ORIGINAL ARTICLE

Clinical and Video-Assisted Examination of the Vestibulo-Ocular Reflex: A Comparative Study

Nicolás Pérez-Fernández,* Vivian Gallegos-Constantino, Luz Barona-Lleo, Raquel Manrique-Huarte

Departamento de Otorrinolaringología, Clínica Universidad de Navarra, Pamplona, Navarra, Spain

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Vertigo;
Dizziness;
Head-thrust;
Canal paresis

Abstract

Introduction: The assessment of the vestibulo-ocular reflex (VOR) is one of the main steps in clinically evaluating patients with dizziness. It can be performed at the bedside with common head-impulse test in which eye position is analysed at the end of the head-thrust. It is an important test due to its high specificity but low sensitivity.

Material and methods: We studied 179 patients with different types of balance-affecting disorders. The results were analysed in contingency tables. The clinical test was classified as normal or abnormal according to the absence or existence, respectively, of fixation saccades once the head-thrust was finished. The video head-impulse test (vHIT) was classified according to vestibulo-ocular reflex (VOR) gain and presence of fixation saccades. The speed of the slow phase of spontaneous nystagmus was also quantified, in addition to the caloric test results.

Results: There were significant differences (Chi-square test, \( P = .00 \)) for the findings in the clinical evaluation and with the vHIT: 32.1% of the tests performed yielded different findings in both tests. In the vHIT, the differences were due to the finding of normal gain with saccades; in these patients, the mean canal paresis was significantly abnormal: 39\% \pm 10\%.

Conclusions: The distribution of findings for the VOR bedside examination and for that with the help of a video system are significantly different; as such, the video head-impulse examination is not simply an added VOR detection and registration system. The difference relies mainly on a vHIT response characterised as of normal gain but with fixation saccades. These have been considered as the cause for the low sensitivity of the bedside VOR examination and sometimes regarded as normal responses; we have demonstrated that these findings are abnormal according to the findings of higher canal paresis in the caloric test.

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* Corresponding author.

E-mail address: nperezfer@unav.es (N. Pérez-Fernández).
Introduction

The response elicited by vestibular stimulation during head movements is, among others, an ocular movement with a minimal compensating delay, in the opposite direction and with the same speed. These characteristics perfectly define the vestibulo-ocular reflex (VOR) whose study and assessment can be made from each of the 5 vestibular receptors in the inner ear. In fact, the most common method is to explore this response by stimulating the horizontal semicircular canal receptor, as in the caloric and rotatory tests.¹

The clinical examination of each receptor in the semicircular canals can be individualised in the head impulse test systematised by Halmagyi and Curthoys.² In such a clinical environment, the test evaluates ocular position, that is, the location of the eye at the end of the head impulse when patients are asked to look forward to a point at a distance of 1 m, or whether saccades appear during or after head impulse. It is an extremely useful test despite the subjectivity-entailed differences both in the stimulus and in the response assessment. In acute vertigo crises, a normal response is the strongest predictor against a suspected cerebellar stroke.³ In chronic peripheral condition, specificity is high but sensitivity is low.⁴

The instrumental examination of this head impulse reflex is performed in an extremely detailed manner, with a corneal coil in a magnetic field test.⁵ The recording of position during this test is accurate and fast, thus enabling a detailed study of eye velocity during head movement. Unfortunately, this test is impractical in a clinical environment with a high workload and even more in an emergency situation.

The development of techniques based on high definition and speed recordings has led to ocular velocity recording tests which have solved almost all the difficulties imposed by the corneal coil study.⁶ The method is named after the device employed (video head-impulse test [VHIT]) and there are currently 2 different approaches, one with an external camera facing the patient and one with the camera attached to the head of the patient. The second method, employed in our study, has been validated against the corneal coil test and has shown an almost complete correspondence of results: the velocity profile recorded was identical and replicability between tests with each system was greater than 0.9.⁷

The aim of this work is to analyse the results in a broad population of patients with various types of balance disorders (referred for evaluation due to dizziness, vertigo or instability) and to carry out a comparative study with easily obtained data during clinical examination.

Materials and Methods

Patients included in this study were those who attended consultation due to suffering dizziness, vertigo or instability.
Additionally, we selected those in whom the cause was clarified unequivocally following diagnostic criteria proven in the literature. We conducted an initial study of spontaneous nystagmus and nystagmus induced by positional changes, with and without visual fixation. Nystagmus was recorded by a VN415® (Interacoustics, Denmark) videonystagmography device. The Dix–Hallpike test was analysed under direct vision, without visual fixation, with conventional Frenzel goggles. Additional vestibular studies were conducted when considered necessary (caloric or rotational testing).

Clinical Exploration of the Vestibulo-Ocular Reflex

The clinical vestibulo-ocular reflex (cVOR) was studied using the instructions of Halmagyi2 as described in other articles. We did not use additional recording devices in our work, but rather used visual examination; the clinical assessment addressed the existence of re-fixation saccades at the time of completing the head impulse. We performed 3 impulses towards the left and right sides, randomly. The test was considered normal if there were no oculac saccades just at the end of head movement in at least 2 impulses towards each side.

Video-Assisted Exploration of the Vestibulo-Ocular Reflex

The study was conducted with a vHIT® device (video Head-Impulse Testing, GN Otometrics, Denmark). This device consisted of a portable mask containing the camera which recorded eye movement, a gyroscope and a laser projector. Placement of the mask was a crucial step, as it had to be firm enough to provide stability and prevent sliding during head movements. Calibration was performed using the laser, which projected 2 points from one side of the mask which switched on and off alternately and subtended a 20° angle at a distance of 1 m from a comfortably sitting patient. The test consisted of small impulses to the right and left sides, firmly grasping the head of the patient from behind with both hands placed on the temporal and parietal areas, whilst avoiding contact with the tape holding the mask or its cable.

We performed at least 20 impulses towards the right and left. The normal response in a series of impulses towards the right is shown in Fig. 1. The final response was analysed based on 2 key aspects of the impulses towards each side: the reflex gain and the existence of re-fixation saccades. Based on previous studies, gain values below 0.6 were considered abnormal and re-fixation saccades were divided into covert or overt. The former were re-fixation saccades occurring during the head impulse and the latter when this had concluded.

Since this exploration yielded detailed information on the VOR, findings were divided into 4 groups: group 1 or normal (gain>0.6, with no re-fixation saccades), group 2, in which the gain was normal (>0.6) but re-fixation saccades were recorded (Fig. 2), group 3, in which the gain was low and there were re-fixation saccades (covert and/or overt) (Fig. 2), and group 4, in which the gain was >1.3 either in isolation or due to the existence of covert saccades (Fig. 3).

### Statistical Study

The information was stored and analysed using the statistical package SPSS® 15.0. The result of each test was divided into normal and pathological for the left and right impulses in each of the study methodology modes, clinical and instrumental. We studied the relationship between both evaluations through contingency tables, using the Chi-square data ($\chi^2$) and Fisher’s exact test, and considering the right and left impulses conducted on each patient as individual assessments. This resulted in a study with 358 tests. Firstly, we classified the findings of both scans as normal/abnormal according to the criteria mentioned previously and secondly, we subclassified the findings of the video-assisted study into the 4 categories defined previously. Next, each patient was classified according to the degree of concordance between cVOR and vVOR. These were classified as identical if the results following both methods were similar (normal or abnormal in both cases) and different if there were differences (one normal and the other one abnormal). In the latter case, we distinguished between VOR studies conducted towards the right and left sides and conducted a study of differences towards either side. We used the Mann–Whitney U-test to analyse the differences in values of canalicular paresis between groups 1 and 2.

### Results

We studied 179 patients distributed according to their diseases as described in Table 1. Of these, 69 (38.5%) patients were male and 110 (61.5%) were female.

Out of these patients, the head impulse response studied clinically (cVOR) was normal in 118 (65.9%), showed right hypofunction in 26 cases (14.5%), left in 26 and bilateral in 9 (5%).

With respect to the stimulus (impulse), the results of the instrumented study (vVOR) were as follows: normal towards the right side in 101 patients (56.4%) and abnormal in 78 (43.6%), whereas towards the left side it was normal in 102 patients (57%) and abnormal in 77 (43%).

The results for the total tests conducted (n=358) are shown in Table 2. We observed that there was an overlap of findings (normal or abnormal) in 67.9% of examinations performed, and discordance in the rest. In most cases, the clinical examination was normal, whereas the instrumented test was abnormal. The result of the Chi-square test was

<table>
<thead>
<tr>
<th>Table 1 Number of Patients Per Type of Disease Studied.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ménière’s disease</td>
</tr>
<tr>
<td>Benign paroxysmal positional vertigo</td>
</tr>
<tr>
<td>Vestibular migraine</td>
</tr>
<tr>
<td>Chronic otitis media</td>
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<tr>
<td>Vestibular neuritis (sequelae)</td>
</tr>
<tr>
<td>Posttraumatic</td>
</tr>
<tr>
<td>Otosclerosis</td>
</tr>
<tr>
<td>Secondary chronic instability</td>
</tr>
<tr>
<td>Vertigo in patients with cochlear implants</td>
</tr>
<tr>
<td>Vestibular Schwannoma</td>
</tr>
<tr>
<td>Childhood benign paroxysmal vertigo</td>
</tr>
</tbody>
</table>
Figure 1  Characteristics of a normal vVOR. The registry is shown in 2D and 3D, scaling the results by stimulus velocity.

44.1 (P=.001), and the significance in Fisher’s exact test was P=.001. Since all subjects were patients and no normal subjects were included, taking the vVOR as “gold standard”, the sensitivity of the cVOR was 35% and specificity was 92%.

Table 3 displays the results of the contingency table when the result of the vVOR study was detailed by abnormal findings, as mentioned in the previous section. In this case, the value of Chi-square was 135.287 (P=.00). We observed that the most frequent cause of disparity occurred in tests in

Figure 2  Class 2 (normal gain and saccades) and class 3 (low gain and re-fixation saccades) according to the vVOR recording.
Clinical and video-assisted examination of the VOR was also towards normal patients, which the vVOR showed a correct gain but re-fixation saccades were recorded.

In 66 patients (36.8%), the vVOR study was normal in both directions (group 1), and in 37 (20.6%) it was normal towards one side whereas towards the other side gain was also normal but there were re-fixation saccades (group 2). There were significant differences between both groups (Mann-Whitney U, \( P=0.02 \)) regarding the value of canalicular paresis in the caloric test: in group 1 it was 17±2 and in group 2 it was 39±10.

Finally, we selected patients in whom there was no doubt about the affected side from the moment of anamnesis, which left us with 157 patients. Of these, we excluded those with an abnormal result on both sides in the cVOR and/or vVOR tests. The comparative results are presented in Table 4. The value of Chi-square was 23.613 (\( P=0.01 \)).

### Discussion

The results of this work support the conclusion that the study of VOR with a video-assisted recording system (vHIT, GN Otometrics) may provide different findings in comparison to those obtained through conventional clinical studies. In the context of a specialist consultation, it provides additional information which can improve the diagnostic accuracy of the study in admitted patients.

There are some fundamental differences between both scans which must be recognised before interpreting the results. Regarding the scanning methodology, firstly we must mention that in the case of the cVOR we only performed 3 impulses towards each side, while in the vVOR we performed at least 20 impulses towards the right side and the same towards the left. Secondly, in the cVOR we did not have a quality assessment of the head movement inducing the reflex, while in the vVOR we obtained an accurate monitoring of the impulses performed through the recording

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**Table 2** Findings Per Exploration Towards the Left and Right Sides in the 179 Patients Included in the Study.

<table>
<thead>
<tr>
<th>cVOR</th>
<th>vVOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Abnormal</td>
</tr>
<tr>
<td>Normal</td>
<td>188</td>
</tr>
<tr>
<td>Abnormal</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Covert saccades</th>
<th>Covert drawn from low gain and reattachment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.jpg" alt="Image" /></td>
</tr>
<tr>
<td></td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

**Figure 3** Class 4 (normal gain and saccades) according to the vVOR recording.

### Table 3

Findings Per Exploration Towards the Left and Right Sides in the 179 Patients Included in the Study.

<table>
<thead>
<tr>
<th>cVOR</th>
<th>Normal</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>188</td>
<td>77</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Abnormal</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>10</td>
</tr>
</tbody>
</table>

**Table 3** Findings Per Exploration Towards the Left and Right Sides in the 179 Patients Included in the Study.

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</tr>
<tr>
<td>Abnormal</td>
<td>15</td>
</tr>
</tbody>
</table>

cVOR: clinically assessed head impulse test; vVOR: head impulse test with video-assisted assessment.

The latter is divided into the different classes mentioned in the work.

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of their speed. Thus, we excluded from the analysis those cases which we considered had not been done properly. Moreover, this also led to a learning curve which successively enabled us to perform tests in a similar way. This led to a third difference, which is the possibility of studying different responses according to the velocity of the stimulus, since we could induce this voluntarily. Fourth and finally, visual fixation in the case of cVOR took place at a short distance (approximately 30 cm), whereas in the case of vVOR it took place at 1 m. Fixation distance during active movement has a relevant influence in the case of VOR gain, which has a significant cognitive component. Finally, and connecting with the following paragraph, the clinical study fixed on the final position, which was influenced by more elements than the vestibular alone. In contrast, the video-assisted method analysed displacement during the first 150 ms, which exclusively represents the contribution of the vestibular system to the VOR.

The method of recording and analysis of results also established significant differences between the two procedures which should be recognised when comparing their results. Knowing the value of VOR gain is crucial when studying the functionality of the peripheral vestibular system, because during the passive movements undergone by the patient the influence of the peripheral vestibular receptor in producing a correct reflex is almost exclusive. We must not forget other elements, such as the monitoring, saccadic system and the cervico-ocular reflex, each of which has a higher latency or a varying influence depending on the form (active or passive) of producing the head impulse and adaptation mechanisms. A second difference is given by the possibility of studying the morphology of ocular speed registration in detail, analysing the characteristics of re-fixation saccades during or after head movement. At present, there is no specific information from studies with corneal coils, but the complexity of these studies has prevented extending the knowledge of this phenomenon and characterising it properly in patients with various types of vestibulopathy.

We can understand the results of the study based on the differences described previously. It could be argued that the information obtained through both methods is not similar and the differences are due to issues inherent to each test, as described above. A similar study which compared the cVOR with VOR gain measured with a corneal coil device in 15 subjects found similar results. The study of cVOR systematised by Halmagyi and Curthoys to be performed in any clinical environment is undoubtedly one of the most important pillars in the study of patients with dizziness, vertigo or instability. Raising a dichotomy in the methodology of clinical examination of patients is far from the intention of the authors of the present article. In fact, one of the current lines of work is to analyse in detail the reasons for the variations between vVOR and cVOR, beyond the differences entailed by the technique, particularly whether these distinctions could be addressed with the results from the caloric and/or rotatory tests. We believe that every patient should be examined in the most thorough manner, and this includes the study of VOR, at least clinically. Nevertheless, the methodology of the study with a VHIT device provides complementary and more detailed information; it is not simply an additional form of recording. Moreover, the duration of the test and simplicity of the device employed add a very short time to healthcare, while providing versatility and enabling its use in any environment: outpatient clinics, admissions, emergencies, etc.

It is somewhat surprising to find results with normal gain and re-fixation saccades. Saccades occurring during head impulse (or after its completion) are intended to correct erroneous ocular position when there are variations between the ocular reflex velocity and the reflex-inducing head velocity. These were identified in 97 tests, of which the cVOR was normal in 77 and abnormal in 20. It is interesting that, precisely the finding of re-fixation saccades in the cVOR study enabled us to differentiate a normal result from an abnormal one, and here they went unnoticed in almost 2/3 of cases. The reason for this lies in their low speed and their proximity to the end of reflex ocular movement. They were intermediate saccades, between overt and covert, with an intermediate speed (they were studied in 23 tests and the value obtained was 83±9 ms) and were probably a residue from some prior and properly compensated vestibular damage (hence the finding of a greater degree of canaliculare paresis), with an almost correct functional restoration. Unfortunately, we do not have complementary information on the function of the receptors from the superior and posterior semicircular canals to produce a more detailed description. Moreover, according to some authors, these unnoticed saccades have the most notable influence on the low sensitivity of the clinical test or cVOR. In this work, we have shown for the first time that they obey a pathological cause, as observed when comparing the values of canaliculare paresis in the caloric test, which were significantly higher in patients with normal gain and re-fixation saccades.

We believe that this re-exploration system opens a new avenue for the investigation of vestibular function based on the study of the vestibulo-ocular reflex and improves clinical studies.

### Conflict of Interests

The authors have no conflict of interests to declare.
References


