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Role of MRI in Diagnosis of Meniere's Disease

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Abstract

Background: The clinical triad of low-frequency fluctuating sensorineural hearing loss, vertigo episodes for at least 20 minutes, auditory fullness & tinnitus describe Meniere's disease. The clinical diagnosis of Meniere's disease (MD) can be supplemented with a variety of test battery including vestibular, audiological, and electrophysiological assessments.

Aim of Study: Was to correlate the results of MRI and cVEMP in diagnosing MD.

Patients and Methods: This is a cross sectional case study who was conducted on 20 adult patients diagnosed with Meniere based on the criteria decided by the European Academy of Otology and Neurotology subjected to Pure tone audiometry, cervical vestibular myogenic potential (cVEMP) and Magnetic resonance imaging (MRI).

Results: The affected ear significantly showed a delay in latency of P13 & N23 in cVEMP and a decrease in the amplitude of N1-P1 compared to the healthy ears. As regard MRI: The sensitivity and specificity of the SURI were 30% and 100% respectively in our results.

Conclusions: In patients with MD, cVEMP is a trustworthy, objective technique for assessing sacular dysfunction. According to saccular morphology, it indicates the degree of cochlear and vestibular hydrops. However, MRI is a reliable, impartial method for verifying the diagnosis of Meniere's illness.

Key Words: *MRI – Menière's disease – Endolymphatic hydrops – Tinnitus – cVEMP.*

Introduction

PROSPER Menière was the first person to find that vertigo might be originated from the inner ear more than 150 years ago. A clinical history consisting of low-frequency hearing loss characterized by being fluctuating & sensorineural, aural fullness with or without tinnitus, and vertigo episodes lasting for at least 20 minutes characterizes the pathology which named after him. A distinctive set of criteria for the diagnosis of Menière's disease (MD) was established in 1995 by the American Academy of Otolaryngology - Head and Neck Surgery (AAO HNS) **[1].**

According to the AAO-HNS Committee (1995), Meniere disease is classified into certain according to histologic proof done postmortem, definite, probable, and possible disease. The Bárány society developed more straight forward standards for diagnosing MD in 2015, reducing it to only two types: probable MD and definite MD **[2].**

Set of tests including audiovestibular, and electrophysiological assessment can be helpful in diagnosing MD; however, the lack of a definite diagnostic tests makes the diagnosis process become more difficult **[3].** Nowadays, inner ear magnetic resonance imaging (MRI) allow us to visualize the endolymphatic hydrops as described by Hallpike in 1938 based on studies depending on the histology of temporal bone **[4].**

Meniere's disease diagnosis depend on clinical history, audiological evaluation, VEMP and MRI. The otolith organs, which represent linear acceleration sensors and associated reflex pathways, are tested clinically in the VEMP test. Nonetheless, it has been believed that the utricular contribution to the ipsilateral VEMP responses is insignificant.5A specific cochlea protocol was used for the MRI. Two techniques were employed to diagnose Meniere's disease using MRI; quantitative method where results are classified as positive or negative for Meniere however numerical value in qualitative method goes in line with the sacculo-utricular ratio index or SURI grading system **[6].**

When the saccule looked to be the same size as the utricle in qualitative assessments, SURI was kept. The patients were then categorized as:

- Grade 0: Negative for MD without saccular abnormalities (SURI <1).

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- Grade 1: Saccule (SURI ≥1) when saccule size was equal to or more than utricle size.
- Grade 2: No visible saccule (MD positive in Grades 1 and 2).

We preferred the Qualitative method.

There is a regression link between the saccule size (Grades 1, 2, and 3) and the audiological value, which indicates if the sensorineural hearing loss is minimal, moderate, severe, or profound. The size of the saccule decreases as the patient's hearing loss rises.

Patients and Methods

Twenty adult patients of both sexes participated in this study, which was carried out at Cairo University, Kasr Al-Ainy Hospital, the Audiology Unit in the period from July 2019 to November 2021. The study was planned as a case study that was cross-sectional. The Research Ethical Committee of Faculty of Medicine authorized the study. (Ms-120-2019).

Inclusion criteria:

Adults of both sexes who have been diagnosed with Meniere's illness based on the standards set by the European Academy of Otology and Neurotology. There were 9 female and 11 male. They experienced hearing loss that may fluctuate, tinnitus, vertigo, auditory fullness, or a combination of these symptoms.

Exclusion criteria:

Individuals who have undergone previous ear surgery & individuals suffering from additional central or vestibular problems.

Methods:

All subjects were subjected to the following:

Full history taking: Complete medical history of vertigo that includes information on the onset, frequency, length, and course of attacks as well as treatment, aggravating and mitigating variables, nausea, and vomiting; Thorough medical history of auditory fullness & tinnitus that includes information on triggering and relieving variables, frequency associated with vertigo or not, and whether hearing loss is present.

Basic audiological evaluation:

Pure tone audiometry, which uses bone conduction from 500 Hz to 4 kHz and air conduction from 250 Hz to 8 kHz for octave frequencies.

Speech audiometry, which includes word discrimination score and speech recognition threshold.

Impedancemetry (acoustic reflex threshold, tympanometry 226 Hz probing tone).

Cervical VEMP (cVEMP):

The surface electrodes were positioned as follows: The inverting (negative) electrode was placed on the upper sternum (suprasternal notch), the remaining electrode (the ground electrode) was placed in the center of the forehead, and the active (positive) electrode was placed on both the upper two thirds of the sternocleidomastoid muscle, left and right. For every condition, two repeatable outcomes were recorded. To prevent weariness, subjects were allowed to unwind for 30 to 60 seconds in between each recording. To guarantee proper muscle tone, the subject was told to raise his head and tilt it away from the stimulated side throughout the recording.

A 500 Hz brief tone burst with a rarefaction polarity, a 4ms rise/fall period, and a 2ms plateau were used to elicit cVEMP responses through acoustic stimulation. 95dBHL of intensity was used, and TDH39 headphones were used to display it. The rate of stimulus repetition was 5.1 beats per second. Two hundred sweeps were the accepted number of replies. Depending on whether the P13-N23 biphasic response was present or missing, VEMP responses were classified as either present or absent.

MRI imaging will be carried out on 1.5 tesla MRI:

MRI was done using a specific cochlea protocol using an Achiva Philips 1.5T scanner with an 8-channel head coil. Axial, coronal, and sagittal oblique T2-Balance fast field echo (BFFE) weighted images were part of the treatment. The MR scanner parameters are as follows: field of view (FOV): 120-180mm; flip angle (FA): 50°-80°; repetition time/echo time: 5.42-12.25ms/2.42-5.9ms; matrix size: 512 x 512; the result is near-isotropic voxel sizes that range in length from 0.5 to 0.7mm.

Statistical analysis:

Version 23 of the Statistical Package for Social Science (IBM SPSS) was used to enter, edit, and review the data. The mean, standard deviations, and ranges of the quantitative data with a parametric distribution were displayed. Quantitative variables were also shown as percentages and numbers.

When the predicted count in any cell was found to be less than 5, the Chi-square test and/or Fisher exact test were used to compare the qualitative data between groups.

To evaluate the diagnostic accuracy of MRI, the receiver operating characteristic curve (ROC) was utilized in the qualitative mode. This included sensitivity, specificity, PPV, NPV, accuracy on cVEMP, and pure tone audiometry as the gold standard.

The allowable margin of error was set at 5%, while the confidence interval was set at 95%. Thus, the following *p*-value was deemed significant:

- Non-significant (NS) *p*-value >0.05.

- $p<0.05$ indicates significance (S).
- Highly significant (HS) is a p-value less than 0.01.

Results

This study was a cross sectional case study. They were 20 patients diagnosed with Meniere's disease divided into 11 males & 9 females.

Table (1): History of the studied patients.

History	No.= 20
Vertigo:	
Negative	0 (0.0%)
Positive	20 (100.0%)
Ear fullness:	
Negative	5 (25.0%)
Positive	15 (75.0%)
Tinnitus:	
Negative	3 (15.0%)
Positive	17 (85.0%)
Hearing loss:	
Negative	2 (10.0%)
Positive	18 (90.0%)

This table shows that 100% of cases had vertigo, 75% had ear fullness, 85% had tinnitus and 90% had hearing loss.

Table (2): Pure tone audiometry (PTA) results of the studied patients.

Pure tone audiometry (PT)	No.= 20
Severity:	
Normal	1 (5.0%)
Mild low frequency	9 (45.0%)
Moderate	6 (30.0%)
Moderately to severe	2 (10.0%)
Severe	1 (5.0%)
Profound	1 (5.0%)
Pure tone results:	
Negative	1 (5.0%)
Positive	19 (95.0%)

This table shows that (40%) of cases showed hearing loss in the right side, (35%) of cases were affected in the left side, (25%) of cases were affected bilaterally and (5%) of cases didn't show any hearing loss.

Table (3): cVEMP results of the studied patients.

cVEMP:	
Negative	2 (10.0%)
Positive	18 (90.0%)
Delayed P13:	
Negative	7 (35.0%)
Positive	13 (65.0%)
Delayed N23:	
Negative	9 (45.0%)
Positive	11 (55.0%)
Decreased amplitude:	
Negative	14 (70.0%)
Positive	6 (30.0%)

The previous table shows (90%) of cases had positive values for cVEMP and (10%) showed negative values (65%) of cases had delayed P13, (55%) had delayed N23 and (30%) of cases had decreased amplitude.

Table (4): MRI results of the studied patients.

MRI	No.= 20
Findings:	
- Scala tympani and scala vestibule in both sides are normal in size	13 (65.0%)
- High arched jugular bulb	4 (20.0%)
- AICA vascular looping	3 (15.0%)
MRI quantitative:	
- Negative for Meniere	10 (50%)
- Negative for Meniere with other pathologies	4 (20%)
- Positive for Meniere	2 (10%)
- Positive for Meniere with other pathologies	4 (20%)
MRI results:	
- Negative	14 (70.0%)
- Positive	6 (30.0%)
MRI results according to SURI (saccule Utricle ratio index) grading:	
- SURI Grade 0	1 (14.3%)
- SURI Grade 1	6 (85.7%)

The previous table shows that the MRI has a sensitivity of 30%; specificity of 100%.

Table (5): MRI results with & without other pathology.

	MRI results			
	Negative		Positive	
	No.	%	No.	%
Without other pathology	10	71.4	2	33.3
With other pathology	4	28.6	4	66.7

This table shows that (33%) of positive cases had other neurological pathologies and (28.6%) of negative cases had other neurological pathologies.

Table (6): Diagnostic accuracy of MRI results on cVEMP as a gold standard.

	cVEMP			
	Negative		Positive	
	No.	%	No.	%
MRI results:				
Negative	1	50.0	13	72.2
Positive	1	50.0	5	27.8
TP	5			
FP	1			
FN	13			
TP	5			
Sensitivity (+)	27.8%			
Specificity (–)	50.0%			
PPV	83.33%			
NPV	7.14%			
Accuracy	30.0%			

TP: True positive. PPV: Positive predictive value.
FP: False positive. NPV: Negative predictive value.
FN: False negative.
TN: True negative

The previous table shows that the MRI has a sensitivity of 27.8%; specificity of 50.0% and accuracy of 30.0% when measured on cVEMP as a gold standard.

Table (7): Diagnostic accuracy of MRI results on pure tone audiometry as a gold standard.

	Pure tone results			
	Negative		Positive	
	No.	%	No.	%
MRI results:				
Negative	1	100.0	13	68.4
Positive	0	0.0	6	31.6
TP	6			
FP	0			
FN	13			
TP	1			
Sensitivity (+)	31.6%			
Specificity (–)	100.0%			
PPV	100.0%			
NPV	7.14%			
Accuracy	35.0%			

TP: True positive. PPV: Positive predictive value.
FP: False positive. NPV: Negative predictive value.
FN: False negative.
TN: True negative

The previous table shows that the MRI has a sensitivity of 31.6%; specificity of 100.0% and accuracy of 35.0% when measured on pure tone audiometry as a gold standard.

Table (8): Comparison between patients with negative MRI and those with positive MRI regarding history of the studied patients.

History	MRI results		Test value*	*p*-value	Sig.
	Negative	Positive			
	No.=14	No.=6			
Vertigo:					
Negative	0 (0.0%)	0 (0.0%)	–	–	–
Positive	14 (100.0%)	6 (100.0%)			
Ear fullness:					
Negative	4 (28.6%)	1 (16.7%)	0.317	0.573	NS
Positive	10 (71.4%)	5 (83.3%)			
Tinnitus:					
Negative	3 (21.4%)	0 (0.0%)	1.513	0.219	NS
Positive	11 (78.6%)	6 (100.0%)			
Hearing loss:					
Negative	2 (14.3%)	0 (0.0%)	0.952	0.329	NS
Positive	12 (85.7%)	6 (100.0%)			

According to the *p*-value the previous table shows that there was no statistically significant difference between patients with negative MRI and those with positive MRI regarding history of the studied patients.

According to the *p*-value the previous table shows that there was no statistically significant difference between patients with negative MRI and those with positive MRI regarding cVEMP parameters.

Table (9): Comparison between patients with negative MRI and those with positive MRI regarding cVEMP parameters.

	MRI results		Test value*	*p*-value	Sig.
	Negative	Positive			
	No.=14	No.=6			
cVEMP:					
Negative	1 (7.1%)	1 (16.7%)	0.423	0.515	NS
Positive	13 (92.9%)	5 (83.3%)			
Site by cVEMP:					
Negative	1 (7.1%)	1 (16.7%)	0.880	0.830	NS
Right	4 (28.6%)	2 (33.3%)			
Left	8 (57.1%)	3 (50.0%)			
Bilateral	1 (7.1%)	0 (0.0%)			
Delayed P13:					
Negative	5 (35.7%)	2 (33.3%)	0.010	0.919	NS
Positive	9 (64.3%)	4 (66.7%)			
Delayed N23:					
Negative	8 (57.1%)	1 (16.7%)	2.780	0.095	NS
Positive	6 (42.9%)	5 (83.3%)			
Decreased amplitude:					
Negative	9 (64.3%)	5 (83.3%)	0.726	0.394	NS
Positive	5 (35.7%)	1 (16.7%)			

Table (10): Comparison between patients with negative MRI and those with positive MRI regarding pure tone audiometry parameters.

Pure tone audiometry (PT)	MRI results		Test value*	*p*-value	Sig.
	Negative	Positive			
	No.=14	No.=6			
Laterality:					
Right	6 (2.9%)	2 (33.3%)	0.340	0.844	NS
Left	5 (5.7%)	2 (33.3%)			
Bilateral	3 (21.4%)	2 (33.3%)			
Severity:					
Normal	1 (7.1%)	0 (0.0%)	3.862	0.569	NS
Mild low frequency	7 (50.0%)	2 (33.3%)			
Moderate	4 (28.6%)	2 (33.3%)			
Moderately severe	1 (7.1%)	1 (16.7%)			
Severe	0 (0.0%)	1 (16.7%)			
Profound	1 (7.1%)	0 (0.0%)			
Pure tone results:					
Negative	1 (7.1%)	0 (0.0%)	0.451	0.502	NS
Positive	13 (92.9%)	6 (100.0%)			

According to the *p*-value the previous table shows that there was no statistically significant difference between patients with negative MRI and those with positive MRI regarding pure tone audiometry parameters.

Discussion

Meniere's disease is a distinct condition of the inner ear that worsens over time and has an unknown etiology. The four main clinical signs of this illness are recognized to be attacks of vertigo, variable sensorineural hearing loss, tinnitus, with or without aural fullness. Nonetheless, the patient's characteristics are consistently somewhat unusual, particularly when they first appear. According to a prior study, auditory symptoms were consistently thought to be the most typical initial presentation of Meniere's illness. Vestibular symptoms and cochle-

ar symptoms generally always occurred separately **[7,8].**

According to its criteria, pure tone audiometry is the sole test required for both suspected and confirmed cases, and sensorineural hearing loss is the required symptom necessary for Meniere's disease diagnosis. Patients' hearing typically varies as the condition progresses, they may recover after each assault. However, Meniere's illness is a disorder in the inner ear that can be extremely debilitating and, in more severe cases, can cause vestibule disruption **[9].**

In the PURE TONE RESULTS (Table 2), even though Meniere's illness was identified over a century ago, researchers and medical professionals from all around the world are still searching for parameters to use as markers for diagnosis and assessment. Pure tone audiometry is the most widely used and widely accessible method of cochlear function and hearing loss measurement. It is a well-established technique that may be used to reflect the kind and degree of hearing loss. According to our findings, sensorineural hearing loss affected 19 of the 20 MD patients (95%) and ranged from mild to severe. In concurrence with Silva et al. **[10]** who found that 11 (36.70%) of the 30 patients with Ménière's disease had hearing loss on one side, 13 (43.30%) had hearing loss in both ears, and six (20%) were normal as regards hearing bilaterally. This means that 80% of cases had sensorineural hearing loss.

To date, the AAO HNS and Barany Society both support pure tone audiometry as the measurement for diagnostic criteria.

After the patients were diagnosed, the current study investigated cVEMP, and the results are displayed in Table (3). Of the 20 MD patients, 13 (65%) had delayed latency in p13, and 11 (55%) had delayed latency in N23. Additionally, 6 (30%) of the 20 MD patients had decreased amplitude.

The research conducted by Silva et al. **[10],** Katayama et al. **[11]** and Taylor et al. **[12]** is in concurrence with these results. According to Silva et al. **[10]**, the most common observation in the group with Meniere's disease was the extension of latency of the P13 and N23 waves. Endolymphatic hydrops was discovered to be substantially correlated with the loss of VEMP **[11].**

According to Taylor et al. **[12]**, there was a difference in cVEMP between MD and control groups that was statistically significant. However, these results lack correlation with data of Quatre et al. **[13]** in the literature that found abnormal cVEMP in only 8 DMD patients (22.9%).

Also, the findings by Zuniga et al. **[14]**, do not align with our result as they found there was no difference in cVEMP latencies between MD and control groups.

The results of MRI obtained from the present work reflect Quantitative approach: (Table 4) of the 20 cases, 6 (30%) tested positive for Meniere's disease, 20 percent also tested positive for other diseases, and 10 percent tested positive for Meniere's disease alone. Out of 20 cases, 14 (or 70%) tested negative for Meniere's disease; 20% of these cases also tested negative for other diseases, and 50% of the cases tested negative for Meniere's disease alone. Additional diseases included AICA vascular looping, which results in tinnitus on the affected side, or a high arched jugular bulb.

In the Qualitative approach: (Table 4), seven out of the twenty cases underwent SURI grading (sacculoutricular ratio index) according to Attye et al.6 SURI was kept when the saccule appeared equal to or larger than the utricle in qualitative evaluations. The seven patients were then categorized into three groups:

- Saccular abnormalities (SURI <1) absent in Grade 0.
- Grade 1: Saccule (SURI ≥1) when saccule size was equal to or more than utricle size.
- Grade 2: No discernible saccule.

Six positive cases (85.7%) were classified as SURI Grade 1 according to our findings. SURI Grade 0 was assigned to 1 out of 14 negative cases (14.3%), but SURI Grade 2 was not found, and an MRI without contrast was performed.

According to our findings, the SURI's specificity and sensitivity were 100% and 30%, respectively. Attye et al.; **[6]** Seo et al.; **[15]** Venkatasamy et al. **[16]** also provided evidence in support of this conclusion.

In the Qualitative way of SURI grading, Attye et al. **[6]** noted that 15 out of 30 patients in the MD group had a grade 1 result. The morphological sign (six on the right, nine on the left) was consistently observed on the side corresponding to the clinical illness. The proportion of SURI patients differed significantly from that of healthy people (p<0.01). The SURI had a 100% specificity and a 50% sensitivity, respectively.

Quatre et al. **[13]** stated that In the MD group, SURI was seen on MRI after intravenous gadolinium injection in 9 out of 25 affected ears, but not in any healthy ears. The SURI had a sensitivity of 36% and a specificity of 100%, respectively. According to Venkatasamy et al.16, patients with Meniere disease who underwent 3 T MRI using a T2-weighted steady state free precession (SSFP) sequence without injection of a contrast material had dilated saccules in 84% of cases, and 8% of patients had round saccules or no saccule at all.

Regarding the quantitative technique, in a specific MD group, 25.7% of patients obtained a positive MRI. Seo et al., *[15]* stated that in the specific Meniere's illness group, the 3D-FLAIR MRI amply confirmed endolymphatic hydrops with signal voids in the saccule (69%) and cochlea (81%) respectively. This study shows that in patients with Meniere's illness, endolymphatic hydrops could be seen with 3D-FLAIR MRI.

There was a distinction between our findings and those of Attye et al.6, the first reader discovered three patients with no apparent saccule (indicating grade 2) out of the fifteen MD patients without SURI (grade 1), while the second reader discovered two (grade 2). The absence of detectable saccule (indicating grade 2) has a specificity of 100% and a sensitivity of 10%. Venkatasamy et al., *[16]* reported that in Meniere illness, the saccule was dilated in 84% of cases; however, 8% of patients had a circular saccule or no saccule at all.

Regarding the patient's history, cVEMP, and pure tone audiometry characteristics, the results of the current study show that there was no statistically significant difference between patients with positive and negative MRIs.

These results support the research by Quatre et al. *[13]*, which demonstrated that there was no significant relationship between MRI and PTA or cVEMP in MD patients.

Conclusion:

cVEMP is a trustworthy, objective technique for assessing the degree of saccular morphology, cochlear and vestibular hydrops in MD patients.

Although MRI has a decreased sensitivity in MD (30%), it is still a valid objective approach for verifying the diagnosis of Meniere's disease.

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دور الرنين المغناطيسى فى تشخيص مرض المنيير

شملت الدراسة الحالية ٢٠ مريضا بالغايعانى من الدوار الحركى. كان الغرض من هذه الدراسة قياس اهميه الرنين المغناطيسى فى تشخيص مرض المنيير.

وقد خضعت جميع الحالات لأخذ التاريخ المرضى بالكامل، والفحص الأذنى الكامل، والتقييم السمعى الأساسى بما فى ذلك، اختبار الاتزان بالجهد المثار العضلى الدهليزى وعمل اشعه الرنين المغناطيسى وقد اظهرت الأذن المصابة تأخرًا كبيرًا فى مدة كمون موجة بى ١٣و ان ٢٣ فى الأذن المتأثرة وانخفاضًا ملحوظًا فيسعة موجة بى ١٣- ان٢٣ وكانت هناك نسبة اختلاف كبير بين نسبة الفرق فى السعة بين الاذنين بين الجانب المتأثر وغير المتأثر وقد اظهرت بعض الحالات فى الرنين المغناطيسى كبر حجم كيس الاذن الداخليه Saccule فى مرض المنيير.

وكشفت هذه الدراسة ان الرنين المغناطيسى له دور هام فى تأكيد تشخيص مرض المنيير.