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Subjective visual vertical in vestibular disorders measured with the bucket test

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Abstract

Conclusion—The “bucket test” may indicate that patients with known vestibular disorders have spatial orientation deficits but due to the low ROC values it is not useful for screening people for vestibular impairments.

Objectives—1) to verify that patients with unilateral peripheral vestibular weakness (UW) differ from normals on the bucket test, 2) to determine if patients with unilateral benign paroxysmal positional vertigo (BPPV) differ from normals, 3) to determine the sensitivity and specificity of the test.

Method—Patients with UW (25) and BPPV (25) were compared to normals (50). Subjects looked into a clean bucket with a vertical line on the bottom, which rested on a table. It was rotated, clockwise or counterclockwise, for three trials per direction until the subject indicated the line was vertical. The dependent measure was the mean absolute value of the deviations from the true vertical.

Results—Some, but not all, patients’ responses differed from normals but responses also differed by age and sex. ROC values were all weak, i.e., < 0.8. No good cut-points differentiated controls from patients. Thus, although the bucket test is useful for describing spatial deficits in patients this test is not useful for screening people for possible vestibular impairments.

Keywords

spatial orientation; benign paroxysmal positional vertigo; unilateral weakness; visual perception

Introduction

Subjective visual vertical (SVV) is an indicator of an impaired sense of spatial orientation in patients with central (1, 2) and peripheral vestibular disorders (3–5). Static SVV may become normal a few weeks after vestibular neurectomy but during eccentric rotation SVV tested in reference to a moving visual background may still show impairments (4, 6).

A few studies have examined SVV in patients with benign paroxysmal positional vertigo (BPPV) but the overall results are inconclusive (4, 7, 8). For example Hong et al found differences in SVV between normals and BPPV patients only when the subjects were being rotated (7). Gall et al. found differences between normals and BPPV patients pre-treatment but von Brevern et al (9) did not. More recently Faralli et al reported slight but statistically

significant differences between normals and pre-treatment BPPV patients (10). No other studies have addressed BPPV and SVV.

Discrepancies among the paradigms of the various studies may be caused by differing methodologic details that affected the outcome of testing (11). For example Hong et al had subjects rotate a manipulandum by hand, thus perhaps inadvertently using kinesthetic information to augment visual input (7). By contrast Gall et al (8) had subjects state the correct orientation of a line that the examiner moved, so the subject's somatosensory input was not involved. Three other groups used paradigms that involved minimal limb movement to push buttons or to operate a remote control device, but not to rotate a device (5, 9, 10).

Recently Zwergal et al (12) described the "bucket test" as a simple, inexpensive method for screening patients for SVV. The equipment is inexpensive and easy to construct, and the test is easy to administer. They reported significant differences between controls and patients with unilateral weakness but did not report patients with BPPV. That preliminary study also did not describe statistical analyses to indicate the usefulness of the test for screening people for potential vestibular impairments. The goals of the present study were to determine if patients with BPPV and unilateral weakness (UW) are impaired on performance of this test and to determine if this test is useful for screening people for vestibular impairments.

Methods

The subjects were 50 normals, 25 patients with unilateral, posterior canal BPPV, and 25 patients with unilateral vestibular weakness (UW). The BPPV and UW groups did not differ significantly by age but normals were significantly younger than the patient groups, $p < 0.02$. (See Table 1.) Normal subjects were recruited from among staff and visitors to the laboratory. Patients were recruited from among the caseload of patients referred for clinical, vestibular diagnostic testing and patients referred to the senior author for vestibular rehabilitation. All patients had been diagnosed by a board-certified physician based on the history and clinical examination, including the Dix-Hallpike maneuver. At the physician's discretion patients may have been referred for objective diagnostic testing in this laboratory; that test battery included Dix-Hallpike maneuvers and bi-thermal caloric tests during which eye movements were recorded with binocular infra-red video-oculography. All BPPV patients in this study had unilateral, positive responses to Dix-Hallpike maneuvers. All unilateral weakness patients had findings that included a unilateral weakness on bi-thermal caloric testing 20 percent. All BPPV patients were tested prior to receiving treatment and positive Dix-Hallpike response was verified by the senior author, who was the treating therapist. All subjects gave informed consent prior to testing. This study was approved for the Institutional Review Board for Human Subjects Research for our institution.

Testing was performed using the bucket method (12). A clean, opaque, white, plastic trash bucket, 38 cm deep, 23 cm diameter was used. It was converted to a test device by marking a 15 cm black line centered on the bottom inside, and a protractor was placed on the bottom outside aligned with the line inside. A small weight was hung from the center of the protractor. The bucket was placed on its side on a table, 29.5×25 cm, atop a height-adjustable tripod to stabilize the bucket in pitch and yaw. In that position when the bucket was rolled in the clockwise and counterclockwise directions the string and weight rotated freely so the investigator could read the protractor. Prior to testing each subject the height of tripod was adjusted so that the subject's face fit into the bucket easily. All measurements were taken by the examiner, monocularly, using the examiner's dominant eye.

Two test conditions were used in random order: vertical roll from the upper end of the line, rightward and leftward of 0° . Subjects were given three trials per condition. The starting

point for each trial was selected randomly, varying from 10° to 20° from the 0° line. Before each trial the subject was instructed to state when the line was vertical while the examiner moved the bucket. The subject did not touch the bucket during testing.

Paired t-tests were used to compare normal and abnormal sides of the same subjects. Unpaired t-tests were used to compare the UW and BPPV groups, to compare the patient group, as a whole, to normals, and to compare males and females. Vestibular function is known to change with age. To examine the effect of age unpaired t-tests were used to test the groups < 50 years or age and ≥ age 50. All variables were initially assessed for normality. In all comparisons, statistical significance was determined with Wilcoxon rank sum tests for non-normal data. $P < 0.05$ was considered statistically significant. All analyses were performed using SAS Statistical Software (SAS, Cary, NC).

Results

The dependent measure was the absolute value of the deviation from the actual vertical. No significant differences by normal and abnormal side were found with the UW and BPPV patient groups, combined, $p=0.53$, or in the groups separately: BPPV, $p=0.92$, UW, $p=0.43$. Thus, the sides did not differ significantly. BPPV and UW groups did not differ significantly. See Table 2. Neither patient group showed consistent deviations toward the abnormal side.

Significant differences were found between the mean of controls vs the normal side in patients, $p=0.004$, between controls and the abnormal side of patients, $p<0.0001$, and between controls and the combined abnormal and normal sides in patients, $p<0.0001$. Thus, patients and controls did differ on this measure. See Table 2.

In females, all comparisons showed statistically significant differences between controls and patients: using patients' normal sides, $p=0.002$, using patients' abnormal sides, $p=0.01$, and using combined normal and abnormal sides, $p=0.0002$. Males showed no differences between controls and patients' normal sides, $p=0.999$, but showed a trend toward differences between controls and patients' combined normal and abnormal sides, $p=0.092$. They showed significant differences between controls and patients' abnormal sides, $p=0.04$. These results should be viewed with caution, however because the sample of patients included more females than males. See Table 2.

Older subjects were not different between controls and patient's normal sides, $p=0.35$; significant differences were found between controls and patients' abnormal sides, $p=0.03$, and between controls and patients' combined normal and abnormal sides, $p=0.02$. See Table 3. In younger subjects significant differences were found between controls and patients' normal sides, $p=0.01$, between controls and patients' abnormal sides, $p=0.03$, and between controls and patients' combined normal and abnormal sides, $p=0.01$. These findings should be considered with caution, however, due to the small sample of patients younger than 50.

To be useful for screening, a good test should show strong differences between groups on receiver operating characteristics (ROC) analyses, high sensitivity to patients and also high specificity to normal controls. ROC analyses of these data, however, revealed no good cut-points, i.e., above 0.80, and the best combinations of sensitivity and specificity yielded values that were all less than 0.80. The best cut-point found was 1.3, using the normal side for patients, < 50 years old even for that cut-point sensitivity and specificity were 0.77 and 0.72, respectively. See Table 4 for the cut-points, ROC values and corresponding sensitivity and specificity using gender, and patients' normal scores, abnormal scores and combined normal and abnormal scores. Note that for males, normal side, the odds ratio associated with the ROC was 1.0, indicating complete lack of ability to differentiate patients and controls.

Discussion

This study supports and extends the findings from previous studies. Unlike Zwergal et al we did not include patients with central lesions, but we did include patients with BPPV. The present study has three main findings: 1) slight but statistically significant differences between patients and normals, 2) significant differences between males and females, but 3) no useful cut-points to differentiate patients from normals overall or when stratified by age and sex. In other words although the patients do differ somewhat from normals, as previously reported by Zwergal et al, patients and normals do not differ enough for this test to be useful for screening people with vestibular impairments. Therefore, this test is not useful for screening.

These results confirm the finding of a difference between groups and clarifies that finding with additional details. Female patients, and younger subjects in general, differed from normal controls when tested toward their “normal” sides, toward their “abnormal” sides and when the means of the normal and abnormal sides were combined. Male patients differed from normals only on their abnormal sides, but approached differing from normals on the combined normal and abnormal sides. A larger sample of males might have yielded a more definitive result about the comparison between the combined normal and abnormal sides. Older subjects had no definitive differences between normal and abnormal sides but approached being different, but did differ on the abnormal and combined normal plus abnormal sides. A larger sample might have yielded more definitive results in older subjects and would also have allowed comparisons among smaller age groups.

Gender-related differences in spatial orientation have been known for many years (13–15). Therefore, the finding of differences between male and female subjects is not surprising. Our finding, with this simple line orientation task in the absence of visual cues, extends that body of work to a sample of people with vestibular impairments.

These findings suggest that using this test for screening is not straightforward. The clinician should consider the age and sex of the patient as well as other information that is already known about the patient’s vestibular function. If the abnormal side is unclear then the clinician who uses this test may use the mean of the two sides. This finding makes the test useful in patients who may have decreased gains on sinusoidal low frequency rotational testing in darkness but who do not have clinically significant differences by side on bi-thermal caloric testing, or who have not had that test. The clinician should be aware, however, that this test will not definitively indicate the side of the impairment.

Clinicians often use tests for screening, such as in the initial visit after taking a history, in a primary care clinic or other clinical setting where a full battery of objective vestibular diagnostic tests is unavailable, or in situations where the clinician must first demonstrate a reason to suspect a vestibular disorder before referring for objective diagnostic testing. For a test to be useful for clinical screening, in any of the situations described above or for population-based epidemiologic studies, the test must not only show statistically significant differences between patients and controls but must also be different enough that cut-points to differentiate the groups can be obtained through ROC analyses. The bucket test does not meet the second criterion, of having strong ROC values to determine cut-points. Consequently, sensitivity to patients and specificity to normal controls was not good enough to recommend this test for use as a screening tool.

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Table 1

Demographic details of the sample. Mean age, (standard deviations and ranges)[n<50 yrs]; Gender, F, female, M, male. Mean length of illness, (standard deviations and ranges).

	Age (years)	Gender	Length of illness (weeks)
Normals	49.5 (11.0, 26.7 to 78.7)[29]	31F, 19M	
BPPV	60.1 (13.2, 30.1 to 78.8)[7]	19F, 6 M	34.8 (73.3, 0.6 to 313.1)
UW	58.3 (11.9, 33.4 to 75.5)[6]	19F, 6 M	127 (250.7, 2 to 1095.8)

Table 2

Mean (SD, range) absolute values of deviations from the vertical in patients vs controls for normal side, abnormal side and combined normal plus abnormal side, by diagnostic group and gender.

	Normal side	Abnormal side	Normal + abnormal
Mean controls	1.2 (0.75, 0 to 3.2)		
Mean male controls	1.0 (0.8 0 to 2.7)		
Mean female controls	1.2 (0.7, 0 to 3.2)		
Mean patients	2.0 (1.5, 0 to 6.3)	2.2 (1.6, 0 to 6.0)	2.1 (1.5, 0 to 5.7)
Mean UW	1.9 (1.5, 0 to 6.3)	2.3 (1.8, 0.3 to 7.5)	2.1 (1.7, 0 to 7.5)
Mean BPPV	2.1 (1.5, 0 to 5.7)	2.1 (1.5, 0 to 6.0)	2.1 (1.5, 0 to 6.0)
Mean male patients	1.0 (0.9, 0 to 3.0)	2.1 (1.5, 0 to 4.3)	1.6 (1.3, 0 to 4.3)
Mean female patients	2.3 (1.5, 0.3 to 6.3)	2.2 (1.7, 0 to 7.5)	2.3 (1.6, 0 7.5)

Table 3

Mean (SD, range) absolute values of deviations from the vertical in patients vs controls for normal side, abnormal side and combined normal plus abnormal side, by diagnostic group and age.

	Normal side	Abnormal side	Normal + abnormal
Controls age < 50	1.1 (0.7, 0 to 3.0)		
Controls age 50	1.2 (0.8, 0 to 3.2)		
Mean patients < 50	2.3 (1.6, 0.3 to 5.7)	1.9 (1.4, 0 to 4.0)	2.1 (1.5, 0 to 5.7)
Mean patients 50	1.9 (1.5, 0 to 6.3)	2.3 (1.7, 0 to 7.5)	2.1 (1.6, 0 to 7.5)
UW < 50	2.0 (1.4, 0.3 to 4.0)	1.8 (1.1, 0.3 to 3.0)	1.9 (1.2, 0.3 to 4.0)
UW 50	1.9 (1.6, 0 to 6.3)	2.5 (2.0, 0.3 to 7.5)	2.2 (1.8, 0 to 7.5)
BPPV < 50	2.9 (1.9, 0.7 to 6.7)	2.2 (1.7, 0 to 4.0)	2.6 (1.0 to 5.7)
BPPV 50	1.8 (1.4, 0 to 4.7)	2.0 (1.4, 0 to 6.0)	1.9 (1.4, 0 to 6.7)

Table 4

Cut-points, ROC values, 95% confidence intervals, sensitivity to patients, and specificity to normals for the following comparisons of patients to normals: normal side, abnormal side, mean of abnormal and normal side (Mean sides), male normal side, male abnormal side, mean of male normal and normal sides (mean male), female normal side, female abnormal side, mean of female normal and abnormal side (mean female).

Group	Best cut-point	ROC value	95% CI	Sensitivity to patients	Specificity to normals
Normal side	1.1	0.67	0.56 – 0.78	0.64	0.56
Abnormal side	1.3	0.69	0.59 – 0.80	0.68	0.60
Mean sides	1.0	0.75	0.65 – 0.84	0.78	0.56
Females, normal side	1.3	0.72	0.598, 0.84	0.71	0.58
Females, abnormal side	1.1	0.68	0.55, 0.81	0.68	0.52
Females, mean sides	1.2	0.76	0.65, 0.87	0.79	0.58
Males, normal side	ROC values could not be determined.				
Males, abnormal side	1.0	0.72	0.50, 0.93	0.75	0.63
Males, mean sides	1.2	0.68	0.48, 0.89	0.75	0.65