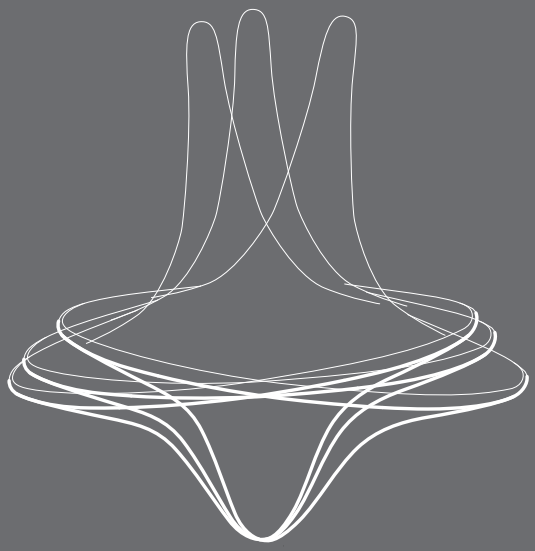
Menière's disease: Clinical aspects, diagnostic tests and interventions

Esch, B.F. van

PART II

EVALUATION OF DIAGNOSTIC TESTS FOR MENIÈRE'S DISEASE



6

DETERMINING VESTIBULAR HYPOFUNCTION: START WITH THE VIDEO-HEAD IMPULSE TEST

Babette F. van Esch
Anne-Jasmijn G.E. Nobel-Hoff
Peter Paul G. van Benthem
Hester J. van der Zaag
Tjasse D. Bruintjes

European Archives of Oto-Rhino-Laryngology 2016 273(11):3733-3739

ABSTRACT

Caloric testing is considered the 'reference standard' in determining vestibular hypofunction. Recently, the video-head impulse test (vHIT) was introduced. In the current study we aimed to assess the diagnostic value of the vHIT as compared to caloric testing in determining vestibular function. In a cross-sectional study between May 2012 and May 2013, we prospectively analysed patients with dizziness who had completed caloric testing and the vHIT. For the left and right vestibular system we calculated the mean vHIT gain. We used a gain cut-off value of 0.8 for the vHIT and presence of correction saccades to define an abnormal vestibular-ocular reflex. An asymmetrical ocular response of 22% or more (Jongkees formula) or an irrigation response with a velocity below 15°/s was considered abnormal. We calculated sensitivity, specificity, positive and negative predictive values with 95% confidence intervals for the dichotomous vHIT. Among 325 patients (195 females (60%); aged 53 ± 17 years), 40 (12%) had an abnormal vHIT gain and 113 (35%) had an abnormal caloric test. Sensitivity was 31% (23%-40%), specificity 98% (95%-99%), positive predictive value was 88% (74%-95%), and negative predictive value 73% (67%-77%). The high positive predictive value of the vHIT indicates that an abnormal vHIT is strongly related to an abnormal caloric test result. In case of vHIT normality, additional caloric testing remains indicated and the vHIT does not replace the caloric test. In case the vHIT is abnormal, additional caloric testing is not necessary and the vHIT is useful as a first test in screening for vestibular hypofunction.

INTRODUCTION

The 'reference standard' for assessing the vestibular function is caloric testing but it uses a nonphysiological, low-frequency stimulus, is time-consuming, unpleasant and yields varying interindividual responses[1,2]. In 1988, Halmagyi and Curthoys [3] introduced a more simple, bedside method to assess vestibular function, the clinical head impulse test which had a low sensitivity, but a high specificity to detect a unilateral vestibular deficit [4,5]. Later, this test was improved by Magnusson *et al.* [6] who used video recordings of the patients' eye movements for the so-called video head impulse test (vHIT). This test measures the eye movements in response to brief, unpredictable passive head rotations (head impulses) [7]. This video-assisted procedure has been demonstrated to be a simple, valid clinical tool for testing vestibular function.

While the relationship between the clinical head impulse test and caloric testing has been investigated in several studies [4,5,8,9] , less is known about the relationship between the vHIT and caloric testing [10-12].

The goal of this study was to assess the diagnostic accuracy of the vHIT in determining vestibular hypofunction when caloric testing is considered the reference standard in dizzy patients.

MATERIALS AND METHODS

We prospectively evaluated patients with dizziness who had been referred to the Apeldoorn Dizziness Centre (ADC), a tertiary referral centre in a teaching hospital. Patients were included for analysis if caloric testing and the vHIT had been completed on the same day. After completion of the caloric test, we scheduled a break of at least 10 minutes. We assured that a nystagmus by previous caloric testing was absent and all patients had an adequate state of alertness before the start of vHIT evaluation. Patients were excluded if they had not undergone either test, if contraindications to perform caloric testing were present (e.g. tympanic membrane perforation, otitis, ear surgery) or if test results were incomplete. The diagnosis was based on a detailed clinical history, current available diagnostic standards [13-15] and/or additional diagnostic tests.

Ethical consideration

All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All data was analysed anonymously.

Caloric testing

Conventional open loop bithermal caloric testing (33°C and 44°C) in both ears was used to elicit vestibular responses. The ocular response was obtained and analysed by means of a video-based system (Vestlab 7.0 ®, Otometrics, Germany). The Jongkees formula [16] was applied to express the vestibular preponderance (VP) and directional preponderance (DP) in percentages, based on the velocity of the slow phase component of nystagmus evoked by each vestibular organ. Based on the values used in previous research [4,9] and on our own experience, caloric tests were considered abnormal if the vestibular preponderance was 22% or more or the directional preponderance was 28% or more. Caloric testing was also considered abnormal if the responses for all irrigations were below normal. The criterion for bilateral weakness was a V_{max} below 15°/s for each vestibular organ (V_{max} is the sum of the slow-phase velocity for irrigation warm water + slow phase velocity for irrigation cold water).

Video head impulse test

The vHIT was measured by means of a commercially available binocular video oculography system (ICS Impulse System, version 1.20, OTOsuite Vestibular software; Otometrics, Taastrup, Denmark). The system consists of light-weight goggles with an integrated video oculography camera with sensors. An elastic band ensures fixation and minimises motion of the goggles. In a dimly lit room, subjects were instructed to maintain fixation at a dot from 1m distance. An experienced laboratory technician delivered at least 20 head impulses (10-20° angle, duration 150-200ms, peak velocity of >150°/s) in the horizontal plane with unpredictable timing and direction. The video images were analysed online by means of software which calculated Vestibular Ocular Reflex (VOR) gains. The VOR gain was defined as the ratio of the mean eye velocity (°/s) over the mean head velocity (°/s). The presence of corrective (catch-up) saccades, either overt or covert, was evaluated by the laboratory technician. To minimise biased interpretation of the vHIT test results they were evaluated by a second independent laboratory technician, who was blinded for the caloric test result. We defined a gain cut-off value of 0.8 for the vHIT, with the presence of correction saccades indicating an abnormal VOR [11,19].

Statistical analysis

The results of the study are reported according to the Standards for Reporting of Diagnostic Accuracy Studies (STARD) [4]. We calculated the mean vHIT gain for the left and right vestibular systems. We assessed whether the side of the abnormal caloric test result corresponded with the abnormal vHIT test result. Various VOR gain cut-off points have been used in previous research [11,19]. We performed a subgroup analysis considering a VOR gain of 0.6 as cut-off point for VOR dysfunction to investigate the effect on

diagnostic accuracy of the vHIT [10]. The diagnostic accuracy was evaluated by combining the caloric test and the vHIT per patient. We calculated the sensitivity, specificity, positive and negative predictive value with 95% confidence intervals (CI). The diagnostic statistical evaluation was performed with the online software from Open Source Epidemiologic Statistics for Public Health (available at http://www.openepi.com)

RESULTS

Between May 2012 and March 2013, 945 patients suffering from dizziness visited our dizziness clinic. **Figure 1** displays the test results of the 325 patients who underwent caloric testing and the vHIT. The sample population had an average age of 53 years ± 17 years and consisted of 195 females (60%). In **Table 1**, details on the diagnoses can be found. In our study population, the two most common diagnoses were hyperventilation (n=55, 17%) and benign paroxysmal positional vertigo (n=44, 14%). In 55 patients the diagnosis remained unclear despite our thorough diagnostic work-up.

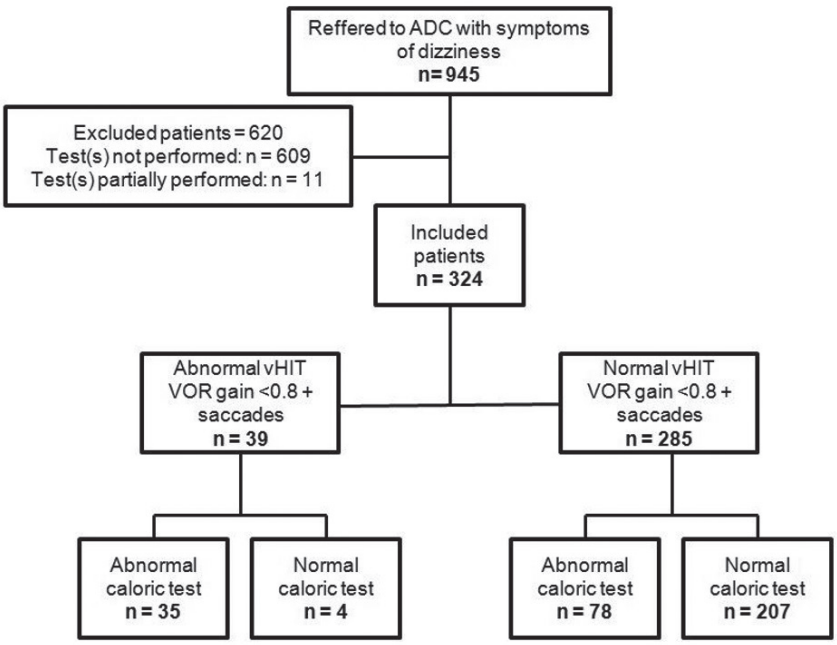


Figure 1. Flow chart for the comparison of video head impulse testing and caloric test. ADC = Apeldoorn Dizziness Centre; vHIT = video head impulse test; VOR = vestibulo-ocular reflex

TABLE 1 Diagnoses of population presenting with dizziness

Diagnosis	n (%)	Abnormal caloric test n (%)
No diagnosis	55(16.9)	8(7.1)
Hyperventilation	55(16.9)	13(11.5)
Positional vertigo	44(13.5)	11(9.7)
Somatoform/phobic	35(10.8)	8(7.1)
Menière's disease	30(9.2)	20(17.7)
Migraine	25(7.7)	6(5.3)
Vestibular neuritis/labyrinthitis	19(5.9)	18(15.9)
Unknown peripheral vestibular syndrome	16(4.9)	7(6.2)
Recurrent vestibulopathy	13(4.0)	5(4.2)
Bilateral vestibular failure	11(3.4)	10(8.8)
Orthostatic hypotension/cardiovascular	8(2.5)	2(1.7)
Central causes	8(2.5)	4(3.5)
Multisensory deficit	3(0.9)	1(0.8)
Other	3(0.9)	0(0.0)
Total	**325(100)**	**113(100)**

An abnormal caloric test was found in 113 of the 325 patients (35%). Asymmetrical responses between the left and right ear at caloric testing were found in 93 patients (29%) (mean caloric deficit 46 % ±25). In three patients the caloric test was abnormal due to abnormality of the DP. Six of these patients had a VP of 100% and thus had a unilateral vestibular paralysis. Hypofunction represented by a V_{max} below 15°/s per system was present in 58 patients (18%); in 45 patients this was unilateral, in 13 bilateral. Complete bilateral areflexia was present in five cases.

The vHIT was abnormal in 40 patients (12%). Video recordings of a normal and an abnormal video-head impulse test are shown in **Figure 2**. In one patient the side of the abnormal VOR gain did not correspond with the side of the abnormal caloric test result. In this patient a congenital (spontaneous) nystagmus reduced our ability to interpret the VOR gain, and the patient was therefore excluded from further analysis, leaving 39 patients with an abnormal vHIT. All but six patients with a VOR gain below 0.8 had either covert or overt saccades. **Figure 3** displays the mean canal paresis deficit as a function of the normal and abnormal vHIT results. Patients with an abnormal vHIT had a significantly higher mean caloric deficit than patients with a normal vHIT (mean difference 30%, 95%CI:18%-42%, $p<0.001$). All patients with a gain below 0.6 had corrective saccades. No adverse events occurred while performing any of the tests.

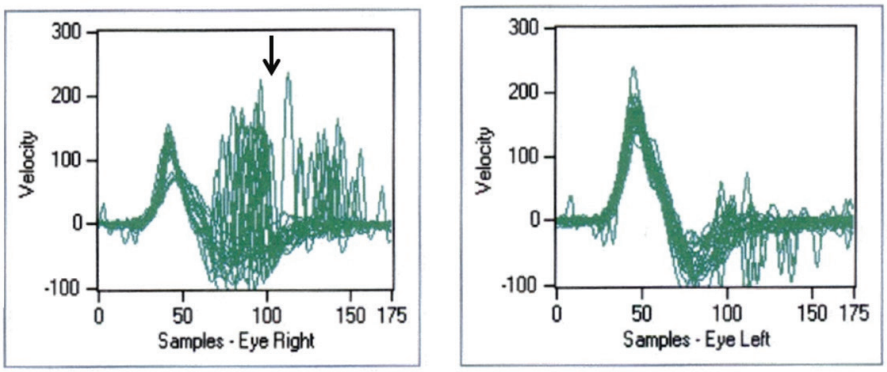


Figure 2. A pathological (eye right) and an unremarkable (left eye) vHIT are shown. In the right eye, the eye velocity is lower including the presence of (overt) correction saccades (*arrow*)

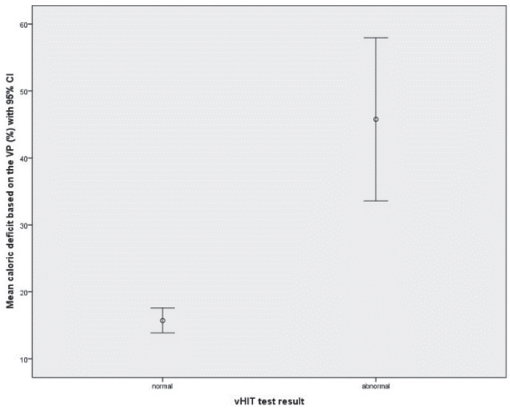


Figure 3. Mean canal paresis deficit as a function of the vHIT test result. Data represent mean and corresponding 95% confidence intervals.

In comparison with caloric testing the vHIT (with a VOR gain < 0.8 and corrective saccades) had a sensitivity of 31% (95% CI: 23%-40%), a specificity of 98% (95% CI: 95%-99%), a positive predictive value (PPV) of 90% (95% CI: 76-96) and a negative predictive value (NPV) of 75% (95% CI: 70-79) (**Table 2a**).

Subanalysis, using a VOR gain of 0.6 as cut-off point for vestibular dysfunction, resulted in 25 patients (7.7%) with an abnormal vHIT (**Table 2b**). Caloric test results were abnormal in all these subjects. The subanalysis on diagnostic accuracy resulted in a sensitivity of 22% (95% CI: 16%-31%), a specificity of 100% (95% CI: 98%-100%), a PPV of 100% (95% CI: 87%-100%), and a NPV of 71% (95% CI: 65%-76%).

TABLE 2a Results of the vHIT and caloric testing with a VOR gain cut-off value of <0.8

	Caloric test*		
vHIT	Abnormal (n)	Normal (n)	Total
Abnormal (n)	35	4	39
Normal per system(n)	78	207	285
	113	211	324
Sensitivity was 31% (95% CI: 23%-40%), specificity 98% (95% CI: 95-99), positive predictive value (PPV) 90% (95% CI: 76-96), negative predictive value (NPV) 75% (95% CI: 70-79)			

*Cut-off values for an abnormal caloric test were a VP ≥ 22%, a DP ≥ 28% and/or a V_{max} < 15°/s per vestibular system.

TABLE 2b Results of the vHIT and caloric testing with a VOR gain cut-off value of <0.6

	Caloric test*		
vHIT	Abnormal (n)	Normal (n)	Total
Abnormal (n)	25	0	25
Normal per system(n)	88	211	299
	113	211	324
Sensitivity was 22% (95% CI: 16%-31%), a specificity was 100% (95% CI: 98%-100%), a PPV of 100% (95% CI: 87%-100%), and a NPV of 71% (95% CI: 65%-76%).			

*Cut-off values for an abnormal caloric test were a VP ≥ 22%, a DP ≥ 28% and/or a V_{max} < 15°/s per vestibular system.

DISCUSSION

Synopsis of key findings

We aimed to assess the diagnostic value of the vHIT compared to caloric testing in determining vestibular function in patients suffering from dizziness. In a large prospective cohort of 325 patients, we found a sensitivity of 31% and a specificity of 98%, a PPV of 90% and a NPV of 75% for the vHIT when compared to caloric testing. In the subgroup analysis, using a VOR gain of 0.6 as cut-off point, the sensitivity decreased to 22%, the specificity and the PPV reached 100% and the NPV decreased to 71%.

Comparison with other studies

Whilst the specificity we found is in line with previous studies, we report a lower sensitivity. Previous studies evaluating the vHIT compared to caloric testing reported specificities between 92% and 100% but sensitivities between 41% and 78% [10-12]. None of these studies reported the predictive values (PPV and NPV) of the vHIT [10-12].

The differences in sensitivities may be explained by the fact that these studies evaluated the diagnostic value of the vHIT in much smaller groups than our study [10-12]. Besides, analyses were performed on retrospectively collected data [10,11] and they used different cut-off values defining abnormal vHIT gain and caloric test results [10-12].
The highest sensitivity of 78% was found by McCaslin *et al.*[12], who analysed 115 patients under the age of 65. A possible explanation for the higher sensitivity may be that the mean caloric deficit values were higher in McCaslin's study population than in ours [12] as the sensitivity of the vHIT depends on the canal paresis factor. For instance, Bartolomeo *et al.*[10] reported a sensitivity of 100% when the caloric vestibular deficit limit value was set to 62.5% or higher. In our population a mean caloric deficit of 46 ±25% was found. Mahringer and Rambold [11] reported a mean caloric deficit of 48±18%. In this study, 71 of the 172 patients were identified with an abnormal vHIT which is comparable to our results. The mean caloric deficit in the population studied by Bartelomeo *et al.*[10] was 78.7±21.2% which explains why in all patients the vHIT was abnormal. McCaslin *et al.*[12] did not provide information on mean caloric deficits. Therefore, it is not clear whether the data are comparable to caloric deficits in our population.

Strengths of the study

Prior studies [10-12] evaluating the diagnostic accuracy of the vHIT did not include the caloric response per se when defining an abnormal test result in patients with symmetrical or non-pathological asymmetrical caloric test responses. They focused on those patients who had a unilateral caloric weakness as calculated by the Jongkees formula [16]. By including patients with a low caloric response per se, represented as a V_{max} below 15°/s per vestibular system, we identified 20 additional patients with vestibular hypofunction. Ten of these patients had a decreased VOR gain based on the vHIT, which implies that it is relevant to include these patients in a diagnostic study. Another important finding was that a vHIT gain cut-off value of 0.6 was clinically useful as a PPV of 100% was reached [10]. An abnormal vHIT using this cut-off value strongly indicates a severe or total canal paresis and excluded patients with a borderline vHIT test result.

Clinical applicability of the study

A practical implication of the present study is that the vHIT may be used as a first diagnostic test in determining vestibular hypofunction. An abnormal vHIT is related to significant canal paresis especially when the gain is less than 0.6, and therefore additional caloric testing is not necessary. The advantage of using the vHIT is that it is a simple, safe and non-invasive test that allows repeated testing within a few minutes. Drawbacks of caloric testing are that results may be influenced by skull characteristics, temporal bone circulation, alertness of the patient and previously administered medication [18,19].

The use of the vHIT as a screening tool for vestibular hypofunction is supported by the economic evaluation performed by Rambold *et al.* [20]. This study assessed the optimal diagnostic sequence for the vHIT and the caloric test expressed as the shortest diagnostic time. The diagnostic time was significantly shortened when the vHIT was performed first, even if additional caloric testing was necessary in case of a normal vHIT test result. Based on the time saving aspect it was concluded that starting with the vHIT was the most optimal diagnostic sequence for economic reasons.

Limitations of the study

It is important to bear in mind that several factors may have influenced study results. First, due to differences in their diagnostic characteristics, the different test results of the vHIT and caloric testing provide unique information regarding the integrity of the horizontal semicircular canals. Evaluation by means of the vHIT involves a high frequency range (up to 5 Hz), whereas the caloric test reflects a low frequency range (approximately 0.003 Hz). The vHIT causes a physiological endolymphatic flow, whereas caloric testing involves a non-physiological non-gravity dependent stimulus. The tests provide complementary information about the horizontal semicircular canals and should be used adjunct to one another. It remains unknown to which extent dissociation of vHIT and caloric testing can be explained by these differences.

Secondly, the diagnostic work-up was performed by multiple, yet experienced, laboratory technicians. Although the vHIT is considered a relatively objective diagnostic method, as VOR gains are calculated by software, lab employees may judge the presence of correction saccades differently.

Thirdly, the clinical meaning of the DP is controversial and does not always correlate with peripheral vestibular disorders [18]. As abnormality of the DP led to an abnormal caloric test result in only three cases little importance should be given to the DP when interpreting caloric test abnormalities in our study.

Lastly, as only 34% of all 925 consecutive test patients could be included for further analysis, selection bias may have influenced our test results. However, all patients who visited our clinic were eligible for inclusion without applying pre-selection based on caloric test abnormalities. Therefore, we believe the low percentage of included patients does not inhibit applicability of our study findings.

CONCLUSIONS

In conclusion, comparison with caloric testing revealed that the vHIT is a very specific rather than sensitive test for detecting vestibular hypofunction. In case of a normal vHIT, additional caloric testing remains indicated and the vHIT does not replace the caloric test.

The high positive predictive value of the vHIT, especially if a gain cut-off point of 0.6 is applied, indicates that an abnormal vHIT is strongly related to an abnormal caloric test result. Therefore, in case of an abnormal vHIT, additional caloric testing is not necessary. We conclude that the vHIT is clinically useful as a first test in determining vestibular hypofunction in dizzy patients.

Competing interests: The authors declare that they have no conflict of interest.

REFERENCES

1. Aw ST, Haslwanter T, Fetter M. Contribution of the vertical semicircular canals to the caloric nystagmus. *Act Otolaryngol* 1998;118:618-27.
2. Schmid-Provisceanu A, Böhmer A, Obzina HH. Caloric and search-coil head-impulse testing in patients after vestibular neuritis. *J Assoc Res Otolaryngol* 2001;2:72–8.
3. Halmagyi GM , Curthoys IS. A clinical sign of canal paresis. *Arch Neurol* 1998;45:737-39.
4. Beynon GJ, Jani P, Baguley DM. A clinical evaluation of head impulse testing. *Clin Otolaryngol* 1998;23:177-22.
5. Harvey SA, Wood DJ, Feroah TR. Relationship of the head impulse test and head-shake nystagmus in reference to caloric testing. *Am J Otol* 1997;18:207-13.
6. Magnusson M, Karlberg K, Halmagyi M, Hafström A. The video-impulse test enhances the possibility of detecting vestibular lesions. *J Vestib Res* 2002;11:231.
7. Weber KP, MacDougall HG, Curthoys IS. Impulsive testing of semicircular-canal function using video-oculography. *An NY Acad Sci* 2009;1664:486-491.
8. Jorns-Haderli M, Straumann D, Palla A. Accuracy of the bedside head impulse test in detecting vestibular hypofunction. *J Neurol Neurosurg Psych* 2007;78:1113-18.
9. Perez N, Rama-Lopez J. Head-impulse and caloric tests in patients with dizziness. *Otol Neurotol* 2003;24:913-17.
10. Bartolomeo M, Biboulet R, Pierre G, Mondain M, Uziel A, Venail F. Value of the video head impulse test in assessing vestibular deficits following vestibular neuritis. *Eur Arch Otorhinolaryngol* 2013;271:681-88.
11. Mahringer A, Rambold HA. Caloric test and video-head-impulse: a study of vertigo/dizziness patients in a community hospital. *Eur Arch Otorhinolaryngol* 2013;271:463-72.
12. McCaslin DL, Gary JP, Marc BL. Predictive properties of the video head impulse test: measures of the caloric symmetry and self-report dizziness handicap. *Ear and Hearing* 2014;34:185-91.
13. Committee on Hearing and Equilibrium. Guidelines for the diagnosis and evaluation of therapy in Meniere's disease. *Otolaryngol Head Neck Surg* 1995;113:181-85.
14. Lempert T, Olesen J, Furman J. Vestibular migraine: diagnostic criteria. *J Vestib Res* 2012:22;167-72.
15. Zingler VC, Cnyrim C, Jahn K. Causative factors and epidemiology of bilateral vestibulopathy in 255 patients. *Ann Neurol* 2007;61:524-32.
16. Jongkees LBW, Maas JPM, Philipszoon AJ. *Clinical nystagmography Pract Otolaryngol* 1962;24:65-93.
17. Bossuyt PM, Reitsma JB, Bruns DE et al. Towards complete and accurate reporting of studies of diagnostic accuracy: the STARD initiative. *BMJ* 2003;326:41-44.
18. Goncalves DU, Felipe L, Lima TMA. Interpretation and use of caloric testing. *Rev Bras Otorhinolaryngol* 2008;73:440-46.
19. MacDougall HG, Weber KP, McGarvie LA. The video head impulse test: diagnostic accuracy in peripheral vestibulopathy. *Neurology* 2009;73:1134-41.
20. Rambold HA. Economic management of vertigo/dizziness disease in a county hospital: video-head-impulse test vs. caloric irrigation. *Eur Arch Otorhinolaryngol* 2015;272:2621-28.