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RESEARCH ARTICLE

Vibration-induced nystagmus in patients with chronic unilateral Meniere's disease

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Abstract

Background and Aim: Meniere's disease (MD) is one of the inner ear disorders associated with fluctuating hearing loss, vertigo, ear fullness, and tinnitus. Vestibular stimulation delas with the integrity of the peripheral vestibular system and may cause nystagmus due to the functional asymmetry between right and lef peripheral vestibular system. This study aimed to assess the vibration-induced nystagmus (VIN) in patients with chronic unilateral MD and investigate the effectiveness of this test in detecting the affected ear in these patients.

Methods: This study was conducted on 29 patients with chronic unilateral MD. For this purpose, spontaneous nystagmus (SN) and VIN at frequencies of 30 Hz and 100 Hz were recorded by videonystagmography test under five recording conditions. The vibratory stimulation was presented to both healthy and affected ears. Collected were analyzed in SPSS v.22 software.

Results: Vibratory stimulation compared to the unstimulated condition, revealed a significant difference in eye movements for both healthy and affected ears. Moreover, the difference between VIN and SN in the affected ear was much greater than in the healthy ear.

Conclusion: In patients with chronic unilateral MD, 100 Hz vibratory stimulation of the affected ear induces more reliable nystagmus than 30 Hz stimulation and unstimulated condition. The VIN test can be used for the evaluation of the vestibular system function and is a promising technique to detect the MD ear.

Keywords: Meniere's disease; spontaneous nystagmus; vibration-induced nystagmus; chronic; definite; vestibular vibrator

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Introduction

Meniere's disease (MD) is an inner ear disorder that affects the vestibular and cochlear structures and is associated with endolymphatic hydrops. The prevalence of MD is 50−200 per 100,000 people [1]. It is more common during the third to the seventh decade of life and mostly affects women. Increased production or decreased resorption of endolymph and alteration in endolymphatic sac (e.g. secretion, immune response) due

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to MD may cause hydrops. Clinical symptoms of MD include sudden vertigo, fluctuating hearing loss, tinnitus, and a feeling of fullness in the ear [1-3]. According to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS), the criteria for defining a definite MD are sudden vertigo at least twice lasting 20 minutes to 12 hours, low- to mid-frequency sensorineural hearing loss in one ear, oscillating aural symptoms (e.g. hearing, fullness, or tinnitus), and not better accounted for by another vestibular diagnosis [4]. Endolymphatic hydrops is the underlying pathophysiology of MD, which can affect different parts of the inner ear at different periods [5,6].

In MD, spontaneous nystagmus (SN) is expected due to the asymmetry of information within bilateral vestibular systems, but SN may not be observed due to differences in severity and chronicity. One method for challenging the vestibular system and provoking the asymmetry of vestibular function is vibratory stimulation [7,8]. In this method, the vibrator can stimulate the peripheral vestibular system including otoliths and semicircular canals, and induce nystagmus. This vibration-induced nystagmus (VIN) acts as a vestibular Weber test [9,10]. The VIN occurs simultaneously with the onset of stimulation without attenuation [11]. The vibrator can produce stimulation with different frequencies (30, 60, and 100 Hz). For optimal excitation, the vibrator should apply a suitable pressure of about 10 N or 1 kg for 20 seconds [9]. In vibratory stimulation, the vibratory stimulus is transmitted through the head to both labyrinths. The vibration applied to the mastoid on one side is an effective stimulus for the vestibular receptors in the labyrinth on both sides, resulting in phase-locking of irregular afferents from both labyrinths. Therefore, the mechanical effect transferred to the hair cells afferent causes excitation [9,12]. Dumas et al. in a study on normal people and those with a unilateral vestibular lesion to detect vestibular asymmetry reported that the vibratory stimulation at 100 Hz provided the strongest nystagmus compared to stimulation at 30 and 60 Hz, and the mastoid location was more efficient than the cervical and vertex sites [13]. In Shaabani et al.'s study on healthy subjects who received 30 and 100 Hz vibratory stimulation, the stimulation at 100 Hz induced higher nystagmus and the direction of nystagmus was towards the stimulated side [14]. In Lee et al.'s study on patients with MD in both acute and interictal phases, the effect of 100 Hz vibratory stimulation was investigated and the results showed that the VIN had a correlation with the degree of canal paresis and was towards the healthy ear [15].

The VIN can also show vestibular asymmetry in chronic disorders because it includes a high-frequency stimulation for the vestibular system [16]. Most of the previous studies on MD patients have been conducted during the acute phase of the disease and after stimulation of both ears, where the stronger VIN response of both ears is considered for analysis [15,17]. In most cases, patients are referred for vestibular assessment when they are in a chronic phase of MD; therefore, their vestibular assessment during the interictal period is important. However, SN may not be observed in this period because of central compensation [18,19]; hence, different frequencies are used to stimulate the vestibular system and show the asymmetry of its function. In this study, we aimed to compare the VIN test results (vestibular asymmetry) and SN in healthy and affected ears of patients with chronic unilateral MD (during the interictal period) exposed to 30 and 100 Hz vibratory stimulation.

Methods

This study that approved by the Ethics Committee of the University of Social Welfare and Rehabilitation Sciences (Code: IR.USWR.REC.1398.144), was conducted in the audiology clinic of Rofeideh Rehabilitation Hospital in Tehran, Iran on healthy and affected ears of 29 patients with chronic unilateral MD (15 female and 14 male) with a mean age of 41.03 ± 12.72 years. Their mean duration of MD based on a self-report was 2.31 ± 0.91 years. Patients were referred by ear, nose, and throat (ENT) specialists from Amir Alam Hospital and Abureihan day-care clinic. According to AAO-HNS, their severity of hearing loss was determined based on the mean pure-tone threshold at different frequencies

Table 1. Technical specifications of Synapsys Vestibular Vibrator VVIB

Vibration frequencies	**30, 60 or 100 hz ± 5%**
Vibration amplitude	1 mm
Classification	Class IIA
Standard	EN 60601-1 / EN 60601-1-2
Manufacturer	Synapsys s.a.

of 0.5, 1, 2, and 3 kHz [20,21]. The mean hearing loss was reported 44.12 ± 12.31 in the MD ear and 12.87 ± 6.47 in the healthy ear. The inclusion criteria were definite unilateral MD according to AAO-HNS guideline, having MD for at least one year, normal vision, having the last vertigo attack more than two weeks ago, no history of intratympanic injection to control vertigo attacks (e.g. gentamicin injection), and no history of any vision or neurological disorders. The patients were asked to avoid taking vestibular suppressants 48 hours before the study under the supervision of a physician. After signing an informed consent form by them, their evaluation was started.

The affected ear was determined based on the symptoms (tinnitus and fullness) and auditory assessments. After case history and audiometry assessments, patients were evaluated by videonystagmogheraphy (VNG) test for detecting SN and VIN. We used a hand-held vibrator (VVIB3F, Inventis, Synapsys, Italy) for vibratory stimulation at 30 and 100 Hz. Technical specifications of Synapsys VVIB are summarized in Table 1. The patients were asked to sit in a dark room and wear a VNG goggle with eyes open and looking straight forward when stimulation was presenting. Then, SN (unstimulated condition) was recorded as a baseline. Next, the mastoid of the affected and healthy ears was stimulated for 20 seconds by a 30 Hz vibrator, while the VNG goggle was recording eye movements. At the next step, vibratory stimulation was provided at 100 Hz. The average of three fastest slow-phase velocities (SPV) in 20 seconds was determined as the nystagmus intensity in all situations (i.e. unstimulated, and stimulated at 30 Hz and 100 Hz). According to the previous studies, a SN (or VIN) with SPV > 2 degrees per second is considered as an abnormal result [7, 13,22] and the concentration is only on the horizontal direction of VIN [7,17].

The analyses were carried out in SPSS v.22 software using descriptive (frequency, percentage, mean, standard deviation, maximum, and minimum) and inferential statistics. Shapiro-Wilk test revealed that the data distribution was not normal; therefore, Wilcoxon test was used for pairwise comparisons based on gender (male and female), age (< 40 and > 40 years), and duration of disease (< 30 and > 30 months). To determine the association between the direction of nystagmus and the lesion side, Chi-Square test was used. A $p < 0.05$ was considered as the significance level. To examine the effect of different stimulation frequencies on nystagmus, comparisons between unstimulated condition and stimulated condition at 30 Hz and 100 Hz and also between the results of 30 Hz and 100 Hz stimulations were first conducted in both affected and healthy ears. Then, the results of 30 Hz and 100 Hz stimulations were compared between the MD and healthy ears. The results can be used to assess VIN at different stimulation frequencies for better detection of the affected ear.

Results

Three out of 29 patients had SN in a dark room but were less than 2˚/s and indicating a normal nystagmus. The average intensity of SN and VIN recorded for MD and healthy ears are presented in Table 2. As can be seen, only in MD ear with 100 Hz stimulation, the average VIN was higher than 2˚/s (3.46˚/s) and, hence, was categorized as abnormal nystagmus. Therefore, vibratory stimulation at 100 Hz can be used to detect the affected ear. The results of pairwise comparisons between VIN at different frequencies and SN in healthy and MD ears are presented in Table 3. The results showed that the vibratory stimulation, especially at 100 Hz on the affected ear, produced significant results (i.e. unmasked the asymmetry of vestibular function). The difference between VIN (at 30 Hz and 100 Hz stimulation) and SN in both

Table 2. Mean (standard deviation), minimum, and maximum of spontaneous and vibration induced nystagmus slow phase velocities with 30 Hz and 100 Hz frequencies in healthy and involved ears of patients with Meniere's disease

	All patients (n = 29)		Males (n = 14)		Females (n = 15)		Age ≤ 40 yrs old (n = 14)		Age >40 yrs old (n = 15)		Duration of disease ≤ 30 months (n = 16)		Duration of duseae > 30 months (n = 13)	
	Mean (SD)	**Min-Max**	**Mean (SD)**	**Min-Max**	**Mean (SD)**	**Min-Max**	**Mean (SD)**	**Min-Max**	**Mean (SD)**	**Min-Max**	**Mean (SD)**	**Min-Max**	**Mean (SD)**	**Min-Max**
SN	0.18 (0.49)	0-1.70	0.11 (0.40)	0-1.50	0.25 (0.57)	0-1.70	0.25 (0.55)	0-1.50	0.11 (0.44)	0-1.70	0.22 (0.52)	0-1.50	0.13 (0.47)	0-1.70
VIN30D	1.29 (1.90)	0-5.93	0.94 (1.56)	0-5.17	1.62 (2.17)	0-5.93	1.29 (2.08)	0-5.93	1.30 (1.77)	0-5.17	1.28 (2.03)	0-5.93	1.31 (1.80)	0-5.17
VIN30H	1.03 (1.54)	0-5.10	0.43 (1.11)	0-3.60	1.59 (1.71)	0-5.10	0.98 (1.71)	0-5.10	1.07 (1.42)	0-3.60	0.88 (1.40)	0-3.60	1.22 (1.74)	0-5.10
VIN100D	3.46 (3.23)	0-11.67	2.34 (2.23)	0-6.80	4.51 (3.72)	0-11.67	3.20 (3.80)	0-11.67	3.70 (2.72)	0-8.07	3.54 (3.76)	0-11.67	3.37 (2.60)	0-8.07
VIN100H	0.90 (1.52)	0-4.40	0.63 (1.36)	0-3.87	1.14 (1.66)	0-4.40	0.90 (1.63)	0-3.87	0.89 (1.47)	0-4.40	1.23 (1.65)	0-3.87	0.48 (1.28)	0-4.40

SN; spontaneous nystagmus, VIN30D; vibration-induced nystagmus of disease ear with 30 Hz stimulation, VIN30H; vibration-induced nystagmus of healthy ear with 30 Hz stimulation, VIN100D; vibration-induced nystagmus of disease ear with 100 Hz stimulation, VIN100H; vibration-induced nystagmus of healthy ear with 100 Hz stimulation

Table 3. Comparison between VIN and SN with different stimulation of involved and healthy ears and also between VIN of involved and healthy ears for all participants, different genders (males and females), ages (less/more than 40 years) and duration of disease (less/more than 30 months)

	P-values of paired comparison*						
Comparison pair	**All**	**Males**	**Females**	**≤ 40 yrs old**	**> 40 yrs old**	**≤ 30 months****	**> 30 months****
VIN100D - SN	< 0.001	0.005	0.001	0.003	0.002	0.001	0.005
VIN100H - SN	< 0.001	0.109	0.043	0.066	0.075	0.018	0.285
VIN30D - SN	0.005	0.055	0.025	0.046	0.038	0.043	0.050
VIN30H - SN	0.008	0.285	0.011	0.173	0.027	0.091	0.043
VIN30D - VIN30H	0.658	0.310	0.937	0.735	0.937	0.484	1.000
VIN100D - VIN100H	< 0.001	0.022	0.001	0.013	0.002	0.007	0.005
VIN100D - VIN30D	< 0.001	0.047	0.004	0.010	0.014	0.004	0.041
VIN100H - VIN30H	0.733	0.593	0.530	1.000	0.575	0.326	0.237

VIN; vibration-induced nystagmus, SN; spontaneous nystagmus, VIN30D; vibration-induced nystagmus of disease ear with 30 Hz stimulation, VIN30H; vibration-induced nystagmus of healthy ear with 30 Hz stimulation, VIN100D; vibration-induced nystagmus of disease ear with 100 Hz stimulation, VIN100H; vibration-induced nystagmus of healthy ear with 100 Hz stimulation

*Wilcoxon

**Duration of disease

MD and healthy ears were significant, where the difference between them in MD ear was more significant than in healthy ear. The mean difference between VIN and SN was more than 2 only at 100 Hz frequency in the MD ear and therefore, the direction of VIN will be investigated only by 100 Hz stimulation on MD ear. Comparison of healthy and MD ears at different stimulation frequencies revealed that the difference between VIN of healthy and MD ears was significant only when 100 Hz stimulation was provided.

Moreover, the results showed an inverse relationship between the direction of nystagmus and lesion side at 100 Hz frequency applied to the affected ear ($X2 = 19.86$, $p < 0.001$). Therefore, the direction of fast phase eye movement was towards the healthy ear. At 100 Hz frequency in the lesion side, fast phase nystagmus was towards the right side in 20 out of 23 patients with MD in the left ear, while it was towards the left side in three out of six patients with MD in the right ear. In MD ear, VIN (> 2˚/s) was recorded in 18 (62%) and 8 patients (27.5%) using stimulation at 100 Hz and 30 Hz, respectively, while in healthy ears, abnormal VIN was recorded in six 6 (20.6%) and 9 patients (31%) when 100 Hz and 30 Hz stimulation, respectively.

To investigate the effect of confounding factors (age, gender, duration of disease), we re-analyzed the data based on these factors. Comparison between the results based on these factors are presented in Table 3. As can be seen, gender had no effect on the VIN of the MD ear. Stimulation at 100 Hz frequency caused significant changes in the MD ear of both male and female groups. At 30 Hz frequency on MD ear, the results showed that female factor had a significant effect, while male gender was close to having significant effect ($p = 0.055$). Age had no effect on the VIN of the MD ear. Stimulation at 100 and 30 Hz frequencies caused significant changes in MD ears of both < 40 and > 40 years age groups. However, the age difference did not affect the results of the MD ear. The duration of

disease had no effects on the VIN of the MD ear, either. Stimulation at 100 and 30 Hz frequencies caused significant changes in MD ears of both < 30 and > 30 months disease duration groups. Overall, the disease duration had no effect on the results of MD ear.

Discussion

In this study, using the VIN test, the effect of vestibular stimulation on 29 patients with unilateral MD was examined and compared with SN. Vibratory stimulation is a useful and valuable method to evaluate the asymmetry of vestibular function [23]. Previous studies have shown that stimulation of mastoid bone is more efficient than stimulating the cervical and vertex sites [10,12]. It reveals a stronger response; therefore, we stimulated mastoid bone in this study. Vibratory stimulation is useful for the evaluation of the vestibular system when it is impossible to use caloric testing due to external canal or middle ear occlusion/effusion. In addition to vestibular evaluation, VIN can be used instead of head impulse and head-shaking tests in patients with vascular or neural damage in the neck who are not able to move their heads [12,14].

We used frequencies of 30 and 100 Hz for vibratory stimulation to evaluate the vestibular system and to record eye movements. Mean values obtained for SN, VIN of healthy ear at 30 Hz and 100 Hz frequencies, and VIN of MD ear at 30 Hz and 100 Hz frequencies were 0.18, 1.03, 0.90, 1.29, and 3.46˚/s, respectively. The vibratory stimulation compared to the condition where no stimulation was performed (SN), made significant changes in both healthy and MD ears. However, the changes in the MD ear were greater than those in the healthy ear ($p < 0.05$). The difference between VIN and SN was greater than two degrees per second when 100 Hz stimulation was applied to the MD ear. Therefore, it is possible to recognize the asymmetry of vestibular function in the affected ear after vibratory stimulation at 100 Hz. With 100 Hz stimulation on MD ear, abnormal nystagmus was recorded in 18 (62.1%) out of 29 MD patients, while with 30 Hz stimulation, it was observed in 8 (27.6%) out of 29 MD patients; none of MD patients had abnormal spontaneous nystagmus. Therefore, by using 100 Hz stimulation, higher asymmetry was reported which may help to detect the affected ear, better. The higher nystagmus obtained by 100 Hz stimulation in this study is consistent with the results of Dumas et al. and Shaabani et al. who reported that 100 Hz stimulation exerted more energy to the labyrinth structures and made stronger nystagmus [12-14].

Regarding the direction of nystagmus using 100 Hz stimulation, results revealed that there is a negative relationship between nystagmus direction and MD in the affected ear. In 23 out of 29 patients, the direction of nystagmus was towards the healthy ear. The direction of VIN is usually towards the healthy ear in patients with peripheral vestibular disorder [10,12]. In studies by Ohki et al. and Kwang Hong et al., the direction of VIN in most of MD patients was also towards the heathy ear [16,17]. According to these studies, the direction of VIN in the chronic phase is related to the severity of vestibular weakness. Therefore, their results are consistent with our findings. In the current study, the detection rate of MD after applying vibratory stimulation at 30 and 100 Hz was 27.5% and 62.1%, respectively; therefore, 100 Hz stimulation can help provide a higher discrimination rate between healthy and affected ears in patients with unilateral MD, and VIN can be used in a battery of tests for evaluation of MD.

One limitation of this study was the difference between forces applied to both ears. Moreover, the exact location of stimulation was different between subjects which can cause lead to the application of different forces on them. To prevent these problems one examiner performed the tests on all participants. Future studies should consider these limitations. Further studies are recommended to follow-up the MD patients after vibratory stimulation in each disease phase, which can be helpful to have information of the vestibular system in each phase of the disease.

Conclusion

The use of a higher frequency for vibratory stimulation increases the vibration-induced nystagmus. Vibratory stimulation at 100 Hz can help

to detect the Meniere's disease (MD) ear and the asymmetry of vestibular function with more accuracy. It can be used for detecting the affected ear for intratympanic injections in patients with unilateral MD with normal audiograms or with no spontaneous nystagmus.

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Conflict of interest

The authors declared no conflicts of interest.

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