EARLY DETECTION AND MANAGEMENT OF HEARING IMPAIRMENT IN PATIENTS WITH CAROTID ARTERY STENOSIS

Khaydarova G.S.
Departement of Otorhinolaryngology
Tashkent State Medical University
haydarovadoc@mail.ru
Shodmonkulova G.R.
Departement of Otorhinolaryngology
Tashkent State Medical University
https://orcid.org/0009-0003-0371-2724
gulruh.rustamovna@mail.ru

Abstract. Carotid artery stenosis (CAS) is a critical vascular condition commonly associated with ischemic stroke, yet emerging studies suggest it may also compromise auditory function through reduced perfusion to the inner ear [1,2]. This review synthesizes current knowledge on the pathophysiological mechanisms linking CAS to hearing impairment, discusses diagnostic tools for early detection, and evaluates the efficacy of different treatment options. A comprehensive literature review was conducted across databases including PubMed, Scopus, and Web of Science, focusing on studies from 2015 to 2025. Evidence supports the utility of audiological tests, such as otoacoustic emissions and auditory brainstem response, in identifying subclinical hearing loss among CAS patients [3,4]. Additionally, imaging modalities such as carotid Doppler ultrasound and MR angiography have proven essential in early vascular assessment [5]. Interventions including carotid endarterectomy and stenting may improve auditory outcomes when performed promptly [6]. Although the link between CAS and hearing loss is increasingly recognized, standardized screening protocols remain underdeveloped. This review highlights the necessity for multidisciplinary collaboration to improve diagnostic accuracy and patient outcomes.

Introduction

Carotid artery stenosis (CAS), a progressive narrowing of the carotid arteries due to atherosclerosis, is a leading cause of ischemic stroke worldwide [7]. However, recent studies have brought attention to its potential impact on cochlear perfusion and auditory function [2,8]. The cochlea is highly sensitive to vascular insufficiency, and even moderate reductions in blood flow can result in significant sensorineural hearing loss (SNHL) [9].

Emerging clinical and electrophysiological data suggest that auditory dysfunction may precede neurological symptoms in CAS patients, particularly in

those with subclinical or asymptomatic stenosis [4,10]. Therefore, recognizing early auditory signs can offer a valuable opportunity for earlier intervention. This review aims to provide a detailed synthesis of available evidence on the mechanisms, diagnostics, and treatment of hearing loss associated with CAS.

Pathophysiology and Etiology of Carotid Artery Stenosis

The primary cause of CAS is atherosclerosis, a chronic inflammatory condition characterized by lipid and fibrous plaque accumulation within the arterial wall, leading to luminal narrowing and impaired cerebral blood flow [7,11]. Major risk factors include hypertension, diabetes mellitus, dyslipidemia, smoking, and aging [12].

The internal carotid artery gives rise to branches that indirectly supply the cochlea, primarily through the anterior inferior cerebellar artery and the internal auditory artery [13]. Inadequate perfusion due to CAS may result in cochlear ischemia and subsequent hair cell degeneration [14]. Additionally, microemboli originating from unstable plaques may obstruct smaller vessels, further exacerbating inner ear damage [15].

Histological studies confirm that even temporary reductions in cochlear blood supply can lead to irreversible auditory neuron loss, making early detection of CAS critical for preserving hearing [9,16].

Association Between Carotid Stenosis and Auditory Dysfunction

Although carotid stenosis has traditionally been studied for its neurological sequelae, increasing evidence links CAS to sensorineural hearing loss (SNHL) [1,3]. The inner ear's dependency on consistent blood flow renders it particularly vulnerable to ischemic injury. Several observational studies have reported unilateral or bilateral hearing impairment in CAS patients, often in the absence of stroke symptoms [4,17].Symptoms such as tinnitus, fluctuating hearing loss, and reduced speech discrimination have been associated with CAS-related hypoperfusion [5,18]. Objective assessments like auditory brainstem responses (ABR) and otoacoustic emissions (OAE) reveal early auditory pathway dysfunction even when standard audiograms appear normal [6,19].

Importantly, hearing loss does not always directly correlate with stenosis severity, suggesting the involvement of compensatory hemodynamic factors and individual vascular variations [8,20].

Diagnostic Methods: Audiological and Imaging Techniques.Early diagnosis of carotid artery stenosis (CAS)-related auditory dysfunction requires an integrated approach involving both audiological and neurovascular assessments. Audiological testing plays a crucial role in identifying early signs of sensorineural hearing loss (SNHL), particularly in asymptomatic or subclinical cases [6].

Pure-tone audiometry remains the standard tool for detecting hearing thresholds, yet it may not capture early cochlear or retrocochlear dysfunction. Therefore, otoacoustic emissions (OAEs)—especially distortion product OAEs (DPOAEs)—are utilized to assess outer hair cell activity and cochlear micromechanics, often revealing dysfunction before hearing loss is clinically evident [21]. Studies have shown reduced DPOAE amplitudes in patients with moderate to severe CAS, even with normal audiograms [3].

Auditory brainstem responses (ABRs) are another sensitive method for evaluating neural conduction along the auditory pathway. Prolonged latencies in wave I–V interpeak intervals have been documented in CAS patients, reflecting delayed auditory transmission due to ischemic effects on the brainstem or cochlear nuclei [8.19]. These changes may be unilateral or bilateral, depending on the pattern of arterial involvement [19].

In addition to audiology, vascular imaging is essential for diagnosing and grading the severity of CAS. Carotid duplex ultrasonography is the first-line, non-invasive method, offering real-time visualization of plaque morphology and flow velocity [23]. Computed tomography angiography (CTA) and magnetic resonance angiography (MRA) provide higher-resolution anatomical detail, allowing accurate stenosis quantification and assessment of collateral flow [24.25].

Recent advancements include transcranial Doppler ultrasonography to evaluate cerebral hemodynamics and perfusion-weighted MRI, which can help correlate auditory symptoms with regional brain perfusion deficits [26]. Combining audiological and imaging modalities has been shown to enhance early detection and guide therapeutic decision-making in patients with suspected CAS-related hearing disorders [10]

Treatment Approaches and Outcomes

The management of carotid artery stenosis (CAS) is aimed at reducing stroke risk, but it may also have positive implications for auditory function, particularly in patients with ischemia-induced hearing impairment [17]. Treatment strategies include medical therapy, surgical interventions, and endovascular procedures.

Medical Management

First-line management typically includes antiplatelet therapy, statins, blood pressure control, and lifestyle modification [31]. Statins, in particular, have demonstrated vascular-protective and anti-inflammatory effects that may enhance microcirculation, including cochlear perfusion [32]. Although conservative treatment does not directly target hearing, stabilization of atherosclerosis may prevent further auditory deterioration.

Carotid Endarterectomy (CEA)

Carotid endarterectomy (CEA) is the gold standard for patients with symptomatic or high-grade stenosis (≥70%), significantly reducing the risk of cerebrovascular events [34]. Several studies have also reported improvement in auditory symptoms post-CEA, particularly in patients with preoperative hearing loss or tinnitus [35]. A prospective study showed that patients with CAS and concurrent hearing dysfunction experienced measurable audiological improvement following CEA, attributed to restored inner ear blood flow [36].

Carotid Artery Stenting (CAS)

Carotid artery stenting is an alternative for patients at high surgical risk or with anatomical challenges. It is less invasive than CEA and has shown comparable efficacy in stroke prevention [37]. Preliminary evidence also suggests that CAS may improve auditory outcomes, although the results are less consistent than with surgical intervention [38]. Doppler flow measurements post-stenting indicate improved hemodynamic status, potentially benefiting cochlear oxygenation [39].

Outcomes and Prognosis

The prognostic impact of treating CAS on hearing largely depends on the timing of intervention. Early detection and management appear to offer the highest likelihood of auditory recovery, whereas prolonged ischemia may lead to irreversible cochlear or neural damage [19]. Furthermore, patients with unilateral CAS are more likely to experience localized auditory improvement compared to those with bilateral or diffuse vascular disease [10].Multidisciplinary management—integrating neurologists, otolaryngologists, and vascular surgeons—is crucial for optimizing both neurologic and audiologic outcomes. As studies increasingly recognize the otologic manifestations of CAS, early vascular assessment should be considered in the differential diagnosis of unexplained sensorineural hearing loss.

Future Directions

Despite growing recognition of the association between carotid artery stenosis (CAS) and auditory dysfunction, several gaps remain in both the understanding of pathophysiology and the development of standardized diagnostic and therapeutic protocols.First, large-scale prospective studies are needed to confirm the causal relationship between CAS and sensorineural hearing loss (SNHL), as current evidence largely stems from observational and cross-sectional data [17]. Many studies report audiological changes in CAS patients, yet a clear temporal and dose-response relationship remains to be established [2].

Second, standardized screening algorithms that include audiological tests for patients at risk of CAS—particularly those with transient or idiopathic hearing symptoms—could significantly improve early diagnosis. Integration of audiological biomarkers, such as otoacoustic emissions or auditory brainstem response delays, into vascular screening protocols is an underutilized but promising area [19].

Third, the role of cerebral perfusion imaging in understanding cochlear and auditory pathway ischemia has not been fully elucidated. Functional imaging techniques such as perfusion-weighted MRI and arterial spin labeling (ASL) may help map the specific neurovascular territories affecting hearing [26,40].Additionally, therapeutic outcomes remain insufficiently characterized. While several studies have reported hearing improvement after carotid endarterectomy (CEA) or stenting, these findings are often anecdotal or derived from small cohorts [35]. Randomized controlled trials are needed to determine whether revascularization directly improves hearing outcomes and to what extent intervention timing affects prognosis [36].

Finally, the genetic and molecular basis of ischemic vulnerability in the auditory system remains an open question. Identification of molecular markers of cochlear ischemia could lead to targeted therapies, such as neuroprotective agents or microcirculatory enhancers [41].

In summary, advancing the field will require multidisciplinary collaboration between audiologists, neurologists, radiologists, and vascular specialists. Establishing unified protocols for diagnosis and management could transform outcomes for patients with both cerebrovascular and auditory pathologies.

Conclusion

Carotid artery stenosis (CAS) is a significant but often underrecognized contributor to sensorineural hearing loss (SNHL), particularly in older adults and patients with vascular risk factors. Accumulating evidence suggests that ischemic compromise of the cochlea and central auditory pathways can manifest as unilateral or bilateral auditory dysfunction, including sudden hearing loss, tinnitus, and delayed auditory brainstem responses [17,2].

While audiological tools such as otoacoustic emissions (OAEs) and auditory brainstem responses (ABRs) offer non-invasive means for early detection, their integration into routine vascular screening remains limited. Simultaneously, neuroimaging modalities—including carotid duplex ultrasonography, CTA, and perfusion MRI—enhance our ability to detect both macro- and microvascular pathologies relevant to hearing [3,5].

Treatment approaches such as carotid endarterectomy (CEA) and carotid artery stenting (CAS) not only reduce the risk of stroke but may also offer secondary benefits to auditory function. However, data remain limited and inconsistent, particularly regarding the timing and extent of hearing recovery after revascularization [6,7]. A better understanding of these outcomes may support the inclusion of audiological assessments in the pre- and post-operative workup for CAS.

Moving forward, interdisciplinary collaboration between otolaryngologists, neurologists, and vascular specialists is essential. Future research should prioritize randomized trials, the development of standardized screening protocols, and

investigation into the molecular mechanisms underlying cochlear ischemia [8,9]. Addressing these gaps will help optimize both neurological and audiological outcomes for patients with CAS.

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