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The Subjective Visual Vertical and Electrocochleography Tests in Individuals with Meniere's Disease

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Abstract

Introduction:

Meniere's disease is an inner ear disorder not associated with central brain structure involvement. Although the ECochG test has been commonly used to diagnose Meniere's disease recently, it has not demonstrated high sensitivity. Therefore, it is recommended that other complementary tests alongside the ECochG test be used to diagnose Meniere's disease. The SVV test has gained popularity recently for this reason, and in this study, it was decided to use the SVV test in both static and dynamic modes, along with the ECochG test, as a tool for diagnosing Meniere's disease and evaluating its diagnostic features.

Materials and Methods:

The study was conducted on 53 patients with confirmed unilateral Meniere's disease and a normal group. Means were calculated with a 95% confidence interval for the groups, and the corresponding graphs were plotted. Independent t-tests were used to examine the difference in SVV results between the normal and Meniere's groups. The ROC curve was then used to determine the cutoff point and calculate.

Results:

After investigating the cutoff point for the three SVV conditions (tilted towards the lesion), a cutoff point of 2.1 degrees with a sensitivity and specificity of approximately 0.7 was identified as the best condition for distinguishing the Meniere's group from the healthy group.

Conclusion:

Finally, based on the findings, it can be concluded that the SVV test has relatively low sensitivity for diagnosing Meniere's disease. Therefore, more than relying solely on its results to identify Meniere's disease is required, and it is suggested that other measures alongside the ECochG and SVV tests be included in future studies for further investigation.

***Keywords*:** Cutoff point, ECochG, Meniere's disease, SVV test, Sensitivity.

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Introduction

Meniere's disease is an inner ear disorder not associated with central brain structure involvement. Clinical symptoms of Meniere's disease include recurrent rotational vertigo, hearing loss, and tinnitus, which may occur with or without accompanying vestibular symptoms.

The severity and duration of vertigo attacks vary and can last from several minutes to several hours, often accompanied by nausea and vomiting. During the attacks, neurological symptoms are usually absent (1,2). Meniere's disease is typically unilateral, affecting one side, but the other can also be affected over time. The reported prevalence of bilateral involvement ranges from 2% to 78% (3). In addition to the cochlea, the vestibular organs play a crucial role in maintaining balance through gravity perception and linear acceleration perception. The utricle and saccule are also affected by Meniere's disease.

In the past, studies on Meniere's disease have primarily focused on the hydrops and saccula, with less attention given to the utricle. Animal studies have shown that obstruction of the endolymphatic sac is the main cause of endolymphatic hydrops, leading to mechanical and structural changes and disruptions in the utricle, cochlea, and endolymphatic sac. Ischemia, inflammation, autoimmune diseases, or viral infections can obstruct the endolymphatic sac, resulting in impaired absorption of endolymph. Generally, the cochlea and saccula are more susceptible to damage than the semicircular canals, and severe hydrops typically occur in the saccula (4,5).

The subjective visual vertical (SVV) test and electrocochleography (ECochG) are employed in the tests used to examine and identify this condition. The SVV test assesses the function of the utricle through information processing by the cortex. In this test, individuals must adjust a line obliquely to align vertically parallel to the gravitational axis (6,7). The SVV test is a valuable clinical tool for evaluating the function of the utricle (2).

It is effective in understanding vertical perception in vestibular peripheral and central disorders. The purpose of the SVV test is to detect mental tilt disorders. In normal individuals, the perception of vertical alignment is relatively good, and this ability relies on inputs from the visual, vestibular, and somatosensory depth systems. The otoliths (utricle and saccule) play a significant role in vertical sensory perception, and damage to the otoliths or the neural pathways that transmit impulses from the inner ear to the brain can lead to difficulties in judging vertical perception. The SVV test can be performed in both static and dynamic forms. The visual background is fixed In the static condition, while in the dynamic condition, the visual environment involves rotation (8).

Most studies in this area have measured SVV in the static condition, where the subject's head remains fixed during the test. However, in this study, the dynamic method was also employed in addition to the static method. In the dynamic condition of the test, the patient's head tilts to the right and left in the coronal axis towards the right and left shoulders before the test is conducted.

Due to expensive equipment and time constraints, the SVV test is not routine in audiology clinics worldwide. Clinicians are more inclined to use other balance tests for peripheral or central vestibular disorders. Another useful test for diagnosing Meniere's disease is the ECochG test, which provides separate information and results for each ear, allowing for the individual identification of the affected ear.

The recording of the ECochG test consists of two important components, Summating Potential (SP) and Action Potential (AP), which are used to identify Meniere's disease. The SP is the cumulative potential, indicating electrical changes within the hair cell of the basilar membrane. Due to increased endolymphatic pressure within the cochlea (scala media) resulting from hydrops, this intracellular potential increases.

The next potential is called AP, which is generated by the activity of the auditory nerve fibers. It represents the neural activity in response to auditory stimuli and is crucial in identifying this condition. The increase in the SP/AP ratio is the main characteristic of this test. Endolymphatic hydrops causes mechanical changes in the cochlear properties, displacing the basilar membrane towards the scala tympani, resulting in alterations in the electrical characteristics of the hair cells and an increase in the amplitude of the SP.

Most researchers believe the SP/AP ratio should be considered within the range of 0.3 to 0.5 as the normal range for this test. However,

this range is subject to considerable variability in the test's results, and approximately two-thirds of Meniere's patients exhibit abnormally increased SP/AP ratios.

Considering the physiological changes following Meniere's disease in the cochlear duct, the use of the ECochG test, although common in recent years, has not been highly sensitive. Using other vestibular tests alongside this test as complementary measures is suggested. Recently, the use of SVV has become prevalent for the same reason. However, this test has been primarily performed in a static position, and the dynamic aspects (such as head rotation, head and neck tilt, or visual background rotation) have received less attention. Therefore, it is necessary to use this test in a dynamic mode (head tilt) despite some limitations better to understand the lesions and outcomes of unilateral vestibular disorders.

In summary, the SVV test and ECochG test are among the tests that are sensitive to peripheral vestibular lesions. However, the SVV test in a static position (with the head fixed) is rapidly compensated for by the compensatory mechanisms, and therefore, the results in this test usually do not deviate from the normal range, making it difficult to rely on the results.

However, in the dynamic mode of the SVV test, as we can directly stimulate the vestibular system, it is better to identify the presence of lesions. Therefore, in this study, it was decided to use the SVV test in a dynamic mode alongside the static SVV test and the ECochG test as a tool for diagnosing Meniere's disease in order to identify better the presence of lesions, which helps in the diagnosis of vestibular disorders. Additionally, the study also examines the role of age and gender on test results, which distinguishes it from other studies.

Materials and Methods

This study was conducted on 53 patients diagnosed with definite unilateral Meniere's disease, with 28 women and 25 men, and an average age of 45.28. Data collection occurred at the Audiology and Balance Clinic in Mashhad between 2020 and 2022. The inclusion criteria for the normal hearing group included age between 18 and 75 years, normal hearing (better than 25 dB and AN tympanogram), no history of neurological disorders, and no use of antidepressant, analgesic, or vestibular suppressant drugs at least 24 hours prior to the test. The diagnostic criteria for the Meniere's group were based on the AAO-HNS (American Academy of Otolaryngology-Head and Neck Surgery) guidelines. Patients were examined by ear, nose, and throat specialists and referred to the Auditory and Balance Center at Mashhad.

The AAO-HNS criteria for diagnosing Meniere's disease include the following:

1. Spontaneous vertigo lasting at least 20 minutes.
2. Tinnitus and hearing loss in the affected ear, with decreased hearing in low frequencies.
3. Absence of lesions in the external and middle ear.

Although many patients with hearing impairments have poorer hearing in low frequencies compared to high frequencies, only patients with hearing thresholds less than 25 dB HL across all frequencies were included in this study. The affected ear was determined based on patient reports, audiometry results, and the physician's diagnosis.

A satisfaction survey form was obtained from all participants in the research. Patients were asked to refrain from taking vestibular suppressant drugs 48 hours before the start of the test to minimize the effects of medications that reduce vertigo symptoms. The SVV test was performed in a dark room using the SYNAPSIS SVV device from SYNAPSIS, France. The participants were seated on a chair 2 meters from the monitor, and SVV goggles were placed on the patient's eyes.

A binocular aperture was provided for participants' vision (Figure 1). An oblique line with a 20-degree tilt was displayed on the monitor screen, and its positive or negative angle at the start of the test was determined based on the direction of the evaluation(clockwise or counterclockwise) in the patient's test direction. (6,7)

The examining individuals were asked to mentally align this oblique line based on their perception of the vertical. They adjusted the line using a remote control until it was parallel to their perceived gravity axis. The alignment direction of the line in the test direction (clockwise) was considered positive, and the

opposite direction (counterclockwise) was considered negative. For each individual, the test was repeated twice in both right and left directions (dynamic) at a 30-degree tilt, totaling four times, and a sharp condition was performed in the static position (0 degrees), resulting in a total of 5 conditions for each individual. The ECochG test was conducted using the BIOLOGIC NATUS device from NATUS, USA, in a closed room. The ECochG test involves measuring many evoked electrical potentials in the inner ear.

Auditory stimuli are presented to the ear, which creates electrical potentials in the basilar membrane and the hair cells on the basilar membrane. The recorded electrical responses are captured by electrodes placed on the skull. The stimulus and recorded responses are repeated within a time interval, and all recorded responses are averaged, called signal averaging. In this study, three electrodes were used, including the negative electrode (reference) placed inside the experimental ear canal, the positive electrode (noninverted) placed on the mastoid of the non-experimental ear, and the ground electrode placed on the forehead to record the echo test. The horizontal method was used in patients. During the ECochG test, patients were informed that it was a non-invasive and painless test, and the approximate duration was 45 minutes. Patients were even allowed to sleep during the test, and the purpose was explained to each individual. The patients were lying supine on the examination bed, and the electrodes were placed on the patient's skin. The electrode covered with a sponge was inserted into the ear canal and placed on the tympanic membrane (Figure 1). Before placing the electrodes, the otoscopic examination was performed, and the patient's skin was cleaned. If there was excessive earwax in the ear canal, the test was postponed until the cerumen was removed.

Fig 1: the SSV and ECochG Devices and positioning. a. ECochG device, b. SVV device, c. SVV test performing position, d. ECochG performing position

Statistical Methods

Central indices such as mean and standard deviation were first calculated for data analysis to examine the data accurately. The means in the groups were calculated with a 95% confidence interval, and the corresponding graphs were plotted. Furthermore, an independent t-test was used to examine the difference in SVV results between the two groups: normal and patients with Meniere's disease. Afterward, a ROC curve was utilized to determine the cutoff point and calculate the sensitivity and specificity of the SVV test in diagnosing Meniere's disease. Finally, an independent t-test was used to assess the impact of demographic variables on SVV results, with gender as the variable, and Spearman's correlation was used for the age variable. All analyses were performed using SPSS v23 for Windows, and the graphs were plotted using MS Excel v2013.

Results

The demographic status of the sample indicated that it consisted of approximately equal numbers of males and females, and 50% of the sample had a problem with their right ear. The age ranged from 15 to 72,with a mean age of 45.28(Table 1).

Table1: demographic data of participants

Variable	State/Range	freq/m	%/sd
sex	Female	28	52.83
	Male	25	47.16
Affected side	Right	27	50.94
	Left	20	37.73
age	15-72	45.28	13.6

Table 2 indicates the SVV status and its deviation level. It indicated that the maximum deviation was associated with the ipsi-lateral or tilt towards the lesion condition (Figure 2).

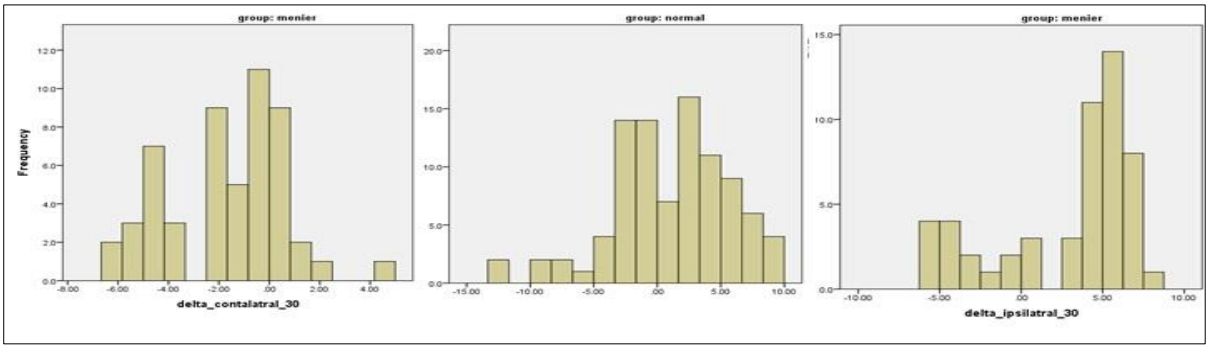

Fig 2: The disturbution of SVV data in Normal and Menier in contralateral and ipsilateral head tilt status

Table 2: characteristic of SVV in Menier group (n=52)

SVV	Mean	sd	lower	Upper
Ipsilateral 30	2.84	4.22	1.67	4.01
Contralateral 30	-1.67	2.37	-2.32	-1.01
Zero	-0.36	1.57	-0.76	0.07

The deviation level was minimal and insignificant in the static or zero-degree position (upright). Table 3 presents the independent t-test comparing the mean deviations of SVV between the Meniere's and healthy groups.

Table 3: Mean comparing between normal and Menier group

Varaible	t	df	P-value	Mean difference	Lower	Upper
Ipsilateral 30	2.47	143	0.01	1.88	0.37	3.39
Contralateral 30	-4.57	141.99	0.0001	-2.62	-3.76	-1.49
Zero	1.05	97	0.29	0.35	-0.31	1.02

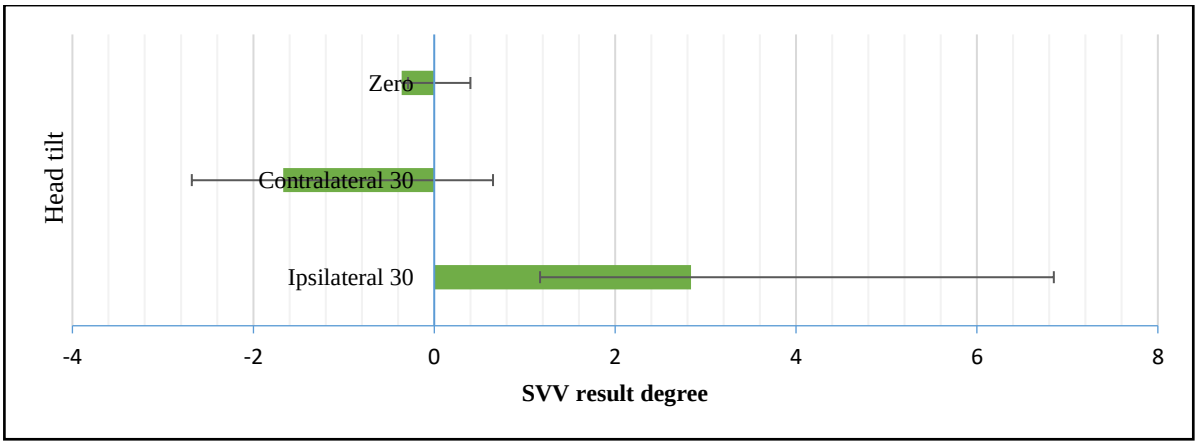

Fig 3: Mean and ci95% of SVV result

These results indicated no significant difference between the healthy and Meniere's groups in performing SVV in the static or zero-degree position. However, in the tilted positions towards the lesion or opposite it, there was a significant difference in the mean deviations of SVV between the Meniere's and healthy groups (Figure 3). Furthermore, the ROC curve was utilized to examine the effectiveness of the SVV test in distinguishing individuals with

Meniere's disease from healthy individuals, and the corresponding ROC curve is presented in (Figure 4). Based on the figure and the results obtained from the data, the SVV test with the tilt towards the lesion has a better discriminatory ability for distinguishing individuals with Meniere's disease from healthy individuals than other tilt positions (Area Under Curve: ipsilateral=0.688, contralateral=0.224, Zero=0.564). The optimal cutoff point obtained for the tilt towards the lesion is 2.1 degrees of deviation towards the lesion, with a sensitivity of 0.698 and specificity of 0.717. In conclusion, this level of sensitivity and specificity for an auditory test is relatively low and unreliable for diagnostic purposes.

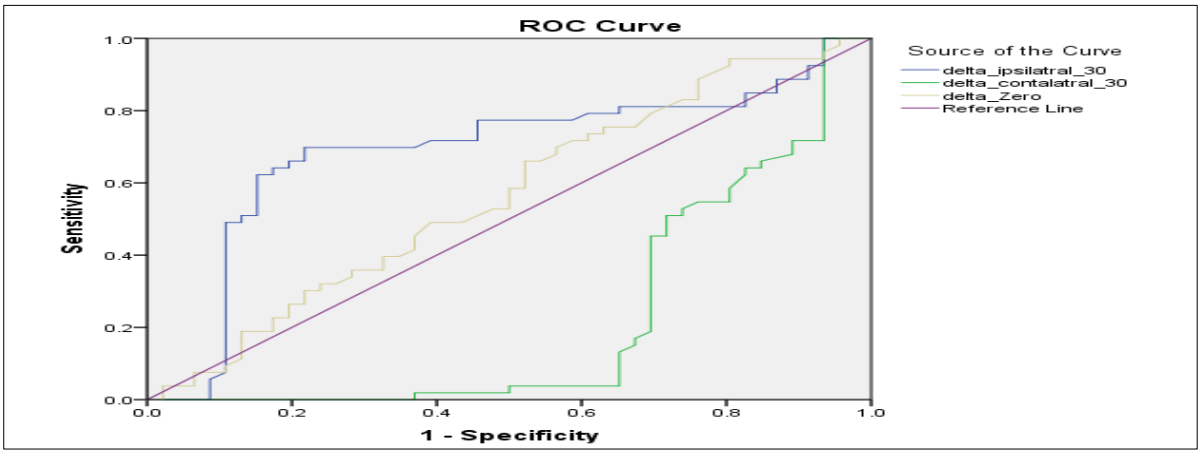

Fig 4: the ROC Curve of SVV data for Menier and normal Group

The analysis of the mean SVV in different head tilt conditions (ipsilateral, contralateral, and zero) did not show a significant difference between the male and female groups. The statistical results were as follows: Ipsilateral: t = -0.45 (51), p = 0.650; Contralateral: t = 0.273 (51), p = 0.786; Zero: t = -1.13 (51), p = 0.264. These results suggested no significant difference in mean SVV between males and females in the different head tilt conditions.

Table 4: the correlation between SVV data and age (n=53)

	delta_ipsilatral_30	**delta_contalatral_30**	**delta_Zero**	**age_year**
delta_ipsilatral_30	1.000	-.100	-.271*	.299*
delta_contalatral_30	-.100	1.000	-.199	-.312*
delta_Zero	-.271*	-.199	1.000	-.080
age_year	.299*	-.312*	-.080	1.000

The examination of the correlation between the results of SVV and the age of the participants is presented in Table 4. The results indicated that an older ages increased in the deviation of SVV towards the lesion in the head tilt towards the lesion condition. Additionally, there was a significant correlation between the deviation level and the head tilt towards the opposite side of the lesion. However, no significant correlation was found between the SVV results in the zero-degree position and age. These findings suggested a meaningful relationship between the results of SVV and age, particularly in the head tilt towards the lesion and head tilt towards the opposite side of the lesion conditions.

Discussion

The present study investigated the characteristics of SVV and ECochG tests in 53 patients with unilateral Meniere's disease. Initially, the dispersion of SVV deviations was evaluated in three head tilt conditions: 30 degrees tilt towards the lesion, 30 degrees tilt towards the opposite side of the lesion, and the no-tilt condition. Subsequently, the difference in mean SVV deviations between the Meniere's and normal groups was examined, which showed that the mean SVV deviations in the head tilt towards the lesion or the opposite side differed from the normal group. After determining the cutoff point for the three SVV

conditions, the head tilts towards the lesion condition with a cutoff point of 2.1 degrees and sensitivity and specificity of approximately 0.7 was identified as the best condition for distinguishing the Meniere's group from the healthy group. Regarding the dispersion of SVV deviation results and the mean deviations and their difference from the normal group, it can be stated that the mean SVV deviations in normal individuals and those with Meniere's disease on the lesion side showed a considerable difference. In Meniere's patients, dilatation of the endolymphatic sac leads to lesions and disturbance in the otoliths and subsequently affects the peripheral vestibular system. If the central pathways are normal, SVV results usually demonstrate normal otolithic function (9). Previous studies have focused on investigating the sacculus and cochlea in Meniere's lesions, but this study specifically addresses the involvement of the utricle, which has yet to be extensively studied in Meniere's disease.

Similar signals are projected from both sides to higher centers in individuals with normal bilateral vestibular function. Therefore, individuals can properly align the tilted line vertically. However, in the case of unilateral lesions, the signals are weaker and directed toward the higher center, creating a kind of asymmetry. As a result, individuals have difficulty perceiving the vertical direction correctly. In unilateral vestibular lesions, the stimulation of neurons on the lesion side is compromised. Due to the weakened signal, SVV deviated towards the lesion, indicating the direction of the lesion (10). Our perception of the vertical direction stems from our perception of the gravitational force, which has linear acceleration and is continuously identified by the otoliths. Therefore, in unilateral peripheral or central lesions, the results of this test are abnormal.

Most studies have reported a deviation of ±2 degrees from the vertical as the normal range for SVV (6,8,11). In this study, normal individuals reported deviations less than 2.1 degrees, while patients reported deviations greater than 2.1 degrees towards the lesion.

In this regard, BOHMER and colleagues demonstrated that patients with Meniere's disease exhibit a significant deviation of SVV towards the lesion, gradually decreasing and becoming similar to normal individuals. Therefore, SVV results are useful in detecting acute unilateral lesions of the otoliths but ineffective in the chronic phase (12). In Friedman's studies, no pathological deviations were reported in patients with Meniere's disease (13). Although the test phase is not mentioned in this study, the present study was conducted one week after the last attack, and all tests were performed at this stage. The SVV test reflects the function of the utricle and the processing of otolithic information in the cortex. The cooperation and participation of the participants are one of the limitations of the SVV test. Another limitation of the test is that it does not indicate the degree of compensation of otolithic disorders by the central system. However, it remains an effective tool for identifying vestibular disorders, especially when performed in a dynamic state, as the asymmetry in the processing and responses of the otoliths disrupts the perception of the vertical direction (7). Lopez and colleagues stated that patients with unilateral vestibular loss experience impaired perception of the vertical axis, balance, and body orientation. This study was conducted on 11 Meniere patients before and after unilateral vestibular nerve section surgery, where the patients had to adjust a luminous line in a dark environment (SVV) in three positions: standing, sitting, and lying down. The data were compared with a control group that matched the patient group regarding age and gender. The SVV results in Meniere's individuals showed a deviation towards the lesion, with an increasing deviation from standing to sitting and then lying down. These findings indicate that perception of the vertical axis is better when the individual requires more body control for balance maintenance (standing position). Therefore, body orientation is a key factor in the perception of the vertical axis during at least the first month after vestibular loss (14).

In a study conducted by Hosseini-Fard and colleagues in 2017 on 32 patients with definite unilateral Meniere's disease, the SVV test was performed in a static. The study concluded that the deviation of SVV test results in Meniere's was greater towards the lesion (15). Kingma reported that Meniere's disease disrupts the SVV results, which deviate towards the lesion, which is in complete agreement with our results (6,16).

In a study conducted by Vibert and colleagues, they measured SVV values in patients with unilateral viral-induced sudden functional loss of labyrinth (vestibular neuritis). They found that 47% of cases showed an SVV deviation greater than 2 degrees during the acute phase of viral labyrinthitis or vestibular neuritis. They concluded that assessing the dysfunction of the otoliths and its impact on SVV results depends on the size and location of the lesion in the peripheral vestibular structures (17). Another test performed in this study was the ECochG test, which has been validated for diagnosing unilateral Meniere's disease. The results of this test are very helpful in diagnosing Meniere's (17). The SP potential in the ECochG test is highly susceptible and reflects slow changes in the mechanical and electrical displacement of the basilar membrane and its associated cells (18). To these observations, the SP range in animals with hydropic endolymphatic conditions is greater than in the normal population (19,20). In patients with hydrops, this increased endolymphatic pressure leads to changes in the resting state of the basilar membrane. The diagnostic application of ECochG is relevant in diseases that cause changes in the mechanical properties of the cochlea, which in turn affect the range of cochlear potentials. For example, the cumulative potential is influenced, and the definitive diagnosis of Meniere's disease with the ECochG test is very helpful in identifying this disorder. In Meniere's disease, an increase in the SP/AP ratio is highly probable, and this parameter is crucial and necessary for diagnosing Meniere's (21).

In this study, normal individuals had normal ECochG results, but in unilateral Meniere's lesions, ECochG results were outside the normal range (greater than 4.0), and the SP/AP ratio was outside the normal range. In the 1970s, two groups underwent initial evaluation with the ECochG test to aid in diagnosing hydrops (22,23). In both groups, a significant increase in the SP range was observed compared to normal individuals. In another study conducted by Chung in 2004, the diagnostic effects of recording ECochG in an extratympanic manner were evaluated for diagnosing Meniere's disease. The study included 158 individuals diagnosed with Meniere's by physicians, and 37 had normal hearing. They set the SP/AP recording ratio at 34.0, and in the end, a sensitivity of 71% was achieved in the ECochG test for diagnosing Meniere's (24). In a study conducted by Ferra in 2000, the ECochG test was evaluated on the day patients had acute symptoms to assess the sensitivity of this tool. The SP/AP ratio had significantly increased, but these values were weak and no longer effective for ears with hearing loss exceeding 70 decibels. Therefore, it is better to consider the degree of hearing loss in patients when using the ECochG test for diagnosing Meniere's (25). In summary, an increase in the SP/AP ratio is highly useful for diagnosing Meniere's, but there have also been reported cases where this ratio remained normal in patients with confirmed medical diagnosis of Meniere's. Therefore, caution is necessary when interpreting the results.

Conclusion

In summary, while the ECochG test shows promise and the SVV test has limitations, a comprehensive diagnostic approach combining multiple tests is recommended to identify Meniere's disease accurately. By considering a range of clinical and diagnostic parameters, healthcare professionals can provide better diagnostic accuracy and improve patient care in managing Meniere's disease.

Based on the current findings, the SVV test has relatively low sensitivity for diagnosing Meniere's disease. Therefore, relying solely on its results to identify Meniere's disease is not recommended. Future studies should explore other avenues besides using ECochG and SVV tests together.

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