Sensitivity of caloric test versus video head impulse test for detection of vestibulo-ocular reflex abnormalities in Meniere's disease

Original Article

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ABSTRACT

Purpose: This study aimed to evaluate vestibulo-ocular reflex (VOR) in subjects with Meniere's disease using caloric test and video head impulse test (vHIT).

Patients and Methods: A case control study included 120 subjects: 60 normal subjects (control group) and 60 subjects diagnosed as Meniere's disease (MD) according to (AAO-HNS) 2015 criteria with hearing loss (study group). All subjects enrolled in this study underwent: Detailed clinical history, audiological and vestibular evaluation. vHIT and bithermal caloric test were done to evaluate the vestibulo-ocular reflex.

Results: The entire control group had normal vHIT, and VNG (bithermal caloric test) results. In the MD group: vHIT reveals (37%) abnormality: (28% for low gain & 8% for saccades). But in bithermal caloric test; unilateral canal paresis was detected in (40%), and bilateral canal paresis in (15%). Thirty three percent had abnormality in both caloric and vHIT.

Conclusion: Caloric test is more sensitive in detection of VOR abnormalities in Meniere's disease. Results of caloric test and, vHIT show discrepancy but complementary to each other. Adding vHIT to the VNG is recommended for diagnosis of vestibular disorders.

Key Words: Caloric test, Meniere's disease, Vertigo, Vestibulo-ocular reflex, vHIT.

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INTRODUCTION

Meniere's disease (MD) is a chronic sickness that is manifested by symptoms of episodic vertigo, tinnitus, aural fullness, and fluctuating sensorineural hearing loss. Other manifestations may include hyperacusis, diplacusis, imbalance, and drop attacks. The pathophysiology of MD till now is not clearly explained. It was formerly concepting that Meniere's disease was closely correlated with endolymphatic hydrops (EH), where endolymph increases due to the presence of obstruction in the endolymphatic sac[1, 2].

Caloric testing provides an indirect method to measure vestibular function based on recording the eye movements in response to vestibular stimulation. Caloric testing focuses only on the horizontal vestibulo-ocular reflex (VOR) because the lateral canal is the easiest canal to be stimulated, there are several reliable methods used nowadays for recording horizontal eye movements[3]. Although caloric stimulation offers an assessment of the horizontal semicircular canal (SCC) only, yet it is a valuable tool as it can measure the function of each labyrinth separately. The equivalent speed of stimulation for this test is a very low frequency and analogous to head movements of 0.003 Hz[4].

Video Head-Impulse Test (vHIT) system can measure the gain of the VOR and register eventual refixation saccades during stimulations (head impulses) that acquire high velocity (>150º/s) and acceleration (1-16 Hz). vHIT is appropriate for both initial evaluation and follow-up of the subjects of MD, as has been presented in MD patients with rapid fluctuations in vestibule function[5]. vHIT assesses high-frequency stimulation with VOR represented at the initial post-stimulus period (<100 ms). However, caloric assesses low-frequency stimulation with smooth pursuit, velocity storage, and the optokinetic nystagmus providing important help to the VOR. So, the caloric test result is very informative[6]. This study aimed to evaluate VOR in subjects with Meniere's disease using the caloric test and vHIT.

PATIENTS AND METHODS:

This study was conducted in Menoufia University Hospital. It was conducted from January 2018 to December 2020. The study groups included 120 subjects. There were two study subgroups, each comprised of 60 subjects. Group A (MD group) represented those diagnosed as Meniere's disease and consisted of (31 males and 29 females), with age ranged from 21 to 62 years with a mean ages of 38.4

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years ± 10.5, and group B (control group) represented those healthy volunteers, with no history of vertigo, nor a past history of vestibular insult, and had normal VNG test finding, consisted of (38 males and 22 females), aged 19 to 60 years with a mean age of 35.5 ± 10.0. Informed consent was obtained from all subjects participating in the study, and the study was approved by the Ethics Committee at Faculty of Medicine Menoufia University (2017). The entire MD group met the candidacy selection criteria for Meniere's disease according to (AAO-HNS) 2015 criteria. On testing, the subjects would have been free from vertigo for at least one week. The exclusion criteria were; Patients unfit for sudden high-velocity head movements (e.g., Advanced Cervical Spondylosis, Cervical Radiculopathy), Patients with ophthalmological pathologies preventing the ability to fixate on the visual target during vHIT. Presence of other otological disorders (e.g., Otitis media with effusion, Chronic suppurative otitis media, etc.).

All subjects enrolled in this study underwent the following: Detailed clinical history, audiological and vestibular evaluation consisting of pure-tone audiometry, using Madsen audiometer Orbiter 922. Immittancemetry using GSI 38, Videonystugmography using NysStarTM VNG Difra system, and vHIT using Head StarTMvHITDifra system. For vHIT, calibration is performed via dots on which the subject is asked to fixate for 1s in each direction. Subjects were instructed to avoid blinking, relax the neck muscles, and maintain their eyes open, to enable the software to keep the focus on their pupil, and the procedure of vestibulo-ocular testing is initiated. vHIT analysis depended mainly on VOR gain and refixation saccades presence[7]. For VNG, the procedure recommended by Shepard and Telian[8] was followed. For Caloric, the bithermal caloric test was performed in line with Fitzgerald and Hallpike. Procedure recommended by the British Society of Audiology[9]. The device used in the study considers that Canal Paresis (CP) is significant when equal to 25% or more.

%CP=[(RC+RW)–(LC+LW)/(RC+RW+LC+LW)] X100.

(CP=canal paresis, RC=right cool, RW=right warm, LC=left cool, LW=left warm).

The data collected were reviewed, coded, and statistically analyzed using SPSS program (statistical package of social science; SPSS Inc., Chicago, IL, USA) version 20 for Microsoft Windows. Statistical analysis was performed using Student's t-test was used to test quantitative data. The Chi-square test was used for comparing categorical variables. Correlation coefficient test (r) was used to detect correlation between 2quantitative variables. Kappa testing was used to detect the degree of correlation between test results. The significance level was set at the *p-value* ≤ *0.05*.

RESULTS:

The demographic distribution of the control and MD group, are disclosed in Table I. There were non-significant differences between the control and the MD groups in both age and sex distribution (*p>0.05*).

A-Clinical picture of Meniere's disease:

The main complaining symptoms were vertigo in (57%) of subjects followed by tinnitus in (28%), then hearing loss in (15%). positive family history in 12% of subjects. Migraine in 15% of the MD group and 8% of the control group which was non-significant (*p = 0.28*).

The audiograms of MD group revealed bilateral hearing loss affection in (35%), right-sided hearing loss in (33%), and left-sided hearing loss in (32%). There was a weak positive significant correlation between the hearing thresholds (average frequencies 0.5,1,2 kHz) and the duration of Meniere's disease (r = 0.23, *p = 0.03*).

B-VNG, Caloric, and vHIT results in the study subgroups:

The entire control group had normal vHIT, VNG, and bithermal caloric test results.

VNG in the MD group: No abnormalities were recorded other than canal paresis.A unilateral canal paresis was detected in 24 subjects (40%) of the MD group (6 right and 18 left ears). Six subjects (10%) had contralateral canal paresis to the hearing loss side. Bilateral canal paresis was detected in 9 subjects (15%)

Thirty-seven percent of the MD group disclosed abnormalities in vHIT. The abnormalities were in the form of low gain only in 17 (28%). The low gain was affecting horizontal canal in 11 (18%), anterior canal low gain in 6 (10%), posterior canal low gain in 9 (15%) of MD subjects. Presence of corrective saccades only in 5 (8%), both low gain and corrective saccades detected in 22 (37%). Table 2 discloses the results of caloric and vHIT in MD group. There was absent correlation between vHIT and canal paresis (*p = 0.55*).

Table 1: Demographic data distribution among studied groups

	MD N = 60	Control N = 60	*P value*
Age (years)			
Mean±SD	38.4±10.5	35.5±10.0	0.13
Sex			
Male	31 (52%)	38 (63 %)	0.20

SD Standard deviation
There was no significant difference between both groups regarding age (Student T test) and sex (Chi square test).

Table 2: vHIT and caloric test in Meniere's disease group

		Caloric test		Total
		Normal	Abnormal	
vHIT	Normal	16 (59%)	22 (67%)	38
	Abnormal	11 (41%)	11 (33)	22
Total		27	33	

Normal gain (= or>0.8 for horizontal, and = or>0.7 for vertical). Abnormal gain (<0.8 for horizontal, and <0.7 for vertical).
Abnormality of vHIT include reduced gain or presence of corrective saccades (covert or overt).
Cut off point for caloric is 25%.
Kappa test was done k =0.07 which is insignificant (*p =0.55*).

DISCUSSION

The present study reported abnormal caloric response in 55%, and abnormal vHIT in 37% of subjects of MD. Kappa test showed no agreement between caloric and vHIT test results. For long time, VNG has been considered the cornerstone test for the evaluation of the dizzy patients.

vHIT is a test acquiring rapid spread of popularity for testing VOR in dizzy patient; due to its reliability, accuracy, convenience[10].

Caloric test is concerned with low acceleration. Although the stimulus is non-physiologic, Caloric testing can stimulate each ear separately. It can detect the affected side in MD with variable accuracy[11,12,13].

vHIT is concerned with high acceleration and is considered more physiologic. Abnormal vHIT findings are noticed in only 40% of patients who have abnormal findings in caloric tests, the rate of abnormal vHIT findings is 10% in ears with normal caloric responses[14]. vHIT is more specific but less sensitive than caloric tests but can provide quite useful information[14,15].

These tests clarify different responses of stimulating crista ampullaris. As in cochlear disorder, the participation of the SCC can lead to specific frequency dysfunctions: whereas vHIT represents stimuli at about 5 Hz, Caloric test stimulus is around 0.003 Hz. Because these tests estimate different sections of the semicircular canals, both are needed for a comprehensive vestibular evaluation[16,17,18,19].

Perez and Lopez reported a paradoxical reaction of the VOR response to different angular accelerations in MD patients had been noted vestibular weakness in 35% in head impulse and 60% in caloric tests[20].

Lee *et al.* reported 81% of subjects of MD would exhibit low gain in at least one of SCC during the vertiginous attacks. In between the attacks, the gain returns to normal in most cases. On the contrary, canal paresis may remain abnormal in between the attacks[21]. In the present study, assessment was done in between attacks. This may partially contribute to the discrepancy between test results.

The caloric test and vHIT results are various and complementary to each other. They can be considered tests that depict the tonotopy of the crista ampullaris relying on the stimulation frequency. In some studies, the Caloric testing was more sensitive to vestibular dysfunction. So, vHIT alone is not an adequate diagnostic tool for MD[4]. While other authors recorded a linear correlation between vHIT gain and Caloric test side asymmetry. To observe an abnormal vHIT result, the asymmetry should be about 40%[22,23].

Halmagyi *et al*.[24] reported that abnormal caloric test (in MD), results from mechanical dysfunction within the dilated SCC rather than sensory abnormality in the VOR. In healthy ears, thermal stimulation in caloric testing causes the hydrostatic pressure to prompt a cupular deflection. However, in MD patients, if the hydropic expansion of the duct permits local flow into the duct, it will recede the hydrostatic pressure caused by thermally induced density variation and eliminate

or diminish the deflection of the cupula. Thus, the diminutive caloric response in MD was due to the hydropic dilation of the endolymphatic duct without compromising the VOR responses in vHIT[25,26]. However, Gurkov *et al.* demonstrated that EH in the SCC correlated with reduced caloric function[27].

Carey *et al.* also gave several potential illustrations for the conflicts between the results of vHIT and caloric in MD[12]. They proposed that MD may cause a differential reduction in the sensitivity of vestibular nerve afferents in the diseased ear during responses to different frequencies of stimulation. The low velocity and acceleration of endolymph movement resulting from a caloric stimulus would then be insufficient to generate a normal response while the high velocity and acceleration of endolymph movement resulting from a vHIT would be adequate to generate a compensatory eye response. A second possibility suggested was that response to head velocity by vestibular nerve afferents in MD is abolished for stimuli of both low and high frequencies, but the central gain for inputs of high frequency is greater[12].

The variation between the vHIT and Caloric test is based on the alterations documented by the VOR. Two pathways are involved in VOR activation: direct -and- fast (type I neuron), and indirect -and- slow (type II neuron) pathways. The latter is responsible for storage velocity. Storage velocity depicts the characteristic of the vestibular system that preserves response from the peripheral organ even after hair cell stimulation has stopped. This capacity results from the joint activation of the primary and secondary neurons which show different characteristics of depolarization and activation. The direct pathway consists of 3 neurons that transmit the signal from the SCCs directly to the ocular effector muscles with no modulation. The indirect pathway also receives information from the SCCs but exhibits a raised time constant for discharge and charge. In this way, the neurons at the indirect pathway ‘‘store’’ the energy gained by the peripheral organ stimulation and keep discharging even after the stimulation has stopped[4]. Caloric stimulus is a typical model of storage velocity. It produces a nystagmus response which starts nearly 20 seconds following the beginning of the stimulation, peaks at about 40 seconds then reduce until it vanishes at about 2 minutes (type II neurons). However, the vHIT response depends mainly on the direct pathway of 3 type-I neurons[28].

CONCLUSIONS

Caloric test is more sensitive in the diagnosis of VOR abnormalities in Meniere’s disease. vHIT results help in the diagnosis of Meniere’s disease. Adding vHIT to the VNG in diagnosing MD and supposedly other vestibular disorders would increase the detection ability of the test battery. The vHIT and caloric test results show discrepancy but complementary to each other.

CONFLICT OF INTEREST

There are no conflicts of interest.

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