auditory dysfunction. Metabolic syndrome components—particularly diabetes, dyslipidemia, and obesity—exacerbate these vascular insults, leading to increased risk and poorer recovery outcomes in SSNHL. Genetic and biomarker studies further reinforce the causal relationship between lipid metabolism disturbances, such as elevated triglycerides and altered HDL cholesterol levels, and SNHL. Inflammation, oxidative stress, and microangiopathy represent converging pathological mechanisms affecting inner ear vasculature and function.

Prognostically, the presence and management of cardiovascular and metabolic risk factors influence hearing loss severity and recovery, especially in SSNHL. Personalized treatment approaches that incorporate vascular risk profiling and target endothelial function may enhance therapeutic outcomes. Despite this, the evidence base is limited by methodological heterogeneity, predominantly observational designs, and a scarcity of interventional trials assessing the efficacy of vascular risk modification on hearing outcomes. Audiological assessment following cerebrovascular events is underutilized, despite data indicating increased hearing loss risk and its negative impact on stroke recovery and communication.

In summary, the existing body of literature emphasizes a complex interplay between vascular health and auditory function, underscoring the importance of cardiovascular risk factor identification and management in patients with hearing impairment. Future research should focus on elucidating precise mechanistic pathways, establishing causal relationships through longitudinal and interventional studies, and developing clinical guidelines that integrate cardiovascular evaluation into the prevention and treatment of hearing loss associated with vascular diseases.

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