The Video Head Impulse Test: Our Experience in 45 Cases

Ayush Chawla¹ · Raees Abdurahiman¹ · Venkatakarthikeyan Chokkalingam¹

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Abstract To evaluate the role of video head impulse test in the diagnosis of peripheral vestibular disorders, we performed an observational study in the outpatient department in a tertiary setup in which the clinical head impulse test and the video head impulse test were performed on 45 patients with clinically suspected peripheral vestibular disorders, and their results were correlated. To analyse our results, each ear was counted individually and hence, among 45 patients, 12 out of 90 ears showed abnormal clinical head impulse test for lateral semicircular canals and 27 out of 90 ears showed abnormal video head impulse test for lateral semicircular canals. This gave us an additional diagnostic accuracy of 21.1% on using video head impulse test for the lateral semicircular canals as compared to the clinical head impulse test. Video head impulse test is a physiological, quick and well tolerated test for assessing the vestibular function, and the only practical test for assessing the vertical semicircular canal function. Video head impulse test provides valuable information in localising the site of lesion as it assesses the semicircular canals individually. Video head impulse is merely not an objectification and registration system for the clinical head impulse test as it provides additional information such as vestibulo–ocular reflex gain, and occurrence of covert refixation saccades which cannot be picked up by naked eyes.

Keywords Video head impulse test · Clinical head impulse test · Vestibulo–ocular reflex · Refixation saccades · Covert saccades · Semicircular canals

Introduction

Dizziness is a common symptom with which a patient presents to an otolaryngologist. First and foremost aim in such patients is to prove or exclude a vestibular impairment.

Evaluation of the vestibular function is challenging due to the complex physiology of balance and equilibrium. However, the observation of eye movements is an indirect indicator of vestibular function, due to the relationship between the function of the vestibular sensory receptors in the inner ear and the eye movements produced by the vestibulo–ocular reflex (VOR).

The bithermal caloric test, which has been the mainstay of vestibular assessment is based on the principle of VOR. Recently, the spectrum of diagnostic tools has been expanded by the introduction of the video head impulse test (vHIT).

The video head impulse test is an objective counterpart of the clinical head impulse test described by Halmagyi and Curthoys in 1988 [1]. Michael Halmagyi and Ian Curthoys introduced this quick bedside test in which eye position is analysed at the end of a head rotation (impulse). A subsequent corrective eye movement following the impulse known as a catch-up saccade is a sign of impairment of VOR.

The video head impulse test involves performing the above test objectively by estimating the VOR gain which is defined as the ratio of eye to head velocity.

✉ Venkatakarthikeyan Chokkalingam
cvk63@yahoo.co.in

Ayush Chawla
ayush.do.it.again@gmail.com; ayush19.ent@gmail.com

¹ Department of ENT and Head and Neck Surgery, Apollo Hospitals, Chennai 600006, India

The vHIT is a new technique for evaluation of vestibular function, and the literature is deficient in defining a role for vHIT in vestibular assessment. In this study, we use the vHIT in a tertiary setup, on a day to day basis, in the initial workup of patients presenting with complaints of dizziness.

The Vestibulo–Ocular Reflex

VOR is a three arc neuron reflex and is responsible for maintaining the stability of objects on the retina during head movements (Fig. 1). The VOR is the fastest and one of the most exquisitely accurate reflexes in the body with latency of about 7 ms and produces eye movements that typically have < 5% error with respect to head movements [2].

The brain interprets stimulation of a particular semicircular canal as motion of the head, and the eyes move reflexely in an equal but opposite amount to compensate. This action leaves the angle of the target relative to the eye unchanged and its image steady on the retina.

The push pull principle of VOR generation is as follows. During head rest, hair cells in both SCC have a resting discharge rate of 90 spikes per second. When head rotation is to the right, endolymph lags behind, i.e. moves relative to the left within each SCC due to inertia. The cupula bends to the left in each canal, hence in the (leading) right SCC, the stereocilia bend towards the kinocilium causing depolarisation. In the (following) left SCC, the stereocilia bend away from the kinocilium causing hyperpolarisation. The vestibular nuclei interpret the difference in discharge rates between left and right SCC as movement to the right, and therefore trigger the oculomotor nuclei to drive the eyes to the left to maintain gaze stabilization.

Similar to the horizontal canal, a push–pull principle also governs the vertical canals. However, ampullopetal movements result in a decreased firing rate. Thus, for the horizontal canal, excitation is elicited upon ampullopetal endolymph movement (towards the vestibulum–utricle), whereas for both the vertical posterior and anterior SCC ampullopetal flow is inhibitory.

Head Impulse Test

In 1988, Michael Halmagyi and Ian Curthoys reported a clinical test known as the head impulse test, that allowed bedside identification of peripheral deficits of horizontal semicircular canal function.

In this test, the examiner looks for the presence of a refixation saccade after a small, rapid, passive, unpredictable, horizontal head rotation (head impulse) while the patient attempts to maintain gaze on a target. If the semicircular canal function is impaired, vestibulo–ocular reflex is inadequate, so the eyes move (off the target) with the head, and at the end of the head rotation, the patient makes a refixation saccade to return gaze to the target (Fig. 2). This corrective saccade is detectable by naked eye as it is made after the head rotation has stopped, and hence termed as “overt” saccades.

Video Head Impulse Test

To make an objective measurement of the vestibulo–ocular reflex by head impulse test, MacDougall et al. [3]. developed a video-oculography system that measures the eye velocity during head rotation. The vHIT separately assesses the six semi-circular canals individually.

Fig. 1 The Vestibulo–ocular reflex pathway (Source: Google)

Fig. 2 The head impulse test (Source: Google)

Horizontal impulses are given in a similar manner, as in clinical head impulse test. To test superior and posterior semicircular canals, the head impulses are given in planes of the respective vertical canals i.e. left anterior right posterior (LARP) and right anterior left posterior (RALP). The patient's head is turned 35–45 degrees to the body on the right or left/right side, then diagonal impulses are given in the plane of vertical canal.

In our study, we have considered two parameters, namely, VOR gain and saccades for analysis. We have taken the cutoff value of VOR gain as 0.7

Methods

We performed the video head impulse test in 45 patients (both males and females in the age group 18–75) presenting to our outpatient department with history of dizziness. Patients having associated CNS symptomatology, suspected cervical spine disease, or vision abnormalities leading to inability to fixate the eye were excluded from the study. Patients with positional vertigo (positive Dix-Hallpike test) were excluded from the study.

After thorough history taking, a complete ENT and vestibular examination was performed including the clinical head impulse test.

The clinical head impulse test was performed by applying quick, sudden and random impulses in the horizontal plane with the patient fixing his eyes on the researcher's nose. Three impulses were performed towards the right and the left side, randomly to look for refixation saccades at the end of the head impulse.

The Video Head Impulse Test

The video head impulse test was performed using the ICS impulse video head impulse system by GN otometrics.

The ICS Impulse is a small, compact and portable system which uses a High speed camera (250 Hz) to record fast eye movements to record overt and covert saccades, Built-in gyroscopes for accurate head velocity measurement, Built-in calibration lasers and Built-in head impulse algorithms by which inaccurate head impulse data is automatically discarded and only accurate data is analysed.

The test was performed as follows:

The patient is made to wear a pair of lightweight, tightly fitting goggles on which the camera is mounted which records the movement of the right eye.

After application of goggles, the patients were instructed to keep eyes wide open and fixate their vision on a target at about 1 m distance and also to keep neck relaxed but teeth clenched to avoid movement artefacts.

To begin the test, the test is setup for the plane of the impulse i.e. lateral, LARP or RALP, and the pupil is marked on the computer screen so that it is detected by the camera.

Before starting the test the system needs to be calibrated for each patient. The ICS impulse has an inbuilt calibration system which makes the patient fix the vision at alternate specified target dots at predefined angles.

Head impulses are delivered in the planes of the semicircular canal with unpredictable timing and direction. The impulses are delivered by placing one hand on top of the head and other hand beneath the chin for testing the posterior and superior semicircular canals or by holding the

head firmly on both sides in the temporal region for testing the horizontal semicircular canals. The test was performed till 20 valid impulses were obtained for each canal.

The automated detection algorithms in the system calculated the vestibulo–ocular reflex (VOR) gain and produced velocity time graphs plotting the eye velocity, head velocity and spotting the occurrence of refixation saccades for individual semicircular canals.

Results

The ICS impulse vHIT system records the head and eye velocity of individual impulses and the data is presented in the form of velocity time graphs, Hexplots, 3D plots, Numerical data (Fig. 3).

The vHIT Report

Velocity time graphs appear on the screen plotting the eye velocity and head velocity for individual semicircular canals. Superimposed plots of eye velocity responses and head velocity stimuli indicates normal SCC function. Absence of superimposition of the plots with low gain and appearance of catch up saccades indicates SCC deficit.

The vHIT reports were assessed based on 2 parameters:

VOR Gain

The ratio of cumulative slow phase eye velocity over cumulative head velocity from onset of head impulse to the moment when head velocity returned zero.

A gain of 1.0 implies that the compensatory eye movement is perfectly opposite to the direction of head

iv.

Fig. 3 The vHIT report. (i) report showing superimposition of head velocity and eye velocity curves, (ii) covert saccades (red) in left posterior canal, (iii) overt saccades (red) in left lateral canal, (iv) vHIT being performed in ENT OPD

movement. However, a gain of less than 0.7 was taken as low gain.

Occurrence of Refixation Saccades (Overt and Covert)

When the compensatory eye movement is slower than the head movement, a fast adaptive eye movement called a saccade is produced. An overt saccade occurs after termination of the impulse. A covert saccade may occur during the head movement and probably represents the brain's anticipation of where the head impulse will end.

Study Analysis

We present the results of video head impulse test in 45 patients (27 females, 18 males).

Observation 1: Video head impulse test showed abnormal findings in all clinically diagnosed patients with peripheral vestibulopathy. Among the 45 patients, an abnormal vHIT report was found in all patients.

Observation 2: 39 out of 45 patients had bilaterally abnormal vHIT findings.

Observation 3: Among the 39 patients with bilateral abnormal findings, 30 patients showed abnormality in the corresponding canals (LARP, RALP, lateral pair), and the remaining 9 showed abnormalities in multiple non corresponding canals.

Observation 4: Among the 30 patients with paired abnormality, 2 patients had a single pair abnormality (1 LARP, 1 RALP), 1 patient had abnormality of all 6 canals, and 9 patients showing abnormality in 2 pairs of canals (7 LARP + RALP), (2 lateral pair + RALP/LARP). Remaining 18 patients showed at least 1 single pair abnormalities associated with unpaired abnormalities.

(In such cases, the side showing a more severe abnormality was considered as the primarily affected side).

Observation 5: Among the 6 patients, showing unilateral abnormality, 1 patient showed abnormality in all 3 canals, 1 patient showed abnormality in both vertical canals, and 4 patients showing single canal involvement (2 anterior, 1 posterior and 1 lateral).

Observation 6: To further analyse the data, each ear was counted individually and hence, out of 90 ears, 27(30%) out of 90 ears had an abnormal video head impulse test for horizontal semicircular canals, 56(62.2%) out of 90 ears showed abnormal findings in posterior semicircular canals and 64(71.1%) out of 90 ears showed abnormal findings in superior semicircular canals.

Observation 7: Individual canals were grouped as follows: Normal gain no saccades, Low gain no

saccades, Normal gain with saccades, Low gain with saccades. (Table 1).

Observation 8: The occurrence of refixation saccades in individual canals were as in Table 2.

Observation 9: On clinical head impulse test, 11(24.4%) out of the 45 patients had refixation saccades horizontal semicircular canals, 5 showing left side impairment, 5 showing right side impairment, and 1 patient showing bilateral impairment.

As clinical head impulse was performed only for the horizontal semicircular canals, only the results of video head impulse test for horizontal semicircular canals were considered for comparison. Hence, among 45 patients, 12 out of 90 ears showed abnormal clinical HIT and 27 out of 90 ears showed abnormal vHIT for horizontal SCC (Table 3).

There was a mismatch in the findings of clinical and video head impulse test in 19 out of 90 ears, giving us an

Table 1 Observation 7: VOR results in individual semicircular canals

Canal	VOR	Normal	Normal gain with saccades	Low gain	Low gain with saccades
Left lateral	33	11		0	1
Left posterior	21	7		10	7
Left anterior	18	0		25	2
Right lateral	30	11		1	3
Right posterior	13	4		24	4
Right anterior	9	2		18	16

Table 2 Observation 8: Refixation saccades in individual semicircular canals

Canal	Saccade	Covert	Overt	Total
Left lateral		3	9	12
Left posterior		10	4	14
Left anterior		1	1	2
Right lateral		6	8	14
Right posterior		5	3	8
Right anterior		15	3	18

Table 3 vHIT versus cHIT contingency table

cHIT	vHIT		Total
	Normal	Abnormal	
Normal	61	17	78
Abnormal	2	10	12
Total	63	27	90

additional diagnostic accuracy of: $(17 + 2)/90 \times 100 = 21.1\%$.

Discussion

In our study, we describe the video head impulse test findings in 45 patients. The video head impulse test report as described earlier, provides us with vast and accurate information regarding the individual semicircular canals, namely the VOR gain, overt and covert refixation saccades and canal asymmetry. The findings are elaborated in the form of 2D analysis, graphs, hexplots as well as 3D analysis.

The video head impulse test shows high sensitivity in localising the site of dysfunction in peripheral vertigo as shown by observation 1 in our study, with vHIT supporting the clinical diagnosis of peripheral vertigo in all of our 45 patients.

The video head impulse test objectively demonstrates the physiological mechanisms involved in maintenance of equilibrium and loss of bilateral symmetry in the vestibular input, leading to symptoms of dizziness. This can be seen in our observation 2, where 39 out of the 45 patients are showing bilateral abnormalities on vHIT testing. The occurrence of paired canal involvement in 30 out of those 39 patients, further reinforces the concept of maintenance of bilateral symmetry as a part of the compensation process.

Although, uncommon, single canal dysfunction was also picked up by the video head impulse test in 4 patients in our study.

As seen in observation 6, in our study of 45 patients with clinically suspected vestibular disorders, only 21 patients showed abnormal video head impulse test for the horizontal canals, whereas remaining 24 patients had abnormal vHIT for vertical canals. In the literature, various studies have compared vHIT with the caloric tests and found its sensitivity to be low, taking caloric test as the gold standard. However, as caloric test doesn't test the vertical canals, this again emphasises the additional advantage of vHIT over the caloric tests, in identifying vertical canal dysfunctions.

The VOR gains were comparatively lower for the vertical canals, and the occurrence of saccades was also more common. Also, there were more covert saccades noted in the vertical canals, which cannot be detected by naked eye (Observation 7, 8).

Also, the clinical head impulse (though a routine part of initial examination of a patient with dizziness) is only being performed for the horizontal canals. Clinical head impulse test for vertical canals, (although has been described in literature), but, is rarely performed as the

impulses given are highly variable and inaccurate for canal stimulation and the eye responses are difficult to pick up by naked eyes.

In observation 9, we have compared the clinical head impulse test results with horizontal video head impulse results counting each ear individually (90 ears), and found 21.1% difference in the results, due to additional detection of covert saccades with normal gain and low gain. This is comparable to a study by Pérez-Fernández N et al. [4] who compared the results of clinical head impulse test with the video head impulse test in 179 patients and found that in 32.1% of the ears examined the findings of both tests were different.

Conclusion

- Video head impulse test is a physiological, quick and well tolerated test for assessing the vestibular function, and the only practical test for assessing the vertical semicircular canal function.
- Video head impulse test provides valuable information in localising the site of lesion as it assesses the semicircular canals individually.
- Video head impulse is merely not an objectification and registration system for the clinical head impulse test as it provides additional information such as VOR gain, and occurrence of covert refixation saccades which cannot be picked up by naked eyes.

Recommendation

- Video head impulse should be considered in the evaluation of peripheral vestibular disorders, as it is the only practical test for evaluating the function of all semicircular canals individually, and it can be performed in an office setting.

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Compliance with Ethical Standards

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

Ethical Approval The study was performed from October 2015 to October 2016 after clearance from the ethical committee of Apollo Hospitals, Chennai.

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