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Introduction

The otolaryngologist is frequently called upon to examine the dizzy patient in consultation when conservative measures have failed. Patients with the complaint of dizziness are among the most commonly seen by the primary care physician and the otolaryngologist. The role of the otolaryngologist in evaluating the dizzy patient is to determine the etiology of the dizziness through thorough evaluation and to assure appropriate treatment for the various underlying etiologies. The object of the evaluation is to separate possible causes into the categories of life threatening or benign, and to distinguish easily treatable causes from more complex causes.

This review will focus on specific clinical and vestibular laboratory tests that are currently available for evaluation of the dizzy patient. A complete knowledge of vestibular function is necessary for evaluation of the dizzy patient and for complete comprehension of this review. The reader is directed to previous grand rounds on vestibular function for reference.

The terms **gain**, **phase**, and **symmetry** are used to describe the various tests. Gain is the ratio of the amplitude of eye movement to the amplitude of head movement (stimulus). Phase is a parameter that describes the timing relationship between head movement and reflexive eye response. When the head and eyes are moving at exactly the same velocity in opposite directions, they are said to be exactly out of phase, or 180°. If the reflex eye movement leads the head movement, a phase lead is present, and if the compensatory eye movement trails the head movement, a phase lag is present. Symmetry is a comparison of the slow component of the nystagmus when rotated to the right compared with rotation to the left.

Screening Examinations of Vestibular Function

Although much has been written about the use of vestibular laboratory tests in the diagnosis of vestibular disorders, a complete history and physical including vestibular screening exams is the most effective tool in evaluating the dizzy patient. Studies have shown that the initial diagnosis by history and physical by experienced clinicians was confirmed by additional

testing over 75% of the time. Screening tests are most effectively used to confirm the etiology of easily diagnosed conditions and to separate this group from those patients who need more extensive workup. A list of commonly preformed office exams are listed below. It is important that a complete review of systems be performed by the physician as conditions such as musculoskeletal instability can limit performing initial exams and may obligate laboratory testing.

Dix-Hallpike Maneuver – This test is the most well-known of office vestibular testing. It is used to provoke nystagmus and vertigo commonly associated with BPPV. In this test, the patient is seated on the exam table with head turned 45 degrees to the side and brought rapidly into the supine position with head hanging over the table. This maneuver allows maximal stimulation of the posterior SCC. Nystagmus that beats upwards, toward the stimulated ear with a rotary component to the affected ear, lasts 15-45 seconds, has a latency of 2-15 seconds, and fatigues are classic signs of BPPV. Nystagmus in the opposite direction can often be elicited by quickly sitting the patient up in the same position. Patients with the classic symptoms above can be treated with an Epley maneuver and do not need further vestibular testing.

Pneumatic Otoscopy – Positive and negative pressure applied to the middle ear with a pneumatic otoscope can elicit vertigo and nystagmus. This is known as Hennebert's symptoms and signs. Hennebert's sign can be seen in patients with perilymphatic fistula, syphilis, Meniere's disease, and superior semicircular canal dehiscence syndrome.

Head Shake Nystagmus – This test is performed to evaluate asymmetry in the vestibular ocular reflex. The patient is instructed to tilt his or her head down 30 degrees to allow maximal stimulation of the horizontal canal and told to shake the head back and forth as quickly as possible for a period of 30 seconds. Immediately following cessation of movement, the eyes are opened and observed for nystagmus. Patients with unilateral vestibular dysfunction will have unopposed stimulation of the intact labyrinth which results in a slow-phase to the side of the lesion and a rapid nystagmus to the intact side. This response is usually brief. No nystagmus is expected in normal subjects. The presence of headshake nystagmus correlates well with peripheral vestibular function but has been identified in patients with cerebellar dysfunction. Patients with cerebellar dysfunction will often have a vertical component of the nystagmus. One study showed low sensitivity (27%) but good specificity (85%) in identifying vestibular dysfunction with this test.

Head Thrust Test – This test is used to evaluate for unilateral vestibular function. In this test, the patient's head is turned 15-30 degrees from center and then rapidly rotated to the other side with the patient focusing on the examiner's eyes. Patients with unilateral vestibular weakness will have a catch-up saccade when rotated rapidly to the side of the lesion. This test is rapidly and easily performed and can identify unilateral weakness of the vestibular system and as such is very useful clinically.

Dynamic Visual Acuity – This simple test can be used to sort out patients with bilateral vestibular weakness when chair testing is unavailable. With this test, a patient is asked to read the lowest line possible on a Snellen eye chart to establish a baseline visual acuity. This is followed by asking the patient to do the same task while rotating the head back and forth at a rate of 1-2 Hz. Loss of one line is considered normal, whereas loss of 2-3 lines suggests vestibular

weakness. This test should be abnormal in patients with bilateral vestibular weakness and can be used to diagnose these challenging patients.

Eye movements – When testing cranial nerve function, the examiner should evaluate for smooth pursuit. Patients with erratic eye movements and saccades in various directions should be evaluated for CNS, specifically cerebellar dysfunction.

Romberg Testing – In this test, patients are asked to stand with feet together with arms folded around the chest or at the side. Patients are asked to stand like this with eyes open, and the amount of sway is compared to the same action with eyes closed. Patients with equal sway have proprioceptive or cerebellar lesions. More sway with eyes closed suggests vestibular lesions, most commonly with sway to the side of vestibular weakness. The test can be performed with foot next to toe to make the test more difficult and to bring out more subtle weakness.

Fukuda Stepping Test – In this test, the patient is asked to march in place with eyes closed and arms held out forward. In the original test, Fukuda had patients march 100 steps. Patients with vestibular weakness will rotate to the side of the weak labyrinth 45 degrees or more with 100 steps. Shorter versions of the test can be used to observe lesser amounts of rotation.

Orthostatic Hypotension – Many patients with the complaint of dizziness will have the diagnosis of orthostatic hypotension causing “light headedness.” Orthostatic hypotension is a reduction of systolic blood pressure of at least 20mm HG or diastolic blood pressure of at least 10mm HG within three minutes of standing. This can be found in asymptomatic individuals, but in patients with corresponding vertigo and drop in blood pressure, the diagnosis is reinforced. Symptoms of orthostatic hypotension include lightheadedness, blurred vision, weakness, fatigue, cognitive impairment, nausea, palpitations, tremulousness, headache, neck ache, and dizziness.

Dysdiadochokinesis Testing – Dysdiadochokinesis is the inability to make finely coordinated antagonistic movements. Patients with cerebellar lesions are often unable to perform these tests. The most common method is to have patients alternate slapping their knees with the palm and dorsum of the hand rapidly. Testing relies on the experience of the examiner who should be looking for patients with difficulty performing this maneuver above and beyond the normal variation. As such, it is only reliable when the physician has much experience in observing this test.

Tandem Gait Testing – Walking heel to toe in a circular pattern requires intact cerebellar function and as such is used by some examiners to screen for cerebellar dysfunction. The specificity of this examination is low because many causes other than cerebellar dysfunction may cause poor performance on tandem walking tests.

Voluntary Hyperventilation – Patients with suspected anxiety caused dizziness or patients with “hyperventilation syndrome” have been diagnosed in the past by having them voluntarily over breathe for a period of 90 seconds to 3 minutes to see if symptoms were reproduced. Recent tests have shown that the test has both poor sensitivity and specificity. Subjects results compared to normals have shown similar results. Some authors have suggested that patients with multiple sclerosis, acoustic neuroma, or vestibular neuritis can have symptoms provoked by hyperventilation, but these claims have not been validated by study.

Vestibular Laboratory Tests

After evaluation by history, physical, and the above mentioned screening tests, the clinician may still be unclear on the diagnosis and further testing may be warranted. Below is a review of the currently used vestibular tests with a detailed review of information obtained with each test. In addition, a brief review of the literature concerning indications and value of each test is provided.

Electronystagmography – ENG is the most widely used vestibular tests by otolaryngologist and relies on the vestibulo-ocular reflex to test the peripheral vestibular function and its ability to generate efficient voluntary eye movements necessary for maintaining visual contact with the environment. It consists of three subtests or subgroupings of tests: 1) oculomotor tests, 2) positional and positioning tests, 3) caloric tests.

The ENG begins with a calibration test in which the patient is asked to follow a dot on the wall, usually laser generated, that moves in a sinusoidal pattern to allow calibration of the eye movements with the monitor recording. In addition, gaze evoked and spontaneous nystagmus are evaluated. It is important to note that these eye movements can be more accurately evaluated by ENG due to the possibility of recording eye movements with closed eyes or with Frenzel glasses which eliminate visual fixation, and therefore suppress the nystagmus.

- **Oculomotor tests** – this first subdivision of ENG is evaluated by saccadic tracking, smooth pursuit tracking, and optokinetic tracking. The common thread of these tests is they all test eye movements that originate in the cerebellum. Abnormalities in these tests suggest a central neurological origin.
- **Saccadic tracking** – Saccades are rapid eye movements made to bring an object of interest into the center of the line of sight. Saccades are tested for accuracy, velocity, and latency. This test is performed with the patient concentrating on a randomly moving target. Latency, or the difference in time between the presentation of a new target and the initiation of eye movement, is considered normal if between 150-250ms in random patterns and shorter than 75ms when the pattern is predictable. Accuracy is measured by looking for eye movements that are equal in amplitude to the distance between the former object of interest and the new target. Hypometria is common in normal subjects and is the act of undershooting a target. If undershoot is less than 15% it is considered normal. Normal subjects with hypometria will quickly adjust to the target. Patients with normal cerebellar function will occasionally overshoot the target, called hypermetria. Hypometria and hypermetria are considered abnormal if they are consistently less than 75-80% or greater than 115-120% of the target value. Velocity is measured during saccade testing. There is no upper limit of normal as peak velocities have been measured as high as 700 degrees per second. Velocities slower than 400 degrees per second for large amplitude saccades and slower than 200 degrees per second for small amplitude saccades are considered abnormal.
- **Smooth pursuit tests**, also known as **sinusoidal tracking**, test the ability of the patient to accurately and smoothly pursue a target. In these tests, a target is rotated back and forth in a sinusoidal pattern. Gain is measured and the eye movements are compared to

the movement of the target. It is important to note that saccade movements are eliminated from the calculations of gain. Asymmetrical eye movements are highly suggestive of CNS disease.

- **Optokinetic tracking** – when a patient is spinning, he relies on the stimulation from the vestibular system and optokinetic nystagmus to allow steady focus on objects as they move in a circular pattern around him. As the patient's vestibular system fatigues with stimulation, the optokinetic system is solely responsible for the stabilization of the visual field. ENG tests the optokinetic tracking of targets by passing a light rapidly in front of a patient from one direction to the other and asking the patient to count the lights. This is done first in one direction, then the other. Asymmetries are noted and are signs of central nervous system dysfunction. Various tests have been done that have shown unacceptable false positive results with this test. Patients with abnormalities in the optokinetic portion of the ENG may not need further neurological work-up.

Positional and positioning tests – Unlike the previous subset of tests, this portion of the ENG tests for abnormalities in the vestibular system. Positional tests are performed to determine whether the vestibular system responds normally and symmetrically to changes in head position. This is based on the concept that when a person receives an insult to one labyrinth, compensation occurs by constant stimulation. It is natural that the subject will become compensated in the position that he most frequently uses, namely the upright position. When placed in different positions, dizziness and nystagmus may occur as a result of incomplete compensation in that particular position. Patients with dizziness and no nystagmus provoked by different positions must have non-vestibular etiologies considered. Also, vertical nystagmus or multidirectional nystagmus is highly suggestive of central disorders. One study noted that ¼ of patients with atypical positional nystagmus were found to have CNS disorders or vascular insufficiency. Conversely, ¾ of patients with these findings have idiopathic or benign causes. When performing positional tests, it is important to eliminate the influence of neck flexion on results as flexion can cause vascular insufficiency that can provoke symptoms suggestive of peripheral vestibular disorders. Positional testing is used to determine the presence of BPPV. It is the movement that generates the response and not the position. BPPV is most commonly the result of otoliths in the posterior canal. Stimulation using the Dix-Hallpike maneuver commonly causes torsional nystagmus which is difficult to measure if traditional ENG is used. As such, several video systems have been developed to record eye movement to be reviewed by the examiner later. It is important to note that patients may fatigue the response, and patients with true BPPV may test negative on the initial visit. It is therefore important in both ENG testing and clinical testing that patients with a strong history of BPPV be tested on multiple occasions using the Dix-Hallpike maneuver.

Caloric Testing - This is the only vestibular test that stimulates one side of the vestibular system at a time. In this test, patients are placed in a 30 degree from prone position to allow the horizontal semicircular canal to be in a vertical orientation. Warm and cold water or air is then flushed into the external auditory canal at 7 degrees above or below body temperature. Varying temperature causes a non-physiologic stimulation of one labyrinth that may evoke vertigo, nystagmus, and occasionally nausea and vomiting. Warm water for example causes the perilymph to rotate towards the ampula, resulting in stimulation of the ipsilateral labyrinth and a drift of the eyes away from the stimulated side. The eyes compensate with a saccade toward the

stimulated side. The opposite occurs with cold water stimulation. The mnemonic COWS is used to remember the direction of nystagmus (Cold Opposite Warm Same). Ice water irrigations can be used if milder stimulation does not result in nystagmus. Because caloric irrigation results in stimulation analogous to head movements of 0.002 to 0.004 Hz, significant vestibular asymmetry can exist in the presence of normal caloric responses as real-life head movements are in the 1 to 6 Hz range. Visual fixation should reduce the strength of caloric responses in the presence of normal CNS function. Failure to suppress nystagmus 50-70% with visual fixation is abnormal.

Rotational Chair Testing

A **Rotational Chair Test** is performed by securing the patient to a rotary chair which rotates at various speeds and directions while eye movements are recorded. Sinusoidal harmonic acceleration tests at several frequencies, visual-vestibular interaction tests, VOR suppression tests, and step velocity tests are frequently performed using the rotary chair test.

- **Sinusoidal Harmonic Acceleration** – In this test, the chair is rotated at frequencies as low as 0.01 Hz and as high as 1.28 Hz. These frequencies are tested and then doubled in consecutive fashion to achieve harmonic acceleration. The chair is moved in either direction to stimulate both labyrinths equally. Gain, phase, and symmetry are measured. Gain at lower frequencies is augmented by the visual pursuit system and does not equal head movement. As higher frequencies are approached, gain and head movement are nearly equal. Patient's results are compared to the manufactures' norms. Patients with two consecutive frequencies out of range are considered abnormal. Patients with unilateral vestibular lesions will often have spontaneous nystagmus in darkness which can create a bias and asymmetry towards the side of the lesion, but this is not always true. After compensation has occurred, gain tends to normalize, but phase generally remains asymmetric. This is the most common abnormality in sinusoidal harmonic acceleration testing. More useful are the results obtained from this test in bilateral vestibular hypofunction. Patients with bilateral vestibular lesions will often demonstrate reduced gain across all frequencies. This may be the first abnormality in patients with vestibular loss associated with gentamicin use. Cerebellar dysfunction is suggested by situations in which VOR gain exceeds the velocity of head movements.
- **Visual-Vestibular Interaction Test** – In this test the patient is rotated in both directions while being asked to track objects on the wall. The goal for the patient is to match eye movement speeds with the speed of the chair. This tests the patient's ability to compensate for deficits in the vestibular ocular reflex with voluntary pursuit. Compensatory eye tracking strategies have utility in aiding recovery from vestibular deficits. This test identifies the patient's ability to use tracking for rehabilitation.
- **Vestibular Ocular Reflex Suppression Test** – In this test, the patient's ability to use visual fixation to suppress the VOR is tested. Patients are asked to fixate on an object spinning at the same speed as the chair, often a thumb held in front of the face. Patients should be able to suppress 90% of VOR gain. Failure to do so suggests a cerebellar lesion.

- **Step Velocity Testing** - In this test the chair is accelerated in one direction at a rate of 100 degrees/ seconds squared to a constant velocity. When sustained rotation is reached, the intensity of the nystagmus response will gradually decrease. The slow component of velocity is recorded as is the time constant. The time constant is the point in seconds at which the slow component velocity decreases to 37% of its peak after acceleration is stopped. The time constant is a measure of the velocity storage mechanism which is the continuation of neural response and persists after the fluid dynamics of the labyrinth have been exhausted. Decreased time constant and reduced gain on step velocity testing are sensitive but nonlocalizing findings for vestibular dysfunction.

Posturography

The term **posturography** may be used to describe any test of postural stability or standing balance, but is most often used to describe computerized dynamic posturography. Where as ENG and rotational chair testing are designed to evaluate the horizontal VOR by stimulating the horizontal semicircular canals, posturography evaluates other components of balance. Balance requires cerebellar integration of the information from vestibular, visual and somatosensory organs. Dysfunction of any of the necessary components of balance results in stronger reliance on other peripheral sensors for maintenance of balance. Posturography systematically takes away one or more sensory components to evaluate which component the patient is reliant upon for balance. This is accomplished through one of six conditions:

- Condition one – Stable platform with eyes open in a stable visual environment (patient has full use of all information: visual, vestibular, and somatosensory)
- Condition two – Stable platform with eye closed (patient must rely on vestibular and somatosensory information)
- Condition three – Stable platform with moving visual surroundings (patient must suppress a false sense of visually induced movement and rely on vestibular and somatosensory inputs)
- Condition four – Unstable platform with eyes open in a stable visual environment (patient must rely on vestibular and visual inputs)
- Condition five – Unstable platform with eyes closed (patient must rely on vestibular input only because visual and somatosensory feedback have been eliminated)
- Condition six – Unstable platform and unstable visual environment (patient must rely on vestibular input alone and suppress a false sense of visually induced movement).

Certain patterns of dysfunction are associated with specific deficits. Poor performance in conditions five and six are seen in patients with vestibular dysfunction. A visual preference is seen when patients positively test for conditions three and six. Because patients in this visual preference group are not unstable when vision is taken away (condition 5), vestibular dysfunction is not present. These patients have visual vestibular integration problems and need neurological referral. Patients with poor balance in conditions four, five, and six have a somatosensory dependence pattern. They should be referred for physical therapy assessment of strength and neurologic assessment of sensation of the lower extremities. When patients fall in conditions two, three, five, and six, a visual dependence pattern suggests that patients are overly

reliant on visual information. Therapy for these patients incorporates gradual reduction in visual feedback while performing exercises. Malingering patients often show difficulty in all conditions equally. This is different from the expected poorer results in more difficult situations.

It has been suggested by Allum that five different patients benefit from posturography:

1. Patients with chronic disequilibrium and normal clinical examinations.
2. Patients who may be malingering.
3. Patients with cervicogenic disequilibrium.
4. Patients with suspected multifactorial disequilibrium.
5. Patients with poorly compensated vestibular injuries.

Conclusion

The dizzy patient is most effectively evaluated by complete history, physical and clinical examination by a physician experienced in vestibular and neurological disorders. For the small subset of patients that need further testing for accurate diagnosis of their underlying disorder, several tests are available to the clinician for evaluation. Further study is needed to determine the efficacy of these tests and their proper use.

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