ORIGINAL ARTICLE

The video head impulse test

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Abstract
Conclusion: Additional research is needed to validate the importance of the video head impulse tests (vHIT), but it provides an important contribution to the evaluation of anterior and posterior semicircular canal disorders. Objectives: To share observations of the vHIT test in clinical neurotology and to discuss the significance of the study findings. Methods: This study comprised 200 patients with a clinical history of vestibular disturbances who were submitted to a vHIT including all six semicircular canals. Results: Abnormal responses of the anterior and posterior canals were found in several patients, either alone or combined with altered responses in the lateral canals. A unilateral hypoactive response of a posterior canal was found in a patient with a small vestibular schwannoma.

Keywords: Vertigo, vHIT, vestibular evaluation

Introduction

The inner ear contains several groups of sensory cells, divided into two main functions: hearing (cochlea) and balance (vestibular) receptors. All these cells have one common characteristic: they have cilia that when subjected to inclinations alter the cell polarization and send electric signals to the adjacent nerve fibers.

The vestibular receptors are located, for each side, in the ampullae of the three semicircular canals and the maculae of the utricle and the saccule.

The vestibular system is highly integrated with the eyes and the proprioceptive system for the maintenance of the body equilibrium. Since the integration of the three systems occurs at the vestibular nuclei, it is reasonable to state that the vestibular system is the main organ related to equilibrium. The clinical evaluation of the vestibular system is, therefore, of absolute necessity in patients with symptoms of disequilibrium, whether they are episodes of vertigo, instability, abnormal eye movements or falls.

The most commonly used techniques for the clinical evaluation of the vestibular system are observations of the spontaneous and gaze nystagmus, recordings of the optokinetic nystagmus and saccadic eye movements, rotational tests, and caloric tests.

There is a neurotological consensus that most of the traditionally used vestibular tests do not explore all of the frequencies involved in the system’s responses.

The vestibular hair cells respond to frequencies from 0 to 16 Hz, being particularly active in the range of 0.1–10 Hz. Rotational tests are usually limited to a frequency of approximately 0.1 Hz and caloric tests are usually in the area of 0.05 Hz.

The caloric tests, devised by Bárány [1] and modified by Hallpike [2], have been traditionally considered as the only feasible technique for examining each labyrinth separately. The caloric stimulus is not physiological, its responses are mainly caused by thermally induced convection currents in the perilymph of the semicircular canals. Furthermore, they are limited to the study of the lateral semicircular
canals and are related to frequencies below 0.1 Hz; they do not, therefore, investigate the most important frequencies of vestibular function.

The present study focused on the head impulse test, a procedure that employs physiological stimuli and can identify responses from all six semicircular canals.

The head impulse test was described by Halmagyi and Curthoys in 1988 [3]. They stated that in a high percentage of cases short and quick head movements would induce saccadic eye movements and demonstrated that these saccades resulted from the stimulation of phasic receptor cells in the crista of one of the lateral semicircular canals, the contralateral one being inhibited by the quick movement, of the order of 200°/s. These physiological principles have been confirmed by other investigators [4].

Aw et al. [5] and Halmagyi et al. [6] verified that with the patient’s head in different positions it was possible to investigate each of the six semicircular canals. Magnusson et al. [7], in 2002, demonstrated that it was possible to improve the reliability and sensitivity of the test using videonystagmoscopy. The video head impulse test (vHIT) is easier to interpret, particularly in relation to the vertical canals.

Several studies [8–17] have confirmed and validated the use of the vHIT in neurotological diagnosis.

The present study investigated normal controls and patients with different types of neurotological disorders who were submitted to the vHIT.

Material and methods

The present study was conducted in 200 patients with different kinds of cochlear and/or vestibular disorders. There were 129 females (64.5%) and 71 males (35.5%). Their ages varied from 16 to 95 years, with a mean of 47.00 and a standard deviation of 15.56. The age distribution is shown in Figure 1.

All the patients were submitted to an evaluation that included a detailed clinical history and otolaryngological examination. Audiological tests were also performed, including pure-tone audiometry, speech discrimination tests, and immittance tests. For some patients auditory brainstem responses were recorded and some underwent electrocochleography.

Vestibular tests were performed, including evaluations of spontaneous and semi-spontaneous nystagmus, positional nystagmus, pendular eye tracking, optokinetic nystagmus, pendular rotatory tests and, in some cases, caloric tests. For some patients cervical vestibular evoked myogenic potential (cVEMP) and ocular VEMP (oVEMP) were recorded.

The vHIT was performed using an Otometrics ICS Impulse system. Recordings were obtained for each of the six semicircular canals in all patients.

This research was approved by the Ethics Committee of the Albert Einstein Hospital (CAAE: 06137 012.3.0000.0071).

Results

Table I summarizes the findings for the 200 patients. Many patients (\( n = 103 \)) had normal results in the vHIT test. Of the patients with reduced vestibulo-ocular reflex (VOR) gain observed in the anterior semicircular canals, 21 presented it on the right side, 4 on the left, and 3 bilaterally, making a total of 28 patients.

Reduced VOR gain of the lateral semicircular canals was observed in 23 patients; 3 on the right side, 18 on the left side, and 2 bilaterally. Of the 14 patients who presented low VOR gain in all
3 semicircular canals, 1 presented it on the right side, 5 on the left, and 8 presented it bilaterally.

In nine patients there was a combination of malfunctioning lateral and posterior canals. In one patient the changes were found on different sides, the left lateral and the right posterior canals presented low VOR gain. Two patients had changes only on the right side, two on the left, and four presented bilateral changes.

In eight patients all six semicircular canals showed high VOR gain.

In seven patients malfunction of the lateral and anterior canals was observed. In three patients these changes were found only on the left side; in three patients the left lateral and the right anterior canals had low VOR gain. One patient showed low VOR gain of the left lateral and right and left anterior canals.

Four patients presented low VOR gain in the posterior semicircular canals, two on the right side and two on the left.

Discussion

Vestibular disorders are common in the population and have been classified into several different types. Despite the fact that each of the vestibular end organs can now be adequately subjected to evaluation, no precise correlations can be established between the clinical findings and the types of disorders presented by each patient.

The clinical diagnoses of the patients in this study were essentially established through their clinical histories and then confirmed by neurotological findings, sometimes corroborated by laboratory tests and/or medical imaging. However, some correlations could be established between the clinical diagnoses and the findings in the vHIT tests.

Table II shows the clinical diagnoses for this group of patients. They will each be considered in turn.

Vestibular neuronitis

In 1952, Dix and Hallpike [18] described vestibular neuronitis as a vestibular disorder characterized by recurring episodes of vertigo associated with either unilateral or bilateral hypoactive responses to the caloric stimulation and normal hearing. This disorder, therefore, is totally different from the vestibular neuritis described by Nylen [19] in 1924, which consists of one single, non-recurring, violent episode of vertigo.

In 55 of the patients in this group, all presenting recurring episodes of vertigo, isolated responses of different canals were recorded. Table III illustrates these findings. It is hypothesized that these are cases of vestibular neuronitis involving different semicircular canals, the diagnosis of which would be impossible with caloric tests.

VOR, vestibulo-ocular reflex.

Table I. Findings in 200 patients.

<table>
<thead>
<tr>
<th>Finding</th>
<th>n</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Normal</td>
<td>103</td>
<td>51.5</td>
</tr>
<tr>
<td>Anterior canal low VOR gain</td>
<td>28</td>
<td>14.0</td>
</tr>
<tr>
<td>Lateral canal low VOR gain</td>
<td>23</td>
<td>11.5</td>
</tr>
<tr>
<td>Low VOR gain in all canals</td>
<td>14</td>
<td>7.0</td>
</tr>
<tr>
<td>Lateral and posterior canals low VOR gain</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td>High VOR gain in all canals</td>
<td>8</td>
<td>4.0</td>
</tr>
<tr>
<td>Lateral and anterior canals low VOR gain</td>
<td>6</td>
<td>3.0</td>
</tr>
<tr>
<td>Posterior canal low VOR gain</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>Covert saccades</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Overt saccades</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Multiple saccades</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

VOR, vestibulo-ocular reflex.

Table II. Vestibular disorders.

<table>
<thead>
<tr>
<th>Disorder</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vestibular neuronitis</td>
<td>47</td>
<td>235</td>
</tr>
<tr>
<td>Ménière’s disease</td>
<td>15</td>
<td>75</td>
</tr>
<tr>
<td>Vestibular migraine</td>
<td>15</td>
<td>75</td>
</tr>
<tr>
<td>Benign paroxysmal postural vertigo</td>
<td>13</td>
<td>65</td>
</tr>
<tr>
<td>Central vestibular disorders</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>Metabolic inner ear disorders</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Kinetosis</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Vascular compression</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Dehiscence of superior semicircular canal</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Vestibular schwannoma</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Table III. Patients with recurring episodes of vertigo showing low VOR gain in semicircular canals (n = 55).

<table>
<thead>
<tr>
<th>Semicircular canals</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right lateral</td>
<td>6</td>
</tr>
<tr>
<td>Left lateral</td>
<td>19</td>
</tr>
<tr>
<td>Right anterior</td>
<td>16</td>
</tr>
<tr>
<td>Left anterior</td>
<td>5</td>
</tr>
<tr>
<td>Right posterior</td>
<td>2</td>
</tr>
<tr>
<td>Left posterior</td>
<td>1</td>
</tr>
<tr>
<td>All canals – unilateral</td>
<td>2</td>
</tr>
<tr>
<td>All canals – bilateral</td>
<td>4</td>
</tr>
</tbody>
</table>

VOR, vestibulo-ocular reflex.
It must be taken into account that vHIT and caloric tests stimulate different frequency ranges. Further studies will be necessary to fully understand the significance of low gain VOR responses of different semicircular canals.

Ménière’s disease

The results for the patients with Ménière’s disease, shown in Table IV, were not consistent. In seven patients, the vHIT was normal. Five patients presented high VOR gain in all semicircular canals, probably related to associated metabolic problems. Vestibular hyperactivity is a common finding in patients with hyperinsulinemia, due to changes in the composition and density of endolymph [20]. The others had one or two canals with low VOR gain. The inconsistency is probably related to the clinical variability of Ménière’s disease in terms of duration, severity, and associated pathologies, such as migraine (one patient) and benign paroxysmal postural vertigo (two patients).

Vestibular migraine

Twelve of the 15 patients with vestibular migraine had normal vHIT; one had a hypoactive left lateral canal, one had bilateral low VOR gain of the anterior canals, and one had low VOR gain in all of the semicircular canals on the left side.

Benign paroxysmal postural vertigo (BPPV)

Twelve of the 14 patients with BPPV presented normal results with the vHIT. This is understandable, since this disorder is essentially mechanical. In one patient with a left anterior canal BPPV, this canal presented low VOR gain. However, one patient with a right posterior canal BPPV presented low VOR gain in all canals on the left side. One patient diagnosed as having BPPV is worth mentioning in detail. In 1992 she had epidemic parotiditis accompanied by profound hearing loss in the left ear. In 1997 she began to present episodes of severe vertigo and was diagnosed as having delayed endolymphatic hydrops. In view of the
profound hearing loss she was submitted to a labyrinthectomy in the left ear, performed through a postauricular approach. The three semicircular canals were destroyed, the stapes was removed, and gentamicin was injected into the vestibule.

After the compensation period she remained asymptomatic for 15 years and then returned with a complaint of postural vertigo. It was felt that a contralateral delayed endolymphatic hydrops had to be discarded, and she was submitted to vHIT (Figure 2) that showed less VOR gain for the left anterior and posterior semicircular canals, but this gain was larger than expected in an ear submitted to labyrinthectomy. A CT scan of the temporal bones showed clearly the destruction of the left semicircular canals. It is conceivable that some reorganization of the VOR may occur at the level of the vestibular nuclei. The Hallpike maneuvers demonstrated that she had BPPV.

Central inner ear disorders

Twelve patients were diagnosed as presenting central vestibular disorders. Two had a clinical history of cerebrovascular accidents, one had marked brain ischemia, one had a brainstem glioma, and one had Ehlers-Danlos syndrome with dysautonomia. Two presented age-related normal pressure hydrocephalus. The other five had less severe vascular problems.

None of these patients had normal vHIT results. The patient with the brainstem glioma and the patient with severe brain ischemia presented bilaterally altered lateral and posterior canals. The patients with normal pressure hydrocephalus had poor responses in all six semicircular canals. The patient with Ehlers-Danlos syndrome presented bilateral hypoactive anterior canals. One patient had hypoactive left anterior and right posterior semicircular canals.

Metabolic inner ear disorders

Six patients presented mild low and high tone hearing losses with normal thresholds for the middle frequencies. One of them was found to have intolerance to lactose, the others had hyperinsulinemia [20]. Two of them had normal vHIT results, the others had hypoactive responses of one of the lateral canals.

Kineticosis

The four patients with intense kineticosis had normal vHIT responses.

Vascular compression

The two patients with vascular compression of the eighth nerve seen in magnetic resonance imaging (MRI) presented normal vHIT responses.

Dehiscence of the superior semicircular canal

Normal vHIT responses were recorded in the one case diagnosed with a dehiscence of a superior semicircular canal.

Vestibular schwannoma

A 68-year-old female patient complained of progressive hearing loss in both ears, starting approximately 10 years earlier. During this period of time she had several episodes of vertigo. A recent audiogram showed a sudden loss of discrimination in the left ear, from 72% to 16%. MRI showed a 1.5 mm schwannoma in the left internal acoustic meatus (Figure 3). The vHIT showed a hypoactive response of the posterior canal on the left side, suggesting that this tumor arose from the inferior vestibular nerve.

Conclusions

The possibility of examining each of the six semicircular canals separately introduces a revolutionary change in clinical neurotology and may in time contribute to newer diagnostic possibilities, particularly when associated with the electrical responses of the saccule and utricle.

However, further research is needed, including comparison with other tests, to validate the contribution of the vHIT. The cases discussed in this study suggest that the vHIT can be significant in neurotological diagnosis, particularly in relation to vestibular disorders related to the anterior and posterior semicircular canals.
Acknowledgments

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References


