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ORIGINAL ARTICLE

Videonystagmography (VNG) Findings in Patients with Vestibular Migraine: A Hospital-Based Study

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Abstract Vestibular migraine (VM) is a disorder where vestibular symptoms are causally related to migraine. It is one of the common causes of recurrent vertigo in the general population. It has often remained as an under-recognized condition with largely unknown pathophysiology. Accurate diagnosis is essential in vestibular pathologies as it determines the management in each case. The aim of this reasearch was to compare vestibular functions of patients with VM and healthy controls using VNG and to study the VNG patterns of patients diagnosed with VM. This study is a retrospective analysis of subjects who have undergone videonystagmography (VNG) testing from October 2018 to October 2020 done in a tertiary referral hospital. Those patients satisfying diagnostic criteria for-vestibular migraine were subjected to VNG testing. Group 1 consisted of 35 vestibular migraine patients, and group 2 consisted of 35 age and sex-matched healthy controls. Statistical comparison of parameters of these groups were made.We found that the mean age of VM patients in the study was 40 ± 9.9, and the females were predominantly affected (Female: Male = 2.8:1). Statistically significant difference was obtained between VM patients and healthy controls in vertical smooth pursuit and in the positional tests using the Dix Hallpike test on the right side (p value $<$ 0.05). We conclude that a careful study of VNG patterns can serve as a valuable tool in hard to diagnose cases of vestibular migraine.

Keywords Vestibular migraine · Videonystagmography (VNG) · Vertigo · Headache

Introduction

Vestibular migraine (VM) is a type of migraine characterized by vertigo, dizziness and imbalance apart from the typical migraine symptoms. It is a broad term used to describe episodic vertigo or vestibular symptoms attributed to migraine. The other terms used to describe this condition are migraine-associated dizziness, migraine-related vestibulopathy, migrainous vertigo and benign recurrent vertigo.

VM is regarded as the second most frequent cause of recurrent vertigo and is estimated to occur in 9% of migraine patients [1]. As with migraine, VM has a female preponderance and the usual onset of symptoms is between 8 and 50 years of age or even older. Clue to the diagnosis of this condition is given by the presentation of migraine symptoms and exclusion of other similar disorders. However, the exact diagnosis often remains difficult in a clinician's perspective because of its varied clinical presentation and absence of "typical" migraine headache during vestibular episodes [2].

Despite the various classification efforts, VM remains clinically under diagnosed [3]. There has been a long-standing interest among the clinicians dealing with

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vestibular pathologies to study the etiology and pathogenesis of VM. However, the exact cause of VM is still not fully understood. The uncertainties around diagnosis have also made advances in the treatment modalities difficult. Previous studies of vestibular function in the giddiness-free period in VM patients have shown various inconsistent abnormalities, indicating the involvement of both central and peripheral vestibular structures [4]. Familial occurrence has been reported in some VM patients, with an autosomal dominant pattern of inheritance and a decreased penetrance noted in men [5]. There could be multiple affected individuals within a family, some with VM and some other migraine variants. There exists no pathognomonic clinical sign or laboratory test that can prove the diagnosis of VM conclusively. Vestibular laboratory abnormalities are quite variable among VM patients, which may reflect inconsistent findings regarding the existence of a peripheral vestibular component. However, vestibular testing is still helpful in ruling out other disorders considered in the differential diagnosis of VM.

Videonystagmography (VNG) is probably the most effective tool currently available to analyze vestibular and balance system. Battery of tests performed in VNG, along with carefully elicited history, helps to clinch the diagnosis in most cases.

Our study aims to compare vestibular functions of patients with VM and healthy controls using VNG. This study also intends to perform comprehensive evaluation of the vestibular functions of patients diagnosed with VM using VNG patterns. In cases where Magnetic Resonance Imaging of brain was taken as part of the assessment was also incorporated into the study to draw suitable conclusions.

Materials and Methods

This case control study was conducted from October 2018 to October 2020. The study was approved by the institutional ethics committee (IEC). The patients satisfying the diagnostic criteria of VM were referred for VNG testing [6]. European CE certified Cyclops BalanceEye device was used for VNG testing. Informed consent was taken from the participants before commencing VNG testing.

Subject Details

Inclusion Criteria

VM patients between the ages 20–60 years.

Exclusion Criteria

Neck problems such as arthritis, neck pain, spasms, surgery, trauma, reduced range of motion, posture problems, uncorrectable visual impairment and neurological disorders.

Study Groups

Two groups were recruited—Group 1 comprising of 35 VM patients and Group 2 comprising of 35 age and gender matched healthy controls. VM patients in the study also included cases that could not be successfully treated by the primary care physicians. The patients who used medication underwent at least 3 days washout period from antivertiginous, anti-epileptic medication and triptans before vestibular testing. This was essential to eliminate any possible effect of these drugs in altering the test results.

All patients underwent pure tone audiometric evaluation and VNG testing. The use of Infrared (IR) cameras in the VNG increased the specificity and sensitivity of each tests. The description of how each parameter of VNG was assessed is described below:

Saccades: The subject is instructed to look at the white square target as it moves to different locations. The subject has to keep the eyes fixed on the target as long as it stays in one location. The saccades are assessed in both horizontal and vertical planes separately.

Smooth pursuit: This is done by asking the subject to track the white square target as smoothly as possible while it oscillates across the screen. The smooth pursuit is assessed in both horizontal and vertical planes separately.

Optokinetic test: The subject is instructed to stare at the stimulation screen which moves from left to right, right to left, top to bottom and bottom to top. Each of these is assessed for 30–60 s.

Spontaneous nystagmus: Spontaneous nystagmus is assessed by asking the patient to look straight ahead. Assessment in the dark is facilitated by closing the visor of the infra red goggles.

High-frequency headshake: The range of head movement of the patient is assessed by turning the head to left and right. The head is then pitched forward by 20–30 degrees to bring the lateral canals into the horizontal plane. The recording is done for 10 s before head shaking to document any baseline nystagmus. Move the head along with the goggles to the right and left, aiming for two cycles per second. The head should move 20 degrees to the right of midline and 20 degrees to the left of midline. Stop after 20 cycles. Record during the head shaking and for 1 min after stopping the head shaking. It is important to record for one full minute following head shaking so that any late response or biphasic nystagmus response is not missed.

Hyperventilation: Any history of seizure disorders or cardiovascular problems, especially arrhythmias form contraindications for testing by this method. This test is performed under medical supervision as hyperventilation can induce seizures in susceptible individuals. The subject should take rapid and deep breaths with mouth open at the rate of one breath per second for 30 s. Following this, the subject is instructed to breathe normally. Continue the recording during the hyperventilation and for 60 s following the hyperventilation. If nystagmus persists, recording is continued till the nystagmus disappears or reaches baseline level. In case of discomfort at any point during the test, stop hyperventilation and breathe normally.

Gaze test (with fixation): Visor is open. The subject is instructed to fixate on the white square target that appears on the screen serially at different locations (Centre, Left, Up, Right Down).

Gaze test (without fixation): Visor is closed. Instruct the subject to look steadily in the direction indicated verbally by the examiner (Centre, Left, Up, Right and Down).

Dix Hallpike test: Right and left ears were assessed separately. Recordings were done for Sit head right, Supine head extension and right and Sit head right. Similarly, for the left ear, Sit head left, Supine head extension and left and Sit head left recordings were done.

McClure Pagnini test: Recordings were done for Sit to supine, Right lateral, Supine head neutral, Left lateral and Supine head neutral positions.

Head Position tests: Recordings were done for Yaw right, Yaw left, Pitch forward, Pitch backward, Roll right and Roll left positions.

Subjective midpoint: The subject has to bring the vertical line to the middle position between the two eccentrically placed white bars. This was done by using the right and left arrows on the remote to move the line right and left respectively. Subjective midpoint was assessed in left to right, right to left and blank background.

Subjective Visual Vertical (SVV): SVV is assessed by asking the subject to place the given line along the vertical orientation. The keys in the remotes are used to turn the line clockwise and anticlockwise. SVV assessed in clockwise, anticlockwise, and blank background.

Head Impulse Test (HIT): The subject is instructed to keep looking at the central dot that blinks red and green on the screen. A rapid, small amplitude impulse is given to the head to the right and left without touching the goggle. At the end of the sideways impulse of twenty degrees, slowly bring the head back to the neutral position. About five impulses in each direction are recorded. The direction of testing is randomly varied to prevent the subject from guessing the direction of head impulse.

Statistical analysis was performed using IBM SPSS version 20.0 software. Categorical variables were expressed using frequency and percentage. Numerical variables were presented using mean and Standard Deviation. Chi-square test was used to study the statistical significance of the association of all VNG parameters between VM patients and healthy controls. Also Chi-square test with continuity correction was used in the case of cells with expected count less than 5. A p value of < 0.05 was considered to be statistically significant.

Results

The mean age of VM patients in the study was 40 (Standard Deviation—SD = 9.9). The maximum proportion of the patients was in the age group 31 to 40, i.e., 16 patients (45.7%) (Fig. 1). The VM patient group comprised of 9 males (25.7%) and 26 females (74.3%) (Fig. 2). VM patients showed female preponderance with the female to male ratio being 2.8:1. For the visual—oculomotor function, eye movements were assessed for saccades, smooth pursuit, and optokinetic movements. For smooth pursuit, abnormal movements were seen in the horizontal direction

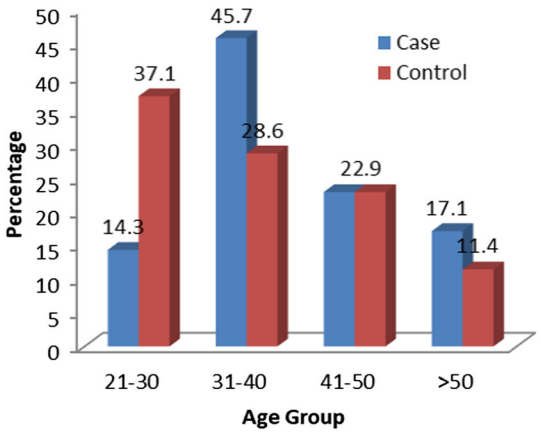

Fig. 1 Age distribution

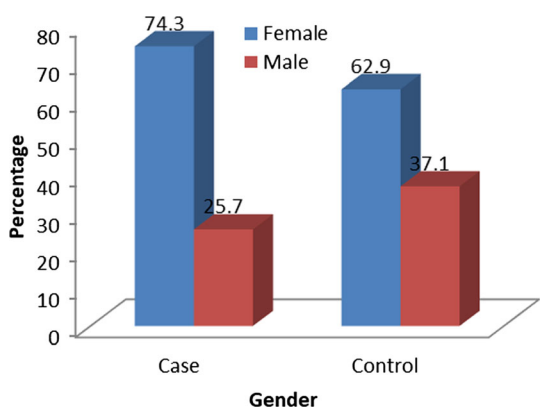

Fig. 2 Gender distribution

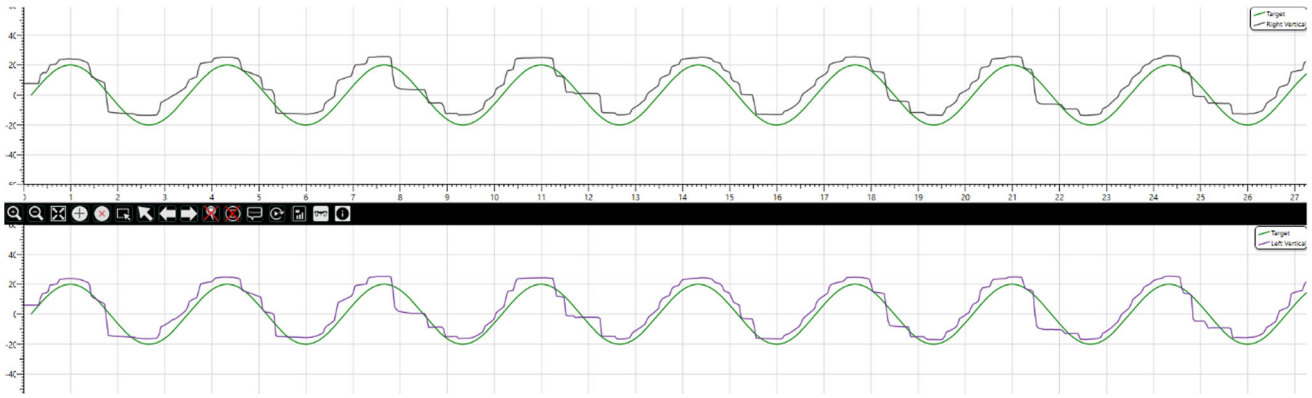

Fig. 3 Vertical saccadic pursuit bidirectional

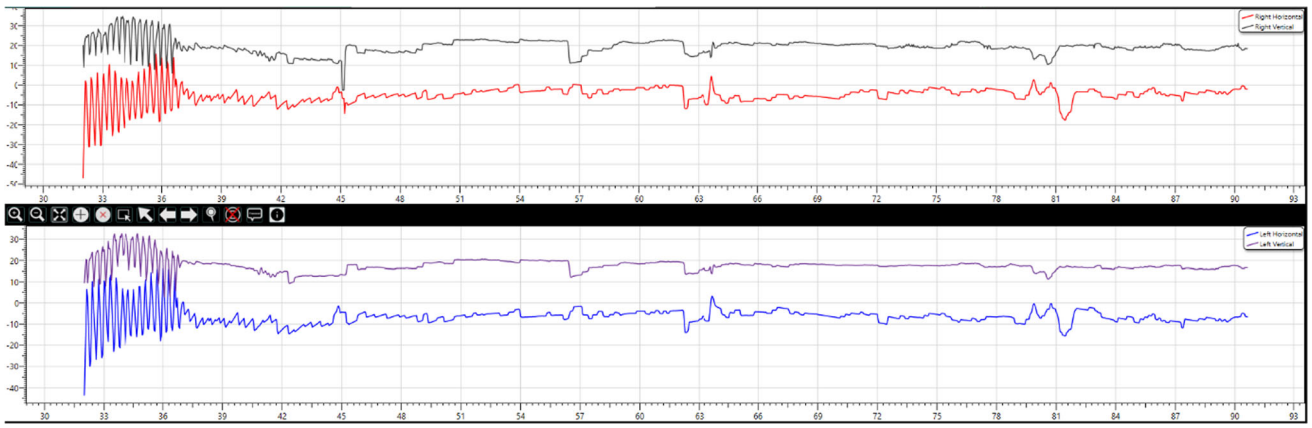

Fig. 4 High frequency head shaking nystagmus

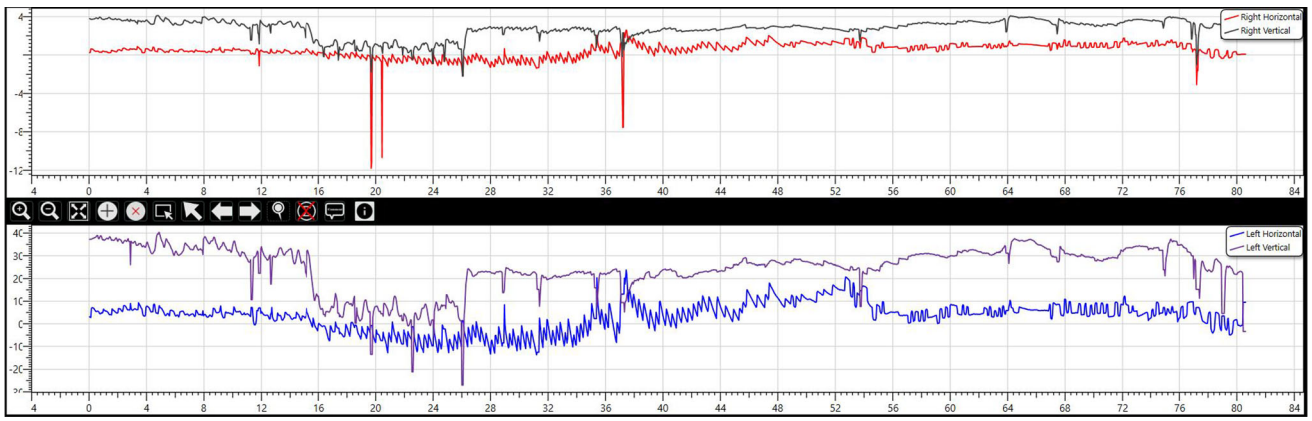

Fig. 5 Hyperventilation induced nystagmus

in 3 VM patients (8.6%) and 2 (5.7%) healthy subjects, whereas in the vertical direction abnormal movements were seen in 14 VM patients (40%) and 5 controls (14.3%) (Fig. 3). The results obtained for smooth pursuit in the vertical direction showed statistically significant difference with the control group. Optokinetic movements were assessed from left to right, right to left, top to bottom and bottom to top and the results of the two groups were not significantly different statistically. Spontaneous nystagmus was assessed for both groups in light and dark

Table 1 Number of abnormal findings in each parameter assessed for VNG testing

Tests	Abnormal findings	
	Patients	Controls
Saccade horizontal	0	0
Saccade vertical	0	0
Smooth pursuit horizontal	3 (8.6%)	2 (5.7%)
Smooth pursuit Vertical	14 (40%)	5 (14.3%)
Optokinetic (Left to Right)	0	0
Optokinetic (Right to left)	2 (5.7%)	0
Optokinetic (Top to bottom)	1 (2.9%)	0
Optokinetic (Bottom to top)	0	0
Spontaneous nystagmus in light	3 (8.8%)	0
Spontaneous nystagmus in dark	8 (23.5%)	11 (31.4%)
High frequency head shake test	14 (41.2%)	10 (28.6%)
Hyperventilation	10 (29.4%)	11 (31.4%)
Gaze with fixation	1 (2.9%)	1 (2.9%)
Gaze without fixation	12 (35.3%)	11 (31.4%)
Subjective midpoint left to right	1 (3%)	0
Subjective midpoint right to left	1 (3%)	0
Subjective midpoint blank	0	0
SVV (Clockwise)	7 (21.2%)	4 (11.4%)
SVV (Anticlockwise)	4 (12.1%)	9 (25.7%)
SVV (Blank)	0	1 (2.9%)
Dix Hallpike (DH) Sit head right	17 (48.6%)	6 (17.1%)
DH Supine head extension and right	21 (60%)	12 (34.3%)
DH Sit head right	18 (51.4%)	8 (22.9%)
DH Sit head left	12 (34.3%)	7 (20%)
DH supine head extension and left	15 (42.9%)	11 (31.4%)
DH Sit head left	12 (34.3%)	7 (20%)
DH Gross	28 (80%)	18 (51.4%)
Head position Yaw Right	6 (17.1%)	4 (11.4%)
Head position Yaw left	3 (8.6%)	7 (20%)
Head position Pitch forward	13 (37.1%)	11 (31.4%)
Head position Pitch backward	9 (25.7%)	9 (25.7%)
Head position Roll right	11 (31.4%)	11 (31.4%)
Head position Roll left	8 (22.9%)	8 (22.9%)
McClure-Pagnini (MP) Sit to supine	11 (31.4%)	7 (20%)
MP Right lateral	8 (22.9%)	9 (25.7%)
MP Supine head neutral	11 (31.4%)	7 (20%)
MP Left lateral	7 (20%)	9 (25.7%)
MP Supine head neutral	6 (17.1%)	5 (14.3%)
Head impulse test	0	0

surroundings, which were also not statistically significant.14 VM patients (41.2%) and 10 controls (28.6%) showed nystagmus after the high-frequency headshake test (Fig. 4), whereas 10 cases (29.4%) and 11 controls (31.4%) showed nystagmus after hyperventilation (Fig. 5) which was not statistically significant. The abnormal eye movements were assessed by gaze tests, positional tests (Dix Hallpike and McClure Pagnini) and head position in yaw, pitch and roll movements. None of these tests showed statistical significance except the Dix Hallpike test on the right side. In the provocative position, that is when the patient was made to lie supine and head hanging below the

couch and turned to right side by 45 degree showed statistically significant results. Our study also revealed that the initial sitting position with the head turned to right and the final sitting position of Dix Hallpike test with head turn maintained to right were statistically significant when compared with control population. Subjective midpoint and SVV assessed in clockwise, anticlockwise and blank showed no statistical significance. The head impulse test was not abnormal in any of the VM cases or controls. The number of abnormal findings in the VNG parameters in cases and controls are summarised in Table 1.

Discussion

The mean age of the VM patients in the study was 40 ± 9.9 years. In the study by Swain et al. (2020), the mean age of the patients with VM was 43.52 years [7]. In the study by Shin et al. (2013) that included 76 patients of VM to compare the vestibular abnormality of patients of VM with that of Meniere's disease, the mean age of the VM patients was 42 years [8]. The female to male ratio in our study was 2.8:1. In the study involving 131 VM patients to assess the clinical features, triggers and examination findings, the female preponderance was 4:1 [2]. VM is more prevalent in individuals without aura and predominantly affects females with a female: male ratio up to 5:1 [9].

The saccadic pursuit was noted in 3 (8.6%) of our patients in horizontal direction and 14 (40%) in vertical direction. Vertical (48%) and horizontal (22%) saccadic pursuits were noted in VM patients in the study by Dietrich et al. [10]. Another study showed abnormal smooth pursuit in electronystagmographic patterns of 3% of patients with migraine-related vestibulopathy [11]. The incidence of saccadic pursuit varies widely among reported studies due to the use of eye-movement recordings and variations in patient cooperation [2]. We found a statistically significant difference ($P < 0.05$) in the smooth pursuit abnormality when assessed in the vertical direction between VM patients and healthy controls. Optokinetic nystagmus was found in 2 VM patients (5.7%) in the right to left direction and 1 VM patient (2.7%) in the top to bottom direction. Impaired optokinetic nystagmus was found in 2% of VM patients in the study by Cass et al. [11]. There is no statistically significant difference in spontaneous nystagmus observed between VM patients and healthy subjects in our study. Boldingh et al. (2013) had compared the vestibular abnormalities in 38 VM patients and 32 migraine patients and found that there is no statistically significant difference in spontaneous nystagmus in the two groups [12].

In our study, nystagmus was elicited after high-frequency headshake in 41.2% and after hyperventilation in 29.4% of VM patients. However, the results in comparison with healthy subjects were not statistically significant. Head-shaking nystagmus (HSN) occurs due to the amplification of a peripheral vestibular asymmetry by the central velocity storage mechanism; it typically indicates peripheral vestibulopathy, but can also be seen in central disorders [13]. Hyperventilation usually reveals latent cerebellar and vestibular diseases by raising serum pH and decreasing serum ionized calcium levels [13, 14]. Head shaking nystagmus was observed in 14 (41.2%) of VM cases and 10 (28.6%) healthy controls. Beh et al. found HSN occurred in 18.3%, whereas hyperventilation induced nystagmus was found in 22.5% of VM patients [2]. Hyperventilation-induced nystagmus was slightly higher than the 19.5% reported in the study by Califano et al. [14].

In our study, we assessed gaze-induced nystagmus with and without eye fixation. One VM patient and one healthy subject showed gaze-induced nystagmus with fixation. Nevertheless, when the fixation was removed, nystagmus was observed in 12 (35.3%) VM patients and 11 (31.4%) controls. No gaze induced nystagmus was observed in the VM patient group and migraine patient group in the study by Boldingh et al. [12].

Subjective visual horizontal (SVH) and subjective visual vertical (SVV) are clinical tests to measure the otolith function which may be compromised in patients with peripheral and central vestibular disorders. We could not find any statistically significant difference between VM patients and healthy subjects in SVV and subjective midpoint. Another study done by Kandemir et al. (2014) could not find any significant difference in SVV measurement [15]. A hospital-based prospective study was conducted by Ashish et al. (2017) in 82 normal adults and 66 adults with VM. Results were further analysed by stratifying cases and controls into two age groups; 20–40 years and 41–60 years and gender. The dynamic SVV and SVH in both age groups and the static SVH in the 41–60 years age group were significantly higher compared to normal individuals ($p < 0.05$). The dynamic SVV and SVH were significantly higher in the cases compared to controls among both males and females ($p < 0.05$) [16]. There are no previous literatures available describing the entity called subjective midpoint which we believe to give more information about vestibular disorders.

Nystagmus was noticed in 17 VM patients (48.6%) and 6 controls (17.1%) in sitting position and turning head to right, 21 VM patients (60%) and 12 controls (34.3%) in supine position with head extended and turned to right and 18 VM patients (51.4%) and 8 controls (22.9%) when subject was brought back to the sitting position with head turn maintained to right. Nystagmus was noticed in 12 VM patients (34.3%) and 7 controls (20%) in sitting position and turning head to left, 15 VM patients (42.9%) and 11

controls (31.4%) in supine position with head extended and turned to left and 12 VM patients (34.3%) and 7 controls (20%) when subject was brought back again to the sitting position with head turn maintained to left. The abnormal nystagmus in VM may be due to altered processing of cervical proprioceptive inputs probably causing a cervico-ocular reflex. This cervico ocular response is perhaps a major mechanism of nystagmus in VM than gravity related response. Surprisingly we also found that the results on the right side were statistically significant whereas on left side it is not statistically significant due to some unknown reasons. The nystagmus elicited during positional testing did not fit into the criteria of Benign Paroxysmal Positional Vertigo (BPPV) like the direction or type of nystagmus of the canal being tested, lack of fatigability, latency and habituation and absence of the crescendo- decrescendo pattern of BPPV. The pathogenesis of positional nystagmus may be related to the asymmetry of afferent vestibular neurons in the central or peripheral nervous system. No significant difference was noted between healthy subjects and patients with VM in the positioning test results in the study by Lofti et al. [17]. In the study by Hazaa and Mowafy et al. (2016) involving 98 patients of VM during the acute attack of dizziness irrespective of headache, positional nystagmus was frequently recorded in 60% of VM patients. The nystagmus was horizontal, horizontal torsional or pure vertical (up beating), none fatigable, abolished with fixation and with minimal subjective sense of dizziness. Positional nystagmus was the most prevalent VNG finding in their study, which is, in fact, non-localizing for central or peripheral pathology [18]. Another study done by Polensk et al. (2010) during the acute spell of VM revealed that nystagmus was noted in all symptomatic patients by positional testing by Dix Hallpike maneuver with fixation blocked, although the characteristics of nystagmus varied [19].

Several mechanisms have been proposed for the pathophysiology of VM. There exists no single unifying hypothesis which can conclusively explain the pathophysiology of VM or migraine itself. Dieterich and Brandt suggested a spreading depression affecting brainstem structures as they found mainly central vestibular disorders in their patient group [10]. On the contrary, Baloh proposed that sudden episodes of vertigo associated with migraine could be explained based on vasospasm of the Internal Auditory Artery in support of the peripheral vestibular dysfunction hypothesis [20]. Nystagmus characteristic of both peripheral and central vestibular deficits have been observed in patients with VM, hence mechanisms involving both structures seem to be more a probable explanation of the pathophysiology of VM. There is also another concept of sensory dysmodulation, in which deficient habituation and potentiation of sensory responses are implicated in migraine pathogenesis. This means exposure to one sensory stimulus results in hypersensitivity that can extend to other sensory stimuli.

None of the patients and healthy subjects in our study showed abnormal head impulse tests. A retrospective chart analysis performed on 81 VM patients by Kang et al. (2016), 9 of 81(11%) exhibited abnormal Video HIT results in the initial visit [21]. Blocking visual fixation during examination with Frenzel lenses or video infrared equipment may be necessary to observe the nystagmus, since patients typically have normal gaze holding in the light and nystagmus velocity is usually low. By examining VM patients during the symptomatic day, the clinician can look for positional nystagmus to aid in the accurate diagnosis of VM.

Limitations of the study: Caloric testing would have yielded additional information but was not routinely performed as a part of this study because we found that the vertiginous feeling and emetic response occurring during caloric testing may reduce the compliance of study population. Post treatment VNG was not done as a part of our study.

Conclusion

VM is one of the important differential diagnoses of vertigo cases referred to a tertiary care centre. VNG helps in ruling out other differential diagnoses of vertigo. Instead of a single test, the application of a battery of tests as in VNG helps to reach the diagnosis of VM. In this study, out of the various VNG parameters, a statistically significant difference was observed between VM patients and healthy control in smooth pursuit measured in the vertical direction and positional tests using the Dix Hallpike test (right side). An accurate diagnosis is crucial because management approaches are different, and in case of incorrect diagnosis, the patient may receive wrong treatment and management. Correct diagnosis helps alleviate the patient's anxiety and improve the quality of life in patients suffering from VM.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Informed Consent Informed consent was obtained by all individuals participating in the study.

Ethical Standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki declaration and its later amendments or comparable ethical standards.

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