Nystagmus Discordance with 2-Dimensional Videonystagmography in Posterior Semicircular Canal Benign Paroxysmal Positional Vertigo

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Abstract

Objective. The Dix-Hallpike test is a standard component of the videonystagmography test battery and can diagnose posterior semicircular canal benign paroxysmal positional vertigo. The purpose of this study is to determine the prevalence of discordant, equivocal, and concordant nystagmus tracings in active posterior semicircular canal benign paroxysmal positional vertigo when compared directly with the eye video.

Study Design. Case series with chart review of patients diagnosed with posterior semicircular canal benign paroxysmal positional vertigo by 2-dimensional videonystagmography from August 1, 2007, to August 1, 2012.

Setting. A tertiary vestibular test laboratory.

Subjects and Methods. Ninety-six adults (4 had bilateral involvement) with posterior semicircular canal benign paroxysmal positional vertigo were included. A total of 100 videos with accompanying videonystagmography tracings were reviewed to determine nystagmus trajectory as well as globe position. Descriptive statistics were used to describe prevalence. Fisher exact test was used to compare proportions.

Results. Sixty-two percent of cases involved benign paroxysmal positional vertigo of the right posterior semicircular canal, while 38% involved the left posterior semicircular canal. The prevalence of discordant, equivocal, and concordant tracings was 65% (65/100), 29% (29/100), and 6% (6/100). All tracing errors involved the horizontal channel. There was no association between tracing accuracy and the ear of involvement or globe position (P > .05).

Conclusions. Two-dimensional videonystagmography tracings are not reliable for identifying nystagmus trajectory in posterior semicircular canal benign paroxysmal positional vertigo.

Keywords

videonystagmography, benign paroxysmal positional vertigo, posterior semicircular canal, tracing

Most clinical vestibular laboratories today use 2-dimensional (2D) videonystagmography (VNG). With this technology, video-oculography goggles (VOG) record the patient’s eyes and software tracks pupil position to assess eye movement. Computerized tracings are generated and provide a graphic representation of eye movements in the horizontal and vertical planes. If nystagmus is present, VNG can measure the eye speed and provides a more quantitative assessment of eye movement compared with bedside evaluation with Frenzel lenses or VOG alone.

A standard component of the VNG test battery is the Dix-Hallpike test, which can diagnose vertical semicircular canal benign paroxysmal positional vertigo (BPPV). This test can also be performed at the bedside where the clinician observes the patient’s naked eyes or with Frenzel lenses or VOG goggles to suppress visual fixation. When BPPV affects the posterior or superior semicircular canal, the patient exhibits a mixed vertical-torsional nystagmus during the Dix-Hallpike test. The vertical component is upbeat and the torsional component rotates toward the affected ear and can be seen on the VNG video but cannot be directly recorded on the tracing. Nevertheles, VNG tracings may identify the general trajectory of the eyes. For example, if a patient has active left posterior semicircular canal BPPV, the VNG tracing can...
show a leftward movement of the eye on the horizontal channel and an upward trajectory on the vertical channel.

Some authors have suggested that tracings can aid in the identification of the affected semicircular canal. However, at our institution, we have observed that VNG tracings are often discordant from the eye video when characterizing nystagmus trajectory in posterior semicircular canal BPPV. To date, there are no published studies that specifically assess the accuracy of 2D VNG tracings in characterizing nystagmus trajectory in posterior canal BPPV. Two small qualitative studies using 3D VNG suggest discordance often occurs but never explored potential reasons for this. Given that 2D systems are more commonly used in the clinical setting, we sought to determine how accurate these VNG tracings are when compared with the eye video in cases of posterior semicircular canal BPPV.

**Methods**

Institutional Review Board approval was obtained from the University of Michigan Health System (study No. HUM00065642: “Retrospective Review of Vestibular Test Results in Benign Paroxysmal Positional Vertigo”). This study is a case series with chart review of adult patients diagnosed with posterior semicircular canal BPPV during VNG testing at a tertiary vestibular testing laboratory between August 1, 2007, and August 1, 2012. All testing was done with Micromedical Technologies Visual Eyes Binocular goggles and Spectrum Balance Software (Chatham, IL). This system records a video of both eyes and generates a tracing of eye movements in the horizontal and vertical planes. By default, the system initially calls up the left eye tracings for analysis by the examiner to quantify nystagmus speed and to label nystagmus trajectory. Unless the software has difficulty tracking the left pupil (which manifests as an unstable crosshair over the pupil and may occur in the setting of ptosis, cataract, or excessive blinking), this default setting is maintained.

Cases were identified from a vestibular test report database by searching for the keyword BPPV. Retrieved reports were reviewed to identify those patients with a positive Dix-Hallpike test. The determination of a positive Dix-Hallpike test was made at the discretion of the testing audiologist or technician. A history of episodic positional vertigo was considered but was not required for a diagnosis of BPPV, given it is known that elderly patients in particular may not report vertigo and instead describe more non-specific symptoms. The corresponding video and tracing were retrieved and analyzed at the peak of the response during the Dix-Hallpike test to determine the direction of the nystagmus in the horizontal and vertical channels and to assess globe position. Globe position was defined according to Figure 1. All videos were reviewed independently by 3 examiners: an otolaryngologist, audiologist, and a physical therapist. Each examiner had at least 5 years of experience analyzing eye movement videos, and they were blinded to each other’s interpretation of the nystagmus trajectory. Videos were included for final analysis if all 3 examiners agreed on the following: (1) the nystagmus seen on video during the Dix-Hallpike test was consistent with posterior semicircular canal BPPV, (2) the trajectory of the eye movement, and (3) globe position. A discordant tracing was defined as one with an error in either the horizontal, vertical, or both channels when compared with the video (Figure 2A). An equivocal tracing was defined as one in which the software could not determine the nystagmus trajectory for at least 1 channel (Figure 2B). A concordant tracing was defined as one in which both the horizontal and vertical channels were accurate (Figure 2C).

Descriptive statistics were used to describe the prevalence of concordant, discordant, and equivocal tracings. Fisher exact test was used to compare proportions. A P value of less than .05 was considered significant. Statistical analysis was performed with the online program R (version 3.02).

**Results**

By searching the database, 174 adult patients were identified. For 31 patients, we could not access their videos, either because the data were not preserved or because the external hard drive was corrupted. This left 143 patients with 148 corresponding videos for review (5 subjects had bilateral BPPV). Thirty-five videos were excluded because all 3 examiners felt the video did not demonstrate a nystagmus pattern consistent with posterior semicircular canal BPPV (this included 4 videos with evidence of superior canal BPPV). An additional 13 videos were excluded because we could not reach a consensus among all 3 examiners regarding nystagmus trajectory (for 1 video, all 3 examiners disagreed on nystagmus trajectory, and for 12 videos, there was agreement among 2 of 3 examiners). This left 100 videos from 96 patients for final inclusion in his study. Tracings from the left eye were analyzed in the vast majority of cases, but 7 cases required right eye analysis because the VNG software had greater difficulty tracking the left pupil.

The patients whose videos were included for final analysis ranged in age from 18 to 89 years, and the mean age was 60.4 years. Seventy-one patients were female and 25 were male, yielding a female-to-male ratio of 2.84:1. These demographics are consistent with other published BPPV studies with regard to average age, but our cohort had a higher female: male ratio.

**Table 1** summarizes globe position and the results when computerized tracings are compared directly with the eye video...
movement video for identifying nystagmus trajectory. Sixty-two percent of cases involved the right posterior semicircular canal, and 38% involved the left posterior canal. The prevalence of discordant, equivocal, and concordant tracings was 65% (65/100), 29% (29/100), and 6% (6/100), respectively. In 56% (56/100) of the videos reviewed, the globe was in a neutral position such that the pupil was centered, while in 44% (44/100) of videos, the globe and pupil occupied an eccentric position. The distribution of discordant tracings is shown in Table 2, and all involved an error in the horizontal channel. To characterize factors that could account for tracing accuracy, we looked at both the ear of involvement as well as globe position. When assessing the role of globe position, we classified this parameter as either neutral or eccentric given there was a wide distribution of eccentric cases, and we felt statistical analysis was more appropriate if those videos were taken in aggregate. There was no association between the ear of involvement and tracing accuracy when considered alone or when accounting for globe position (Table 3; Fisher exact test \(P > .05\)). The lack of association between globe position and tracing accuracy was further confirmed when those 2 parameters were compared independent of the ear of involvement (Table 4; Fisher exact test \(P = .329\)).

**Discussion**

This is the first study to assess the accuracy of 2D VNG tracings in identifying nystagmus trajectory in posterior semicircular canal BPPV. Our results show that these tracings cannot reliably identify nystagmus trajectory. In all cases, the error was in the horizontal channel. It has been suggested that tracings may help diagnose superior semicircular canal BPPV by identifying the vertical component of nystagmus.\(^1\) We did not specifically assess superior semicircular canal BPPV in this study given there were so few cases, but the absence of vertical channel error among these cases of posterior canal BPPV suggests the software can reliably identify this component of the nystagmus. However, given that superior semicircular canal BPPV can be elicited with the ipsilateral or contralateral Dix-Hallpike test, it is still important to review the eye video to determine the torsional component to correctly identify the affected side.\(^1,9,10\)

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**Table 1. Summary of the 100 Videos with Corresponding Tracings Included in the Study.**

<table>
<thead>
<tr>
<th>Semicircular Canal</th>
<th>Number of Cases</th>
<th>Concordant Tracing (Globe Position)</th>
<th>Equivocal Tracing (Globe Position)</th>
<th>Discordant Tracing (Globe Position)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right posterior</td>
<td>62</td>
<td>5 (3E, 1A, 1F)</td>
<td>20 (9E, 7A, 4C)</td>
<td>37 (20E, 8A, 5C, 4F)</td>
</tr>
<tr>
<td>Left posterior</td>
<td>38</td>
<td>1 (1E)</td>
<td>9 (4E, 2I, 3F)</td>
<td>28 (19E, 4F, 3I, 2I)</td>
</tr>
<tr>
<td>Total</td>
<td>100 (56E/44non-E)</td>
<td>6 (4E, 2non-E)</td>
<td>29 (13E, 16non-E)</td>
<td>65 (39E, 26non-E)</td>
</tr>
</tbody>
</table>

\(^*\)The letters identifying globe position correspond to the positions shown in Figure 1.

**Table 2. Summary of the 65 Discordant Cases.**

<table>
<thead>
<tr>
<th>Semicircular Canal Involved</th>
<th>Horizontal Channel Discordant</th>
<th>Vertical Channel Discordant</th>
<th>Both Channels Discordant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right posterior</td>
<td>37</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Left posterior</td>
<td>28</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3. Effect of Right versus Left Ear Involvement when Comparing Accuracy of Computerized Tracing to Video.ª

<table>
<thead>
<tr>
<th></th>
<th>Left Posterior</th>
<th>Right Posterior</th>
<th>Left Posterior</th>
<th>Right Posterior</th>
<th>Left Posterior</th>
<th>Right Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concordant</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Discordant</td>
<td>28</td>
<td>37</td>
<td>19</td>
<td>20</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Equivocal</td>
<td>9</td>
<td>20</td>
<td>4</td>
<td>9</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>P values</td>
<td>.331</td>
<td>.486</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ªFisher exact test was used to determine the P value.

Table 4. Effect of Globe Position when Comparing Accuracy of Computerized Tracing to Video.ª

<table>
<thead>
<tr>
<th></th>
<th>Neutral Position</th>
<th>Eccentric Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concordant</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Discordant</td>
<td>39</td>
<td>26</td>
</tr>
<tr>
<td>Equivocal</td>
<td>13</td>
<td>16</td>
</tr>
</tbody>
</table>

ªFisher exact test; P = .329.

The most likely explanation for tracing inaccuracy is that the software tracks pupil position and can measure eye movements only in the horizontal and vertical plane. Significant torsional nystagmus may result in little linear deviation of the pupil, making it difficult to characterize eye trajectory. We considered other factors as well. A technical factor that could have affected tracing accuracy was the fact that our VNG system defaults to the left eye to determine nystagmus trajectory. The nystagmus of the posterior semicircular canal BPPV is disconjugate; the ipsilateral eye has a greater torsional component because of excitation of the ipsilateral superior oblique and contralateral inferior rectus muscles.11 If analyzing left eye movement affected only software accuracy, you would expect cases of left posterior semicircular canal BPPV to have a greater percentage of discordant or equivocal tracings because the video would capture a predominantly torsional eye movement, which the system cannot directly measure. However, we did not identify a significant association between right or left ear involvement and tracing accuracy. The effect of globe position on tracing accuracy was also evaluated because the nystagmus associated with semicircular canal stimulation always aligns in the plane of the canal. That is, with active posterior semicircular canal BPPV, if the patient’s gaze is directed toward the affected side during the Dix-Hallpike test, the globe appears to have a purely torsional movement, whereas it adopts a vertical trajectory if the gaze is directed upward.12 In this study, there was no association between globe position and tracing accuracy, which suggests that discordance is likely a software issue and not simply due to eccentric globe position from patient inattention or inadequate instruction.

There are several limitations to this study. It is retrospective in nature, and therefore a selection bias cannot be ruled out. We could not access the videos for 31 patients who were reported to have a positive Dix-Hallpike test during VNG testing. For 31 videos, the audiologist or technician who administered the VNG battery documented a positive Dix-Hallpike test on the report, but review of the eye video did not show a nystagmus pattern consistent with posterior semicircular canal BPPV. These misclassified subjects were excluded from analysis in this study. Finally, all of our data were collected using equipment from a single manufacturer, so our findings regarding tracing accuracy may be related to this particular system’s pupil-tracking algorithm.

Despite these limitations, we believe the results from this study raise significant questions regarding tracing accuracy for nystagmus associated with posterior semicircular canal BPPV and are relevant to clinical care on several levels. First, when the Dix-Hallpike test is performed as part of the VNG battery, the examiner should observe the eye video in real time rather than rely on the tracing to determine nystagmus trajectory. Second, it is important to save the video and not simply the tracings from this portion of the test battery if the examiner is reviewing a case there is need for future review. Third, if additional studies confirm that tracing inaccuracy is common with other VNG systems, it would lend additional support to a clinical practice guideline that recommended against vestibular testing in this population.13 Formal VNG can be differentiated from bedside evaluation with Frenzel lenses or VOG in that it provides a tracing of nystagmus, quantifies nystagmus speed, and typically includes caloric testing. Accounting for how these 3 factors meaningfully affect BPPV diagnosis and prognosis would be important for justifying use of a complete VNG battery in this population. Our study suggests tracings are often erroneous. Some clinicians maintain that VNG should be performed in those with BPPV to detect co-existing vestibulopathy by caloric testing.14 However, it should be noted that this can often be detected on examination with head thrust testing, and its prognostic significance in BPPV remains controversial.15 Finally, to our knowledge, there are no studies that have identified any prognostic value from measuring the nystagmus speed associated with posterior semicircular canal BPPV.

For patients with a history strongly suggestive of BPPV, a Dix-Hallpike test done at the bedside is sufficient for diagnosis. In our practice, we have moved away from performing VNG on all patients who present for evaluation of
dizziness. Instead, those with positional vertigo are now evaluated by a physician or vestibular-certified physical therapist in the office, where examination includes Dix-Hallpike testing under VOG goggles or Frenzel lenses. If there is a history of antecedent vestibular crisis or positive head thrust test to suggest co-existing vestibulopathy, we tailor the vestibular exercise regimen accordingly. VNG or imaging studies are reserved for those who do not improve with therapy, exhibit atypical nystagmus patterns, or have other findings such as asymmetric sensorineural hearing loss.

Conclusions
Computerized tracings from a commonly used 2D VNG system are not reliable for identifying nystagmus trajectory in posterior semicircular canal BPPV as the horizontal channel is often discordant. To identify the affected ear and semicircular canal with certainty, it is advisable to observe the eye video in real time or to review a recording of the eye video. Such eye movements can be observed at the bedside with VOG alone or with Frenzel lenses.

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Author Contributions
Crystal M. VanDerHeyden, design of work, data acquisition and analysis, drafting of manuscript, final approval of manuscript, agreed to be accountable for all aspects; Wendy J. Carender, design of work, data acquisition and analysis, drafting of manuscript, final approval of manuscript, agreed to be accountable for all aspects; Katherine D. Heidenreich, design of work, data acquisition and analysis, drafting of manuscript, final approval of manuscript, agreed to be accountable for all aspects.

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References