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Utility of quick oculomotor tests for screening the vestibular system in the subacute and chronic populations

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Abstract

Objective—The goal of this study was to determine the sensitivity and specificity of some widely used, easily administered clinical tests.

Background—Simple tests of oculomotor function have become widely used for clinical screening of patients suspected of having vestibular disorders despite a paucity of evidence showing good statistical support for their use in this highly variable population.

Methods—Healthy controls with no history of otologic or neurologic disorders (n=291) were compared to patients with known vestibular disorders (n=62). All subjects performed passive and active head shaking, un-instrumented head impulse tests (HT) and video head impulse tests (vHIT) recorded with infrared video-oculography.

Results—For both passive and active head shaking, using presence/absence of vertigo and of nystagmus, sensitivity was low, < 0.40. Sensitivity of presence/absence of saccades on HT was even lower, < 0.15. On vHIT, gains were all approximately 1.0, so sensitivity was very low, approximately 0.15 to 0.35. Sensitivity and specificity for presence/absence of saccades were moderately poor, less than 0.70.

Conclusions—None of these tests are adequate for screening patients in the out-patient clinic for vestibular disorders or for screening people in epidemiologic studies to determine the prevalence of vestibular disorders.

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Introduction

Screening tests have a long history in health care as a way to provide valid and reliable data which the clinician can use to begin the process of clinical decision making. Such tests are easily administered in a short period of time, with minimal equipment but are easily interpreted as being normal or abnormal. Screening tests are not used to make specific medical diagnoses, but may help a physician to determine if objective diagnostic tests of a particular system are needed. For example, weight, blood pressure, and temperature are screening tests that are used world-wide and are required in virtually all primary care clinics.

Simple, relatively inexpensive screening tests of oculomotor function have become widely used by physicians and therapists around the world to help determine the occurrence of vestibular impairments. These tests include the head impulse test with or without instrumentation and head shaking tests either passive or active. They may be useful for screening in the physician's clinic, and in ancillary clinics such as occupational and physical therapy practices, nursing homes, rehabilitation centers, and other health care settings. These tests may also be useful for screening large samples of the population in epidemiologic studies to determine the prevalence of vestibular disorders. As with all screening tests, the purpose of these tests is to identify individuals who are likely to have vestibular impairments, not to make diagnoses.

Head shaking tests have been described by many authors (1-3). The test is controversial because its value has not yet been well-established. For example, Jacobson et al. reported poor sensitivity of only 27% and reasonably high specificity of 85%. Despite that evidence, the head shaking test is the preferred screening test by some neurotologists although others do not like it, even within the same institution. It can be performed passively, with the observer shaking the patient's head 10 to 30 times, or it can be done actively by having the patient shake his or her own head.

The head impulse test without instrumentation (HT) was initially described by Halmagyi et al. and has become widely used (4-6). That test is not useful for patients who are relatively young or have a vestibular deficit or weakness on bi-thermal caloric testing of less than 60% (7). Nevertheless, it continues to be used by clinicians as a vestibular screening test. Several manufacturers have developed video-oculography and software to record and interpret head impulse tests. These tests, too, have become widely used, known as the video head impulse test (vHIT).

The goal of this study were to determine sensitivity and specificity for the oculomotor tests described above when they are used for screening people for vestibular disorders. We expect these tests to be used eventually in the clinic with subacute and chronically ill patients and in population-based epidemiologic studies. Because we used patients who had already been tested with a "gold standard" objective diagnostic battery, were surgical patients, or who met specific diagnostic criteria we were able to determine if the oculomotor screening tests correctly identified individuals with known vestibular disorders.

Materials and Methods

Subjects

Subjects were 291 healthy controls and 62 patients with known vestibular disorders. Control subjects were recruited from the caseloads of the geriatricians, and from among staff and visitors to our institution. Control subjects who had not been prescreened by a geriatrician were screened with a medical questionnaire prior to participation. Patient subjects were recruited from among patients seen by the senior author and other clinicians in the otology section of the otolaryngology department. Patient subjects had been diagnosed by their board-certified physicians, mostly otolaryngologists and neurologists and some primary care physicians, based on their clinical examinations as well as the results of Dix-Hallpike tests, bi-thermal caloric tests (> 20% unilateral weakness), cervical vestibular evoked myogenic potentials and low frequency sinusoidal tests of the vestibulo-ocular reflex in darkness. Patient subjects who had unilateral benign paroxysmal positional vertigo of the posterior semicircular canal (BPPV) were symptomatic at the time of testing, and were treated subsequently. See Tables 1 and 2 for details. All subjects had active and passive cervical range of motion within functional limits. No subjects had neurologic or significant musculoskeletal disorders. Controls had no history of vestibular disorders and no significant otologic problems, including no history of ear surgery. All subjects gave informed consent prior to participating. The study was approved by the Institutional Review Board for the corresponding author's institution.

Methodology

Subjects were tested using a Micromedical Technologies Visual Eyes Four Channel VNG system, which is a binocular, infra-red video-oculography (VOG) system. To perform head shaking tests, the subject's eyes were covered and closed during testing. When the head movement stopped the subject opened his eyes. For active head shaking, subjects were instructed to shake their heads 3 times but most subjects shook their heads 4 or 5 times. For passive head shaking the observer shook the subject's head 20 times. Passive head movements were limited to $\pm 15^\circ$ to avoid cervical injury. For either test, when the head movement stopped the subject was asked to look straight ahead in the dark for up to 30 seconds to determine the presence/absence of nystagmus. Nystagmus was determined to be present if at least 3 beats were observed. Subjects were asked if they had vertigo; vertigo was rated as present or absent. The angular velocity sensor on the VOG system was used to determine the actual frequency of the yaw head movements.

Subjects were tested on HT using two trials leftward and two trials rightward, as in the literature (7). The dependent measure was the presence/absence of saccades while the subject stared at the observer's nose. For vHIT subjects were given 15 rightward and 15 leftward head impulses while staring at a fixation point 1 meter away at eye level, per the manufacturer's instructions (8). The dependent measures were gain and presence/absence of saccades for each eye in each direction as calculated by the system software.

Statistical methods

Patients and controls were compared via t-tests for continuous variables or chi-square/Fisher exact tests for grouped ones. Logistic regression was performed for estimation of area under the curve (AUC), where cut offs for best combinations of sensitivity/specificity were determined. $P < .05$ was considered significant. Due to the known age-related changes in the vestibulo-ocular reflex (9) the age range was divided into two groups. All analyses were performed in SAS statistical software (version 9.4, Cary, NC).

Results

Head shaking tests

For active head shaking, subjects moved their heads at a mean of 1.8 Hz (SD 0.6). For passive head shaking subjects' heads were moved at a mean of 2.5 Hz (SD 0.4). The dependent measures were presence or absence of saccades and the presence or absence of vertigo. Because these data are binary, ROC values were not calculated. For both active and passive conditions, and both vertigo and presence of nystagmus, sensitivity was low, less than 0.40. For both conditions and both measures, i.e. vertigo and presence of nystagmus, specificity was very high, 0.96-0.99. See Table 3.

Head impulse tests

The dependent measure for HT was the presence or absence of saccades. Because these data are binary ROC values were not calculated. Sensitivity was extremely low, < 0.15 for both sides and both age groups, and specificity was very high, > 0.96 for both sides and both age groups. See Table 4.

Video Head Impulse Tests

The dependent measures for vHIT were sum gain, and presence or absence of saccades. No significant differences in gain were found between younger (age < 60 years) and older (age ≥ 60 years) age groups, Wilcoxon rank sum test, $p=0.563$. The gains for controls were all approximately 1.0. For all patients, together, the mean gain was 1.08 (SD 0.24, range 0.45 – 1.5). The gains did not differ between younger and older age groups: mean gain in subjects $< 60 = 1.1$ (SD=0.24, range 0.45 – 1.5); gain in subjects $\geq 60 = 1.07$ (SD=0.29, range 0.45 – 1.5). ROC values were approximately 0.5. ROC values for sum gains were all less than 0.60. For saccades, sensitivity was 0.13 to 0.35 and specificity was 0.85 to 0.90 for individual trials. For all trials combined, sensitivity and specificity were poor: less than 0.70. See Tables 5 and 6 for details.

The sensitivity and specificity of a test are related to the percentages of true and false positives and negatives, i.e. the percentages of patients who are correctly or incorrectly identified (true and false positives, respectively) and the percentages of controls who are correctly identified (true and false negatives, respectively). Those values are derived from the same analyses as sensitivity and specificity. Because physicians may be more familiar with those concepts than sensitivity and specificity, Table 7 provides an alternative way to consider the data, showing the percentages of true and false negatives and positives, which

are derived from the ROC values. Similar to the sensitivity and specificity, the percentages of true positives are low and the percentages of false negatives are high.

Discussion

These tests are easily administered and have some intuitive logic. Therefore, they have become widely used. These results, however, indicate that these tests, when used as we did in this study, are not helpful for screening people – either patients or research subjects -- to determine if they have vestibular impairments. The head shaking tests, although popular, have not been shown by other investigators to be useful as a clinical test for screening patients. Our results confirm that they have such low sensitivity that they should not be used for screening. They do identify healthy control subjects well but they do not identify patients at even a mediocre level. Although head shaking might cause nystagmus and vertigo in patients, more often than not nystagmus was not observed and vertigo was not reported by the subject. If a physician had relied on head shaking to screen these patients for vestibular disorders when they initially visited the clinic, before the patients had had objective diagnostic tests, quite likely even a very experienced physician would have drawn the wrong conclusion. Therefore, we recommend against the use of either active or passive head shaking for screening people to determine if they have vestibular disorders, in either research or clinical situations.

Head shaking does have some limited clinical utility. In patients with known vestibular disorders that cause vertigo elicited by head movement, i.e. disorders excluding Meniere's disease and benign paroxysmal positional vertigo, active head shaking may be useful to help the occupational or physical therapist determine which head movements are most provocative and should be incorporated into a vestibular rehabilitation program. That issue, however, was not addressed in this study.

Our present results replicate the previous finding of low sensitivity for HT (7). This work also supports the finding of Lawson and Bamiou, who reported that older subjects may be particularly difficult to test (10). We agree that older subjects are more difficult to test due to reduced cervical flexibility or pain from arthritis. Therefore, we recommend against the use of un-instrumented head impulse tests for screening patients for vestibular disorders, for patients who are not acutely vertiginous.

With the development of VOG, development of the vHIT was a logical next step and was widely accepted in the clinical community in short order. Several manufacturers have developed user-friendly technology to record eye movements. Therefore, the assumption that vHIT was useful for screening was intuitively satisfying. We obtained low ROC values, low sensitivity and specificity, and low true positives and true negatives in our results, however, indicating that even with instrumentation head impulse testing is not useful for screening. Although some patients did have saccades some healthy control subjects did, too. Having subjects maintain concentration on a focal point while relaxing the neck enough for the examiner to move the head passively was challenging. As with the head shaking test, if a physician had relied on head shaking to screen these patients for vestibular disorders when they initially visited the clinic, before the patients had had objective diagnostic tests, quite

likely even a very experienced physician would have drawn the wrong conclusion. Thus, we recommend against use of vHIT for screening patients for vestibular disorders, on an initial visit when the diagnosis is not already known and the examining physician has no evidence to indicate a vestibular disorder.

VHIT has been shown to have low sensitivity or specificity in other studies, too (11, 12). VHIT gain has been shown to be unrelated to recovery from vertigo, and unrelated to the presence of saccades, so it is not useful for predicting symptom recovery (13, 14). Other investigators have shown that vHIT gain in the yaw plane is approximately 1.0 and changes minimally with age (15-17). Our results support that finding.

These tests may have other uses. For example, head impulse tests have been shown to be useful for screening acutely ill patients in the emergency room. Vanni et al found that in an emergency room 84% of 24 subjects who were screened with head impulse tests had positive responses (18). Cada et al. screened patients after chemical acoustic neuroma ablation and found that results of head impulse tests were consistent with bi-thermal caloric weakness equal to or greater than 80% (19). VHIT has been reported to be useful for following Meniere's patients after intra-tympanic gentamicin (20), including predicting short-term control of vertigo attacks (21). The data in the present study have no bearing on those other findings.

This study had some limitations. We did not test patients in the acute phase of an attack of labyrinthitis, a Meniere's attack, or in the acute phase of recovery after surgery. No patients were seen in the emergency room or acute care hospital. Thus, we have no information about the use of these tests for screening acutely vertiginous patients. Our results apply only to patients who have passed that acute stage. Some individuals who did have vestibular disorders might not have been detected had they been tested. For example, people with well-controlled Meniere's disease or vestibular migraine did not have positive responses in this study and similar patients probably would not have had positive responses if tested. Because the clinician who sees a new patient for the first time cannot know the diagnosis, and these tests do not help to determine if the diagnosis is even within the category of a vestibular disorder, as opposed to some other disorder that might cause vague "dizziness" intermittently such as a cardiovascular problem, we recommend against using these tests. A new patient coming from a different clinical practice, e.g. someone who has relocated to a new city owing to a change in employment, who has Meniere's disease or vestibular migraine and who has been diagnosed already is probably maintained on medication and would not need screening because the patient would already know the diagnosis.

Similarly, individuals who had compensated so quickly after having an acute attack of vertigo that they never saw a physician, or pre-operative acoustic neuroma patients might not have been detected, either. Acoustic neuromas are rare. Objective hearing tests and imaging measures are used to make the diagnosis. Screening tests are not useful.

We did not test elderly people with mental retardation or dementia who were unable to follow directions or give informed consent, or individuals with cervical range of motion

limitations, disorders of ocular motility, severe visual limitations, or neurologic deficits so we do not know if these screening tests would have been useful with those populations.

Vestibular disorders are generally more common in middle-aged and older people. Therefore, the patients we tested were mostly middle-aged and geriatric, with fewer younger patients. If we had been able to recruit more younger patients, the results might have been somewhat different.

The main limitation for the reader, however, is that these tests are not diagnostic and are not intended to replace objective diagnostic testing. They are one component of a clinical examination that could be used by a physician but could also be performed by a physician assistant, nurse practitioner, occupational or physical therapist, or a well-trained technician in a variety of contexts for a variety of purposes. We recommend against the use of these tests because they are so insensitive that no useful information is obtained from them. Taking a good history, using well-validated questionnaires, and screening with balance tests and Dix-Hallpike tests would be preferred.

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Biographies

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Table 1

A study sample size demographics; mean and SD duration of symptoms. Six subjects also reported symptoms > 100 months, but those data are outliers.

	Age (mean years, SD, ranges)	Sex (males, females)	Duration of symptoms (months)
Controls (n=291)	55.1 ± 18.9, 21-95	109M, 182 F	N/A
Patients (n=62)	58.3 ± 14.3, 29-88	28M, 34F	Median, 9; Mean 20, SD 27, range 0.25 to 528

Table 2

Diagnoses of patient subjects. Benign paroxysmal positional vertigo (BPPV). Unilateral, peripheral vestibular weakness on bi-thermal caloric testing > 20% (UW), consistent with labyrinthitis or vestibular neuronitis. Meniere's disease (Meniere's). Acoustic neuroma (AN)

Disorder	Sample size
UW	33
Dual BPPV and UW	8
Meniere's	7
Vestibular Migraine	3
Pre-operative AN	5
Post-operative AN	2
Bilateral vestibular weakness	2
Dual BPPV and migraine	2

Table 3

Active and passive head shaking sensitivity (sensit) to patients and specificity (specif) to controls by age group. Active head shaking (AHS). Passive head shaking (PHS).

Test	59 years				60 years			
	Vertigo		Nystagmus		Vertigo		Nystagmus	
	Sensit	Specif	Sensit	Specif	Sensit	Specif	Sensit	Specif
AHS	0.290	0.980	0.323	0.994	0.161	0.963	0.194	0.985
PHS	0.258	0.962	0.387	0.975	0.161	0.963	0.290	0.970

Table 4

Un-instrumented head impulse test sensitivity and specificity by age group, side and combined sides.

	Age 59 years		Age 60 years	
	Sensitivity	Specificity	Sensitivity	Specificity
Head impulse leftward	0.13	0.99	0.03	0.99
Head impulse rightward	0.03	0.99	0.07	0.97
Combined leftward and rightward	0.13	0.99	0.07	0.97

Table 5

ROC values for VHIT gain. Sensitivity and specificity are not included because the ROC values are too low for those measures to be meaningful.

	Age 59 years	Age 60 years
	ROC	ROC
Left eye head moving leftward, for rightward slow phase	0.539	0.544
Right eye, head moving leftward for rightward slow phase	0.510	0.518
Left eye, head moving rightward for leftward slow phase	0.512	0.50
Right eye, head moving rightward for leftward slow phase	0.511	0.572
All trials combined	.520	0.519

Table 6
VHIT saccades, sensitivity and specificity

	59 years		60 years	
	Sensitivity	Specificity	Sensitivity	Specificity
Left eye head moving leftward, for rightward slow phase	0.39	0.86	0.13	0.92
Right eye, head moving leftward for rightward slow phase	0.63	0.78	0.25	0.84
Left eye, head moving rightward for leftward slow phase	0.35	0.85	0.17	0.86
Right eye, head moving rightward for leftward slow phase	0.19	0.81	0.17	0.86
All trials combined, saccades present in any trial	0.68	0.68	0.32	0.68

Table 7

VHIT saccades, percentages of true positives (TP) and false negative (FN) for patients and true negatives (TN) and false positives (FP) for controls, combined left and right trials. True positives correctly identify patients, true negatives correctly identify controls.

Age		60 years			
		Patients	Controls		Controls
Test +	67.7% (TP)		32.3% (FP)	Test +	31.9% (FP)
Test –	32.3% (FN)		67.7% (TN)	Test –	68.2% (TN)