Vestibular schwannoma in patients with asymmetric sensorineural hearing loss: when to screen for it?

Original Article

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Abstract

Objectives: (1) To compare clinical and audiometric parameters between patients with vestibular schwannoma (VS) and patients with asymmetric sensorineural hearing loss (ASNHL) of unknown etiology; (2) to evaluate proposed protocols for VS screening.
Study Design: Retrospective and cross-sectional.
Materials and Methods: Demographic, clinical, and audiometric data were analyzed and compared in 208 patients with ASNHL with and without VS on MRI. The sensitivity, specificity, and accuracy of different protocols for VS screening were analyzed.
Results: Eighteen patients (8.3%) had VS. Female gender, absence of smoking, unilateral tinnitus, facial sensory and motor symptoms, positive head impulse test (HIT), and suggestive auditory brainstem response (ABR) results were significantly more associated with the VS group. Audiometric asymmetry was greater at 4 kHz in patients with VS. Analysis of a new proposed protocol with clinical and audiometric criteria revealed higher sensitivity (94.6%), specificity (46.5%), and accuracy (50.9%) compared to exclusively audiometric protocols evaluated.
Conclusions: In addition to audiometry, this study demonstrated the benefit of including clinical indicators in a new decision protocol for VS screening.

Keywords: vestibular schwannoma; asymmetric sensorineural hearing loss; screening; magnetic resonance imaging; retrocochlear pathology.

Introduction

The definition of asymmetric sensorineural hearing loss (ASNHL) and its clinical management are not yet well established. The etiology of ASNHL is often multifactorial and evaluation for retrocochlear lesions, particularly in the cerebellopontine angle (CPA) or internal auditory canal (IAC) by magnetic resonance imaging (MRI) is recommended based on the level of clinical suspicion.[1]

Vestibular schwannoma (VS), also known as acoustic neuroma, is a benign tumor that arises from the Schwann cells covering the axons of the vestibulocochlear nerve. VS accounts for approximately 90% of tumors in the CPA. The most common clinical manifestation of VS is progressive or sudden ASNHL, resulting from the compression of the adjacent neurovascular structures by the tumor. Other symptoms include unilateral tinnitus, imbalance, vertigo, headache, hypoesthesia, spasm, or hemifacial motor function changes.[2]

According to previous studies, the prevalence of VS in patients undergoing MRI for evaluation of ASNHL ranges between 1.09–8.4%.[3,4] Current protocols to help decide when to request an MRI to rule out retrocochlear pathology are essentially based on audiometric criteria, which have low specificity. The high cost of MRI examination and high proportion of non-diagnostic results culminate in low cost-effectiveness, posing a financial burden for healthcare institutions when screening for VS.[5,6] This aims of this study were: (1) to compare the clinical and audiometric parameters between individuals with VS and those with ASNHL of unknown etiology; (2) to assess the sensitivity, specificity, and accuracy of the existing audiometric protocols for VS screening in individuals with ASNHL; and (3) to evaluate the sensitivity, specificity, and accuracy of a new protocol combining audiometric and clinical criteria.

Materials and methods

In this cross-sectional retrospective study, a total of 314 patients with ASNHL who underwent MRI to rule out retrocochlear lesions between 2015 and 2023, and were followed up at the department of otorhinolaryngology at our institution, were identified using the Carestream Vue Motion electronic platform. The search terms used (originally in the Portuguese language) were “hearing loss/sensorineural hypoacusis/asymmetric sensorineural,” “retrocochlear lesion,” and “cerebellar-pontine angle.”

We used a comprehensive definition of ASNHL that included patients with a simple tonal audiogram documenting one of the following: a) an interaural difference of ≥ 10 dB at ≥ 3 consecutive frequencies;[7] or b) an interaural difference of ≥ 15 dB at ≥ 1 frequencies.[8] A total of 97 individuals were excluded from the study: 26 due to non-compliance with the audiometric inclusion criteria, 68 due to insufficient clinical or audiometric data, and three due to previous ear surgery.

We analyzed the MRI reports of 217 patients and classified them into two groups based on the presence or absence of VS. Individuals with MRI findings attributable to other ASNHL etiologies were subsequently excluded from the group without VS (wVS).

Several factors were compared between the two groups. Demographic parameters included sex, age, smoking status, and unilateral or bilateral exposure to sound. Clinical parameters comprised time since the onset of hearing loss; presence of tinnitus, vertigo, imbalance, hemifacial motor function and sensory changes (paresthesia or trigeminal neuralgia); Fukuda test; and head impulse test (HIT). Audiometric parameters included interaural differences in the hearing thresholds between 250–8,000 Hz and in the speech recognition threshold (SRT). Additionally, electrophysiological parameters were evaluated using brainstem auditory evoked potentials (BAEP). An analysis was conducted to evaluate the sensitivity and specificity of 14 audiometric protocols (seven tested in previous studies),[6] along with a new protocol that incorporates both clinical and audiometric parameters.

MRI protocol

All participants underwent a conventional MRI examination using a 1.5-T or 3.0-T scanner. The specific protocol varied depended on the equipment and radiologist’s preference. The most frequently obtained sequences were axial and coronal T2 fast-spin-echo (FSE), axial or coronal T1 FSE, axial T2 fluid attenuated inversion recovery (FLAIR), axial T2*****, and axial diffusion-weighted imaging

(DWI). Additionally, high-resolution three-dimensional T2-weighted sequences focusing on the IAC and axial and coronal post-contrast T1-weighted sequences were also obtained.

Statistical analysis

Statistical analysis was conducted using the IBM® SPSS® software version 29.0 (IBM Corp., Armonk, New York, USA). A descriptive analysis was conducted using measures of central tendency and dispersion according to the distribution of the data. Categorical variables were compared between the two groups using the Pearson's chi-square test (X^2), while numerical variables were initially tested for normality of distribution across both groups and subsequently compared using the Mann–Whitney U or Student's t-test. Binary logistic regression was performed to determine the potential audiovestibular variables predictive of VS. Sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios, and accuracy were calculated for each of the included protocols using contingency tables. Significance level was set at 5%.

Results

Among the 217 patients initially enrolled with ASNHL, 18 (8.3%) had VS, 141 (70.8%) exhibited no radiological changes, 49 (24.6%) presented with cranioencephalic findings on MRI that were considered incidental, and nine (4.1%) had MRI changes possibly attributable to other etiologies of ASNHL. The latter category included six (3.0%) cases of vascular loops in the IAC, two (1.0%) cases of labyrinthitis, and one (0.5%) case of glomus jugulare, which were excluded from the wVS group.

A comparative analysis of the clinical characteristics between the two groups (Table 1) revealed a statistically significant predominance of female gender in the VS group (p = 0.027). The mean age was similar between the groups (62 years). The prevalence of active or previous smoking as a comorbidity was lower in the VS group (p = 0.039), but showed no statistical significance in logistic regression analysis (odds ratio [OR] = 6.33, p = 0.076). Progressive ASNHL was more frequent in the VS group (p = 0.045). Unilateral tinnitus (p = 0.004), hemifacial sensory changes (p = 0.003), and positive HIT (p = 0.004) ipsilateral

Table 1
Association between clinical characteristics and VS detection on MRI in individuals with ASNHL

Parameter	Individuals, N (%)		X^2 / *t test* (p-value)	Logistic regression	
	VS	wVS		OR[a] (95%CI[b])	p-value
Females	14 (77.8)	96 (50.5)	0.027	3.46 (1.10-10.89)	0.033
Age (mean ± SD[c], years)	62.4±19.4	62.3±13.8	0.957	1.00 (0.97-1.04)	0.944
Active or previous smoking	1 (5.6)	53 (27.9)	**0.039**	1.58 (0.02-1.21)	0.076
Bilateral sound exposure	3 (16.7)	43 (22.6)	0.560	0.67 (0.18-2.39)	0.533
Unilateral sound exposure	1 (5.6)	11 (5.8)	0.968	0.99 (0.12-8.175)	0.996
Progressive onset of hearing loss (vs. sudden)	16 (88.9)	125 (65.8)	**0.045**	3.97 (0.88-17.78)	0.061
Right ear	11 (61.1)	77 (40.5)	0.091	2.33 (0.86-6.28)	0.092
Unilateral (ipsilateral) tinnitus	15 (83.3)	90 (47.4)	**0.004**	5.47 (1.54-19.50)	**0.009**
Vertigo	7 (38.9)	107 (56.3)	0.156	1-44 (0.88-2.36)	0.150
Imbalance	8 (44.4)	63 (33.2)	0.334	1.24 (0.76-2.02)	0.384
Changes in hemifacial sensitivity	4 (22.2)	5 (2.6)	**0.003**	3.33 (1.64-6.78)	**< 0.001**
Changes in hemifacial motor function	2 (11.1)	2 (1.1)	0.003	2.47 (1.02-5.99)	**0.046**
Fukuda test with ipsilateral lateral deviation	3 (16.7)	17 (8.9)	0.288	2.14 (0.56-8.14)	0.264
Positive ipsilateral HIT	5 (27.8)	11 (5.8)	**0.004**	2.35 (1.30-4.22)	**0.004**
BAEP suggestive of retrocochlear pathology (N = 79)	6 (33.3)	26 (13.7)	**0.039**	3.37 (1.24-9.87)	0.033

[a]Odds ratio; [b]Confidence interval; [c]Standard deviation

Table 2
Comparative analysis of the interaural difference in hearing thresholds between 250–8,000 Hz in individuals with and without VS

Frequencies	Average values in the Mann–Whitney U test		p-value
	wVS (n = 190)	VS (n = 18)	
250 Hz	120.6	107.3	0.354
500 Hz	115.7	105.4	0.656
1000 Hz	121.1	107.9	0.393
2000 Hz	124.6	107.5	0.265
4000 Hz	137.7	106.5	**0.046**
8000 Hz	118.3	108.1	0.498

Table 3
Comparative analysis of the probability of VS detection along with the sensitivity, specificity, and accuracy of audiometric protocols for ASNHL

Critério audiométrico de assimetria interaural	Regressão logística		Sensibilidade (%)	Especificidade (%)	Exatidão (%)
	ORa (95% ICb)	Valor-p			
≥ 10 dB at ≥ 3 consecutive frequencies1[c]	0.00 (0.00)	0.998	100.0	9.7	17.6
≥ 15 dB at ≥ 2 consecutive frequencies[d]	2.64 (0.68-10.23)	0.159	83.5	7.0	13.4
≥ 15 dB at ≥ 3 consecutive frequencies[e]	1.03 (054-1.97)	0.922	83.6	17.6	23
≥ 20 dB at ≥ consecutive frequencies[f]	1.54 (0.48-5.01)	0.466	77.9	15.6	20.7
≥ 15 dB at ≥ 2 frequencies between 2-8kHz[g]	1.16 (0.61-2.20)	0.657	83.4	21.1	26.3
≥ 15 dB at ≥ 1 frequencies between 0.5-4kHz[h]	0.00 (0.00)	0.999	100	1.0	9.2
≥ 20 dB at ≥ 1 frequencies between 0.5-4kHz[i]	2.36 (0.47-11.72)	0.293	88.9	5.0	12.0
≥ 20 dB at 2kHz[e]	1.53 (0.55-4.29)	0.419	66.7	24.6	28.1
≥ 20 dB at 4kHz[j]	1.62 (0.97-2.99)	0.075	77.6	44.9	48.1
≥ 20 dB at 8kHz[e]	1.07 (0.65-1.80)	0.777	66.7	36.6	39.2
≥ 15 dB on an average of 0.5,1 and 2kHz[l,e]	1.43 (0.48-4.26)	0.512	72.2	21.1	25.3
≥ 15 dB on an average of 0.5,1, 2 and 4kHz[l,e]	1.35 (0.46-4.01)	0.583	72.2	22.1	26.3
≥ 15 dB on an average of 1, 2, 4 and 8kHz[m,e]	0.12 (0.59-2.14)	0.727	83.3	20.1	25.3
≥ 15 dB by SRT[e]	1.12 (0.26-4.88)	0.634	60.1	12.7	14.9
≥ 10 dB at ≥ 3 consecutive frequencies + 1 clinical criterion (unilateral tinnitus, hemifacial sensory or motor function, positive HIT, suggestive BAEP)[e,j]	14.92 (1.97-114.31)	0.009	94.6	46.5	50.9

[a]Odds ratio; [b]Confidence interval; [c]Ahsan, 2015[7]; [d]Cave, 2004[9]; [e]Protocols not tested in previous studies; [f]Dawes, 2001[10]; [g]Gimsing, 2010[11]; [h]Welling, 1990[6]; [i]UK Department of Health[6]; [j]Schlauch, 1995[8]; [l]Adapted from the American Academy of Otolaryngology-Head and Neck Surgery[6] (originally evaluating 3 kHz); [m]Hunter, 1999[6].

to the sensorineural hearing loss were more significantly associated with VS. Among the study participants, only 77 (37%) underwent BAEP prior to MRI. A BAEP result suggestive of retrocochlear pathology was significantly more prevalent in patients with VS (p = 0.039). Binary logistic regression also revealed that female gender (OR, 3.46; 95 % confidence interval [CI], 1.10–10.89), unilateral tinnitus (OR, 5.47; CI, 1.54–19.50), hemifacial sensory changes (OR, 3.33; CI, 1.64–6.78), hemifacial motor function changes (OR, 2.47; CI, 1.02–5.99), positive HIT (OR, 2.35; CI, 1.30–4.22), and BAEP suggestive of retrocochlear pathology

(OR, 3.37; CI, 1.24–9.87) were predictive risk factors for VS on MRI.

The interaural difference in the hearing thresholds at each frequency was analyzed and compared between the two groups using the Mann–Whitney U test (table 2), which demonstrated a statistically significant difference at 4 kHz (p = 0.046).

There were no statistical differences between the groups in the 14 exclusively audiometric ASNHL criteria adopted (Table 3). The interaural tonal threshold difference ≥ 20 dB at 4 kHz demonstrated an accuracy of 48.1%, sensitivity of 77.6%, and specificity of 44.9%. Although this result indicates a higher probability of detecting VS, there was no statistical significance (p = 0.075).

Based on the comparative analysis of variables between the two groups, a new protocol including both clinical and audiological criteria was proposed and tested. The protocol included 1) an interaural difference of ≥ 10 dB at ≥ 3 consecutive frequencies[7]; and 2) at least one of the following: unilateral tinnitus, hemifacial sensory or motor function changes, a positive HIT result, or BAEP suggestive of retrocochlear pathology.

This model demonstrated statistical significance in predicting VS (OR, 14.92, p = 0.009) in logistic regression analysis. This new protocol also demonstrated superior sensitivity (94.6%), specificity (46.5%), and accuracy (50.9%) compared to the other audiometric protocols evaluated (Table 3).

Discussion

ASNHL is the most common clinical symptom of VS, occurring in approximately 90% of cases. Due to its easy availability, technical quality, and sensitivity, MRI is widely used as a screening tool to rule out VS and other retrocochlear pathologies. However, the low prevalence of VS detected by MRI in patients with ASNHL and the associated financial burden justify the need to analyze and define criteria for imaging evaluation.[6] In this study, the prevalence of VS was 8.3%, which is higher than the estimate provided by Cheng et al. (1.09–5.23%) in a cross-sectional analysis of eight institutions.[3] However, this prevalence rate is comparable to the one reported by Celis-Aguilar et al. (8.4%).[4] It should be noted that not all patients with ASNHL in our institution were included in the analysis; only those who underwent MRI. The lack of an established protocol for MRI at our institution may be considered a source of selection bias.

The predominance of female gender and inverse correlation with smoking in the VS group are consistent with the findings of a recent population study.[12]

Previous studies compared audiometric asymmetry between individuals with and without VS, with conflicting results. Concurrent with the present study, Gimsing and Saliba et al. demonstrated significant asymmetry at 4 kHz. However, this difference was also identified in two studies conducted at 1, 2, and 3 kHz[11] and at 2 and 8 kHz,[8] respectively, which contrasts with our findings. The greater asymmetry observed in individuals with VS at medium to high frequencies can be attributed to the compression of the more superficial layer of the cochlear nerve, where the nerve fibers corresponding to these frequencies are located[9].

Recent trials have revealed that this audiometric asymmetry is not statistically significant.[4,13] The lack of a statistically significant difference in audiometric asymmetry criteria between the two groups was corroborated by the findings of Celis-Aguilar et al.[3]. In contrast, two studies found a statistically significant difference in interaural asymmetry of ≥ 15 dB at 3 kHz.[7,11] The 3 kHz frequency was not included in the audiometry reading because it is not routinely evaluated at our institution. It is only included when there is a difference of ≥ 20 dB between measurements at 2 and 4 kHz. This may be a limitation of this study because the average threshold at these two frequencies is an unreliable predictor of the threshold at 3 kHz.[8,14]

A position paper published by the European Academy of Otology and Neuro-Otology (EAONO)[6] highlights the importance of determining the sensitivity and specificity of each protocol, noting that the balance between these factors can vary depending on the clinical settings (primary, secondary, or tertiary care) and available financial resources. The protocol proposed by Gimsing et al. incorporates two criteria: 1) asymmetry ≥ 20 dB at two consecutive frequencies or unilateral tinnitus; or 2) asymmetry ≥ 20 dB at two frequencies between 2–8 kHz (sensitivity, 92%; specificity, 55%). However, in our study, the balance between sensitivity and specificity of audiometric protocols was less satisfactory. Sensitivity is often prioritized to enable earlier detection, which can lead to better outcomes with regard to tumor resection and hearing preservation.

Despite the well-documented range of clinical presentations of VS besides ASNHL, including involvement of the cochlear, vestibular, facial, or trigeminal nerves and possible cochlear damage, there has been limited discussion on the inclusion of clinical parameters into imaging screening decisions for VS in previous studies.[11] The identification of clinical characteristics associated with a higher risk of detecting VS on MRI in this study led to the development and evaluation of a new protocol. This protocol, which comprises one audiometric criterion and five clinical criteria, demonstrated higher sensitivity, specificity, and accuracy compared to audiometric protocols alone.

The retrospective design of this study is an important limitation, as it indicates subjectivity and insufficient records. Additionally, the low prevalence of VS means that the sample size may not be representative. Since all study participants did not undergo high-resolution MRI scans focused on the IAC, the possibility of smaller lesions going undetected should not be overlooked.

Conclusion

This study found that 8.3% of patients with ASNHL had VS on MRI. Interaural audiometric asymmetry at 4 kHz was significantly higher in individuals with VS. Our findings highlight the benefits of incorporating clinical and electrophysiological indicators, such as unilateral tinnitus, changes in hemifacial sensory and motor function, positive HIT, and BAEP suggestive of retrocochlear pathology, into a new decision-making protocol for VS screening. We recommend conducting a future multicenter prospective study based on a computerized algorithm that integrates audiological and clinical data to improve VS prediction.

Conflict of Interests

The authors declare that they have no conflict of interest regarding this article.

Data Confidentiality

The authors declare that they followed the protocols of their work in publishing patient data.

Human and animal protection

The authors declare that the procedures followed are in accordance with the regulations established by the directors of the Commission for Clinical Research and Ethics and in accordance with the Declaration of Helsinki of the World Medical Association.

Privacy policy, informed consent and Ethics committee authorization

All the processed data were based in published reports that fulfilled privacy policy and ethical considerations.

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Scientific data availability

There are no publicly available datasets related to this work.

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