

HEARING LOSS AS AN INDICATOR OF CAROTID ARTERY STENOSIS: MECHANISMS, DIAGNOSIS, AND TREATMENT

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Abstract

Carotid artery stenosis (CAS) is an underrecognized contributor to sensorineural hearing loss (SNHL). The underlying vascular mechanisms and implications for stroke risk require further exploration.

Objective: To summarize the prevalence, pathophysiology, diagnostic tools, and treatment options for CAS-related SNHL.

Methods: A review of current literature, including epidemiological data, vascular pathophysiology, imaging modalities, biomarkers, and emerging therapies.

Results: Approximately 10–30% of CAS patients experience SNHL before major cerebrovascular events. Inflammatory pathways, oxidative stress, and endothelial dysfunction contribute to cochlear ischemia. Advanced imaging techniques, such as functional MRI and transcranial Doppler ultrasound, offer early detection of vascular-induced hearing loss. Pharmacologic interventions (vasodilators, antioxidants, statins) and cochlear implants may improve outcomes.

Conclusion: Hearing loss may serve as an early biomarker for carotid disease. Routine audiometric screenings in high-risk populations could aid early intervention and stroke prevention. Further studies are needed to assess the impact of vascular interventions on hearing function.

Keywords: Sensorineural hearing loss, carotid artery stenosis, cerebrovascular disease, oxidative stress, cochlear ischemia, vascular biomarkers

1. Introduction

Carotid artery stenosis (CAS) is a progressive vascular condition associated with an increased risk of stroke. Emerging evidence suggests that CAS may also contribute to sensorineural hearing loss (SNHL) through ischemic and inflammatory mechanisms. However, this connection remains underrecognized in clinical practice. This review explores the epidemiology, underlying pathophysiology, diagnostic approaches, and emerging therapeutic strategies for CAS-related SNHL.

2. Prevalence and Risk Factors of Hearing Impairment in Carotid Artery Stenosis

2.1 Epidemiology

Studies estimate that 10–30% of patients with significant CAS develop SNHL before experiencing major cerebrovascular events [1]. Common vascular risk factors, including older age, smoking, hypertension, diabetes, and hyperlipidemia, have been implicated in both carotid stenosis and hearing impairment [2].

A 2022 meta-analysis in the Journal of Stroke & Cerebrovascular Diseases demonstrated that mild-to-moderate CAS increases the risk of auditory dysfunction, even in asymptomatic patients [3]. Silent cerebrovascular disease has also been implicated as a cause of subtle auditory deficits before major ischemic events occur [4].

New Consideration: Could subclinical carotid stenosis serve as an early biomarker for hearing decline? Further prospective studies are needed to assess this association.

Section	Key Findings
Prevalence & Risk Factors	10–30% of CAS patients develop SNHL before major cerebrovascular events. - Risk factors: Age, smoking, hypertension, diabetes, hyperlipidemia. - Silent cerebrovascular disease linked to early SNHL.
Mechanisms of Hearing Loss	Endothelial dysfunction reduces nitric oxide (NO), impairing cochlear circulation. - Atherosclerosis & microvascular occlusions lead to hair cell apoptosis. - Pro-inflammatory cytokines (TNF-α, IL-6, IL-1β) contribute to cochlear neurodegeneration.
Biomarkers for Early Detection	Elevated CRP, TNF-α, IL-6, ADMA levels correlate with CAS severity and SNHL. - High homocysteine levels linked to vascular-related hearing loss.

Advanced Diagnostic Tools	Functional MRI (fMRI): Detects ischemic changes in the auditory cortex. - Transcranial Doppler (TCD): Assesses cerebrovascular reactivity and cochlear ischemia. - Optical Coherence Tomography Angiography (OCTA): Identifies microvascular damage in the inner ear.
Hearing Loss as a Stroke Predictor	Unexplained SNHL increases stroke risk (1.4–2.3×) within 5 years. - Microembolic events from carotid plaques can cause sudden SNHL. - Routine audiometry in high-risk groups may aid early stroke detection.
Treatment Strategies	- Vasodilators (Pentoxifylline, Nimodipine): Improve cochlear microcirculation. - Antioxidants (Resveratrol, Coenzyme Q10, NAC): Protect against oxidative stress. - Statins & Antiplatelets (Aspirin + Clopidogrel): Reduce embolic risk and improve cochlear blood flow
Cochlear Implant Considerations	Vascular impairment affects spiral ganglion survival, impacting CI success. - Preoperative vascular assessment may be necessary for CAS patients.
Clinical Implications & Future Directions	SNHL may serve as an early biomarker for cerebrovascular disease.

3. Mechanisms: How Inflammation and Endothelial Dysfunction Contribute to Hearing Loss

3.1 Pathophysiology of Cochlear Ischemia

Endothelial dysfunction in CAS leads to reduced nitric oxide (NO) production, impairing cochlear microcirculation and oxygenation [5].

Atherosclerosis and microvascular occlusions restrict oxygen supply to the cochlea, leading to hair cell apoptosis and progressive hearing loss [6].

Pro-inflammatory cytokines (TNF- α , IL-6, IL-1 β) accelerate cochlear neurodegeneration, while oxidative stress contributes to mitochondrial dysfunction in auditory hair cells [7].

3.2 Biomarkers for Early Detection

C-reactive protein (CRP), TNF- α , IL-6, and asymmetric dimethylarginine (ADMA) levels correlate with CAS severity and SNHL progression [8].

Plasma homocysteine levels have been associated with vascular-induced cochlear dysfunction in recent studies [9].

Future Research Question:

Can anti-inflammatory and antioxidant therapies mitigate vascular-induced SNHL?

4. Advanced Diagnostic Tools for Early Detection

4.1 Modern Imaging Modalities

Functional MRI (fMRI): Detects ischemic changes in the auditory cortex before hearing loss becomes clinically significant [10].

Transcranial Doppler (TCD) Ultrasound: Evaluates cerebrovascular reactivity and subclinical cochlear ischemia [11].

Optical Coherence Tomography Angiography (OCTA): Identifies inner ear and retinal microvascular abnormalities, paralleling cochlear ischemic injury [12].

Potential Biomarkers for Early Diagnosis:

Vascular Endothelial Growth Factor (VEGF) as an indicator of cochlear microvascular impairment.

Oxidative stress markers (malondialdehyde, superoxide dismutase, glutathione levels) as early indicators of cochlear ischemia [13].

5. Hearing Loss as an Early Warning Sign for Stroke & Cardiovascular Disease

5.1 Hearing Loss and Stroke Risk

A 2021 JAMA Otolaryngology study found that unexplained SNHL increases the risk of stroke by 1.4 to 2.3 times within five years [14].

Silent ischemic events in the auditory brainstem pathways are detected in subclinical CAS patients, even before neurological symptoms appear [15].

Clinical Consideration:

Routine audiometric screenings in high-risk populations (diabetics, hypertensives, smokers) may help identify early cerebrovascular disease.

Future Research Question:

Can carotid artery stenting or endarterectomy improve auditory function?

6. Novel Treatment Strategies & Hearing Rehabilitation

6.1 Pharmacological Interventions

Vasodilators (Pentoxifylline, Nimodipine) improve cochlear microcirculation and may slow vascular-related SNHL progression [17].

Antioxidants (Resveratrol, Coenzyme Q10, NAC) reduce oxidative stress and protect cochlear hair cells [18].

Statins & Antiplatelets (Aspirin + Clopidogrel) may protect cochlear microcirculation and prevent embolic events [19].

6.2 Cochlear Implantation in Vascular-Related Hearing Loss

Cochlear implants (CIs) may help, but vascular impairment affects spiral ganglion neuron survival, influencing CI outcomes [20].

Future Consideration:

Should vascular assessments be performed before CI surgery in patients with carotid disease?

7. Conclusion

✓ Carotid artery stenosis is an underrecognized cause of SNHL.

✓ Inflammation, oxidative stress, and microvascular occlusions contribute to cochlear ischemia.

✓ Hearing loss may serve as an early biomarker for stroke risk.

✓ Advanced imaging (fMRI, OCTA, TCD) and biomarkers (CRP, VEGF, ADMA) could aid early diagnosis.

✓ Emerging treatments, including vasodilators, antioxidants, and statins, show promise.

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