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REVIEW

Vestibular schwannoma inducing unilateral tinnitus and auditory impairment: A literature review

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ABSTRACT

Background: Vestibular schwannoma (VS) is a noncancerous tumor of the vestibulocochlear nerve that usually causes ringing in the ears and hearing loss in one ear. Modern clinical challenges extend beyond mere tumor eradication to encompass the early identification of retrocochlear disease, safeguarding functional hearing, managing tinnitus-related disorders, and choosing treatment approaches that maintain facial nerve function and enhance quality of life.
Methods: This literature review integrates the most recent evidence regarding epidemiology, clinical presentation, diagnostic assessment, natural history, observation, stereotactic radiotherapy, microsurgery, tinnitus outcomes, and auditory rehabilitation.
Results: Recent guidelines, cohort studies, systematic reviews, and meta-analyses all point to MRI of the internal auditory canal as the best way to diagnose asymmetric hearing loss or suspicious unilateral audiovestibular symptoms. Small tumors that don't affect hearing are often good candidates for active surveillance, but hearing can get worse even when the tumor isn't growing much on imaging. Radiosurgery offers lasting tumor control for specific small to medium-sized tumors, although long-term preservation of hearing diminishes over time. Microsurgery is still important for big tumors, brainstem compression, radiosurgery failure, or certain patient needs. However, keeping hearing is very dependent on the patient's hearing before the surgery, the size of the tumor, the approach used, and the monitoring done during the surgery. Tinnitus is prevalent, clinically significant, and not entirely predictable by tumor size or treatment approach.
Conclusion: The literature endorses a personalized, multidisciplinary methodology that incorporates audiometry, MRI-based surveillance, patient-reported outcomes, and collaborative decision-making.

Keywords: vestibular schwannoma, acoustic neuroma, tinnitus, one-sided hearing loss, sensorineural hearing loss, magnetic resonance imaging, radiotherapy, microsurgery, hearing preservation

Introduction

Vestibular schwannomas are non-malignant, generally indolent neoplasms arising from Schwann cells in the vestibular segment of cranial nerve VIII and represent the predominant tumor type in the cerebellopontine angle among adults.[1] Modern epidemiological studies have contested the conventional belief that vestibular schwannomas are exceedingly rare, revealing global incidence estimates that surpass historical data of roughly 1 case per 100,000 person-years.[2] A national study in Denmark also shows that more access to MRI and more clinical awareness have moved the diagnosis toward older patients and smaller tumors.[3]

Asymmetric or unilateral sensorineural hearing loss is the most common clinical sign. It is often accompanied by tinnitus and, in some cases, imbalance or vertigo.[4] This condition is still very important for otolaryngologists, neurologists, neurosurgeons, radiologists, audiologists, and primary care doctors because

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the early signs are similar to those of other otologic disorders that happen more often.[5] A delayed diagnosis can limit options for hearing-preserving strategies, despite the intricate relationship between symptom duration, tumor size, and functional outcome.[6]

The approach to treating VS has changed from one that focuses on surgery to one that protects function. Present choices encompass observation, microsurgical resection, stereotactic radiotherapy, fractionated radiotherapy, and auditory rehabilitation, with selection contingent upon tumor dimensions, growth rate, initial auditory function, patient age, comorbid conditions, facial nerve risk, and patient preference. The main goal of this review is to summarize the current evidence about VS that causes tinnitus and hearing loss in one ear. It will focus on how to diagnose the condition, compare treatment outcomes, and talk about the practical effects of publishing literature reviews.

Method

This article is set up as a narrative literature review. It concentrates on peer-reviewed journal articles released between 2018 and 2026, emphasizing publications from Scopus-indexed medical journals, and encompasses selected high-impact clinical guidelines, cohort studies, systematic reviews, and meta-analyses. The main search terms are "vestibular schwannoma," "acoustic neuroma," "tinnitus," "unilateral hearing loss," "asymmetric sensorineural hearing loss," "MRI," "observation," "wait and see," "stereotactic radiosurgery," "microsurgery," "hearing preservation," and "quality of life."

Studies were included if they directly examined clinical presentation, audiological screening, MRI diagnosis, natural history, tumor growth, hearing outcomes, tinnitus outcomes, comparative treatment effectiveness, or quality of life in adults with sporadic vestibular schwannoma. Articles that only talked about pediatric tumors, non-vestibular schwannomas, or full-text articles that were not in English were not given priority.

Epidemiology and Clinical Presentation

VS usually starts with hearing loss in one ear before it becomes a clear neurological disease. In a recent registry-based cohort, around 90% of patients presented with unilateral hearing loss, approximately 60% reported tinnitus, and a small yet clinically significant percentage exhibited balance disorders.[4] This pattern elucidates the reason the initial clinical encounter frequently transpires in an audiology or otolaryngology clinic rather than a neurosurgical unit.[7]

In VS, hearing loss in one ear is usually sensorineural and can get worse over time, change, or even happen suddenly. Recent studies on hearing loss in sporadic vestibular schwannomas stress that hearing loss can happen even with small tumors. This means that tumor diameter alone can't be used to tell if someone can hear.[6] A systematic review of how hearing works found that tumor growth patterns, cochlear dysfunction, vascular disruption, and biochemical injury may all work together to cause hearing loss.[8]

Tinnitus is not a minor concomitant symptom; it frequently serves as a significant catalyst for distress, sleep disruption, concentration difficulties, and diminished disease-specific quality of life. A systematic review juxtaposing microsuggestion and Gamma Knife radiotherapy indicated that tinnitus prevalence was significant prior to treatment, and that postoperative enhancement exhibited variability among studies.[9] A later systematic review found that the evidence comparing tinnitus outcomes after microsurgery and stereotactic radiotherapy was not very good in terms of how it was done. Nonetheless, certain studies indicated a tendency for microsuggestion to be more efficacious in enhancing tinnitus.[10]

The biological etiology of hearing loss and tinnitus is presumably multifactorial. Biomarker-based studies have found links between inflammatory mediators, tumor secretions, markers of cochlear injury, and genetic pathways with hearing loss associated with VS.[11] Recent mechanistic studies have underscored the significance of Schwann cell biology and interactions within the neural microenvironment in auditory dysfunction.[12] These numbers help us understand why some people with small tumors in their brains have very bad symptoms, while others with bigger tumors can still hear well.[13]

Diagnostic Evaluation

The diagnostic process commences with a meticulous medical history, otoscopic examination, cranial nerve assessment, pure-tone audiometry, speech discrimination evaluation, and analysis of vestibular symptoms. Even though pure-tone audiometry protocols are still a good way to screen for hearing loss, they can't take the place of MRI when there is a strong clinical suspicion.[14] Current guidelines advocate for MRI

when asymmetric sensorineural hearing loss reaches defined audiometric criteria, especially in the presence of unilateral tinnitus or imbalance.[7]

A gadolinium-enhanced T1-weighted sequence MRI of the internal auditory canal and cerebellopontine angle is the best way to find VS and tell it apart from meningiomas, epidermoid cysts, facial nerve schwannomas, vascular lesions, or inflammatory diseases.[15] CNS imaging guidelines stress the use of MRI for diagnosis, initial tumor measurements, treatment planning, and post-treatment monitoring.[16] A recent systematic review of MRI evaluation showed that VS studies need to have more standardized ways of getting, measuring, and defining growth.[17]

The diagnostic efficacy of MRI is significantly influenced by the clinical context. A meta-analysis revealed a markedly low combined detection rate for vestibular schwannoma (VS) in patients exhibiting unilateral tinnitus without asymmetric hearing loss. This indicates that isolated unilateral tinnitus necessitates more refined imaging strategies compared to unilateral tinnitus accompanied by audiometric asymmetry.[18] On the other hand, asymmetric sensorineural hearing loss is still the most commonly used MRI trigger because it shows typical cases without going too far in low-risk cases.[5]

Once VS is diagnosed, the initial assessment must record tumor location, intrameatal and extrameatal dimensions, Koos grade, assistive hearing category, facial nerve functionality, vestibular impairment, tinnitus intensity, and patient-reported quality of life. Present EANO guidelines regard MRI diagnosis, multidisciplinary evaluation, and personalized management as essential elements of care.[19]

Natural History and Active Surveillance

The natural progression of untreated VS is variable. Some tumors grow steadily, some stay the same size for years, and a small number of them go away on their own. So, not every small lesion that is newly diagnosed needs to be treated right away.[19] A predictive modeling study indicates that risk-stratified surveillance may diminish unnecessary imaging while maintaining the safety of patients at elevated risk of growth.[20]

The deterioration of hearing during observation cannot be attributed solely to tumor growth. In a cohort study investigating tumor volume and auditory function, a larger initial tumor volume was associated with inferior pure-tone average and word recognition scores at baseline. However, the relationship between tumor growth and subsequent irreversible hearing loss diminished after controlling for baseline hearing levels.[21] Another study that looked at volumetric growth rate found that faster growth and bigger tumors were linked to hearing loss. This supports the idea that volumetric assessment is useful when it is possible.[22]

A systematic review of growth determinants in untreated vestibular schwannomas found that initial tumor size, location, and some symptoms can help predict growth risk, but the predictions are not always right.[23] This is an important finding for doctors because patients often think that "wait and see" means doing nothing. Active surveillance, on the other hand, is a structured management strategy that calls for regular MRIs, repeat audiometry, and timely discussions of treatment thresholds.[20]

Management Strategies

The CNS executive summary also talks about adult VS management in terms of observation, resection, stereotactic radiosurgery, and radiotherapy instead of a single path.[24] Observation is typically indicated for small tumors, elderly or medically compromised patients, incidental tumors, and patients exhibiting stable symptoms who prioritize minimizing treatment-related morbidity. A recent network meta-analysis determined that observation continues to be a viable initial strategy in specific unilateral vestibular schwannomas, particularly when the baseline functional status is favorable and there is no evidence of radiographic progression.[25] Systematic evidence comparing watchful waiting and scanning with radiosurgery for small to medium-sized tumors indicates that observation can yield advantageous hearing outcomes and quality of life in suitably selected patients.[26]

Stereotactic radiosurgery is a common choice for small to medium-sized VSs to control a tumor without open surgery. CNS radiosurgery guidelines endorse radiosurgery as a therapeutic option for specific adults, especially when tumor dimensions and anatomical considerations yield an acceptable risk profile.[27] A systematic review of long-term hearing outcomes post-radiosurgery indicated that hearing preservation is attainable in numerous patients; however, it deteriorates with prolonged follow-up, necessitating long-term counseling.[28] Observational data indicate that hearing outcomes post-radiotherapy and observation are significantly affected by baseline hearing and tumor characteristics.[29]

Table 1. A summary of the comparison of recent studies on vestibular schwannoma presenting as tinnitus and unilateral hearing loss

Research	Design / Population	Focus	Most important results	Consequences of this review
Fernández-Méndez et al. (2023)[4]	Registry group; newly diagnosed VS	Presentation	Unilateral hearing loss and tinnitus are the predominant primary symptoms; balance disorders frequently occur as well.	Advocates for prompt MRI evaluation in cases of unilateral hearing loss associated with tinnitus.
Javed et al. (2023)[18]	Systematic review/meta-analysis; unilateral tinnitus absent asymmetric hearing loss	Results of the MRI test	In cases where there was only tinnitus, the combined VS detection rate was very low.	Imaging choices need to be able to tell the difference between tinnitus by itself and tinnitus with audiometric asymmetry.
Conley and Diaz (2020)[5]	A narrative review of imaging prompts	SNHL that is not the same on both sides	Audiometry protocols differ, yet MRI continues to be the principal instrument when asymmetry indicates retrocochlear pathology.	Helpful for deciding who to see in an outpatient setting and who to refer.
Gan et al. (2021)[8]	A systematic review	How hearing loss happens	Hearing loss probably has to do with how tumors grow, problems with the cochlea, problems with blood vessels, and damage to molecules.	Explains why the symptoms might not be in line with the size of the tumor.
Brooks and Vivas (2023)[6]	Review of clinical	The natural history of hearing	Even small tumors and during the observation period, hearing loss can happen.	Counseling should not assume that radiographic stability means hearing stability.
Patel et al. (2020)[21]	Cohort from the past	Volume of the tumor and hearing	Larger baseline volumes are linked to worse baseline hearing, and baseline hearing has a big effect on hearing that can't be changed later.	Baseline audiometry is very important for making predictions.
Gurewitz et al. (2022)[22]	Group without treatment and volumetric assessment	Hearing and growth levels	Hearing loss is linked to volumetric growth and initial size.	When possible, it helps to keep an eye on the volume.
Hentschel et al. (2021)[20]	Model for predicting cohorts	Planning to wait and scan	Predictive modeling can find patients who need more attention.	Risk-stratified surveillance can decrease superfluous imaging examinations.
Goldbrunner et al. (2020)[19]	EANO Rules	Management in general	The choice between observation, surgery, radiotherapy, and radiosurgery should be based on the size of the tumor, the patient's symptoms, how the tumor is growing, and other factors.	Main structure for managing multiple disciplines.
Carlson et al. (2018)[1]	CNS systematic review and guidelines	Protection for your ears	Enhanced fundamental word recognition skills and pure tone thresholds indicate sufficient hearing preservation.	Hearing screening is an important part of counseling for treatment.
Balossier et al. (2023)[28]	Meta-analysis/systematic review	Hearing results after surgical radiotherapy	It is possible to keep your hearing after radiation therapy for a long time, but it gets worse over time.	Patients require enduring auditory optimism, rather than merely an assessment of tumor management.
Pontillo et al. (2024)[30]	Review and analysis of the system	Surgery to keep hearing	Hearing preservation surgery can be helpful in some cases, but the results are not always the same.	Choosing the right patients and having the right surgical skills are very important.
King et al. (2024)[9]	A systematic review	Tinnitus following microsurgery	Studies show that tinnitus gets better after treatment, but not all of them do.	It is important to measure tinnitus as a separate outcome.

		versus Gamma Knife treatment		
Brito et al. (2024)[26]	A systematic review or meta-analysis	Wait and scan or SRS	For some small to medium-sized tumors, a wait-and-see approach may be better for hearing and PANQOL outcomes.	Observation can be an active first-line approach.
Huo et al. (2024)[25]	Meta-analysis of networks	Observation, microsurgery, and radiation therapy	The results of the comparison depend on the endpoint, so each person still has to make their own choice.	There is no one best way to do things.

SNHL: sensorineural hearing loss; SRS: stands for stereotactic radiotherapy; PANQOL: Penn Acoustic Neuroma Quality of Life Scale; VS: vestibular schwannoma.

In some anatomical or clinical situations, fractionated stereotactic radiotherapy and hypofractionated methods can be used instead. A meta-analysis comparing single-fraction stereotactic radiosurgery with hypofractionated radiosurgery revealed that tumor control and hearing preservation were generally similar across the studies analyzed.[31] A narrative review of radiotherapy underscored that dose planning, cochlear dose, tumor size, pretreatment auditory function, and follow-up duration significantly affect reported functional outcomes.[32]

Microsurgery evaluation is generally preferred for large tumors, brainstem compression, hydrocephalus, cystic changes with mass effect, or progressive neurologic deficits. CNS surgery guidelines say that the goals of surgery should be to balance the amount of resection with the function of the facial nerve, the preservation of hearing, and the long-term control of the tumor.[33] Intraoperative facial nerve monitoring is advised to improve functional safety, and eighth nerve monitoring is suggested when attempting to preserve hearing in suitably small tumors.[34]

Hearing-preserving microsurgery may be pursued in specific patients, generally those with diminutive tumors and satisfactory preoperative auditory function. A systematic review and meta-analysis indicated that hearing-preserving surgery is applicable in meticulously selected patients, yet produces inconsistent hearing outcomes depending on the surgical approach and tumor type.[30] It is harder to do salvage microsurgery after primary radiotherapy has failed than it is to do primary surgery. In a multicenter cohort, it has been linked to reduced total resection rates and increased long-term incidences of facial paresis.[2] CNS hearing preservation guidelines indicate that effective pretreatment word recognition and pure tone thresholds are the most reliable indicators of viable hearing preservation.[35]

Radiographic control alone should not be used to make treatment decisions; patient-reported outcomes should also be considered. According to prospective disease-specific quality-of-life data, observation, radiosurgery, and microsurgery all have different short-term effects on quality of life and recovery.[36] Longitudinal quality-of-life studies indicate that aspects of hearing, balance, facial function, anxiety, and energy may evolve variably over time, necessitating customized counseling instead of a singular "best" treatment approach.[37]

Hearing Rehabilitation and Tinnitus-Oriented Care

The management of unilateral hearing loss extends beyond tumor surveillance or directed treatment. Patients who can't hear may benefit from contralateral device signal redirection, bone-conduction systems, cochlear implantation in some cases, communication counseling, and support for tinnitus. Auditory rehabilitation a key part of modern VS care, especially since many patients live for decades with hearing loss.[1]

Tinnitus treatment should be seen as symptom management, not as a sure sign that the tumor is under control. Recent reviews suggest that tinnitus may ameliorate, remain stable, or reemerge following microsurgery or radiosurgery, necessitating that pretreatment counseling explicitly confront this ambiguity.[9] Tumor size and hearing threshold do not fully predict tinnitus severity, making validated tinnitus questionnaires and shared decision-making particularly useful in clinical settings where tinnitus is the primary complaint.[10]

New treatments are still only available for sporadic VS. The CNS guidelines for new treatments say that bevacizumab is a good treatment for some cases of neurofibromatosis type 2, but they don't say that it should be used regularly for sporadic tumors.[38] The EANO guidelines assert that pharmacotherapy lacks a

defined role in sporadic vestibular schwannomas, except within particular hereditary frameworks and clinical research environments.[19]

Discussion

The literature shows that there is always a conflict between controlling tumors and keeping their function. Imaging can find tumors that are very small, but finding them early doesn't always mean that treatment is needed right away. This is because the way hearing loss, tinnitus, and future tumor growth happen is different.[20] This uncertainty is especially significant for patients whose main issue is tinnitus, as tumor treatment does not always eradicate tinnitus and may lead to new auditory or vestibular complications.[9]

For patients with unilateral hearing loss, evidence supports the exclusion of retrocochlear pathology via MRI when audiometric asymmetry is present. The low MRI yield for isolated unilateral tinnitus without hearing asymmetry indicates that diagnostic algorithms should distinguish between tinnitus-only presentations and those with tinnitus accompanied by asymmetric hearing loss.[18] This distinction is significant for healthcare systems as extensive MRI screening elevates the occurrence of incidental findings, necessitates follow-up imaging, induces patient anxiety, and escalates costs.[5]

If chosen correctly, observation is not a lower-quality treatment option. The ideal candidates are patients exhibiting small tumors, intact facial nerve function, manageable symptoms, advanced age, comorbidities, or a preference to defer immediate intervention.[26] However, observation necessitates a clear dialogue regarding the potential decline in hearing, which can occur even in the absence of substantial tumor growth. Additionally, the option of delayed intervention may need to be reassessed if there are changes in tumor growth, hearing progression, or patient priorities.[21]

For many small to medium-sized tumors, radiosurgery is a middle ground between watching and doing open surgery. It is appealing because it can be done as an outpatient procedure and has high tumor control rates. However, it is important to make it clear during counseling that radiosurgery can cause long-term hearing loss.[28] Radiosurgery for large tumors is more contentious, and global practice guidelines advocate for meticulous selection due to mass effect, trigeminal symptoms, hydrocephalus, and the intricacy of future salvage, which modify the risk-benefit ratio.[39]

Microsurgery continues to be essential despite progress in conservative and radiosurgical techniques. Microsurgery offers decompression, tissue diagnosis when required, and definitive tumor excision in specific patients; however, it entails approach-dependent risks for auditory function, facial nerve integrity, cerebrospinal fluid leakage, vestibular compensation, and recovery duration.[33] Modern surgical philosophy increasingly emphasizes the preservation of function, encompassing subtotal or near-total resection succeeded by monitoring or supplementary radiosurgery, particularly when this approach safeguards the facial nerve.[2]

There are still problems with the evidence that is available. Many studies look back in time, treatment groups are affected by selection bias, follow-up times are not the same, and outcome measures differ between hearing scales, tinnitus measurements, tumor volume definitions, and quality-of-life instruments.[17] Future studies ought to standardize MRI measurements, document tinnitus severity both at baseline and longitudinally, stratify by preserved hearing, and incorporate patient-reported outcome measures as primary endpoints instead of secondary descriptors.[35]

Conclusion

Vestibular schwannoma manifesting with tinnitus and unilateral hearing loss is optimally characterized as a functional neuro-otologic disorder rather than merely a benign tumor at the base of the skull. MRI confirms the diagnosis, but treatment is based on audiometry, tinnitus assessment, vestibular evaluation, tumor measurements, and the patient's goals. For many small or stable tumors, watching them is the best option. For some patients, radiotherapy can effectively control the tumor. For large, progressive, compressive disease or tumors that don't respond to radiotherapy, microsurgery is still necessary. A single treatment cannot guarantee hearing preservation or improvement in tinnitus. Consequently, the most effective modern methodology is multidisciplinary, evidence-driven, and transparently communicated to the patient.

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