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Screening people in the waiting room for vestibular impairments

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Abstract

Objective—Primary care physicians need good screening tests of the vestibular system to help them determine whether patients who complain of dizziness should be evaluated for vestibular disorders. The goal of this study was to determine if current, widely-used screening tests of the vestibular system predict subsequent performance on objective diagnostic tests of the vestibular system (ENG).

Setting and subjects—Of 300 subjects who were recruited from the waiting room of a primary care clinic and were screened there 69 subjects subsequently volunteered for ENGs in the otolaryngology department. The screening study included age, history of vertigo, head impulse tests, Dix-Hallpike maneuvers, and Clinical Test of Sensory Integration and Balance (CTSIB) with head still and head pitching at 0.33 Hz. The ENG included Dix-Hallpike tests, vestibular evoked myogenic potentials, bi-thermal water caloric tests, and low frequency sinusoids in the rotatory chair in darkness.

Results—The scores on the screening were related to the total ENG but odds ratios were not significant for some variables probably due to the small sample size.

Conclusions—A larger sample may have yielded stronger results but in general the high odds ratios suggest a relationship between the ENG score and Dix-Hallpike responses and between the ENG scores and some CTSIB responses.

Keywords

Public health; screening assessment; inner ear; dizziness

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Introduction

Few studies validate screening tests of the vestibular system in the absence of the lengthy, expensive and equipment-intensive battery of objective diagnostic tests (ENG battery). The ENG battery often includes low and high frequency sinusoidal rotatory chair tests of the vestibulo-ocular reflex (VOR), bi-thermal caloric tests, Dix-Hallpike maneuvers (D-H) and other positional tests of the VOR, vestibular evoked myogenic potential tests, and tests of saccadic, smooth pursuit and optokinetic eye movements. When an ENG battery is unavailable or too expensive, or the physician wants to determine if the ENG battery is necessary, a screening battery with head movements, D-H, and balance tests may be used in conjunction with the health history, as in a recent study to determine whether people with HIV/AIDS are at increased risk for vestibular disorders (1).

The D-H is an old, widely-known test (2), performed by turning the patient’s head toward the side to be tested and having the patient rapidly lie supine with the neck hyperextended. Eye movements, i.e. nystagmus, are easily observed when recorded with infra-red video-oculography (VOG). A classical, positive response on this test, i.e. nystagmus beating toward the test side, is pathognomonic for benign paroxysmal positional vertigo (3, 4).

The head impulse test (HIT) is widely used for screening the horizontal VOR. The examiner sits in front of the subject, instructs the subject to stare at the examiner’s nose and briskly, rotates the head approximately 20° leftward or rightward in yaw rotations, stopping suddenly and approximating a step of velocity. The response is positive if the examiner observes a saccade contralateral to the head movement. A positive response may be consistent with impaired horizontal semicircular canal function (5–8).

One version of the Romberg test for standing balance, the Clinical Test of Sensory Interaction and Balance (CTSIB) has become widely used among clinicians (9, 10). The patient stands with feet together on the floor or compliant foam with eyes closed. The condition on foam with eyes closed is considered a screening test for vestibular impairments although testing with the head still has limited sensitivity and specificity (11). Younger (aged 21 to 59) and older (aged 60 +) adults differ in the time to perform the test, and sensitivity/specificity improve when the head oscillates in pitch at 0.33 Hz. The ability to perform 5 or more pitch rotations of the head during the test is consistent with normal vestibular function (12). We used both head still and head pitching conditions.

The goal of this preliminary study was to determine if the results of a screening battery accurately predicted the outcome of the ENG battery. Volunteers took the screening battery. Some people then agreed to have the ENG battery.

METHODS

Subjects

Initially we recruited 300 volunteers, aged 21 to 79, from the waiting room of a primary care clinic and from staff and other visitors to our institution. They were all ambulatory without gait aides. Exclusion criteria included: a history of known otologic disease or surgery; use of vestibular-suppressant medication, e.g. meclizine, diazepam, benzodiazepines; musculoskeletal conditions that prevented independent gait; recent surgery if the surgeon had not yet approved return to full activities; and history of significant neurologic disease, e.g. stroke, Parkinson's disease, multiple sclerosis, lower extremity peripheral neuropathy, cerebellar disease, or dementia that precluded giving informed consent. Because CTSIB performance does not differentiate vestibular disorders from presbystasis or various neurologic conditions, and many people have more than one disorder, we relied on subjects' histories to rule out nonvestibular disorders.

Subjects reported their age, sex, and history of vertigo. Except for one subject with a strongly positive Dix-Hallpike response they were not told whether their screening results were normal or abnormal. Subsequently, 69 subjects volunteered to visit the diagnostic laboratory for the full ENG battery. Other subjects declined the ENG battery due to the time needed for the battery (2.5 hours), the need to take the tests at another time, the inconvenience traveling between campuses, or lack of interest.

All subjects gave informed consent prior to participating in the screening. This study was approved by the Institutional Review Board for Human Subjects Research for our institution. Data were collected between June and November 2011.

Screening battery

The 15-minute screening battery included HIT, D-H, and tests of standing balance using the modified CTSIB, given in a private room in random order. Screening tests were performed by one of three laboratory technicians who had 8 to 25 years of experience doing research and diagnostic testing with patients suspected of having vestibular disorders.

Prior to performing HIT the examiner determined that the subject had at least 30° of yaw cervical range of motion. This brief examination also allowed the subject to get used to having the examiner move her head passively. Then, the examiner gave the subject two trials of HIT to each side. A response was considered positive if the examiner observed a saccade on both trials to one side.

D-H was performed on a stretcher with the wheels locked, and a firm foam mattress. Eye movements were recorded with infrared video-oculography. A positive D-H response was defined as three or more beats of nystagmus with a latency to onset of at least 2 seconds. A classical response was defined as having quick phases up-beating, with horizontal and torsional components beating ipsilaterally (3). A positive but nonclassical response was defined as any other response with three or more beats of nystagmus. Subjects were also asked if they had vertigo, defined as the illusion of self motion.

CTSIB trials were given for a maximum of 30 seconds, in the same order, in increasing order of difficulty, with feet together and arms crossed. Tests were given on the floor before being given on 10 cm, medium density, compliant Sunmate® foam (Dynamic Systems, Leicester, NC). Tests were given with eyes open before being given with eyes closed. Tests were given without augmented head motions (head still) before being given with pitch head rotations (pitch). For tests given with head pitch the 0.33 Hz frequency of head movement was cued with use of an iPod (Apple, Inc) portable music player, attached to desktop amplifiers or an ear bud earphone, and played at a comfortable intensity level.

Every subject wore a 28.3 g inertial motion sensor (IMU; Xsens North America Inc., Los Angeles, CA) on a plastic band atop the head. A single data acquisition program (LabView, National Instruments, Austin, TX, USA) collected time-synchronized data from the IMUs, which were sampled at 100 Hz. Data were used to verify the trial duration and the number of head movements during head still and head pitch CTSIB trials.

CTSIB trials had two dependent measures, time, i.e., trial duration, and number of head motions the subject could make during the test. Time scores were considered abnormal if the trial duration was less than one standard deviation of the age-based scores for normals aged 21 to 59 and 60 to 79 years and head nodding was considered abnormal if the subject made less than 5 head motions during the trial. These normative values were based on previously collected data from our lab (12).

ENG battery

All subjects were invited to have the standard clinical ENG battery used at our institution. The laboratory where the ENG battery was given is located in the Department of Otolaryngology, in a separate facility, 5.7 km away. Therefore, subjects would have had to travel between campuses to have had the ENG battery on the same day as the screening battery. Due to the distance, the time needed for the ENG battery, and the possibility of nausea elicited by bi-thermal caloric testing patients and research subjects must avoid eating for three hours before testing. Thus, ENG's are usually scheduled in advance. Subjects were tested within one month of the day of screening, as their schedules allowed. The ENG technician was blinded to the outcome of the screening tests. Prior to beginning the ENG battery the technician ascertained that the subject had not had a change in health status.

The ENG battery included cervical vestibular-evoked myogenic potentials (VEMP); low frequency sinusoidal tests of the vestibulo-ocular reflex in darkness in the horizontal plane using the computerized rotatory chair (Contraves-Goertz) at 0.0125, 0.05, and 0.2 Hz ± 60°/sec, while eye movements were recorded with electronystagmography; and tests of smooth pursuit and saccades using a light bar; D-H, positional tests and bi-thermal water caloric tests while eye movements were recorded with infra-red video-oculography while the subject lay on a firm, padded examination table.

Test results were interpreted by the neurotologist who reads all of the ENG's from the laboratory. Therefore, he was blinded to the study. If the ENG results were abnormal the neurotologist summarized the response pattern as: non-localizing, peripheral vestibular unilateral weakness; central impairment; superior canal dehiscence; or benign paroxysmal positional vertigo. We were concerned with finding any possible abnormality that might indicate a vestibular impairment, not with specific diagnoses. Therefore, for the purposes of this study, the summary result of the overall ENG battery was scored as either normal or abnormal. Subjects were provided with copies of their test results and, if abnormal, were advised to consult their physicians.

Statistical methods

We compared patients with normal and abnormal ENG scores by t-tests for continuous variables and chi-square/Fisher exact tests for grouped variables. Logistic regression was used for estimation of odds of abnormal ENG by screening test result. Adjustments were made for potential confounders, specifically age and history of vertigo, by including those variables on the regression model. P< 0.05 was considered statistically significant.

RESULTS

Although we recruited 300 volunteers for the screening battery 231 of them declined to return for the ENG; 156 of initial subjects who declined the ENG had abnormalities on at least one subtest of the screening battery.

The rest of this section describes only the 69 subjects who had both the screening battery and the ENG. The age of subjects with normal ENG results approached being significantly less than subjects with abnormal ENG results, p=0.07. Every one-year increase in age increased the odds for ENG by 4 % (OR=1.04). ENG results were not related to subjects' sex. History of vertigo was four times more prevalent among subjects with abnormal ENG scores than among subjects with normal results (OR=4.0), although this difference did not reach statistical significance (p=0.12), possibly due to the small sample size. See Table 1.

Dix-Hallpike maneuvers

During the screening 40% of the 69 subjects had positive responses to D-H. One response was classical; the other responses were nonclassical. During the ENG 35% to 39% of subjects had positive responses on D-H in supine and sitting, respectively. As shown in Table 1, abnormal D-H (supine) responses were more than three times more common in subjects with abnormal ENG compared to subjects with normal ENG results (OR=3.23). The results approached significance univariately (p=0.09), but after adjustment for potential confounders (OR=3.2, p=0.11) were not statistically significant, probably due to the relatively small sample size. These results suggest that in a larger sample the results might have been significant.

CTSIB

The percentage of subjects who took the ENG and who had abnormal CTSIB pitch nodding scores did not differ between groups with normal and abnormal ENG scores (see Table 1). On CTSIB with head still and with head pitch the time scores were not related to the total ENG score, p=0.18 and p=0.62, respectively. The score on CTSIB with head still was significantly related to having a normal/abnormal score on VEMP when adjusted for age, p=0.04, but CTSIB with head pitch was not significantly related to VEMP. The score for nodding during CTSIB, either < 5 or ≥ 5, was examined. The age-adjusted relationship between the score on VEMP and CTSIB approached significance for head still, p=0.09, but was not significant for head pitch, p=0.68. For subjects younger than 50 years no relationship was found between VEMP or the total screening score and nodding during head still or head pitch. For subjects older than 50 years no relationship was found between nodding and VEMP, or the total screening score during head still, but the relationship approached significance during head pitch, p=0.08. When adjusted for age, no relationship was found between the total ENG score and the nodding score with head still or head pitch.

Head impulse tests

Only one subject in the abnormal ENG group had a positive HIT (see Table 1). The total HIT score was not related to the total ENG score: Chi-square = 0.38, p=0.99; the rotatory score: p=0.99; or the caloric score: p=0.21. Of the 20 subjects with abnormal scores on caloric testing and/or rotatory chair testing, only that one subject also had a positive HIT.

History

The association between a history of vertigo and a positive finding on the ENG battery approached significance, p=0.12. Having a history of vertigo was not related to having a normal or abnormal subtest response including VEMP, p=0.16; bi-thermal caloric tests, p=0.25; or rotatory chair tests, p= 0.85. The ENG was abnormal among 89.5% of subjects with a history of vertigo, but among only 68% of subjects without a history of vertigo. See Table 1.

Total screening score

The total screening battery was also scored as either normal or abnormal. No significant relationship was found between the total screening score (TSS) and the total ENG score; Chi-square = 0.19, p=0.65, but the TSS was significantly related to the VEMP score after controlling for age, p=0.02. No relationship was found between the TSS and the score on bi-thermal caloric testing; Wald Chi-square = 0.68, or the rotatory chair test score; Wald Chi-square = 0.80, after controlling for age for both tests.

DISCUSSION

Several variables from the screening battery were promising for use in future studies. History of vertigo had a particularly high odds ratio. Responses to D-H testing -- to the maneuver, itself, and to sitting up after the maneuver -- also had high odds ratios. Somewhat lower odds ratios were found for CTSIB but those responses, especially to time and nodding for the head still condition, are still likely to be useful for screening. The absence of positive HIT responses suggests that this screening measure may have limited utility despite its popularity among clinicians.

Subjects were recruited regardless of their histories of vertigo although no subjects were actively vertiginous. The age difference between people with and without histories of vertigo confirms previous findings (13). Similarly the finding that subjects with positive responses to D-H testing were older than subjects with negative responses was consistent with previous work showing that BPPV and central vertigo occur in middle and older age (14). We expected to find that a preponderance of subjects with positive, classical D-H responses were female, but the sample of people in that category was so small that the analysis by sex is probably not meaningful.

The discrepancy between the screening D-H and the ENG D-H has several explanations. The slight differences in compliance of the surfaces used for testing might have had an effect. At screening some patients may have felt slightly unwell without having positive responses on the day of testing but that sense of being unwell may have been their reason for volunteering for the ENG. During routine clinical testing sometimes patients have negative responses when tested initially but have positive responses on another day, due to the variability of vestibular responses.

The lack of a statistically significant relationship between the ENG and screening results was probably due to the relatively small sample size. Most components of the ENG battery, evaluate the VOR elicited by stimulation to the lateral semicircular canal or to the superior branch of the vestibular nerve. The HIT is approximately two sharp ramps of increasing and then decreasing head velocity with peak velocities of 150°/sec to 350°/sec and accelerations of 4000°/sec^2 to 5000°/sec^2 (6, 7). Bi-thermal caloric testing approximates low frequency VOR testing at 0.003 Hz and 0.58°/sec^2 (15). Although some studies have shown that patients known to have UW have impaired responses to HIT (6, 7) other investigators have suggested that the test sensitivity is low, 0.34 to 0.63 (16–18). All of rhose studies had small samples so the sensitivity of HIT remains unclear. The velocity profiles of the stimuli in the ENG battery and the head impulse are different. We gave rotatory tests at three frequencies, 0.0125 Hz, 0.05 Hz, and 0.2 Hz, none of which matched HIT. These differences might account for the lack of relationship between tests but this point remains to be clarified.

Age, history of vertigo, D-H supine responses, CTSIB still time, CTSIB still nodding (i.e., number of head rotations), and CTSIB pitch nodding had odds ratios that approached significance. Thus, those variables may be useful for screening although this suggestion should be tested and confirmed in larger, adequately powered studies. Except for D-H tests, we cannot state with assurance which screening variables are directly related to particular ENG variables.

The VOR tests and CTSIB measure different constructs. Balance testing, e.g. CTSIB, is more likely to detect abnormalities associated with the vestibulospinal tracts, which get their input primarily from the otoliths, including both utricular and saccular inputs, although the vertical canals probably contribute, too (19, 20). During CTSIB with pitch vertical canal signals must also be involved. The ENG battery did not include the relatively new test of ocular VEMP (21–23), because standard clinical procedures are not well defined yet. Ocular VEMP might have shown a relationship to CTSIB performance.

The comparison between the screening and ENG results may have been affected by a sampling bias due to the smaller sample of subjects who had the ENG. Unfortunately, due to constraints of time and funding, we could not continue to recruit until we had the planned complement of 300 subjects who had had the ENG. The strategy of recruiting subjects by asking strangers in a waiting room to participate may not have been optimal. Had the local physicians been able to encourage participation we might have recruited a larger sample, however, we might have had a bias of a different type.

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Key points

1. A description of true vertigo, i.e., the illusory sensation of self-motion rather than a vague sense of dizziness, should be considered when taking the history.
2. Dix-Hallpike maneuvers should be performed during office screening.
3. Romberg standing balance tests on foam with eyes closed are somewhat useful; head impulse tests are less useful for screening.

Table 1

Odds for abnormal ENG results by patient characteristics at screening. N, sample sizes; SD, standard devations; OR, odds ratios (95% confidence intervals). Adjusted OR was adjusted for age and history of vertigo. Age (yrs): mean (SD). History of vertigo, sample size Yes (% Yes). Sex, sample size female (% female). D-H supine, Dix-Hallpike maneuver, sample size (% abnormal either classical or nonclassical). D-H sitting, sitting up from D-H supine, sample size (% abnormal). CTSIB still, CTSIB with head still, sample size (% abnormal); CTSIB pitch, CTSIB with head pitching, sample size (% abnormal). CTSIB still, pitch, nodding sample size (% abnormal, < 5 head motions). Head impulse test, % abnormal.

Baseline variables				
	Normal ENG (N= 18 (26%))	**Abnormal ENG (N=51 (74%)**	**Univariate OR**	**P-values**
Age (mean, 51.2; SD, 13.2)	46.3 (13.2)	52.9 (12.9)	1.04 (0.99 – 1.08)	0.07
Sex (N male, 39 (56.5%))	8 (44.4%)	22 (43%)	0.95 (0.32–2.86)	0.92
History of vertigo (yes, 19 (27.5%))	2 (11.11%)	17 (33.3%)	4.0 (0.98–27.16)	0.12
Screening variables				
	Normal ENG	Abnormal ENG	Univariate OR	Adjusted OR
D-H supine	3 (16.7%)	20 (39.2%)	3.23 (0.92–15.21), p=0.09	3.20 (0.84–15.95), p=0.11
D-H sitting	3 (16.7%)	18 (35.3%)	2.73 (0.77–12.0), p=0.15	2.92 (0.77–14.64), p=0.14
CTSIB still time	6 (33.3%)	25 (49.0%)	1.92 (0.64–6.26), p=0.25	1.28 (0.38–4.49), p=0.69
CTSIB pitch time	12 (66.7%)	29 (56.9%)	0.40 (0.11–1.23), p=0.12	0.41 (0.11–1.33), p=0.15
CTSIB still nodding	4 (22.0%)	22 (44.0%)	2.75 (0.85–10.77), p=0.11	1.93 (0.54–7.92), p=0.33
CTSIB pitch nodding	11 (68.8%)	29 (74.4%)	1.32 (0.35–4.66), p=0.67	1.05 (0.25–4.00), p=0.94
Head impulse test	9 (4%)	1 (1%)	---	---