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Original Article

Temporal Bone Magnetic Resonance Imaging in Sudden Sensorineural Hearing Loss: Low Frequency Versus Other Types

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BACKGROUND: Gadolinium-enhanced magnetic resonance imaging (MRI) is the gold standard for diagnosing vestibular schwannoma (VS). This study aimed to compare the incidence of VS among patients with low-frequency, high-frequency, and flat-type sudden sensorineural hearing loss (SSNHL) and to assess the effectiveness of MRI for each SSNHL type.

METHODS: We analyzed 755 patients diagnosed with SSNHL at a single tertiary center between January 2014 and March 2020. All underwent temporal bone MRI. Logistic regression was used to determine the associations of SSNHL types with VS. Additionally, we conducted a correlation analysis to examine the relationship between word recognition scores (WRS) and the size of tumors measured on MRI at the time of diagnosis.

RESULTS: Magnetic resonance imaging identified VS in 23 of 755 cases (3.0%). Of the patients, 123 (16.3%) had low-frequency SSNHL; none of these patients had VS. The incidence of VS differed significantly between the low-frequency SSNHL group and other SSNHL types ($P < .001$). A significant negative correlation was found between initial tumor size and WRS ($r^2 = 0.2905$, $P = .008$).

CONCLUSION: The prevalence of VS was rare in patients with low-frequency SSNHL. The pattern of hearing loss may provide insights into the likelihood of tumor presence, thereby aiding in more effective audiometric screening and decision-making regarding MRI for detecting VS.

KEYWORDS: Sudden hearing loss, vestibular schwannoma, low-frequency, magnetic resonance imaging

INTRODUCTION

Sudden sensorineural hearing loss (SSNHL) is defined as a sudden loss of hearing in 3 or more contiguous frequencies, with a decrease in hearing of more than 30 dB, occurring within a period of 3 days.[1] The various etiologies leading to SSNHL include viral, vascular, immunologic, thrombotic, and traumatic causes, as well as retrocochlear lesions.[2] Vestibular schwannoma (VS) is the most common retrocochlear cause of SSNHL.[3] Vestibular schwannoma typically presents with sudden or progressive hearing loss, unilateral tinnitus, and imbalance, and is often characterized by progressive high-frequency hearing loss with poor speech discrimination.[4,5] However, approximately 15% of patients have normal hearing.[6] As no single symptom can definitely confirm VS, auditory brainstem response (ABR) has traditionally been used as a diagnostic tool. Recently, however, gadolinium-enhanced magnetic resonance imaging (MRI) has been recognized as the gold standard for diagnosing VS.

Vestibular schwannoma has been reported as the cause of SSNHL in 1% of patients.[7] However, a study in South Korea by Lee et al[8] observed VS in 4% of patients with SSNHL, a difference that was attributed to the widespread use of MRI. In South Korea, national health insurance covers MRI for SSNHL patients with moderate to severe hearing loss, allowing them to pay approximately US $200 for an MRI, making it a cost-effective modality.

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Sudden sensorineural hearing loss can be classified according to the affected hearing frequency. Various efforts have been made to define and differentiate low-frequency SSNHL. In Japanese regional surveys, the estimated incidence of low-frequency SSNHL is 40-60 cases per 100 000 people.[9] Low-frequency SSNHL has a better prognosis than high-frequency SSNHL.[10] However, low-frequency SSNHL has a higher chance of progression to Meniere's disease.[11,12] Electrocochleography studies have suggested that cochlear endolymphatic hydrops may be the underlying cause of low-frequency SSNHL.[12,13]

Current guidelines for patients with SSNHL recommend MRI to detect retrocochlear lesions such as VS.[14] However, these recommendations are not specified based on the affected hearing frequency. In VS patients, a specific audio pattern has not been clearly established, but low-frequency hearing loss is known to be rare.[15-17] According to a previous study, it has been reported to occur in only 1 out of 139 cases.[18] Therefore, we compared the incidence of VS between low-frequency and other types of SSNHL to determine whether specific MRI indications for patients with SSNHL are feasible.

Some studies suggest a correlation between the initial size of tumors and the severity of hearing loss, while others have reported no association, indicating that this issue remains controversial.[19,20] With the widespread use of MRI, there has been an increase in patients undergoing a "wait-and-scan" approach.[21] Since hearing level plays a crucial role in determining treatment plans for these patients, it is important to clarify the relationship between tumor characteristics and hearing impairment. Therefore, we also investigated how initial tumor size relates to hearing levels and compared the word recognition scores (WRS) between groups with and without VS.

METHODS

The patients diagnosed with SSNHL who underwent a temporal bone MRI at A Asan Medical Center between January 2014 and March 2020 were included. Patients who did not meet the criteria for SSNHL or did not undergo a temporal bone MRI were excluded. Individuals with a history of Meniere's disease, previously diagnosed SSNHL, ear surgery, or conductive hearing loss were excluded from this study. Meniere's disease was diagnosed according to the 2015 Barany diagnostic criteria.[22]

The pure-tone average was calculated as the mean value of air conduction thresholds at 0.5, 1, 2, and 4 kHz. This study defined low-frequency SSNHL as hearing loss where the average of 2 low frequencies (250 and 500 Hz) was at least 10 dB worse than the average of 3 high frequencies (2, 4, and 8 kHz). High-frequency SSNHL was defined as hearing loss where the average of 3 high frequencies (2, 4, and 8 kHz) was at least 10 dB worse than the average of 2 low frequencies (250 and 500 Hz). Patients not meeting the definitions for low-frequency or high-frequency SSNHL were categorized as having flat-type SSNHL. We did not include the hearing level at 125 Hz because it was not routinely tested at our center. We compared low-frequency, high-frequency, and flat-type SSNHL.

Vestibular schwannoma was diagnosed using gadolinium-enhanced MRI, confirmed by radiology specialists. The size of the tumor was measured as the maximum linear dimension.[23] Subsequently, a correlation analysis was conducted to examine the relation between tumor size and WRS. Additionally, we compared speech discrimination between the VS and non-VS groups.

The analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM SPSS Corp.; Armonk, NY, USA). To compare the characteristics among the 3 hearing loss groups, a one-way analysis of variance was conducted. This study received approval from the Ethics Committee of Asan Medical Center (approval number: 2020-0335, date: March 18, 2020) of our center. Informed consent was waived by the IRB because this study was designed as a retrospective chart review, and the analysis used anonymous clinical data.

RESULTS

A total of 755 patients with SSNHL met the inclusion criteria and were included in the study. Sudden sensorineural hearing loss affected the right ear in 337 patients (44.6%) and the left ear in 418 patients (55.4%). The mean pure tone audiometry (PTA) was 58.9 ± 30.5 dB. Among these patients, 123 (16.3%) had low-frequency SSNHL. Vestibular schwannoma was detected on MRI in 23 of the 755 cases (3.0%) (Table 1).

The demographic and clinical characteristics of the patients by SSNHL type are shown in Table 2. In the low-frequency SSNHL group, patients were younger (mean age 48.1 years; $P = .005$) and the proportion of male patients was lower (31.7%; $P = .001$) compared to the other groups. In the low-frequency group, no patients were diagnosed with VS, while in the flat-type and high-frequency groups, 4 (1.5%) and 19 (5.1%) patients were diagnosed with VS, respectively ($P < .001$).

Figure 1 shows the hearing thresholds at each frequency according to the type of hearing loss. In cases of flat-type SSNHL, differences in PTA threshold were observed to be within 10 dB across all frequencies. Except for 1K Hz, there was a significant difference

Table 1. Patient Demographics and Clinical Characteristics

Characteristics		n = 755
Age (range)		51.14 ± 14.91 (5-88)
Sex	Male	351 (46.49%)
	Female	404 (53.51%)
Side	Right	337 (44.64%)
	Left	418 (55.36%)
SSNHL type	Low-frequency type	123 (16.3%)
	Flat type	262 (34.7%)
	High-frequency type	370 (49.0%)

SSNHL, sudden sensorineural hearing loss.

MAIN POINTS

- Temporal bone MRI is considered the gold standard for confirming the presence of retrocochlear lesions in patients with sudden sensorineural hearing loss.
- Given the rarity of confirmed vestibular schwannoma cases in patients with low-frequency sudden sensorineural hearing loss, a conservative approach to MRI may be reasonable.
- The initial size of the acoustic tumor correlated with word recognition scores, indicating a potential impact on hearing ability.

Table 2. Clinical Characteristics Based on Types of Hearing Loss

	Low-Frequency Ttype SSNHL (n = 123)	Flat-Type SSNHL (n = 262)	High-Frequency Type SSNHL (n = 370)	*P*
Age (years)	48.1 ± 13.7	53.2 ± 15.2	50.7 ± 14.9	.005
Male (%)	39 (31.7)	120 (45.8)	192 (51.9)	.001
Left (%)	64 (52.0)	142 (54.2)	212 (57.3)	.534
*VS (%)	0 (0)	4 (1.5)	19 (5.1)	<.001

SSNHL, sudden sensorineural hearing loss; VS, vestibular schwannoma.
*Referring to the number of cases identified in temporal bone MRI findings that suggest vestibular schwannoma.

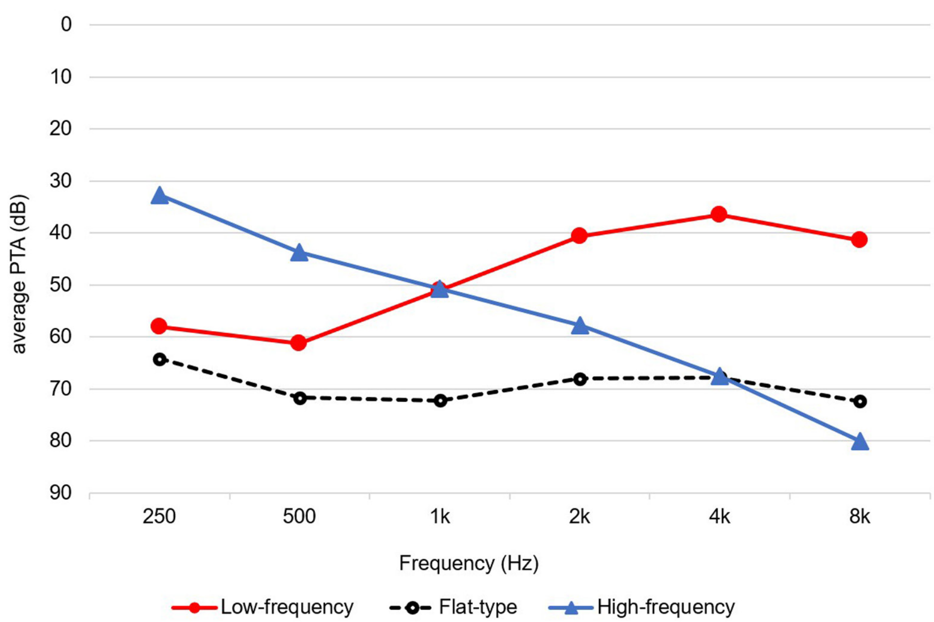

Figure 1. For the flat-type SSNHL, the difference between the best frequency (250 Hz) and the worst frequency (8K) was 8.2 dB (black dashed line). Except for 1K Hz, there was a significant difference in hearing thresholds between low-frequency type SSNHL (red line) and high-frequency type SSNHL (blue line) ($P < .05$).

in hearing thresholds between low-frequency SSNHL and high-frequency SSNHL ($P < 0.05$).

We analyzed the clinical characteristics of VS within each subgroup (Table 3). No significant differences in gender or tumor side were observed between the 2 groups ($P = .604$, $P = .222$). The average VS sizes were 19.5 ± 10.8 and 14.3 ± 9.2 mm in each group, with no statistically significant difference ($P = .328$).

Spearman correlation analysis showed a statistically significant correlation between the initial VS size and WRS ($r^2 = 0.2905$, $P = .008$) (Figure 2). This suggests that as the tumor size increases, there is a likelihood of a decline in WRS.

We analyzed the correlation between PTA averages and WRS by separating patients into VS and non-VS groups (Figure 3). Both groups showed a statistically significant negative correlation (VS group: $\beta = -1.293$, $P = .0003$; non-VS group: $\beta = -1.364$, $P < .0001$) with nearly identical slopes.

Changes in VS size and hearing over time were analyzed in 21 patients, excluding the 2 patients who were lost to follow-up. Of

Table 3. Clinical Characteristics of VS Based on Types of Hearing Loss

	VS in Flat-Type SSNHL (n = 4)	VS in High-Frequency Type SSNHL (n = 19)	*P*
Male (%)	3 (75)	10 (52.6)	.604
Tumor side (left, %)	2 (50)	11 (57.9)	.222
Tumor size (mm)	19.5 ± 10.8	14.3 ± 9.2	.328

SSNHL, sudden sensorineural hearing loss; VS, vestibular schwannoma.

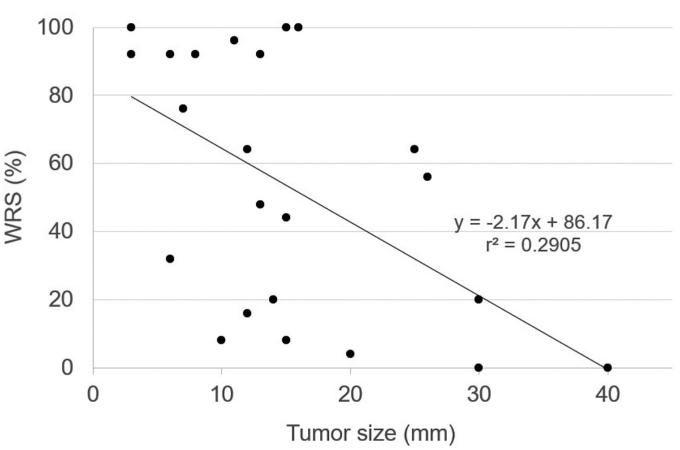

Figure 2. Upon analyzing the initial MRI at the time of diagnosis, a negative correlation was observed between the diameter of the tumor and the word recognition score (WRS). This suggests that as the tumor size increases, there is a tendency for WRS to deteriorate ($r^2 = 0.2905$, $P = .008$).

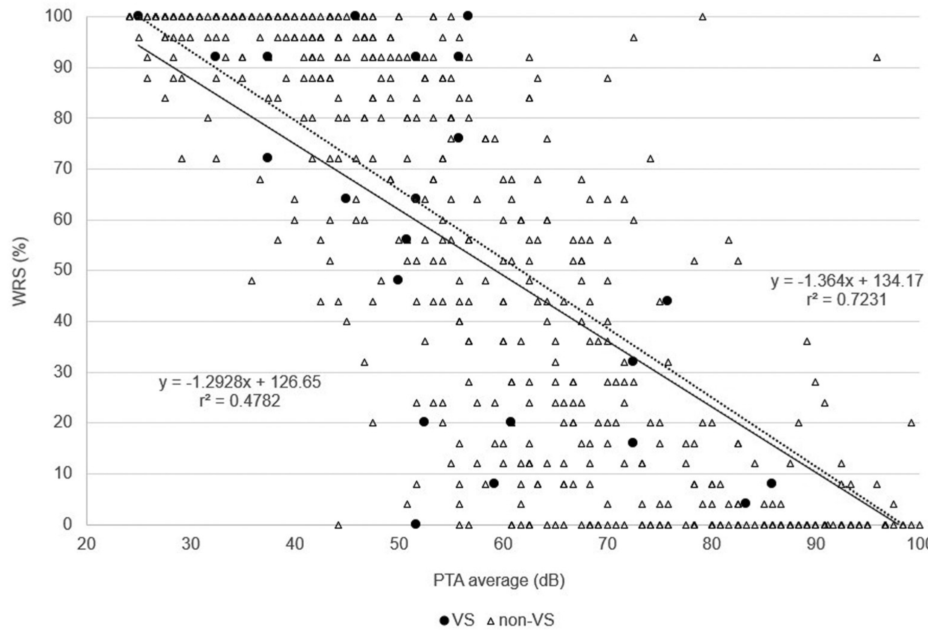

Figure 3. Scatter plot showing the relationship between pure tone audiometry (PTA) average and word recognition score (WRS) for patients with and without vestibular schwannoma (VS) (VS: black circles; non-VS: open triangles). The dotted and solid lines represent the linear regression models for non-VS and VS groups, respectively. Pure tone audiometry and WRS showed a negative correlation in both groups (VS: $r^2 = 0.4782$, $P = .0003$; non-VS: $r^2 = 0.7231$, $P < .0001$).

these patients, 2 (9.5%) with tumor sizes of 30 mm or larger at the time of initial diagnosis underwent surgical resection. A total of 4 patients (19%) received Gamma Knife Radiosurgery (GKRS) as initial treatment. Out of the 15 patients (71.4%) who were managed with a watch-and-scan approach without any therapeutic intervention, tumor growth was identified in 3 patients, leading to the implementation of GKRS. Among the remaining 12 patients with no changes in VS size during the mean follow-up of 59.41 ± 28.0 months, 6 (50%) showed no interval change in WRS, 2 (16.7%) improved, and 4 (33.3%) worsened. These results suggest that changes in tumor size do not directly lead to worsening of hearing.

DISCUSSION

Magnetic resonance imaging is considered the optimal approach to determine the presence of VS in patients with SSNHL.[14] Given the low prevalence and detection rate of approximately 1%-4%, ongoing research aims to improve the efficiency of MRI by predicting the presence of an accompanying tumor based on hearing results.[24,25] In our study, VS was found in 3% of 755 patients with SSNHL, and no cases of low-frequency type SSNHL were observed among these patients, consistent with previous reports. This result further suggests that the likelihood of VS is very low in cases of hearing loss restricted to low frequencies.

Several methods are used to define low-frequency SSNHL. First, it is defined in patients with an average hearing level at 125, 250, and 500 Hz that is at least 10 dB worse than that at 2, 4, and 8 kHz, with a difference between the hearing level at 1 kHz and both adjacent frequencies (500 Hz and 2 kHz) of less than 10 dB.[26] Second, it can be defined as an average hearing level at 125, 250, and 500 Hz of ≥30 dB and an average hearing level at 2, 4, and 8 kHz of ≤20 dB.[27] In this study, we defined the low-frequency hearing loss type by comparing the averages of 250 Hz and 500 Hz with the averages of 2 kHz, 4 kHz, and 8 kHz, while modifying the criteria presented by the former study.

There is still controversy over the mechanism of hearing loss in patients with VS. Research aimed at elucidating the mechanism of hearing loss associated with tumors suggests various hypotheses, including not only the compression effect of the tumor but also changes in the growth rate of the tumor, alteration in the chemical composition of endolymph, and factors secreted from the tumor.[19,28,29] According to our results, there was a negative correlation between initial tumor size and WRS. Several studies have reported no relationship between speech discrimination and tumor size,[30-32] whereas other research indicates that such a relationship does exist.[15,33,34] During the approximately 5-year follow-up period, half of the patients who showed no change in tumor size also showed no change in hearing, but about one-third experienced worsening of hearing. This suggests that while a correlation between tumor size and hearing might be expected, tumor size alone, which is thought to cause a compression effect, is not the sole determinant of hearing, indicating the presence of other influencing factors.

Endolymphatic hydrops, caused by changes in the metabolism of inner ear lymph fluid, is another proposed potential mechanism.[18] According to Inoue et al[15], since about 20% of VS patients showed rapid recovery of hearing loss within a week, it suggests that metabolic changes like endolymphatic hydrops might not be the cause. It has also been suggested that in VS, low frequencies tend to be preserved. Similarly, in our study, cases with low-frequency hearing loss were not observed, making it less likely that this mechanism is responsible.

This study aimed to investigate the diagnostic value of MRI under very restrictive conditions. We targeted patients diagnosed with SSNHL for the first time, limited to low frequencies. Since earlier identification of VS leads to more treatment options and increases the chances of preserving hearing and facial nerve function, it is recommended to perform an MRI without delay in cases where an SSNHL patient presents with recurrent hearing loss, experiences instability, or has other accompanying neurological symptoms including paresthesia. Therefore, when evaluating all SSNHL patients, a comprehensive hearing assessment—including stapedial reflexes—should be conducted and interpreted in the context of the patient's other symptoms and medical history.

While the availability of MRI is increasing, its widespread application is still hindered by cost and accessibility issues. To improve the cost-effectiveness of performing MRI, more than 10 audiometric protocols have been proposed for screening VS.[35-38] The sensitivity and specificity of these protocols have been reported at widely varying levels.[24,25] However, the commonality among these methods is that they are based on specific frequencies and dB levels in PTA. None of these protocols specifically address low frequencies; it is anticipated that including such criteria could enhance the effectiveness of tumor prediction.

A recent study reported that the WRS distribution in the VS group was similar to that in the control group.[39] Our study also found that the relationship between the PTA average and WRS was similar in both the VS and non-VS groups. Therefore, predicting tumors based on speech discrimination is likely to be limited.

This study has some limitations. First, the number of patients with low-frequency SSNHL was relatively small compared to the number of patients with flat-type or high-frequency SSNHL. Further research involving a larger number of cases with low-frequency SSNHL is needed. Second, more patients were included in the low-frequency group when low-frequency SSNHL was defined as hearing loss where the average from 250 and 500 Hz was at least 10 dB worse than the average from 2, 4, and 8 kHz, compared to when it was defined by the methods of Fushiki or Im.[26,27] Even if more patients are included, there is no standard definition of low-frequency SSNHL. Our definition has advantages in that it is simpler and more intuitive than others.

CONCLUSION

In conclusion, in our study, none of the patients with low-frequency SSNHL were diagnosed with VS. The incidence of VS differed significantly between low-frequency and flat-type or high-frequency hearing loss. Our results suggest that it is possible to predict the likelihood of an accompanying tumor based on the pattern of hearing loss. We hope these findings will help improve the current audiometric screening protocols for VS. Ultimately, they will serve as valuable clinical diagnostic cues and aid in the decision to proceed with MRI. Additionally, tumor size may not be the only factor influencing hearing impairment, and it seems challenging to predict the presence of a tumor based solely on speech discrimination. Continuous extensive research is necessary to uncover the mechanisms of hearing loss in patients with VS.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Asan Medical Center (approval number: 2020-0335, date: March 18, 2020).

Informed Consent: Informed consent was waived by the ethical committee because this study was designed as a retrospective chart review, and the analysis used anonymous clinical data.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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REFERENCES

1. Wilson WR. Why treat sudden hearing loss. *Am J Otol*. 1984;5(6):481-483.
2. Schreiber BE, Agrup C, Haskard DO, Luxon LM. Sudden sensorineural hearing loss. *Lancet*. 2010;375(9721):1203-1211. [CrossRef]
3. Jackler RK, De La Cruz A. The large vestibular aqueduct syndrome. *Laryngoscope*. 1989;99(12):1238-1243. [CrossRef]
4. Ogawa K, Kanzaki J, Ogawa S, Tsuchihashi N, Inoue Y. Acoustic neuromas presenting as sudden hearing loss. *Acta Otolaryngol Suppl*. 1991;111(suppl487):138-143. [CrossRef]
5. Johnson EW. Auditory test results in 500 cases of acoustic neuroma. *Arch Otolaryngol*. 1977;103(3):152-158. [CrossRef]
6. Beck HJ, Beatty CW, Harner SG, Ilstrup DM. Acoustic neuromas with normal pure tone hearing levels. *Otolaryngol Head Neck Surg*. 1986;94(1):96-103. [CrossRef]
7. Shaia FT, Sheehy JL. Sudden sensori-neural hearing impairment: a report of 1,220 cases. *Laryngoscope*. 1976;86(3):389-398. [CrossRef]
8. Lee JD, Lee BD, Hwang SC. Vestibular schwannoma in patients with sudden sensorineural hearing loss. *Skull Base*. 2011:21(2):75-78.
9. Fushiki H, Junicho M, Aso S, Watanabe Y. Recurrence rate of idiopathic sudden low-tone sensorineural hearing loss without vertigo: a long-term follow-up study. *Otol Neurotol*. 2009;30(3):295-298. [CrossRef]
10. Jung AR, Kim MG, Kim SS, Kim SH, Yeo SG. Clinical characteristics and prognosis of low frequency sensorineural hearing loss without vertigo. *Acta Otolaryngol*. 2016;136(2):159-163. [CrossRef]
11. Imamura S, Nozawa I, Imamura M, Murakami Y. Clinical observations on acute low-tone sensorineural hearing loss: survey and analysis of 137 patients. *Ann Otol Rhinol Laryngol*. 1997;106(9):746-750. [CrossRef]
12. Yamasoba T, Kikuchi S, Sugasawa M, Yagi M, Harada T. Acute low-tone sensorineural hearing loss without vertigo. *Arch Otolaryngol Head Neck Surg*. 1994;120(5):532-535. [CrossRef]
13. Noguchi Y, Nishida H, Tokano H, Kawashima Y, Kitamura K. Comparison of acute low-tone sensorineural hearing loss versus Meniere's disease by electrocochleography. *Ann Otol Rhinol Laryngol*. 2004;113(3 Pt 1):194-199. [CrossRef]
14. Chandrasekhar SS, Tsai Do BS, Schwartz SR, et al. Clinical practice guideline: sudden hearing loss (update). *Otolaryngol Head Neck Surg*. 2019;161(1_suppl):S1-S45. [CrossRef]
15. Inoue Y, Kanzaki J, Ogawa K. Vestibular schwannoma presenting as sudden deafness. *J Laryngol Otol*. 2000;114(8):589-592. [CrossRef]
16. Harner SG, Fabry DA, Beatty CW. Audiometric findings in patients with acoustic neuroma. *Am J Otol*. 2000;21(3):405-411. [CrossRef]
17. Ho SY, Kveton JF. Acoustic neuroma. Assessment and management. *Otolaryngol Clin North Am*. 2002;35(2):393-404, viii. [CrossRef]
18. Sauvaget E, Kici S, Kania R, Herman P, Tran Ba Huy P. Sudden sensorineural hearing loss as a revealing symptom of vestibular schwannoma. *Acta Otolaryngol*. 2005;125(6):592-595. [CrossRef]

19. Patel NS, Huang AE, Dowling EM, et al. The influence of vestibular schwannoma tumor volume and growth on hearing loss. *Otolaryngol Head Neck Surg*. 2020;162(4):530-537. [CrossRef]
20. Gan J, Zhang Y, Wu J, et al. Current understanding of hearing loss in sporadic vestibular schwannomas: a systematic review. *Front Oncol*. 2021;11:687201. [CrossRef]
21. Solares CA, Panizza B. Vestibular schwannoma: an understanding of growth should influence management decisions. *Otol Neurotol*. 2008;29(6):829-834. [CrossRef]
22. Lopez-Escamez JA, Carey J, Chung WH, et al. Diagnostic criteria for Menière's disease. *J Vestib Res*. 2015;25(1):1-7. [CrossRef]
23. Brown A, Early S, Vasilijic S, Stankovic KM. Sporadic vestibular schwannoma size and location do not correlate with the severity of hearing loss at initial presentation. *Front Oncol*. 2022;12:836504. [CrossRef]
24. Gheorghe L, Negru D, Cobzeanu MD, et al. The diagnostic accuracy of pure-tone audiometry screening protocols for vestibular schwannoma in patients with asymmetrical hearing loss-A systematic review and meta-analysis. *Diagnostics (Basel)*. 2022;12(11), [CrossRef]
25. Vnencak M, Huttunen E, Aarnisalo AA, Jero J, Liukkonen K, Sinkkonen ST. Evaluation of pure-tone audiometric protocols in vestibular schwannoma screening. *J Otol*. 2021;16(3):138-143. [CrossRef]
26. Fushiki H, Junicho M, Kanazawa Y, Aso S, Watanabe Y. Prognosis of sudden low-tone loss other than acute low-tone sensorineural hearing loss. *Acta Otolaryngol*. 2010;130(5):559-564. [CrossRef]
27. Im GJ, Kim SK, Choi J, Song JJ, Chae SW, Jung HH. Analysis of audiovestibular assessment in acute low-tone hearing loss. *Acta Otolaryngol*. 2016;136(7):649-654. [CrossRef]
28. Mahmud MR, Khan AM, Nadol Jr JB. Histopathology of the inner ear in unoperated acoustic neuroma. *Ann Otol Rhinol Laryngol*. 2003;112(11):979-986. [CrossRef]
29. Roosli C, Linthicum Jr FH, Cureoglu S, Merchant SN. Dysfunction of the cochlea contributing to hearing loss in acoustic neuromas: an underappreciated entity. *Otol Neurotol*. 2012;33(3):473-480. [CrossRef]
30. Pensak ML, Glasscock ME, 3rd, Josey AF, Jackson CG, Gulya AJ. Sudden hearing loss and cerebellopontine angle tumors. *Laryngoscope*. 1985;95(10):1188-1193. [CrossRef]
31. van de Langenberg R, de Bondt BJ, Nelemans PJ, Dohmen AJ, Baumert BG, Stokroos RJ. Predictors of volumetric growth and auditory deterioration in vestibular schwannomas followed in a wait and scan policy. *Otol Neurotol*. 2011;32(2):338-344. [CrossRef]
32. West N, Møller MN, Hansen S, Cayé-Thomasen P. Audiovestibular loss of function correlates in vestibular schwannomas. *J Int Adv Otol*. 2018;14(2):161-165. [CrossRef]
33. Massick DD, Welling DB, Dodson EE, et al. Tumor growth and audiometric change in vestibular schwannomas managed conservatively. *Laryngoscope*. 2000;110(11):1843-1849. [CrossRef]
34. Selleck AM, Rodriguez JD, Brown KD. Predicting hearing outcomes in conservatively managed vestibular schwannoma patients utilizing magnetic resonance imaging. *Otol Neurotol*. 2021;42(2):306-311. [CrossRef]
35. Welling DB, Glasscock ME, 3rd, Woods CI, Jackson CG. Acoustic neuroma: a cost-effective approach. *Otolaryngol Head Neck Surg*. 1990;103(3):364-370. [CrossRef]
36. Urben SL, Benninger MS, Gibbens ND. Asymmetric sensorineural hearing loss in a community-based population. *Otolaryngol Head Neck Surg*. 1999;120(6):809-814. [CrossRef]
37. Margolis RH, Saly GL. Asymmetric hearing loss: definition, validation, and prevalence. *Otol Neurotol*. 2008;29(4):422-431. [CrossRef]
38. Saliba I, Bergeron M, Martineau G, Chagnon M. Rule 3,000: a more reliable precursor to perceive vestibular schwannoma on MRI in screened asymmetric sensorineural hearing loss. *Eur Arch Otorhinolaryngol*. 2011;268(2):207-212. [CrossRef]
39. Jason Qian Z, Vaisbuch Y, Gianakas SP, et al. Evaluation of asymmetries in speech-in noise abilities in audiologic screening for vestibular schwannoma. *Ear Hear*. 2023;44(6):1540-1547. [CrossRef]